# Request for Bids
# Plant
## Design, Supply, and Installation
**(Without Prequalification)**

# Procurement of Dominica Geothermal Risk Mitigation Project

## PART 2 – Employer's Requirements

# Request for Bids
# Plant
# Design, Supply& Installation
## (Without Prequalification)

## Procurement of

Dominica Geothermal Risk Mitigation Project

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**RFB No:** **DGDC-RFB-001**
**Project:** Dominica Geothermal Risk Mitigation Project
**Employer:** Dominica Geothermal Development Company Limited
**Country:** Commonwealth of Dominica
**Issued on:** 22 July 2019

# Standard Procurement Documents

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# PART 2 - Employer's Requirements

# Section VII - Employer's Requirements

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|---|---|---|
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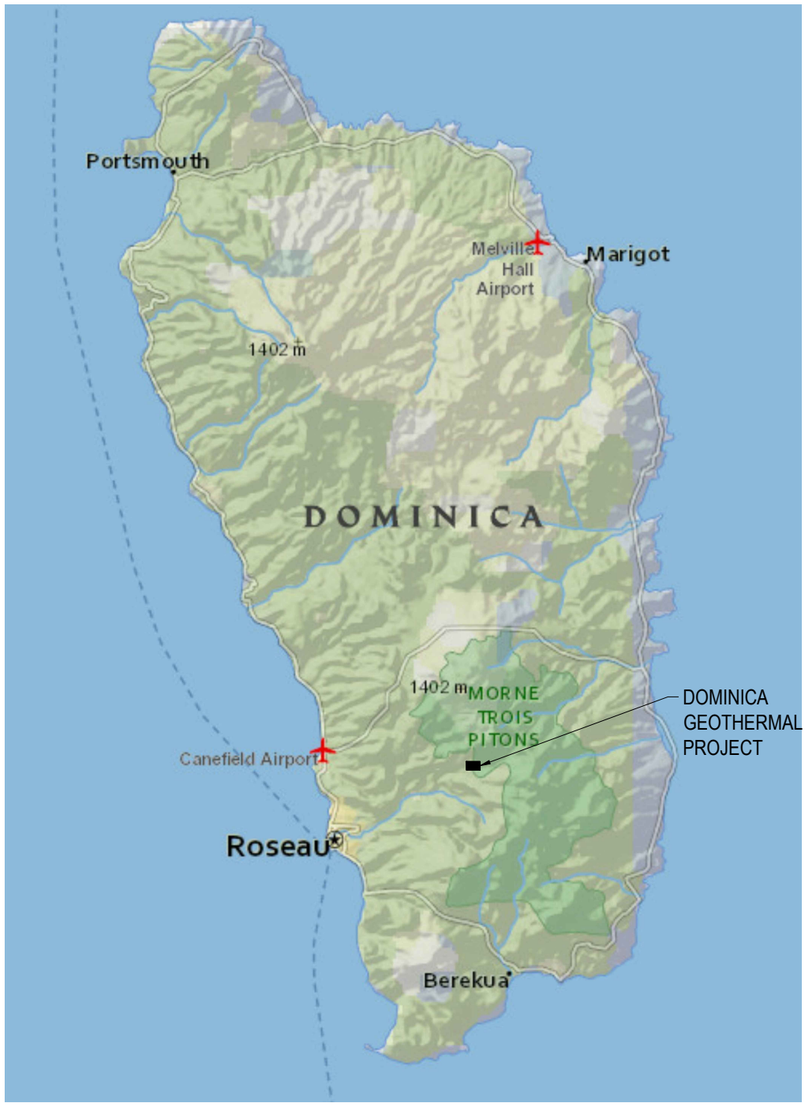
# Part 2 - Employer’s Requirements

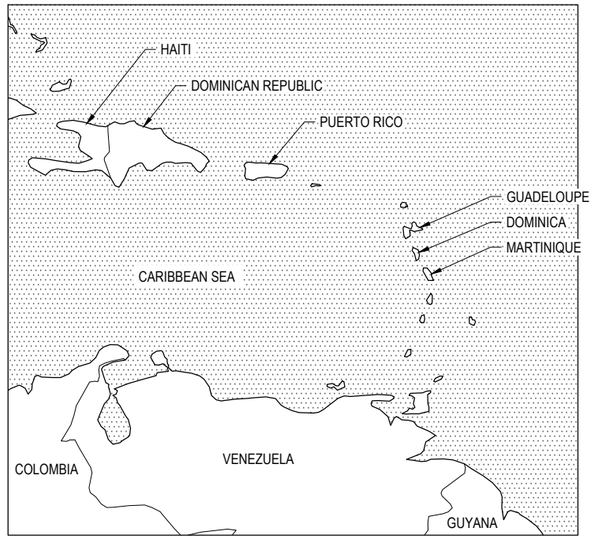
Section VII - Employer’s Requirements

# 1. Drawings

DATE: 19/07/2018 9:50:55 AM NAME: FAR, PAULA.M
LOCATION: J:\RP\Projects\PI\RZ042100\01 Design\Drawings\RZ042100-GN-DRG-0001.dwg




ISSUED FOR BID

| REV | DATE | DRAWN | REV'D | APP'D | REVISION |
|---|---|---|---|---|---|
| 0 | 19/07/18 | PMF | LJS | LJS | ISSUED FOR BID |

| DRAWING NUMBER | REFERENCE DRAWING TITLE |
|---|---|
| | |

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Web: www.jacobs.com

DGDC DRAWING NUMBER:

CLIENT: DOMINICA GEOTHERMAL DEVELOPMENT COMPANY
PROJECT: DOMINICA GEOTHERMAL POWER PLANT

| DRAWN | DRAWING CHECK | REVIEWED | APPROVED |
|---|---|---|---|
| MMR | PMF | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE 19/07/18 | DATE 19/07/18 |
| SJP | LJS | | |

TITLE: PROJECT LOCATION MAP

| SCALE ON ANSI D | DRAWING No | REV. |
|---|---|---|
| N.T.S. | RZ042100-GN-DRG-0001 | 0 |

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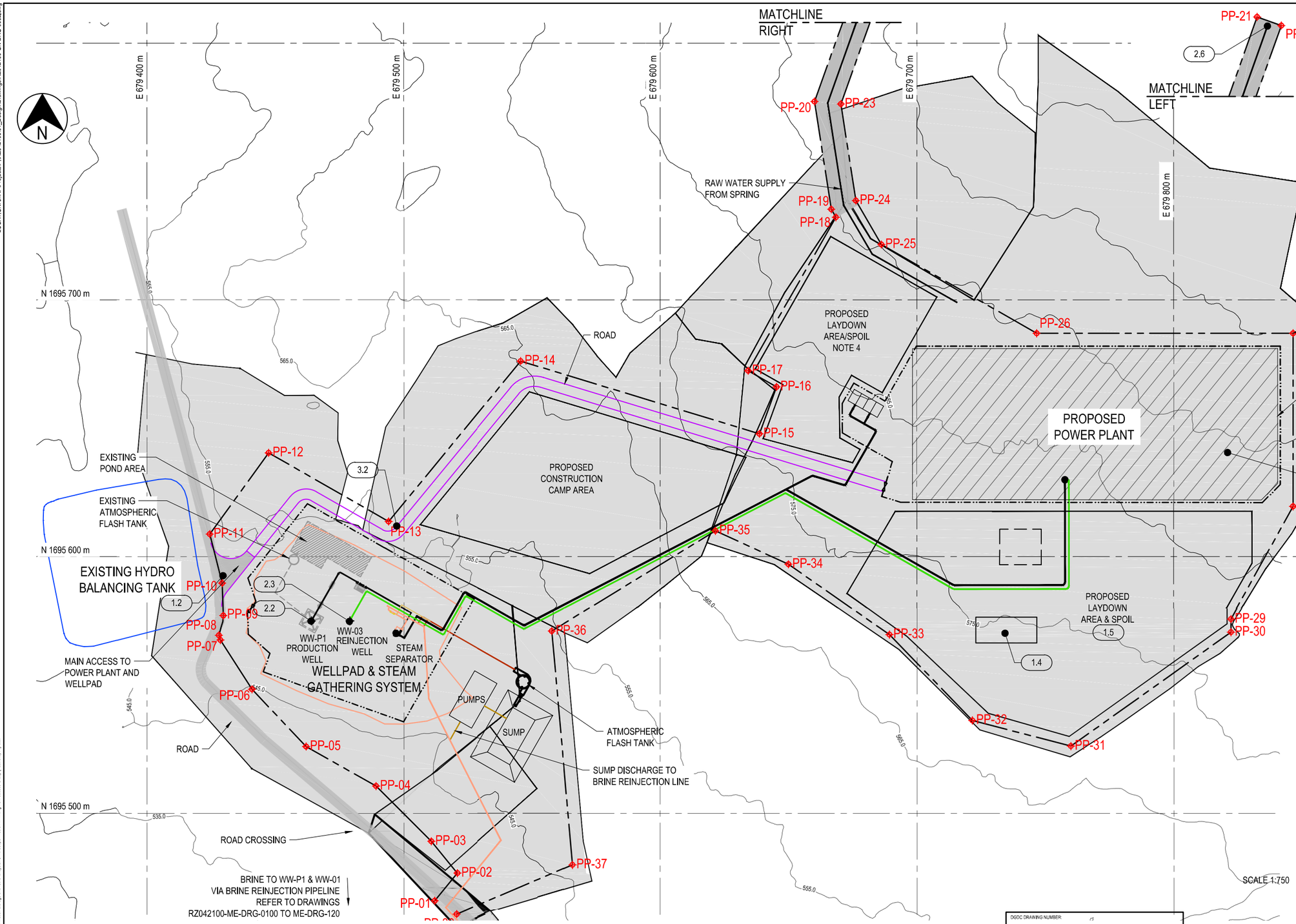


## NOTES

1. REFER TO SLD FOR INDICATIVE GRID CONNECTION ARRANGEMENT. ROUTE ALLOWS FOR OVERHEAD LINE AND BURIED CABLES.
2. PROPOSED POWER PLANT LAYOUT BASED ON LARGER FOOTPRINT REQUIRED FOR BINARY TECHNOLOGY OPTION. OUTER SITE EXTENT TO BE REDUCED IF CONDENSING PLANT OPTION IS SELECTED.
3. POWER PLANT LAYOUT IS INDICATIVE AND BASED ON LARGER ORGANIC RANKINE CYCLE TECHNOLOGY WITH AIR COOLED CONDENSER. FLASH PLANT OPTION WITH WET EVAPORATIVE COOLING EXPECTED TO USE LESS SPACE.
4. EXCESS EARTH DURING SITE WORKS SHOULD BE USED TO DEVELOP A BUND/SOUND BARRIER AROUND VENT STATION.
5. REFER TO RZ042100-GN-SPC-0002 INTERFACE SCHEDULE.

## LEGEND

- SITE BOUNDARY
- LAND TO BE PURCHASED/LEASED
- PROPERTY BOUNDARIES
- PP-01 SITE BOUNDARY POINT NODES, NOTE 5

## INTERFACE POINTS TABLE

| | |
|---|---|
| 1.2 | MAIN SITE ACCESS |
| 1.4 | FOUL WATER DISPOSAL |
| 1.5 | LAYDOWN/SPOIL |
| 2.2 | PRODUCTION WELL |
| 2.3 | CONDENSATE REINJECTION WELL |
| 2.6 | RAW WATER SUPPLY |
| 3.1 | GRID CONNECTION |
| 3.2 | CONSTRUCTION POWER SUPPLY |

SCALE 1:750 (ANSI D) 0 10 20 30 40 50 60 70m 10 0.2

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DGDC DRAWING NUMBER:

| REV | DATE | DRAWN | REV'D | APP'D | REVISION | DRAWING NUMBER | REFERENCE DRAWING TITLE |
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| 0 | 19/07/18 | PMF | LJS | LJS | ISSUED FOR BID | | |

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CLIENT: DOMINICA GEOTHERMAL DEVELOPMENT COMPANY
PROJECT: DOMINICA GEOTHERMAL POWER PLANT

| DRAWN | DRAWING CHECK | REVIEWED | APPROVED |
|---|---|---|---|
| PMF | PMF | LJS | LJS |
| DESIGNED | DESIGN REVIEW | | |
| SJP | LJS | DATE 19/07/18 | DATE 19/07/18 |

TITLE: GENERAL PROJECT INTERFACE PLAN

SCALE ON ANSI D: 1:750
DRAWING No: RZ042100-GN-DRG-0002
REV: 1

DATE: 31/01/2019 12:06:59 AM NAME: ROBERTSON, KAREN (NZ)
LOCATION: J:\RP\Projects\P\RZ042100\01_Design\Drawings\RZ042100-GN-DRG-0002.dwg
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DATE: 30/01/2019 8:16:55 PM NAME: ROBERTSON, KAREN (NZ)
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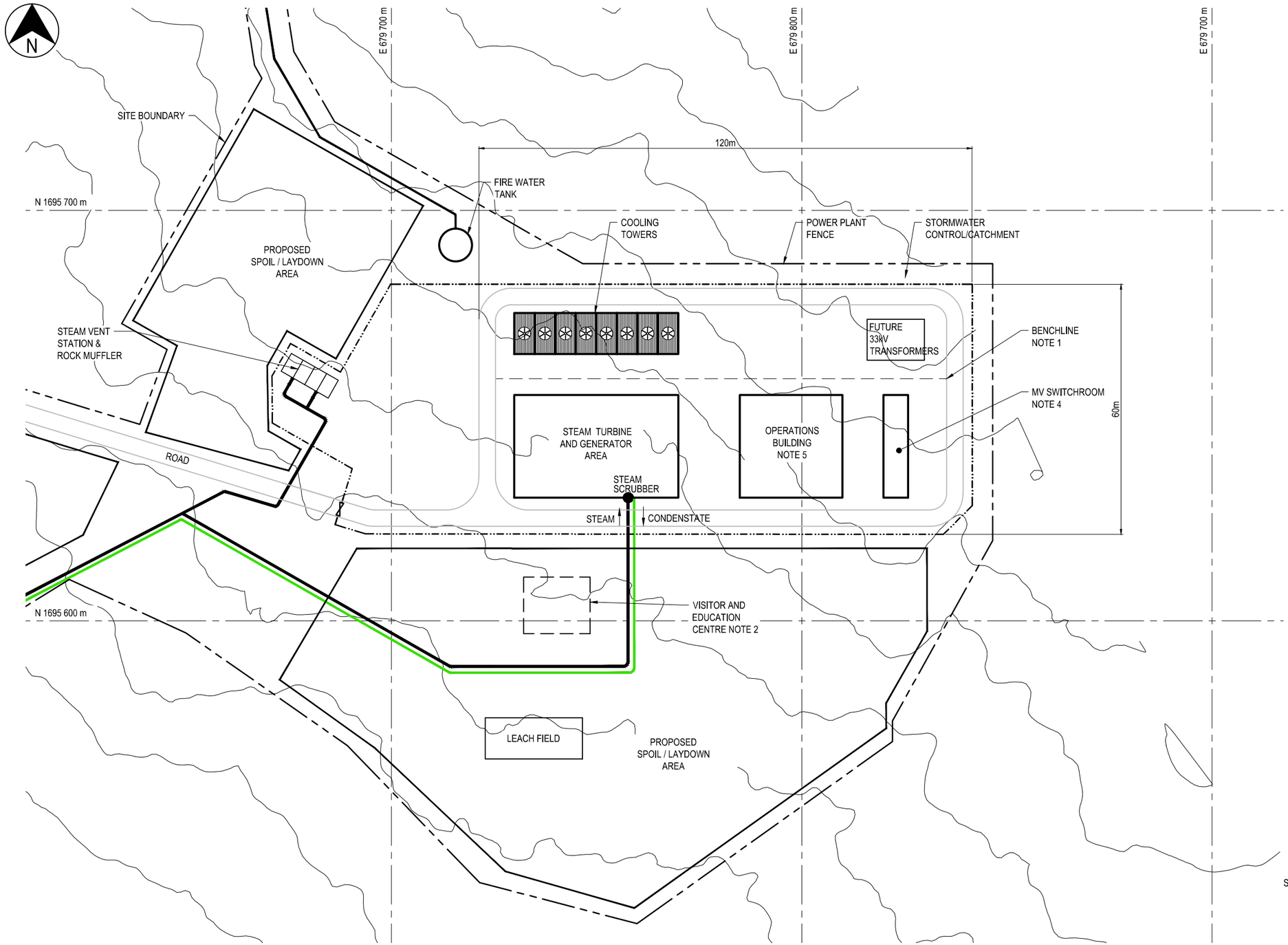


## NOTES

1. SITE BENCHLINE, COOLING TOWER, AIR COOLED CONDENSER CAN BE ON BENCH AT HIGHER ELEVATION THAN MAIN GENERATION PLANT.
2. INDICATIVE AREA ALLOWED FOR VISITOR AND EDUCATION CENTRE BUILDING FOLLOWING USE OF THE LAYDOWN AREA.
3. PROPOSED POWER PLANT LAYOUT BASED ON LARGER FOOTPRINT REQUIRED FOR BINARY TECHNOLOGY OPTION. OUTER SITE EXTENT TO BE REDUCED IF CONDENSING PLANT OPTION IS SELECTED.
4. MV SWITCHROOM TO BE DESIGNED SUITABLE TO CONTAIN HIGH VOLTAGE SWITCHGEAR. REFER TO EMPLOYER REQUIREMENTS FOR DETAILS. DESIGN AND LAYOUT OF CABLEWAYS/TRENCHES TO ALLOW FOR FUTURE 33kV CABLES AND SWITCHING EQUIPMENT.
5. OPERATIONS BUILDING AS DESCRIBED IN THE EMPLOYERS REQUIREMENTS.
   A SEPARATE FIRE PUMP HOUSE SHALL BE PROVIDED.
6. FINAL CUT SLOPES SHALL BE STABILISED TO PROTECT THE POWER PLANT FROM CONTINUED ROCK FALL FOR THE DESIGN LIFE OF 50 YEARS.
7. POWER PLANT LAYOUT AND ARRANGEMENT WITHIN THE SITE IS INDICATIVE. CONTRACTOR TO PROVIDE DETAILED DESIGN AND OPTIMISE POWER PLANT LAYOUT WITHIN THE SITE BOUNDARY.

## LEGEND

SITE BOUNDARY

SCALE 1:1000 (ANSI B) 0 20 40 60 80 100m (20 10)

SCALE 1:500 (ANSI D) 0 10 20 30 40 50m (10 8 6 4 2)

ISSUED FOR BID

| REV | DATE | DRAWN | REVD | APP'D | REVISION |
|---|---|---|---|---|---|
| 1 | 30/01/19 | SM | LJS | LJS | SITE BOUNDAY REVISED - ISSUED FOR BID |
| 0 | 19/07/18 | PMF | LJS | LJS | ISSUED FOR BID |

DRAWING NUMBER | REFERENCE DRAWING TITLE

Dominica Geothermal Development Company Limited
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Web: www.jacobs.com

DGDC DRAWING NUMBER:

CLIENT: DOMINICA GEOTHERMAL DEVELOPMENT COMPANY
PROJECT: DOMINICA GEOTHERMAL POWER PLANT

| DRAWN | DRAWING CHECK | REVIEWED | APPROVED |
|---|---|---|---|
| PMF | PMF | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE 19/07/18 | DATE 19/07/18 |
| SJP | LJS | | |

TITLE
GENERAL PROJECT PLAN
POWER PLANT
STEAM TURBINE CONDENSING PLANT OPTION

SCALE ON ANSI D: 1:500 | DRAWING No: RZ042100-GN-DRG-0010 | REV: 1

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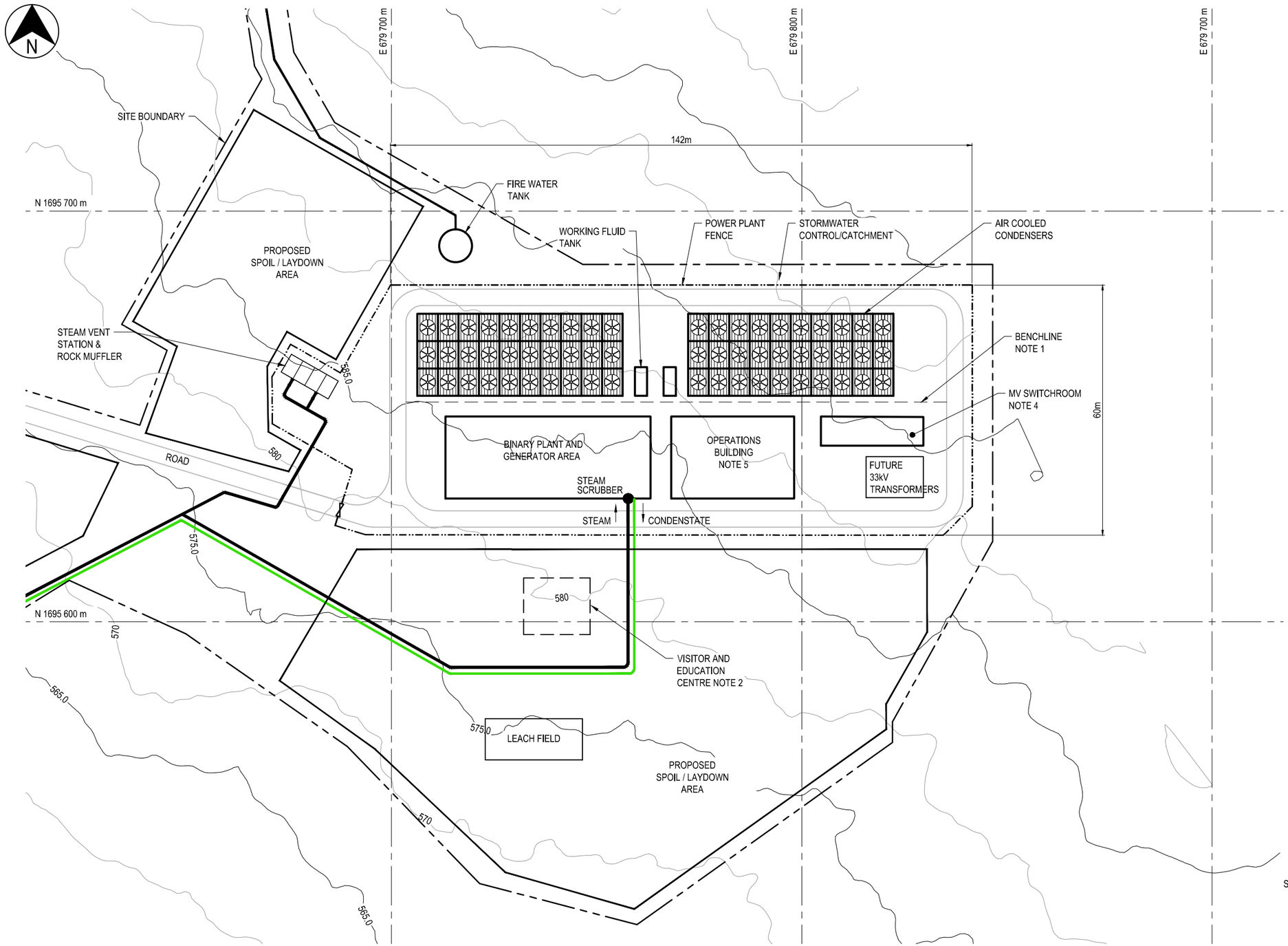


## NOTES

1. SITE BENCHLINE, COOLING TOWER, AIR COOLED CONDENSER CAN BE ON BENCH AT HIGHER ELEVATION THAN MAIN GENERATION PLANT.
2. INDICATIVE AREA ALLOWED FOR VISITOR AND EDUCATION CENTRE BUILDING FOLLOWING USE OF THE LAYDOWN AREA.
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7. POWER PLANT LAYOUT AND ARRANGEMENT WITHIN THE SITE IS INDICATIVE. CONTRACTOR TO PROVIDE DETAILED DESIGN AND OPTIMISE POWER PLANT LAYOUT WITHIN THE SITE BOUNDARY.

## LEGEND

SITE BOUNDARY

SCALE 1:1000 (ANSI B) 0 20 40 60 80 100m
20 10

SCALE 1:500 (ANSI D) 0 10 20 30 40 50m
10 8 6 4 2

ISSUED FOR BID

| REV | DATE | DRAWN | REV'D | APP'D | REVISION |
|---|---|---|---|---|---|
| 1 | 30/01/19 | SM | LJS | LJS | SITE BOUNDARY REVISED - ISSUED FOR BID |
| 0 | 19/07/18 | PMF | LJS | LJS | ISSUED FOR BID |

DRAWING NUMBER | REFERENCE DRAWING TITLE

Dominica Geothermal Development Company Limited
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CLIENT: DOMINICA GEOTHERMAL DEVELOPMENT COMPANY
PROJECT: DOMINICA GEOTHERMAL POWER PLANT

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|---|---|---|---|
| PMF | PMF | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE 19/07/18 | DATE 19/07/18 |
| ZS | SJP | | |

TITLE
GENERAL PROJECT PLAN
POWER PLANT
BINARY PLANT OPTION (AIR COOLED)

SCALE ON ANSI D: 1:500
DRAWING No: RZ042100-GN-DRG-0011
REV: 1

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## VALVE SYMBOLS

| NORMALLY OPEN | NORMALLY CLOSED | |
|---|---|---|
| | | GATE VALVE |
| | | SMALL GATE VALVE (<DN 100) |
| | | THROUGH-CONDUIT GATE VALVE |
| | | GLOBE VALVE |
| | NC | BUTTERFLY VALVE |
| | | NEEDLE VALVE |
| | | BALL VALVE |
| | | NON RETURN VALVE |
| | | PRESSURE RELIEF VALVE |
| | | 3-WAY VALVE |
| | | VACUUM RELIEF VALVE |
| | | SOLENOID VALVE |

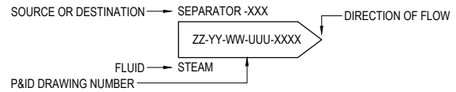
## ACTUATOR SYMBOLS

- DIAPHRAGM
- ELECTRO-HYDRAULIC
- HYDRAULIC
- SOLENOID
- ELECTRIC MOTOR
- CYLINDER
- HANDJACK OR HAND WHEEL
- SPRING
- FLOAT
- FLOW — PRESSURE REDUCING REGULATOR SELF CONTAINED
- FLOW — BACK PRESSURE REGULATOR SELF CONTAINED

## LINE SYMBOLS

- PRIMARY PROCESS PIPING
- SECONDARY PROCESS PIPING
- EXISTING PRIMARY PROCESS PIPING
- EXISTING SECONDARY PROCESS PIPING
- PROCESS DEMARCATION OR EQUIPMENT PACKAGE BOUNDARY
- ELECTRICAL SIGNAL
- PNEUMATIC SIGNAL OR AIR SUPPLY
- SOFTWARE LINK
- MECHANICAL LINK
- CAPILLARY TUBE
- HYDRAULIC CONNECTION

## LINE CONTINUATION



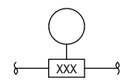

## INSTRUMENT AND FUNCTION SYMBOLS

DISCRETE FIELD INSTRUMENT (NOTE 1)

## PIPING AND EQUIPMENT SYMBOLS

- CONCENTRIC REDUCER
- ECCENTRIC REDUCER
- FLANGE
- BLIND FLANGE
- REMOVABLE SPOOL
- HOSE CONNECTION
- PIPE CAP WELDED
- PIPE CAP THREADED
- PIPE PLUG
- UNION
- LINE SPACER (NORMALLY OPEN)
- LINE BLANK (NORMALLY CLOSED)
- THERMOWELL
- DIAPHRAGM SEAL
- INLINE SPRAY NOZZLE
- RUPTURE DISC
- DRAIN POT
- STEAM TRAP
- FILTER/SEPARATOR WITH AUTO DRAIN
- Y-STRAINER
- Y-STRAINER WITH DRAIN VALVE
- BASKET STRAINER
- SOLIDS TRAP
- DRAIN
- OPEN VENT

## PIPING AND EQUIPMENT SYMBOLS




FLOW METER:
PDL = PADDLE
MAG = MAGNETIC
MASS = MASS
ROT = ROTAMETER
U = ULTRASONIC
VOR = VORTEX

- ORIFICE PLATE
- VENTURI
- PITOT TUBE
- AVERAGING PITOT TUBE (ANNUBAR)
- FILTER
- SCREEN
- LINE NUMBER CHANGE
- SPECIFICATION BREAK (XXX YYY)
- TIE-IN POINT (TP-XXX)
- FLOW DIRECTION ARROW
- DIRECTION OF FALL
- SILENCER
- INLINE SILENCER (S)
- SAMPLING POINT (S)
- VENT (V)
- DRAIN (D)
- FLEXIBLE HOSE
- EXPANSION JOINT
- EYE WASH
- SAFETY SHOWER

## PIPING AND EQUIPMENT SYMBOLS

- DIFFUSER
- SUMP
- ROCK MUFFLER
- ROCK PIT
- CENTRIFUGAL PUMP
- DOSING/METERING PUMP
- SUBMERSIBLE SUMP PUMP
- POSITIVE DISPLACEMENT PUMP
- SCREEN

## ABBREVIATIONS

| | | | | | |
|---|---|---|---|---|---|
| A | - | AUTO | MIN | - | MINIMUM |
| AS | - | AIR SUPPLY | M/W | - | MANWAY |
| ATM | - | ATMOSPHERE | N | - | NORMAL |
| CDP | - | CONDENSATE DRAIN POT | NDE | - | NON DRIVEN END |
| CV | - | CONTROL VALVE | NO | - | NORMALLY OPEN |
| D | - | DRAIN | NC | - | NORMALLY CLOSED |
| DE | - | DRIVEN END | O | - | OFF |
| DGDC | - | DOMINICA GEOTHERMAL DEVELOPMENT COMPANY | PCV | - | PRESSURE CONTROL VALVE |
| | | | PI | - | PRESSURE INDICATOR |
| DN | - | NOMINAL DIAMETER | PIT | - | PRESSURE INDICATOR TRANSMITTER |
| EDV | - | EMERGENCY DUMP VALVE | | | |
| FC | - | FAIL CLOSED | PSE | - | PRESSURE SAFETY ELEMENT |
| FF | - | FAIL FIXED | PV | - | PROCESS VARIABLE |
| FIT | - | FLOW INDICATOR TRANSMITTER | R | - | REMOTE |
| FO | - | FAIL OPEN | RED FLG | - | REDUCING FLANGE |
| FOB | - | FLAT ON BOTTOM | RO | - | RESTRICTION ORIFICE |
| FOT | - | FLAT ON TOP | RTJ | - | RING TYPE JOINT |
| H | - | HAND | S | - | SAMPLE POINT |
| HCV | - | HAND CONTROL VALVE | SC | - | SAMPLE CONNECTION |
| HH | - | HIGH HIGH | S/D | - | SHUT DOWN |
| HP | - | HIGH PRESSURE | SP | - | SET POINT |
| ISO | - | ISOKINETIC | SR | - | SHORT RADIUS |
| L | - | LOCAL | SS | - | STEAM SUPPLY |
| LCV | - | LEVEL CONTROL VALVE | TI | - | TEMPERATURE INDICATOR |
| LIT | - | LEVEL INDICATOR TRANSMITTER | TIT | - | TEMPERATURE INDICATOR TRANSMITTER |
| LL | - | LOW LOW | | | |
| LC | - | LOCKED CLOSED | V | - | VENT |
| LO | - | LOCKED OPEN | X° | - | DEGREES CLOCKWISE IN DIRECTION OF FLOW 0° = TOP OF PIPE |
| LP | - | LOW PRESSURE | | | |
| LSH | - | LEVEL SWITCH HIGH | | | |
| LSHH | - | LEVEL SWITCH HIGH HIGH | | | |
| MAX | - | MAXIMUM | | | |
| MCC | - | MOTOR CONTROL CENTRE | | | |
| MCV | - | MOTOR CONTROL VALVE | | | |

## GENERAL NOTES:

1. INSTRUMENTATION AND CONTROL SHOWN IN HIGHLY SIMPLIFIED WAY. BUT SHOWS THE MINIMUM ACCEPTABLE INSTRUMENTATION AND CONTROL DEVICES.

DGDC DRAWING NUMBER:

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DRAWING NUMBER | REFERENCE DRAWING TITLE

Dominica Geothermal Development Company Limited
*Powering a New Generation...*

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CLIENT: DOMINICA GEOTHERMAL DEVELOPMENT COMPANY
PROJECT: DOMINICA GEOTHERMAL POWER PLANT

| DRAWN | DRAWING CHECK | REVIEWED | APPROVED |
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| PMF | PMF | LJS | LJS |
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TITLE: PIPING AND INSTRUMENTATION DIAGRAM LEGEND SHEET SHEET 1

| SCALE ON ANSI D | DRAWING No. | REV. |
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DATE: 28/01/2019 10:49:14 AM NAME: VIOLA, MARCO

## NOTES:

1. VENTS AND DRAINS TO BE PROVIDED AS REQUIRED.
2. WARM UP LINES.
3. SCROLLED INLET.
4. CONTRACTOR HAS FULL RESPONSIBILITY FOR ALL EQUIPMENT AND LINE SIZING.
5. THOUGH NOT SHOWN, INSTRUMENTATION SHALL BE PROVIDED TO INDICATE PRESSURE RELIEF DEVICE HAS OPERATED (TRIPPED)
6. TFT SAMPLE POINTS. INJECTION POINT LOCATED AT 270° OUTLET SAMPLE POINT MIN. DISTANCE 25Ø DOWNSTREAM OF INJECTION, LOCATED AT 0° AND 225°.
7. RELIEF AND START UP LINE TO FLASH TANK TO BE SIZED FOR RELIEF CASE.
8. MEASURING POINT AS DEFINED FOR GUARANTEE TESTS.
9. REMOVABLE SPOOL FOR ISOLATION AT GRADE LEVEL.
10. TAKE OFF TO BE FROM TOP OF PIPE.
11. BLEED LINE.
12. INDICATIVE PUMP SHOWN. CONTRACTOR TO ESTABLISH AND DEFINE PUMP REQUIREMENTS.
13. CONTRACTOR TO PROPOSE METHODOLOGY TO DISPOSE OF SUMP CONTENTS TO INJECTION WELL WW-03.

PRODUCTION WELLPAD
ELEVATION 549.5 m

STEAM SCRUBBER
RZ042100-BP-DRG-0003
CONDENSTAE

WW-P1

SEPARATOR

ATMOSPHERIC FLASH TANK

SCRUBBER
RZ042100-BP-DRG-0003
STEAM + NCG

ORC POWER PLANT UNIT 1
BRINE

ORC POWER PLANT UNIT 2
BRINE

REINJECTION PADS
RZ042100-BP-DRG-0004
BRINE

FREE DRAINING

ROCK MUFFLER
RZ042100-BP-DRG-0003
CONDENSATE

ROCK MUFFLER
RZ042100-BP-DRG-0003
CONDENSATE

WW-03
RZ042100-BP-DRG-0004
SUMP CONTENTS

SUMP

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|---|---|---|---|---|---|---|---|
| 1 | 29/01/19 | PMF | LJS | LJS | ISSUED FOR BID - MINOR CHANGES | | |
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TITLE
PIPING AND INSTRUMENTATION DIAGRAM
PRODUCTION WELLPAD SEPARATOR

SCALE ON ANSI D: N.T.S.
DRAWING No: RZ042100-BP-DRG-0002
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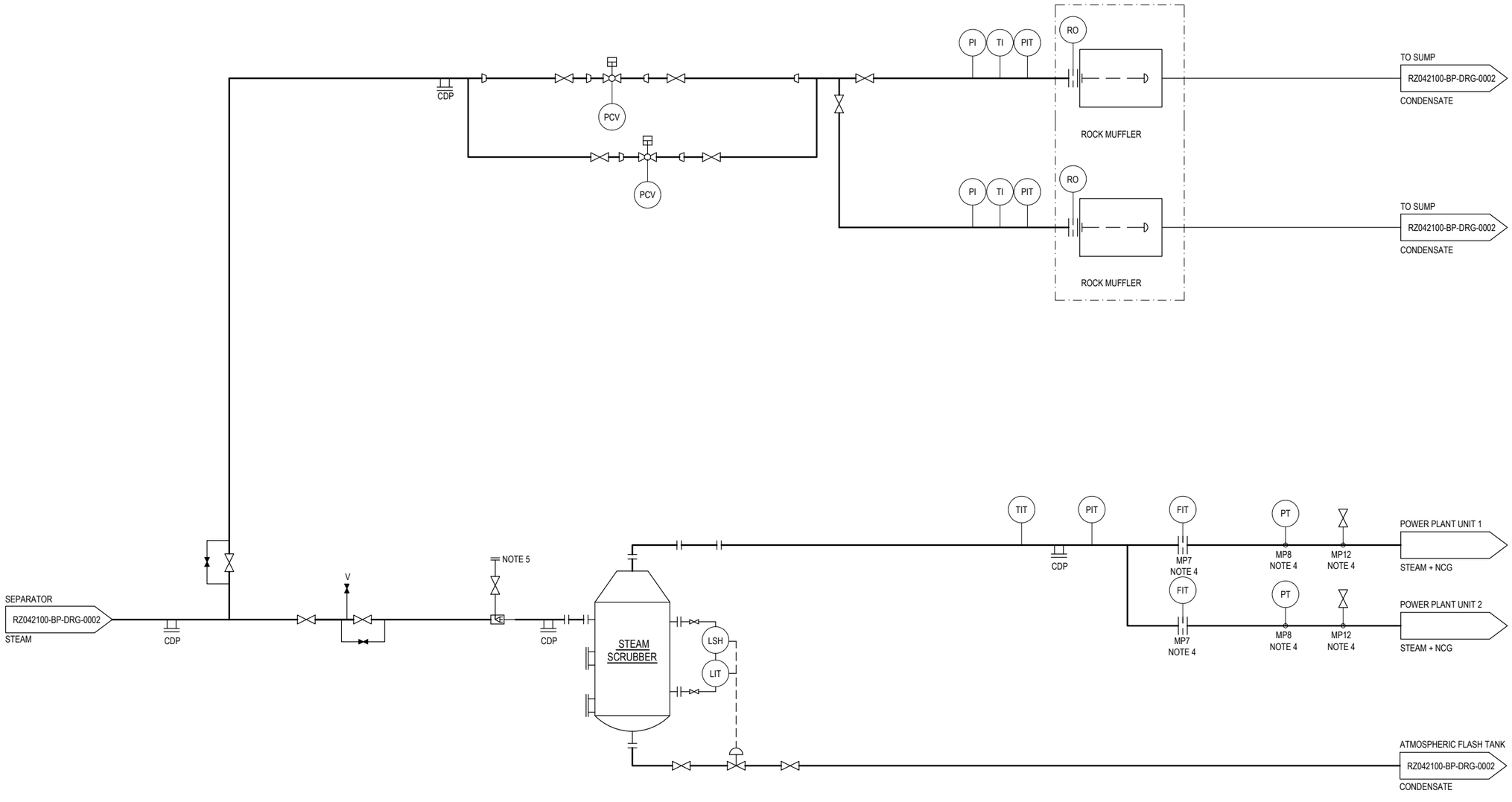
## NOTES:

1. CONTRACTOR HAS FULL RESPONSIBILITY FOR ALL EQUIPMENT AND LINE SIZING.
2. VENTS AND DRAINS TO BE PROVIDED AS REQUIRED.
3. CONTROL VALVES AT THE STEAM VENT STATION CONTROLLED BY PRESSURE AT POWER PLANT. SMALLER DIAMETER VALVES WILL MODULATE TO DISCHARGE EXCESS STEAM. BOTH VALVES WILL OPEN ON PLANT TRIP.
4. MEASURING POINT AS DEFINED FOR GUARANTEE TESTS.
5. CONTRACTOR TO DEFINE PROVISIONS FOR FUTURE WATER WASH.

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TITLE
# PIPING AND INSTRUMENTATION DIAGRAM STEAM VENT STATION AND SCRUBBER

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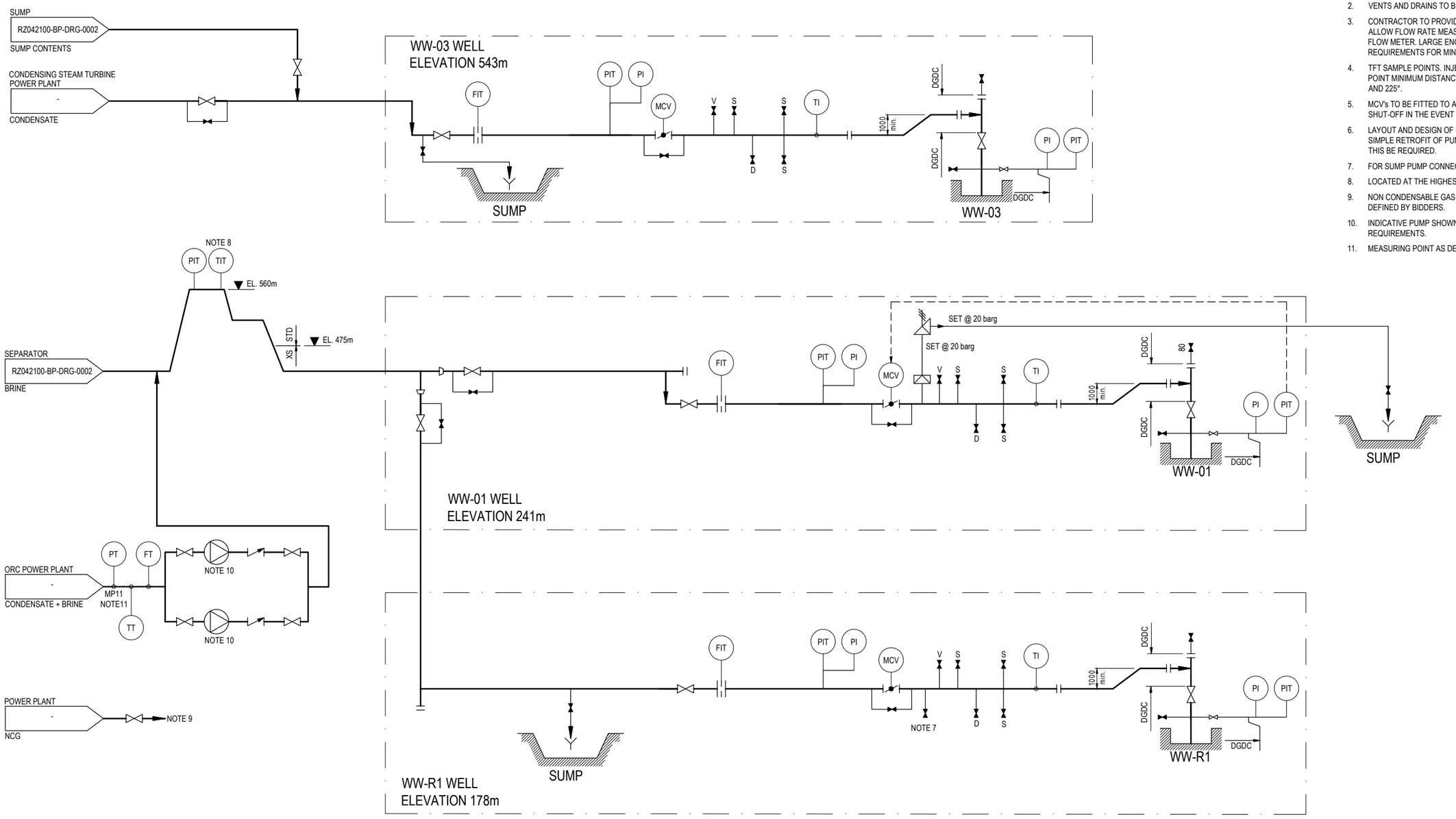


## NOTES:

1. CONTRACTOR HAS FULL RESPONSIBILITY FOR ALL EQUIPMENT AND LINE SIZING.
2. VENTS AND DRAINS TO BE PROVIDED AS REQUIRED.
3. CONTRACTOR TO PROVIDE A REMOVABLE SECTION OF PIPE INSULATION TO ALLOW FLOW RATE MEASUREMENT USING PORTABLE ULTRA SONIC TYPE FLOW METER. LARGE ENOUGH AND POSITIONED AS PER MANUFACTURER'S REQUIREMENTS FOR MINIMUM UPSTREAM AND DOWNSTREAM LENGTHS.
4. TFT SAMPLE POINTS. INJECTION POINT LOCATED AT 270° OULTLET SAMPLE POINT MINIMUM DISTANCE 25Ø DOWNSTREAM OF INJECTION, LOCATED AT 0° AND 225°.
5. MCV's TO BE FITTED TO ALL RE-INJECTION WELLS TO ALLOW FOR AUTOMATIC SHUT-OFF IN THE EVENT OF REVERSE FLOW DETECTED.
6. LAYOUT AND DESIGN OF PIPEWORK AT WW-01 AND WW-R1 TO ENABLE SIMPLE RETROFIT OF PUMP BY OTHERS FOR INJECTION PURPOSES SHOULD THIS BE REQUIRED.
7. FOR SUMP PUMP CONNECTION.
8. LOCATED AT THE HIGHEST POINT TO CONTROL INJECTION WELL VALVES.
9. NON CONDENSABLE GAS EXTRACTION EQUIPMENT AND METHODOLOGY TO BE DEFINED BY BIDDERS.
10. INDICATIVE PUMP SHOWN. CONTRACTOR TO ESTABLISH AND DEFINE PUMP REQUIREMENTS.
11. MEASURING POINT AS DEFINED FOR GUARANTEE TESTS.

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TITLE: PIPING AND INSTRUMENTATION DIAGRAM
BRINE & CONDENSATE REINJECTION WELLPADS

SCALE ON ANSI D: N.T.S.
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WELLPAD & STEAM GATHERING SYSTEM

POWER PLANT PAD

ATMOSPHERIC FLASH TANK

SUMP

SUMP PUMP

NOTE 5

STEAM SCRUBBER

LI

LCV

PT

PCV

STEAM VENT STATION AND ROCK MUFFLER

STEAM SEPARATOR

WW-P1 (552 masl)

EDV

NOTE 4

POWER PLANT UNIT (CONDENSING STEAM TURBINE OPTION SHOWN)

NOTE 2

CONDENSING STEAM TURBINE

COOLING TOWER

CONDENSER

HOTWELL PUMP

WW-03 (543 masl)

POWER PLANT UNIT (BINARY PLANT OPTION SHOWN)

EVAPORATOR

PRE-HEATER

RECUPERATOR

AIR COOLED CONDENSER/ WATER COOLED CONDENSER

TURBINE

FEED PUMP

WW-01 WELLPAD

REINJECTION WELL HEAD

WW-01 (235 masl)

WW-R1 WELLPAD

REINJECTION WELL HEAD

WW-R1 (187 masl)

## NOTES

1. POWER PLANT UNIT 1 AND UNIT 2 WILL BE THE SAME. TYPE OF POWER PLANT WILL BE DEPENDANT ON BID OUTCOME.
2. NON-CONDENSABLE GAS EXTRACTION EQUIPMENT AND METHODOLOGY NOT SHOWN. TO BE DETERMINED BY BIDDERS.
3. INDICATIVE PROCESS SCHEMATIC ONLY. NOT ALL REQUIRED EQUIPMENT, INCLUDING INSTRUMENTATION, IS SHOWN.
4. INDICATIVE PUMP SHOWN CONTRACTOR TO ESTABLISH AND DEFINE PUMPS REQUIREMENTS.
5. CONTRACTOR TO PROPOSE METHODOLOGY TO DISPOSE OF SUMP CONTENTS TO INJECTION WELL WW-03.

## LEGEND

- 2 PHASE
- STEAM
- BRINE
- CONDENSATE
- NON-CONDENSABLE GASES
- WORKING FLUID

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TITLE: PROCESS SCHEMATIC

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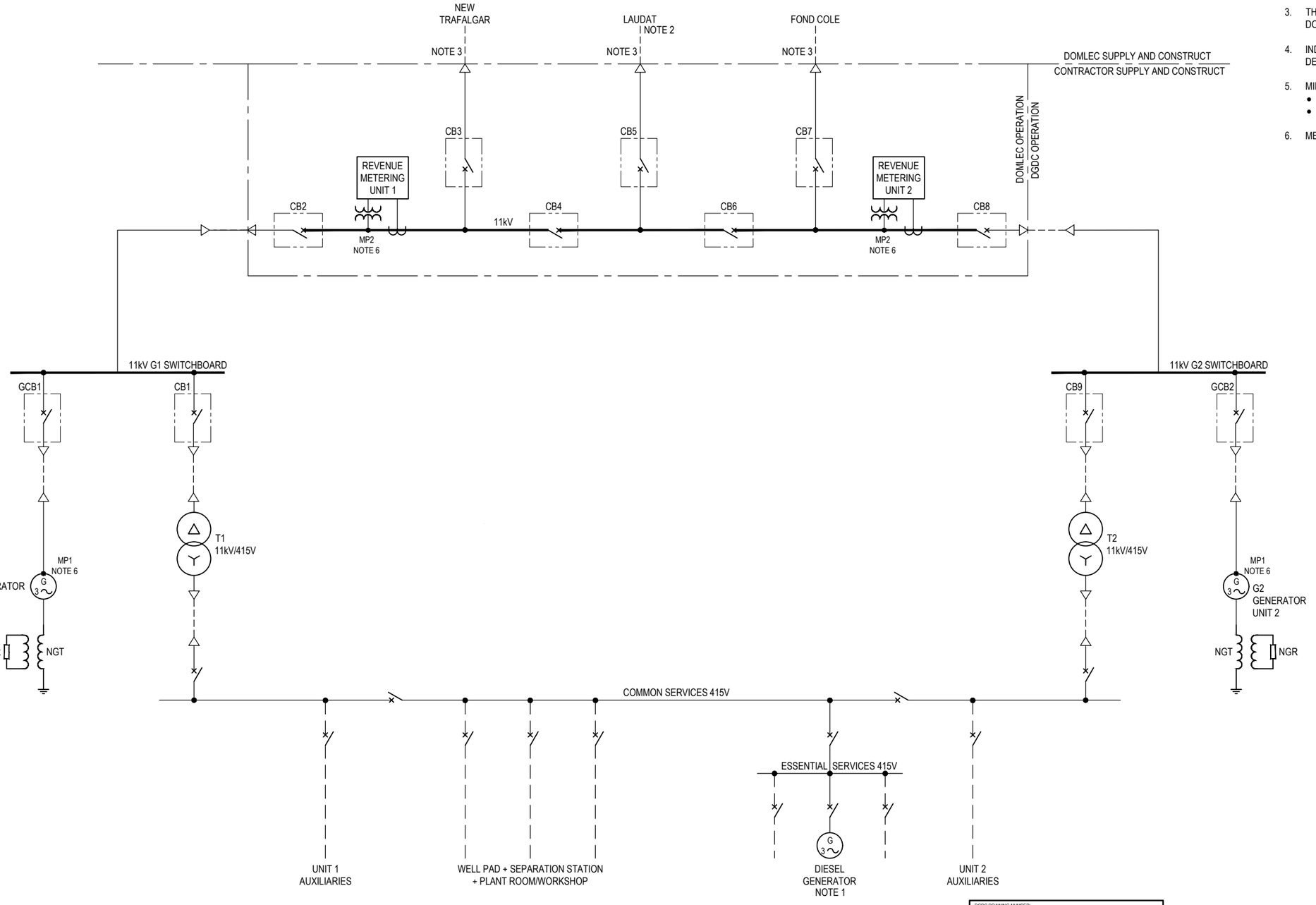


## NOTES

1. DIESEL GENERATOR FOR ESSENTIAL POWER ONLY. NOT TO BE CAPABLE OF BLACK START.
2. 11KV SPUR CIRCUIT TO THE LAUDAT HYDRO POWER STATION.
3. THE THREE INCOMING 11KV CIRCUITS TO BE CONSTRUCTED BY DOMLEC.
4. INDICATIVE. CONTRACTOR RESPONSIBLE TO UNDERTAKE DETAIL DESIGN.
5. MINIMUM MV BREAKER RATINGS:
   - 1250A NOMINAL CURRENT
   - 20kA 3s RATED SHORT TIME CURRENT
6. MEASURING POINT AS DEFINED FOR GUARANTEE TESTS.

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| MMR | PMF | LJS | LJS |
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TITLE: INDICATIVE SINGLE LINE DIAGRAM

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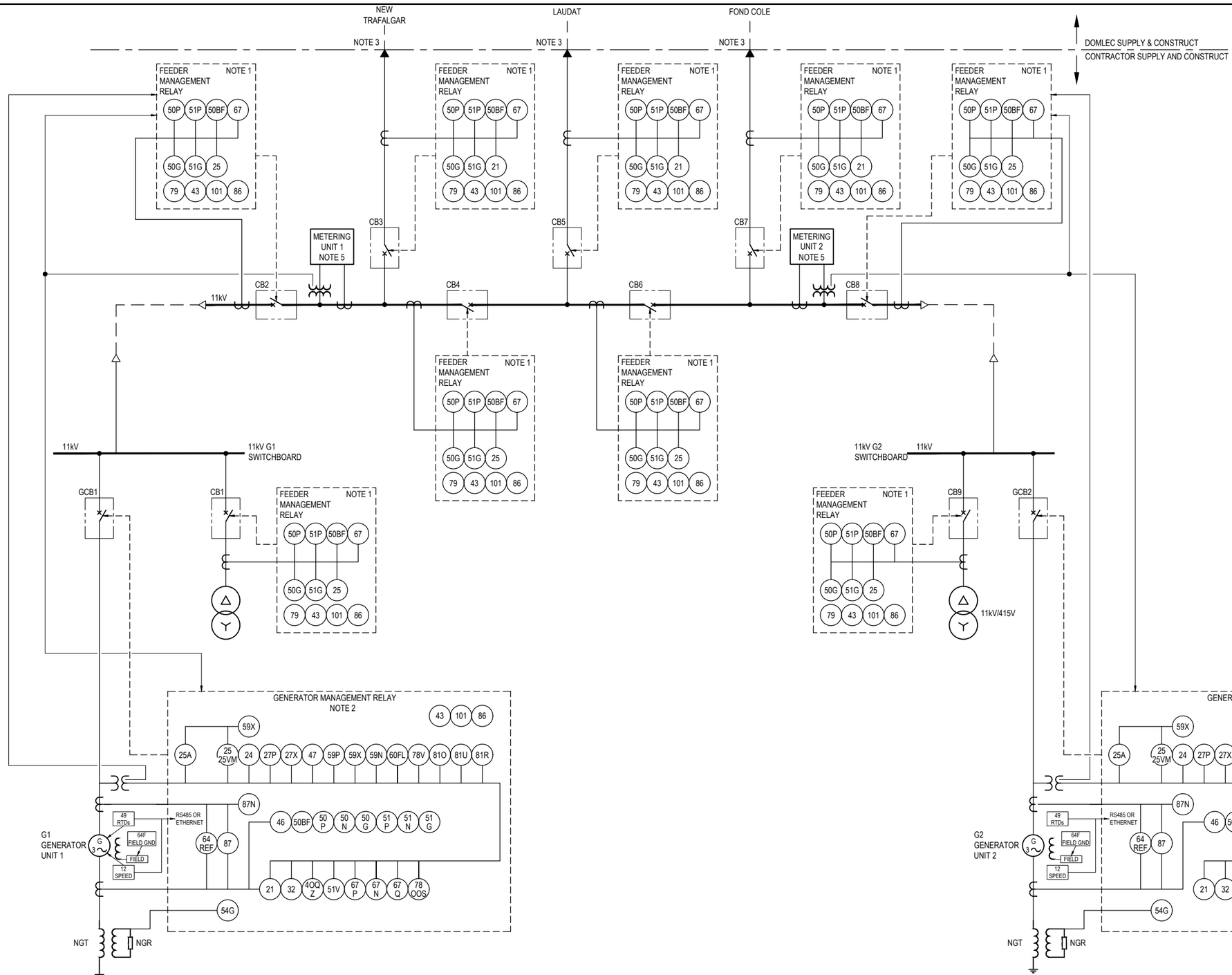
DATE: 19/07/2018 10:46:06 AM NAME: MAKKAR, SAGAR




## NOTES

1. FEEDER MANAGEMENT RELAYS TO BE SCHWEITZER (SEL).
2. DUPLICATE GENERATOR MANAGEMENT RELAYS TO BE INSTALLED FROM INDEPENDENT RELAY VENDORS. PRIMARY RELAY TO BE SCHWEITZER AND SECONDARY RELAY TO BE BECKWITH.
3. THE THREE INCOMING 11kV CIRCUITS TO BE CONSTRUCTED BY DOMLEC.
4. INDICATIVE. CONTRACTOR RESPONSIBLE TO UNDERTAKE DETAIL DESIGN.
5. MAIN AND SEPARATE CHECK METERING TO BE PROVIDED.

DGDC DRAWING NUMBER:

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TITLE: INDICATIVE R&I DIAGRAM

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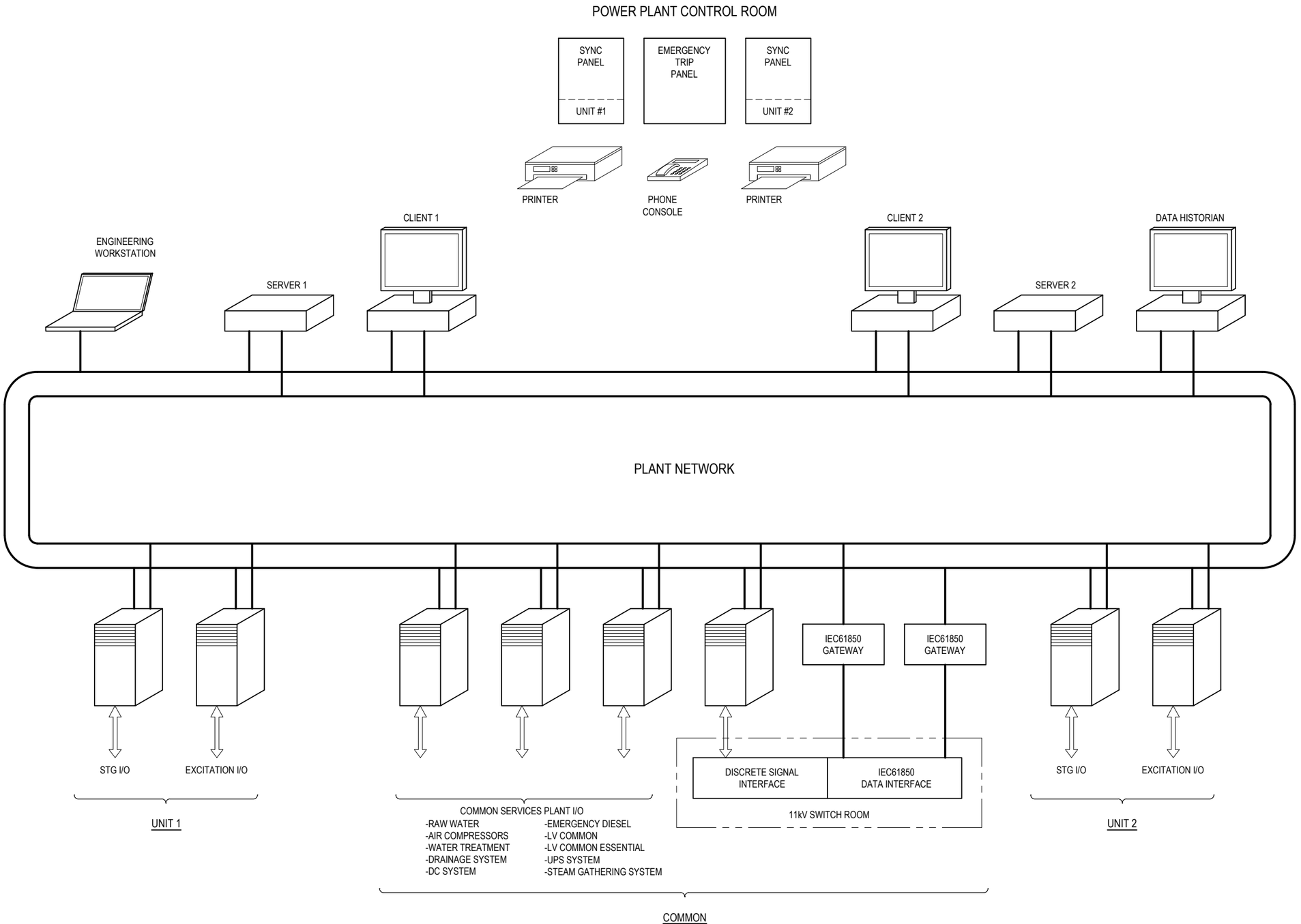


## NOTES:

1. CONCEPT DESIGN FOR A TWO UNIT POWER PLANT. THE CONTROL SYSTEM HARDWARE SHALL BE UNITISED FOR TWO UNIT, COMMON SERVICES ARRANGEMENT.
2. SERVERS AS REQUIRED DEPENDING ON VENDORS STANDARD CONFIGURATION. UNITISATION SHALL BE AS SHOWN WITH COMMON FUNCTION AVAILABLE ON EITHER UNIT SERVER PAIR.
3. INDICATIVE. CONTRACTOR RESPONSIBLE TO UNDERTAKE DETAIL DESIGN.

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TITLE: CONTROL BLOCK DIAGRAM CONCEPT DESIGN

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# BILL OF MATERIALS
# DOMINICA BRINE LINE

| ITEM NO | DESCRIPTION | REFERENCE DOCUMENT | QUANTITY | UNIT | NOTES |
|---|---|---|---|---|---|
| 1 | PIPE | | | | |
| 1.1 | DN300, STD WT, A53 GR B (OR APPROVED EQUIVALENT), ERW, ASME B36.10 | | 1000 | m | INCLUDES ALLOWANCE FOR 6 EXPANSION LOOPS |
| 1.2 | DN250, STD WT, A53 GR B (OR APPROVED EQUIVALENT), ERW, ASME B36.10 | | 1200 | m | INCLUDES ALLOWANCE FOR 10 EXPANSION LOOPS |
| 1.3 | DN250, XS, A53 GR B (OR APPROVED EQUIVALENT), ERW, ASME B36.10 | | 2250 | m | INCLUDES ALLOWANCE FOR 12 EXPANSION LOOPS |
| | | | | | |
| 2 | PIPE FITTINGS | | | | |
| 2.1 | DN300, STD WT, ELBOW, BUTT WELD, 90, ASTM A234 Gr WPB, ASME B16.9 | | 46 | No | INCLUDES ALLOWANCE FOR 6 EXPANSION LOOPS |
| 2.2 | DN300, STD WT, ELBOW, BUTT WELD, 45, ASTM A234 Gr WPB, ASME B16.9 | | 13 | No | |
| 2.3 | DN250, STD WT, ELBOW, BUTT WELD, 90, ASTM A234 Gr WPB, ASME B16.9 | | 44 | No | INCLUDES ALLOWANCE FOR 10 EXPANSION LOOPS |
| 2.4 | DN250, STD WT, ELBOW, BUTT WELD, 45, ASTM A234 Gr WPB, ASME B16.9 | | 5 | No | |
| 2.5 | DN250, XS, ELBOW, BUTT WELD, 90, ASTM A234 Gr WPB, ASME B16.9 | | 63 | No | INCLUDES ALLOWANCE FOR 12 EXPANSION LOOPS |
| 2.6 | DN250, XS, ELBOW, BUTT WELD, 45, ASTM A234 Gr WPB, ASME B16.9 | | 34 | No | |
| 2.7 | DN300 x DN250, REDUCER, CONC, STD, WT, ASTM A234 Gr WPB, ASME B16.9 | | 1 | No | |
| | | | | | |
| 3 | FLANGES, GASKETS AND BOLTS | | | | |
| 3.1 | DN250, FLANGE, WN, ASTM A105, ASME B16.5, CLASS 300 | | 46 | No | |
| 3.2 | STUD BOLT SET FOR DN250, CLASS 300 WN FLANGE, ASTM A194 Gr 2H, ASME B18.2.2 THREAD TO ASME B1.1 CLASS 2B | | 23 | No | |
| 3.3 | DN250. CLASS 300 ASME B16.5 SPIRAL WOUND GASKET WITH 316 METAL WINDING AND INNER RING, CS CENTERING RING AND FLEXIBLE GRAPHITE FILLER MATERIAL. | | 23 | No | |
| | | | | | |
| 4 | INSULATION AND CLADDING | | | | |
| 4.1 | DN300, INSULATION, PIPE, 80mm THK, CALCIUM SILICATE C/W ALI. CLADDING | | 1000 | m | |
| 4.2 | DN300, INSULATION, ELBOW, 90, 80mm THK, CALCIUM SILICATE C/W ALI. CLADDING | | 46 | No | |
| 4.3 | DN300, INSULATION, ELBOW, 45, 80mm THK, CALCIUM SILICATE C/W ALI. CLADDING | | 13 | No | |
| 4.4 | DN250, INSULATION, PIPE, 80mm THK, CALCIUM SILICATE C/W ALI. CLADDING | | 3450 | m | |
| 4.5 | DN250, INSULATION, ELBOW, 90, 80mm THK, CALCIUM SILICATE C/W ALI. CLADDING | | 107 | No | |
| 4.6 | DN250, INSULATION, ELBOW, 45, 80mm THK, CALCIUM SILICATE C/W ALI. CLADDING | | 39 | No | |
| 4.7 | DN300 x DN250, INSULATION, REDUCER, CONC, 80mm THK, CALCIUM SILICATE C/W ALI. CLADDING | | 1 | No | |
| 4.8 | DN250, INSULATION, FLANGE-WN, CLASS 300 Total, 80mm THK, CALCIUM SILICATE C/W ALI. CLADDING | | 46 | No | |
| | | | | | |
| 5 | PIPE SHOES | | | | |
| 5.1 | PIPE SHOE, TYPE: GV, DN250 | RZ042100-ME-DRG-0150 | 450 | No | |
| 5.2 | PIPE SHOE, TYPE: LV, DN250 | RZ042100-ME-DRG-0151 | 45 | No | |
| 5.3 | PIPE SHOE, TYPE: GV, DN300 | RZ042100-ME-DRG-0150 | 120 | No | |
| 5.4 | PIPE SHOE, TYPE: LV, DN300 | RZ042100-ME-DRG-0151 | 10 | No | |
| | | | | | |
| 6 | PIPE SUPPORTS | | | | |
| 6.1 | PIPE SUPPORT, CONSTANT WEIGHT | RZ042100-SC-DRG-0001 / 0002 | 3 | No | |
| 6.2 | PIPE SUPPORT PAD, TYPE FA-1,( H=1.5m) | RZ042100-SC-DRG-0003 | 325 | No | |
| 6.3 | PIPE SUPPORT PAD, TYPE FA-2, (H=2m) | RZ042100-SC-DRG-0003 | 140 | No | |
| 6.4 | PIPE SUPPORT PAD, TYPE FA-3 (H=2m) | RZ042100-SC-DRG-0003 | 53 | No | |
| 6.5 | PIPE SUPPORT, MID HEIGHT TYPE M | RZ042100-SC-DRG-0004 | 41 | No | |
| 6.6 | PIPE SUPPORT, HEIGHT TYPE H | RZ042100-SC-DRG-0004 | 45 | No | |
| | | | | | |
| 7 | MISCELLANEOUS | | | | |
| 7.1 | PIPE BRIDGE, TYPE 1 | RZ042100-SC-DRG-0005, 0006 | 1 | No | |
| 7.2 | PIPE BRIDGE, TYPE 2 | RZ042100-SC-DRG-0020, 0021, 0022 | 1 | No | |
| 7.3 | SUSPENSION BRIDGE | RZ042100-SC-DRG-0030, 0031, 0032 | 1 | No | |
| 7.4 | CLIFF BRIDGE TRUSS | RZ042100-SC-DRG-0010, 0011 | 1 | No | |
| 7.5 | PIPE CROSSING - CULVERT | RZ042100-SC-DRG-0015 | 8 | No | |

## NOTES

1. THIS BILL OF MATERIALS FOR THE CROSS COUNTRY BRINE REINJECTION PIPELINE EXCLUDES VALVING, INSTRUMENTS AND OTHER REQUIREMENTS WHICH ARE PART OF THE CONTRACTORS DETAILED DESIGN.
2. THE BILL OF MATERIALS DOE NOT INCLUDE PIPING AND FITTINGS REQUIRED ON THE REINJECTION WELLPADS AND WITHIN THE POWER PLANT SITE BOUNDARY.

| REV | DATE | DRAWN | REV'D | APP'D | REVISION |
|---|---|---|---|---|---|
| 1 | 30/01/2019 | KR | LJS | LJS | GENERAL REVISION - ISSUED FOR BID |
| 0 | 19/07/18 | SM | LJS | LJS | ISSUED FOR BID |

DRAWING NUMBER | REFERENCE DRAWING TITLE

Dominica Geothermal Development Company Limited
*Powering a New Generation...*

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NEW ZEALAND
Tel: +64 9 928 5500
Fax: +64 9 928 5501
Web: www.jacobs.com

DGDC DRAWING NUMBER:

CLIENT: DOMINICA GEOTHERMAL DEVELOPMENT COMPANY
PROJECT: DOMINICA GEOTHERMAL POWER PLANT

| DRAWN | DRAWING CHECK | REVIEWED | APPROVED |
|---|---|---|---|
| SM | KR | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE 19/07/18 | DATE 19/07/18 |
| KR | SJP | | |

ISSUED FOR BID

TITLE: BILL OF MATERIALS
DOMINICA BRINE LINE

SCALE ON ANSI D: N.T.S.
DRAWING No: RZ042100-BM-DRG-0010
REV: 1

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DATE: 1/08/2018 3:01:15 PM NAME: MAKKAR, SAGAR
LOCATION: \\acobs.com\ANZ\RP\Projects\PIR\RZ042100\01. Design\Drawings\RZ042100-BM-DRG-0020.dwg

# BILL OF MATERIALS
# MAIN GORGE BRIDGE

| S. NO. | ITEM | LOCATION | DESCRIPTION | QUANTITY | UNIT | COMMENTS |
|---|---|---|---|---|---|---|
| 1 | ANCHORS | MAIN CABLE ANCHORS, LATERAL CABLE ANCHORS, TOWER STAY ANCHORS | 32MM GRADE 500 STEEL ROCK BOLTS (40) | 720.0 | m | QUANTITY TO BE VERIFIED BY INVESTIAGTIVE DRILLING |
| 2 | PILES | TOWER FOUNDATION PILES | STEEL MICROPILES (12) | 180.0 | m | TYPE, LENGTH AND QUANTITY TO BE CONFIRMED BY DRILLING |
| 3 | CONCRETE | TOWER FOUNDATION, MAIN CABLE ANCHOR BLOCKS, LATERAL CABLE ANCHOR BLOCKS, TOWER STAY BLOCKS | 30MPA CONCRETE | 43 | cu m | |
| 4 | STEEL REINFORCEMENT | TOWER FOUNDATION, MAIN CABLE ANCHOR BLOCKS, LATERAL CABLE ANCHOR BLOCKS, TOWER STAY BLOCKS | GRADE 300 REINFORCING | 6,500 | kg | |
| 5 | MAIN SUSPENSION CABLES | MAIN SUSPENSION SPANS (2) | 36MM DIAM STEEL WIRE ROPE, GALVANISED | 1495.0 | kg | |
| 6 | LATERAL CATENARY CABLES | HORIZONTAL CATENARIES (2) | 40MM DIAM STEEL WIRE ROPE, GALVANISED | 1270.0 | kg | |
| 7 | LATERAL LINK CABLES | LATERAL CONNECTOR CABLES (16), TOWER STAYS (4) | 24MM DIAM STEEL WIRE ROPE, GALVANISED | 670.0 | kg | |
| 8 | BARRIER CABLES | HORIZONTAL INFILL | 12MM DIAM STEEL WIRE ROPE, GALVANISED | 194.0 | kg | |
| 9 | MAIN CABLE TERMINATIONS | ENDS OF MAIN CABLES (4), LATERAL CABLES (4) | RIGGING SCREWS OR SIMILAR ADJUSTERS, 336KN SWL | 8.0 | ea | |
| 10 | TOWER STRUCTURE | MAIN TOWER VERTICALS | 273 X 9.3 CHS GRADE 300 STEEL | 3250.0 | kg | |
| 11 | TOWER STRUCTURE | TOWER TRANSOMS | 168.3 X 4.8 CHS GRADE 300 STEEL | 440.0 | kg | |
| 12 | TOWER STRUCTURE | TOWER CROSS BRACING | 90X90X10 EA GRADE 300 STEEL | 560.0 | kg | |
| 13 | STEEL BAR | SUSPENSION HANGERS (20) | 12MM DIAM GRADE 500 STEEL BAR | 110.0 | kg | |
| 14 | DECK STRUCTURE | TRANSOMS | 168 X 7.1 CHS | 664.0 | kg | |
| 15 | DECK STRUCTURE | DECK BEAMS | 180 PFC | 7100.0 | kg | |
| 16 | STEEL GRATE | DECKING | 25MM THK WELDED BAR PANEL | 102.0 | sq m | |
| 17 | MISCELLANEOUS HARDWARE | HANGER CONNECTIONS, LATERAL STAY CONNECTIONS, HANDWIRE CONNECTIONS, BOLTS ETC | MISCELLANEOUS | 500.0 | kg | ESTIMATED |

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| REV | DATE | DRAWN | REV'D | APP'D | REVISION |
|---|---|---|---|---|---|
| 0 | 19/07/18 | SM | LJS | LJS | ISSUED FOR BID |

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NEW ZEALAND
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Fax: +64 9 928 5501
Web: www.jacobs.com

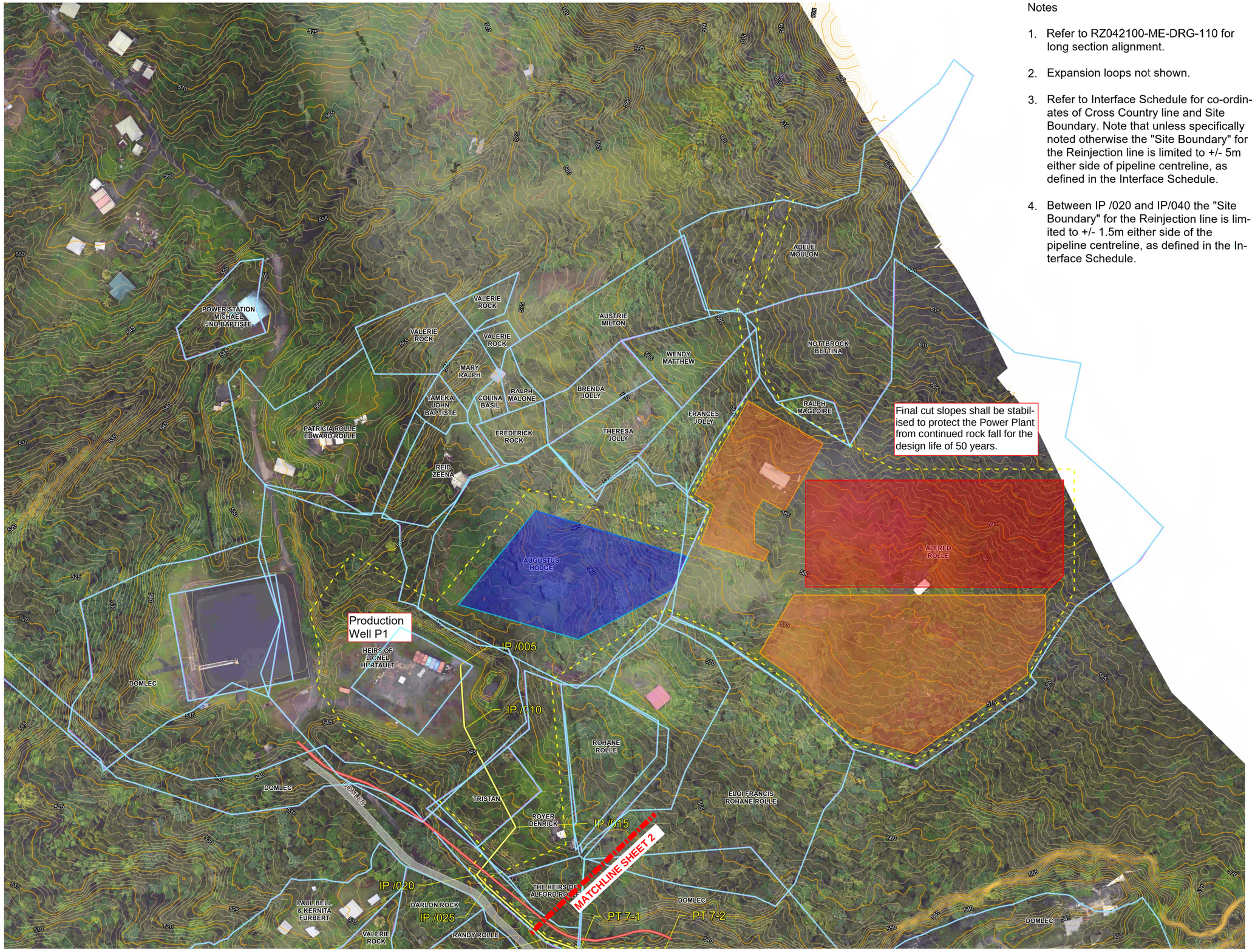
DGDC DRAWING NUMBER:

ISSUED FOR BID

| | | | |
|---|---|---|---|
| CLIENT | DOMINICA GEOTHERMAL DEVELOPMENT COMPANY | | |
| PROJECT | DOMINICA GEOTHERMAL POWER PLANT | | |
| DRAWN: SM | DRAWING CHECK: KR | REVIEWED: LJS DATE 19/07/18 | APPROVED: LJS DATE 19/07/18 |
| DESIGNED: FRAME | DESIGN REVIEW: FRAME | | |

TITLE: BILL OF MATERIALS
MAIN GORGE BRIDGE

SCALE ON ANSI D: N.T.S.
DRAWING No: RZ042100-BM-DRG-0020
REV: 0



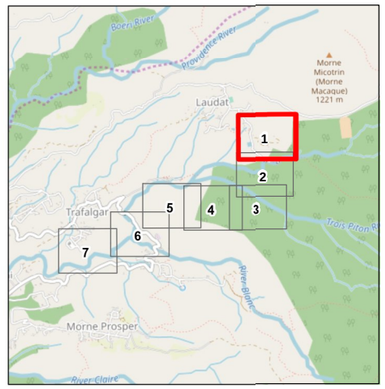

Notes

1. Refer to RZ042100-ME-DRG-110 for long section alignment.
2. Expansion loops not shown.
3. Refer to Interface Schedule for co-ordinates of Cross Country line and Site Boundary. Note that unless specifically noted otherwise the "Site Boundary" for the Reinjection line is limited to +/- 5m either side of pipeline centreline, as defined in the Interface Schedule.
4. Between IP /020 and IP/040 the "Site Boundary" for the Reinjection line is limited to +/- 1.5m either side of the pipeline centreline, as defined in the Interface Schedule.

- Site
- Power Plant
- Laydown
- Camp
- Properties
- DOMLEC Pipeline
- Reinj. Route
- Road

Contours

- Major
- Minor




N

0 25 50 100 m

**Brine Re-injection Pipeline**
**Sheet 1**
**RZ042100-ME-DRG-0100**

CLIENT
Dominica Geothermal Development Company

PROJECT
Dominica Geothermal

SCALE
1:1,000 @ ANSI D

PROJECT CODE
RZ042100

PROJECT MANAGER
LJS

DRAWN
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PROJECT DIRECTOR
AB

DATE
30/01/2019

FIGURE NO
1

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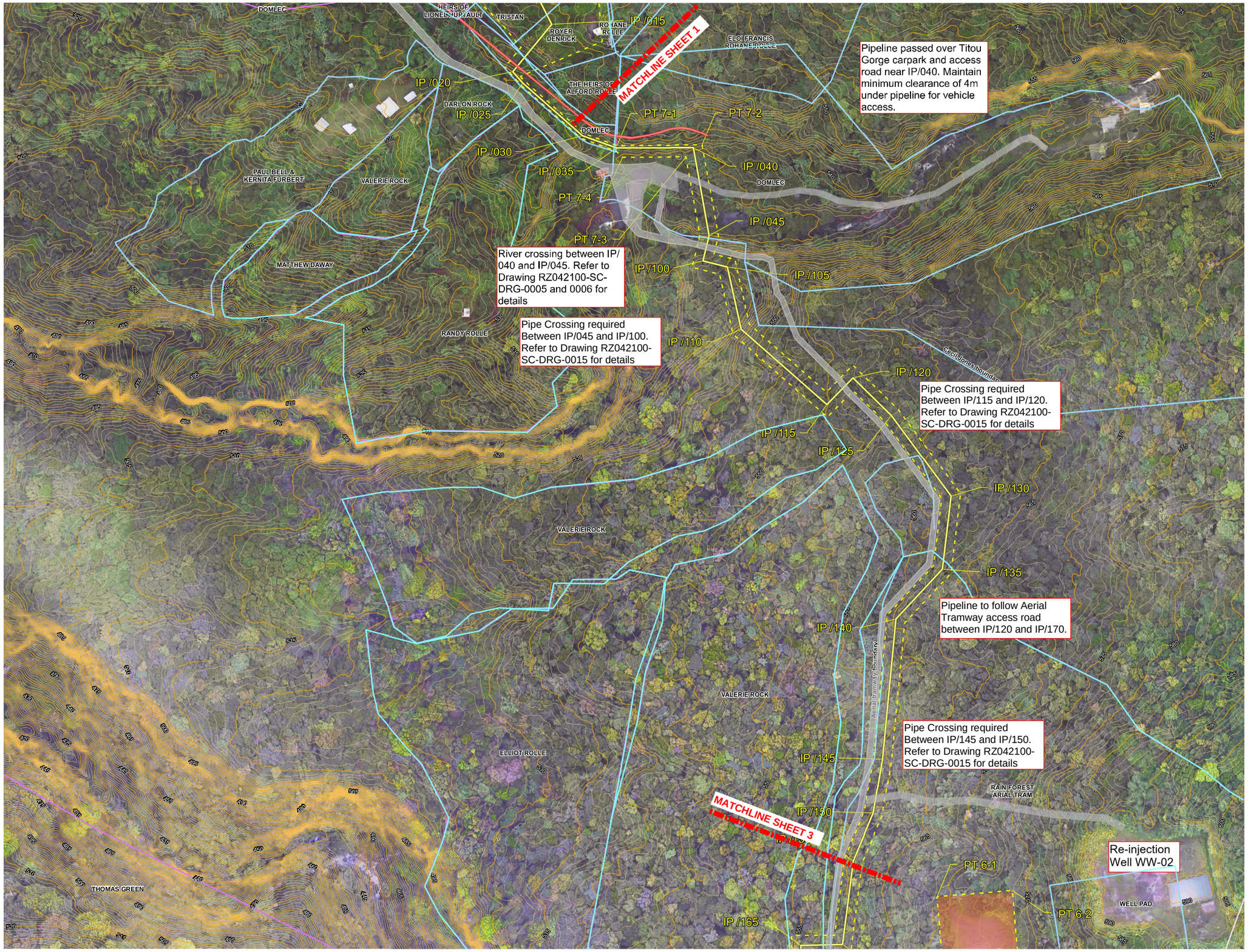
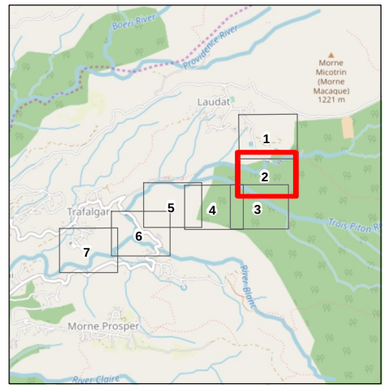



Site
Power Plant
Laydown
Camp
Properties
DOMLEC Pipeline
Reinj. Route
Road

Contours
Major
Minor

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0 25 50 100 m

**Brine Re-injection Pipeline**
**Sheet 2**
**RZ042100-ME-DRG-0100**

CLIENT
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PROJECT
Dominica Geothermal

SCALE
1:1,000 @ ANSI D

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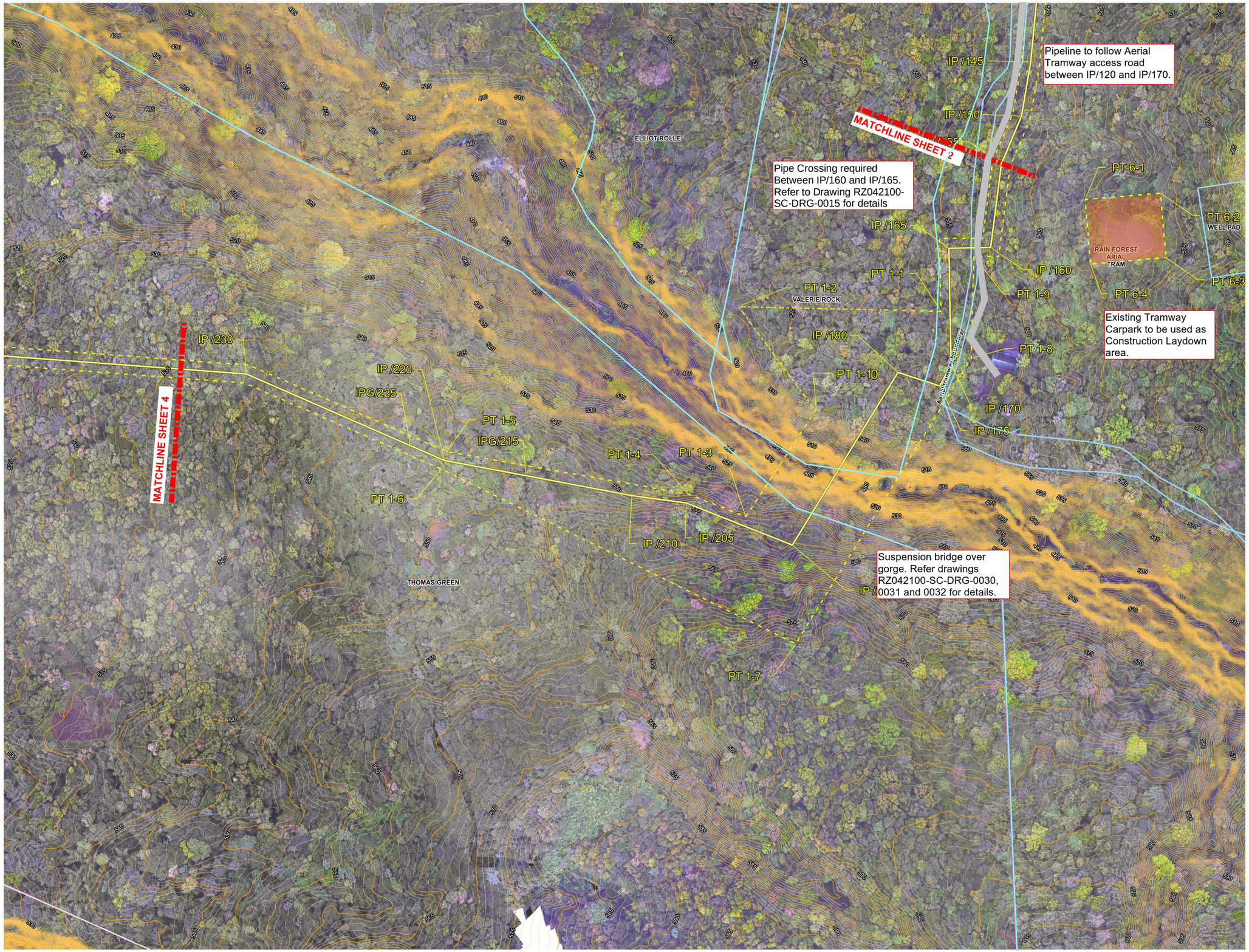
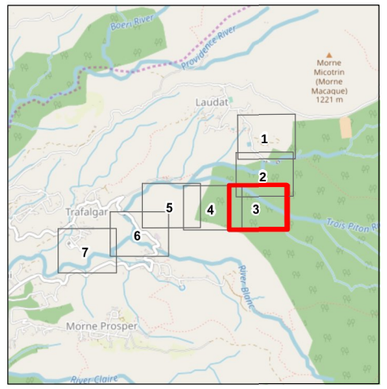



Site
Power Plant
Laydown
Camp
Properties
DOMLEC Pipeline
Reinj. Route
Road

Contours
Major
Minor

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0 25 50 100 m

**Brine Re-injection Pipeline**
**Sheet 3**
**RZ042100-ME-DRG-0100**

*CLIENT*
Dominica Geothermal Development Company

*PROJECT*
Dominica Geothermal

*SCALE*
1:1,000 @ ANSI D

*PROJECT CODE*
RZ042100

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3

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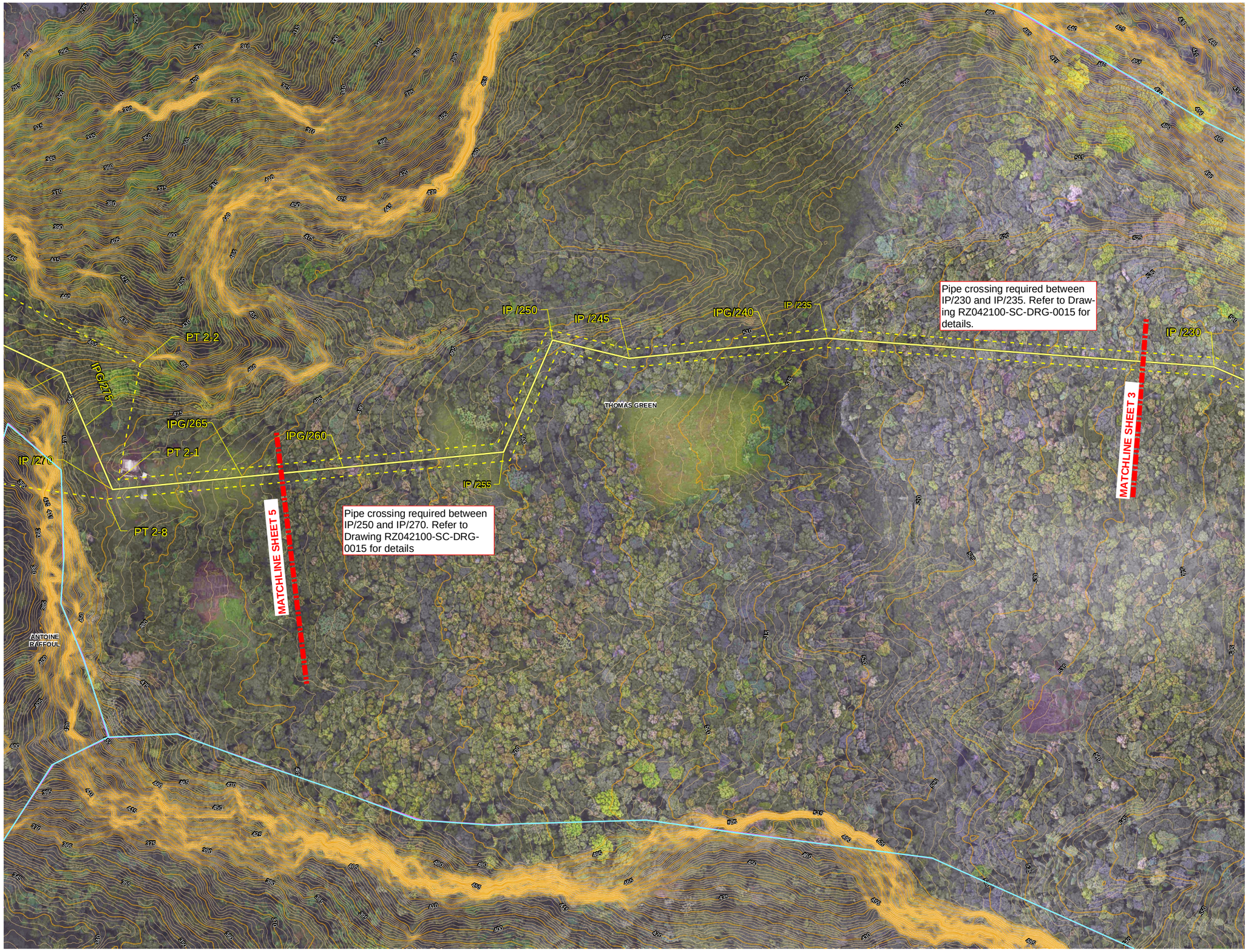
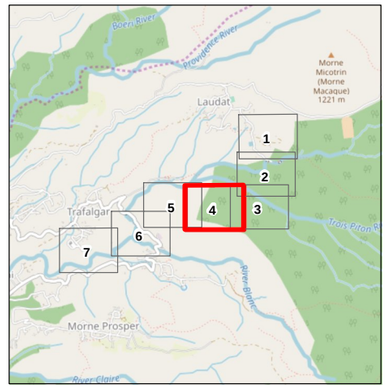



Site
Power Plant
Laydown
Camp
Properties
DOMLEC Pipeline
Reinj. Route
Road

Contours
Major
Minor

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0 25 50 100 m

**Brine Re-injection Pipeline**
**Sheet 4**
**RZ042100-ME-DRG-0100**

CLIENT
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PROJECT
Dominica Geothermal

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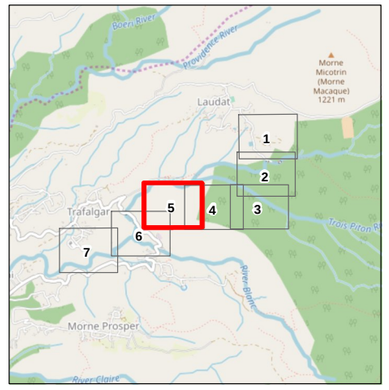
Site
Power Plant
Laydown
Camp
Properties
DOMLEC Pipeline
Reinj. Route
Road

Contours
Major
Minor

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0 25 50 100 m

**Brine Re-injection Pipeline**
**Sheet 5**
**RZ042100-ME-DRG-0100**

CLIENT
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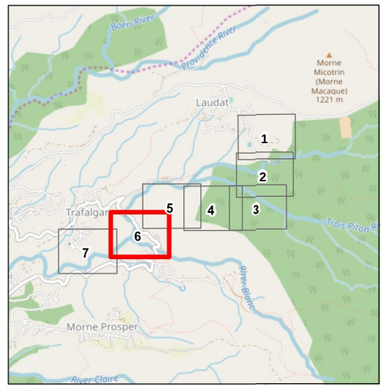
Site
Power Plant
Laydown
Camp
Properties
DOMLEC Pipeline
Reinj. Route
Road

Contours
Major
Minor

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0 25 50 100 m

**Brine Re-injection Pipeline**
**Sheet 6**
**RZ042100-ME-DRG-0100**

CLIENT
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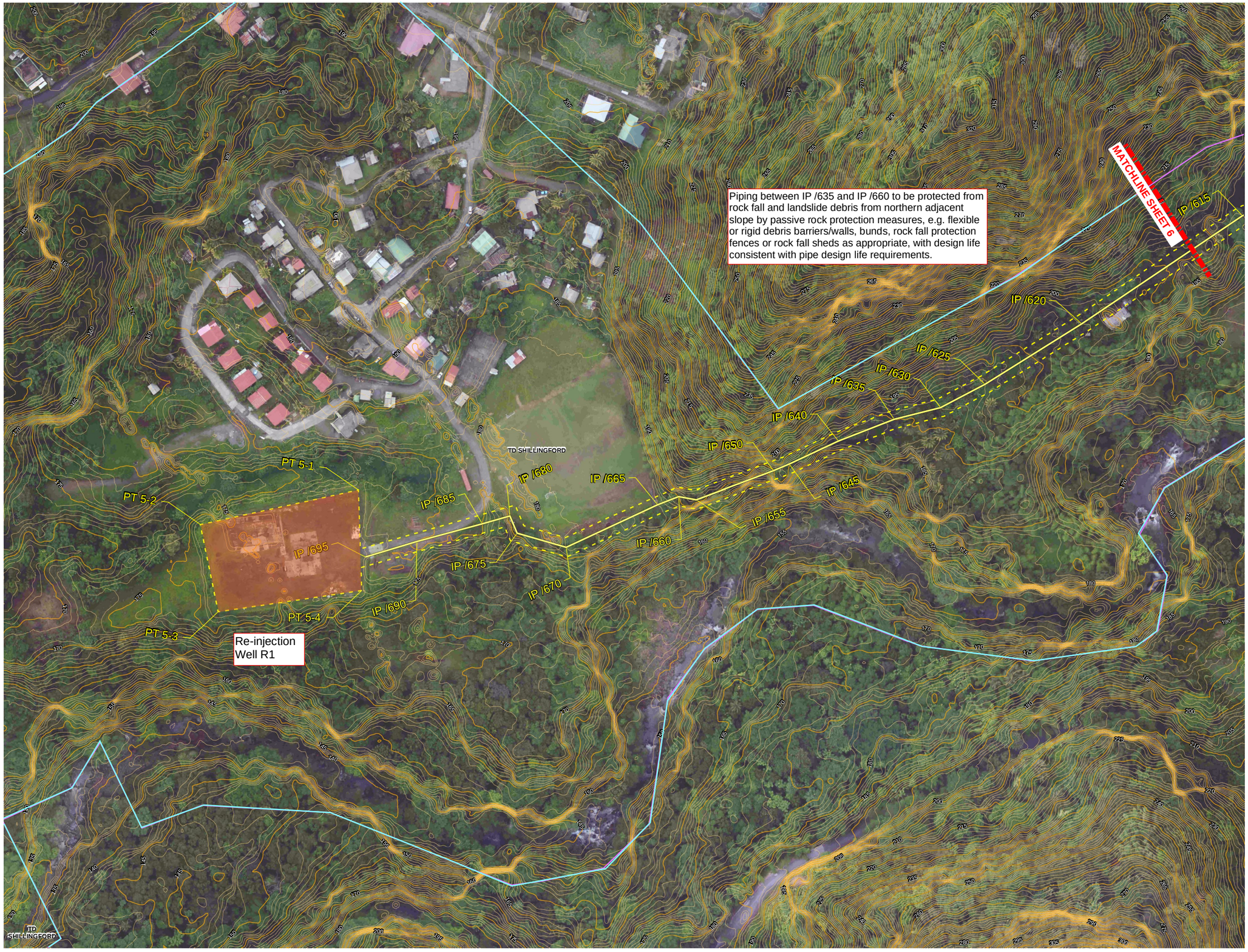
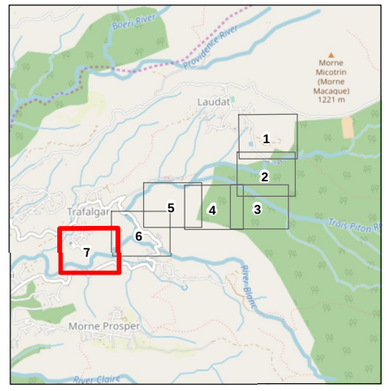



- Site
- Power Plant
- Laydown
- Camp
- Properties
- DOMLEC Pipeline
- Reinj. Route
- Road

Contours

- Major
- Minor

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**Brine Re-injection Pipeline**
**Sheet 7**
**RZ042100-ME-DRG-0100**

*CLIENT*
Dominica Geothermal Development Company

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Dominica Geothermal

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30/01/2019

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7

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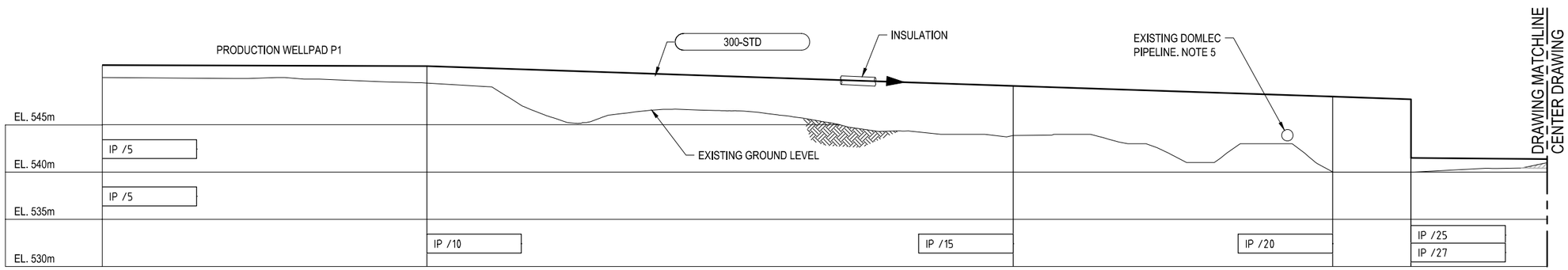
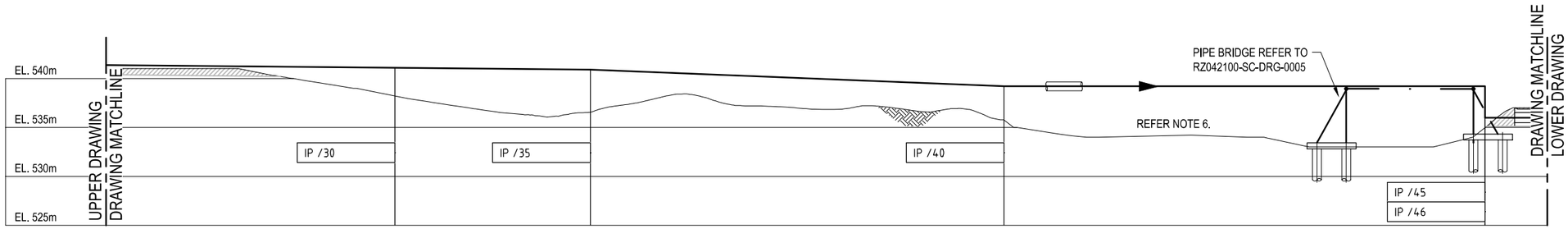
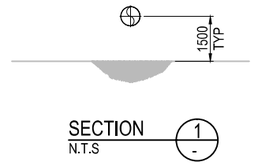
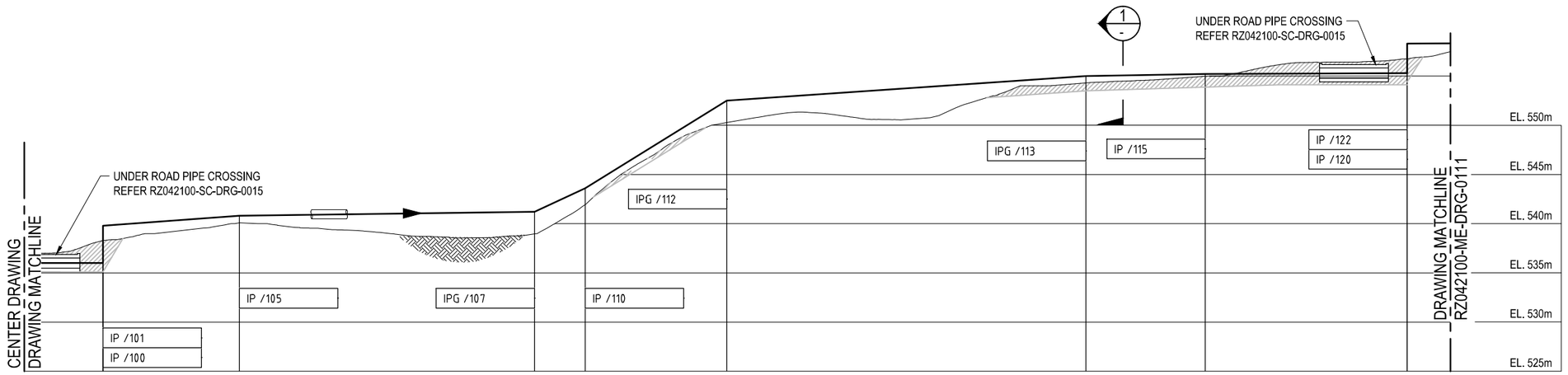
DATE: 30/01/2019 4:55:03 PM NAME: ROBERTSON, KAREN (NZ)
LOCATION: J:\RP\Projects\PIR\RZ042100\01_Design\Drawings\RZ042100-ME-DRG-0110.dwg




LONG SECTION
SCALE 1:250 (TYP)

| PIPELINE INFORMATION | | | |
|---|---|---|---|
| INT. POINT (I.P.) | NORTHING (m) | EASTING (m) | PIPE CL ELEV. (m) |
| IP /5 | 1 695 579.080 | 679 507.620 | 551.300 |
| IP /10 | 1 695 544.779 | 679 509.823 | 551.200 |
| IP /15 | 1 695 489.437 | 679 537.942 | 549.000 |
| IP /20 | 1 695 463.308 | 679 516.458 | 548.000 |
| IP /25 | 1 695 457.096 | 679 521.951 | 547.700 |
| IP /27 | 1 695 457.096 | 679 521.951 | 541.500 |
| IP /30 | 1 695 427.959 | 679 554.957 | 541.100 |
| IP /35 | 1 695 421.341 | 679 573.821 | 540.900 |
| IP /40 | 1 695 421.341 | 679 616.143 | 539.200 |
| IP /45 | 1 695 372.909 | 679 624.892 | 539.200 |
| IP /46 | 1 695 372.909 | 679 624.892 | 536.000 |
| IP /100 | 1 695 358.948 | 679 621.458 | 536.000 |
| IP /101 | 1 695 358.948 | 679 621.458 | 539.800 |
| IP /105 | 1 695 355.637 | 679 634.922 | 540.800 |
| IPG /107 | 1 695 326.348 | 679 641.415 | 541.200 |
| IP /110 | 1 695 321.317 | 679 642.530 | 543.600 |
| IPG /112 | 1 695 311.818 | 679 653.353 | 552.500 |
| IPG /113 | 1 695 287.740 | 679 680.785 | 555.000 |
| IP /115 | 1 695 279.732 | 679 689.909 | 555.200 |
| IP /120 | 1 695 294.438 | 679 704.246 | 555.300 |
| IP /122 | 1 695 294.438 | 679 704.246 | 558.300 |

SCALE 1:250 (ANSI D) 0 5 10 15 20 25m

ISSUED FOR BID

| REV | DATE | DRAWN | REV'D | APP'D | REVISION | DRAWING NUMBER | REFERENCE DRAWING TITLE |
|---|---|---|---|---|---|---|---|
| 1 | 30/01/19 | SM | LJS | LJS | GENERAL REVISION - ISSUED FOR BID | | |
| 0 | 31/07/18 | SM | LJS | LJS | ISSUED FOR BID | | |

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Fax: +64 9 928 5501
Web: www.jacobs.com

DGDC DRAWING NUMBER:

CLIENT: DOMINICA GEOTHERMAL DEVELOPMENT COMPANY
PROJECT: DOMINICA GEOTHERMAL POWER PLANT

| DRAWN | DRAWING CHECK | REVIEWED | APPROVED |
|---|---|---|---|
| SM | KR | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE 31/07/18 | DATE 31/07/18 |
| KR | SJP | | |

TITLE
BRINE RE-INJECTION PIPELINE
LONG SECTION - SHEET 1

| SCALE ON ANSI D | DRAWING No | REV |
|---|---|---|
| 1:250 | RZ042100-ME-DRG-0110 | 1 |

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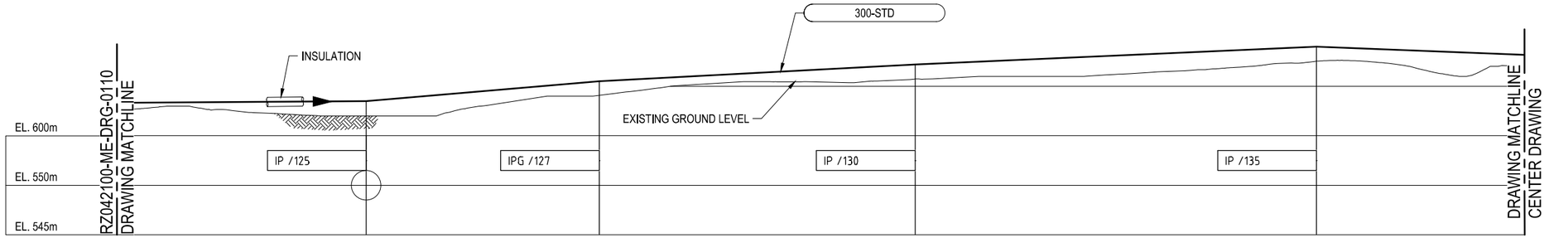
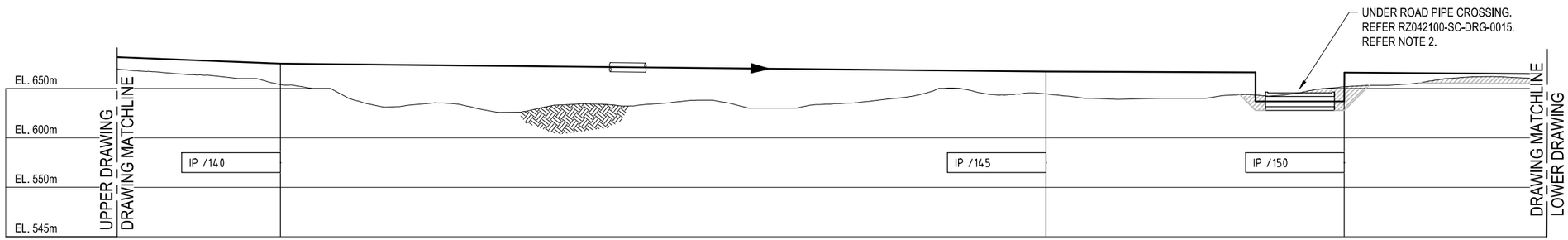
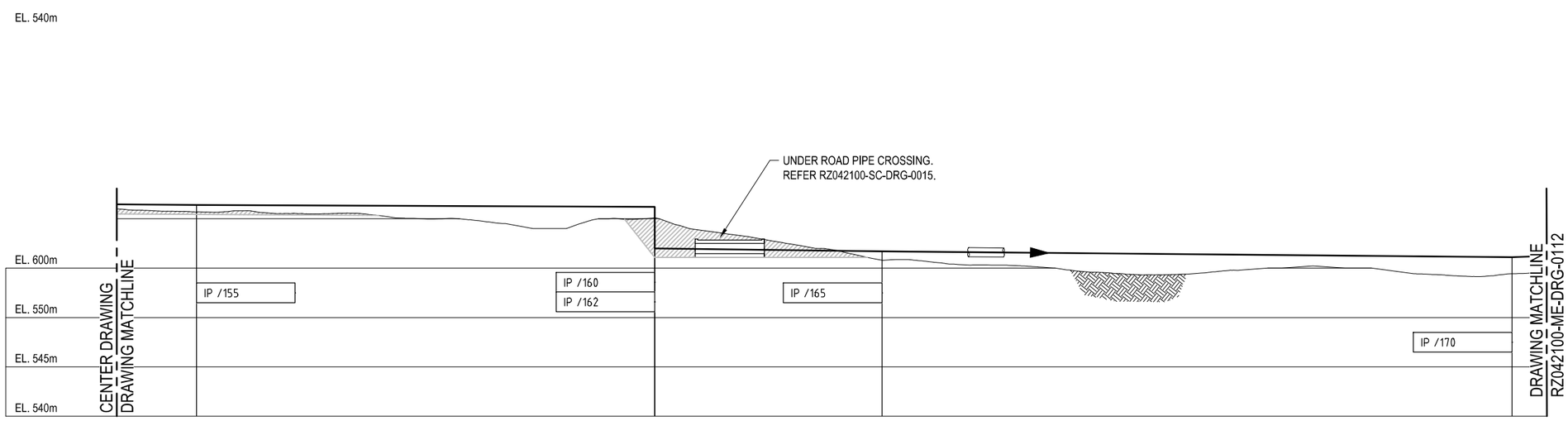
DATE: 30/01/2019 5:01:43 PM NAME: ROBERTSON, KAREN (NZ)
LOCATION: J:\RP\Projects\PIR\RZ042100\01_Design\Drawings\RZ042100-ME-DRG-0111.dwg




NOTES :

1. REFER SHEET RZ042100-ME-DRG-0110 FOR GENERAL NOTES.
2. PIPE CROSSING REQUIRED NEAR IP/150 TO PROVIDE VEHICLE ACCESS TO AERIAL TRAMWAY CARPARK.

PIPELINE INFORMATION

| INT. POINT (I.P.) | NORTHING (m) | EASTING (m) | PIPE CL ELEV. (m) |
|---|---|---|---|
| IP /125 | 1 695 273.741 | 679 725.477 | 558.500 |
| IPG /127 | 1 695 254.749 | 679 739.487 | 560.500 |
| IP /130 | 1 695 229.029 | 679 758.461 | 562.200 |
| IP /135 | 1 695 188.688 | 679 753.653 | 564.000 |
| IP /140 | 1 695 161.170 | 679 727.964 | 562.500 |
| IP /145 | 1 695 083.878 | 679 720.654 | 561.700 |
| IP /150 | 1 695 054.062 | 679 715.548 | 561.600 |
| IP /155 | 1 695 027.711 | 679 704.416 | 561.400 |
| IP /160 | 1 694 981.611 | 679 698.551 | 561.200 |
| IP /162 | 1 694 981.611 | 679 698.551 | 557.000 |
| IP /165 | 1 694 981.146 | 679 675.512 | 556.700 |
| IP /170 | 1 694 917.277 | 679 676.802 | 556.100 |

LONG SECTION
SCALE 1:250 (TYP)

SCALE 1:250 (ANSI D) 0 5 10 15 20 25m
5 4 3 2 1

ISSUED FOR BID

| REV | DATE | DRAWN | REV'D | APP'D | REVISION | DRAWING NUMBER | REFERENCE DRAWING TITLE |
|---|---|---|---|---|---|---|---|
| 1 | 30/01/19 | SM | LJS | LJS | GENERAL REVISION - ISSUED FOR BID | | |
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DGDC DRAWING NUMBER:

CLIENT: DOMINICA GEOTHERMAL DEVELOPMENT COMPANY
PROJECT: DOMINICA GEOTHERMAL POWER PLANT

| DRAWN | DRAWING CHECK | REVIEWED | APPROVED |
|---|---|---|---|
| SM | KR | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE 31/07/18 | DATE 31/07/18 |
| KR | SJP | | |

TITLE
BRINE RE-INJECTION PIPELINE
LONG SECTION - SHEET 2

SCALE ON ANSI D: 1:250
DRAWING No: RZ042100-ME-DRG-0111
REV: 1

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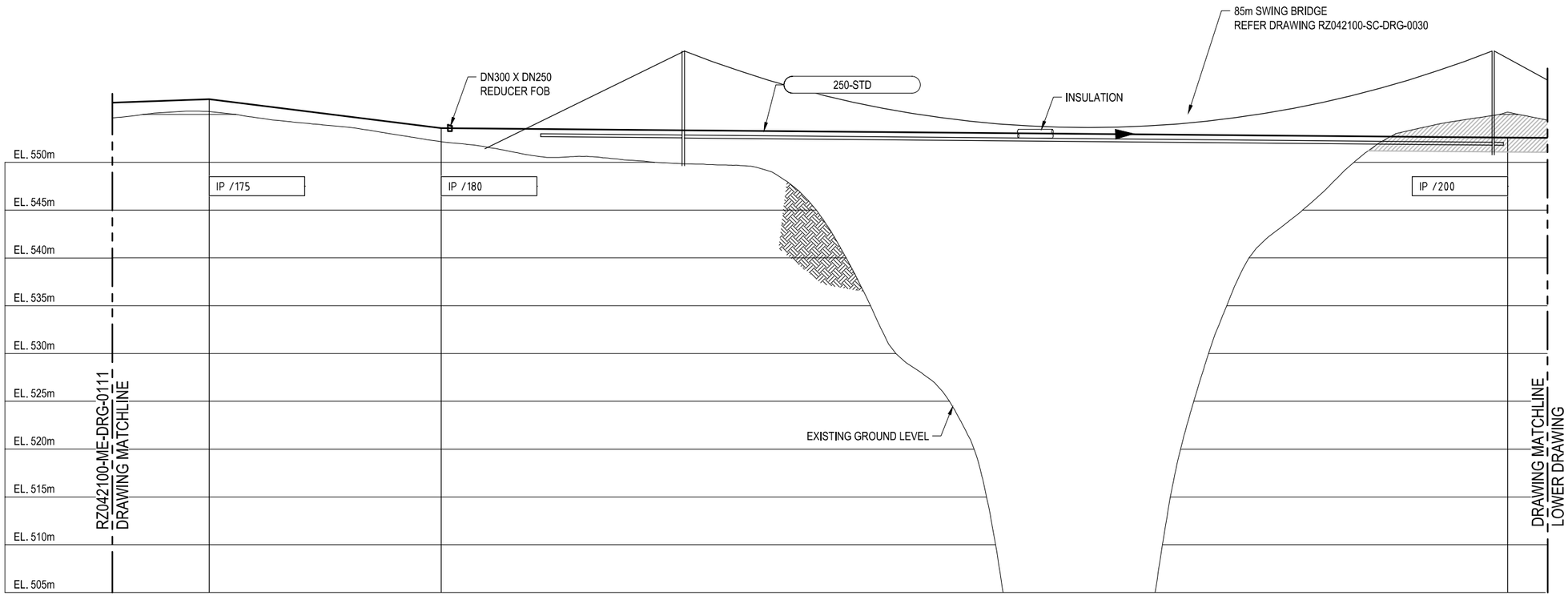
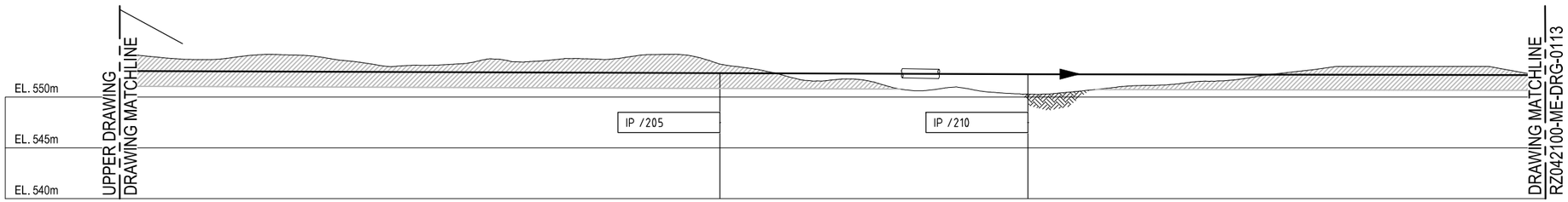
LOCATION: J:\RP\Projects\PIR\RZ042100\01_Design\Drawings\RZ042100-ME-DRG-0112.dwg

NOTES :

1. REFER SHEET RZ042100-ME-DRG-0110 FOR GENERAL NOTES.




PIPELINE INFORMATION

| INT. POINT (I.P.) | NORTHING (m) | EASTING (m) | PIPE CL ELEV. (m) |
|---|---|---|---|
| IP /175 | 1 694 905.071 | 679 670.645 | 556.595 |
| IP /180 | 1 694 912.591 | 679 647.553 | 553.572 |
| IP /200 | 1 694 817.379 | 679 589.311 | 552.572 |
| IP /205 | 1 694 840.601 | 679 530.648 | 552.333 |
| IP /210 | 1 694 844.638 | 679 500.673 | 552.243 |

LONG SECTION
SCALE 1:250 (TYP)

SCALE 1:250 (ANSI D) 0 5 10 15 20 25m

ISSUED FOR BID

| REV | DATE | DRAWN | REV'D | APP'D | REVISION |
|---|---|---|---|---|---|
| 1 | 30/01/19 | SM | LJS | LJS | GENERAL REVISION - ISSUED FOR BID |
| 0 | 31/07/18 | SM | LJS | LJS | ISSUED FOR BID |

DRAWING NUMBER | REFERENCE DRAWING TITLE

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Web: www.jacobs.com

DGDC DRAWING NUMBER:

CLIENT: DOMINICA GEOTHERMAL DEVELOPMENT COMPANY
PROJECT: DOMINICA GEOTHERMAL POWER PLANT

| DRAWN | DRAWING CHECK | REVIEWED | APPROVED |
|---|---|---|---|
| SM | KR | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE | DATE |
| KR | SJP | 31/07/18 | 31/07/18 |

TITLE
BRINE RE-INJECTION PIPELINE
LONG SECTION - SHEET 3

SCALE ON ANSI D: 1:250
DRAWING No: RZ042100-ME-DRG-0112
REV: 1

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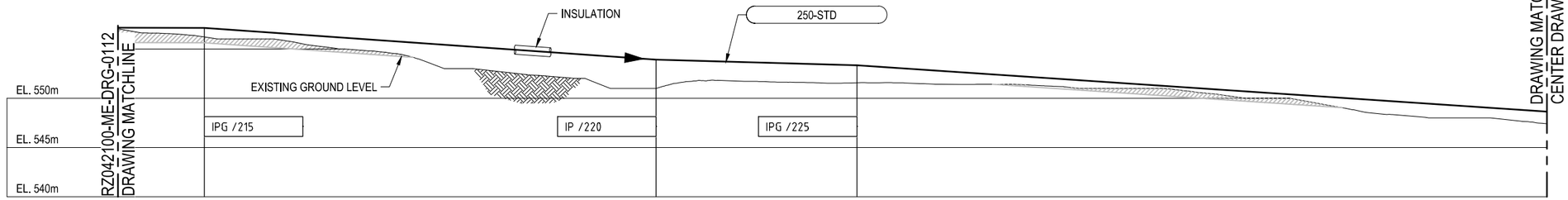
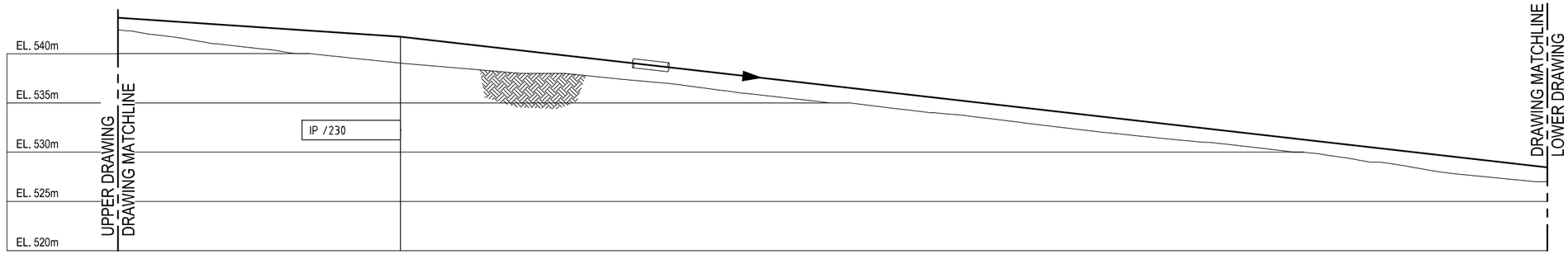
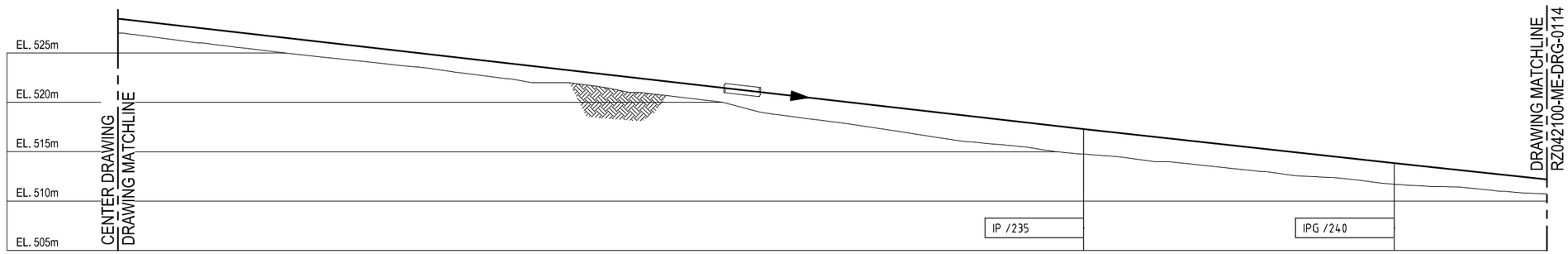
LOCATION: J:\RP\Projects\PIR\RZ042100\01_Design\Drawings\RZ042100-ME-DRG-0113.dwg




NOTES :

1. REFER SHEET RZ042100-ME-DRG-0110 FOR GENERAL NOTES.

| PIPELINE INFORMATION | | | |
|---|---|---|---|
| INT. POINT (I.P.) | NORTHING (m) | EASTING (m) | PIPE CL ELEV. (m) |
| IPG /215 | 1 694 855.600 | 679 442.108 | 552.135 |
| IP /220 | 1 694 864.034 | 679 397.050 | 548.917 |
| IPG /225 | 1 694 872.181 | 679 378.374 | 548.336 |
| IP /230 | 1 694 911.641 | 679 287.914 | 541.726 |
| IP /235 | 1 694 927.401 | 679 074.189 | 517.291 |
| IPG /240 | 1 694 924.201 | 679 042.852 | 513.845 |

## LONG SECTION
SCALE 1:250 (TYP)

SCALE 1:250 (ANSI D) 0 5 10 15 20 25m
5 4 3 2 1

ISSUED FOR BID

| REV | DATE | DRAWN | REV'D | APP'D | REVISION | DRAWING NUMBER | REFERENCE DRAWING TITLE |
|---|---|---|---|---|---|---|---|
| 1 | 30/01/19 | SM | LJS | LJS | GENERAL REVISION - ISSUED FOR BID | | |
| 0 | 31/07/18 | SM | LJS | LJS | ISSUED FOR BID | | |

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DGDC DRAWING NUMBER:

CLIENT: DOMINICA GEOTHERMAL DEVELOPMENT COMPANY
PROJECT: DOMINICA GEOTHERMAL POWER PLANT

| DRAWN | DRAWING CHECK | REVIEWED | APPROVED |
|---|---|---|---|
| SM | KR | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE 31/07/18 | DATE 31/07/18 |
| KR | SJP | | |

TITLE
BRINE RE-INJECTION PIPELINE
LONG SECTION - SHEET 4

| SCALE ON ANSI D | DRAWING No | REV |
|---|---|---|
| 1:250 | RZ042100-ME-DRG-0113 | 1 |

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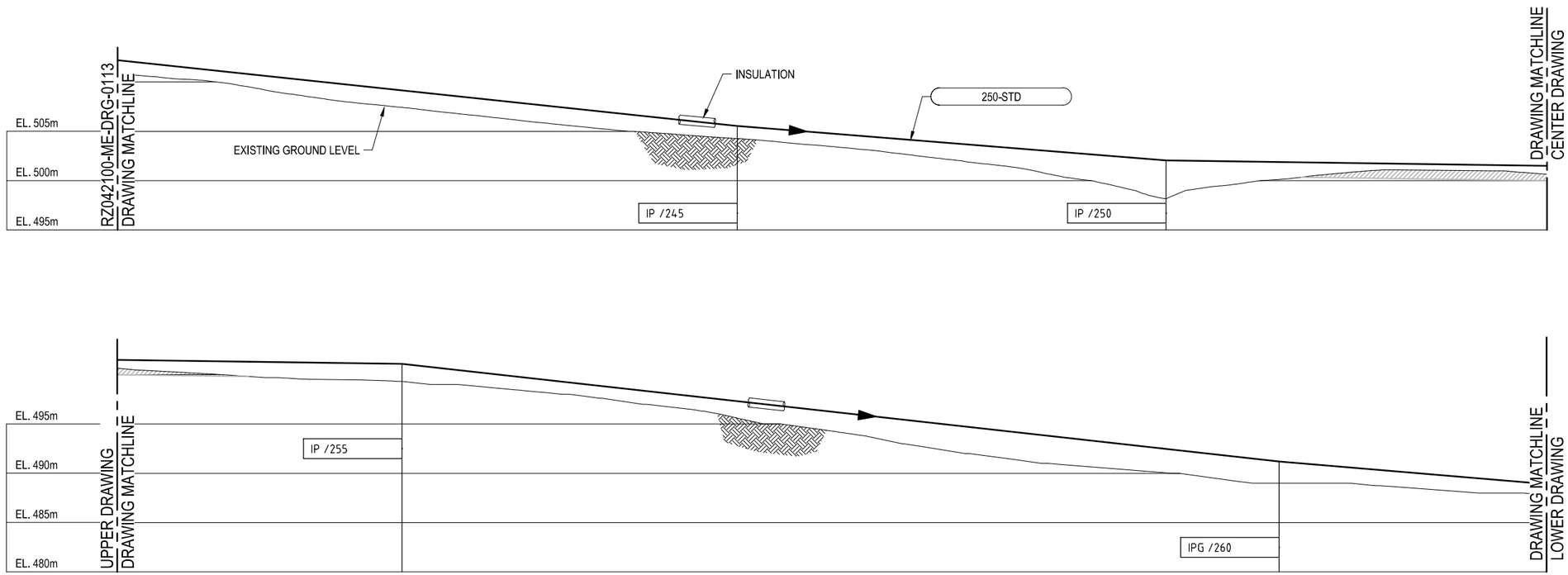
LOCATION: J:\RP\Projects\PIR\RZ042100\01_Design\Drawings\RZ042100-ME-DRG-0114.dwg

NOTES :

1. REFER SHEET RZ042100-ME-DRG-0110 FOR GENERAL NOTES.




| PIPELINE INFORMATION | | | |
|---|---|---|---|
| INT. POINT (I.P.) | NORTHING (m) | EASTING (m) | PIPE CL ELEV. (m) |
| IP /245 | 1 694 916.236 | 678 964.855 | 505.546 |
| IP /250 | 1 694 926.398 | 678 922.568 | 502.041 |
| IP /255 | 1 694 864.534 | 678 895.504 | 501.092 |
| IPG /260 | 1 694 856.065 | 678 806.908 | 491.194 |
| IPG /265 | 1 694 850.736 | 678 751.162 | 486.499 |
| IP /270 | 1 694 843.869 | 678 679.328 | 477.513 |
| IPG /275 | 1 694 878.779 | 678 664.318 | 474.255 |

LONG SECTION
SCALE 1:250 (TYP)

SCALE 1:250 (ANSI D) 0 5 10 15 20 25m
5 4 3 2 1

ISSUED FOR BID

| REV | DATE | DRAWN | REV'D | APP'D | REVISION | DRAWING NUMBER | REFERENCE DRAWING TITLE |
|---|---|---|---|---|---|---|---|
| 1 | 30/01/19 | SM | LJS | LJS | GENERAL REVISION - ISSUED FOR BID | | |
| 0 | 31/07/18 | SM | LJS | LJS | ISSUED FOR BID | | |

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DGDC DRAWING NUMBER:

CLIENT: DOMINICA GEOTHERMAL DEVELOPMENT COMPANY
PROJECT: DOMINICA GEOTHERMAL POWER PLANT

| DRAWN | DRAWING CHECK | REVIEWED | APPROVED |
|---|---|---|---|
| SM | KR | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE 31/07/18 | DATE 31/07/18 |
| KR | SJP | | |

TITLE
BRINE RE-INJECTION PIPELINE
LONG SECTION - SHEET 5

| SCALE ON ANSI D | DRAWING No. | REV |
|---|---|---|
| 1:250 | RZ042100-ME-DRG-0114 | 1 |

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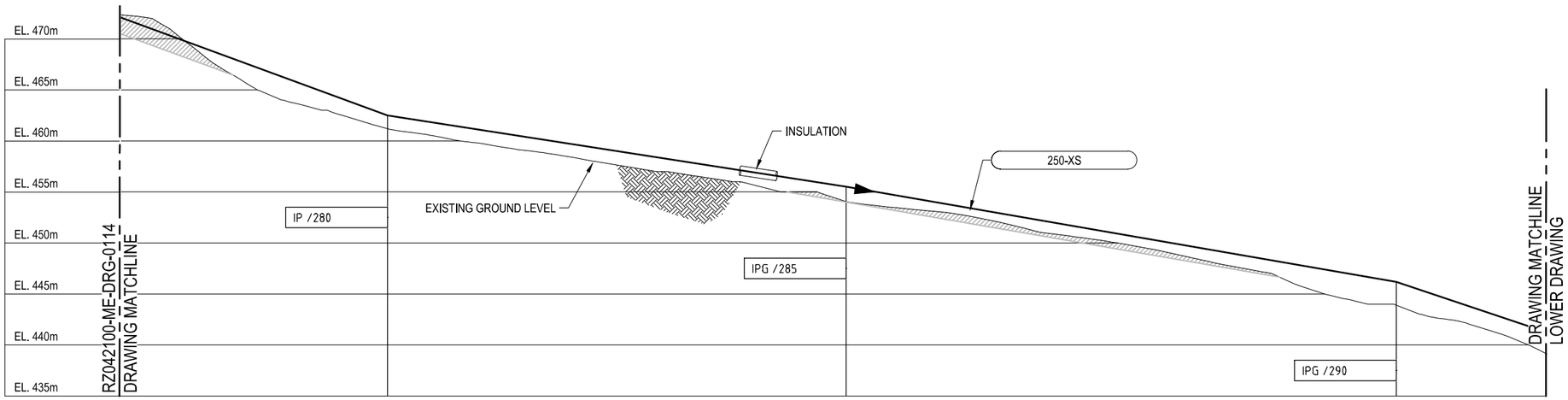


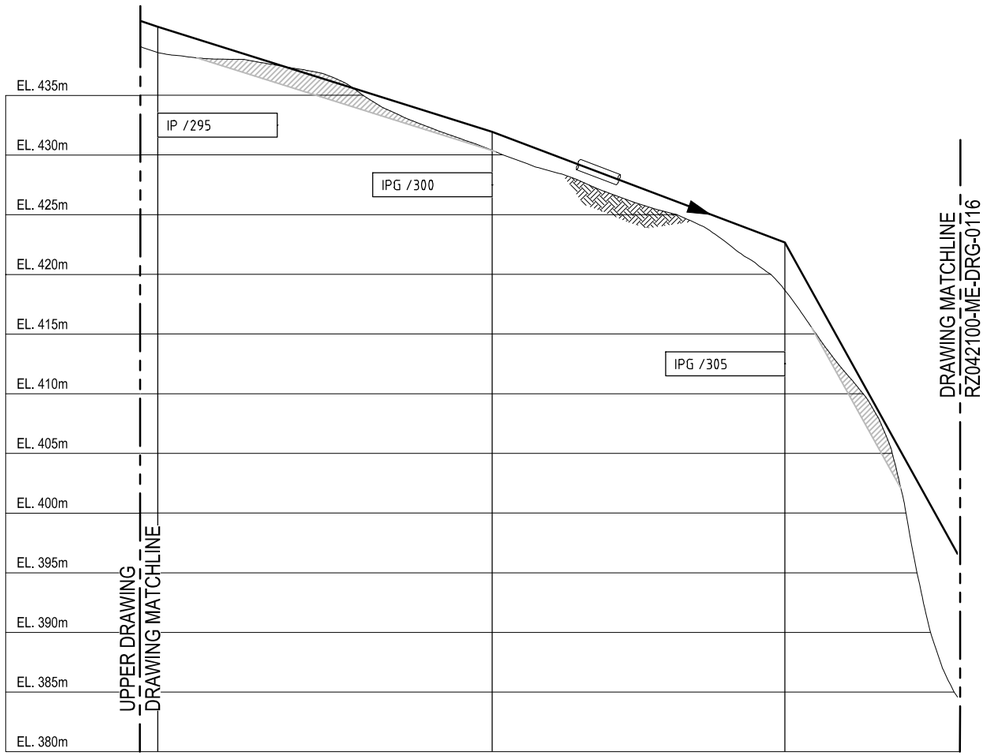


LONG SECTION
SCALE 1:250 (TYP)

NOTES :

1. REFER SHEET RZ042100-ME-DRG-0110 FOR GENERAL NOTES.

| PIPELINE INFORMATION | | | |
|---|---|---|---|
| INT. POINT (I.P.) | NORTHING (m) | EASTING (m) | PIPE CL ELEV. (m) |
| IP /280 | 1 694 908.299 | 678 651.626 | 462.504 |
| IPG /285 | 1 694 927.405 | 678 610.883 | 455.518 |
| IPG /290 | 1 694 950.331 | 678 561.991 | 446.189 |
| IP /295 | 1 694 957.248 | 678 547.239 | 440.732 |
| IPG /300 | 1 694 946.331 | 678 521.455 | 431.940 |
| IPG /305 | 1 694 936.764 | 678 498.860 | 422.674 |

SCALE 1:250 (ANSI D) 0 5 10 15 20 25m

ISSUED FOR BID

| REV | DATE | DRAWN | REVD | APPD | REVISION |
|---|---|---|---|---|---|
| 1 | 30/01/19 | SM | LJS | LJS | GENERAL REVISION - ISSUED FOR BID |
| 0 | 31/07/18 | SM | LJS | LJS | ISSUED FOR BID |

DRAWING NUMBER | REFERENCE DRAWING TITLE

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Web: www.jacobs.com

DGDC DRAWING NUMBER:

CLIENT: DOMINICA GEOTHERMAL DEVELOPMENT COMPANY
PROJECT: DOMINICA GEOTHERMAL POWER PLANT

| DRAWN | DRAWING CHECK | REVIEWED | APPROVED |
|---|---|---|---|
| SM | KR | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE 31/07/18 | DATE 31/07/18 |
| KR | SJP | | |

TITLE: BRINE RE-INJECTION PIPELINE
LONG SECTION - SHEET 6

SCALE ON ANSI D: 1:250
DRAWING No: RZ042100-ME-DRG-0115
REV: 1

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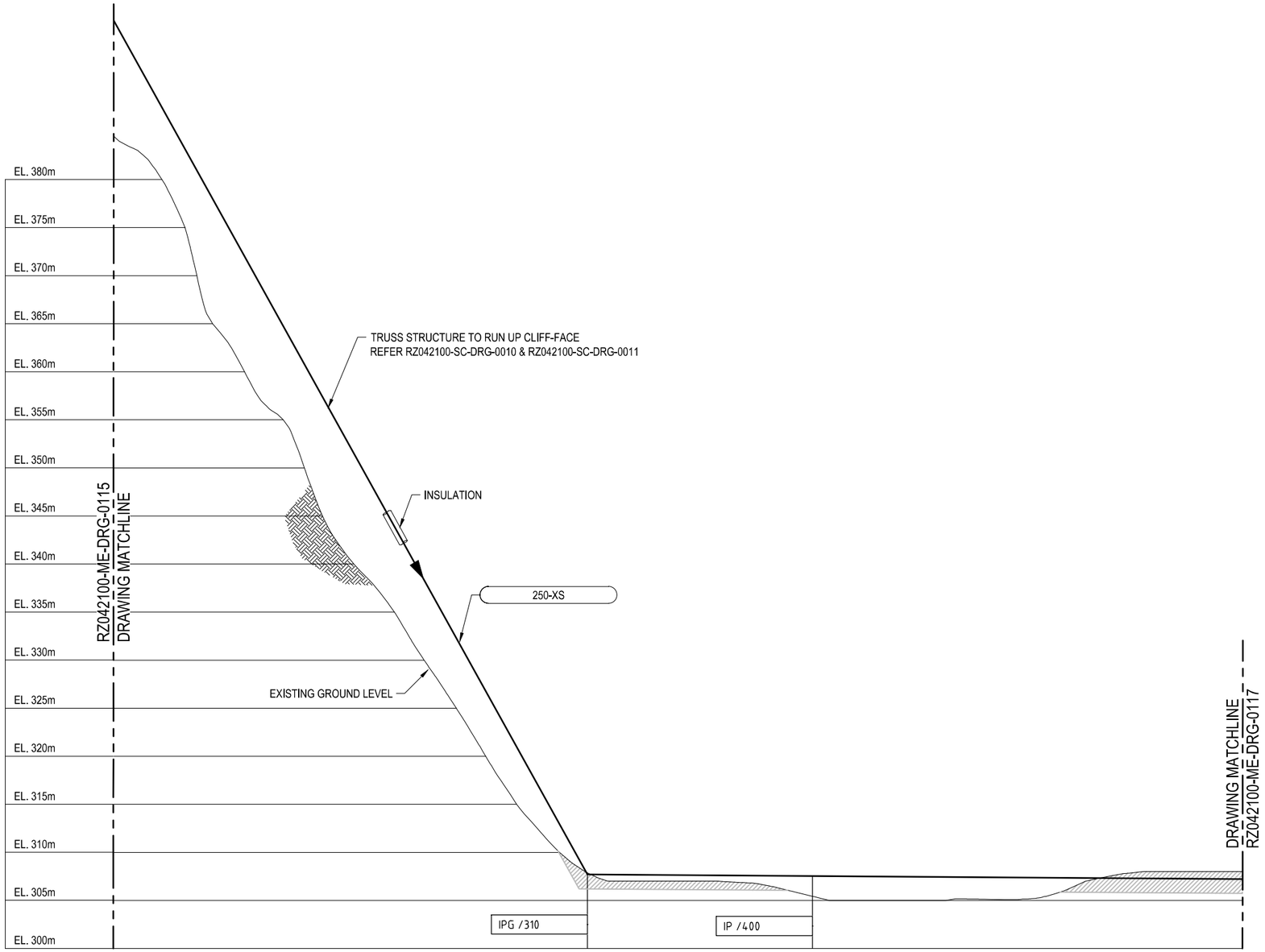
LOCATION: J:\RP\Projects\PIR\RZ042100\01_Design\Drawings\RZ042100-ME-DRG-0116.dwg

NOTES :

1. REFER SHEET RZ042100-ME-DRG-0110 FOR GENERAL NOTES.




LONG SECTION
SCALE 1:250 (TYP)

| PIPELINE INFORMATION | | | |
|---|---|---|---|
| INT. POINT (I.P.) | NORTHING (m) | EASTING (m) | PIPE CL ELEV. (m) |
| IPG /310 | 1 694 911.895 | 678 440.122 | 307.704 |
| IP /400 | 1 694 902.776 | 678 418.583 | 307.540 |

SCALE 1:250 (ANSI D) 0 5 10 15 20 25m

ISSUED FOR BID

| REV | DATE | DRAWN | REVD | APPD | REVISION |
|---|---|---|---|---|---|
| 1 | 30/01/19 | SM | LJS | LJS | GENERAL REVISION - ISSUED FOR BID |
| 0 | 31/07/18 | SM | LJS | LJS | ISSUED FOR BID |

DRAWING NUMBER | REFERENCE DRAWING TITLE

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Tel: +64 9 928 5500
Fax: +64 9 928 5501
Web: www.jacobs.com

DGDC DRAWING NUMBER:

CLIENT: DOMINICA GEOTHERMAL DEVELOPMENT COMPANY
PROJECT: DOMINICA GEOTHERMAL POWER PLANT

| DRAWN | DRAWING CHECK | REVIEWED | APPROVED |
|---|---|---|---|
| SM | KR | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE 31/07/18 | DATE 31/07/18 |
| KR | SJP | | |

TITLE
BRINE RE-INJECTION PIPELINE
LONG SECTION - SHEET 7

SCALE ON ANSI D: 1:250
DRAWING No: RZ042100-ME-DRG-0116
REV: 0

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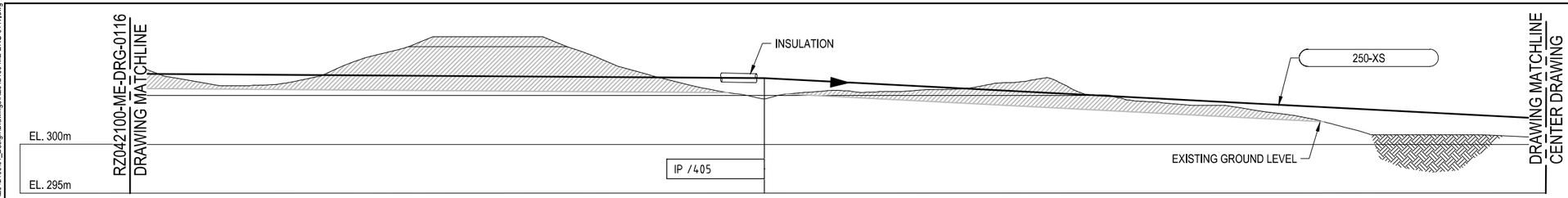


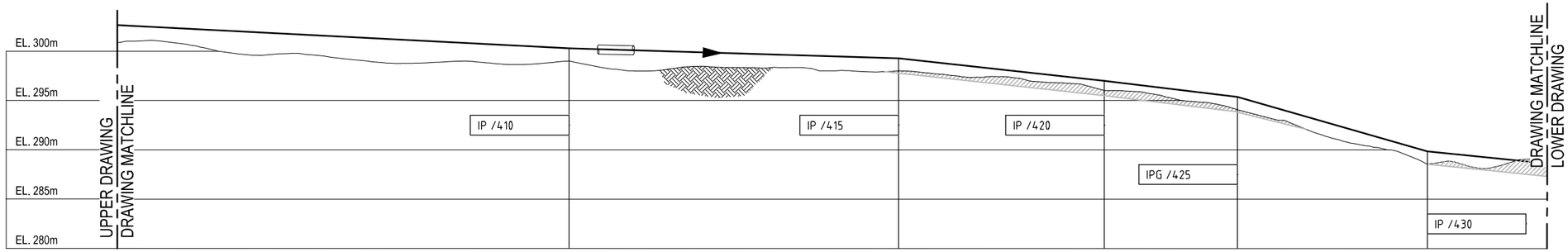


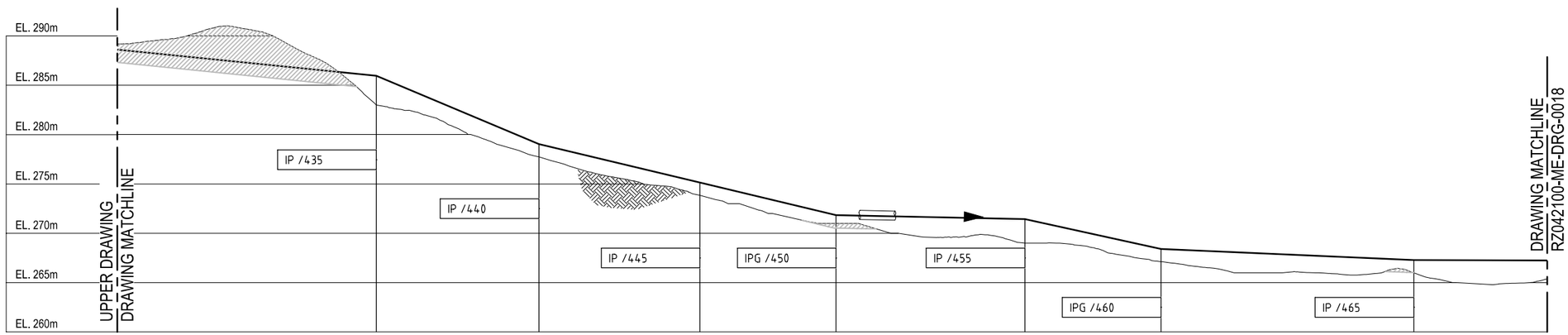


LONG SECTION
SCALE 1:250 (TYP)

NOTES :

1. REFER SHEET RZ042100-ME-DRG-0110 FOR GENERAL NOTES.

| PIPELINE INFORMATION | | | |
|---|---|---|---|
| INT. POINT (I.P.) | NORTHING (m) | EASTING (m) | PIPE CL ELEV. (m) |
| IP /405 | 1 694 824.342 | 678 341.838 | 306.770 |
| IP /410 | 1 694 703.746 | 678 377.762 | 300.289 |
| IP /415 | 1 694 685.578 | 678 349.708 | 299.271 |
| IP /420 | 1 694 679.635 | 678 329.712 | 297.000 |
| IPG /425 | 1 694 671.248 | 678 319.134 | 295.363 |
| IP /430 | 1 694 659.283 | 678 304.044 | 289.847 |
| IP /435 | 1 694 630.773 | 678 329.789 | 285.951 |
| IP /440 | 1 694 627.025 | 678 345.851 | 279.027 |
| IP /445 | 1 694 617.315 | 678 358.982 | 275.145 |
| IPG /450 | 1 694 605.033 | 678 365.274 | 271.840 |
| IP /455 | 1 694 587.989 | 678 374.005 | 271.437 |
| IPG /460 | 1 694 574.841 | 678 378.198 | 268.418 |
| IP /465 | 1 694 550.422 | 678 385.986 | 267.301 |

SCALE 1:250 (ANSI D) 0 5 10 15 20 25m

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Web: www.jacobs.com

DGDC DRAWING NUMBER:

CLIENT: DOMINICA GEOTHERMAL DEVELOPMENT COMPANY
PROJECT: DOMINICA GEOTHERMAL POWER PLANT

| DRAWN | DRAWING CHECK | REVIEWED | APPROVED |
|---|---|---|---|
| SM | KR | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE | DATE |
| KR | SJP | 31/07/18 | 31/07/18 |

TITLE: BRINE RE-INJECTION PIPELINE
LONG SECTION - SHEET 8

SCALE ON ANSI D: 1:250
DRAWING No: RZ042100-ME-DRG-0117
REV: 1

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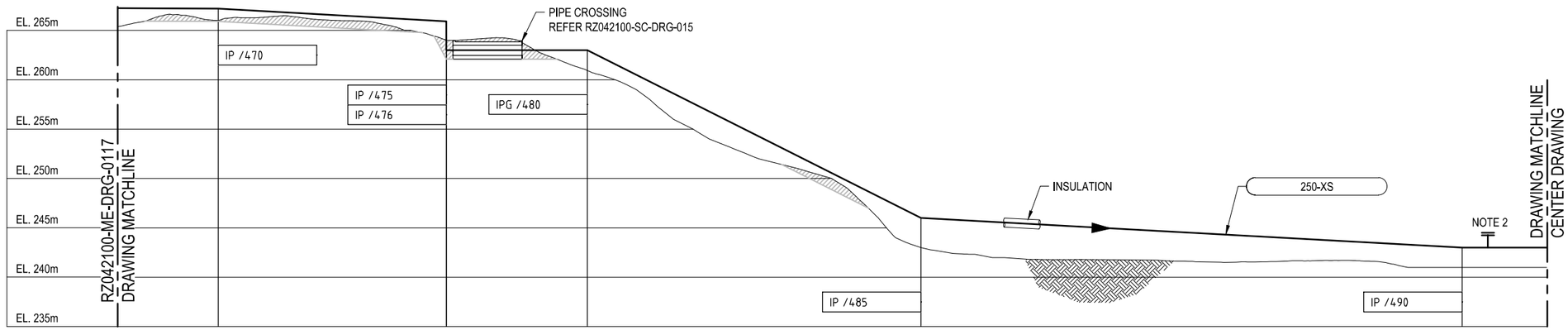


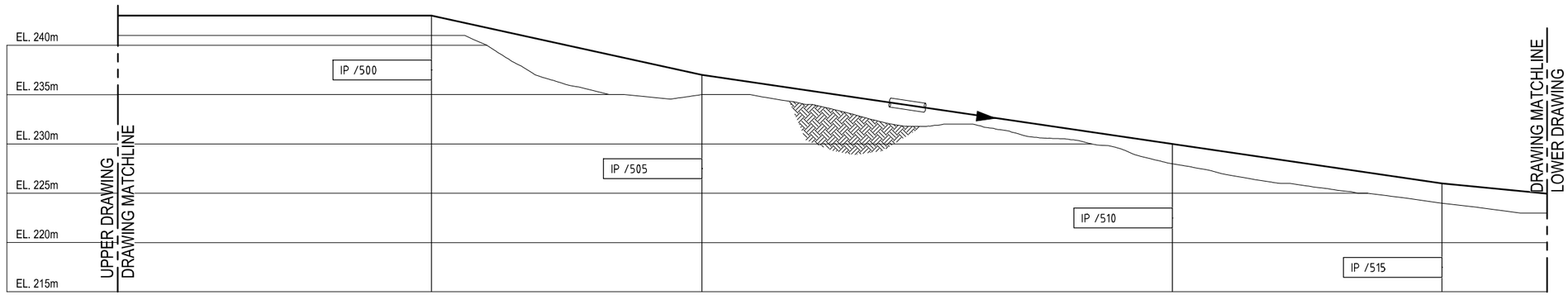


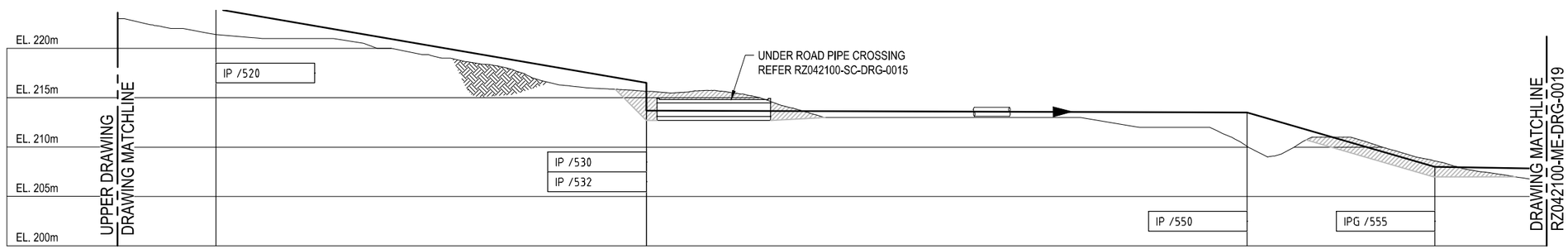


## NOTES :

1. REFER SHEET RZ042100-ME-DRG-0110 FOR GENERAL NOTES.
2. TAKE-OFF POINT FOR WW-01 RE-INJECTION BRANCH LINE.

| PIPELINE INFORMATION | | | |
|---|---|---|---|
| INT. POINT (I.P.) | NORTHING (m) | EASTING (m) | PIPE CL ELEV. (m) |
| IP /470 | 1 694 527.291 | 678 380.696 | 267.195 |
| IP /475 | 1 694 504.263 | 678 383.111 | 265.921 |
| IP /476 | 1 694 504.263 | 678 383.111 | 262.995 |
| IPG /480 | 1 694 502.719 | 678 368.894 | 262.995 |
| IP /485 | 1 694 499.041 | 678 335.246 | 246.000 |
| IP /490 | 1 694 543.690 | 678 303.279 | 243.000 |
| IP /500 | 1 694 520.162 | 678 270.428 | 243.000 |
| IP /505 | 1 694 514.166 | 678 243.651 | 237.000 |
| IP /510 | 1 694 546.923 | 678 208.939 | 230.000 |
| IP /515 | 1 694 561.635 | 678 185.880 | 226.000 |
| IP /520 | 1 694 570.435 | 678 167.187 | 224.000 |
| IP /530 | 1 694 558.709 | 678 125.135 | 216.500 |
| IP /532 | 1 694 558.709 | 678 125.135 | 213.700 |
| IP /550 | 1 694 505.327 | 678 095.726 | 213.500 |
| IPG /555 | 1 694 507.363 | 678 076.775 | 208.000 |

## LONG SECTION
SCALE 1:250 (TYP)

SCALE 1:250 (ANSI D) 0 5 10 15 20 25m (5 4 3 2 1)

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DGDC DRAWING NUMBER:

CLIENT: DOMINICA GEOTHERMAL DEVELOPMENT COMPANY
PROJECT: DOMINICA GEOTHERMAL POWER PLANT

| DRAWN | DRAWING CHECK | REVIEWED | APPROVED |
|---|---|---|---|
| SM | KR | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE 31/07/18 | DATE 31/07/18 |
| KR | SJP | | |

TITLE: BRINE RE-INJECTION PIPELINE
LONG SECTION - SHEET 9

SCALE ON ANSI D: 1:250
DRAWING No: RZ042100-ME-DRG-0118
REV: 1

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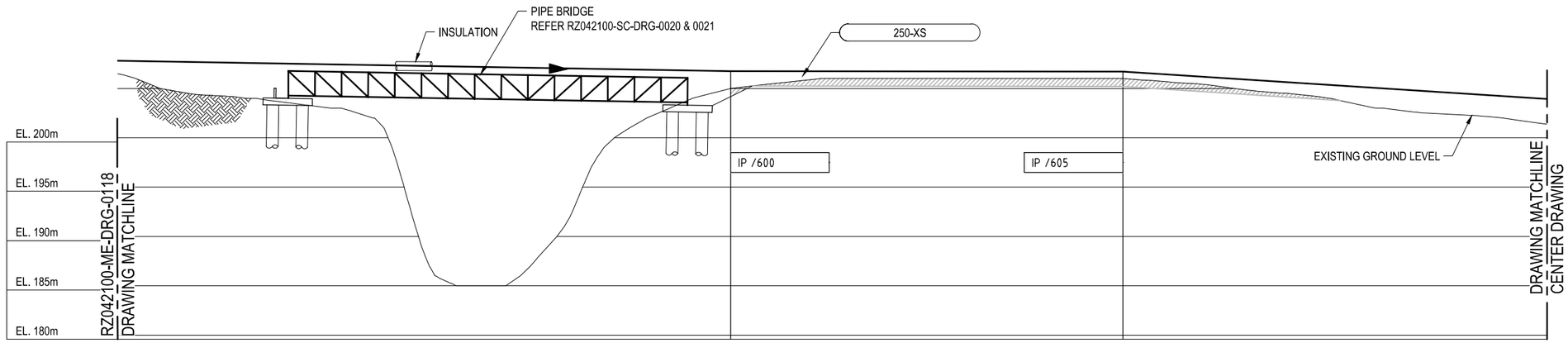


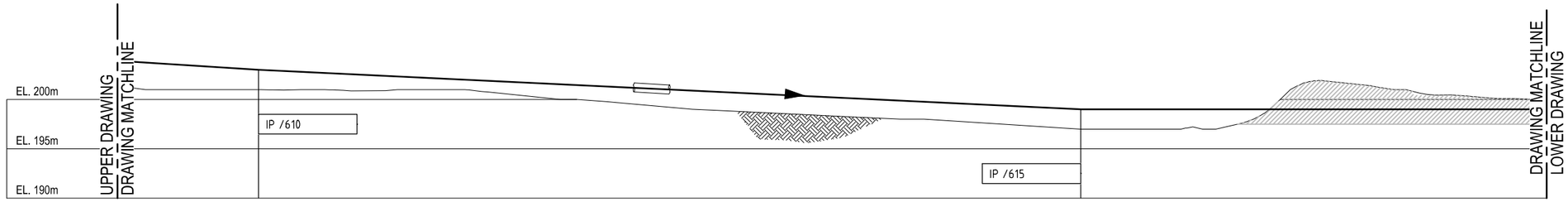


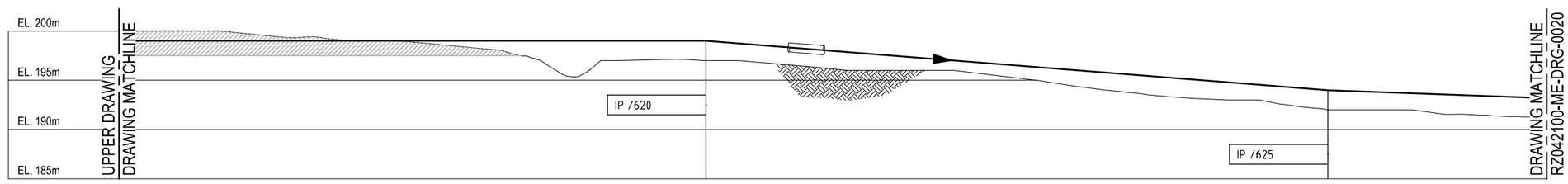


## LONG SECTION
SCALE 1:250 (TYP)

NOTES :

1. REFER SHEET RZ042100-ME-DRG-0110 FOR GENERAL NOTES.

| PIPELINE INFORMATION | | | |
|---|---|---|---|
| INT. POINT (I.P.) | NORTHING (m) | EASTING (m) | PIPE CL ELEV. (m) |
| IP /600 | 1 694 515.217 | 678 003.651 | 206.750 |
| IP /605 | 1 694 524.356 | 677 964.930 | 206.700 |
| IP /610 | 1 694 521.856 | 677 907.651 | 203.000 |
| IP /615 | 1 694 490.819 | 677 830.237 | 199.000 |
| IP /620 | 1 694 431.013 | 677 741.651 | 199.000 |
| IP /625 | 1 694 397.635 | 677 688.018 | 194.000 |

SCALE 1:250 (ANSI D) 0 5 10 15 20 25m

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PROJECT: DOMINICA GEOTHERMAL POWER PLANT

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|---|---|---|---|
| SM | KR | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE 31/07/18 | DATE 31/07/18 |
| KR | SJP | | |

TITLE
BRINE RE-INJECTION PIPELINE
LONG SECTION - SHEET 10

SCALE ON ANSI D: 1:250
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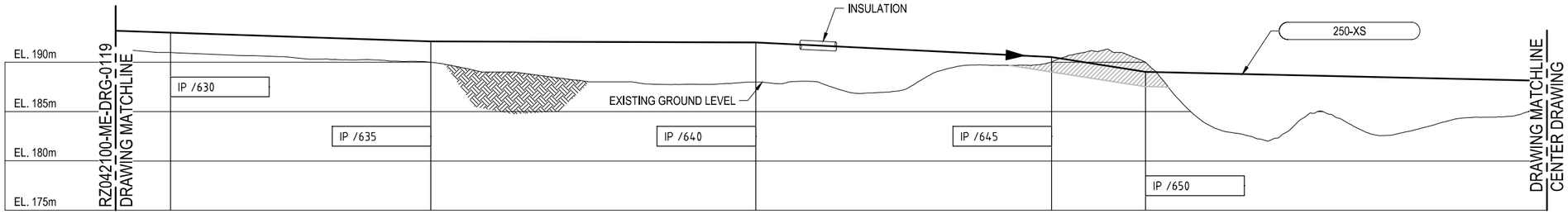


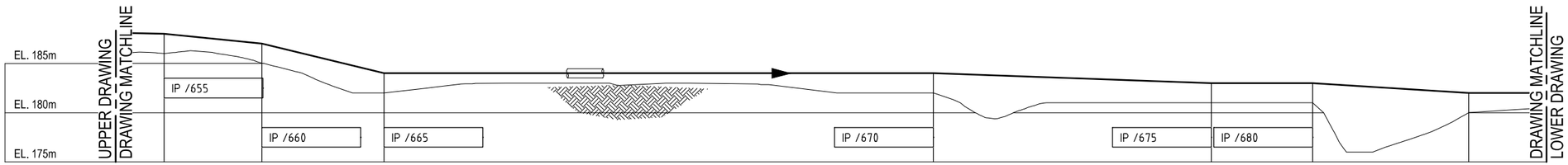


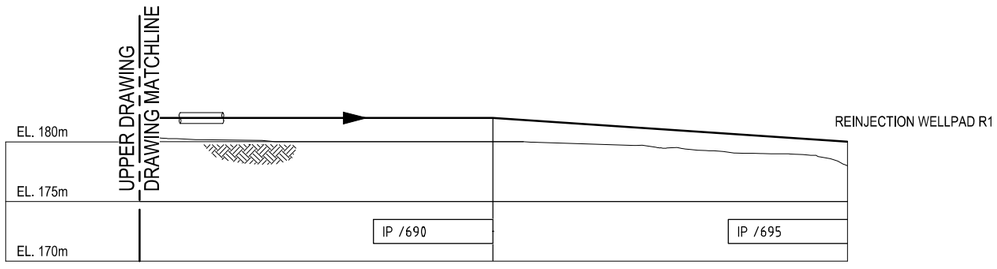


LONG SECTION
SCALE 1:250 (TYP)

NOTES :

1. REFER SHEET RZ042100-ME-DRG-0110 FOR GENERAL NOTES.
2. PIPING BETWEEN IP635 AND IP660 IS TO BE PROTECTED FROM ROCK FALL AND LANDSLIDE DEBRIS FROM NORTHERN ADJACENT SLOPE BY PASSIVE ROCK FALL PROTECTION MEASURES; e.g. FLEXIBLE OR RIGID DEBRIS BARRIERS/WALLS, BUNDS, ROCK FALL PROTECTION FENCES OR ROCK FALL SHEDS AS APPROPRIATE, WITH DESIGN LIFE CONSISTENT WITH PIPE DESIGN LIFE REQUIREMENTS.

| PIPELINE INFORMATION | | | |
|---|---|---|---|
| INT. POINT (I.P.) | NORTHING (m) | EASTING (m) | PIPE CL ELEV. (m) |
| IP /630 | 1 694 384.635 | 677 663.476 | 193.000 |
| IP /635 | 1 694 378.187 | 677 637.882 | 192.100 |
| IP /640 | 1 694 366.244 | 677 607.198 | 192.000 |
| IP /645 | 1 694 353.453 | 677 580.080 | 190.532 |
| IP /650 | 1 694 349.870 | 677 571.250 | 189.032 |
| IP /655 | 1 694 333.959 | 677 528.500 | 188.000 |
| IP /660 | 1 694 335.665 | 677 518.741 | 187.000 |
| IP /665 | 1 694 331.183 | 677 507.199 | 184.000 |
| IP /670 | 1 694 307.788 | 677 456.698 | 184.000 |
| IP /675 | 1 694 315.519 | 677 429.607 | 183.000 |
| IP /680 | 1 694 324.999 | 677 425.651 | 183.000 |
| IP /685 | 1 694 320.751 | 677 410.420 | 182.000 |
| IP /690 | 1 694 310.976 | 677 374.310 | 182.000 |
| IP /695 | 1 694 302.456 | 677 345.830 | 180.000 |

SCALE 1:250 (ANSI D) 0 5 10 15 20 25m
5 4 3 2 1

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|---|---|---|---|---|---|
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|---|---|---|---|
| SM | KR | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE 31/07/18 | DATE 31/07/18 |
| KR | SJP | | |

TITLE
BRINE RE-INJECTION PIPELINE
LONG SECTION - SHEET 11

| SCALE ON ANSI D | DRAWING No | REV |
|---|---|---|
| 1:250 | RZ042100-ME-DRG-0120 | 1 |

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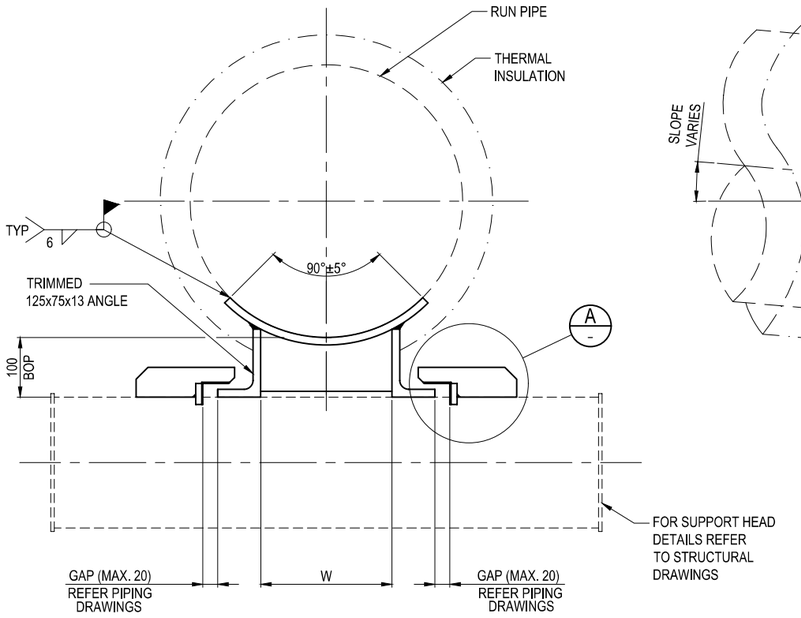


END VIEW
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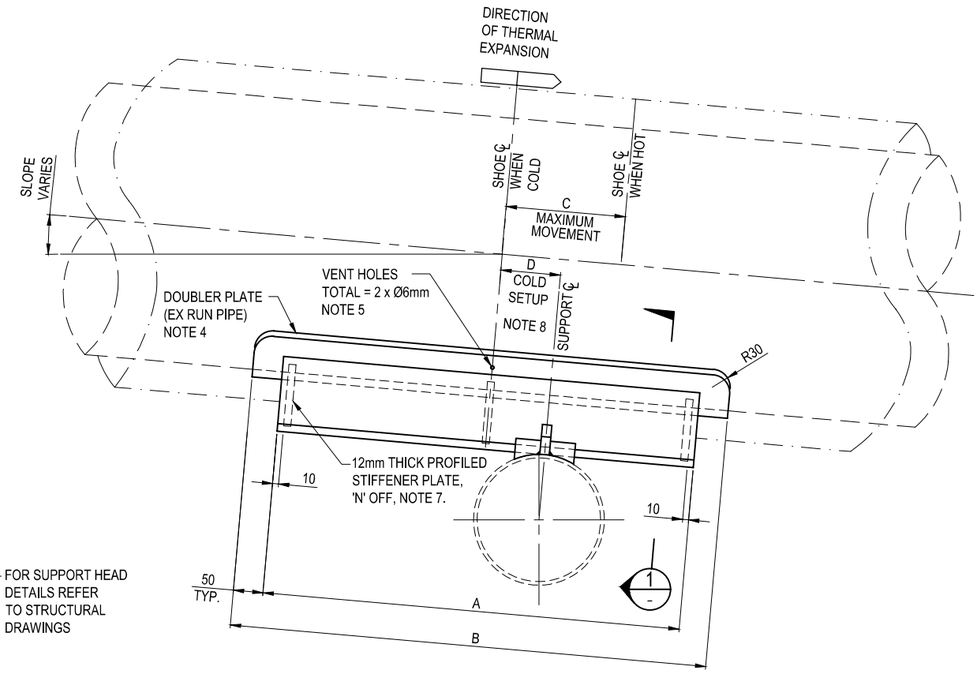
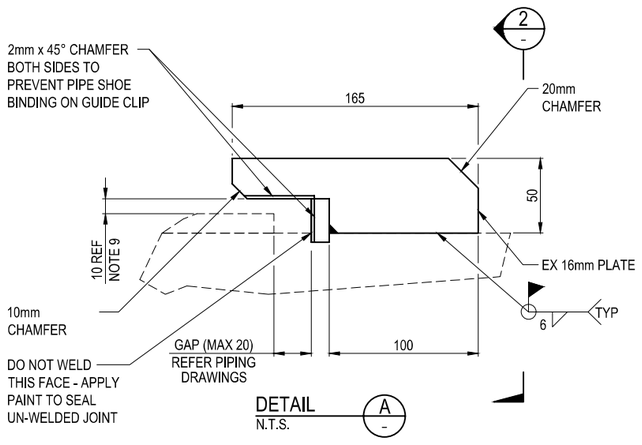
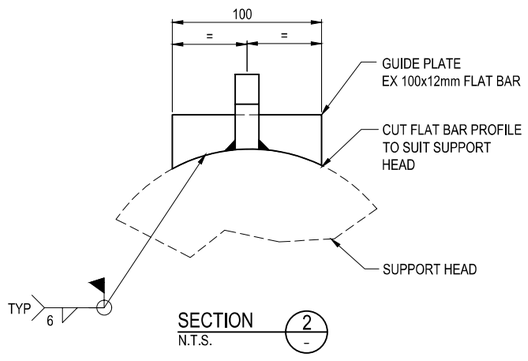



SIDE VIEW
N.T.S.

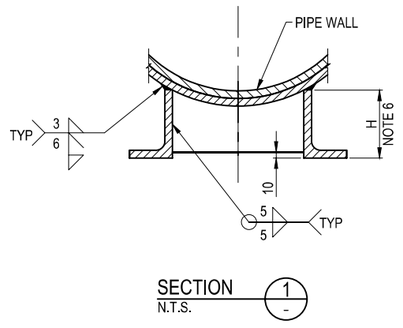
## PIPE SHOE - TYPE GV




DETAIL A
N.T.S.




SECTION 2
N.T.S.




SECTION 1
N.T.S.

## GUIDE CLIPS

### CORROSION PROTECTION:

THE PIPE SHOE SHALL BE PAINTED PRIOR TO INSTALLATION ON THE PIPELINE.

A 20mm WIDE STRIP AROUND EDGE OF DOUBLER PLATE SHALL BE LEFT UN-PAINTED FOR WELDING TO PIPE.

### NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS NOTED OTHERWISE.
2. ALL JOINTS TO BE WELDED 6mm FILLET WELD ALL AROUND UNLESS NOTED OTHERWISE.
3. STEEL PLATE AND STEEL SECTION MATERIAL TO BE TO ASTM A36 OR APPROVED EQUIVALENT WITH YIELD STRENGTH OF 36 ksi (250 MPa) MINIMUM.
4. DOUBLER PLATES TO BE SAME MATERIAL AND THICKNESS AS PIPE.
5. VENT HOLES REQUIRED ON DOUBLER PLATE ONLY.
6. DIMENSION 'H' VARIES DEPENDING ON THE THICKNESS OF THE REINFORCING PAD. ANGLES MUST BE TRIMMED TO SUIT.
7. PROFILE STIFFENER PLATES TO MATCH DOUBLER PLATE. STIFFENER PLATES ARE TO BE EQUALLY SPACED ALONG THE LENGTH OF THE SHOE.
8. IN WELLPAD AND PLANT AREAS, (E.G. SEPARATOR STATIONS AND VENT STATIONS) ALL PIPE SHOES TO BE INSTALLED WITH NO COLD SET UP UNLESS SPECIFICALLY NOTED ON PIPING DRAWINGS.
9. INSTALL CLIP WITH 10mm TOP GAP UNLESS SPECIFIED OTHERWISE ON PIPING DRAWINGS.

### PIPE SHOE DIMENSIONS

| PIPE SIZE | TYPE | SHOE LGTH 'A' | DOUBLER PLATE 'B' | MAXIMUM MOVEMENT 'C' | COLD SETUP 'D' | WIDTH 'W' | NO. OF PLATES 'N' |
|---|---|---|---|---|---|---|---|
| DN200 (NPS 8) | GV03 | 300 | 400 | 50 | 0 | 80 | 2 |
| | GV05 | 500 | 600 | 150 | 75 | 80 | 3 |
| DN250 (NPS 10) | GV03 | 300 | 400 | 50 | 0 | 100 | 2 |
| | GV05 | 500 | 600 | 150 | 75 | 100 | 3 |
| DN300 (NPS 12) | GV03 | 300 | 400 | 50 | 0 | 120 | 2 |
| | GV05 | 500 | 600 | 150 | 75 | 120 | 3 |
| DN350 (NPS 14) | GV03 | 300 | 400 | 50 | 0 | 160 | 2 |
| | GV05 | 500 | 600 | 150 | 75 | 160 | 3 |
| DN400 (NPS 16) | GV05 | 500 | 600 | 150 | 75 | 200 | 3 |
| | GV07 | 700 | 800 | 350 | 175 | 200 | 4 |
| DN450 (NPS 18) | GV05 | 500 | 600 | 150 | 75 | 220 | 3 |
| | GV07 | 700 | 800 | 350 | 175 | 220 | 4 |

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DRAWING NUMBER | REFERENCE DRAWING TITLE

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DGDC DRAWING NUMBER:

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| DRAWN | DRAWING CHECK | REVIEWED | APPROVED |
|---|---|---|---|
| SM | KR | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE | DATE |
| KR | SJP | 19/07/18 | 19/07/18 |

TITLE
STANDARD DETAILS
PIPE SHOE - TYPE GV
DN200 TO DN450 PIPELINES

SCALE ON ANSI D: N.T.S.
DRAWING No: RZ042100-MP-DRG-0150
REV: 0

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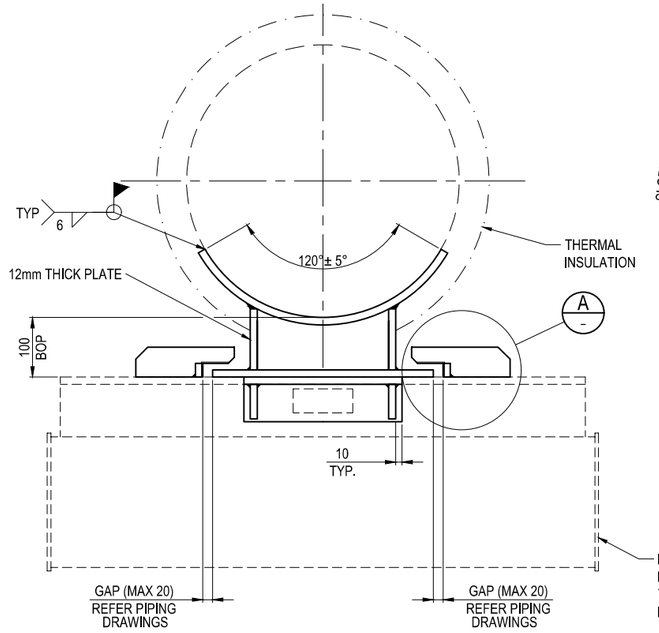
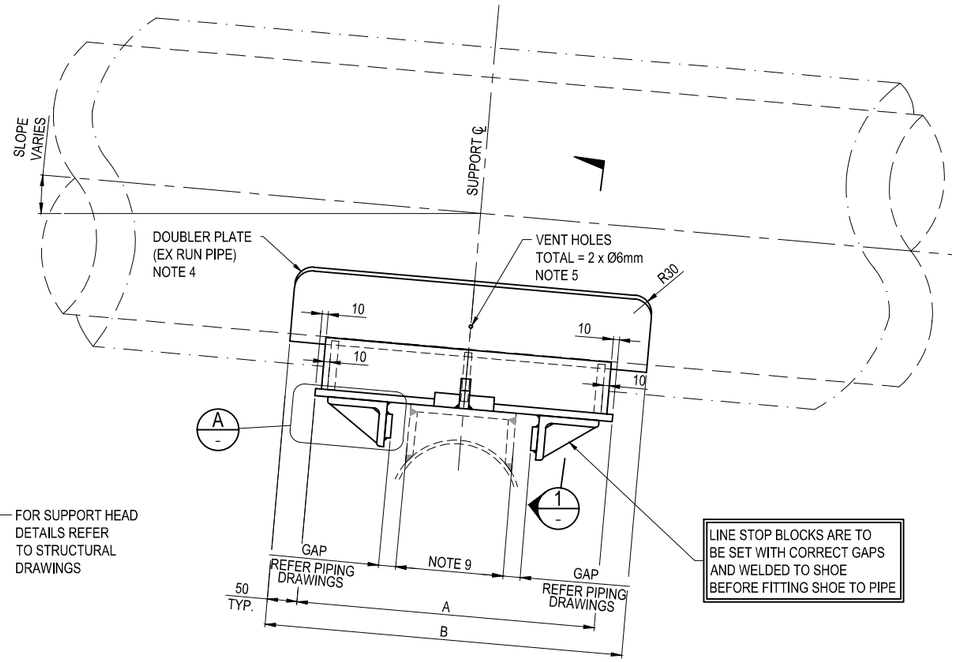
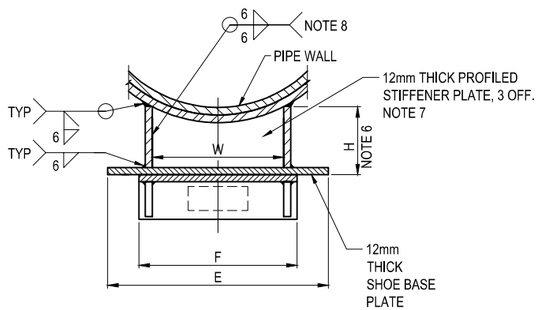



## NOTES:

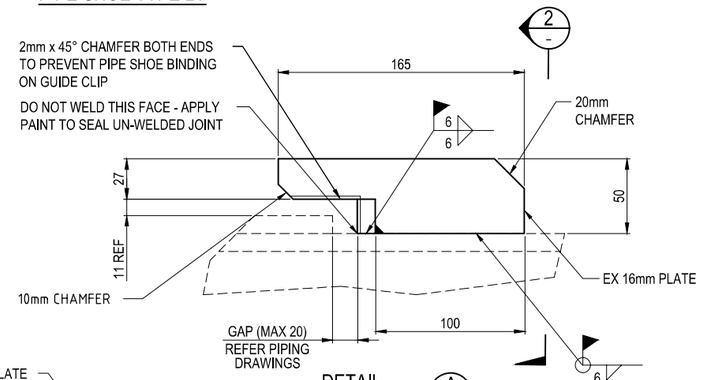
1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS NOTED OTHERWISE.
2. ALL JOINTS TO BE WELDED 6mm FILLET WELD ALL AROUND UNLESS NOTED OTHERWISE.
3. STEEL PLATE AND STEEL SECTION MATERIAL TO BE TO ASTM A36 OR APPROVED EQUIVALENT WITH YIELD STRENGTH OF 36 ksi (250 MPa) MINIMUM.
4. DOUBLER PLATES TO BE SAME MATERIAL AND THICKNESS AS PIPE.
5. VENT HOLES REQUIRED ON DOUBLER PLATE ONLY.
6. DIMENSION 'H' VARIES DEPENDING ON THE THICKNESS OF THE REINFORCING PAD. PLATES MUST BE TRIMMED TO SUIT.
7. PROFILE STIFFENER PLATES TO MATCH DOUBLER PLATE. STIFFENER PLATES ARE TO BE EQUALLY SPACED ALONG THE LENGTH OF THE SHOE.
8. END STIFFENER PLATES ARE TO BE WELDED ON ALL FOUR SIDES. INSIDE STIFFENER PLATES DO NOT REQUIRE WELDS TO THE DOUBLER PLATE.
9. LENGTH OF PIPE SHOE AND DOUBLER PLATE BASED ON A CHANNEL WIDTH OF MAXIMUM 150mm AND A MAXIMUM LINE STOP GAP OF 60/60mm FOR LV05.

## END VIEW
N.T.S.



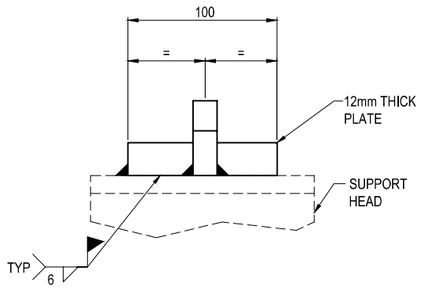

SECTION 1 — SCALE 1:2

## PIPE SHOE TYPE LV

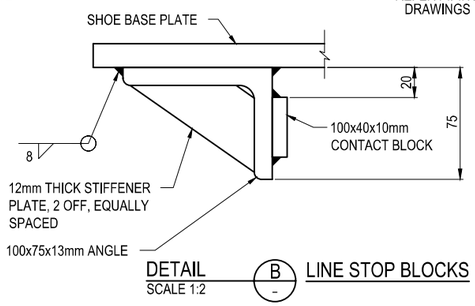



DETAIL A — SCALE 1:2

## SIDE VIEW
N.T.S.




SECTION 2 — SCALE 1:2




DETAIL B — SCALE 1:2

## LINE STOP BLOCKS

## GUIDE CLIPS

| PIPE SHOE DIMENSIONS | | | | | | |
|---|---|---|---|---|---|---|
| PIPE SIZE | TYPE | SHOE LGTH 'A' | DOUBLER PLATE 'B' | WIDTH 'W' | PLATE LGTH 'E' | PLATE LGTH 'F' |
| DN200 (NPS 8) | LV05 | 500 | 600 | 80 | 230 | 125 |
| DN250 (NPS 10) | LV05 | 500 | 600 | 100 | 250 | 145 |
| DN300 (NPS 12) | LV05 | 500 | 600 | 120 | 270 | 165 |
| DN350 (NPS 14) | LV05 | 500 | 600 | 160 | 310 | 205 |
| DN400 (NPS 16) | LV05 | 500 | 600 | 200 | 350 | 245 |
| DN450 (NPS 18) | LV05 | 500 | 600 | 220 | 370 | 265 |

## CORROSION PROTECTION:

THE PIPE SHOE SHALL BE PAINTED PRIOR TO INSTALLATION ON THE PIPELINE.

A 20mm WIDE STRIP AROUND EDGE OF DOUBLER PLATE SHALL BE LEFT UN-PAINTED FOR WELDING TO PIPE.

SCALE 1:2 (ANSI D) 0 40 80 120 160 200mm (40 20)

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TITLE: STANDARD DETAILS
LINE STOP PIPE SHOE - TYPE LV
DN200 TO DN450 PIPELINES

SCALE ON ANSI D: AS SHOWN | DRAWING No: RZ042100-MP-DRG-0151 | REV: 0

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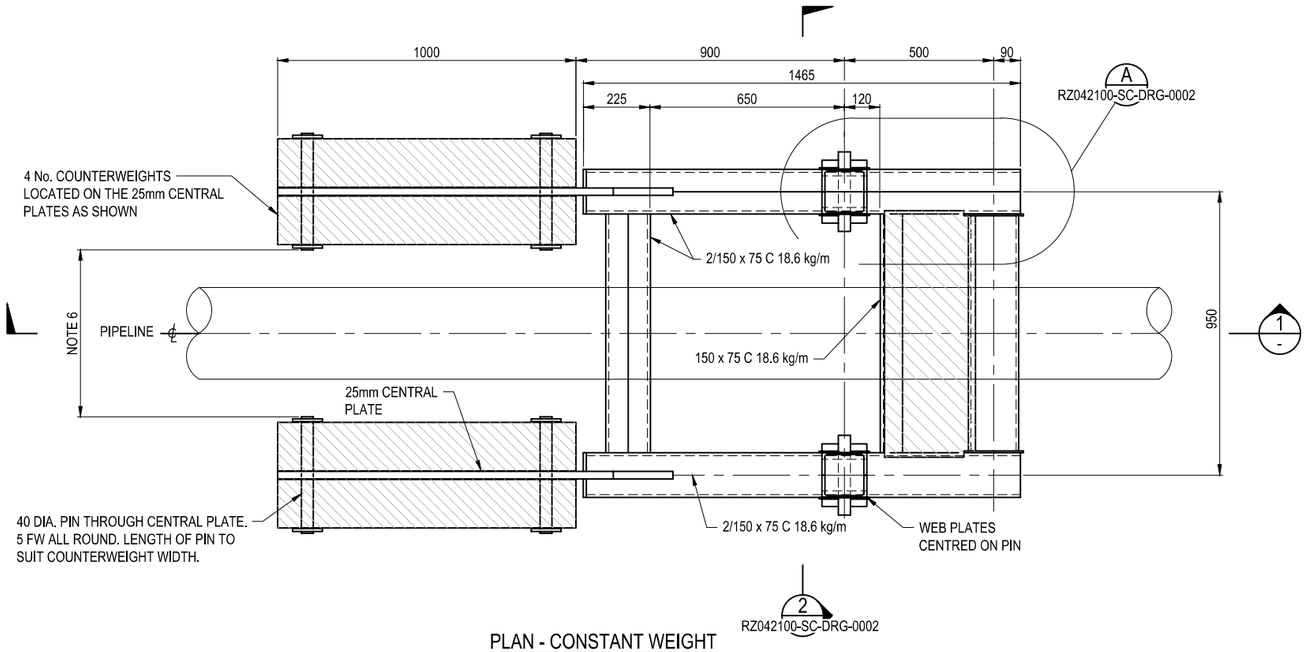
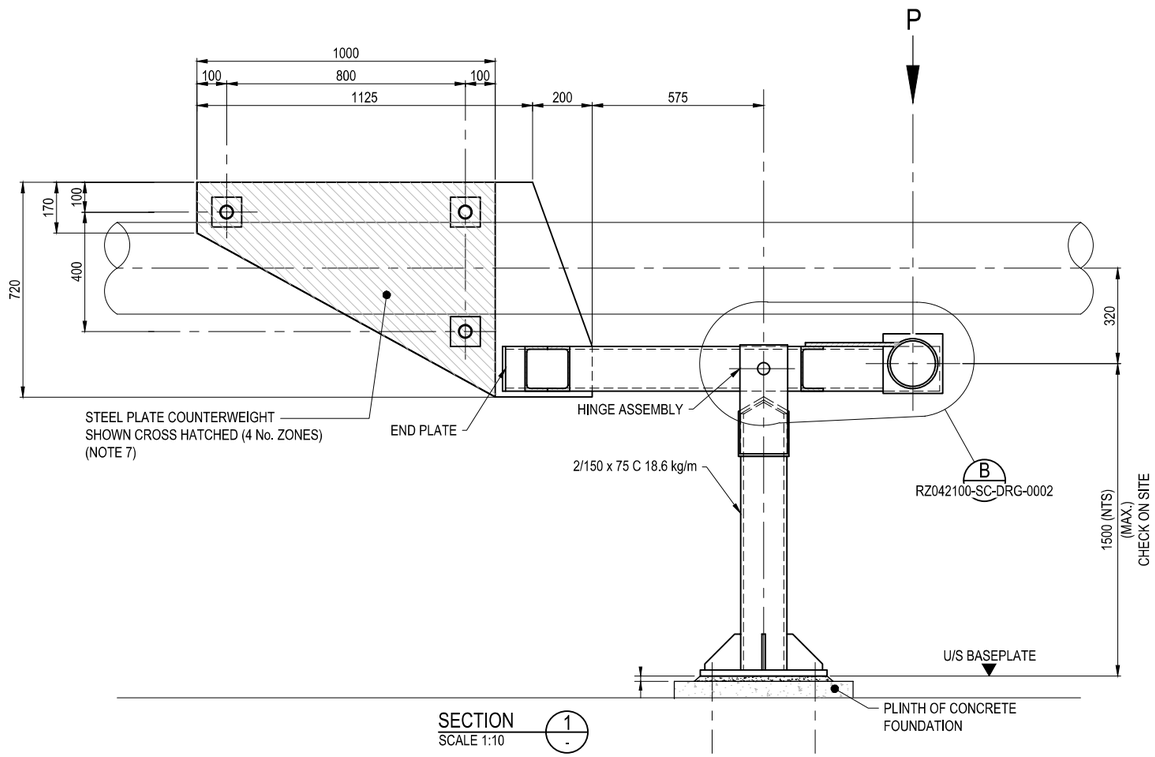



PLAN - CONSTANT WEIGHT
SCALE 1:10

| 25mm STEEL PLATES | | |
|---|---|---|
| NUMBER "N" | WEIGHT (kg) | FORCE 'P' (N) (REFER NOTE 7) |
| 18 | 1805 | 50500 |
| 16 | 1631 | 46000 |
| 14 | 1458 | 41500 |
| 12 | 1284 | 37000 |
| 10 | 1111 | 32500 |
| 8 | 937 | 28500 |
| 6 | 764 | 24000 |

## NOTES :

1. ALL STRUCTURAL STEEL CHANNEL, ANGLE AND PLATE MATERIAL TO BE ASTM GRADE A36.
2. ALL STEEL PIPE TO BE ASTM A53 GRADE B.
3. ALL HOLLOW SECTIONS TO HAVE 6mm END CAPS UNLESS NOTED OTHERWISE.
4. ALL STEEL TO BE HOT DIP GALVANISED AND/OR PAINTING TO BE IN ACCORDANCE WITH SPECIFICATION FOR CORROSION PROTECTION.
5. CONSTANT WEIGHT SUPPORT SHOULD BE IN A HORIZONTAL POSITION AS SHOWN WHEN THE PIPE IS COLD.
6. CHECK CLEARANCE BETWEEN COUNTERWEIGHT AND INSULATED PIPE.
7. THE NUMBER "N" GIVEN IN THE TABLE IS THE TOTAL NUMBER STEEL COUNTERWEIGHT REQUIRED FOR THAT PIPE SUPPORT. THIS "N" IS TO BE DIVIDED INTO 4 No. EQUAL WEIGHTS AND LOCATED ON THE ARMS AS SHOWN IN THE PLAN ABOVE. WHERE "N" IS NOT DIVISIBLE BY 4 THE STACK CLOSEST TO THE PIPE SHALL HAVE ONE LESS PLATE.
8. CONCRETE
   - MINIMUM 28 DAY COMPRESSIVE STRENGTH OF CONCRETE SHALL BE 20 MPa (3000 psi)
   - MINIMUM COVER TO REINFORCING SHALL BE 75mm
9. DETAILED DESIGN BY CONTRACTOR.
10. SOIL MUST HAVE A MINIMUM ULTIMATE BEARING CAPACITY OF 300 kPa.




SECTION 1
SCALE 1:10

SCALE 1:10 (ANSI D) 0 200 400 600 800 1000mm
200 100

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TITLE: CONSTANT WEIGHT SUPPORT SHEET 1

| SCALE ON ANSI D | DRAWING No | REV |
|---|---|---|
| 1:10 | RZ042100-SC-DRG-0001 | 0 |

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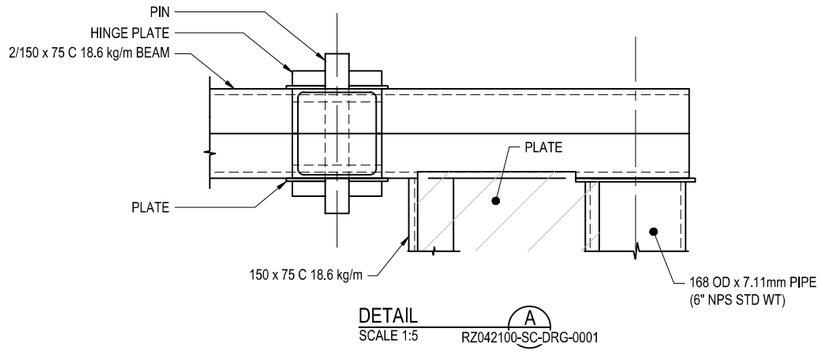
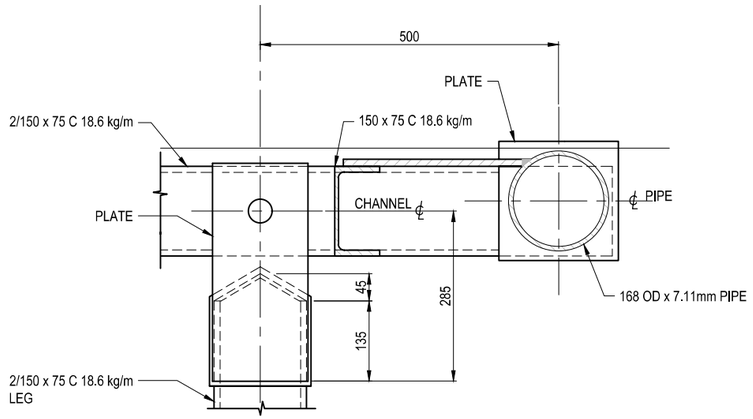
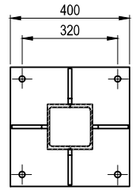


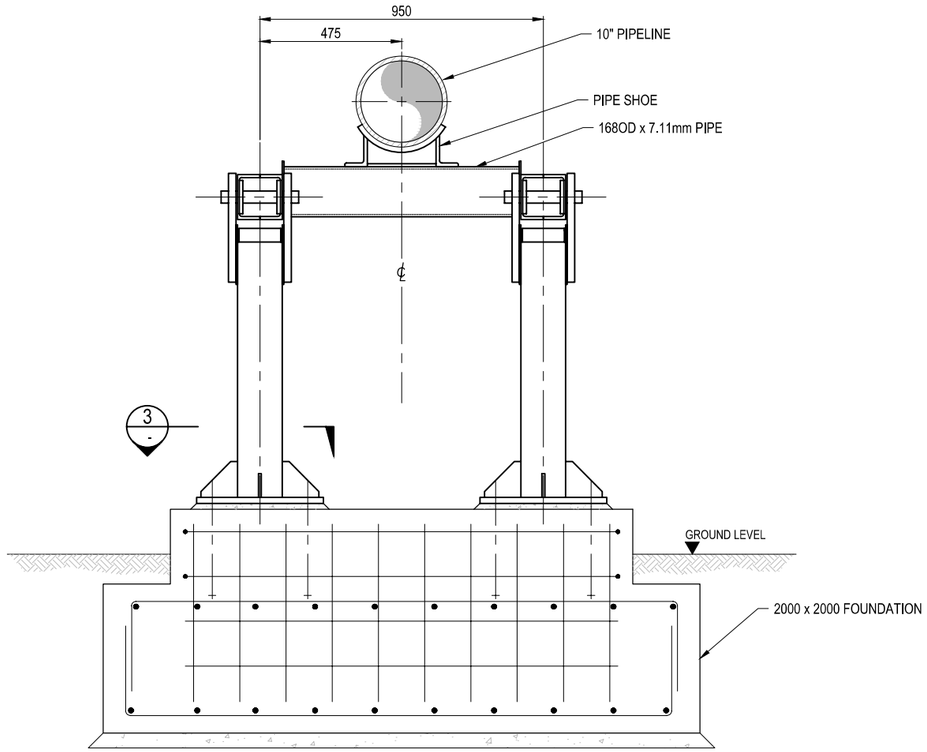

DETAIL A
SCALE 1:5 RZ042100-SC-DRG-0001




DETAIL B
SCALE 1:5 RZ042100-SC-DRG-0001




SECTION 3
SCALE 1:10 RZ042100-SC-DRG-0001




SECTION 2
SCALE 1:5 RZ042100-SC-DRG-0001

## NOTES :

1. REFER TO DRAWING NO. RZ042100-SC-DRG-0001.

SCALE 1:5 (ANSI D) 0 100 200 300 400 500mm
100 50

SCALE 1:10 (ANSI D) 0 200 400 600 800 1000mm
200 100

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TITLE: CONSTANT WEIGHT SUPPORT SHEET 2

SCALE ON ANSI D: AS SHOWN
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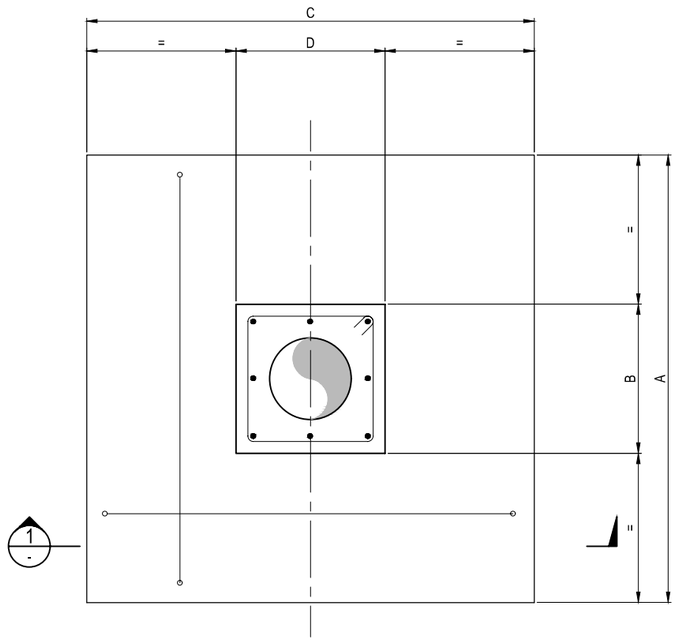
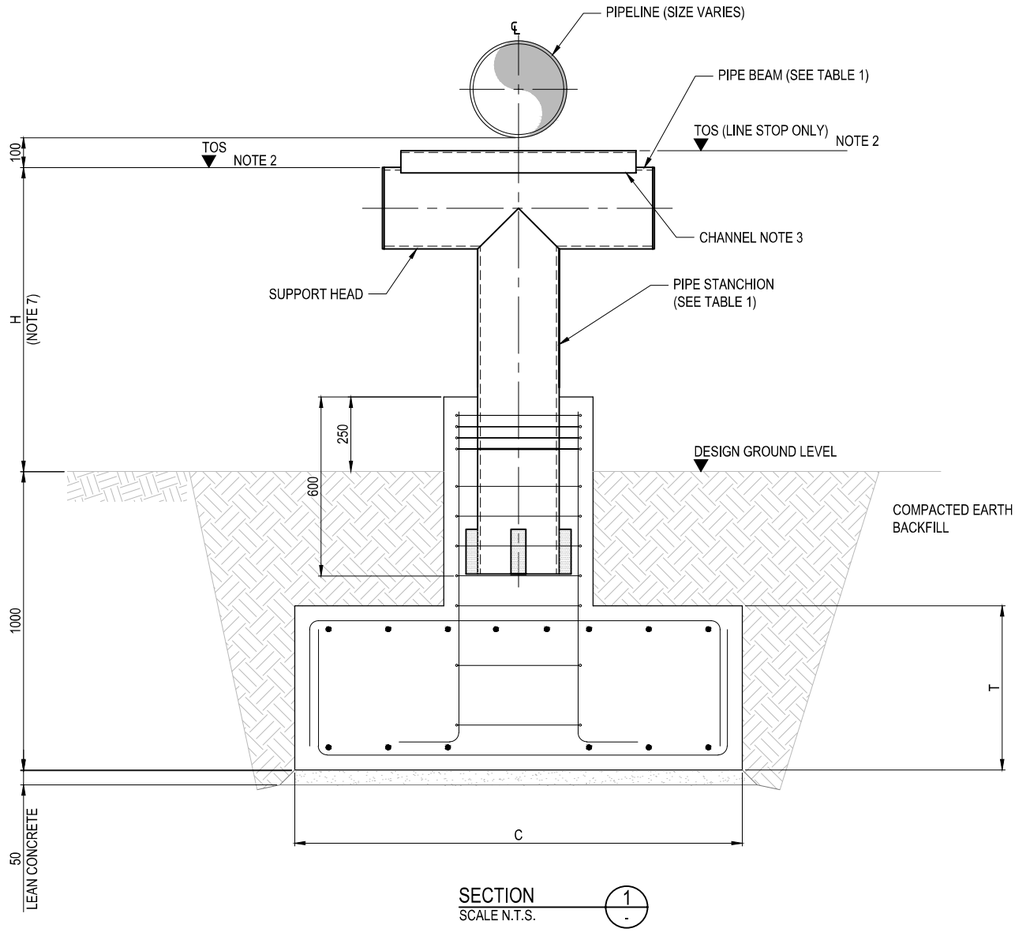



PLAN
SCALE N.T.S.




SECTION
SCALE N.T.S.
1
-

## NOTES :

1. MINIMUM REINFORCING STEEL CONCRETE COVER SHALL BE 75mm.
2. TOP OF STEEL (TOS) DENOTES THE ELEVATION AT THE INTERFACE OF PIPE SHOE AND SUPPORT HEAD. (WITH OR WITHOUT BUILT-UP CHANNEL) TOP OF STEEL (TOS) LEVEL SHALL BE 100mm BELOW BOTTOM OF PIPE SHOE.
3. BUILT UP CHANNEL SHALL BE PROVIDED FOR LINE STOP TYPE SUPPORTS ONLY. TOP OF CHANNEL TO BE PARALLEL TO PIPE RUN.
4. PAINT STEEL WORKS IN ACCORDANCE WITH THE SPECIFICATION.
5. DETAILED DESIGN BY CONTRACTOR.
6. SOIL MUST HAVE A MINIMUM ULTIMATE BEARING CAPACITY OF 300 kPa.
7. SUPPORT HEIGHT, H, TO SUIT DISTANCE FROM GROUND TO TOS LEVEL MAXIMUM H=2m.

TABLE 1

| PIPE SUPPORT NAME | LINE SIZE (in) | FOOTING/PAD DIMENSION | | | | | PIPE BEAM | PIPE STANCHION |
|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | T | | |
| FA-1 | 10/12 | 1500 | 600 | 1500 | 600 | 400 | DN250 | DN250 |
| FA-2 | 10/12 | 1800 | 600 | 1800 | 600 | 400 | DN250 | DN250 |
| FA-3 | 10/12 | 2300 | 600 | 1000 | 600 | 400 | DN250 | DN250 |

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TITLE: STANDARD PAD TYPE PIPE SUPPORT

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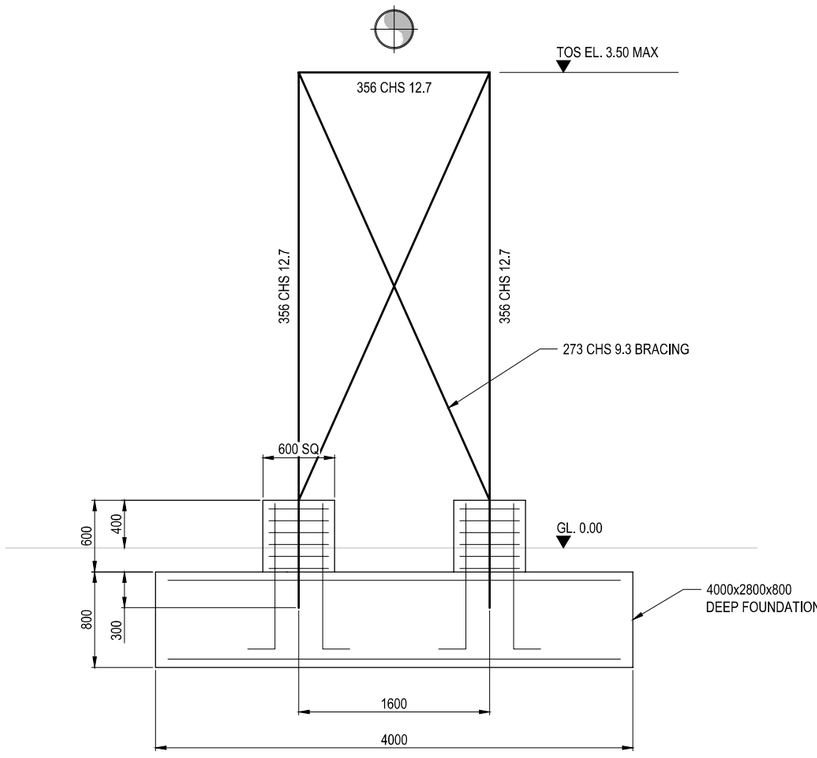
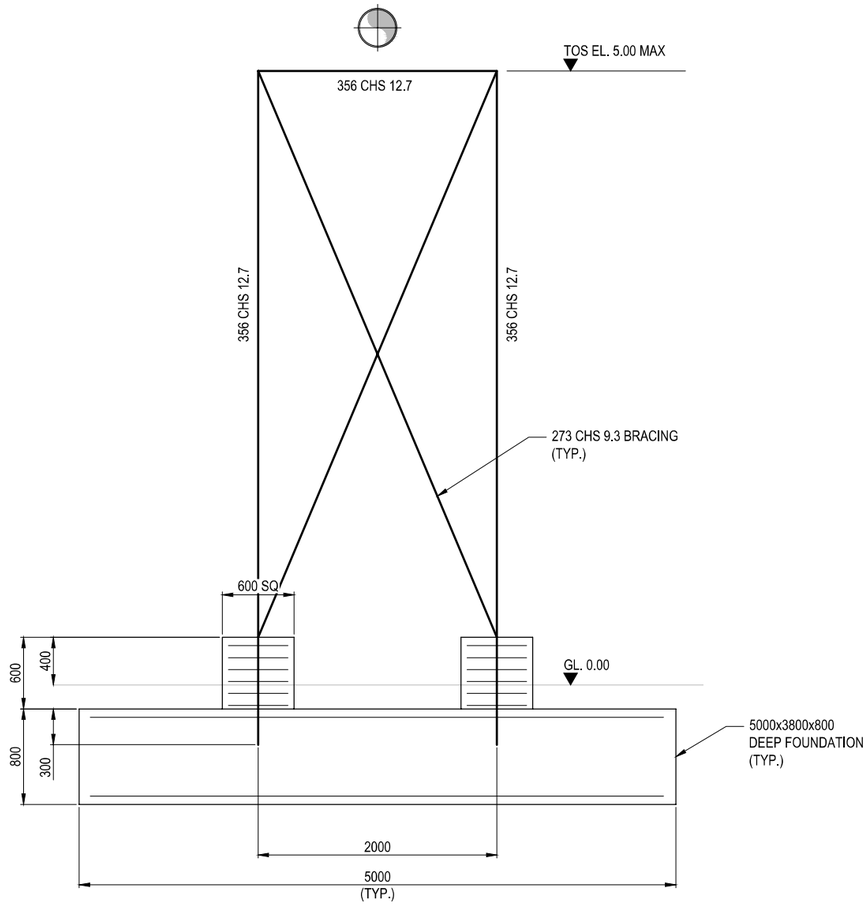
## NOTES :

1. REFER TO DRAWING RZ042100-SC-DRG-0003 FOR GENERAL NOTES.




TYPE M MID HEIGHT PIPE SUPPORTS
SCALE 1:25




TYPE H HIGH PIPE SUPPORTS
SCALE 1:25

SCALE 1:25 (ANSI D) 0 500 1000 1500 2000 2500mm

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| HW | KR | LJS | LJS |
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TITLE: STANDARD PIPE SUPPORTS TYPE M AND H

| SCALE ON ANSI D | DRAWING No | REV |
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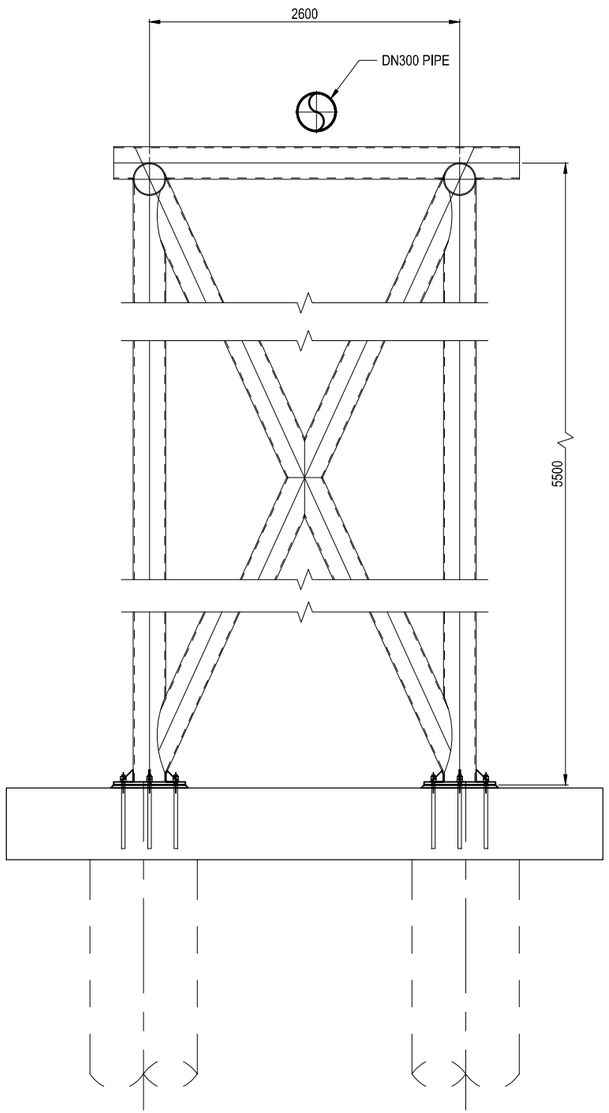


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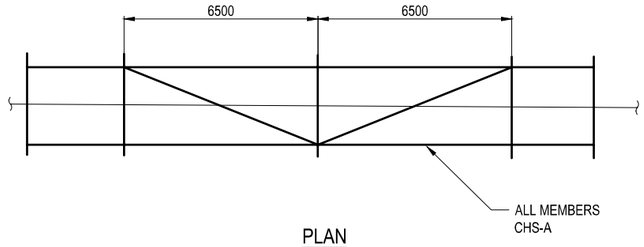
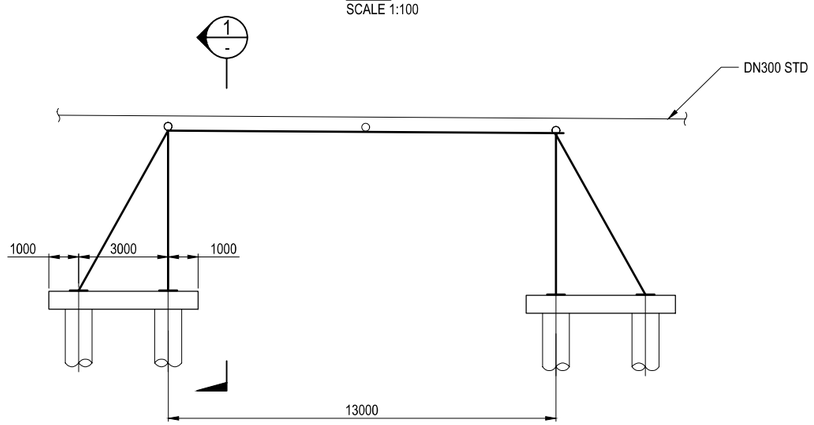



PLAN
SCALE 1:100




ELEVATION
SCALE 1:100

## NOTES:

1. ALL STRUCTURAL STEEL WORK SHALL BE AS PER THE SPECIFICATION.
2. DETAILED DESIGN BY CONTRACTOR.

## LEGEND:

CHS-A = 273.10 OD X 9.27mm CHS

SCALE 1:25 (ANSI D) 0 500 1000 1500 2000 2500mm

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TITLE
PIPE BRIDGE TYPE 1
SHEET 1

| SCALE ON ANSI D | DRAWING No | REV |
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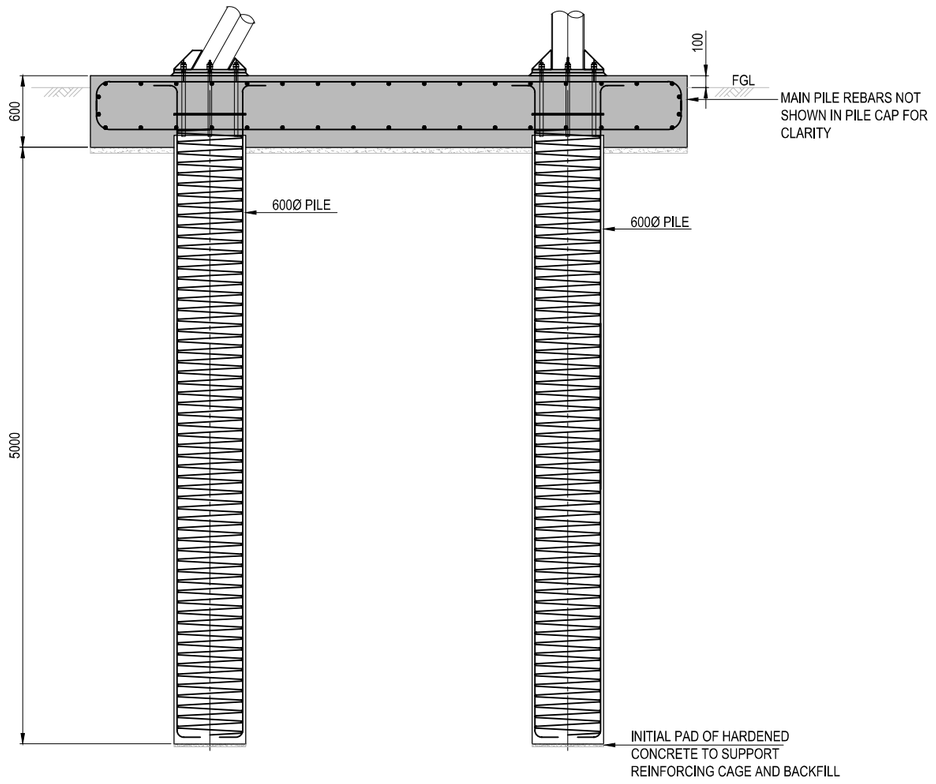
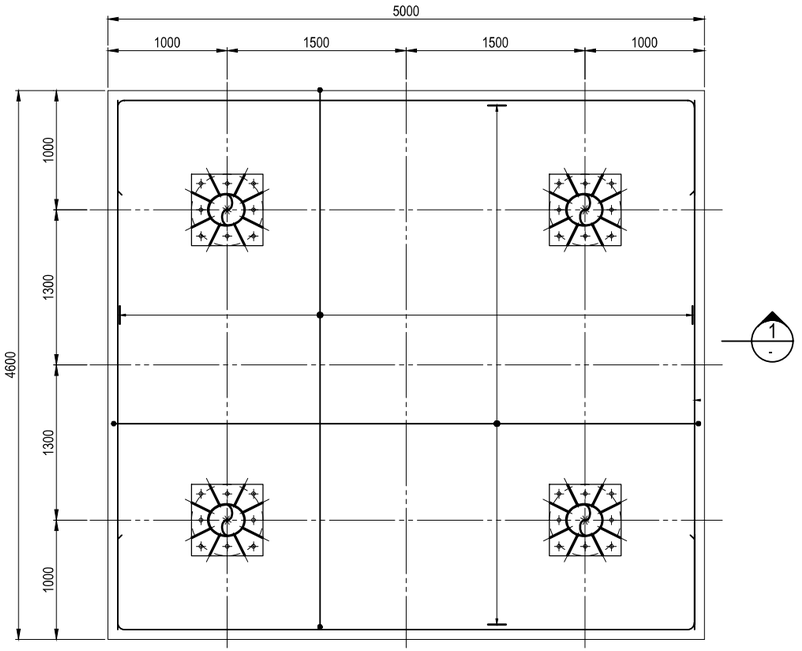



SECTION 1-1
SCALE 1:25




PLAN - REINFORCED CONCRETE PILE CAP DETAIL
SCALE 1:25

## NOTES:

1. MINIMUM CONCRETE COVER TO REINFORCEMENT SHALL BE 75mm.
2. ALL STRUCTURAL CONCRETE SHALL HAVE A MINIMUM COMPRESSIVE CUBE STRENGTH OF 30MPa AT 28 DAYS.
3. THE MINIMUM PILE EMBEDMENT DEPTHS ARE BASED ON VOLCANIC ASH.
4. DETAILED DESIGN BY CONTRACTOR.

SCALE 1:25 (ANSI D) 0 500 1000 1500 2000 2500mm
500

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TITLE: PIPE BRIDGE TYPE 1
SHEET 2

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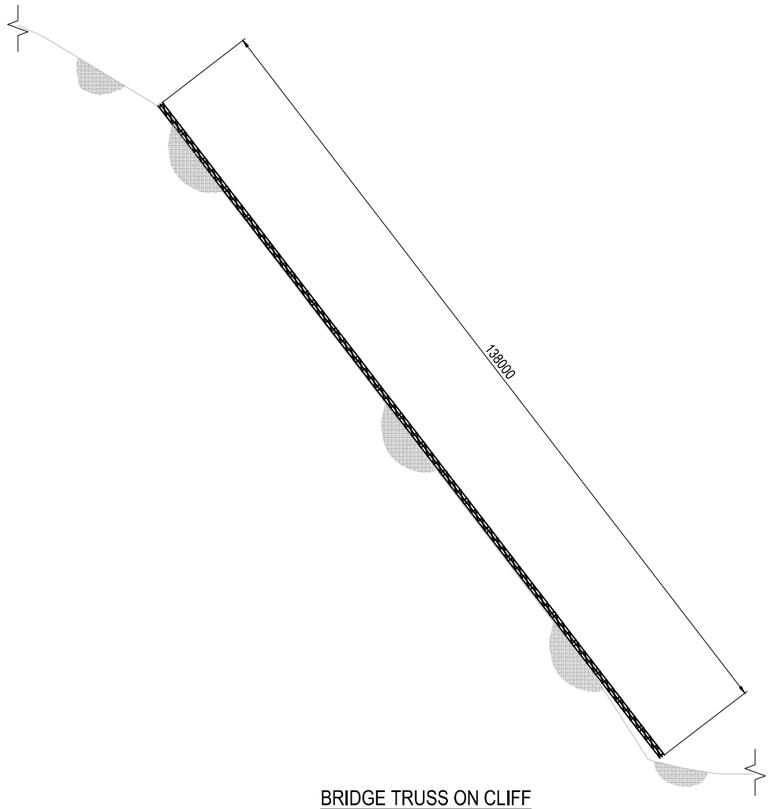
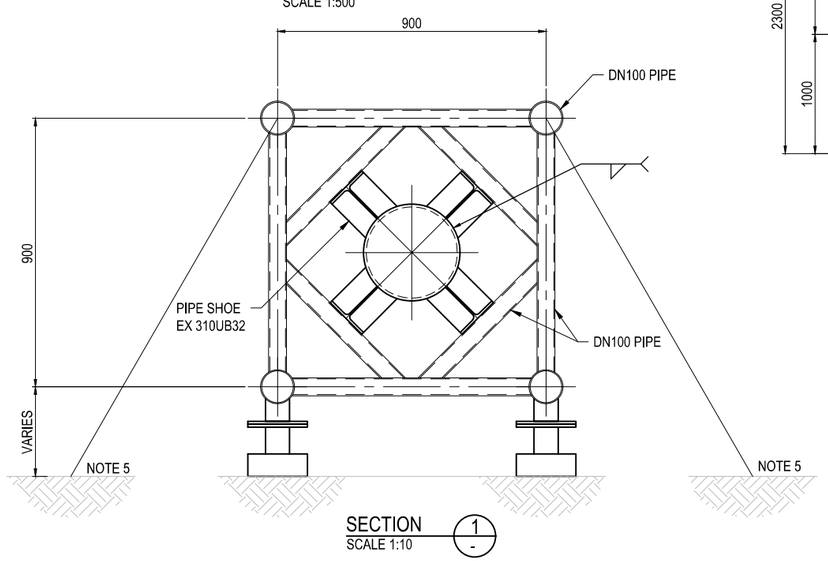
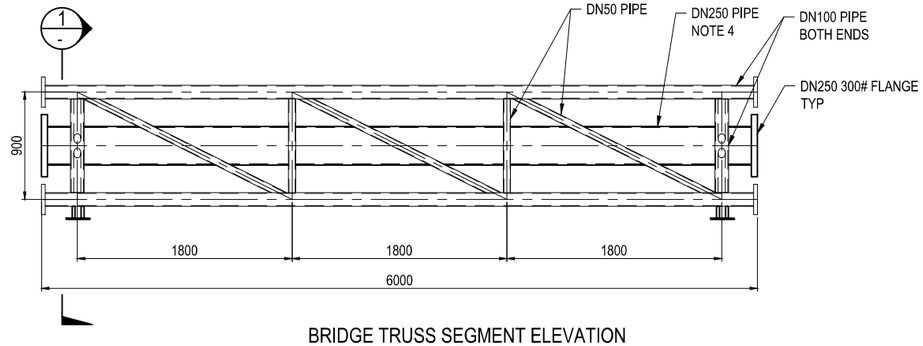


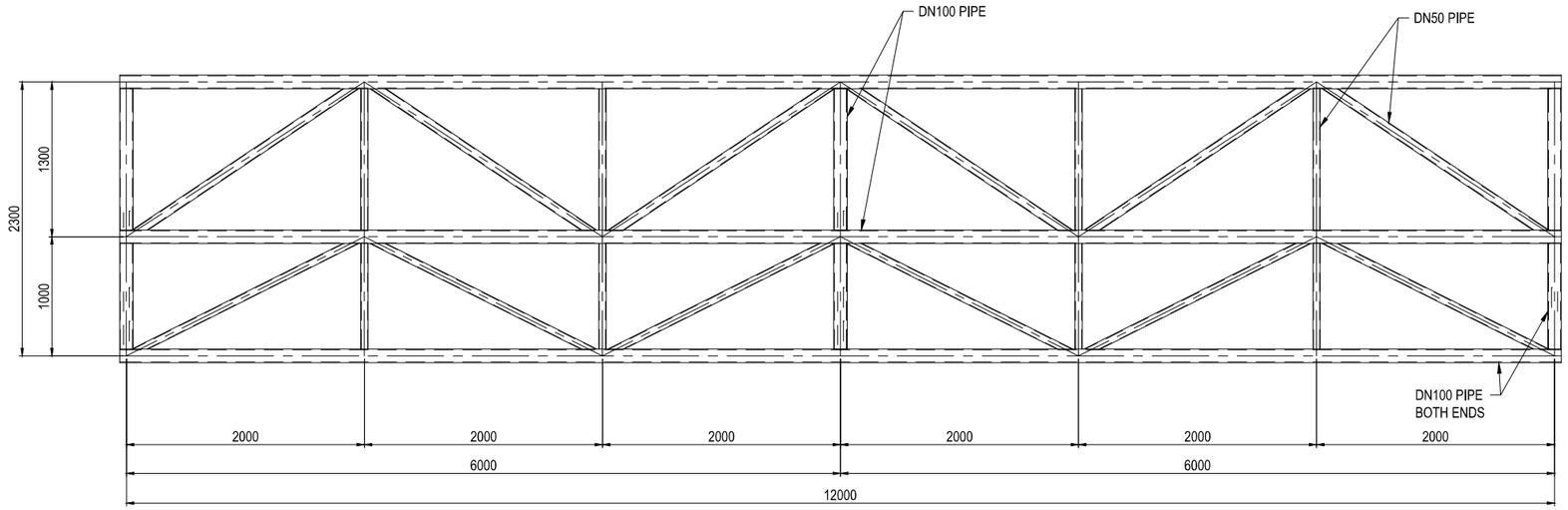

BRIDGE TRUSS ON CLIFF
SCALE 1:500




SECTION 1/-
SCALE 1:10



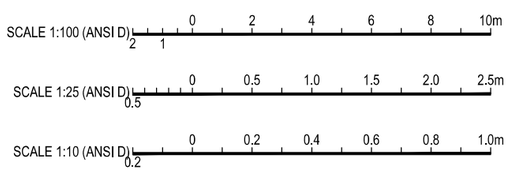

BRIDGE TRUSS SEGMENT ELEVATION
SCALE 1:25




TRANSPORT TRUSS
SCALE 1:25

## NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.
2. BRIDGE TRUSS TO BE CONSTRUCTED IN SEGMENTS, USING TRANSPORT TRUSS. REFER TO RZ042100-SC-DRG-0011 FOR PROPOSED CONSTRUCTION METHODOLOGY.
3. PROPOSED CONSTRUCTION METHODOLOGY IS ONLY INDICATIVE AND FOR COSTING PURPOSE ONLY. DETAILED DESIGN AND METHODOLOGY TO BE PREPARED BY CONTRACTOR PRIOR TO CONSTRUCTION.
4. BRINE PIPELINE TO BE PRE-INSTALLED INTO TRUSS AND INSULATED PRIOR TO ERECTION OF TRUSS SEGMENT.
5. EACH SECTION OF TRUSS TO BE FIXED AND ANCHORED TO CLIFF FACE. PROVIDE ADDITIONAL STAY OR STRUTS ANCHORED TO THE CLIFF FACE AS NECESSARY.
6. TRUSS CONNECTIONS TO CLIFF FACE TO BE DESIGNED FOR TRUSS AND PIPE WITH CONTENT SELF WEIGHT PLUS SEISMIC AND WIND LOADS. SLOPE GEOMETRY UNCONFIRMED, BUT POTENTLY TRUSS SUPPORT CONNECTIONS WILL EXTEND UP TO 7 m BETWEEN TRUSS AND CLIFF FACE. TRUSS (ONLY) SELF WEIGHT AS SHOWN ON INDICATIVELY 260 kg/m (UNFACTORED).
7. SLOPE STABILITY TO BE ASSESSED AND STABILISATION MEASURES IMPLEMENTED AS NECESSARY TO PROVIDE ADEQUATE FACTOR OF SAFETY UNDER STATIC AND SEISMIC LOADING CONDITIONS. LOCAL AND OVERALL / GLOBAL STABILITY TO BE ASSESSED.

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PROJECT: DOMINICA GEOTHERMAL POWER PLANT

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TITLE: GENERAL ARRANGEMENT
CLIFF BRIDGE TRUSS

SCALE ON ANSI D: AS SHOWN
DRAWING No: RZ042100-SC-DRG-0010
REV: 0

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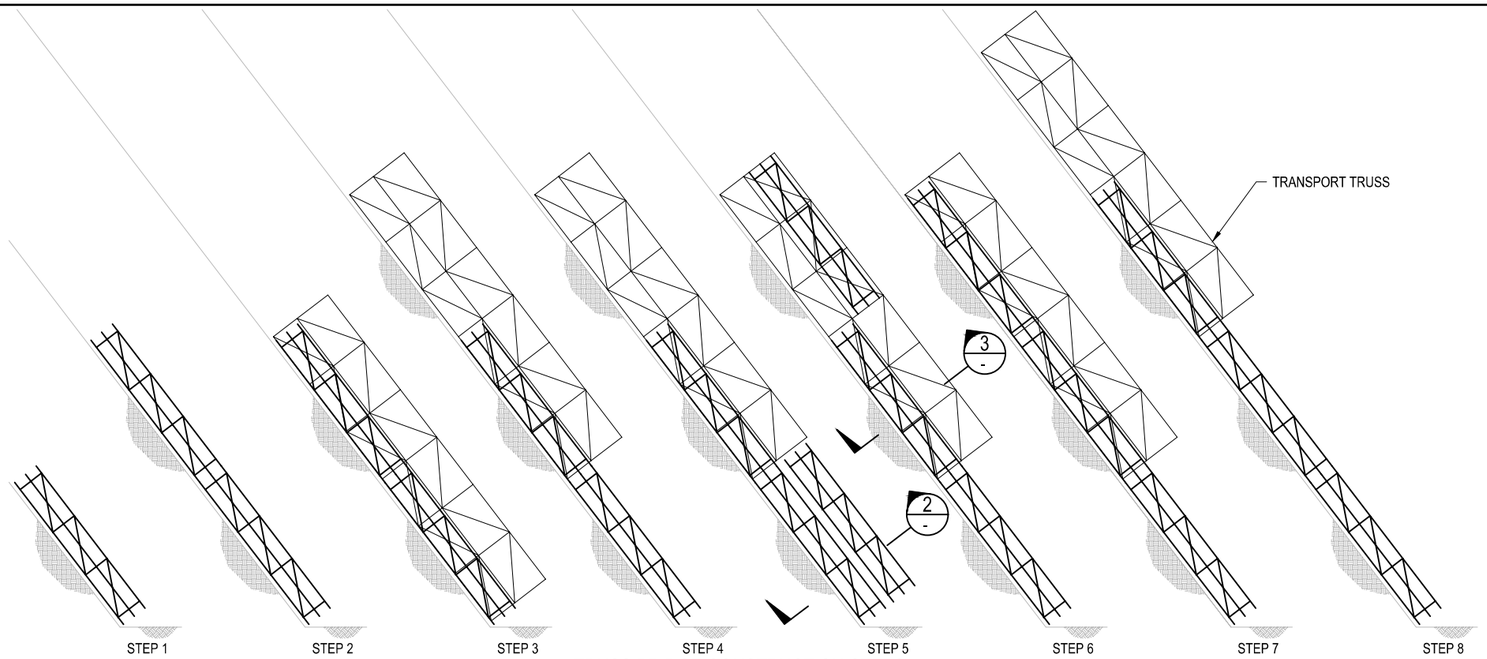
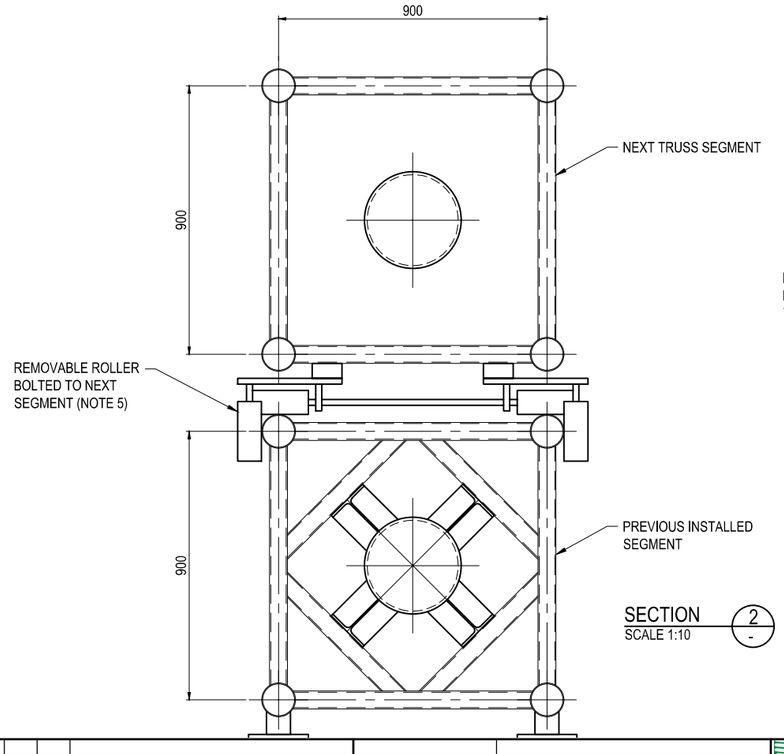
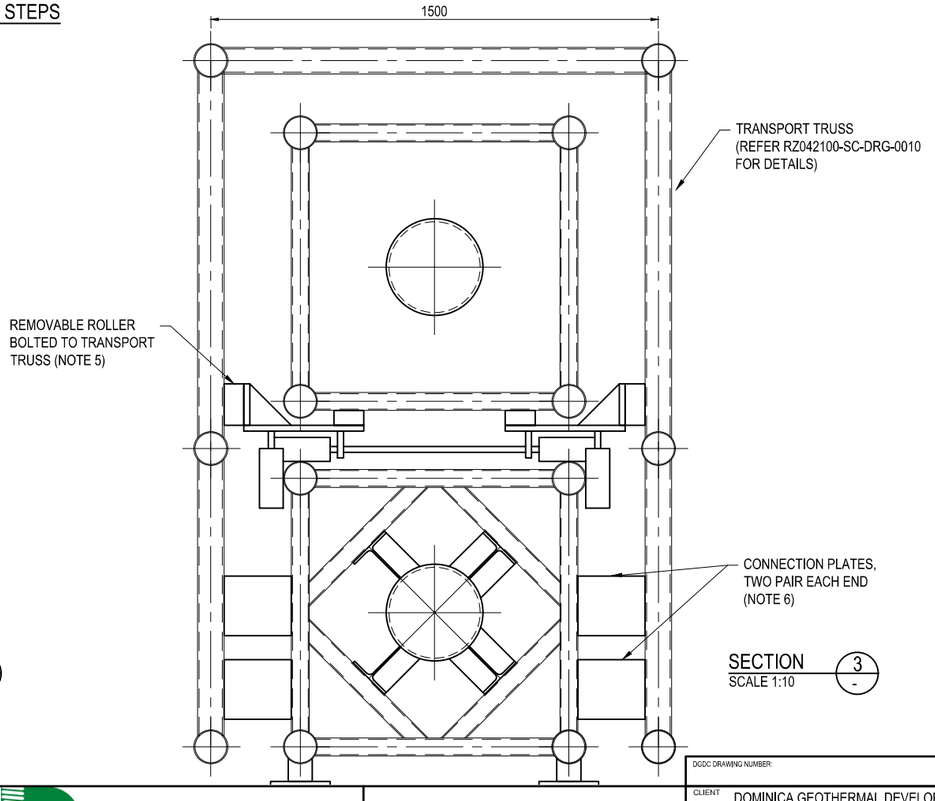



TRUSS BRIDGE CONSTRUCTION STEPS
SCALE 1:100




SECTION 2 / SCALE 1:10




SECTION 3 / SCALE 1:10

## NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.
2. PROPOSED PIPELINE SUPPORT AND CONSTRUCTION METHODOLOGY IS ONLY INDICATIVE AND FOR COSTING PURPOSE ONLY. DETAILED DESIGN AND METHODOLOGY TO BE PREPARED BY CONTRACTOR PRIOR TO CONSTRUCTION.
3. EACH SEGMENT EXCEPT THE FIRST TWO SEGMENTS SHALL BE POSITIONED IN PLACE BY THE USE OF THE TRANSPORT TRUSS.
4. TRANSPORT TRUSS AND SUCCEEDING SEGMENTS SHALL BE LIFTED OR SLID INTO PLACE WITH THE USE OF A 20T HOIST ON TOP OF THE CLIFF.
5. A REMOVABLE ROLLER WHICH CAN BE BOLTED TO EITHER THE TRUSS SEGMENT OR TRANSPORT SEGMENT AND SHALL BE USED WHEN LIFTING THE PIPE TRUSS SEGMENT OR THE TRANSPORT TRUSS SEGMENT.
6. A REMOVABLE CONNECTING PLATE OR ASSEMBLY SHALL BE USED TO SECURE THE TRANSPORT TRUSS.
7. ADDITIONAL PRECAUTIONARY PROCEDURES / HARDWARE SUCH AS TIES, HOLD DOWNS SHALL BE PROVIDED BY THE CONTRACTOR TO ENSURE THAT ITEMS / SEGMENTS ARE SECURED DURING LIFTS AND INSTALLATION.
8. REFER TO TABLE 1 FOR PROPOSED CONSTRUCTION METHODOLOGY.

### TABLE 1 - PROPOSED CONSTRUCTION METHODOLOGY

| NO. | DISCRIPTION |
|---|---|
| 1 | FRIST SEGMENT TRUSS BRIDGE CONSTRUCTED AND ANCHORED. |
| 2 | SECOND TRUSS BRIDGE SEGMENT IS INSTALLED AND ANCHORED. |
| 3 | TRANSPORT TRUSS/DOLLY PLACED ON INSTALLES TRUSSES, WITH ROLLERS BOLTED. |
| 4 | TRANSPORT TRUSS IS PULLED INTO POSITION. HALF-LENGTH OF TRANSPORT TRUSS TO EXTEND BEYOND INSTALLED TRUSS SEGMENT. ONCE IN PLACE, THE TRANSPORT TRUSS IS SECURED IN POSITION BY BOLTING IT TO THE INSTALLED SEGMENT OF THE TRUSS BRIDGE, ROLLERS ARE REMOVED. |
| 5 | NEXT SEGMENT OF TRUSS BRIDGE IS PREPARED. ROLLERS REMOVED FROM THE TRANSPORT TRUSS ARE TRANSFERRED AND BOLTED TO THE NEXT PIPE TRUSS SEGMENT. |
| 6 | NEXT SEGMENT IS PULLED UP TO THE END OF THE TRANSPORT TRUSS. ROLLERS ARE REMOVED. |
| 7 | NEXT SEGMENT IS LOWERED INTO POSITION, PIPE TRUSS IS BOLTED TO THE PREVIOUS SEGMENT AND ANCHORED TO THE GROUND. PIPE FLANGES ARE CONNECTED WITH THE PIPE IN LOWER SEGMENT. |
| 8 | ROLLERS ARE ATTACHED TO THE TRANSPORT TRUSS, UNBOLTED FROM THE PREVIOUS SEGMENT, PULLED INTO POSITION, STEP 4 IS REPEATED UNTIL TOP OF CLIFF IS REACHED. |

SCALE 1:100 (ANSI D) 0 2 4 6 8 10m

SCALE 1:10 (ANSI D) 0 0.2 0.4 0.6 0.8 1.0m

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TITLE: CLIFF BRIDGE TRUSS CONSTRUCTION DETAILS

SCALE ON ANSI D: AS SHOWN
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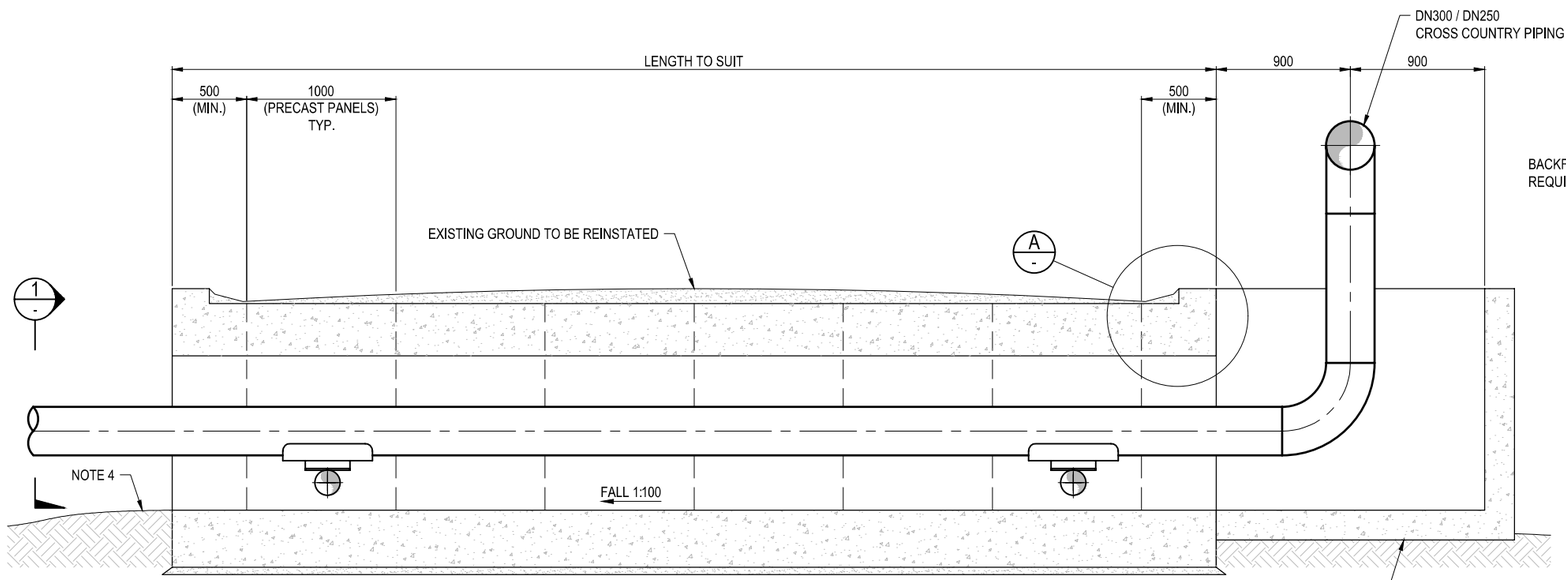
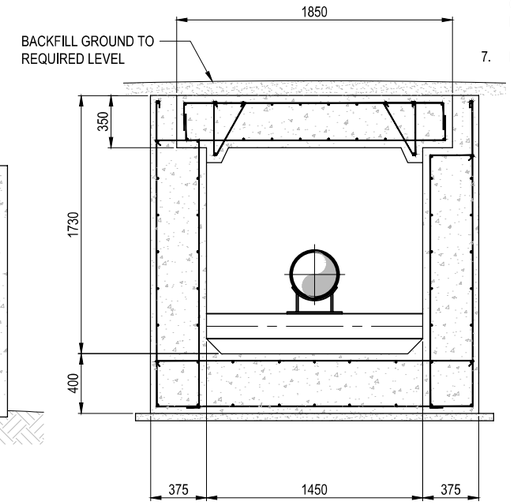


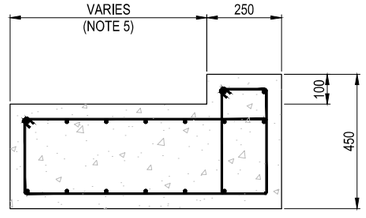

FRONT ELEVATION
SCALE 1:20



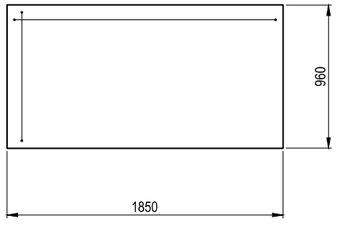

SECTION 1 -
SCALE 1:20

## NOTES :

1. FINAL CULVERT LENGTH TO BE CONFIRMED ON SITE. ADJUST NUMBER OF PRECAST PANELS AS NECESSARY TO SUIT ACTUAL CULVERT LENGTH.
2. SAFETY RAILING TO BE PROVIDED AS NEEDED.
3. CUT EXISTING SOIL LEVEL TO DRAIN WATER AWAY FROM CULVERT.
4. CULVERT DEPTH TO BE ADJUSTED TO SUIT REQUIRED SLOPE FOR DRAINAGE.
5. ADJUST NIB LENGTH TO SUIT ACTUAL NUMBER OF PRECAST COVER PANELS AND LENGTH OF CULVERT.
6. CULVERT TO BE DESIGNED FOR 20 TON TRUCK LOAD, EXCEPT FOR CULVERT ACROSS ROAD TO AERIAL TRAMWAY, WHICH IS TO BE DESIGNED FOR DRILLING RIG WEIGHT.
7. MASONRY ENRTY/EXIT BOX TO BE PROVIDED WITH COVER.




DETAIL A -
SCALE 1:10




PRECAST PANEL DETAIL PLAN
SCALE 1:20

SCALE 1:10 (ANSI D) 0 200 400 600 800 1000mm
200 100

SCALE 1:20 (ANSI D) 0 400 800 1200 1600 2000mm
400 200

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TITLE: TYPICAL PIPE CROSSING CULVERT

SCALE ON ANSI D: AS SHOWN
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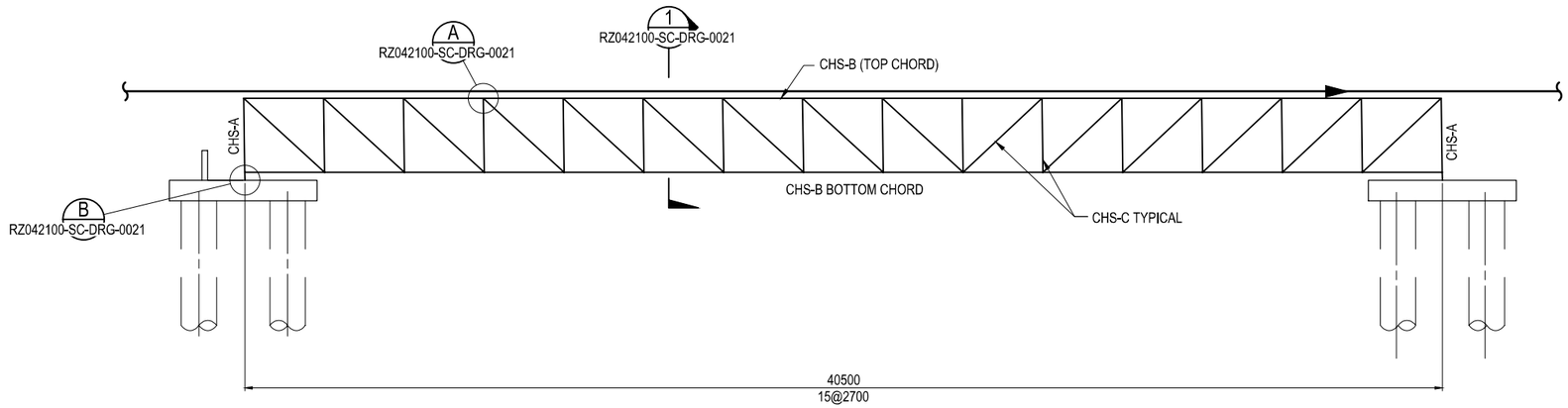



LONG SECTION
SCALE 1:100

## NOTES:

1. ALL STRUCTURAL STEEL WORK SHALL BE AS PER THE SPECIFICATION.
2. ALL STRUCTURAL STEEL WORK SHALL HAVE FULL PENETRATION BUTT WELDS UNLESS SHOWN OTHERWISE.
3. DETAILED DESIGN BY CONTRACTOR.

## LEGEND:

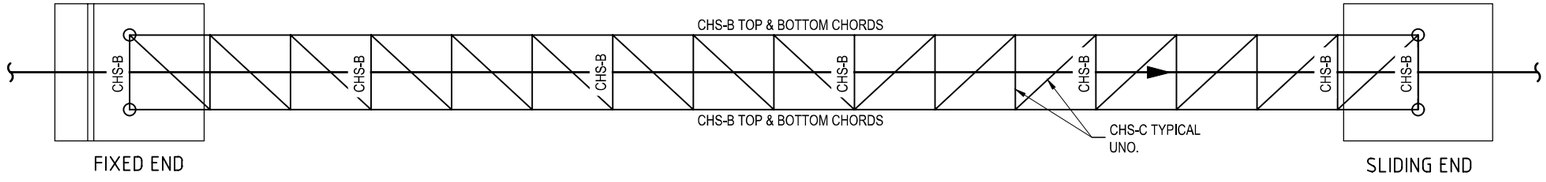
CHS-A = DN300 x STD WT PIPE

CHS-B = DN250 x STD WT PIPE

CHS-C = DN150 x STD WT PIPE

PIPE SECTIONS SHALL BE GRADE 240Mpa STEEL SPIRAL WELDED TO ASTM A53, ASTM A106 & API 5L




PLAN
SCALE 1:100

SCALE 1:100 (ANSI D) 0 2 4 6 8 10m

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TITLE: PIPE BRIDGE TYPE 2
PLAN & LONG SECTION

SCALE ON ANSI D: 1:100
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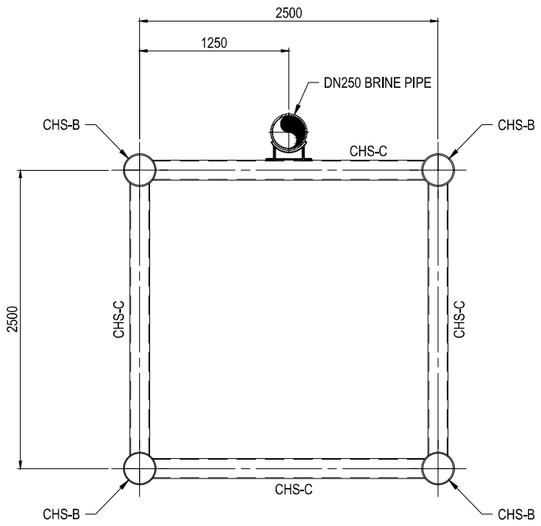
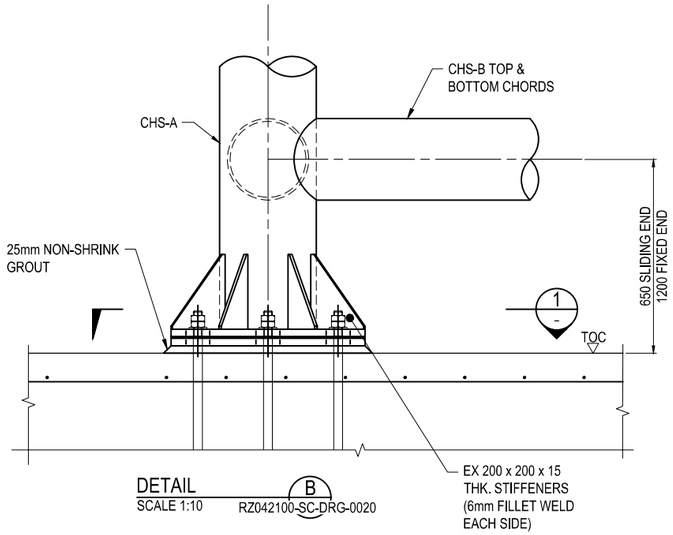


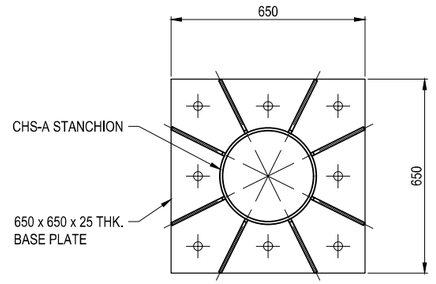

SECTION 1 — SCALE 1:25 — RZ042100-SC-DRG-0020



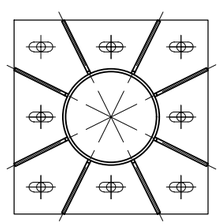

DETAIL B — SCALE 1:10 — RZ042100-SC-DRG-0020




DETAIL A — SCALE 1:5 — RZ042100-SC-DRG-0020




SECTION 1 — SCALE 1:10 — FIXED END



SECTION 1 — SCALE 1:10 — SLIDING END

## NOTES:

1. REFER TO RZ042100-SC-DRG-0020.

SCALE 1:25 (ANSI D) 0 500 1000 1500 2000 2500mm
500

SCALE 1:10 (ANSI D) 0 200 400 600 800 1000mm
200 100

SCALE 1:5 (ANSI D) 0 100 200 300 400 500mm
100 50

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TITLE: PIPE BRIDGE TYPE 2
SECTION AND DETAILS

| SCALE ON ANSI D | DRAWING No | REV |
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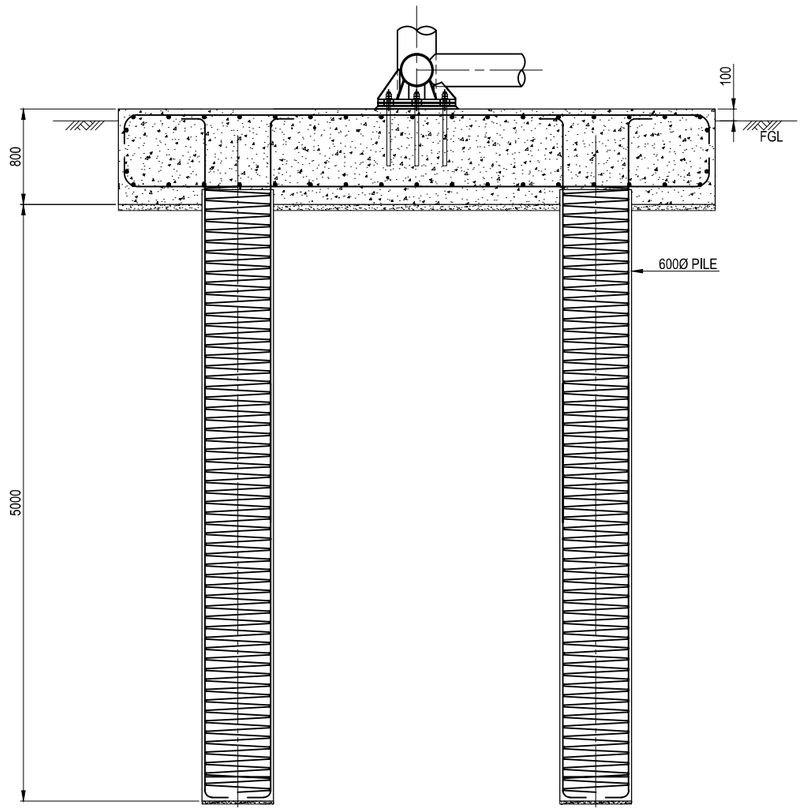
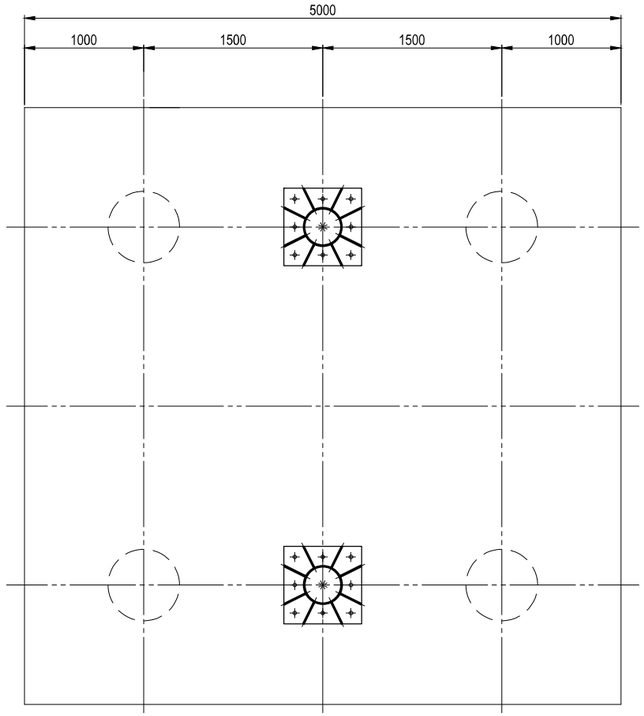



SECTION A
SCALE 1:25




PLAN - REINFORCED CONCRETE PILE CAP DETAIL
SCALE 1:25

## NOTES:

1. MINIMUM CONCRETE COVER TO REINFORCEMENT SHALL BE 75mm.
2. ALL STRUCTURAL CONCRETE SHALL HAVE A MINIMUM COMPRESSIVE CUBE STRENGTH OF 30MPa AT 28 DAYS.
3. THE MINIMUM PILE EMBEDMENT DEPTHS ARE BASED ON VOLCANIC ASH.
4. DETAILED DESIGN BY CONTRACTOR.

SCALE 1:25 (ANSI D) 0 500 1000 1500 2000 2500mm

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TITLE: PIPE BRIDGE TYPE 2
PILE CAP FOUNDATION DETAILS

| SCALE ON ANSI D | DRAWING No | REV |
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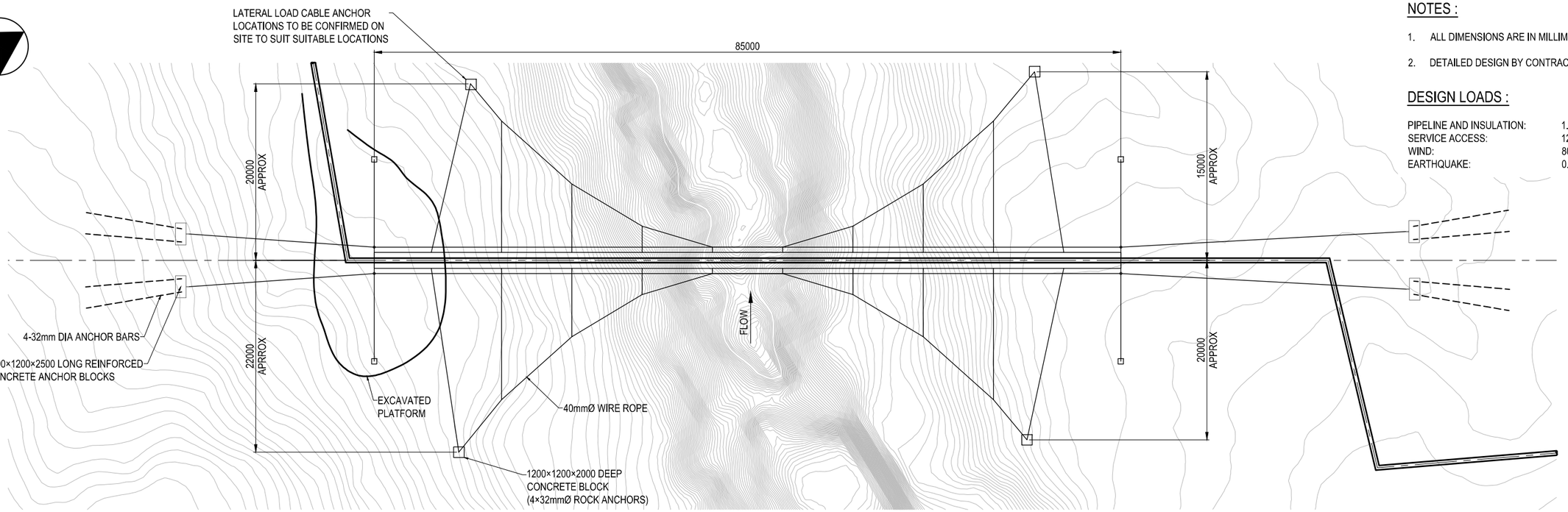


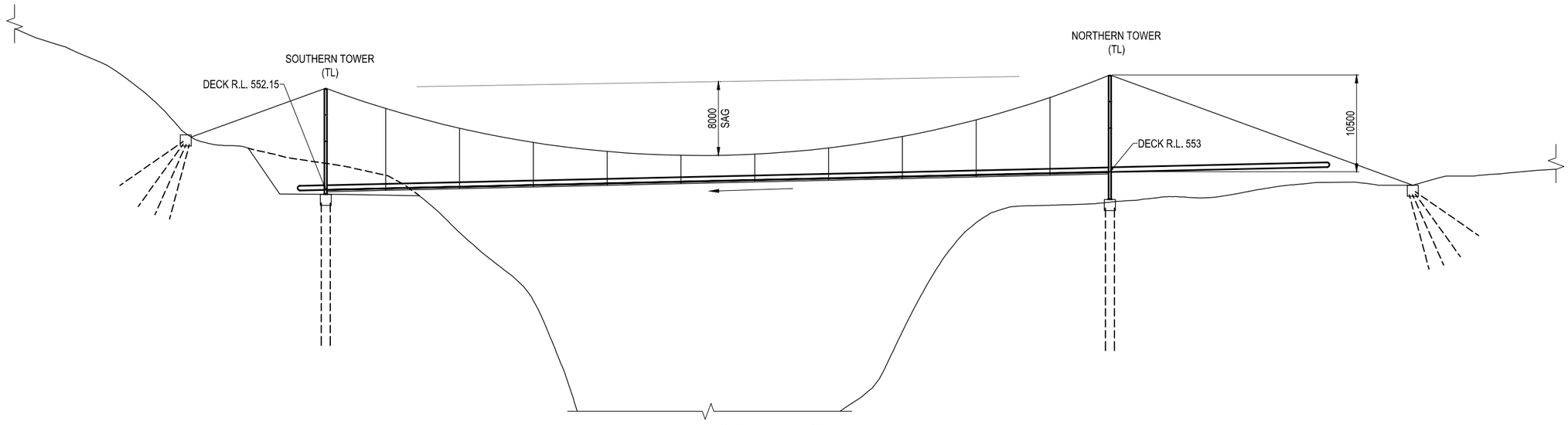

BRIDGE PLAN
SCALE 1:250

## NOTES :

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.
2. DETAILED DESIGN BY CONTRACTOR.

## DESIGN LOADS :

| | |
|---|---|
| PIPELINE AND INSULATION: | 1.9 kN/m |
| SERVICE ACCESS: | 12 kN |
| WIND: | 80 m/sec |
| EARTHQUAKE: | 0.6g |




BRIDGE ELEVATION
SCALE 1:250

SCALE 1:250 (ANSI D) 0 5 10 15 20 25m

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| REV | DATE | DRAWN | REV'D | APP'D | REVISION |
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DGDC DRAWING NUMBER:

CLIENT: DOMINICA GEOTHERMAL DEVELOPMENT COMPANY
PROJECT: DOMINICA GEOTHERMAL POWER PLANT

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| SM | KR | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE 19/07/18 | DATE 19/07/18 |
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TITLE: PLAN & ELEVATION

SCALE ON ANSI D: 1:250
DRAWING No: RZ042100-SC-DRG-0030
REV: 0

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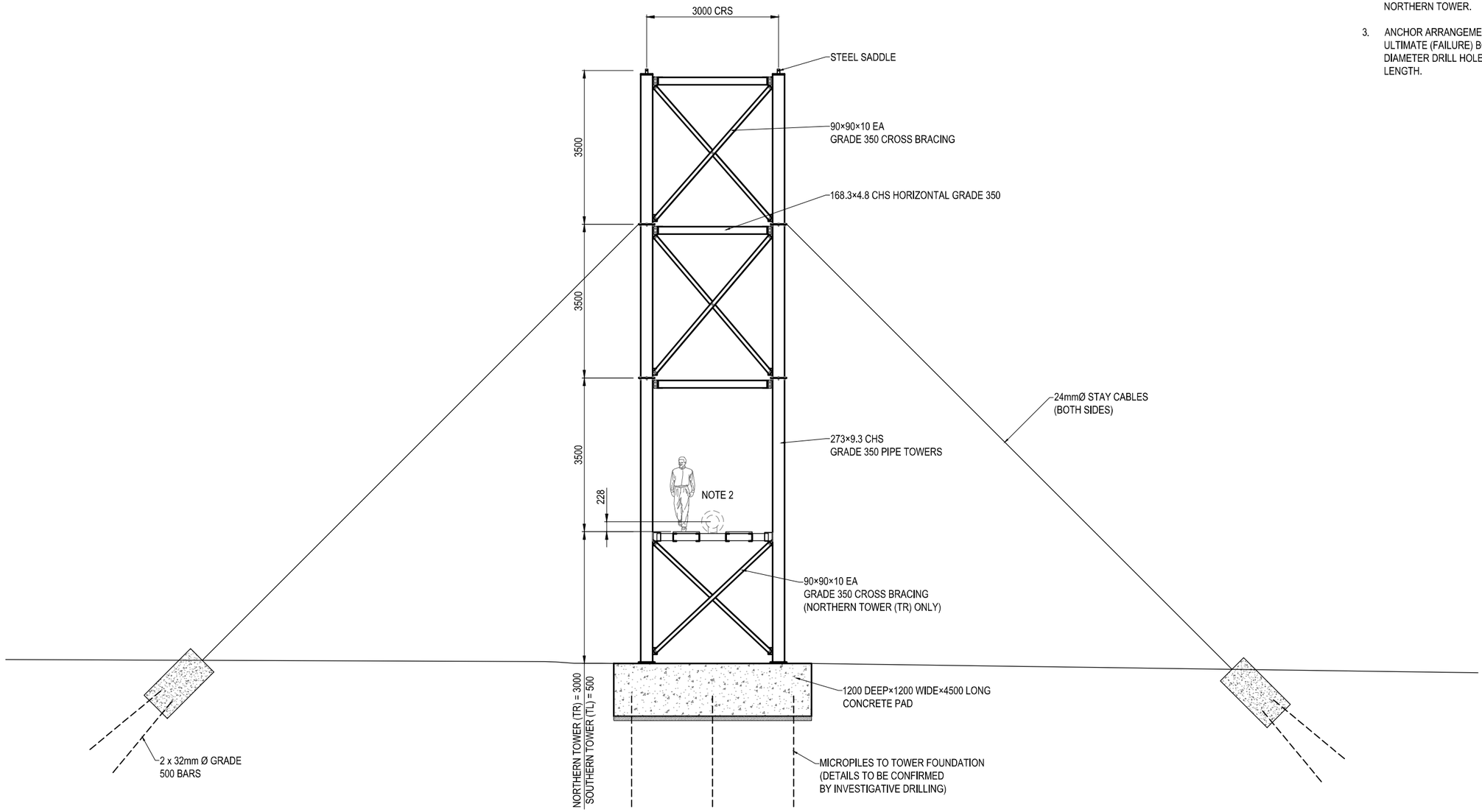
LOCATION: \\acobs.com\ANZ\RP\Projects\P\RZ042100\01_Design\Drawings\RZ042100-SC-DRG-0031.dwg
DATE: 1/08/2018 2:51:35 PM NAME: MAKKAR, SAGAR




## TOWER ELECATION
SCALE 1:50

## NOTES :

1. REFER DRAWING RZ042100-ME-DRG-0030.
2. PROVIDE STAIR CASE ACCESS TO PIPE BRIDGE DECK FOR NORTHERN TOWER.
3. ANCHOR ARRANGEMENT SHOWN ASSUMES A ROCK TO GROUT ULTIMATE (FAILURE) BOND STRENGTH OF 500KPa AND 150mm DIAMETER DRILL HOLE AND MINIMUM 3m LONG ANCHOR BOND LENGTH.

SCALE 1:50 (ANSI D) 0 1 2 3 4 5m
1 0.5

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|---|---|---|---|
| SM | KR | LJS | LJS |
| DESIGNED | DESIGN REVIEW | DATE 19/07/18 | DATE 19/07/18 |
| FRAME | FRAME | | |

TITLE: BRIDGE TOWER ELEVATION

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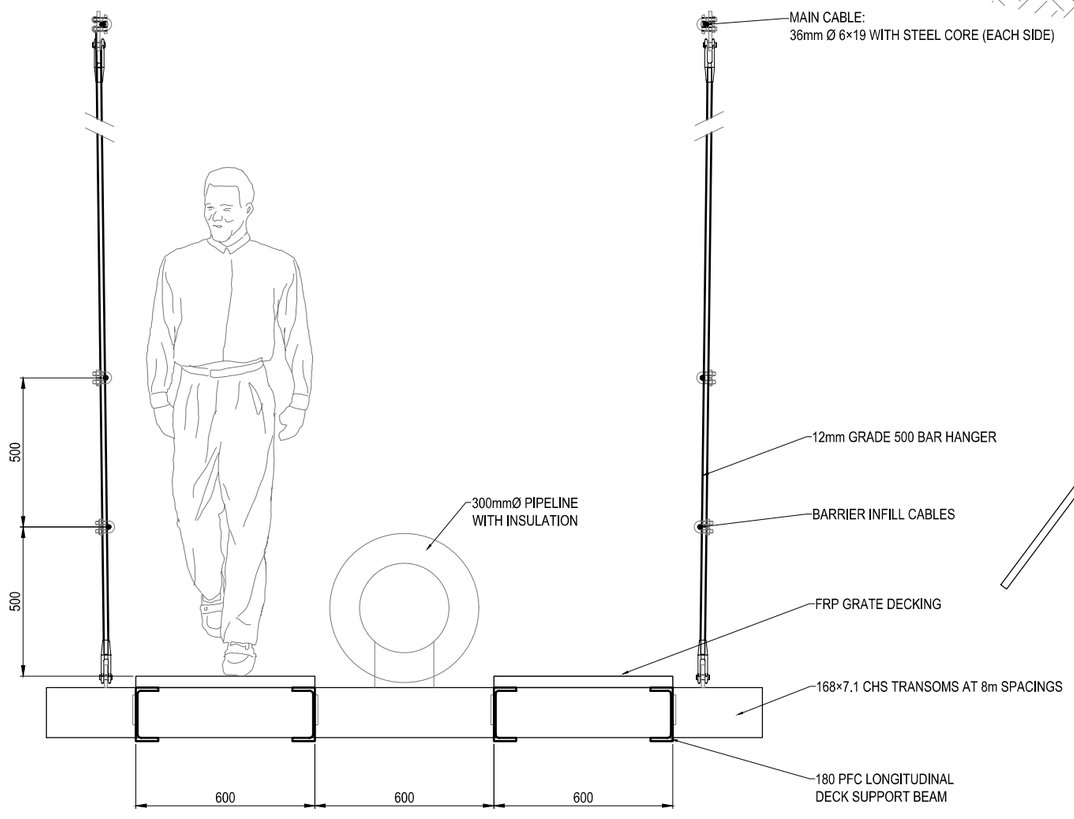
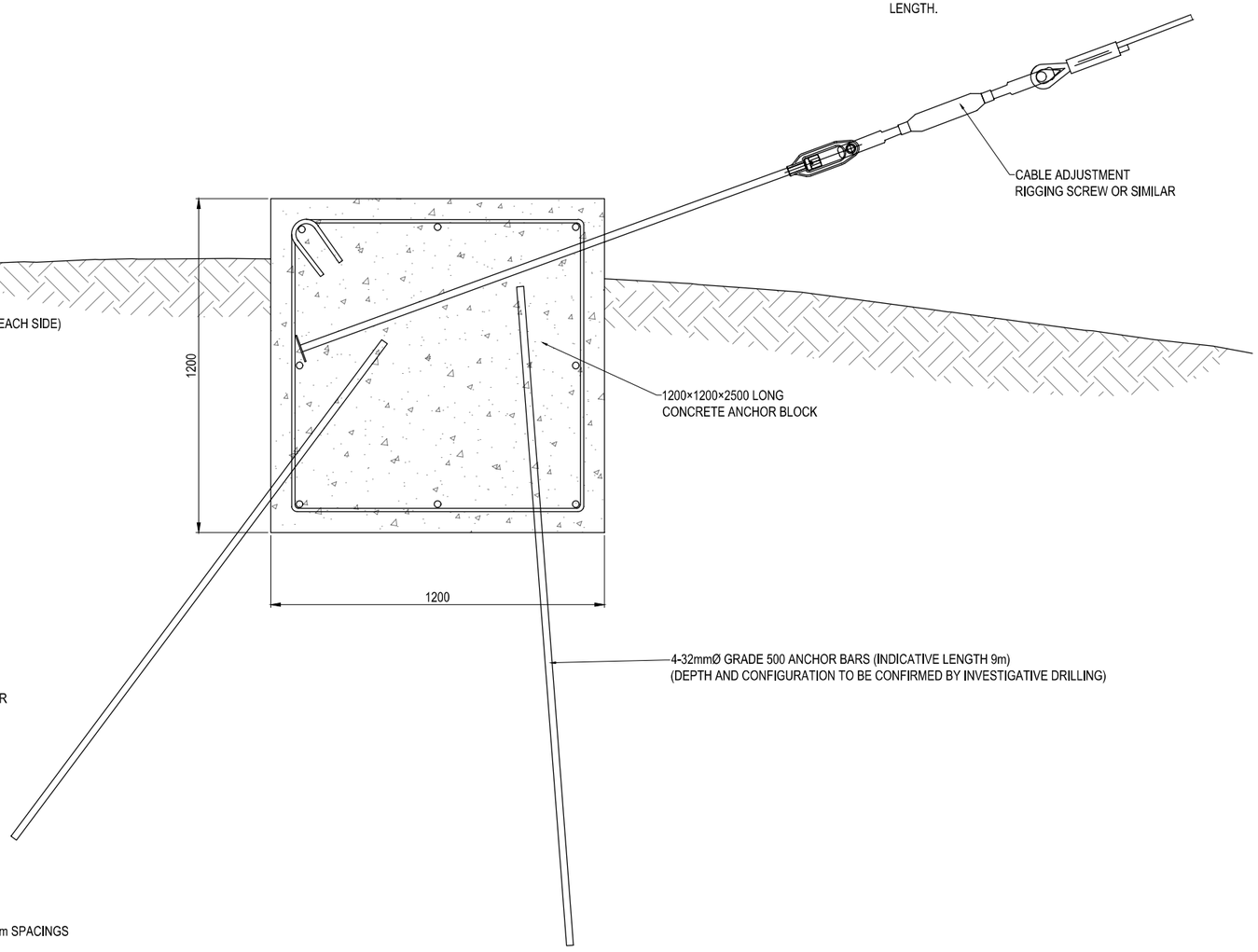
DATE: 1/08/2018 2:53:10 PM NAME: MAKKAR, SAGAR
LOCATION: \\acobs.com\ANZ\RP\Projects\P\RZ042100\01_Design\Drawings\RZ042100-SC-DRG-0032.dwg

## NOTES :

1. REFER DRAWING RZ042100-ME-DRG-0030.
2. ANCHOR ARRANGEMENT SHOWN ASSUMES A ROCK TO GROUT ULTIMATE (FAILURE) BOND STRENGTH OF 500KPa AND 150mm DIAMETER DRILL HOLE AND MINIMUM 3m LONG ANCHOR BOND LENGTH.




TYPICAL BRIDGE SECTION
SCALE 1:10




TYPICAL MAIN CABLE ANCHORAGE ARRANGEMENT
SCALE 1:10

SCALE 1:50 (ANSI D) 0 1 2 3 4 5m
1 0.5

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PROJECT: DOMINICA GEOTHERMAL POWER PLANT

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| DESIGNED | DESIGN REVIEW | DATE 19/07/18 | DATE 19/07/18 |
| FRAME | FRAME | | |

TITLE: BRIDGE SECTION AND CABLE ANCHORAGE DETAIL

| SCALE ON ANSI D | DRAWING No | REV |
|---|---|---|
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# Part 2 - Employer’s Requirements

Section VII - Employer’s Requirements

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# Specification

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# 1. General Requirements

## 1.1 General Description of Project

The Employer is developing the Dominica Geothermal Power Plant, located in Laudat, Roseau Valley, Dominica and has assessed that the geothermal resource has sufficient capacity to support the operation of a nominal 7MWe gross generating plant. The Project Site is as shown in the drawings' Project Location Map.

The drawings referenced within this Specification are provided in the Bid documentation, Part 2 – Employer's Requirements, Section VII.

### 1.1.1 Scope of Supply

The Contractor Scope of Supply shall include the following and are further described in the main body of this Specification:

1. Site preparation including all earth works, civil works, concrete foundations, roading, pavements, storm water management and drainage.
2. Project buildings and structures, operator platforms
3. Steam Gathering System (SGS)
    a. Two phase pipeline from a single geothermal production well.
    b. Steam Separator
    c. Steam System and piping including steam cleaning
    d. Brine pumping and brine piping injection to the reinjection wells.
    e. Condensate piping and condensate injection system
4. Power Plant according to the energy conversion technology (steam condensing cycle or Organic Rankine Cycle plant)
    a. Turbine and generator sets and ancillaries such as machine protection, governor/supervisory, lube and seal oil systems and similar.
    b. All Heat exchangers
    c. Feed pumps and motors
    d. Generators, complete with exciters and excitation control systems
    e. Switchgear including generator breaker and controls, and motor controls
    f. 11kV grid connection switchgear and coordination activities with DOMLEC the national electrical authority.
5. Control system and instrumentation for the project.
6. Commissioning for the works.
7. Operation and Maintenance support

The Power Plant shall comprise of at least two Units and each unit shall have the same equal capacity. The Power Plant layouts provided in the Bid drawings are indicative only. The Contractor shall locate and optimise the layout design to suit the technology offered as well as to minimise costs and to facilitate mitigation measures for emissions.

A Unit is considered as the turbine and generator system and its associated equipment and auxiliaries. A Unit may have more than one turbine and generator.

References to “Unit” shall be taken to refer separately and jointly to the two or more Units.

The Units shall be designed to operate separately or simultaneously at full output, and maintenance of each Unit shall be carried out whilst the other remains operational.

### 1.1.2 Complete System

The Contractor shall provide a fully integrated and complete operating SGS and Power Plant with subsystem functions and overall performance as required by the Contract, including all interfaces to DOMLEC. The Employer’s Requirements are not a detailed design specification, but provide functional and descriptive definitions of equipment, materials and services, and define the minimum performance and quality requirements the Plant shall achieve.

The responsibility for care and custody of the Plant together with the risk of loss or damage thereto shall remain with the Contractor until Operational Acceptance of the Facilities or the part thereof in which such Plant are incorporated.

It is the responsibility of the Contractor to provide a complete and operating system and to achieve satisfactory operation and performance as stated herein, whether or not individual system components are specifically addressed in the Contract.

The Plant shall be designed and guaranteed to operate to over the full range of interface and ambient conditions specified in the Interface Schedule. The Interface Schedule is provided in the Bid documentation, Part 2 – Employer’s Requirements, Section VII.

The Plant shall be designed to maximise the net electrical output available from the input process fluid in a cost effective manner and, consistent with utility industry standards, require the minimum reasonable operating and maintenance costs.

The Plant shall utilise standard plant and components made to proven designs with good long term operating experience in a similar environment and application. Any changes to proven equipment shall be subject to agreement by the Project Manager. Recently identified or developed improvements which the Contractor considers advantageous to the Employer shall be proposed to and discussed and agreed with the Project Manager prior to adoption.

### 1.1.3 Power Plant Energy Conversion Technology

The Energy Conversion Technology for the Power Plant shall be from the following options:

1. Steam condensing power plant

2. Organic Rankine Cycle (ORC) power plant

The power plant technologies proposed shall utilise the separated geothermal steam with the option of also utilising the separated geothermal brine in order to meet the minimum net electrical power output as defined in the Functional Guarantees of the Bid document.

The ORC Power Plant shall use a secondary motive fluid such as pentane, butane, or refrigerants as the motive (working) fluid, which receives thermal energy by heat transfer from the geothermal fluids through vaporizers and preheaters.

The Power Plant shall be primarily designed for flexible operation and able to reliably operate to meet despatch requirements of the System Operator. The Plant will normally operate 24 hours per day, 7 days per week, and shall be suitable to operate

in a dispatched mode on a per unit basis continuously at any part loading down to 25 percent load. At loads from 25% NCR down to house load the unit shall be able to operate continuously for a period of not less than two hours.

The Plant shall be designed to operate continuously over the range of conditions expected at the plant site including seasonal ambient variations and wind loading.

The Power Plant availability factor shall be higher than 93%.

Generated electricity will be sold to Dominica Electricity Services Ltd (DOMLEC) under a separate commercial arrangement. Required grid upgrades to transmit and distribute the electricity will be undertaken by others.

### 1.1.4 Steam Gathering System

The Government of the Commonwealth of Dominica (GoCD) has completed the drilling of geothermal exploration, production and injection wells in order to enable the Project. The completed wells are referred to as follows:

- Production well: WW-P1
- Brine Injection wells: WW-R1 and WW-01
- Condensate Injection Well: WW-03 (on same pad as WW-P1)
- A further well was drilled, WW-02, but is not anticipated to be required for the Project

The SGS shall include the two phase piping, two phase separator, steam piping, steam scrubber, brine piping, brine pumping station and all required piping fittings, brine and condensate sumps, flash tank, control valves and instrumentation.

The general requirements for the SGS are provided in the Process and Instrumentation Diagrams as well as the preliminary reinjection route drawings.

### 1.1.5 Layout

The Employer has prepared a concept layout drawing for the Plant.

Whilst the Contractor is free to lay out the Plant as they feel is best within the Site, the concept drawings convey general expectations of the Employer and have been compiled considering the topography, access and general constructability.

### 1.1.6 Design Life

The design life of the Plant, with exceptions as noted below, shall be thirty (30) years and the design, manufacture and construction shall be undertaken to ensure compliance with this requirement.

The design life for all buildings shall be taken as 50 years for the application of the structural design codes.

Piping shall be analysed and designed for a minimum of 7,000 equivalent full temperature displacement cycles.

### 1.1.7 Performance Requirements, NCR & Operational Conditions

The conditions for NCR are defined by the Functional Guarantees and the Interface Schedule. The design of eequipment common to both Units shall account for both Units operating at NCR conditions.

The Plant shall be designed to provide best efficiency at NCR conditions and be suitable for operating over a range of inlet conditions, flows and ambient conditions to enable the Employer to maximize generation.

Within the range defined in the Interface Schedule, increases in Plant output as a result of lower than design ambient temperatures should not be limited by any major equipment capacity constraints. The design of the Plant shall allow the output of the turbine generator to increase to take advantage of the increased turbine output resulting from the effects of lower ambient dry bulb / wet bulb temperature as appropriate. The Plant shall be capable of delivering such increased output at dry bulb / wet bulb temperatures down to the 5$^{th}$ percentile according to the ambient data provided by The Employer.

## 1.2 Operability

### 1.2.1 General

The Plant will be operated and maintained as an integrated entity. Primary operation of the SGS and Power Plant shall be via a fully integrated Distributed Control System (DCS) with operator workstations in the Operator Control Room

The Plant control and instrumentation system shall provide a safe, reliable, efficient and essentially automatic system for coordinated control and monitoring of the Plant in all modes of operation. The system shall satisfy the following objectives:

1. Maintain the plant in a safe condition at all times. Automatic protection and plant trips shall be provided so that if a potentially dangerous or undesirable situation should occur, the plant and associated equipment will be maintained in a safe and undamaged condition without the need for any operator action.

2. Ensure that all automatic control functions shall have an acceptable level of fail-safe design and be capable of override by operator intervention. Manual mode shall be backed up by various inputs from automatic systems to a degree to provide safe, effective control, without distraction of the plant operator.

3. Provide for smooth start-up and shutdown of the Plant in accordance with pre-planned operating procedures with a minimum of operator intervention. The control and automation systems shall be designed so that start-up and shut-down of the Plant is normally and comfortably carried out with one control room operator and one field operator.

4. The start-up and shut-down process of the Plant shall be guided by the DCS using an interactive flowchart as a visual guide to operators. Each step of the process, whether manual or automatic, shall be depicted in the flowchart. The conditions / interlocks / operator intervention etc. required to satisfy to progress from one step to the next shall be depicted in the flowchart together with their current state. Plain English descriptions shall be used as well as asset tag numbers / descriptions as appropriate. Links shall be provided to interlocks or condition (or other “active” point) that is part of the start-up and shut-down processes, which when selected (clicked) shall automatically navigate to the relevant DCS logic; this view shall then show, in current live state, all logic associated with the stage of the process relevant at the time.

5. Provide for efficient steady-state control of the Plant.

6. Provide reliable steady Plant operation at all outputs up to and including net rated capacity.

7. Minimize the effects of abnormal process conditions, load upsets, and equipment malfunctions on Plant operations.

8. Minimise operator skill requirements by incorporating comprehensive safety features, automatic operation, diagnostics and alarms and operator interfaces that minimize the potential for operator error.

9. Minimize the number of plant forced outages and spurious trips.

10. Provide for reliable, economical/optimum operation of the turbine, generator and related systems.

11. Provide a control system that allows for maximum flexibility to expand the system and/or modify control functions that affect the performance of the unit during initial start-up, testing and operation.

12. Minimize the effects of corrosion and scaling through proper equipment and material selection, equipment location, environmental control, and on-line maintenance capability.

13. Provide systems for prompt, effective communications within the Plant and externally to the System Operator.

14. Allow remote access and control of the Plant over the public internet system via an appropriate firewall. This will enable remote HMI access.

### 1.2.2 Start-Up and Loading

The Plant shall be capable of being started up from cold to synchronisation in 3 hours and from hot stand-by to synchronisation in 10 minutes.

The facility shall be capable of the following:

- A MW ramp rate of 20% of full load per minute under hot start conditions.
- A MW ramp rate of 10% of full load per minute under cold start conditions.
- Under normal operating conditions after completion of turbine start-up, the ability to maintain normal operation in the event of instantaneous load changes of up to 10 per cent of rated output.

### 1.2.3 Power Factor, Reactive Power and Voltage Control

The operator shall have the choice of operating in power factor control mode or in reactive power control mode or in voltage control mode. The normal operation of the AVR is voltage control mode. In power factor control mode, the power factor shall be maintained by the continuous automatic control of the generator excitation and shall be demonstrated at 0.80 lagging and 0.95 leading at full load. In reactive power control mode, the reactive power shall be maintained by the continuous automatic control of the generator excitation and shall be demonstrated at a lagging VAr level of 60 percent of MW rating and a leading VAr level of 31 percent of MW rating lagging. In voltage control mode the generator terminal voltage shall be capable of controlling voltage to an operator setpoint with the range of voltage being -5% to + 10% of the rated line voltage.

### 1.2.4 Loss of Grid Connection

Loss of the grid connection shall result in the Power Plant continuing to generate to match “islanded” or “house” load, maintaining all necessary systems such that it may be resynchronised to the external grid without the need to stop generating. Electrical protection systems shall be designed and co-ordinated with the grid protection such that the Plant systems are as stable as possible for grid events while adequately protecting the plant, enabling the Plant to either “ride through” or trip to house load for low level grid events.

Following a trip to house load the operator will then have the choice of initiating a safe and orderly shutdown of the plant, or "Hold at House Load" until grid power is re-established and then re-synchronising.

### 1.2.5 Operating Regime

The following methods of operation of the Plant shall be provided. Individual items of plant shall be able to operate continuously and unattended except for supervision from the OCR or remotely at a location away from Site but connected to the internet. In the event of failure of an item of equipment, it shall be automatically made safe, its duty taken over by a standby item of plant as appropriate and an alarm generated to the appropriate control system.

- Plant Start Up and Shutdown

  To be managed and directed from the OCR. The operator in the OCR shall be able to start and stop auxiliary Plant and initiate automatic turbine run-up and run-down. Local-to-plant operating and surveillance at each plant item as

required including manual operation of drain valves used during cold starting. Generator automatic synchronisation shall be initiated from the OCR.
The overall system shall be designed with sufficient automation and remotely operated equipment such that a single OCR operator with a roving field operator can safely start-up, shut down, monitor and control the Plant from the OCR on the Site.

- Normal Operation

  Turbine load control, supervision of the operating Plant and any standby Plant shall be provided from both the OCR and via remote operation with periodic surveillance and monitoring by roving operators under the direction of the OCR operator.
  The plant will have the ability to be operated unmanned for extended periods of time. During unmanned periods the plant shall have the ability to be remotely operated from various off-site web based facilities.

- Fault Conditions

  Fault conditions shall, where possible, initially provide warnings to the Plant operator to permit remedial actions to be taken. A continued or further degrading fault condition shall cause the Plant to automatically fail into a safe condition. Initial assessment will be undertaken by the operator who will take corrective action as necessary and call out roving operator/maintenance staff to take local corrective actions. If the Plant is running unmanned, faults or alarms shall alert the nominated operator located off-site who will be able to access the remote operation facility to check the Plant status and make any plant operational changes required.

  In the event the Plant trips under fault conditions including a loss of grid event, the control of the brine and steam systems will place these systems in a safe state to give the operators sufficient time to reconnect to the grid before automated steps are taken to undertake a controlled shut down of steam field production. The local main brine sump located on the production wellpad shall be sized to accommodate at least 8 hours of brine discharge equivalent to full load conditions.

### 1.2.6 Consumables

The Contractor shall submit to the Project Manager a schedule of operational consumable items, listing the items and the quantities required per month of operation of the Plant supplied under this Contract. The listing shall include sufficient detail to enable the Employer to order the materials directly, where possible, from a local supplier.

## 1.3 Maintainability

### 1.3.1 General

The maintenance facilities shall be designed and constructed to effectively support the operation of the Plant for 30 years.

The Plant shall be designed and constructed in a manner that facilitates routine, periodic and forced outage maintenance. This shall include adequate provision of facilities such as equipment withdrawal spaces, access ladders, stairs and platforms, crane access and lifting points and laydown areas. Isolating facilities shall be provided to allow the safe and efficient maintenance of all items of the Plant.

Sufficient space and access shall be provided to allow the generator rotor to be withdrawn from the generator body for major overhauls. This shall include ability to load the rotor onto a truck for transport away from Site.

Sufficient space and access shall be provided to allow the turbine rotor to be removed from its casing for major overhauls. This shall include ability to load the rotor onto a truck for transport away from Site.

A covered laydown area shall be provided within the Power Plant which is sufficient for the efficient major overhaul of an entire turbine generator plus all related auxiliary plant.

The Plant shall be arranged so that one Unit can be easily and safely isolated from the other Unit without the need to take the remaining Unit out of operation.

Drawings shall be provided showing the intended maintenance clearance envelopes and, where required, withdrawal routes and laydown spaces.

Lifting equipment shall be provided to ensure safe removal of all plant and equipment provided as part of the Facility so that lifting by human power only is limited to items of less than 50kg.

The plant and duplicated equipment shall be arranged identically to each other Unit to ensure full interchangeability of parts and eliminate any possible disorientation of operators between Units. This shall include the relative placement of all components including, but not limited to, electrical and control panels.

### 1.3.2 Maintenance Facilities

The Plant shall be provided with:

1. Sufficient capacity (including unloading bay, laydown areas, crane facilities and crane access) for the efficient execution of the complete overhaul of the main rotating plant and its auxiliaries, in addition to the normal routine station maintenance work.

2. A workshop and a stores facility as specified elsewhere in this specification.

### 1.3.3 Tools and Special Tools

The Contractor shall furnish all necessary hand tools, machine tools, special tools and test equipment for the installation, operation, regular maintenance and repair of the Plant over its life. In addition, special tools shall be provided to allow extraction of the generator and turbine rotors for major overhauls, including the temporary supports needed to safely support the rotors in the laydown areas in accordance with manufacturer's requirements.

Programming and configuration software tools shall be provided for all software based systems provided under the contract. Software licenses for maintenance tools shall be provided under the name of the Employer.

For the purposes of this clause, special test equipment with an individual value that exceeds USD 5,000 may be provided at additional cost with the Project Manager's prior approval

Immediately prior to "Operational Acceptance" the Contractor shall hand over to the Project Manager all tools and equipment as follows:

1. Each item shall be new in good working order and condition.

2. Each item shall be included in a schedule of where purchased together with the contact information for the supplier.

3. Each item shall be tagged and uniquely identified to reference documentation.

4. Each item shall be preserved for storage as appropriate to the expected utilisation of the item for future operational or maintenance requirements

5. Each item shall be placed in the nominated storage location on the Site

6. Where applicable, written operating and maintenance instructions for each item shall be provided to the Project Manager

7. Lifting equipment, cranes, pressure vessels and other similar items requiring certification or other form of regulatory approval for use shall be handed over together with all necessary certifications and approvals in a valid condition. Items requiring re-certification based on use or time shall be re-certified at the expense of the Contractor at the time of handover.

## 1.4 General Management Requirements

### 1.4.1 General

The area of land provided for the Steam Gathering System (SGS), Power Plant, and Medium Voltage (MV) Switch room, which together is the Site, is indicated on drawings provided with the Employers Requirements.

The Contractor shall be responsible for the security of the Site and for the storage, maintenance and security of all materials and equipment delivered to the Site, until the final Operational Acceptance Certificate has been issued in accordance with General Conditions of Contract 25.3.

The Contractor shall be responsible for dust control on the Site including water spraying of roads or other suitable remedies as appropriate.

The Contractor shall be responsible for the clean-up of the Site on a daily basis. The Site is to be kept clean and tidy at all times and clean-up shall be performed throughout the day with a final emphasis on site clean-up at the end of each shift. This clean-up emphasis is to contribute to the safe working conditions on the Site. Disposal of waste materials, both solid and fluid, shall be in accordance with local regulations, good hygiene and good construction practise, including the avoidance of oil or chemical spillage or run-off into local water ways.

The Contractor shall be responsible for all accommodation and transport needs of the Contractor's personnel taking note of any provisions of the Employers Requirements.

### 1.4.2 Health & Safety, Environmental and Social

The overall safety of the Employer's personnel, the Contractor's personnel, the public, the environment and the Plant is the overriding requirement in the design, construction, operation and maintenance of the Facilities.

The Contractor shall develop and submit a comprehensive Health & Safety, Environment and Social Plan for the delivery of the Facilities for the review and approval of the Project Manager. This plan shall incorporate the requirements of any Governmental Authorities having legal jurisdiction in such matters. This plan shall be completed in accordance with the paragraphs below, submitted to the Project Manager and approval obtained before any activities are undertaken outside of the Contractor's home office location(s).

The Contractor's plans, procedures and practices for the management of Health & Safety, Environment and Social shall be fully in accordance with the Conditions of Contract and the Employer's Requirements (in particular the Employer's Environmental and Social Management Plan), the Dominica safety, health and environment legislation, and the safety, health and environment requirements of the electrical grid authority.

The Contractor shall provide the necessary human and material resources and shall be responsible for the management of Health & Safety, Environment and Social on the Site until the final Operational Acceptance Certificate has been issued in accordance with General Conditions of Contract 25.3.

The Contractor shall ensure that all of the Contractor's and Contractor's subcontractors' personnel comply with the requirements of the Safety, Health and Environment Plan.

The Contractor shall convene and chair a monthly Safety, Health and Environment meeting to be attended by the Project Manager and lead Safety, Health and Environment personnel from the Contractor and subcontractors engaged on site. The Contractor shall distribute minutes of these meetings within three days.

The Contractor shall participate in inspections and audits conducted by the Project Manager and shall respond to corrective actions arising from audit and inspection findings in a timely manner. The Contractor's records shall be available for inspection by the Project Manager.

The Contractor shall appoint full time dedicated Health & Safety, Environmental and Social professionals who are appropriately qualified. There shall be three persons with responsibility for:

a. Health and Safety

b. Environment

c. Social

The professionals shall be responsible for the following:

1. Implementing and maintaining the Contractor's Health & Safety, Environmental and Social Plan
2. Ensuring the Health & Safety, Environmental and Social systems and processes are implemented, maintained and complied with by the Contractor and subcontractors
3. Reporting on the Health & Safety, Environmental and Social performance of the Contractor and subcontractors
4. Hazard management and mitigation by the Contractor and subcontractors;
5. Incident, accident prevention and mitigation
6. Incident investigation and reporting
7. Maintaining records
8. Conducting inspections, identifying corrective actions
9. Ensuring compliance to the Employer's Health & Safety, Environmental and Social requirements
10. Ensuring compliance to the Contractors Health & Safety, Environmental and Social plan

The Contractor's lead Health & Safety, Environmental and Social professinals shall be the point of contact for the Project Manager in regard to Health & Safety, Environmental and Social matters.

The Contractor shall provide, as part of the Health & Safety, Environmental and Social plan, a complete description of their Health & Safety, Environmental and Social team, including individual responsibilities, qualifications and past experience.

### 1.4.3 Work at Site

The Contractor shall carry out all activities in accordance with the approved Health, Social, Environmental and Safety plan. Copies of this plan shall be maintained at all locations where activities related to the Facilities are being undertaken.

This plan shall include all the arrangements required to ensure the health and safety of all personnel undertaking and affected by the Facilities.

As a minimum the Health, Social, Environmental and Safety Plan shall include the following:

Contract Description

A description of the work and scope of the plan including a summary of the major activities and types of work

Details of specialist tasks or procedures required

Areas of the Contract requiring special consideration and procedural requirements, e.g. presence of public, working adjacent to other contractors.

Contract Health, Social, Environmental and Safety Structure and System

Copy of the Contractor's Health, Social, Environmental and Safety policy

Organisation structure

Description of roles and responsibilities of all personnel covered by the plan

Position and name of the Contractor's senior person who will liaise with the Project Manager.

Contract Inductions and Health, Social, Environmental and Safety Training

Outline of induction procedures for all personnel working on the construction site

Details of induction modules or induction course content

Induction records

Register of employee training relevant to the work

Register of personnel holding authorisations, permits, competency certificates, licences required for the contract

Dissemination of health and safety information regarding the plan, site hazards and mitigations to be implemented to the Contractor's and subcontractor's personnel

Health, Social, Environmental and Safety Work Practices and Procedures

List of Company safe work and environmental procedures relevant to the Contract.

Copies of safe work and environmental procedures or instructions

Details of contract operations subject to work permits

Permit to work process and procedures

Register of issue of permits

Register of inductions in permit and safe work procedures

Identification of the appropriate equipment to be used including personal protective equipment

Working at Height Procedures including scaffolding erection certification and use

Hot Work Permit procedures

Lift plans for lifting of plant for transport and installation purposes on site including crane lift/reach curves.

Visual identification of live/in service Plant.

Lockout/isolation procedures for commissioning Plant

Formal written permit to work system listing lockout points and identifying Plant to be isolated

Copies of other relevant safe work procedures

Risk Assessment

Identification and ranking of existing and potential construction hazards and risks

Procedures for the elimination, isolation or mitigation of hazards and risks

Workplace Safety, Health and Environment Inspections

Procedures for monitoring and enforcing the plan including frequency of inspections, inspection checklists and close-out of actions arising from inspections

The maintenance of a register of hazards for the Site

Reporting of hazards

Emergency Procedures

Emergency procedures including all necessary contact details for emergency and support personnel/services

First aid procedures including contact details for all first aid staff

Fire prevention and evacuation procedures

Incident Reporting

Procedure for incident (near-miss) and accident investigations and reporting including:

- Notification to the Project Manager within 1 hour of all serious harm accidents occurring
- Notification to the Project Manager of all other incidents/accidents within 24 hrs;
- Delivery to the Project Manager fully documented reports within 48hrs.

The report shall include the problem, root cause and corrective actions to prevent recurrence.

Accident register

Health, Social, Environmental and Safety Performance Monitoring

Procedure for review of the plan

Audit procedure

Records to be maintained on site

Register of Plant and any inspection records, licences, etc

Material safety data sheets for all hazardous goods and chemicals brought onto the Site

Worker grievances as per Workers Grievance Mechanism

Reporting requirements

Contractor's on-site Safety, Health and Environment committee which shall be convened at least monthly

Other

Management of visitors (describe in detail the management of visitors)

Regular, daily site toolbox meetings shall be held to ensure all personnel are aware of the current activities on the Site as they affect Safety, Health and Environment and to maintain safety and safe working practices at the top of all personnel's mind.

Records shall be maintained to include licences or certificates of competency held by personnel appropriate to site activities, e.g. vehicle licence, crane operation, rigger.

A register of plant and equipment and inspection records shall be kept.

### 1.4.4 Safety, Health and Environment Induction and Training

The Contractor shall ensure that all of the Contractor's personnel shall have participated in a site induction training programme before they commence work at the Site.

The Contractor shall also ensure that all Employer's and Project Manager's personnel and any other person visiting the Site shall have participated in a site induction training programme before entering the Site. The Contractor shall be responsible for, shall run and keep records of the induction programme. The induction programme shall ensure that the personnel inducted are fully familiar with the Safety, Health and Environment plan and their responsibilities under that plan.

No personnel shall be allowed to work at the Site without prior formal induction training taking place. Personnel who have not successfully completed the induction training shall be escorted under direct and continuous supervision by a person who holds the relevant and current induction and Safety, Health and Environment training competences.

A refresher course for Safety, Health and Environment shall be held for every member of the Contractor's personnel every twelve months of their service on Site. The refresher course shall cover the base original requirements and all new or additional requirements,

The Contractor shall submit the Safety, Health and Environment induction training package to the Project Manager for review and approval and thereafter keep the Project Manager informed of updates and changes.

The Contractor shall ensure no personnel perform a task on their own for which they are not trained or competent, unless that person is working under the direct and continuous supervision of a person who is trained or competent. The Contractor shall demonstrate to the Project Manager upon request, evidence of any Contractor or subcontractor personnel training/competencies related to a work task.

### 1.4.5 Hazard Management

The Contractor shall maintain a comprehensive hazard management system covering all work activities on and off the Site, in order to systematically identify, assess, and control hazards at the site that could cause harm or serious harm.

Hazard identification shall take full account of any special requirements concerning the nature, handling and storage of hazardous materials including fuel oils, gases and chemicals etc., and provide plant, equipment, buildings, handling procedures, material safety data sheets and other services accordingly.

Hazards shall be reviewed at least weekly and all updates shall be clearly communicated to all personnel on the site.

Output from the hazard management system shall be included in the monthly report (Clause 1.5.2).

The hazard management system shall be made available to the Project Manager on request in a fully auditable format.

### 1.4.6 Project Management Plan

The Contractor shall, within fourteen (14) Days following the Effective Date, prepare and submit to the Project Manager for review and approval, a Project Management Plan. The Project Management Plan shall, among other aspects, include the following:

a. Define the coordination and management of all technical, safety, quality assurance, quality control and other project activities in accordance with the Contract;

b. Determine the implementation of key quality plans and quality control procedures in accordance with Contract;

c. Determine the approach to regular Project control meetings with the Project Manager to a pre-determined programme to monitor progress of the Project including as necessary technical and progress review meetings, Site safety meetings, routine coordination weekly project meetings and daily construction and/or commissioning meetings;

d. Ensure the readiness of the Operation and Maintenance Manuals and documentation to be suitable for commissioning, and for operation and maintenance of the Plan;

e. Determine the management of the commissioning and testing of the Facilities;

f. Define the arrangements for operation and maintenance training on the Facilities for the Employer's personnel.

## 1.5 Project Controls

### 1.5.1 Schedule

The Contractor shall prepare and submit to the Project Manager for review and acceptance a detailed critical path schedule for the Facilities in both CPM and Gantt chart format. The schedule shall be prepared in Microsoft Project.

The schedule shall be developed to a Class 3, Level 4 detail in accordance with the AACEI guidelines.

Both hard (printed) and soft (native format) copies shall be submitted. In addition, outputs as .pdf files shall be provided for review by those without access to the scheduling software. The Contractor shall co-operate with the Project Manager in ensuring that the schedule incorporates the effects of other work being undertaken on the Facilities, or the wider project.

The schedule shall be constructed to allow electronic extraction of summaries in such a way as to enable roll up to higher levels for management reporting purposes. In particular, the schedule shall have separate sections covering engineering design, manufacture, procurement and shipping, civil/structural construction, erection and commissioning and appropriate schedule logic and links between tasks.

The schedule shall clearly identify the critical path for the Work and interface milestones. It shall contain information on resource loadings, both for labour and equipment.

The schedule shall incorporate sub-schedules as required covering work by subcontractors.

### 1.5.2 Progress Reports

The Contractor shall provide detailed monthly progress reports to the Project Manager. Each report shall indicate the state of progress as at the last working day of the month. The monthly progress report shall contain:

1. Health & Safety, Environmental and Social reports including:

    a. Summary of Contractor and Sub-Contractors on site and numbers of respective personnel

    b. Safety statistics including accidents, incidents and near misses

    c. Commentary on significant incidents

    d. Comment on inductions

    e. Comment on updates to Contractor’s Safety, Health and Environment Plan

    f. Contractor’s Safety, Health and Environment activities

    g. Details of safety meetings and toolbox talks

    h. Details of site audits and inspections undertaken

    i. Planning for future safety activities.

    j. Environmental compliance

k. Any other items of significance or interest to the Facilities

2. An updated hard and soft copy of the schedule
3. Additional written comments (also to be provided in hard and soft format) describing the status of the Facilities
4. The percentage completion of all activities also indicating those activities currently in progress.
5. The achievements of the previous month
6. Drawings – status
7. Weather status during the last period
8. Activities to be undertaken during the following 3 months, including resource requirements
9. Any impacts being experienced on the critical path and milestone dates
10. Actions being undertaken to maintain or recover the critical path and milestone dates
11. Actions required of the Project Manager
12. Plant & equipment procurement including:
    a. Specification number and revision, title
    b. Vendor
    c. Date purchase order placed
    d. Manufacturing status
    e. Inspection schedule
    f. Promised shipping date
    g. Actual shipped date
    h. Promised delivery date
    i. Actual delivery date
    j. Current physical location.
13. Coloured photographs showing the progress of work on site

The Contractor shall submit their proposed progress report structure to the Project Manager within 14 days of the Effective Date for agreement.

### 1.5.3 Meetings

Progress review meetings shall be held at least once per month. The timing shall permit informed discussion of the most recent monthly progress report and shall normally be 7 days following the submission of the monthly progress report. The

venue of such meetings shall normally be at the Site, but may be changed by mutual agreement between the Project Manager and the Contractor.

Additional meetings shall be held as required by the Employer. In particular, more frequent meetings shall be held on Site to coordinate Site activities.

Minutes of all meetings will be prepared by the Employer. These minutes will document the main points of discussion and any agreements reached, rather than providing a verbatim record of the discussions. The draft minutes prepared by the Employer shall be forwarded to the Contractor for review, and shall be completed and returned with comments to the Employer within 5 days of receipt. The minutes thus prepared by the Employer, and incorporating the Contractor's comments, shall be the official record of the meeting.

### 1.5.4 Quality Assurance

The Contractor shall develop an overall Quality Assurance (QA) Plan for the Facilities and submit if for approval. as per the Conditions of Contract.

The QA Plan shall be in accordance with the requirements of ISO 9001 and shall cover all phases of the Facilities, including design, manufacture, construction, inspection and testing.

The QA Plan shall include Inspection and Test plans for all individual packages of the Facilities including the manufacturing and testing of major plant and equipment.

The Contractor shall be fully responsible for ensuring and monitoring that the QA procedures and practices of all subcontractors are fully compatible with the requirements of the overall QA plan.

The Contractor shall be responsible for obtaining all approvals, permits, licenses or similar releases, necessary for the design, manufacture, delivery, construction, inspection and testing of the Facilities.

The Contractor's overall program for the Facilities shall include the necessary provisions for obtaining all such approvals and permits. No extensions of time will be granted as a result of any delays resulting from the Contractor failing to obtain the necessary approvals within the allotted time periods.

## 1.6 Documentation Submission and Review

### 1.6.1 General

The Contractor shall provide sufficient information to enable compliance with the specifications in respect of the quality, operability, maintainability, and safety of the Facilities.

The Contractor and the Project Manager shall set up and maintain a document control procedure to enable all Parties (including the Employer) to control and monitor all project documents. The Contractor shall utilise the internet accessed document control and mail communication system nominated by the Employer – "Aconex".

Aconex will provide the following functionality:

- Email correspondence, automatically numbered according to the Employer's document numbering standard.
- Document control, document revision, document meta data and document numbering.
- Transmittals
- Document review workflows

### 1.6.2 Design Documents Including Drawing Schedule

The Contractor shall produce a comprehensive schedule of the information to be submitted pursuant to the requirements of the Contract to the Project Manager. The Contractor shall also maintain and regularly update, in a separate schedule, the status of the project documents produced throughout the duration of the Contract.

The comprehensive schedule shall be submitted to the Employer for review and approval. The Employer will indicate which documents are to be submitted to the Employer for review and approval. The remaining documents shall be for information only. The Contractor's Progress Reports shall include a section pertaining to the actual status of each such project document at the time of the submission of the progress report.

Each project document shall be clearly stamped to indicate the applicable status (whether it is "For information", "For review", "Issued for Construction", or "As-built").

If modifications are made to the project documents during the Defects Liability Period, the Contractor shall update the final project documents including drawings and supply the Employer with revised copies.

In addition to the Contractor's and OEM standard proprietary document numbers each Contract document deliverable will also include an unique, separate Employer defined document number. The Employer document number shall be in accordance with the Employer's document numbering system.

#### 1.6.2.1 Submittal of Project Documents by the Contractor

Copies of project documents shall be submitted by the Contractor to the Project Manager in accordance with the progress of the Facilities. A detailed list of project documents are to be mutually agreed by the Contractor and the Employer no later than one Month after the Effective Date and prior to submitting any such project documents for the Project Manager for review.

All Project Documents submitted shall be subject to the Project Manager's comments.

The Project Manager and the Contractor shall, no later than two (2) Months after the Effective Date, agree a list of drawings involving items whose manufacturing schedules are on the critical time path.

The Project Manager may, within 30 days of receipt of the plan, and in consultation with the Contractor, select one or more submissions as a mandatory "HOLD" point before the item concerned can be released for further design, procurement, fabrication or construction.

Where a "HOLD" point has been identified by the Project Manager in accordance with this section of the Employer's Requirements, the Contractor shall not proceed beyond the "HOLD" point without an instruction from the Project Manager advising that the "HOLD" has been released. Where the item for submission is on the critical path for the completion of the Facilities, the Contractor shall so advise the Project Manager of the status of the submission. The Contractor shall take account, in his programming of the work, for the time required for the review and release of drawings and documentation, whether the documents are critical or not.

### 1.6.3 Document review procedure

This procedure is intended to be followed for the review of the Contractor's agreed deliverables list for Client review.

The Project Manager shall review the submitted project documents and return such project documents to the Contractor within the time periods specified below.

Ten (10) working days - with respect to selected drawings involving items whose manufacturing schedules are on the critical time path, as agreed in accordance with clauses above; and

Fifteen (15) working days - with respect to all other project documents.

The relevant time period that the Project Manager takes to review a project document shall be calculated by reference to the date of receipt of such project documents by the Project Manager until the date of dispatch of such review comments by the Project Manager to the Contractor. Aconex workflows shall be used to guide and assist in managing this process.

The Project Manager shall provide comments or responses to the submitted project document using a Document Review Sheet (DRS). The Contractor shall provide the DRS for each project document and the DRS will be transmitted to the Employer along with the associated project documentation. The DRS shall have the same project number designate as the project document but will have an additional suffix.

Project documents which do not comply with the requirements under the Contract must be revised by the Contractor. The Project Manager shall clearly indicate the areas of concern and/or objection and shall provide reasons/explanations for the comment and stamp such project document with a status as described below.

In the event the Project Manager fails to respond within the applicable period stated above for any project document, it shall be deemed to accept such project document. In the event the Project Manager rejects any project document, the Contractor shall promptly revise the design information in such project document, and re-submit the project document for the Project Manager's review and approval.

The Project Manager reserves the right to carry out independent review and verification of any aspect of the Contractor's design. Where such review identifies non-compliance with the Contract requirements, the Contractor shall make modifications to the design to ensure compliance. Such modifications shall not be considered to be grounds for any extension of time or variation. Documents submitted for review shall have been processed in accordance with the Contractor's QA procedures and shall be certified by the Contractor as having been fully examined and in compliance with the requirements of the Contract.

The procedure for the submission of project documents for review shall follow the following steps:

1. The Contractor transmits via Aconex a workflow of documents for review including their DRS(s) – these are delivered to the Employer's document controller.

2. The Employer's document controller acknowledges receipt of the workflow.

3. The Employer's document controller reviews the document numbers and status against the information on the document schedule (provided initially by Contractor and updated regularly). Any inconsistencies with the submitted workflow such as missing DRS(s), missing documents etc shall result in the workflow being terminated and returned to the Contractor for correction and resubmission.

4. The Employer's document controller forwards the workflow to the discipline reviewers via Aconex including information on the required response time and names of other reviewers.

5. The reviewers complete their review process by adding their review comments to the Document Review Sheet (DRS). The DRS is unique to the deliverable being reviewed.

6. The workflow documents are reviewed against the Contract Specification. It is intended that all review comments be on the DRS rather than marked up on the drawing or document. DRS may include "snips" of the marked up drawing or document. The intention is not to return a marked up drawing to the Contractor.

7. DRS comments shall include the following:

    - non-compliances or clarifications referenced back to the Specification or Contract document.

    - Snips for drawings

    Individual items commented on will each be assigned a status as per the "options" column in the DRS as follows.

- (REL) Released: document or drawing is released for use (Overall status comment only). This is used if the document is acceptable and information compliant with the Specification.

- (REL-N) Released (as Noted): comment or overall status, resubmittal not required before use of document, but requierment is that the comment made will be actioned in the drawing or document, and also the Contractor will respond to the comment in a return of the DRS

- (NFI) Noted for information: Comment or suggestion – applies to comments only. Contractor not required to action or return updated DRS with response,

- (NCN) Non-Compliant as Noted, applies to individual comment or overall document status. Document is not approved for use and the updated document and revised DRS with comments to be returned for review. This classification should be used where the item is non-compliant in some way with the specification – but not considered a significant departure from a clearly stated requirement (where REJ should be used – see below)

- (REJ) Rejected, applies to individual comment or overall document status. Document is not approved for use and the updated document and revised DRS with comments to be returned for review. This classification should be used where there is a clear and significant departure from a clearly stated requirement.

8. Once the review comments have been entered on the DRS the workflow shall be progressed to the Project Manager for approval.

9. The approved DRS is issued back to the Contractor via the Aconex workflow and the workflow is then complete.

#### 1.6.3.1 Further Submission of revised Project Documents to the Project Manager

The Project Manager shall review all project documents revised by the Contractor as per the procedure described above and shall return them to the Contractor within the time periods specified below:

Five (5) working days - with respect to selected drawings involving items whose manufacturing schedules are on the critical time path,

Ten (10) working days - with respect to all other project documents, unless due to the nature of the information contained therein, such project document may not require a review period of ten (10) working days, in which case the period for the Project Manager to review and return such project document shall be reduced to five (5) working days. This reduction in the review period shall be at the discretion of the Project Manager based on a request from the Contractor.

### 1.6.4 As-Built Drawings

The Contractor shall revise such project documents to show the “as-built” status and submit such project documents to the Project Manager and the Employer within six weeks of Operational Acceptance.

### 1.6.5 Contract Drawings

After submittal of the as-built project documents the Contractor shall submit, for the purposes of the final record of such project documents, full sets of all approved project documents as per the requirements in the Contract.

#### 1.6.5.1 Provision Requirements of final as-built and contract drawings

Project documents of as-built and contract drawings shall be submitted as follows:

- One (1) copy for the Project Manager;

- Five (5) copies for the Employer; and

- One (1) copy, or more copies where further required, for the Lender's Technical Advisor.

Project documents shall also be submitted electronically by means of a data link or by provision of the information on transportable media (two (2) copies), as agreed between the Contractor and the Project Manager or as further indicated in the Contract.

### 1.6.6 Contract Documents Language and Measurement Unit

All Project documents required for submittal by the Contractor/Subcontractors (including suppliers/vendors/manufacturers/etc.) under the Contract, shall be in English and based on the SI units of measure system.

### 1.6.7 Documents and Drawings List

The following table identifies specific submissions which have been identified in the Contract and Employers Requirements. This schedule is not intended to be an exhaustive list of all required submissions from the Contractor and shall only be used as a guide for the Contractor to prepare the controlled list of project documents.

| Submission |
|---|
| Safety, Health and Environment Plan |
| Safety, Health and Environment induction training package |
| Project Management Plan |
| Critical Path Schedule |
| Proposed Progress Report Structure |
| Progress Reports |
| Equipment Purchase Specifications |
| Quality Assurance Plan |
| Schedule of Documents to be Submitted |
| Status of Project documents |
| Drawings |
| Geotechnical Report |
| Earthing Design Report |
| Civil and Structural Design Report |
| Seismic Report |
| Power Plant Electrical System Design |
| SGS Design Intent Report |
| Constructability, Operability and Maintainability Report |
| Process, Control and Energy HAZOP Report |
| Hurricane Proofing and Measures Report |
| HAZOP Action Report |
| Asset Register |
| Design and Construction Manual |

| Submission |
|---|
| Operating and Start up Manual |
| Operation and Maintenance Management System |
| Operation and Maintenance Manual |
| As Built Documentation |
| Weld Report |
| Workshop and Maintenance Procedures |
| Training Programme & Lessons Plans |
| Training schedule |
| Training Manuals |
| Course Summary Manual |
| Correction Curves |
| Schedule of Operational Consumables |
| Spare Parts List |
| Painting Specification |
| Corrosion Control Report |
| Colour Scheme for Plant |
| Transport Study |
| Instrument Loop Identification System |
| Plant Identification System |
| Flood Design Report |
| Drainage Design Report |
| Concrete Sample Test Results |
| Road and Bridge Design Report |
| Fire Protection Report |
| Pipe Stress Analysis Report |
| Overall Inspection and Test Plan |
| Manufacturer’s Works Testing Procedures |
| Sub Contractors’ QA Systems and Procedures |
| Quality Records |
| Storage and Handling Plan for Radioactive Sources |
| Site Inspection, Testing & Commissioning Plan |
| Guarantee Test Procedure |

### 1.6.8 Drawings

#### 1.6.8.1 Identification

A title block shall be provided at the bottom right hand corner of each document with a window in each for the following minimum information:

1. Name of the Contractor, address, facsimile and telephone number
2. Drawing Title and a brief description of the content
3. Contractor's Drawing and Revision Number
4. Drawing Number suitable for document management system
5. Drawing Scale
6. Drawing Date
7. Drawn By
8. Design By
9. Check By
10. Approved By
11. Other items as required by the document management system

#### 1.6.8.2 Codes and Standards

Drawings shall be to the latest edition of the following:

ISO 128 Technical Drawings - General Principal of Presentation

ISO 129 Engineering Drawings – Dimensions

ISO 2553 Representation of Welding

#### 1.6.8.3 General Requirements

A scale bar shall be included to permit use following a photo-reduction.

All drawings which relate to another will have a reference to that drawing located in a Table placed in a prominent position on the drawing.

All cross sections which are taken from another drawing will be cross-referenced to the parent drawing.

Similarly, all section indications will indicate the drawing number the section appears on.

American paper sizes shall be used, ANSI A, ANSI B, ANSI C, ANSI D and ANSI E. Drawings shall be prepared in such a way that photo-reduction to size ANSI B shall result in a legible and useable drawing. Particular attention shall be paid in this respect to selection of fonts. When drawings larger than ANSI B are submitted, an ANSI B print shall also be submitted.

Each drawing submitted shall clearly indicate the applicable status, e.g. Preliminary, for Information, for Review, for Tender, for Construction, As Built.

#### 1.6.8.4 **Drawing Contents**

General Assembly Drawings

Outline of all components with overall dimensions including any space requirements for maintenance or installation access.

Locations of connection points for various services and other equipment should be dimensioned and labelled.

Where applicable, the drawing shall show where and how the equipment is fitted or connected to other plant equipment without infringing the space provided for other civil, structural, mechanical and electrical equipment such foundations, steel supports, piping ducts, cables, conduit, clear ways, valves, etc.

Cross Section Drawings

Parts and construction details shown fully dimensional and where necessary a Parts Table showing materials and description of components shall be included in the same drawing.

Electrical Drawings

Electrical drawings shall be provided in sufficient quantity and with sufficient detail to enable easy and comprehensive fault finding.

Electrical equipment locations shall be provided on site plan drawings

Single line diagrams shall be used to represent major electrical components, their ratings, and how they are interconnected. In such diagrams, a single line is used to represent three phases. Relay and instrument one line diagrams shall include details of protective and metering devices and their points of connection. Where arrangements on any one phase is different to the others, three line diagrams shall be provided, in which each phase is shown independently.

Panel drawings shall be provided including equipment layout, device list, labelling, schematics and wiring, assembled forms, and terminations

Device “assembled form” drawings shall be provided to indicate the device elements and terminals used or connected and those that are spare

Schematics shall be used to represent control circuits, and shall include power sources, terminal details, device identification, cable and core numbers, and control system node information. As far as practicable schematics shall show the circuit in entirety. Where it is necessary to continue a circuit on another drawing, clear reference to the drawing, the grid point at which the circuit is continued, and the remote circuit function shall be provided. A top-down representation is preferred with each specific circuit function contained within a limited vertical band or column, the function being indicated at the top.

Wiring diagrams shall be provided to represent specific device or cubicle arrangements, and shall contain terminal, device, and internal wiring layouts. Unless otherwise agreed, wiring diagrams shall be provided for all circuit boards which the Employer could reasonably be expected to be able to repair.

Cable schedules shall list all power and control cables, and shall include details of cable type, cross sectional area, overall number of cores, spare cores, cable route, termination points, function, and drawing references.

Termination schedules shall be provided for construction purposes, integrated with cable schedules if necessary, giving the termination details of each cable core.

As built drawings shall be supplied to the Employer in hard and soft format.

Logic drawings shall be provided to represent the logic which governs control loops, interlocks, permissives, and protective functions.

Support Load Drawings

Forces and movement shall be shown in the local axis of the drawing. All loads shall be divided into dead, live, occasional and operating loads.

Loads shall have the following definitions:

| | |
|---|---|
| Dead Load | Self weight of static components. |
| Live Load | Weight of moving components. |
| Occasional Load | Seismic, wind, etc. |
| Operating Load | Loads which are created during normal operation. |

#### 1.6.8.5 Revisions

Any document that has been submitted to the Project Manager shall have all subsequent revisions submitted sequentially.

Revised drawings shall be identified in a revision table. The revisions shall be clouded and the revision symbol and revision number or letter should appear adjacent to the revision cloud. For subsequent revisions the previous revision clouds and revision symbols shall be removed from the drawing.

The Revision Table shall consist of the following:

1. Revision number/letter
2. Reason for revision
3. Drawn
4. Checked
5. Approved
6. Date

#### 1.6.8.6 Schematic Diagrams

Mechanical, electrical and control schematics, process flow diagrams, utility flow diagrams and piping and instrumentation diagrams which extend beyond a single sheet shall be logically arranged such that printed sheets can be joined together to provide a continuous diagram. All lines extending beyond one sheet shall be clearly marked to identify the continuation line. Where other drawings are also required for cross reference in reading the drawing, the reference and relationship of such drawings shall be clearly stated on the drawings.

#### 1.6.8.7 Use of CAD

The Contractor shall use a 3D CAD system for the Power Plant layout design and submit models from this (in a format which is readable by the Employer using software such as Navisworks) to the Employer for review. These shall show mechanical plant, electrical plant, building structure, platforms, supports, building services, large valves, cable supports systems and instruments as a minimum.

### 1.6.9 Design Reports

#### 1.6.9.1 Design Calculations & Reports

Each design report submitted shall include, but shall not be limited to, the following:

1. General description of system, philosophy, principles, methodology etc relevant to the subject matter of the report.
2. List of codes and standards used in the report

3. A list of all assumptions implicit or explicit in the report

4. A summary of the results of any calculations, plus a full set of calculations where appropriate, including when required for statutory approvals (eg pressure vessels)

5. A set of ANSI B drawings associated with the report, bound into the report, with sets of full size drawings supplied separately

6. All other information relevant to the subject matter of the report

7. An appropriate QA certification for the report, bound into the front of the report after the title page.

#### 1.6.9.2 Geotechnical Report

The detailed geotechnical report shall include at least the following information:

1. Records of all geotechnical investigations and soil tests undertaken. Each test and investigation shall be included as a separate appendix to the report. A brief description shall be provided of each test, including the test equipment, along with a reference to the applicable code or standard to which the work was undertaken.

2. Plans showing the location of the sites and locations of all soil sample/tests on and off the site (ie. test pits, bore holes, penetrometer tests etc).

3. General geological description of region and its formation and geological hazards (including landslide hazards) from all available published information.

4. Description of soil and rock types encountered on and off the site, referenced to borehole/testpit logs.

5. Geological cross sections of key locations that include site investigation data and groundwater levels (e.g. deep excavations and fills, foundations of significant structures, landslide locations, areas of ground improvement).

6. Schedule of physical and derived engineering properties of soil and rock types that capture the inherent uncertainty and variation in geotechnical parameters and methods of analysis for the design of all geotechnical elements.

7. Statement on recent calibration or certification of test equipment used.

8. Summary of expected loads (short or long term) from the main structures/buildings.

9. Statement on suitability of the ground conditions to support the expected loads and any recommendations for any ground improvement requirements.

10. Recommended foundation types for the different structures on the site.

11. Susceptibility of soils to liquefaction or cyclic softening under earthquake scenarios, or vibration from rotating machinery.

12. Assessment of site subsoil category for seismic design.

13. Recommended design methods and formulas for determining allowable soil pressures for shallow and deep foundations.

14. Recommended allowable pressures and appropriate safety factors or load factors to be used for different load cases/combinations. Provide these both for Ultimate Limit State (ULS) and Serviceability Limit State (SLS).

15. Assessment of probable settlement of foundations under short and long term conditions (with due reference to vibration or dynamic loads from rotating machinery).

16. Stability of natural, cut and filled slopes with recommended set back clearances for buildings, roads and similar features. Identify areas with unacceptable or marginal stability and specified remedial options, including rock fall protection, stabilisation or mitigation.

17. Recommended compaction standard for fill, (optimum density, water content and permitted variation) including field test methods and assessment of suitability of soil and rock for material re-use.

18. Summarise details of proposed instrumentation and systems for monitoring.

19. Recommended design parameters for retaining walls and structures.

20. Recommended design parameters for roads and other pavements.

#### 1.6.9.3 Earthing Design Report

The Contractor shall submit to the Project Manager (prior to construction) an electrical earthing design report based on site resistivity measurements and CDEGS earthing software modelling.

#### 1.6.9.4 Civil and Structural Design Report

The Civil and Structural Design Report shall address at least the following issues: -

- Adoption of solutions to issues raised in the Geotechnical Report
- Expected settlements
- Drainage and all wastewater systems
- Pavement and external ground works
- Foundation systems
- Floor systems
- Building frame, seismic and wind load resistivity systems
- Landscaping
- Specific measures, design elements and standards used to address hurricane risk

#### 1.6.9.5 Seismic Design Report

A specialist seismic engineer shall, prior to manufacture and construction, certify in writing that he has personally reviewed the calculations/drawings/test results and concepts adopted for the detailed design of the Plant (e.g. buildings, structures, and the seismic coefficients and holding down arrangements for mechanical equipment and electrical equipment), and has found them to satisfy the requirements of this seismic specification.

At construction documentation stage, the Contractor shall provide for the Project Manager's review a Seismic Design Report which shall describe in detail for all aspects of the Plant the following:

- The seismic design concepts, assumptions and seismic load derivations used in satisfying the performance requirements specified. This shall include detailed descriptions of all the matters listed below:

- A description of the intended seismic design codes and associated material design codes. This shall include a statement as to the design method (eg, Ultimate Strength Design, Working Stress design) and load combinations.

- A description of interpretation of the specified hazard spectra for use with the nominated seismic codes, including any adjustments for ductility, damping and risk.
- A categorisation of the principal items of structure, plant, equipment and control systems which identifies which items are critical to the safe shutdown of the Power Plant in the event of the Design Earthquake (DE) occurring.
- A description of the likely damage to the Power Plant if the DE occurs.
- The hierarchy of failure expected with increasing levels of seismic shaking above the Operating Basis earthquake (OBE) level up to the DE and also for earthquake shaking in excess of DE.
- For brittle components, factors of safety assumed in methods of design.
- Intended methods of demonstration of seismic adequacy of complex and/or proprietary items.

The report shall also report on the geotechnical investigations in so far as they define the subsoil category and any potential for liquefaction.

Special analytical and/or physical modelling studies undertaken to confirm that the design concepts chosen will meet the requirements.

#### 1.6.9.6 Power Plant Electrical System Design Report

The ratings, sizes, capacities and quality of all electrical equipment shall be determined by the Contractor based on the standards defined in this document and in accordance with the rules and regulations of Dominica. The Contractor shall provide reports, including calculations, to support these decisions and submit for the Project Manager review.

The Power Plant Electrical System Design Report shall also include the information for the MV Switchroom Design.

It shall verify that the proposed design is acceptable and meets the Employers requirements. The report shall include details of civil and structural works, switchgear systems, protection and control and auxiliary systems.

#### 1.6.9.7 Steam Gathering System (SGS) Design Intent Report

A Design Intent Report (DIR) for the SGS shall be submitted to verify that the proposed SGS design is acceptable and meets the Employers Requirements. The DIR shall be submitted and approved prior to commencement of the detailed design. The Contractor's design programme shall clearly take this into account.

The structure of DIR shall be as follows:

**Section 1 Executive Summary**

**Section 2 Civil and Structural Works**

- Geotechnical
- Seismic (structures)
- Structures
- Piping support systems

**Section 3 SGS Systems**

- Variance to concept design
- Draft Process Flow Diagrams

- Electrical Reticulation
- Control System

**Section 4 Materials and Equipment**

- Variance to concept design
- Piping materials
- Vent valves selection
- Separator design
- Atmospheric Flash Tank design

### 1.6.9.8 Constructability, Operability and Maintainability Report

The Contractor shall complete a study and provide a report on the constructability, operability and maintainability of the Plant. The report shall detail how the Plant will be constructed in a safe manner. It will also include what provisions have been made for operational requirements including isolation and earthing, access to and maintenance of the Facilities.

### 1.6.9.9 Hurricane Proofing and Measures Report

The Contractor shall complete a study and provide a report on the measures and features of the proposed design to address Hurricane risk, including but not limited to high winds, flying debris, and flooding.

### 1.6.9.10 Process Control & Energy Hazards & Operability Study (HAZOP)

A Process & Control (P&C) and Energy HAZOP Study (HAZOP) shall be carried out for the Plant.

The HAZOP shall be carried out by the Contractor as a comprehensive check during the detailed process design process. The HAZOP is conducted to reduce risk and operability problems for the Plant and provide consideration for future development.

The Contractor shall carry out the HAZOP at Site or other location agreed with the Project Manager. The HAZOP study is to be carried out in accordance with IEC 61882.

As a minimum the Contractor shall provide staff for the HAZOP process roles:

- An independent, suitably-experienced chairperson familiar with HAZOP procedures.
- The Contractor's principal design engineers for the development of the Piping and Instrumentation Diagrams under review.
- The Contractor's Commissioning Supervisor.
- The Contractor's instrument and control engineer principally involved with the P&I Diagrams under review.
- A secretary to record action items arising from the reviews.

The Contractor shall provide a programme for the HAZOP meetings 42 days prior to the commencement of the HAZOP to ensure the Employer personnel can make arrangements to attend the meetings.

The Contractor shall submit a data package prior to commencement of the HAZOP, including all material relevant to the study being undertaken. This data shall include but is not limited to latest revisions of:

- Process and instrument diagrams (P&IDs)
- Process/Control description
- Heat and mass balance
- Process Flow Diagram
- Electrical single line diagram and
- Layout drawings.

The Contractor shall record action items arising from the HAZOP meeting and provide copies of these action items to subsequent meetings.

A fully detailed report of the HAZOP studies incorporating the process descriptions, P&IDs, HAZOP matrix and closed out HAZOP action report shall be submitted by the Contractor.

Prior to commencement of construction work on site, the Contractor shall provide the Project Manager with written confirmation that the action items have been attended to or clear action plans are in place as to how remaining items will be attended to.

### 1.6.10 Plant Manuals

The Contractor shall compile, index and prepare the following manuals:

- Asset Register of all Project Equipment
- Design manual
- Construction manual.
- Operating and start-up manual.
- Shop and maintenance manual.
- As-built documentation.

The Contractor shall prepare manuals for the entire Plant.

The manuals shall be structured in accordance with the identification system specified. All cross referencing and indexing shall be based on the same Identification system.

The purpose of these manuals is to document the design and construction and to provide procedures for the start-up, operation, and maintenance of the Plant.

In addition to a fully electronic hyperlinked version of the manuals seven (7) hard copies in individual expandable binders and a soft copy of each of the manuals shall be submitted. The thickness of the books is to be limited to approximately 100 mm. If an individual manual would be too small to justify a separate binder, it can be combined with another manual with the approval of the Project Manager.

Large drawings shall be reduced to ANSI B size sheets. The reduced drawings must be legible. Full-size drawings, folded to fit into the manual, are acceptable if reduction would reduce legibility and if approved by the Project Manager.

Before the manuals are printed, draft copies of the volumes shall be submitted for the Project Manager's approval in both hard and soft format.

Manuals shall use multiple cut plastic laminated index tabs to distinguish between and within major sections. Organisation and indexing shall be based on logical groupings (eg. plant items, systems, event sequences).

#### 1.6.10.1 Asset Register

An Asset Register shall be supplied in a format suitable for direct import into any industry standard maintenance management system.

The register shall include individual entries for each individually maintainable component of the Plant.

#### 1.6.10.2 Design and Construction Manual

The Contractor shall submit seven (7) copies of a Design and Construction Manual (D&CM) to the Project Manager.

The D&CM shall provide comprehensive documentation of the Contractor's engineering, fabrication, and testing.

The D&CM shall include the following items.

- Engineering Calculations, analyses, studies, reports, etc.
- Inspection and Test Plans (ITP).
- The Contractor's procedures used for engineering, fabrication, testing, loadout, and transportation (as applicable).
- Change Order Log and Change Orders.
- Purchase Order information for the Contractor furnished items.
- Manufacturing and fabrication test and inspection reports. (This shall also include logs of all destructive and non-destructive examinations).
- Manufacturing and fabrication compliance and exception reports.
- Pre-commissioning records.
- Certification manuals for fabrication, installation, mechanical completion and all equipment.
- Weld reports

#### 1.6.10.3 Operating and Start-Up Manual

The Contractor shall provide a comprehensive Operating and Start-Up Manual for the Plant. The manual shall provide operating information about each system within the Plant

The Operating and Start-up manual shall be a standard document and shall include appropriate information from vendor catalogues where appropriate to supplement overall operating descriptions to ensure that all necessary information is available from one source.

Phrasing and vocabulary shall be suitable for understanding by the Employer's operating and maintenance personnel.

Operating instructions shall include:

- Process Control Diagrams for use by the operators, showing capacity of plant, and key valves and operational information required for starting, operating and stopping plant.
- Descriptions of plant operation, normal operating conditions to be expected, alarm conditions and abnormal operating parameters.
- Caution notes as to dangerous or critical situations which may occur due to poor operating procedures or malfunction of equipment.
- Trouble-shooting check lists.
- Detailed step by step descriptions of plant start-up procedures

- Detailed step by step descriptions of plant shutdown procedures under normal and emergency conditions.
- Detailed step by step description of procedures preparing plant for maintenance.
- Safety practices shall be included in all procedures in every section of the manual. A drawing should be included showing the interconnection of alarms and shut-downs.
- Appendix of key drawings and schedules.

#### 1.6.10.4 **Shop and Maintenance Procedures**

An index of maintenance schedules shall be provided to indicate each maintenance activity that is to be performed on each item specified in the Asset Register giving time periods between the tasks and a direct link to the specific instructions within the manual.

Maintenance instructions shall include:

- Pictures and diagrams showing means of disassembly for all components.
- Description of calibration, repair, adjustment procedures.
- Expanded views with parts lists of each item of assembled plant.
- Normal routine preventative maintenance procedures and scheduling.
- Lubrication schedule for all plant.
- Gland packing schedule for all plant.
- Special tool requirements.

Where the maintenance instructions include the manufacturer's general plant information relating to a range of plant manufactured, specific reference to the actual model numbers included within the Plant shall be made by striking out of model numbers not applicable to these Plant, or alternative methods approved by the Project Manager.

Shop and maintenance procedures documentation shall be organised into two basic volumes:

- Shop and Maintenance Manual (S&MM)
- Drawing Record Book (DRB)

The S&MM shall have two major tabs; one marked "Equipment" and one marked "Instruments". Within the Equipment section each service shall have a separate tab with the item's name and tag number. Within the Instrument section each type of instrument shall have a separate tab. (eg. flow, level, pressure).

The S&MM shall contain the vendor-supplied dossier information such as:

- Equipment Data Sheets.
- Special shipping, handling, and storage instructions.
- Lubrication requirements.
- Maintenance and repair instructions, including procedures, tolerances, special tool or facility needs, etc.
- Bill of materials.
- Vendor descriptive literature.
- Parts Lists (commissioning spares, start-up spares, two-year spares, complete parts lists)

The S&MM shall be organised as follows:

- Equipment section, by alpha-numeric equipment tag.
- Instrument section, as follows:
- DCS/ESD system
- Flow instruments
- Level instruments
- Pressure instruments
- Temperature instruments
- Control valves
- Relief valves
- Miscellaneous instruments

In the S&MM, data sheets shall be placed first in each subsection, followed by all other documents.

The DRB shall contain all as-built drawings.

#### 1.6.10.5 Weld Reports

The Contractor shall maintain complete records for all the welds performed so that they can be traced. The Contractor shall submit for approval a weld recording proposal demonstrating the traceability of welds.

Copies of all WPS, PQR, Welder's certification, NDE examination results, and any other documentation required by this specification shall be retained by the Contractor until the work is completed. At the completion of the work all the documents shall be systematically filed, bound and delivered to the Employer in the form of Weld Reports for retention.

#### 1.6.10.6 As-Built Documentation

During execution of the Facilities, the Contractor shall update and maintain on file current mark-ups of all drawings and data sheets to agree with actual work undertaken. The file of current mark-ups shall be available for audit by the Project Manager at any time.

The Contractor shall prepare as-builts of the documentation to fully describe the entire Plant. As-builts shall be submitted to the Project Manager for review and approval.

As-builts shall be prepared on the original drawings or data sheets. Documents shall be re-drafted as necessary to incorporate final information. Mark-up sketch, referencing, and other field marking techniques are not acceptable.

Contractor shall provide as-builts which are clear and readable in both full size and A3 reduction. In the case of any non CAD produced drawings the Contractor shall prepare new drawings if the Project Manager judges originals to be too damaged, deteriorated, or illegible.

As-builts shall be issued as the next sequential revision from previous releases. The revision block shall state “Certified As-Built”.

All clouds, revision diamonds, and other interim control marking shall be removed from as-built documents.

The Contractor shall provide soft copy source files of all as-built drawings. Soft copy files shall be in agreed formats. Licensed software as used to create the as-built documentation shall be provided.

Seven (7) copies of as-built documentation are required.

### 1.6.11 Other document requirements

#### 1.6.11.1 PDF format

Submitted documents shall not contain PDF markups. All PDF contents shall be permanent (either by printing the markup file to a new PDF or using a feature such as “flatten” in Adobe Acrobat).

All documents shall be rotated to view correctly when they are opened. This includes objects such as drawings or other pages that are inserted into a larger document – these shall also be rotated to view correctly when the document is displayed on screen.

Documents delivered in pdf format shall not be password protected.

#### 1.6.11.2 Identification

Multiple page documents shall show on every page:

- DGDC Project document Number
- Vendor Document Number (if applicable)
- Document Title
- Revision
- Total-/Number of pages in the document (page X of Y pages).

#### 1.6.11.3 Bookmarks

PDF format documents larger than 20 pages shall contain bookmarks for major sections. PDF format documents larger than 100 pages shall contain bookmarks for major and minor sections.

Documents with bookmarks shall be configured to open with the bookmark tab displayed, and with pages set to display full page (i.e. fit one full page to window).

#### 1.6.11.4 Printing Drawings

Drawings shall be printed to PDF using exact size for size or size reductions. (not plot to fit).

#### 1.6.11.5 Legibility

Raster versions of sub-contractor documents pasted into contract title blocks are not acceptable. Documents shall be directly produced from the native application to PDF format in order to minimise file size and ensure best possible legibility and clarity.

#### 1.6.11.6 File Size

Document file size shall be managed to a practical minimum, typically less than 10MB.

#### 1.6.11.7 Colour

The preference is for colour to be used only when necessary to provide contrast or clarity in a document. Coversheets and logos should be monochrome wherever possible.

For example a document that is generally monochrome shall not be produced in colour in order to display a colour corporate logo.

#### 1.6.11.8 **Digital Documents**

All electronic documents shall be submitted to the Employer using the pdf format, until the documents have been marked as final. The handover Documentation must be provided in native Formats as shown below and agreed on this project.

| Data Formats | | |
|---|---|---|
| CAD based engineering formats | AutoCad | (*.dwg) |
| Word processor / text formats | Microsoft Word from Version 2010 | (*.doc) |
| Database formats | Microsoft Access from Version 2010 | (*.mdb) |
| Spreadsheet formats | Microsoft Excel from Version 2010 | (*.xls) |
| Calculations | Adobe Acrobat | (*.pdf) |
| Picture formats | Tagged Image File | (*.tif) |
| Schedules | Microsoft Project | (*.mpp) |
| Other formats | ASCII text | (*.txt) |

## 1.7 Training

### 1.7.1 General

The Contractor shall provide a person in the role of Training Coordinator. The Training Coordinator shall ensure all of the contractual training requirements are met in a consistent manner including coordination of the Contractor and subcontractor's required inputs.

The Contractor shall provide training under a specific training programme for the Employer's engineering, operating and maintenance personnel or assigned contractors on the safe, reliable, and efficient operation of the Plant supplied under this contract.

All aspects of training shall be delivered using the English language and all of the Contractor's personnel involved in delivering training shall be totally fluent in written and spoken English.

The Contractor shall ensure that the number of training support staff and the duration of training shall be sufficient to meet the requirements specified herein.

### 1.7.2 Methodology

Training shall consist of three main elements:

1. General overview of geothermal power plants and this Plant – delivered to all Employer's staff or assigned contractors by the Contractor.

2. Train the trainer enabling key Employer's staff or assigned contractors to deliver operation and maintenance training to the remainder of the Employer's staff – delivered to ten (10) of the Employer's key personnel and assigned contractors by the Contractor.

3. Detailed end user operation and maintenance training to enable the Employer's personnel or assigned contractors to safely and efficiently operate and maintain the Plant –delivered by the Employer's key personnel supported by the Contractor.

The Contractor shall deliver an initial training programme to the entire Employer's team. This initial training programme is intended to provide an overview of geothermal power plants with particular reference to this entire Plant. On completion of this initial training the Employer's staff or assigned contractors are expected to have a sound knowledge of the entire Plant.

The Contractor shall deliver training to ten (10) Employer's key staff and assigned contractors primarily at the Site but also in the manufacturer's design offices and other facilities as deemed appropriate by the Contractor. Training shall ensure that these key staff have sufficient knowledge of the Plant to enable them to deliver end user training to the balance of the Employer's personnel or assigned contractors to enable them to operate and maintain the Plant in a safe and efficient manner.

On completion of the training of the Employer's key staff and assigned contractors, the Contractor's Training Coordinator shall facilitate the examination and assessment of training recipients to evaluate student performance during and after the training and competence safely and efficiently operate and maintain the Plant.

Each training session delivered by the Employer shall be delivered a minimum of two times with the Contractor's support.

The Contractor's training instructors shall have suitable background in Power Plant operations, have relevant experience in training/teaching, recent classroom experience, and shall have site-specific knowledge of the plant gained by their participation in the development of the Work's operation and maintenance (O&M) Manuals.

Formal training outlined above shall be augmented by including the Employer's staff or assigned contractors in the construction and commissioning activities. Such involvement shall generally be in an observational role, "hands-on" activities shall be under the direction of and fully supervised by the Contractor.

### 1.7.3 Training Schedule and Materials

The Contractor shall arrange the training schedule to ensure that the Employer's key personnel have sufficient time to customize the end user training material, have those customizations reviewed and agreed by the Contractor and finally deliver it to the Employer's personnel in time for the Employer's personnel to assist with the commissioning of the SGS and the Power Plant and MV Switchgear. Lack of adequate training of the Employer's personnel shall not be grounds for delay.

Due to the technical content of the programs, instruction will be limited to 8 hours per day. Deviations from and/or changes to the programs are to be discussed and agreed in writing prior to the commencement of training

Ninety days prior to the start of classroom training, the Contractor shall review with the Project Manager a detailed schedule of the training to be conducted, tentative lesson plans, and the proposed instructors for the Project Manager's approval. Completed lesson plans, based on the draft Operating and Maintenance Manuals, and all handouts and other training aids shall be submitted to the Project Manager for review before commencement of training.

The training program to be submitted by the Contractor for review and approval by the Employer shall typically include as a minimum:

1. Course outline

2. Detailed lesson plans for review and comment. The lesson plans shall include a training manual as a student handout.

3. A listing of training aids to be used (e.g. actual equipment, equipment manuals, viewgraphs, etc).

4. Training schedule, including proposed duration(s) based on Jobsite assembly and testing, and completion of training on or before plant energization. The schedule shall identify each segment, if the program shall be conducted at various times and locations.

5. A listing of prerequisite training or knowledge level of the personnel attending the training program.

6. The resumes of the program instructor(s)

7. The complete details of any proposed offsite training.

The Contractor shall provide training manuals and supplies for each participant in the training program. Training manuals shall be written in English and kept in a ring binder file large enough for storing additional materials presented in the course. For each lecture or presentation, each student shall receive a copy of the applicable O&M procedures (or other relevant documentation), a lesson plan, and copies of any drawings, PowerPoint slides, overhead projections, etc. used in the training session. Lesson plans shall describe the objective of lecture and tell trainees what they are expected to do or be able to do after the training session is completed. Lesson plans shall also identify applicable technical references and training aids to be used and include a detailed breakdown of the points of discussion to be addressed in the training presentation. Supplies provided to the trainees shall include, but not be limited to, pens, pencils, paper, and ring binders.

The Contractor shall provide and maintain all the IT systems and hardware required to complete the training programme.

The students' lesson text shall incorporate as a minimum the following elements:

1. Course objectives - What the student is required to learn.

2. Systems overview - What the system does and how the system does it.

3. Major component description - Functional description.

4. Flow path and controls - Major flow paths, instrumentation, protective devices, controls, and interlocks (included all alarm, trip, limits and logics).

5. Principles of operation

6. Startup, normal operation, shutdown, and infrequent operation procedure

7. Support systems - Systems needed for operations

8. Hazards and Safety Features

9. Routine maintenance

10. Emergency procedures

11. Troubleshooting

The classroom training presentations shall be professionally recorded with three complete sets of the audio visual recording provided to the Project Manager for use in training future plant personnel.

After the conclusion of the classroom training, the Contractor shall provide the Project Manager for use in the plant's continuing training program, a course summary manual in both hard and soft format that includes the training programmes,

copies of the training materials (lesson plans, drawings, overheads, etc) used in each session, and copies of the examinations (with answers) used to evaluate student performance during and after the training. Each section of the course summary should reference the specific audio visual recording that corresponds to the training.

### 1.7.4 Scope of Training

Training shall include, but not be limited to:

1. Power Plant systems
2. SGS plant and systems
3. MV Switchgear and systems
4. Generators
5. Transformers
6. Switchgear
7. Control system
8. Electrical protection and earthing, include overall explanation of Power Plant and MV Switchgear protection systems as a whole
9. Condenser and cooling tower / air cooled condenser
10. Cooling water systems
11. Gas extraction system
12. Plant auxiliaries
13. Electrical equipment, systems and utility interface
14. Preventive maintenance
15. Safe isolation procedures for all forms of motive power (electrical, air, mechanical etc.), based in industry best practice

Manufacturer's training is required on all major mechanical, electrical and control equipment and shall be coordinated by the Contractor's training co-ordinator. Manufacturer's training shall include both classroom and practical sessions.

Safe operation and maintenance (including isolation practices and procedures) shall be at the core of every training module.

Each training module shall be concluded with a test to confirm that participants have gained the required level of knowledge of the subject matter presented.

The Employer notes that students may have no prior experience with similar equipment. The training programme will be attended by operators, maintenance personnel, instrument technicians and supervisors.

Curricula should be designed to suit the scope and knowledge required by each group of trainees. Curricula shall include no less than 160 classroom hours and be oriented towards specific equipment comprising the Plant. In addition to the training outlined above, the Contractor shall provide informal, hands-on training throughout the start-up of the plant.

### 1.7.5 Control System Training

The Contractor shall provide specific training followed by hands-on involvement of the Employer's staff through all phases of the development and implementation of the control systems.

Training shall include in-detail hands-on involvement of [two] of the Employer's suitably qualified staff during the factory design and configuration and during the on-site commissioning of the systems.

On completion of the commissioning of the control systems the Contractor shall provide additional training on the actual final configuration and detailed fault finding techniques.

The Employer's staff or assigned contractors that participate in this training will already be competent in the principles of control and instrumentation systems.

The Contractor shall put in place such systems and processes as they see necessary to ensure that any actions or in-actions by the Employer's personnel have no adverse impact on the Plant including but not limited to the functionality, reliability and the time schedule.

## 1.8 Environmental and Social Compliance

The Employer has produced an Environmental and Social Impact Assessment (ESIA) and associated Environmental and Social Management Plan (ESMP). The ESMP summarises the mitigation and monitoring measures that are to be employed during pre-construction, construction and operation of the Project. The ESMP summarises the Employer's commitments to address, mitigate and monitor risks and impacts identified as part of the ESIA, through avoidance, minimisation and compensation / offset. The Contractor shall be responsible for ensuring that the entire Plant is designed and constructed in accordance with the requirements of the ESIA and ESMP in order to comply with World Bank Performance Standards and Wordl Bank Group Environmental, Health and Safety Guidelines and GOCD legislation.

The Employer is responsible for establishing the Environmental and Social Management Systems (ESMS), which are in compliance with the World Bank Group Standards. The ESMS sets out how the mitigation and monitoring identified in the ESMP will be implemented, checked and reviewed for the life of the Project.

In addition to any other provisions of the Employers Requirements, the Contractor shall provide the Contractor's Environmental and Social Management Plan (CESMP) and undertake the mitigation measures outlined therein. The CESMP should be submitted for approval prior to mobilisation to site.

The following tables outline the responsibility of the Contractor for mitigation measures identified in the ESMP:

Summary table of proposed mitigation during construction (1):

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| Air quality | All Project construction works – emissions and dust control | The EPC Contractor will develop an Air Quality Management Procedure that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the document. The Air Quality Management Procedure will include the following measures:<br>• Construction vehicles will be periodically checked to ensure that they are not emitting excessive pollutants.<br>• Construction dust will be suppressed with water applied by water sprinklers and/or water carts. For access tracks, it is recommended that water is sprayed on roads at least twice a day during the dry periods.<br>• Dust on the wheels of vehicles will be removed through wheel washing prior to leaving the site.<br>• Vehicle speed on the construction site will be set to a maximum of 15 mph to reduce dust release from road surfaces.<br>• In the event of high winds during dry periods, it may be necessary to cease some construction activities until the wind subsides.<br>• When transporting material that is prone to wind blow, vehicles will be equipped with a tarpaulin cover when passing through residential areas.<br>• Windblown material from stockpiles of soil, aggregate, sand etc. will be held in bins or other enclosures, and stockpiles of material including soil, and where practicable covered with a tarpaulin.<br>• To reduce windblown material, the EPC Contractor will sow grass seed on soil stockpiles that will remain dormant for more than three months. |
| Cultural Heritage | All Project construction works | • The EPC Contractor will implement a Chance Find Procedure as set out in Volume 3: SIA during all Project construction works. DGDC will be responsible for checking and reviewing the document. The Chance Find Procedure outlines the measures taken during construction if an artefact of cultural heritage significance is found (i.e. documentation of the artefact, informing local museum).<br>• The EPC Contractor's Worker's Code of Conduct will include a section on Cultural Heritage and respect of local beliefs and traditions in the local communities. All workers will be made aware of the EPC Contractor's Worker's Code of Conduct and awareness sessions will be organised for all new recruits. DGDC will be responsible for checking and reviewing the document. |
| Environmental and Social Management Systems (ESMS) | All Project construction works | • Management of environmental and social risks and impacts during construction will primarily be the responsibility of the EPC Contractor through the EPC Contract.<br>• During the construction phase, DGDC will review and monitor EPC Contractor's performance in accordance with their Health, Safety and Environment (HSE) Plans and related management plans/procedures to ensure alignment with the overarching Project ESMS. Management of environmental and social aspects associated with the Project will be carried out in accordance with the ESMS. The ESMS will consist of a set of sub-ordinate plans and procedures, which may include, but are not limited to, the following topics:<br>- Construction environmental management;<br>- Pest and weed management;<br>- Biodiversity restoration;<br>- Waste management;<br>- Hazardous substance management;<br>- Soil and erosion management;<br>- Air quality/dust management; |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
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| | | - Environmental and social monitoring;<br>- Stakeholder engagement;<br>- Grievance mechanism (community and workers);<br>- Emergency preparedness and response;<br>- Noise and vibration management;<br>- Recycling plan;<br>- Landscape management;<br>- Chance find procedure;<br>- Subsidence risk management;<br>- Landslide stabilisation risk management;<br>- Occupational safety and health management; and<br>- Traffic management.<br>• Key personnel will be responsible for ensuring good environmental practice on site during construction. These will include the DGDC Project Manager and the EPC Contractor Site Manager.<br>• Staff will be trained in environmental management, auditing and monitoring procedures as per the framework that has been outlined in the Framework Environmental and Social Management System (see Section 3).<br>• Reporting of mitigation activities will be issued by DGDC to the Lenders every 6 months in the Biannual Environmental and Social Report. |
| Existing Infrastructure | All Project construction works | Construction activities will be operated in a way that will not encroach into the existing infrastructure facilities (e.g. electricity lines, information system, water supply system, offices, etc.). |
| Hazardous Substances and Waste | All Project construction works – general measures for waste | • The EPC Contractor will develop a Waste Management Procedure that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the document. Particular attention should be given to the use and re-use of materials to minimise waste and, whenever practicable, using materials and products from sustainable sources. The Waste Management Procedure will be prepared in accordance with the waste hierarchy and include the following steps:<br>  • Consideration will be given to recycling to minimise waste disposal; and<br>  • Waste will be stored in closed containers away from direct sunlight, wind and rain. Waste packaging will be in good condition, undamaged, corrosion and leak free.<br>• Waste will be stored so as to prevent or control accidental releases to air, soil, and water resources.<br>• Waste signs will be put on all waste containers and collection areas. Each sign will be highly visible and easily seen by the person using the waste container or area. Each container or waste area sign will be labelled as Domestic Waste, Non-Hazardous Waste or Hazardous Waste and include the responsible person with contact information and how to handle the waste.<br>• Waste will be stored in a manner that prevents the commingling or contact between incompatible wastes. Sufficient space is needed between incompatibles or physical separation such as walls or containment curbs. |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
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| | | • Solid waste produced during construction will be disposed of in compliance with the regulations and will be outlined in the Waste Management Procedure.<br>• When entrusting wastes for disposal, the Site Manager or Environmental Manager shall:<br>- Select proper waste disposal companies certified by GoCD for the type of waste being disposed of;<br>- Prepare all required documentation and permits if required by Dominican law for the type of waste being disposed of; and<br>- Ensure the waste is disposed of by the third party waste contractor to the agreed disposal facility. |
| | All Project construction works - hazardous substances use and disposal of hazardous waste | • The EPC Contractor will develop a Hazardous Substances Management Procedure that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the document.<br>• Under the Hazardous Substances Management Procedure, the EPC Contractor will induct the workforce to be made aware of hazardous substances, with reference to the applicable Safety Data Sheets (SDS). They will also attend mandatory safety training in the correct way to use and handle the hazardous substances. Training must be adjusted to be compliant with the laws of Dominica and any other relevant regulations prescribed by the competent authorities.<br>• Workers will be provided with the appropriate Personal Protective Equipment (PPE) for the handling and use of hazardous substances.<br>• Emergency facilities, first aid points, clinics, eye wash fountains, emergency showers will be identified/provided where required.<br>• Other facilities that will be available include fire extinguishers, first aid, communication equipment, emergency doors and alarms.<br>• Smoking will be restricted to designated areas and all flammable liquids will be kept away from hot work areas.<br>• Oil, fuel and lubricants storage and dispensing stations will be restricted to established locations. Dispensing area should be located on an impervious surface and under shelter where possible.<br>• Storage areas will be identified and unauthorised entry will be controlled by use of barriers warning signs and close supervision. All hazardous substances will be stored away from construction activities under covered stores. 'No Smoking' signs will be placed at these locations and all storage areas shall have minimum one dry powder type fire extinguisher.<br>• Hazardous and toxic wastes stored on site will be minimised by increasing the frequency of pick-ups where necessary. The producer of hazardous waste may store hazardous and toxic waste on-site for a maximum of 90 days. This period may be extended if the amount that is produced is less than 50 kg/day.<br>• Adequate ventilation will be provided where volatile wastes are stored.<br>• Secondary containment should be included wherever liquid wastes and hazardous substance are stored in volumes greater than 220 litres. The available volume of secondary containment should be at least 110% of the largest storage container, or 25% of the total storage capacity (whichever is greater), in that specific location.<br>• Triple rinsing must be undertaken before empty chemical containers can be treated as non-hazardous solid wastes.<br>• Hazardous waste will be collected by a licensed contractor and treated, reclaimed or disposed offshore.<br>• Wherever possible, less hazardous substances will be obtained as substitutes. |
| | All Project construction works - spill management | • The EPC Contractor will develop an Emergency Response Plan that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the document. The EPC Contractor, alongside DGDC will communicate the plan |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
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| | | with the local community. Further details of the outline of an Emergency Response Plan are located in ESIA Volume 5: Technical Appendices, Technical Report - Occupational Health and Safety and Working Conditions.<br>• Vehicles will only be fuelled in designated locations where the area is hard paved and the collection sump is connected to the wastewater treatment system.<br>• In the event of a spill during construction, spill containment and clean up equipment will be located onsite. This will include equipment for:<br>- Containing and cleaning any spill such as a shovel, broom, drain covers, sandbags, booms and absorbent material. All spills will be handled with compatible materials.<br>- Storing and disposing of spilled material such as safe containers, bags, and drums.<br>- Protecting the safety of staff through PPE.<br>- Any spills will be contained and cleaned up immediately and disposed of at an approved facility. Incidents will be recorded and reported following the accident reporting system as detailed in the HSE Plan. This includes the preparation of an Accident/Incident Report. |
| Landscape | All Project construction works | • The EPC Contractor will develop a Pest and Weed Management Procedure that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the document.<br>• Plants used in any landscape planted will be nursery grown and will be sound, healthy, and vigorous and free from insect infestations. Trees and shrubs will be chosen to tolerate weather conditions and other such site characteristics.<br>• Any lighting requirements will be designed to ensure light spill is directed into the construction site.<br>• Where possible the selection of neutral/muted cladding and external finishing would aid in limiting the extent of adverse visual impacts.<br>• After construction works are completed, it is proposed that the power plant site will be landscaped in order to improve visual amenity.<br>• The soil removed during earthworks for construction will be reinstated and used as topsoil for the proposed landscaping bunds (piles of earth mounted at the Project site boundary that are planted with trees to provide screening and natural noise attenuation for local residents).<br>• For visual appearance and to limit erosion from surface water during heavy rains, stockpiled topsoil will be used for landscaping and to create 'green zone' areas on the power plant site as soon as practicable.<br>• Site fencing has the potential to aid in mitigating adverse visual effects of the power plant by partially screening and softening the visual impact of the site and ensuring light spill from the site is minimised. |
| Hydrology | Power plant construction | A Stormwater Management Procedure (SMP) (embedded within the Erosion and Sediment Control Procedure) will be developed by the EPC Contractor before the construction phase. DGDC will be responsible for checking and reviewing the document.<br>• Following surveying of the boundary of the construction pad, diversion drains should be excavated around the perimeter of the site to convey overland flow to appropriate locations downstream. During construction these could be temporary excavations, rock or geotextile lined to reduce erosion.<br>• Direct site runoff should be captured via interceptor ditches and sumps/sediment ponds. In localised areas, sediment runoff could be managed through silt fences. Grading the construction site to ensure runoff is captured and detained in these locations is essential, as its highly likely surface water will be sediment laden and will need some settling before discharge to the nearby Titou Gorge Stream (likely through a decant structure or overflow spillway in a sediment pond). |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
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| | | • Any discharges of concentrated flow should be to watercourses that have adequate erosion protection in place to prevent gullying of channels, bank collapse and increased sedimentation downstream. This may require installation of reno mattresses or rock rip rap (adequately sized to convey flows and velocities) at the discharge point. The remaining channel (if it exists) may require further excavation to convey the increased flows, and subsequently the installation of a permanent channel draining from the construction pad settling ponds to the Titou Gorge Stream would be recommended (a distance of ~250 m).<br>• Should local water sources be required for meeting some construction demands including vehicle and equipment washdown, the use of a temporary portable storage tank is advised. A 25,000 L plastic tank (3.6 m x 2.8 m) could provide storage for firefighting and water supply, and be topped up from Titou Gorge Stream at low abstraction rates (<2 L/s) to minimise environmental impact. A full assessment of construction water demands will be needed to verify the infrastructure required. |
| | Reinjection pipeline construction | • Near stream works will require local sediment controls such as silt fences or downstream sediment traps to reduce the effects of disturbance. Water supply for concrete mixing will be minimal and infrequent, primarily used for support foundations. |
| Noise and Vibration | All Project construction works | The EPC Contractor will be responsible for the following mitigation measures during construction:<br>• A Construction Noise Management Plan (CNMP) should be formulated to provide a framework for addressing construction noise levels. Noise control options including site mitigation and the investigation of low noise plant should be detailed and direction provided for the delivery of best practice noise management on site.<br>• Construction works should adopt Best Management Practice (BMP) and Best Available Technology Economically Achievable (BATEA) practices. BMP includes factors discussed within this report and encouragement of a project objective to reduce noise emissions. BATEA practices involve incorporating the most advanced and affordable technology to minimise noise emissions.<br>• Limit construction works to daytime hours where reasonable and feasible.<br>• Locating haul routes as far as possible from residential receivers.<br>• Using equipment that has been well maintained so that noise emissions are minimised.<br>• Provide localised noise screening where works are to be conducted within 200 metres (the compliance distance) of any sensitive receivers.<br>• Where possible, static construction plant such as generators should be located adjacent to on-site structures to impede noise propagation.<br>• Engines shall not be started and on-site activities shall not be undertaken outside of the daytime construction hours. Non noise generating works can be undertaken at staging areas where works are not adjacent to residential receivers.<br>• Construction activities should be undertaken in accordance with BS 5228, Code of Practice for Noise Control on Construction and Demolition Sites. All equipment used on site would be required to demonstrate compliance with the noise levels recommended within BS 5228.<br>• Appropriate use of all plant and equipment, with reasonable work practices applied, including no extended periods of 'revving', idling or 'warming up' in proximity to existing residential receivers. Any excessively loud activities should be scheduled during periods of the day when general ambient noise levels are greatest. This would reduce the potential for cumulative noise impacts (relating to worst-case elevated operations) and extended periods of off-site annoyance.<br>• Minimising reversing alarm noise emissions from mobile plant and transport truck operations should be considered, provided occupational health and safety requirements are satisfied. Where practicable, site entry and exit points should be managed to limit the need for reversing. |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
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| | | • Construction plant source noise levels should be confirmed prior to the commencement of works to verify construction noise impacts and noise management measures.<br>• Provide a summary of required construction noise management practices to all staff and contractors and be included during site inductions. The summary should include, as a minimum, the permitted hours of construction work, work site locations and site ingress/egress.<br>• Local residents and land owners are to be notified a minimum of 2 weeks prior to the commencement of construction works. The notification would detail proposed construction works, permitted hours of work and potential noise impacts. |
| Landslides | All Project construction works | • It is also recommended that the EPC Contractor develop an Erosion and Sediment Control Procedure that will incorporate a Landslide Management Procedure, which will contain measures to reduce potential impacts of landslides (slope stabilisation, planting, sandbags etc.). DGDC will be responsible for checking and reviewing the document. |
| Social / Economic | All Project construction works | *General*<br>• The EPC Contractor and all Subcontractors will respect and apply industrial good practices as highlighted in WBG EHS Guidelines. This includes among others: no operation during night time near inhabited settlements, implementation of noise and dust control measures, low speed limits for the Project's vehicles in inhabited areas. DGDC will ensure that this is being completed through regular site visits and auditing of reports.<br>*Grievance*<br>• DGDC will implement regular consultations with PAPs, their grievances will be lodged, treated and addressed.<br>• The Grievance Mechanism defined in the Stakeholder Engagement Plan will be disclosed by DGDC to the neighbouring communities and implemented, and grievances registered and addressed on a case by case basis. Note: The Grievance Mechanism was disclosed to Laudat, Trafalgar and Wotten Waven communities in July 2017. It will be disclosed again to these communities at least six months before the start of construction.<br>*Jobs / Employment*<br>• DGDC, the EPC Contractor and all Subcontractors will ensure a transparent hiring process is conducted to help the community to understand strategic staffing decisions for the Project.<br>• DGDC will establish a local employment brokerage that will publicise job vacancies and put in place initiatives to ensure employment opportunities for hard to reach groups.<br>• DGDC will make efforts to facilitate the growth and development of new entrepreneurs, both individuals and groups originating from affected communities.<br>• DGDC will provide opportunities for women and women's groups to participate in the work force to the extent safe and practical, and assist them in having good quality work standards so they can train others and are able to work with other companies in the future.<br>• DGDC will define targets for women employment (at all levels and skills). It will be disclosed that recruitment is also open to women in the local communities. Specific recruitment strategies targeting women will be defined.<br>*Skills and Training*<br>• DGDC will develop a Workforce Development Strategy – a commitment to maximize employment and skills opportunities for local people which the EPC Contractor will follow.<br>*Community Development* |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
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| | | • DGDC will develop a Community Development Fund to undertake a range of community development initiatives.<br>• DGDC will develop Corporate Social Responsibility (CSR) programmes implemented in partnership with local governments to create business opportunities for the local workforce that is no longer involved in the construction of the Project. CSR programmes will also seek to improve levels of education and skills for people affected by the Project.<br>*Health and Social Initiatives*<br>• To prevent social tensions between the workforce and the local population, the EPC Contractor will develop a Worker's Code of Conduct, which will be checked and verified by DGDC. The Worker's Code of Conduct will address issues such as anti-social behaviour, drug and alcohol consumption, banning weapons, and including respect for women.<br>• The EPC Contractor will provide free and anonymous health surveillance and active screening and treatment of workers including sexually transmitted diseases. Onsite health care shall be provided to ensure prompt medical attention.<br>• The EPC Contractor will prevent illness among workers in local communities by undertaking health awareness and education amongst the workforce and in the neighbouring communities. An important aspect of minimising the spread of communicable diseases within the community is worker health screening, particularly as many workers are anticipated to be sourced from outside of Dominica. A worker health screening programme shall be developed and implemented during the peak construction period.<br>• The EPC Contractor will prepare and implement a Sexually Transmitted Disease (STD) Management Plan. DGDC will be responsible for checking and reviewing the document.<br>• DGDC and the EPC Contractor will collaborate with local authorities to enhance access to public health services and promote immunisation.<br>• DGDC will define vector-borne diseases prevention measures (such as avoidance of stagnant water, measures to avoid mosquito development) which the EPC Contractor will implement.<br>• The EPC Contractor will provide adequate and sufficient sanitation facilities for both female and male workers.<br>*Access and Security*<br>• The EPC Contractor will control access to all construction sites with no unauthorised access from local communities permitted.<br>• The EPC Contractor will train the security guards on human rights issues. The security guards will not be armed. They will coordinate with local government security forces in case of need and will ensure that security and human rights of local communities' members are respected.<br>• For the reinjection line, access restriction and safety measures of the general public will be defined implemented along the Right of Way (RoW) during pipeline construction. |
| Soils, Geology and Groundwater | All Project construction works - soil erosion | • The EPC Contractor will develop an Erosion and Sediment Control Procedure and Hazardous Substances Management Procedure that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the documents.<br>• The EPC Contractor and Subcontractors will ensure that they undertake the following mitigation activities:<br>- Excavated earth should be strongly compacted and cut-off ditches should be dug in erosion prone areas to divert water away for the earthworks and to settling ponds before discharge to nearby water courses.<br>- Along the reinjection pipeline route catchment areas will be kept to small sizes with their own temporary drains and specific treatment devices. |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
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| | | - Silt curtains, fibrous mats etc. will be placed across as temporary stormwater drains to reduce the efflux velocity of the water and to aid settling of suspended sediment from the water. |
| | All Project construction works - soil and groundwater pollution | The EPC Contractor and Subcontractors will ensure that they undertake the following mitigation activities:<br>• Spill kits should be located on the construction site to manage and contain any fuel or hazardous substance spillage. If an accident does occur, then contaminated soil should be excavated and replaced with clean fill to minimise (or prevent) groundwater contamination with treatment of any stormwater runoff or process water prior to disposal.<br>• All wastewater should be collected prior to discharge.<br>• Oily and/or hazardous waste will be separately collected and disposed of by an appropriately licensed operator.<br>• All vehicle maintenance should be done in garages.<br>• The laying of overland flow diversion drains and preload fill should be completed preferable during the dry season and prior to the power plant construction earthworks commencing.<br>• Drainage water collection and treatment systems should be installed as a priority to prevent discharge to the adjacent rivers and streams. |
| | All Project construction works - excavated material | The EPC Contractor and Subcontractors will ensure that they undertake the following mitigation activities:<br>• Excavated topsoil will be transported to, and stockpiled in, designated topsoil storage areas.<br>• Prior to filling, sub-grade surfaces of depressions will be free of standing water and unsatisfactory soil materials will be removed.<br>• All unnecessary excavated materials will be transported and deposited outside of the site at an approved facility.<br>• Where excavated material is suitable to be used for fill and backfill, the material will be segregated and transported to a stockpile location at the construction site. |
| Terrestrial Ecology | All Project construction works | The EPC Contractor and Subcontractors will ensure that they undertake the following mitigation activities:<br>• Implement dust-suppression measures such as covering vehicles transporting materials, ensuring vehicles use wheel wash facilities at site, and use of water spray dust suppression systems.<br>• Highly noisy activities will be undertaken during daylight hours where possible.<br>• Inductions/tool-box talks for staff will include reference to measures required to protect biodiversity.<br>• Appropriate provision will for be made for waste disposal.<br>• Vegetation clearance activities should commence outside the breeding season for five key threatened species identified, to minimise impacts on breeding animals. The breeding seasons of the three bird species are overlapping, between January and August[1]. The amphibian species are thought to breed year-round, but primarily between May and July.<br>• Habitat cleared will be the minimum possible, with any way-leave area required of the minimum width necessary.<br>• Use temporary fencing to prevent inadvertent damage outside designated construction areas.<br>• Avoid piling of clear-felled vegetation on standing live vegetation which would hinder movement of wildlife.<br>• Any replanting / landscaping will use native or endemic species to prevent the incursion of opportunistic invasive species.<br>• Machinery and vehicles should be cleaned upon entry/exit, and any soil brought on or off site screened for invasive species or plant pathogens. |

[1] http://www.iucnredlist.org/ (Accessed September 2017)

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
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| | | • Minimise potential for sedimentation impacts by ensuring good construction site practices are implemented.<br>• Appropriate disposal of solid and liquid wastes, in line with recommendations in international and national standards, and using designated facilities as required.<br>• Any effluent discharged to surface watercourses must meet the more stringent of international water quality discharge standards prior to release to remove pollutants.<br>• Minimise potential for pollutants and surface water run-off to migrate off-site by ensuring standard good construction site practices are implemented.<br>• Ensure all standard safe storage measures for n-pentane are implemented, as detailed in ESIA Volume 2: EIA, Chapter 15.<br>• The 6-7m of the construction corridor of the reinjection line that is not required permanently will be replanted with native species as soon as possible after construction.<br>• A Habitat Management Plan (HMP) will be developed that sets out the establishment and maintenance required for a biodiversity offset, to be created with minimum extent 1.7 ha (equivalent to the Natural habitat lost under the Project Area). This will be developed with input from local specialists and stakeholders as appropriate and will incorporate measures identified in *Post-Hurricane Maria Specific Actions* below, as appropriate.<br>• It is expected that the pipeline will be designed such that smaller animals can pass under it. In addition, the pipeline will have under/overpasses installed at intervals along its length to minimise fragmentation effects and allow passage of animals across the corridor. |
| | All Project construction works - Post-Hurricane Maria Specific Actions | DGDC will develop a Habitat Management Procedure (HMP) that will be adhered to be the EPC Contractor and all Subcontractors during all Project construction works. The HMP will aim to provide enhancement measures for post-Maria terrestrial biodiversity of the area:<br>• Stabilise bare slopes or improve resilience on slopes where trees have fallen – promote tree and shrub planting to stabilise lose soil and rock, prevent further erosion and slips. This could also include supporting local nurseries to grow more trees which in turn could be used by local communities.<br>• Areas of fallen trees surrounding well pads and other infrastructure – plant native tree species to stabilise ground conditions, improve ecological resilience and reduce rainwater run-off which in turn could pollute water courses and cause soil erosion.<br>• Restore river courses – remove bulky items where possible such as fallen trees, logs and other detritus and large rocks which could block river flow and cause flooding; destabilise slopes or cause soil erosion to surrounding terrestrial areas.<br>• Removal of habitat cover – provide hibernacula of log piles, stone/rock piles for amphibians and other animals which might have been lost along with tree canopy cover.<br>• Exposed ground - plant native grass seed with fertilizer where exposed ground is still visible or where slopes are too steep or where soil has been washed away. |
| Morne Trois Piton National Park World Heritage Site | All Project construction works | Alongside the HMP described above, the EPC Contractor and Subcontractors will ensure that they undertake the following mitigation activities:<br>• Implement dust-suppression measures such as covering vehicles transporting materials, ensuring vehicles use wheel wash facilities at site, and use of water spray dust suppression systems.<br>• Highly noisy activities will be undertaken during daylight hours where possible.<br>• Inductions/tool-box talks for staff will include reference to measures required to protect biodiversity. |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
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| | | • Proposals for the MTPNP buffer zone should be progressed, and this area maintained as a development-free zone. Activities that would facilitate access to the MTPNP should not be encouraged.<br>• Any replanting / landscaping will use native or endemic species to prevent the incursion of opportunistic invasive species.<br>• Machinery and vehicles should be cleaned upon entry/exit, and any soil brought on or off site screened for invasive species or plant pathogens.<br>• Minimise potential for sedimentation impacts by ensuring good construction site practices are implemented.<br>• Appropriate disposal of solid and liquid wastes, in line with recommendations in international and national standards, and using designated facilities as required.<br>• Vegetation clearance activities will commence outside the breeding season for five key threatened species identified, to minimise impacts on breeding animals. The breeding seasons of the three bird species are overlapping, between January and August[2]. The amphibian species are thought to breed year-round, but primarily between May and July[3].<br>• Habitat cleared will be the minimum possible, with any way-leave area required of the minimum width necessary.<br>• Use temporary fencing to prevent inadvertent damage outside designated construction areas.<br>• Avoid piling of clear-felled vegetation on standing live vegetation which would hinder movement of wildlife.<br>• Minimise potential for sedimentation impacts by ensuring good construction site practices are implemented.<br>• Appropriate disposal of solid and liquid wastes, in line with recommendations in international and national standards, and using designated facilities as required.<br>• Minimise potential for pollutants and surface water run-off to migrate off-site by ensuring standard good construction site practices are implemented.<br>• Detailed measures to minimise the likelihood and magnitude of a BLEVE occurring is provided in ESIA Volume 2: EIA, Chapter 15, including:<br>- Induction and training;<br>- Standard Operating Procedures;<br>- routine inspections;<br>- good record keeping; and<br>- suitable firefighting equipment. |
| Traffic Management and Access | All Project construction works | The EPC Contractor will develop a Traffic Management Procedure (TMP) that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the documents. The TMP will:<br>• Identify routes within the site and from Roseau and the port to the site;<br>• Identify weight/height restrictions and alternative routes;<br>• Develop a signing strategy for the routes; |

[2] http://www.iucnredlist.org/ (Accessed September 2017)
[3] http://www.amphibianark.org/pdf/Husbandry/Leptodactylus%20fallax%20-%20Management%20Guidelines.pdf (Accessed September 2017)

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
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| | | • Ensure controls to mitigate for any obstruction to walkers using the Waitukubi National Trail route: and<br>• Formulate mechanisms for vehicle control.<br>The EPC Contractor and Subcontractors will ensure that they undertake the following mitigation activities:<br>• All routes must be clearly signed from the main highway, and through to the catchment areas. The signing strategy must allow unique identification of each route, along with speed and other restrictions. All drivers should have access to a schedule of the routes and a delivery control mechanism put in place to ensure all goods and material deliveries are clearly routed.<br>• The strategy may also include further restrictions such as a restriction upon the time during which vehicles may operate and the use of hazard warnings.<br>• Signs must clearly indicate that they relate to vehicles serving the power plant construction so that they are not misunderstood by other road users.<br>• Work at night should be avoided for safety reasons.<br>• The EPC Contractor will provide safe access for pedestrians and cyclists throughout the duration of construction phase of the Project.<br>• Consideration will be given to the speed at which the vehicles are advised to travel on the public road network and especially in rural areas.<br>• A vehicle awareness program could be conducted with the villagers most likely to be impacted, which will warn them of increased vehicle movements and the hazards posed due to the Project.<br>• Construction traffic drivers will be asked to reduce speeds in built up areas and ensure that braking distances are acceptable.<br>• Operators of the vehicles should regularly maintain vehicles to reduce excessive emissions.<br>• Drivers of all vehicles leaving the site should wash their wheels at the facility before entering the main road (refer to Air Quality mitigation strategies above)<br>• Other procedures to prevent the deposition of slurry, clay or other materials on roads by vehicles leaving the site will include:<br>- use of asphalt millings to surface the internal site haul road;<br>- provision of cleaning facilities including hoses, brooms and shovels;<br>- twice daily monitoring, and education of all construction staff/drivers to monitor for any material which may be accidently spilt onto public roads from construction traffic; and<br>- maintaining a contingency of sweeper equipment on call at all times to clean up material which may be accidently spilt onto public roads.<br>• Adherence to the TMP will be included within site induction and weekly toolbox meetings as required to ensure all site staff are aware and practice the required clean roads protocols.<br>The TMP should outline methods for controlling noise and vibration associated with construction traffic.<br>• It is recommended that a Travel Plan is written and distributed to staff to inform them of the best ways to travel to the sites of the Project. Staff should be encouraged to take public transport, car pool or that the contractor provides transport for them. |
| Working Conditions, Occupational Health and Safety | All Project construction works | • DGDC will be required to develop an Occupational Health Safety (OHS) Plans for the construction activities at the Project site, which will apply to all personnel involved in the Project, including EPC Contractors, Subcontractors and part-time workers. The primary health and safety objectives will be to ensure effective measures and management of occupational health and safety to minimise workplace accidents and injuries. The health and safety procedures within the OHS Plans will comprise a comprehensive Health and Safety Management System |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| | | HSMS. They will meet the requirements specified in the WBG EHS Environmental, Health and Safety Guidelines pertaining to occupational safety and health. In addition, any Subcontractors appointed by the EPC Contractors will be required to submit their own OHS Plans/Health and Safety Management System. Further details for the requirements of OHS Plans are presented in ESIA Volume 5: Technical Appendices, Technical Report – OHS and Working Conditions.<br>• The EPC Contractor will develop an Occupational Health Safety Management System which covers their staff and sets out the safety performance standards which the EPC Contractor and its subcontractors will meet. The EPC Contractor will actively monitor and audit the safety performance of its subcontractors.<br>• As well as the main OHS Plans, specific Safety Management System procedures shall be developed for each element of the Project, including the following:<br>- safety management organisation / reporting chain;<br>- construction methodology;<br>- hazard / risk assessment and proposed mitigation measures; and<br>- safety checklists.<br>• The Safety Management System will have a procedure for identifying all hazards associated with the activity in question. A hazard in this context is defined as any aspect of the Project activities which could result in harm to onsite personnel.<br>• The EPC Contractors and Subcontractors will be made aware of their role in ensuring the Project meets international standards related to labour and working conditions, and will be contractually obliged to do so. The EPC Contractor will establish a hierarchy of responsibility with regards for the provision of health and safety.<br>• DGDC and the EPC Contractors will establish a hierarchy of responsibility with regards for the provision of health and safety. The precise titles and roles of each member will be determined by DGDC and the EPC Contractors prior to work on the site.<br>• A DGDC and the EPC Contractor Health and Safety Management Committee will be appointed to evaluate health and safety at the site and to assess and recommend changes to equipment, policy and/or procedures where required by health and safety issues.<br>• Staff will be trained in safety procedures and provided with Personal Protective Equipment (PPE). Working conditions and occupational safety and health procedures framework has been outlined in ESIA Volume 5: Appendices, Technical Report – Working Conditions and Occupational Health.<br>• The EPC Contractors will issue all Project staff with an individual contract of employment detailing their rights and conditions in accordance with the national law and WBG requirements related to hours of work, wages, overtime, compensation and benefits such as maternity or annual leave, and update the contract when material changes occur.<br>• Generic rules shall be provided within employment contracts and task specific procedures will be communicated during tool box talks and displayed on machinery or within hazardous work areas.<br>• All hazardous work shall require the completion of a permit-to-work form and approval by the OHS Manager prior to commencement.<br>• A security procedure shall be included within the OHS Plan covering areas of security control, working hours etc. |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| | | • Emergency Response Procedures will form an integral part of the OHS Plans/HSMS. As part of these, an Emergency Response Plan shall be prepared to address emergencies of all scales. Further details of the outline of an Emergency Response Plan are located in ESIA Volume 5: Technical Appendices, Technical Report - Occupational Health and Safety and Working Conditions.<br>• A worker's grievance mechanism will be established. In compliance with World Bank Group Standards, this grievance mechanism will be designed to receive and facilitate resolution of concerns and grievances about the Project's working conditions and safety performance. |
| | Worker's Accommodation Camp | • The Worker's Accommodation Camp on site will be kept clean, tidy and pest-free.<br>• The EPC Contractor will ensure that standards are kept in accordance with the guidance document 'Workers' accommodation: processes and standards' (IFC and EBRD, 2009).<br>• Provide a cultural education programme for workers from outside the area to help reduce community conflict.<br>• Work camp regulations shall be developed to minimise local nuisance.<br>• |
| Water Quality and Freshwater Ecology | Power Plant - earthworks during construction | The EPC Contractor will develop an Erosion and Sediment Control Procedure (ESCP) that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the documents. The ESCP will aim to manage and mitigate suspended solid discharges to the Roseau River to an acceptable level. This will be managed in accordance with the EHS general Guidelines. The ESCP will include the following mitigation:<br>• Clean water diversions – An overland flow path crosses the proposed power plant location. This should be diverted around the site area first to minimise clean water ingress to bare earth areas.<br>• Access road sealing – the access road should be gravelled or sealed as a first stage in construction to minimise erosion.<br>• Staging – the works should progress in stages where possible to minimise the amount of bare earth. This is likely to include clearing the laydown area first, then providing erosion and sediment control to it before then moving onto the power plant area.<br>• Reducing catchment sizes – work areas should be created that involve small sub catchments in which flows can be reduced, channelized concentration or water minimised to reduce erosion.<br>• Installation of temporary stormwater drains through each of the catchment areas to collect and direct stormwater to sedimentation ponds.<br>• Erosion protection – when flows have been concentrated into channelized flows these should be within protected channels. These could be either temporary protection using geotextiles or more permanent hard protection.<br>• Sediment retention - Silt fences should be used around all the downstream site earthwork boundaries and within the site around each subcatchment. These will work to slow water flow and retain sediments. Silt fences should also be provided on the downstream side of the access road where earthworks are proposed.<br>• Sediment settlement – prior to discharge, all collected stormwater shall be directed by temporary drains through sedimentation ponds.<br>• To minimise any potential adverse environmental effects from flooding or erosion (inclusive of land or watercourses) from the stormwater discharge from the operation of the steamfield and plant. |
| | Power Plant – Worker's Camp | A package plant will be used by the EPC Contractor that will treat sewage and wastewater during the construction phase. |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| | Reinjection pipeline construction activities - earthworks during construction | The ESCP recommendations for the power plant location will also apply with the following additional mitigation to manage specific risk activities for the reinjection pipeline:<br>• Staging – The works should progress in stages where possible to minimise the amount of bare earth. This is likely to include clearing the route in sections with installation of settlement retention features for each section before pipeline construction in that section. The next sections should not be cleared till works are ready to progress.<br>• Clean water diversions – overland flow paths going through work areas should be directed directly through the pipeline corridor and not allowed to travel down the cleared pipeline route to minimise erosion.<br>• Sediment retention - Silt fences should be used around all the downstream pipeline route boundaries. These will work to slow water flow and retain sediments. Silt fences should also be provided on the downstream side of the access road where earthworks are proposed.<br>• Temporary stream crossings – where streams will be regularly crossed temporary protection should be installed (culverts) to minimise direct disturbance and sediment generation. These should be removed after works are complete. |
| | Reinjection pipeline construction activities - discharge of sewage and site amenity wastewater | • Portable toilets will be installed and used by workers to prevent contamination of waterways. |

Table of Monitoring activities during construction

| Issue | Location of Monitoring | Proposed Monitoring Measures |
|---|---|---|
| General | All construction works | • Independent third-party auditing of the implementation of the ESMP will be undertaken at regular intervals. The budget for this auditing and its frequency will be specified in the ESMP and verified by the relevant regulators. |
| Air quality | All construction works | • To determine the effectiveness of dust mitigation measures used during construction, the EPC Contractor will ensure that ambient air monitoring is undertaken on the site boundary. DGDC will monitor the performance of the EPC Contractor. Sampling should be conducted for:<br>- Visual dust inspection of the site on a daily basis during the dry season to gauge the effectiveness of dust mitigation measures will occur at least 400m from construction works.<br>- The monitoring provides a means of ensuring control systems such as dust suppression sprays are operating correctly and should be undertaken by a qualified laboratory using appropriate sampling equipment. Visual inspections of cleaning truck tyres and road watering activities will also be monitored and recorded. The results will be reported on a monthly basis and included in publicly available reports.<br>• As part of good working practice the EPC Contractor will complete routine checks on dust generation from construction activities, and confirm that dust suppression and appropriate storage is being used where required. In addition, a mechanism for complaints regarding dust will be available to locals, and due regard given to any issues raised.<br>• Safety monitoring systems with warning alarms for high emissions of potentially hazardous gases, including $H_2S$, incorporated at the well sites (e.g. the power plant and reinjection sites), as well as providing direct safety measures in the event of a blowout, will highlight potential H2S emissions issues which could arise during well commissioning and operation. All personnel and local residents will be made aware of the procedure should an alarm be activated. |
| Cultural Heritage | All construction works | No monitoring measures are proposed during construction, with the exception of the EPC Contractor ensuring implementation of the Chance Find Procedure. |
| Environmental and Social Management System (ESMS) | All construction works | • The ESMS will set out DGDC's policies and procedures for managing, mitigating and monitoring environmental and social impacts. Monitoring will be carried out in order to determine whether environmental and social outcomes are being achieved. Monitoring requirements will be specified in a monitoring plan (or plans), which identify:<br>- The type of monitoring that is to be carried out including monitoring the performance of the EPC Contractor;<br>- Where monitoring is to take place;<br>- How frequently monitoring will be carried out;<br>- The parameters that will be tested for;<br>- The applicable objectives and performance standards; and<br>- Staff responsible for conducting the monitoring.<br>• DGDC will undertake reviews of the ESMS will be conducted throughout construction and operation of the Project and where necessary changes should be made to the documentation to ensure that it remains relevant. For instance, once construction has been completed, the construction related environmental and social aspects will no longer be relevant.<br>• DGDC will be responsible for overall monitoring and reporting every six months to relevant authorities regarding the findings of the reports.<br>• Reporting of monitoring activities will be issued by DGDC to the Lenders every 6 months in the Biannual Environmental and Social Report. |

| Issue | Location of Monitoring | Proposed Monitoring Measures |
|---|---|---|
| Hazardous Substances and Waste | All construction works | The EPC Contractor will ensure that:<br>• The amount and destination of the wastes will be recorded and monitored.<br>• A record of all spillages will be maintained.<br>• All bund enclosures will be regularly inspected for water and sheens prior to the collected water being discharged.<br>• Regular inspection of storage facilities to check for leaks, spills and inappropriate storage practices.<br>• As part of the Waste Management Procedure a monitoring plan will be developed to inspect waste collection skips, to check wastes are being separated correctly and hazardous wastes are not being included with non-hazardous. The inspection should also include a check of the waste skips and bins condition to be sure waste is being held securely and not able to impact the environment through leakage or being blown away.<br>• Regular inspections to check that wastes are being separated and deposited in the correct bins for recycling and disposal.<br>DGDC will monitor the performance of the EPC Contractor. |
| Hydrology | All construction works | The EPC Contractor will ensure that visual monitoring is undertaken at stream banks and the construction of diversion channels to identify any areas that may be performing inadequately (resulting in bank collapses, localised erosion hot spots and scouring). DGDC will monitor the performance of the EPC Contractor.<br>Prior and during construction it is recommended that monitoring of the flow rates be conducted at the small stream used for abstraction of water. |
| Geothermal Resource | Key geothermal sites | A Reservoir Monitoring Procedure (RMP) will be developed by DGDC and monitoring undertaken by DGDC staff. The RMP will consider all possible changes that may occur to the deep reservoir and the surface thermal activity. DGDC will ensure that a baseline monitoring programme is undertaken at selected natural geothermal features before the power plant is commissioned, to establish the natural seasonal variability of surface spring activity including flowrate, temperature and fluid chemistry. Springs can change over time so the baseline data is needed for objective assessment, post commissioning. |
| Natural Hazards | All construction works – risk of landslide | • The EPC Contractor will undertake monitoring during construction for identified geo-hazards of moderate or high landslide risk that have not been avoided. |
| Noise and Vibration | All construction works | • The EPC Contractor will undertake noise monitoring to confirm the actual construction noise levels at representative sensitive receiver locations should be undertaken, for example, adjacent to the power plant site). This monitoring should be carried out at the start of the construction of the Project and on a quarterly basis. DGDC will monitor the performance of the EPC Contractor.<br>• Direct observation of machine maintenance should also be made to ensure that any noise-creating faults are repaired. Direct observation of machine maintenance should be made to ensure that any noise-creating faults are repaired. |
| Water Quality and Aquatic Ecology | All construction works | The EPC Contractor will ensure the following:<br>• Inspection and maintenance – the ESCP shall specify who is responsible for inspecting all physical elements of the erosion and sediment control measures. These shall be inspected daily to ensure they are installed and working correctly. Any defects shall be rectified before earthworks occur in that area of the site. Accumulated sediment shall be removed from all features when it reaches 25% of the available space. Records of all inspection and maintenance shall be kept. |

| Issue | Location of Monitoring | Proposed Monitoring Measures |
|---|---|---|
| | | • Visual inspection of the river - the ESCP shall specify who is responsible for inspecting the river upstream and downstream of the works on a daily basis. The inspection should identify whether any visible change in water clarity or turbidity occurs after the site discharges. If no discharge is occurring the inspection should identify if any sediment builds up is obvious within the channel downstream of the site. If visible changes are observed, then modification of site operations and/or site erosion and sediment control practises should be made to reduce the impact. Records of all inspection and response activities shall be kept.<br>• The discharge from the sedimentation ponds should be monitored during rain events. At least once per month for total suspended solids for comparison with the discharge limit of 50 mg/l and to determine the effectiveness of the pond.<br>• Monitoring of treated effluent from the Workers' Accommodation package sewage treatment plant on a monthly basis.<br>• Prior and during construction it is recommended that water quality and ecological (i.e. aquatic invertebrates) monitoring will be conducted at the small stream used for abstraction of water.<br>DGDC will monitor the performance of the EPC Contractor. |
| Social | All construction works | • DGDC will monitor the number of people being employed by the Project in: 1) the three key villages (Laudat, Trafalgar and Wotten Waven) and 2) the wider Roseau Valley, against predicted numbers of employees.<br>• DGDC will undertake surveys to determine the number of new businesses generated by the development and the level of indirect employment.<br>• A DGDC Community Liaison Officer will be responsible for updating and monitoring the implementation of the RAP and Grievance Mechanism defined in the Stakeholder Engagement Plan.<br>• DGDC will undertake ongoing consultation and communication with the local community will be required particularly with PAPs, vulnerable groups and key stakeholder groups. The minutes of meetings and signed lists of attendees will be completed and documented.<br>• An independent third party review is recommended of the effective implementation of the RAP, one year after civil construction works commence at the power plant and reinjection line.<br>• The following will be monitored through on-site visits by DGDC on a quarterly basis:<br>- effectivity of the implementation of good practices as per World Bank HSE Guidelines;<br>- existence of access control;<br>- number of sanitation facilities available for men and for women at each construction site; and<br>- effectivity of access restriction measures along the transmission line and its towers.<br>• The DGDC Human Resources Department will monitor the following on a quarterly basis:<br>- effectivity of the implementation of good practices as per World Bank HSE Guidelines.<br>• The records are to be reported to DGDC and any applicable regulatory authorities who then can document and respond to this information as part of their responsibilities. |
| Soils and Groundwater | All construction works | • The EPC Contractor will undertake routine monitoring of any spring flows (cold water), both baseline and during development in order to determine any potential effects on the system. DGDC will monitor the performance of the EPC Contractor. |
| Terrestrial Ecology | All Project construction works - | The Habitat Management Procedure (developed by DGDC) will provide baseline terrestrial biodiversity monitoring recommendations for the site. Although detrimental in general terms, the recent decimation of local habitats and ecosystems at least provides a clear baseline to develop a monitoring programme |

| Issue | Location of Monitoring | Proposed Monitoring Measures |
|---|---|---|
| | Post-Hurricane Maria Specific Actions | especially for forest recovery and the key animal groups that use it along with monitoring improvements of aquatic species in water courses. DGDC will be responsible for monitoring of the Habitat Management Procedure. |
| MTPNP World Heritage Site | All construction activities | • DGDC will develop a MTPNP monitoring programme will be implemented for the five key species considered Threatened by IUCN: giant ditch frog, imperial parrot, red-necked parrot, forest thrush, and a species of tree frog (*Eleutherodactylus amplinympha*), recommended to be at every six months from pre-construction until the completion of one year of construction, and annually thereafter for a minimum of five years of operation. The programme should also include the ongoing monitoring in the Laudat and Trafalgar area for any other potential impacts on the OUV of the WHS.<br>• The MTPNP monitoring programme will be agreed with input from the MTPNP managing authorities (National Parks Unit of the Division of Forestry, Wildlife and National Parks), and implemented prior to construction where appropriate. The monitoring programme outlined will enhance understanding of the ecology of the MTPNP and surrounding areas, and ensure that if any adverse effects on OUV were to occur, these would be detected in a timely manner and properly mitigated. |
| Traffic Management | All construction works | The EPC Contractor will undertake monitoring of construction traffic and traffic management measures to ensure compliance with the traffic management requirements outlined within the TMP. Activities to be monitored include:<br>• Construction traffic movements to ensure truck drivers use the designated routes;<br>• Traffic incidents/complaints from the public or officials to ensure that unpredicted changes in travel time due to incidents such as, for example traffic accidents, emergencies, natural disasters can be managed by specially trained personnel; and<br>• Public roads to ensure that the roads in the vicinity of the site are clean at all times of clay, slurry or materials from the site.<br>DGDC will monitor the performance of the EPC Contractor. |
| Working Conditions, Occupations and Safety | All construction works | • The EPC Contractor will undertake a schedule of regular safety inspections and monitoring of exposure to hazards. This will include the state of the site as well as the maintenance of equipment and a comparison to internationally published exposure guidelines.<br>• The EPC Contractor Site Manager shall instigate measures to correct non-conformance in safety performance found during safety checks and inspections. A record of the safety checks and inspections, and resulting actions, shall be provided to the Health and Safety Management Committee every month.<br>• DGDC, as principals, undertake independent audits of the EPC Contractor and their Subcontractor's Health and Safety performance to ensure that the health and safety practices as set out in their health and safety plans are being complied with. The audits will also check that no unsafe practices are being carried out at site. If unsafe practices are identified during the audits, work at the site should cease. The audits should be carried out once every two months.<br>• All staff at DGDC and the EPC Contractor should be notified of all incidents/accidents which result in first aid treatment during the soil improvement programme and the construction of the power plant. Minor incidents along with the incident/accident investigation report should be supplied to DGDC once a month. Serious accidents that are Lost Time Incidents, or result in serious harm or a fatality should be reported immediately to DGDC.<br>• Notification of accidents and incidents at the site during soil improvement and construction provide another means of monitoring the Contractor's safety performance.<br>DGDC will monitor the performance of the EPC Contractor. |

### 1.8.1 Noise Requirements

The Facilities shall be designed and constructed to operate with the least practicable noise emissions. The Contractor shall guarantee that the noise levels at 1 metre from any surface of any operating item including valves or acoustic enclosures shall not exceed an A-weighted sound pressure level of 85dB(A). If the equipment produces impulsive or narrow band noise, the above limit shall be reduced by 5dB(A).

The above noise limit shall not apply to noise arising from water cascading in the cooling tower.

The above noise limit shall not apply to emergency pressure relief devices during emergency operational situations.

The above noise limit may be relaxed to 90dB(A) for the gas removal system ejector if supplied.

These conditions are to be met with the turbine-generator units operating simultaneously at NCR design conditions from 25% to maximum load and all auxiliary and ancillary equipment in their normal operating condition. This includes noise emissions from the rock muffler / steam vent station during reduced load operation.

The maximum sound pressure level measured at the Site perimeter (as defined in this Contract and indicated on the drawings) shall comply with the requirements in the ESIA and ESMP and shall in any case, not exceed 55 dB(A) during the day and 45 dB(A) overnight at the nearest residence.

The maximum sound pressure level measured within the operations building including workshop / machinery room, operator control room, chemical storage locker / area, and any electrical room shall not exceed 55 dB(A).

When the noise contains a distinct tone and/or other distinctive audible character, this limit shall be reduced by 5 dB(A).

If necessary suitable acoustic enclosures or insulation shall be applied on equipment, but this must give due regard to access requirements for operation and maintenance of the equipment.

### 1.8.2 $H_2S$ Concentrations and Dispersion

The Contractor shall design and test the Facilities to ensure that the H2S concentration levels in and around the Site are within acceptable levels as determined by the WHO ambient air guidelines.

Tests during and after commissioning shall confirm the gas concentrations. This will include conducting atmospheric dispersion modelling to confirm compliance with WHO ambient air guidelines.

### 1.8.3 Waste Water

Waste water during the construction period and thereafter for operation shall be treated by an on site packaged sewage treatment plant. The requirements are as set out in the ESMP. The Contractor shall size, install and maintain the treatment plant and dispersion field area for the duration of the project.

### 1.8.4 Onsite Worker Accommodation

The Contractor shall provide the on site construction worker accommodation facilities for the duration of the construction period. The standards for the accommodation shall be in accordance with the World Bank requirements

These facilities shall include:

1. Worker sleeping quarters
2. Ablution facilities
3. Kitchen and dining area

4. Recreation area

## 1.9 Functional Performance and Operation Requirements

### 1.9.1 General

The Plant shall be designed and guaranteed to operate over the full range of interface and ambient conditions specified in the Interface Schedule.

The Plant shall be designed to maximise the net electrical output available from the input process fluid in a cost effective manner and, consistent with utility industry standards, require the minimum reasonable operating and maintenance costs.

The Plant shall utilise standard plant and components made to proven designs with good long term operating experience in a similar environment and application. Any changes to proven equipment shall be subject to agreement by the Project Manager. Recently identified or developed improvements which the Contractor considers advantageous to the Employer shall be proposed to and discussed and agreed with the Project Manager prior to adoption.

### 1.9.2 Layout

The Employer has prepared a concept layout for the Plant. The drawings which describes this are provided as part of the Employers Requirements.

Whilst the Contractor is free to lay out the Plant as they feel is best within the Site, the concept drawings convey general expectations of the Employer and have been compiled considering the topography, access and general constructability.

### 1.9.3 Design Life

The design life of the Plant, with exceptions as noted below, shall be thirty (30) years and the design, manufacture and construction shall be undertaken to ensure compliance with this requirement.

The design life for all buildings shall be taken as 50 years for the application of the structural design codes.

Piping shall be analysed and designed for a minimum of 7,000 equivalent full temperature displacement cycles.

### 1.9.4 Performance Requirements, NCR & Operational Conditions

The conditions for NCR are defined by the Functional Guarantees and the Interface Schedule.

The Plant shall be designed to provide best efficiency at NCR conditions and be suitable for operating over a range of inlet conditions, flows and ambient conditions to enable the Employer to maximize generation.

## 1.10 Operability

### 1.10.1 General

The Plant will be operated and maintained as an integrated entity. Primary operation of the SGS and Power Plant shall be via a fully integrated Distributed Control System (DCS) with operator workstations in the Operator Control Room

The Plant control and instrumentation system shall provide a safe, reliable, efficient and essentially automatic system for coordinated control and monitoring of the Plant in all modes of operation. The system shall satisfy the following objectives:

1. Maintain the plant in a safe condition at all times. Automatic protection and plant trips shall be provided so that if a potentially dangerous or undesirable situation should occur, the plant and associated equipment will be maintained in a safe and undamaged condition without the need for any operator action.

2. Ensure that all automatic control functions shall have an acceptable level of fail-safe design and be capable of override by operator intervention. Manual mode shall be backed up by various inputs from automatic systems to a degree to provide safe, effective control, without distraction of the plant operator.

3. Provide for smooth start-up and shutdown of the Plant in accordance with pre-planned operating procedures with a minimum of operator intervention. The control and automation systems shall be designed so that start-up and shut-down of the Plant is normally and comfortably carried out with one control room operator and one field operator.

4. The start-up and shut-down process of the Plant shall be guided by the DCS using an interactive flowchart as a visual guide to operators. Each step of the process, whether manual or automatic, shall be depicted in the flowchart. The conditions / interlocks / operator intervention etc. required to satisfy to progress from one step to the next shall be depicted in the flowchart together with their current state. Plain English descriptions shall be used as well as asset tag numbers / descriptions as appropriate. Links shall be provided to interlocks or condition (or other “active” point) that is part of the start-up and shut-down processes, which when selected (clicked) shall automatically navigate to the relevant DCS logic; this view shall then show, in current live state, all logic associated with the stage of the process relevant at the time.

5. Provide for efficient steady-state control of the Plant.

6. Provide reliable steady Plant operation at all outputs up to and including net rated capacity.

7. Minimize the effects of abnormal process conditions, load upsets, and equipment malfunctions on Plant operations.

8. Minimise operator skill requirements by incorporating comprehensive safety features, automatic operation, diagnostics and alarms and operator interfaces that minimize the potential for operator error.

9. Minimize the number of plant forced outages and spurious trips.

10. Provide for reliable, economical/optimum operation of the turbine, generator and related systems.

11. Provide a control system that allows for maximum flexibility to expand the system and/or modify control functions that affect the performance of the unit during initial start-up, testing and operation.

12. Minimize the effects of corrosion and scaling through proper equipment and material selection, equipment location, environmental control, and on-line maintenance capability.

13. Provide systems for prompt, effective communications within the Plant and externally to the System Operator.

14. Allow remote access and control of the Plant over the public internet system via an appropriate firewall. This will enable remote HMI access.

### 1.10.2 Flexible Operation

The Power Plant shall be designed for flexible operation so it can reliably operate to meet dispatch requirements of the System Operator. The Plant will normally operate 24 hours per day, 7 days per week, and shall be suitable to operate in a dispatched mode on a per unit basis continuously at any part loading down to 25 percent of NCR.

At loads from 25% NCR down to house load the unit shall be able to operate continuously for a period of not less than two hours.

The Plant shall be designed to operate continuously over the range of conditions expected at the plant site including seasonal ambient variations and wind loading.

### 1.10.3 Start-Up and Loading

The Plant shall be capable of being started up from cold to synchronisation in 3 hours and from hot stand-by to synchronisation in 10 minutes.

The facility shall be capable of the following:

- A MW ramp rate of 20% of full load per minute under hot start conditions.
- A MW ramp rate of 10% of full load per minute under cold start conditions.
- Under normal operating conditions after completion of turbine start-up, the ability to maintain normal operation in the event of instantaneous load changes of up to 10 per cent of rated output.

### 1.10.4 Power Factor, Reactive Power and Voltage Control

The operator shall have the choice of operating in power factor control mode or in reactive power control mode or in voltage control mode. The normal operation of the AVR is voltage control mode. In power factor control mode, the power factor shall be maintained by the continuous automatic control of the generator excitation and shall be demonstrated at 0.80 lagging and 0.95 leading at full load. In reactive power control mode, the reactive power shall be maintained by the continuous automatic control of the generator excitation and shall be demonstrated at a lagging VAr level of 60 percent of MW rating and a leading VAr level of 31 percent of MW rating lagging. In voltage control mode the generator terminal voltage shall be capable of controlling voltage to an operator setpoint with the range of voltage being -5% to + 10% of the rated line voltage.

### 1.10.5 Loss of Grid Connection

Loss of the grid connection shall result in the Power Plant continuing to generate to match “islanded” or “house” load, maintaining all necessary systems such that it may be resynchronised to the external grid without the need to stop generating. Electrical protection systems shall be designed and co-ordinated with the grid protection such that the Plant systems are as stable as possible for grid events while adequately protecting the plant, enabling the Plant to either “ride through” or trip to house load for low level grid events.

Following a trip to house load the operator will then have the choice of initiating a safe and orderly shutdown of the plant, or "Hold at House Load" until grid power is re-established and then re-synchronising.

### 1.10.6 Operating Regime

The following methods of operation of the Plant shall be provided. Individual items of plant shall be able to operate continuously and unattended except for supervision from the OCR or remotely at a location away from Site but connected to the internet. In the event of failure of an item of equipment, it shall be automatically made safe, its duty taken over by a standby item of plant as appropriate and an alarm generated to the appropriate control system.

- Plant Start Up and Shutdown

  To be managed and directed from the OCR. The operator in the OCR shall be able to start and stop auxiliary Plant and initiate automatic turbine run-up and run-down. Local-to-plant operating and surveillance at each plant item as required including manual operation of drain valves used during cold starting. Generator automatic synchronisation shall be initiated from the OCR.
  The overall system shall be designed with sufficient automation and remotely operated equipment such that a single OCR operator with a roving field operator can safely start-up, shut down, monitor and control the Plant from the OCR on the Site.

- Normal Operation

Turbine load control, supervision of the operating Plant and any standby Plant shall be provided from both the OCR and via remote operation with periodic surveillance and monitoring by roving operators under the direction of the OCR operator.
The plant will have the ability to be operated unmanned for extended periods of time. During unmanned periods the plant shall have the ability to be remotely operated from various off-site web based facilities.

- Fault Conditions

  Fault conditions shall, where possible, initially provide warnings to the Plant operator to permit remedial actions to be taken. A continued or further degrading fault condition shall cause the Plant to automatically fail into a safe condition. Initial assessment will be undertaken by the operator who will take corrective action as necessary and call out roving operator/maintenance staff to take local corrective actions. If the Plant is running unmanned, faults or alarms shall alert the nominated operator located off-site who will be able to access the remote operation facility to check the Plant status and make any plant operational changes required.

  In the event the Plant trips under fault conditions including a loss of grid event, the control of the brine and steam systems will place these systems in a safe state to give the operators sufficient time to reconnect to the grid before automated steps are taken to undertake a controlled shut down of steam field production. The local main brine sump shall be sized to accommodate at least 8 hours of brine discharge equivalent to full load conditions.

### 1.10.7 Consumables

The Contractor shall submit to the Project Manager a schedule of operational consumable items, listing the items and the quantities required per month of operation of the Plant supplied under this Contract. The listing shall include sufficient detail to enable the Employer to order the materials directly, where possible, from a local supplier.

## 1.11 Maintainability

### 1.11.1 General

The maintenance facilities shall be designed and constructed to effectively support the operation of the Plant for 30 years.

The Plant shall be designed and constructed in a manner that facilitates routine, periodic and forced outage maintenance. This shall include adequate provision of facilities such as equipment withdrawal spaces, access ladders, stairs and platforms, crane access and lifting points and laydown areas. Isolating facilities shall be provided to allow the safe and efficient maintenance of all items of the Plant.

Sufficient space and access shall be provided to allow the generator rotor to be withdrawn from the generator body for major overhauls. This shall include ability to load the rotor onto a truck for transport away from Site.

Sufficient space and access shall be provided to allow the turbine rotor to be removed from its casing for major overhauls. This shall include ability to load the rotor onto a truck for transport away from Site.

A covered laydown area shall be provided within the Power Plant which is sufficient for the efficient major overhaul of an entire turbine generator plus all related auxiliary plant.

The Plant shall be arranged so that one Unit can be easily and safely isolated from the other Unit without the need to take the remaining Unit out of operation.

Drawings shall be provided showing the intended maintenance clearance envelopes and, where required, withdrawal routes and laydown spaces.

Lifting equipment shall be provided to ensure safe removal of all plant and equipment provided as part of the Facility so that lifting by human power only is limited to items of less than 50kg.

The plant and duplicated equipment shall be arranged identically to each other Unit to ensure full interchangeability of parts and eliminate any possible disorientation of operators between Units. This shall include the relative placement of all components including, but not limited to, electrical and control panels.

### 1.11.2 Maintenance Facilities

The Plant shall be provided with:

1. Sufficient capacity (including unloading bay, laydown areas, crane facilities and crane access) for the efficient execution of the complete overhaul of the main rotating plant and its auxiliaries, in addition to the normal routine station maintenance work.

2. A workshop and a stores facility as specified elsewhere in this specification.

### 1.11.3 Tools and Special Tools

The Contractor shall furnish all necessary hand tools, machine tools, special tools and test equipment for the installation, operation, regular maintenance and repair of the Plant over its life. In addition, special tools shall be provided to allow extraction of the generator and turbine rotors for major overhauls, including the temporary supports needed to safely support the rotors in the laydown areas in accordance with manufacturer's requirements.

Programming and configuration software tools shall be provided for all software based systems provided under the contract. Software licenses for maintenance tools shall be provided under the name of the Employer.

For the purposes of this clause, special test equipment with an individual value that exceeds USD 5,000 may be provided at additional cost with the Project Manager's prior approval

Immediately prior to "Operational Acceptance" the Contractor shall hand over to the Project Manager all tools and equipment as follows:

1. Each item shall be new in good working order and condition.

2. Each item shall be included in a schedule of where purchased together with the contact information for the supplier.

3. Each item shall be tagged and uniquely identified to reference documentation.

4. Each item shall be preserved for storage as appropriate to the expected utilisation of the item for future operational or maintenance requirements

5. Each item shall be placed in the nominated storage location on the Site

6. Where applicable, written operating and maintenance instructions for each item shall be provided to the Project Manager

7. Lifting equipment, cranes, pressure vessels and other similar items requiring certification or other form of regulatory approval for use shall be handed over together with all necessary certifications and approvals in a valid condition. Items requiring re-certification based on use or time shall be re-certified at the expense of the Contractor at the time of handover.

## 1.12 Operation and Maintenance Systems and Support

The Contractor shall ensure that the Plant and supporting documentation systems are delivered in accordance with this specification to facilitate full operation and maintenance management by others at a future date.

Utilising the developed Operation and Maintenance system as detailed in the following paragraphs, the Contractor is to provide operation and maintenance support to the O&M Contractor for two years following Operational Acceptance of Portion A.

The advice, development and implementation of systems covering Operation, Maintenance and Management Systems shall include, but not be limited to:

1. Operation:
    - Well startup from cold
    - Steam production facilities warmup
    - Steam production
    - Plant start up from cold
    - Plant start up hot
    - Synchronisation to grid
    - Loading to fixed load
    - Operation in load-following mode
    - Tuning of steam production facilities to match plant output in fixed load mode
    - Tuning of steam production facilities to match plant output in load-following mode
    - Tuning of generating plant to achieve optimum efficiency
    - Monitoring of steam production facilities
    - Monitoring of brine and condensate reinjection facilities
    - Monitoring of generation facilities
2. Maintenance:
    - Condition monitoring of operating plant
    - Routine observation, monitoring and testing of operating plant
    - Repair or replacement of defective items
    - Scheduling of routine maintenance
    - Scheduling of plant or steamfield shutdowns
3. Management Systems
    - Scheduling of shift staff efficiently
    - Meeting agreed targets for availability factor
    - Meeting agreed targets for capacity factor
    - Eliminating unscheduled outages
    - Recording operating incidents for the purposes of identifying training shortfalls
    - Scheduling routine maintenance in accordance with the Operation and Maintenance Manuals
    - Scheduling the purchase of consumable fluids and materials
    - Recording all defects whether trivial, minor or major, and the associated costs of repair
    - Recording training undertaken by individuals and identifying training shortfalls
    - Capturing changes to the Facilities to keep as-built drawings up to date.

- Identifying beneficial capital works replacement projects
- Facilitating ease of use / transfer / import to other industry user management systems

### 1.12.1 Personnel Schedule

The Contractor shall provide the following personnel to advise on the operation and maintenance of the Facilities:

1. One Operations Advisor for each shift, on a continuous basis. These Advisors will liaise directly with the Employer's Operations Superintendent through the Shift Supervisor. The Employer expects to implement a three 12-hr shifts system

2. One Mechanical Maintenance Advisor and one Electrical Maintenance Advisor. These Advisors will liaise directly with the Employer's Maintenance Superintendent. They are expected to work a standard 40hour week, but are required to be on 24hour standby, seven days a week. One of the Maintenance Advisors is to be designated as the Lead Operation and Maintenance Advisor.

3. Temporary replacement personnel when any of the above Advisors are required to be absent from site.

4. Other staff on call at 3 days' notice for civil engineering and building services maintenance.

The Employer will have no responsibility for any matter relating to the employment of the Contractor's Advisors.

### 1.12.2 Performance Review

The Contractor's performance will be reviewed by the Project Manager at three monthly intervals. Matters that will be taken into account include but are not limited to:

1. An assessment of the competence of individual Advisors

2. Review of the plant availability

3. Review of the plant's capacity factor

4. Review of maintenance activities undertaken

5. Review of maintenance activities being scheduled

### 1.12.3 Employer's Obligations

The Employer's operation and maintenance personnel will have suitable education but are likely to have little or no experience in the operation and maintenance of geothermal power plants. Not all of the Employer's personnel will have undertaken the training courses to be provided by the Contractor as required by the Specification.

The Advisors are expected to share facilities with the Employer's personnel. The Employer will make available suitable office and amenities space for the Maintenance Advisors.

### 1.12.4 O&M Contractor's Obligations

The O&M Contractor (by others) will have mitigation measures as well as monitoring responsibilities as defined in the two tables provided in this section.

The O&M Contractor will have primary responsibility to undertake these actions. The EPC Contractor's Advisors shall be responsible in aiding and supporting the O&M Contractor in an advisory capacity to perform these tasks. The duration for this support shall be over the required two years' operations and maintenance support period.

Summary table of proposed mitigation during operation

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| Air quality | All power plant operation activities related to emissions and dust control | The O&M Contractor will ensure the following:<br>• Routine maintenance checks will be undertaken on wellheads and blowout prevention equipment to check it is in operable condition.<br>• If a wet cooling tower system is to be used for the Project, drift eliminators will be incorporated into the final design to minimise particulate emissions.<br>• Impacts from the operational station will be dependent on the geothermal fluid chemistry and the plant design. Given the predicted level of effects is predicted to be at an acceptable level, additional measures such as total or partial re-injection of gases with geothermal fluids; and abatement systems to remove hydrogen sulphide emissions from NCGs (e.g. wet/dry scrubbers), are not required. |
| Cultural Heritage | All Project operation activities | The O&M Contractor will ensure the following:<br>• The mitigation measures employed during operation will be the same as those described above for construction (Table 2.1), namely the implementation of the Chance Find Procedure if an asset of cultural heritage value is discovered as part of the operational activities of the power plant or transmission line<br>• The Worker's Code of Conduct used during operation will also include a section on the importance of cultural heritage preservation and understanding. |
| Environmental and Social Management Systems (ESMS) | All Project operation activities | • The O&M Contractor will operate the power plant and will be responsible for recordkeeping and reporting, maintenance inspections, execution of routine maintenance, periodical maintenance and major overhaul in accordance with the Project ESMS, and emergency stop of operation and incident reporting. The O&M Contractor will prepare separate operation management plans and procedures that align with the Project ESMS. The O&M Contractor will also develop an overall organisational structure for environmental responsibilities on site. DGDC will have responsibility for reviewing and auditing the O&M Contractor's documents.<br>• The O&M Contractor, in collaboration with DGDC, will establish, maintain, and strengthen as necessary an organisational structure that defines roles, responsibilities and authority to implement the ESMS and ESMP. Specific personnel with clear lines of responsibility and authority are designated in this section. Key ESMS responsibilities are defined and will be communicated to the relevant personnel and to the rest of the O&M Contractor workforce as well as |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| | | DGDC and any Subcontractors. Sufficient management sponsorship and human and financial resources will be provided on an ongoing basis to achieve effective and continuous ESMS performance.<br>• Reporting of mitigation activities will be issued by DGDC to the Lenders every 6 months in the Biannual Environmental and Social Report. |
| Geothermal Resource | All Project operation works | The O&M Contractor will ensure that the Reservoir Management Procedure will be implemented during operation that considers all possible change that may occur to the deep reservoir and the surface thermal activity. |
| Hydrology | Power plant operation activities | The O&M Contractor will ensure the following:<br>• Power plant site and laydown area will have a stormwater system designed to capture and treat any runoff.<br>• The power plant's stormwater system will drain through a sump or settling pond. This would capture any runoff from the pad and settle out rubbish and sediment, while reducing flow velocities.<br>• Diversion drains will be installed around the site, the capacity of these drains needs to convey adequate flood events to reduce the likelihood of this occurring.<br>• Sourcing a water supply for firefighting will be infrequent, however would require >500 $m^3$ stored in a tank. |
| Hazardous Substances and Waste | All Project operation activities | The O&M Contractor will ensure the following:<br>• Heat and pentane sensors will be fitted around the storage tank and the plant to detect any leaks and heat changes.<br>• A deluge fire extinguishment system is suppled which when activated will quickly extinguish any fire. |
| Natural Hazards | All Project activities – subsidence | The O&M Contractor will ensure a Subsidence Management Plan will be prepared and implemented. |
| Noise and Vibration | Power plant operation activities | The O&M Contractor will ensure the following:<br>• Commissioning testing should be conducted during daytime periods only.<br>• Erect temporary localised screening during commissioning testing. Potential noise impact reduction of up to 6 dB(A) is achievable where acoustic screens are located within 5 m of the construction works, be at least 300 mm above the height of the noise source and provide a solid façade impeding line of sight to nearest receivers – any gaps negate noise reduction performance.<br>• Notify local residents and landowners prior to any commissioning testing. |
| Landscape and Visual | All Project operation works | During operation it is proposed that the power plant site will be landscaped in order to improve visual amenity. Additionally, this will aid in limiting soil erosion at the site during heavy rainfall events. The soil removed during earthworks for construction will be reinstated and used as topsoil for the proposed landscaping.<br>Plants used for landscaping will be nursery grown and will be healthy and free from insect infestations. Trees and shrubs will be chosen in keeping with prevailing weather conditions and other such site characteristics. Maintenance operations will begin immediately after planting by mulching, watering, pruning, spraying, weeding and other necessary operations of maintenance. Planting beds will be kept free of weed, grass and other undesired vegetation growth. It is anticipated |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| | | that vegetation will grow up around the power plant site quickly, given the climate and high rainfall in the valley. See Section 13 – Terrestrial Ecology and ESIA Volume 5: Appendices – Terrestrial Ecology Impact Assessment, for more recommendation regarding planting regimes and the use of a Habitat Management Plan.<br>The following recommendations are proposed for consideration for the buildings and power plant site:<br>• Any planted beds will be kept free of weeds and other undesired vegetation growth, as per the measures proposed in the Pest and Weed Management Plan.<br>• Site fencing has the potential to aid in mitigating adverse visual effects of the power plant by partially screening and softening the visual impact of the site and ensuring light spill from the site is minimised.<br>• Any lighting requirements should be designed to ensure light spill is directed into the construction and operation site.<br>• Where possible the selection of neutral/muted cladding and external finishing's would aid in limiting the extent of adverse visual impacts.<br>• Installation of drift elimination, if wet cooling towers options is selected to reduce particulate emissions and plume visibility.<br>The reinjection pipeline should be coloured so that it is conspicuous with the surrounding environment.<br>An overall recommendation is to make the public aware that potentially affected parties can use the public grievance mechanism. This will be monitored in accordance with the measures set out in ESIA Volume 3: Social Impact Assessment. |
| Social / Economic | All Project operation works | The mitigation for social and economic issues will be the same as that stated above during the construction phase, under the management of the O&M Contractor. |
| Soils, Geology and Groundwater | Power plant operation activities | The mitigation for soils, geology and groundwater issues will be the same as that stated above during the construction phase, under the management of the O&M Contractor. |
| Terrestrial Ecology | All operation activities | The O&M Contractor will ensure the following:<br>• Appropriate disposal of solid and liquid wastes, in line with recommendations in international and national standards, and using designated facilities as required.<br>• Any effluent discharged to surface watercourses must meet the more stringent of international water quality discharge standards prior to release to remove pollutants.<br>• Machinery and vehicles should be cleaned upon entry/exit, and any soil brought on or off site screened for invasive species or plant pathogens.<br>• Ensure all standard safe storage measures for n-pentane are implemented, as detailed in ESIA Volume 2: EIA, Chapter 15. |
| | All Project operation works - Post-Hurricane Maria Specific Actions | DGDC will implement a Habitat Management Procedure for the Project that will aim to provide enhancement measures for post-Maria terrestrial biodiversity. The Habitat Management Procedure will be the same as that set out above in Table 2.1. The O&M Contractor will assist in the facilitation of this Habitat Management Procedure. |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| MTPNP World Heritage Site | All operation activities | Mitigation measures are the same as those outlined above during construction, with the exception of the following (the O&M Contractor will be responsible for this):<br>• Standard safe storage for n-pentane includes storage under a nitrogen blanket; incorporation of a Pressure Relief Valve; appropriate bunding; and a deluge fire extinguishment system. Heat and pentane sensors are also fitted around the storage tank and the plant to detect any leaks and heat changes. |
| Traffic Management | Power plant operation activities | • The O&M Contractor will implement a Traffic Management Plan will be distributed to staff to inform them of the best ways to travel to the sites of the Project. Staff should be encouraged to take public transport, car pool or that the contractor provides transport for them. |
| Working Conditions, Occupations and Safety | All operation activities | • The O&M Contractor will be required to develop an Occupational Health and Safety (OHS) Plans for the operation and maintenance of the Project, which will apply to all personnel involved in the Project, including subcontractors and part-time workers. The primary health and safety objectives will be to ensure effective measures and management of occupational health and safety to minimise workplace accidents and injuries. The health and safety procedures within the OSH Plans will comprise a comprehensive Health and Safety Management System. They will meet the requirements specified in the WBG Environmental, Health and Safety Guidelines pertaining to occupational safety and health. DGDC will be responsible for auditing and reviewing the document. Further details for the requirements of OHS Plans are presented in ESIA Volume 5: Technical Appendices, Technical Report – OHS and Working Conditions.<br>• As well as the main OHS Plans, specific Safety Management Systems shall be developed for each element of the Project, including the following:<br>- safety management organisation / reporting chain;<br>- construction methodology;<br>- hazard / risk assessment and proposed mitigation measures; and<br>- safety checklists.<br>• Each Safety Management System will have a procedure for identifying all hazards associated with the activity in question. A hazard in this context is defined as any aspect of the Project activities which could result in harm to onsite personnel.<br>• The O&M Contractor will establish a hierarchy of responsibility with regards for the provision of health and safety.<br>• Health and Safety Management Committee will be appointed by the O&M Contractor to evaluate health and safety at the site and to assess and recommend changes to equipment, policy and/or procedures where required by health and safety issues.<br>• O&M Contractor staff will be trained in safety procedures and provided with Personal Protective Equipment. Working conditions and occupational safety and health procedures framework has been outlined in the ESIA Volume 5: Appendices, Technical Report - Working Conditions, Occupational Safety and Health.<br>• The O&M Contractor's Worker's Grievance Mechanism and Worker's Code of Conduct will continue to run throughout operational period. |
| Water Quality and Aquatic Ecology | Power plant operation activities – discharge of treated wastewater | • During operation wastewater will be treated initially in a package plant. The package plant would be to a sand filter or similar medium that allows the treated effluent to infiltrate to ground below the soil surface and receive further treatment. This infiltration system should be located close to the edge of the power plant area to maximise distances to watercourses. |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| | | • The power plant's stormwater system should ideally drain through a sump or settling pond. This would capture any runoff from the pad and settle out rubbish and sediment, while reducing flow velocities. Areas of the plant that are at risk of having contaminant discharges (such as oil leaks from vehicles or fluid spills) should be isolated, with their flows first draining through an oil water separator. The outflows from this separator could then drain to the sump/settling pond for further treatment. |

Summary table of monitoring activities during operation

| Issue | Location of Monitoring | Proposed Monitoring Measures |
|---|---|---|
| Air quality | Power Plant operation activities | The O&M Contractor will ensure the following monitoring is undertaken during operation:<br>• Ambient monitoring for $H_2S$ can be easily undertaken at sensitive locations (e.g. nearby residential areas) using low-level ambient $H_2S$ monitors such as Odalog, which can be deployed at multiple locations for up to two months at a time.<br>• Safety monitoring systems with warning alarms for high emissions of potentially hazardous gases, including $H_2S$, incorporated at the well sites (e.g. the power plant and reinjection sites), as well as providing direct safety measures in the event of a blowout, will highlight potential $H_2S$ emissions issues which could arise during well commissioning and operation. All personnel and local residents will be made aware of the procedure should an alarm be activated.<br>• For the Organic Rankine Cycle option, there will be infrared heat detectors and pentane vapour monitors installed at the power plant site around the working fluid condenser/equipment and cooling tower, for early detection of any leaks of pentane or heat sources.<br>• All heat and pentane sensors if an ORC plant is selected will be checked and calibrated on an annual basis or as per the manufacturer's specifications.<br>DGDC will monitor the performance of the O&M Contractor. |
| Environmental and Social Management Systems (ESMS) | All Project operation activities | During operation, DGDC will monitor and audit the operational ESMS, as described above for construction activities. Reporting of monitoring activities will be issued by DGDC to the Lenders every 6 months in the Biannual Environmental and Social Report. |
| Geothermal Resource | Key geothermal sites | • The O&M Contractor will conduct regular a monitoring programme of selected natural geothermal features to determine any changes to that measured in the baseline monitoring outside seasonal variations. Springs can change over time so there is a need for objective assessment, post commissioning.<br>• During operation reservoir change (pressure, temperature and chemistry) will be monitored by O&M Contractor for regular testing of production wells.<br>• The Reservoir Management Plan will include a monitoring system (such as slimhole downhole pressure sensors) that will monitor reservoir pressure throughout operation, both at the production and reinjection wells. In the event of any significant changes in reductions in reservoir pressure, in the vicinity of WW-01 that may cause adverse change to thermal features, this will be mitigated in the first instance by adjusting the relative flows to WW-R1 and WW-01.<br>DGDC will monitor the performance of the O&M Contractor. |
| Hydrology | Settling ponds | The O&M Contractor will monitor the effectiveness of the settling pond on sediment should be undertaken during construction and ongoing operations, with spot samples assessed for Total Suspended Solids (TSS) at the inlet and outlet locations. Imhoff settling cones offer a cheap and viable method for quick onsite estimates of TSS from the inlet and outlet. |
| Hazardous Substances and Waste | Power plant operation activities | • To ensure the processes and procedures are operating effectively, the O&M Contractor will conduct regular audits of hazardous substance storage and the operation of the Hazardous Substance Management Plan. Audits will involve reviewing storage procedures, ensuring staff are appropriately trained and supervised, ensuring materials are stored and used in accordance with good international industrial practice, and identifying and recommending any areas for continual improvement. |

| Issue | Location of Monitoring | Proposed Monitoring Measures |
|---|---|---|
| | | • As part of the Waste Management Procedure a monitoring plan will be developed to inspect waste collection skips, to check wastes are being separated correctly and hazardous wastes are not being included with non-hazardous. The inspection should also include a check of the waste skips and bins condition to be sure waste is being held securely and not able to impact the environment through leakage or being blown away.<br>• Regular inspections to check that wastes are being separated and deposited in the correct bins for recycling and disposal.<br>DGDC will monitor the performance of the O&M Contractor. |
| Noise and Vibration | Power plant operation activities | • The O&M Contractor will measure noise levels on a quarterly basis at the power plant site and the nearest settlements for a duration of at least 48 hours. Results from this monitoring are to be used to assess compliance with Dominica guidelines (Environmental Standards for Protection against Noise (June 2003)) and the WBG EHS Guidelines and to be reported to the relevant authorities. Noise monitoring data should also be made available for public access.<br>• Power plant workers will make direct observation of machine maintenance should also be made to ensure that any noise-creating faults are treated. |
| Water Quality and Aquatic Ecology | Power plant operation activities | The O&M Contractor will ensure the following:<br>• Visual inspection of oil interceptors for visible oil and settling ponds.<br>• Monitoring of the discharge from oil interceptors and settling ponds every three months (with comparison to WBG EHS Discharge Guidelines)<br>• Monitoring of effluent discharged from the package plant every six months.<br>DGDC will monitor the performance of the O&M Contractor. |
| Social | All Project operation activities | The O&M Contractor and DGDC will ensure that the number of people being employed by the Project will be recorded and monitored from: 1) the three key Villages (Laudat, Trafalgar and Wotten Waven) and 2) the wider Roseau Valley, against predicted numbers of employees.<br>• Surveys should be conducted to determine the number of new businesses generated by the development and the level of indirect employment.<br>• A DGDC Community Liaison Officer will be responsible for updating and monitoring the implementation of the RAP and Grievance Mechanism defined in the Stakeholder Engagement Plan.<br>• Ongoing consultation and communication with the local community will be required particularly with PAPs, vulnerable groups and key stakeholder groups. The minutes of meetings and signed lists of attendees will be completed and documented.<br>• During the first four years of operation, on a quarterly basis, DGDC's department responsible for CSR will record the number of inhabitants of the three villages affected by the power plant to have received training, and nature of training received, disaggregated by age, sex and village/block.<br>• During the first four years of operation, on a quarterly basis, the number of regular and ad-hoc meetings with communities will be recorded, as well as the minutes of meetings and signed lists of attendees.<br>• During the first four years of operation, the number of consultations with PAPs and number grievances received, treated and solved will be recorded through minutes of meetings and signed lists of attendees.<br>• The Grievance database will be monitored with progress reported on a quarterly basis. |
| Soils and Groundwater | Power plant operation activities | The O&M Contractor will ensure routine monitoring of any spring flows (cold water) to be undertaken, both baseline and during development in order to determine any potential effects on the system. DGDC will monitor the performance of the O&M Contractor. |

| Issue | Location of Monitoring | Proposed Monitoring Measures |
|---|---|---|
| Terrestrial Ecology | All Project operation works - Post-Hurricane Maria Specific Actions | DGDC will develop a Habitat Management Procedure that will provide baseline terrestrial biodiversity monitoring recommendations for the site. |
| MTPNP World Heritage Site | All operation activities | • The monitoring programme during operation will be the same as that outlined above for construction. DGDC will be responsible for this monitoring programme. |
| Working Conditions, Occupational Health and Safety | All operation works activities | • The O&M Contractor OHS Plans and Health and Safety Management System will include a schedule of regular safety inspections and monitoring of exposure to hazards. This will include the state of the site as well as the maintenance of equipment and a comparison to internationally published exposure guidelines. Further details for the requirements of OHS Plans are presented in ESIA Volume 5: Technical Appendices, Technical Report – OHS and Working Conditions.<br>• The O&M Contractor Site Manager shall instigate measures to correct non-conformance in safety performance found during safety checks and inspections. A record of the safety checks and inspections, and resulting actions, shall be provided to the Health and Safety Management Committee every month.<br>• DGDC will undertake audits to check that no unsafe practices are being carried out at site. If unsafe practices are identified during the audits, work at the site should cease. The audits should be carried out once every two months.<br>• All staff at the O&M Contractor should be notified of all incidents/accidents which result in first aid treatment during the soil improvement programme and the construction of the power plant. Minor incidents along with the incident/accident investigation report should be supplied to DGDC once a month. Serious accidents that are Lost Time Incidents, or result in serious harm or a fatality should be reported immediately to DGDC.<br>• Worker occupational monitoring such as hearing and vision will be undertaken on an annual basis.<br>• All heat and pentane sensors if an ORC plant is selected will be checked and calibrated on an annual basis or as per the manufacturer's specifications.<br>• DGDC, as principals, undertake independent audits of the O&M Contractor Health and Safety performance to ensure that the health and safety practices as set out in their health and safety plans are being complied with. The audits will also check that no unsafe practices are being carried out at site. If unsafe practices are identified during the audits, work at the site should cease. The audits should be carried out once every two months. |

## 1.13 Spare Parts

The Contractor shall ensure that sufficient spare parts are available for its use during testing and commissioning of the Plant. Such spares shall be in addition to any spares provided as part of the Plant.

A spare parts list, in MS Excel format, shall be provided by the Contractor, including the following detail for all spares provided or listed:

1. Description, purpose and plant designation code.
2. Delivery time for all spares
3. Name, address and contact details of all original part suppliers
4. Cross reference to drawing number and item number on drawing
5. Contractors' spare part number
6. OEM spare part number
7. Any spare having a limited shelf life or requiring a special storage condition shall be separately identified.
8. A complete list of all special tools shall be included as a subsection of the list.

All spares supplied shall be strictly interchangeable with the parts that they are intended to replace, and shall be tested and packed for long storage under the climatic and atmospheric conditions prevailing at Site.

Each spare shall be clearly marked with the description, purpose and plant designation code.

If the Contractor's practice is to assign its part numbers to parts purchased from other manufacturers, a part number list shall be furnished which provides a cross-reference between the Contractor's part number and the part number of the Original Equipment Manufacturer.

## 1.14 General Technical

### 1.14.1 General

The Contractor shall provide reports for review by the Project Manager that detail the basis for the design of each system and part of the Plant.

Where possible the plant shall be standardised so that common equipment is used. Maintenance and spare parts shall be available for all parts of the Plant for at least five calendar years after expiry of the Defects Notification Period.

### 1.14.2 Service Conditions

All components incorporated in the Plant shall be suitable for their specified duty and shall be capable of continuous operation for the design life in an atmosphere that is made corrosive by traces of chemicals (notably hydrogen sulphide) normally present in a geothermal production facility.

Components shall be suitable for normal operation in the full range of environmental conditions included in the Interface Schedule.

### 1.14.3 Codes, Standards & Regulations

As a minimum the Plant shall comply with the current editions, at the Commencement Date, of relevant internationally recognised Codes, Standards and Regulations, together with Dominica Codes, Standards and Bylaws. Where conflict between International Standards and the equivalent local Standards exist, the more stringent requirements shall prevail. Deviations from relevant standards shall only be implemented with the written approval of the Project Manager.

Use of Codes and Standards other than those published by Institutions from the following list shall require approval from the Project Manager: -

| | |
|---|---|
| AAMA | Architectural Aluminium Manufacturers Association |
| AASHTO | American Association of State Highway and Transportation Officials |
| ACI | American Concrete Institute |
| ASCE | American Society of Civil Engineer |
| AFBMA | Antifriction Bearing Manufacturer's Association |
| AGMA | American Gear Manufacturer's Association |
| AISC | American Institute of Steel Construction |
| ANSI | American National Standards Institute |
| API | American Petroleum Institute |
| ARI | Air-Conditioning & Refrigeration Institute standards and guides |
| AS | Australian Standard |
| ASHRAE | American Society for Heating, Refrigeration and Air Conditioning Engineers |
| ASME | American Society of Mechanical Engineers |
| ASNT | American Society for Non-destructive Testing |
| ASTM | American Society for Testing and Materials |
| AWS | American Welding Society |
| AWWA | American Water Works Association |
| BOCA | Building Office Codes Association |
| BS | British Standard |
| BSRIA | Building Services Research & Information Associations recommendations and guides |
| CIBSE | Chartered Institute of Building Services Engineers' guides |
| CTI | Cooling Tower Institute |
| DIN | Deutsche Institut fur Normung |
| EJMA | Expansion Joint Manufacturer's Association |
| EN | European Standard |
| HEI | Heat Exchanger Institute |
| HI | Hydraulic Institute |
| HVCA | Heating & Ventilating Contractor's Association, DW/144, Specification for sheet metal ductwork, low, medium and high pressure/velocity systems |
| IEC | International Electrotechnical Commission |

| | |
|---|---|
| IBC | International Building Code |
| IEEE | Institute of Electrical and Electronics Engineers |
| IPCEA | International Power Cable Engineers Association |
| ISA | Instrument Society of America |
| ISO | International Organisation for Standardisation |
| JEC | Japanese Electrotechnical Committee |
| JEM | Japan Electrical Manufacturers' Association |
| JIS | Japanese Industrial Standards |
| MSS | Manufacturer’s Standard Society |
| NACE | National Association for Corrosion Engineers |
| NEC | National Electrical Code |
| NEMA | National Electrical Manufacturer's Association |
| NESC | National Electric Safety Code |
| NFPA | National Fire Protection Association |
| OSHA | USA Department of Labour Occupational Safety and Health Administration |
| SSPC | Steel Structures Painting Council |
| TEMA | Tubular Exchanger Manufacturers’ Association |
| UFC | Uniform Fire Code |
| UL | Underwriters Laboratories Inc. |
| UPC | Uniform Plumbing Code, International Association of Plumbing and Mechanic Officials |
| WRC | Welding Research Council |

Specific dates and revisions of Codes, Standards and Regulations shall be identified in design reports and on issued drawings and specifications.

### 1.14.4 Component Inter-Changeability

All similar parts, including repair parts, of corresponding apparatus furnished shall be interchangeable without additional machining or selective assembly and with a minimum of hand fitting. As far as practicable, equipment or machinery that is functionally interchangeable shall also be physically, electrically, and mechanically interchangeable.

### 1.14.5 Language, and Units of Measure

The Contractor shall comply with the following provisions governing language, weights, and measures:

1. All communications, documents, drawings, plans, training material and other writings provided by the Contractor hereunder shall be in the English language.

2. With the exception of the following, all units and measures shall be recorded in the “System International d’Unites” system.

| Usage | Unit | Symbol |
|---|---|---|
| All Pressures | Bar | bar |
| Electrical Energy | Kilowatt hour | kWh |

## 1.15 Painting and Corrosion Protection

### 1.15.1 General Requirements

The Contractor shall construct the Plant in full accordance with the construction drawings and specifications. The Contractor shall follow the manufacturer's' recommendations for installation, storage, commissioning, operation and maintenance of all of the Plant.

### 1.15.2 Materials

Particular attention is to be paid to the selection of materials for long life of the Plant in a geothermal environment. All materials and equipment furnished shall:

1. Be new, unused, and undamaged when installed or otherwise incorporated in the Plant and properly identified by appropriate stampings and markings and shall be accompanied with original manufacturer's documentation where appropriate,

2. Be of industrial type suited for their intended function, specifically geothermal service, and

3. Possess acceptable resistance to the types of corrosion generally encountered in geothermal facilities and tropical environments. No such material or equipment shall be used by the Contractor for any purpose other than that intended or specified, unless such use is specifically authorised in writing by the Project Manager for each case.

A Corrosion Control Report is to be submitted to the Project Manager for review. This report shall contain a comprehensive review of all materials of construction to be used in the Plant; a commentary on installation methodologies to eliminate damage to protective coatings; a schedule of all protective coatings to be used, both factory and field applied; and statements on the methods to be used for the installation of pipe hangers, cable tray, small brackets and the like. The use of materials differing from those specified for a given application shall be subject to approval by the Project Manager.

The following materials shall not be used under any circumstances:

1. Cadmium or cadmium plating

2. Chromium plating

3. Silver

4. Exposed copper or copper based alloys; copper busbars and the exposed ends of power cabling shall be tin plated

5. Electroplated zinc coated carbon steel may only be used in an environment treated to remove H2S.

6. Asbestos

7. Cupronickel

8. PCBs or other similar hazardous materials

### 1.15.3 Painting & Protective Coatings

All parts of the Plant shall be completed with protective coatings as required to ensure that they will suffer no deterioration due to corrosion in their intended location without surface washing for a period of no less than five years and only requiring minor (no more than 5% of total surface) touch-up painting after ten years. Repainting shall not be required for at least 10 years.

Appropriate preventative maintenance shall be specified to ensure that all parts of the Plant will continue to provide adequate service for the design life of the Plant.

Surfaces to be painted shall be free of rust, mill scale, dirt, oil, grease, deteriorated paint, and other surface contaminants, which shall be removed by acid pickling, blasting, wire brush or other mechanical means, or by any combination thereof necessary to accomplish removal as required by the paint manufacturer's instructions. All paint shall be applied in accordance with manufacturer's application recommendations. Prime coat shall be applied on the same day as the surface is cleaned. Steel surfaces shall generally be painted with a zinc rich primer. For two-coat systems, subsequent coats shall not be applied until the preceding coat has become properly dry and hard. Before the application of any coat, all bare spots on the preceding coat shall be touched up. Steel shall be painted per SSPC SP2 or SP-3 standards.

All concrete walls and concrete block surfaces used for building (both interior and exterior) shall be given a first coat of manufacturer's recommended masonry filler, followed by two subsequent coats (each to the minimum thickness recommended by the manufacturer) of low-gloss acrylic latex of the Project Manager approved product type and colour.

Except where otherwise specified, all outdoor plant and structures to be painted shall be painted with an approved two pot epoxy paint system.

Unless otherwise specified, all external surfaces of machinery and equipment shall be painted as follows:

1. Machined surfaces shall not be painted prior to mating;

2. Painting the external surfaces of non-ferrous metal castings, piping, or other machinery parts is required unless otherwise specified; and

Galvanised surfaces, nameplates and smooth aluminium sheet need not be painted, with the exception of outdoor steelwork, which shall be both hot dip galvanised and painted.

The Contractor shall ensure that all items requiring painting are painted prior to shipment to Site. On site painting shall be limited to touch up painting wherever possible. Where touch up painting is necessary, the paint finish, quality and colour shall be to the same standard as the original paint system.

Where parts are protected by a galvanised finish then all parts shall be hot dip galvanised at the factory. There shall be no drilling, cutting or welding of parts on site. All attachments to galvanised components shall be by suitable mechanical fastening designed specifically for the purpose.

Any galvanised component that requires modification on site shall be returned to the factory for re-galvanising after modification.

The Contractor shall submit painting specifications to the Project Manager for review and approval.

The Contractor shall prepare and submit a colour scheme for the Plant for approval by the Project Manager. Piping will be colour coded and banded or identified with standard pipe labels. All coatings shall have a minimum life of ten years before major re-application. The Contractor shall provide a written guarantee from the paint manufacturer warranting the service life of all paint systems applied.

### 1.15.4 Cleaning and Protection before Shipment

All plant shall be covered before shipment with a protective compound or export packaged and be protected adequately during shipment to Site. This protective compound shall remain in place during storage on Site until such time that it must be removed for erection and installation purposes

Subsequent cleaning and polishing shall be performed by the Contractor.

Before testing at the manufacturer's works all steel and cast iron pipes shall be thoroughly cleaned by pickling, washing, wire brushing, grit or shot blasting, as appropriate, ensuring all scale and sand have been removed. Protective coatings shall be applied after tests have been carried out.

Pipes, valves and other similar parts of the plant which are subject to hydraulic test and are readily accessible for drying out shall, on completion of tests at the manufacturer's works, be drained out by washing with de-watering oil prior to the application of surface protection.

Valve packing shall be removed after hydraulic testing and replaced with dry packing.

## 1.16 Packing, Marking and Transport

### 1.16.1 General

All plant and equipment shall be packed in accordance with the requirements of the equipment manufacturer's recommendations. Nothing in these instructions shall relieve the Contractor of liability for any loss or damage arising out of deficient or inadequate packing.

### 1.16.2 Packing Design

Packaging shall be in accordance with BS 1133.

Precautions shall be taken to ensure that tube ends and other similar open ends are protected from both external damage and ingress of dirt and moisture during transit and while awaiting erection. A part of the end closure shall be of greater diameter than the tube or pipe bore such that the end of the closure cannot, as a whole, be pushed into the tube bore.

Flanged pipes shall have their open ends protected by adhesive impervious tape or jointing and then covered with a wooden blind flange secured by bolts.

Precautions shall be taken to protect shafts and journals where they rest on wooden or other supports likely to contain moisture. At such points wrapping impregnated with anti-rust composition or vapour phase inhibitors shall be used of sufficient strength to resist chafing and indentation due to movement which is likely to occur in transit. The form of the protective wrappings and impregnation shall be suitable for the period of shipment and storage at site prior to erection.

All machined surfaces shall be protected with wooden blocks or similar approved means and reinforced externally with metal bands or plates.

Hoop metal bindings of cases shall be properly tightened and the ends crimped together by means of a purpose made tool.

In the case of ball or roller bearings installed in any item of plant, the Contractor shall take precautions to avoid indentation of the bearing races. The Contractor shall replace any indented bearings

Contents of cases shall be bolted securely or fastened in position with struts or cross battens and not with wood chocks wedged in place, unless these are fastened firmly in place. All struts or cross battens shall preferably be supported by cleats fixed to the case above and below to form ledges on which the batten may rest. Where parts are required to be bolted to the

sides of the case, large washers shall be used to distribute the pressure and the time shall be strengthened by means of a pad.

Wood wool shall be avoided as far as possible for packing purposes.

Waterproof paper and felt linings shall overlap at seams at least 15mm and the seams secured together but the enclosure shall be provided with screened openings to provide ventilation.

### 1.16.3 Packaging and Transport

The Contractor shall prepare a Transport Study which considers the transportation requirements to Site for all plant and materials required for the construction of the Plant.

The Transport Study shall evaluate options for route selection, considering;

- Minimising impact on the local communities through selection of routes that avoid built up areas as far as possible,
- Selecting routes which have lowest risk profiles, and
- Minimising overall length of transport routes

For the route, or routes selected by the Contractor, the Contractor is required to implement any required improvements, in accordance with all applicable Dominica standards and regulations, in order that the proposed transport vehicles and their loads can move along the route(s) safely and with minimal of disruption to local traffic.

For each major item of plant, a transport plan shall be provided which details packaging, transport routes, shipping details, lifting plans, licensing, approvals and any other relevant details.

All apparatus shall be carefully packed and secured for transport in such a manner that it is protected from all dust and climatic conditions during loading, transport, unloading and subsequent storage in the open. Equipment shall be suitably packed and protected against vibration, movement and shock which may occur during loading and transport. Particular care in packing shall be taken when the apparatus is transported by road.

Heavy and bulky equipment shall be provided with adequate lifting fixtures to facilitate ready handling during transit and on arrival at site.

Major items of plant such as transformers, turbines, generators and switchgear shall have dual redundant seismic impact monitoring sensors fitted the readings of which shall be recorded before and after transport for each leg of the journey.

The Contractor shall submit their proposals to the Project Manager for protection of equipment during transit; however, the responsibility for safe delivery remains with the Contractor.

For equipment manufactured outside Dominica every case made of or containing timber shall be certified as free from insect infestation within the terms of the Government of Dominica import and quarantine regulations. Such certification shall be in a form acceptable to the appropriate department of the Government of Dominica and shall be shown on the case and in the shipping documents.

All equipment supplied under this Contract shall be clearly identified on the outside of any case with the type and number of items contained therein and the gross weight. Large crates are to be marked on three sides, and smaller crates which can be easily manhandled are to be marked on two sides at least.

The Contractor shall nominate in advance the locations to which construction plant and materials will be delivered and shall agree with the Project Manager the arrangements for their arrival and storage.

A consolidated list of all consignments of equipment shall be maintained by the Contractor and shall be available for inspection by the Project Manager on request.

The Contractor shall provide all necessary transport, all labour, plant and materials necessary for unloading and shall be entirely responsible for their efficient and correct operation. The Contractor shall inform himself fully as to all relevant transport facilities, requirements and loading gauges and shall ensure that the equipment as packed for transport shall conform to any relevant limitations. The Contractor shall take all reasonable steps to prevent any highways or bridges or overhead lines from being damaged by his traffic, and shall select routes, choose and use vehicles, and restrict and distribute loads so that all damage shall be limited as far as is reasonably possible.

### 1.16.4 Marking of Packages

All packages shall be marked with the following on two opposite sides and the top of the package, using fade-proof, waterproof and salt-proof black ink, in English:

1. Employer name
2. Contract name
3. Contract number
4. Equipment number
5. Gross weight
6. Net weight
7. Country of origin
8. Package number
9. Name of vessel

Fragile or perishable materials shall be marked with the appropriate symbol. e.g. FRAGILE, USE NO HOOKS. Sling-marks shall be shown as required.

A copy of the packing list shall be placed inside each shipping package. A copy of the packing list in a waterproof envelope shall be securely fastened to unpacked pieces or bundles.

### 1.16.5 Erection Marks

All members comprising multi-part assemblies, e.g. steel framework and piping installations shall be marked with distinguishing numbers and/or letters corresponding to those of the drawings or material lists. These erection marks, if impressed before painting or galvanising, shall be clearly readable afterwards.

Colour banding shall be used to identify members of similar shape or type but of differing strengths or grades.

The Contractor shall ensure all packages are marked appropriately for identification through the importation process.

### 1.16.6 Corrosion Prevention Prior to Installation

Special measures shall be taken by the Contractor during shipment and on-site storage to prevent corrosion or other deterioration of equipment and material provided hereunder, especially to unpainted, polished, or moving parts, and to electrical equipment.

Sensitive equipment shall be stored under roof cover away from geothermal environments to prevent damage by hydrogen sulphide. Such equipment includes:

1. Electrical switchgear
2. Control system components and cabinets
3. Instrumentation
4. Plant designed for indoor installation

## 1.17 Plant Identification

### 1.17.1 General

The Contractor's standard hierarchical identification system shall be applied to the entire Plant. A consistent hierarchical identification system shall be applied to the entire Plant. All Project Equipment down to individually maintainable components shall be assigned an identifier within the identification system herein specified.

### 1.17.2 Identification System

All Plant equipment shall be labelled.

The Plant shall employ a coherent identification system throughout for pipelines, valves, instruments and equipment. It is recognised that relatively complex systems may be employed during the design and construction process, wherein the identification system will carry such information as pipe line size and pipe specification class, valve size and type etc., however the identification system will ensure that identification codes can be logically truncated and simplified for long term operational purposes. The truncated identification system shall comply with the Employer's plant identification.

The Contractor shall submit the proposed plant identification system to the Project Manager for review and approval. Key features of the identification system are to include:

1. Identification of individual equipment items shall be unique.
2. Operationally connected items of plant shall be numbered to preserve logical connections.
3. The numbering system shall generally follow the direction of energy flow through the facility. Hence, valve numbering shall progress from the source of fluid along the system to the fluid sink or discharge point. Blocks of higher numbers shall be reserved for allocation to small fittings and valves.
4. For machines and their ancillary equipment, numbering shall alternate from right (odd numbers/letters) to left (even numbers/letters) from a position at the prime mover end of the machine, facing the machine (eg for a turbine/generator Unit standing facing the turbine at the governor end). For non-rotating plant, the same principle shall be applied, based on the point of fluid inflow to the plant.

5. System codes shall be a maximum of three letters selected by the abbreviation of the fluid flowing in the system (eg MS for main steam, ACW for auxiliary cooling water). Codes shall have an easily identifiable relationship to the system name.

6. System codes shall be consistent with the terminology used during training.

### 1.17.3 Identification Plates

Nameplates or labels shall be of 316 stainless steel with engraved or stamped numbering and lettering.

Each process piece of equipment shall be given a number in accordance with the P&IDs.

Each electrical piece of equipment shall be given a number as designated on the corresponding single line diagram and /or relay and instrumentation diagram.

Rating plates shall be provided for all applicable equipment upon which shall be engraved any identifying name, type or serial number, together with details of the loading conditions under which the item of plant in question has been designed to operate, and such diagram plates as may be required by the Project Manager.

Text height shall be 30mm on all operating mechanisms and 60mm or larger in height on principal items of plant.

### 1.17.4 Instrument Identification System

#### 1.17.4.1 General

The Contractor shall develop an instrument loop identification system for process plant based on ANSI/ISA-5.1 (2009) and submit this for the Project Manager's approval.

The appropriate identification number shall be used on all communications and it shall be entered on all drawings, schedules, labels, software etc. on which the specific device is referred to.

#### 1.17.4.2 Summary of Loop Identification System

Each loop shall have an individual identification of the form given below:

XXX- XXX XXX XXX

(A) (B) (C) (D)

A - Plant Area Three alpha characters relating to a specific area of the project i.e SGS, Power Plant, reinjection line and similar.

B - Functional Identification Lettered according to the ANSI/ISA 5.1 "Instrumentation Symbols and Identification" standard.

C - Sub Group Three KKS standard alpha characters relating to the medium/system to be measured or for certain specialist plants and sub systems a blanket reference is used.

D - Suffix Used for:

Instrument and loop number.

Example:

"SGS-PIC-LBA-001"

| | |
|---|---|
| SGS | Steam Gathering System |
| P | Pressure |
| I | Indicating |
| C | Controller |
| LBA | Steam piping |
| 001 | Reference Number |

#### 1.17.4.3 Individual Instrument Identification

When an instrument is part of a loop, then a similar identification or "tagging" system is used for the control device.

### 1.17.5 Electrical Equipment Labels

All electrical equipment shall be provided with labels or name plates in accordance with requirements stated elsewhere in this document, giving any identifying name, type or serial number, together with information regarding the rating, nominal voltage and current and the like under which the item of Plant in question has been designed to operate.

Panel mounted components shall be labelled with a function description. All apparatus within cubicles shall be labelled with either a complete description of the function or a non-ambiguous code relating to the circuit diagrams.

Bold danger and warning notices shall be displayed where the removal of covers exposes live voltage above extra low voltage. These labels shall be red lettering on yellow background. They shall be of adequate size and be easily readable.

Exterior electrical equipment labels shall be permanently attached to each item by 316SS wire.

### 1.17.6 MV Switchroom Identification System

The identification of equipment in the MV Switchroom shall comply with the identification requirements of the Dominica Generation Code or as required by the System Operator. Where no requirements exist then the Contractor shall propose a switchgear identification methodology. The proposed scheme shall be documented in the MV Switchroom DIR for review.

# 2. Quality Assurance and Works Testing

## 2.1 General

The Contractor and its major subcontractors shall each have a certified Quality System that meets the requirements of ISO 9000 or equivalent.

The Contractor's overall project quality assurance system shall cover all aspects of the Facilities, including design, procurement, fabrication and testing, site construction activities, pre-commissioning, start up, performance testing, training and handover.

In general, the Contractor shall perform factory quality assurance inspections at major equipment suppliers' facilities during fabrication to ensure equipment is being built to specifications in a timely manner. As a part of, or prior to, such inspections, the Contractor shall review supplier's quality assurance and quality control program and manuals to assure their adequacy for equipment being supplied. During the inspection, the Contractor shall verify that the supplier's quality program is being adhered to.

The Contractor shall provide a copy of the referenced testing standard for the Employer's use.

## 2.2 Quality Assurance System

The Contractor shall submit for approval its proposed quality assurance system to the Project Manager for review. This program shall include procedures for quality assurance of all design, manufacturing, construction, commissioning and testing activities for the entire Plant. As a minimum, it shall address the following:-

- Roles, responsibilities and authorities
- Document control
- Design verifications
- Design review procedures
- Subcontractor assessment and control
- Calibration requirements
- Traceability
- Non-conformance control
- Inspection and test plans
- Internal audits
- Records

Where it is not appropriate to include detailed procedures or inspection and test plans in the first-issue Quality Assurance System documentation, the need for them and the responsibility and timetable for producing them shall be identified in the submitted document.

## 2.3 Overall Inspection and Test Plan

The Contractor shall submit to the Project Manager for review an overall inspection and test plan which shall include pertinent manufacturing and inspection operations. The site inspection and test plan may be an integral part of this, or may come later if that is more appropriate.

The Project Manager may, within 60 days of receipt of the inspection and test plan, and in consultation with the Contractor, select a range of points as mandatory hold points and witness points.

As a minimum, the Contractor shall conduct inspections and works testing of the equipment listed below:

1. Prime Mover - Steam or Binary Turbine including auxiliary systems
2. Generator including auxiliary systems
3. Main condenser (including Air Cooled Condenser)
4. Evaporative Cooling Tower or Air Cooled Condenser and Motor / Gearbox / Fan assemblies
5. Control panels
6. DCS hardware
7. DCS configuration and software
8. Auxiliary transformers
9. Steam scrubber
10. Inter/after condensers
11. Ejectors
12. Major vessels
13. Major pumps
14. Major control and isolation valves
15. Lubrication and control oil systems
16. Instrument air packages
17. MV Circuit Breakers
18. MV Isolators & Earth Switches
19. MV Instrument Transformers
20. MV Surge Arresters
21. MV & LV switchboards
22. DC Systems
23. UPS Systems
24. Emergency diesel generator

25. Switchboards

26. Protection relay panels

## 2.4 Manufacturers' Works Testing and Inspection

Major items supplied by the Contractor shall be given standard applicable tests at the factory during and at the completion of manufacture, whether manufacture is by the Contractor or a third party. A test procedure shall be prepared for each such test which shall describe the test to be performed, the applicable item of equipment being tested, the standards and method of testing, pass/fail criteria, and the testing facility's capabilities and shall state a proposed test date. All test procedures shall be submitted to the Project Manager for review. Documented successful completion of such tests shall be a precondition to shipment of the tested item of plant. The Project Manager shall be notified in writing at least 30 days prior to any final factory test of any major components to be supplied. The Project Manager may elect to attend some or all of the factory tests. Any type tests may, at the discretion of the Project Manager, be waived upon submission of type test certificates or reports for identical plant.

The following lists typical tests that, amongst others, are to be undertaken:

1. Prime Mover: Steam / Binary Turbine
    a. Turbine rotor final balance and 20 per cent overspeed test
    b. Turbine casing hydrostatic test at 1-1/2 times operating pressure
    c. NDT thickness test, penetrant test
2. Stop and Control Valves
    a. Hydrostatic test of body
    b. Seat leakage test
    c. Functional tests including stroke/closing time
    d. Stem run out test
    e. Surface contact test
3. Hydraulic Control Systems
    a. Hydraulic control system functional and operational closed loop test.
    b. Hydraulic system 24 hours operational run for flushing, leak check and performance analysis.
4. Generator
    a. Generator stator

        All tests in accordance with factory acceptance tests specified in IEC60034
5. Transformers

a. All routine and type tests in accordance with IEC 60076-1.

6. Switchgear

   a. Generator Circuit Breaker: All tests in accordance with factory acceptance tests specified in IEEE C37.013

   b. MV Switchgear: All tests in accordance with factory acceptance tests specified in IEC60694 and 62271.

   c. LV Switchgear: All tests in accordance with factory acceptance tests specified in IEC60439, 60947 and 60292.

   d. Protection & Control Equipment: All tests in accordance with relevant IEC Recommendations

7. Motors

   a. Routine tests shall be performed on each motor in accordance with IEC 60034 or, for motors greater than 200 kW in size, API 541. The following motor tests in accordance with IEEE 112 as to test methodology.

      i. No load current input and speed at rated voltage and frequency (Section 4.6).

      ii. Locked rotor current input at rated or reduced voltage (Section 4.8 for integral horsepower motor only).

      iii. Dielectric test (Section 6.2)

      iv. Measurement of winding resistance (Section 6.3 for large motors only).

   b. Guaranteed efficiencies shall be determined using IEEE 112, Method F (direct measurement of stray load loss) or for motors less than 100kW in rating using Method F1 (assumed stray load loss).

   c. Rotor losses shall be calculated using the rotor resistance determined from the low frequency impedance test (IEEE 112, 6.7.1.2, Method 2) or from the reduced load running test (IEEE 112, 6.7.1.2, Method 3).

8. Pumps

   a. As per API 610; head, flow rate, power, vibration and temperature test

   b. Casing visual inspection including verification of material certificates and heat numbers

   c. Rotor balancing tests

   d. Casing hydrostatic test

   e. Performance tests, including flow tests from no flow to 110 per cent of design flow, NPSH tests and vibration tests.

9. Pressure Vessels & Pipelines

   a. Radiographic and other weld tests as required by the relevant code.

   b. Hydrostatic and proof tests as required by the relevant design code.

   c. Baseline measurements at routine NDE inspection points

10. Valves and Control Valves

    a. Leak tests (gas and hydrostatic where appropriate)

    b. Valve stroke and performance tests

11. DCS

    a. Full factory acceptance test which shall be fully integrated and demonstrate the functionality of all aspects of the DCS. The requirements of WIB report M 2784-X-10 to the bronze level for system acceptance testing shall be complied with / incorporated into the DCS factory testing.

    b. Inspection of hardware.

## 2.5 Type Tests

Some plant and equipment supplied may be to a standard design, for which “type testing” has been previously carried out by the manufacturer. The Project Manager requires copies of all certificates for such type testing as evidence that the equipment meets the Employer’s Requirements. In the case where these test certificates are considered acceptable by the Project Manager, then manufacturer’s works testing and inspection and the requirements of type tests as described elsewhere in this document will be waived.

## 2.6 Mandatory Hold Points

Mandatory hold points require inspection by the Project Manager before the item concerned can be released for further manufacture or shipment.

The Contractor shall give the Project Manager at least 14 working days’ prior notice in writing of the date and the place at which any plant shall reach a mandatory hold point or shall be ready for independent inspection and testing.

Notification by the Contractor of any witness or inspection points shall indicate that the Contractor believes that the relevant item is complete and correct in full compliance with the Contract.

Unless the Project Manager advises the Contractor not to proceed with the inspection and testing prior to seven days before the date which the Contractor has stated in its notice, the Contractor may proceed and any inspection and tests shall be deemed to have been made in the Project Manager’s presence, and the Contractor shall forthwith forward to the Project Manager duly certified copies of the inspection and test results. Within seven days of receiving these results, the Project Manager shall advise the Contractor either that it may proceed past the mandatory hold point or what steps it must take to meet its obligations.

Should defects or omissions be discovered during witness inspections then the entire costs for re-inspection, including the Employer’s related costs and direct expenses shall be borne by the Contractor.

The Contractor shall give (and cause third parties to give) any representative designated by the Project Manager, full cooperation and assistance in any factory inspection at the premises of the Contractor or any other place of manufacture of items supplied hereunder (or components thereof) and the Project Manager shall have the right at any time to request such an inspection on reasonable notice in writing to the Contractor.

The Contractor shall at the monthly meeting with the Project Manager, provide a list of all tests to be performed in the next month and the date scheduled for such tests, as well as a summary of tests conducted in the previous month and their outcomes.

## 2.7 Witness Points

The Project Manager will also select a number of witness points for which the Contractor shall provide a minimum of 21 days' notice of the availability of the plant or materials availability for inspection.

## 2.8 Employer's Factory Inspections

The Employer will witness the following tests at the manufacturer's works, for which four weeks' notice shall be given by the Contractor:

1. Turbine rotor balancing and overspeed
2. Generator rotor balancing and overspeed
3. Generator testing
4. DCS Factory Acceptance Test
5. Hotwell pump (condensiing plant technology) or ORC working fluid feed pump

## 2.9 Subcontractor's' Quality Assurance Systems

The Contractor shall be responsible for the review, comment and acceptance of the quality assurance system of its subcontractors. In addition, the Contractor shall be responsible for its subcontractor's' work. At the request of the Project Manager, the Contractor shall submit details of the subcontractor's' quality assurance systems and procedures.

## 2.10 Quality Records

Three copies of all appropriate quality records as required by applicable codes and standards shall be submitted to the Project Manager for review and acceptability prior to, or concurrent with, shipment or as otherwise agreed to by special arrangement with the Project Manager.

## 2.11 Identification and Traceability

The Contractor shall implement a system that ensures traceability of all critical parts and components of the supplied plant and the associated Quality Records. The extent of traceability required shall be agreed upon with the Project Manager.

# 3. Civil Requirements

## 3.1 Geotechnical Investigation

The Employer will make available to the Contractor a Geotechnical Factual Report. The report provides:

- Geotechnical borehole logs and corebox photos.
- Groundwater conditions encountered on site during drilling.
- In-situ test results.
- Laboratory test results.
- Site location plan(s) detailing where investigations and testing were undertaken.
- Overview observations and photos of the investigation locations and surrounding area.

In addition, the Contractor will be provided a copy of the following report:

- Geotechnical Investigation on Well Site N. 3 (Trafalgar), Drilling and Testing Activities, Wotten Waven Geothermal Field, Commonwealth of Dominica, West Indies

Numerous geotechnical and geological information in the region is publicly available, including desk-based assessments of slope stability susceptibility (C.J. Van Western 2016, National Scale Landslide Susceptibility Assessment for Dominica, CHARIM Caribbean Handbook on Risk information Management, World Bank GFDRR, ACP-EU National Disaster Risk Reduction Programme) for background information on hazard and risk mitigation.

The Contractor shall not relysoley on the geotechnical information provided by the Employer for detailed design. The Contractor shall conduct additional site inspections and geotechnical investigations as required for the basis of their design of the type and to the extent necessary, to determine and develop the concepts and prepare detailed designs for foundations best suited for the structures and facilities and to determine the extent, if necessary, of foundation piling required for the work. Geotechnical investigations shall also be conducted as required for the basis of design for new access roads, upgrade of existing access roads, new wellpad, and any other pavements, and slope stabilisation measures. Contractor shall undertake groundwater investigations as part of the geotechnical investigation to inform the potential locations of natural springs and their impact to surface water collection and conveyance.

The Contractor shall submit to the Project Manager three hard copies and one soft copy of the Contractor’s Geotechnical Factual Report and Contractor’s Geotechnical Design Report.

## 3.2 Earthworks and Site Preparation

The Contractor shall take over the Site as is and shall carry out site works, the minimum of which shall include:

- Clearance of vegetation and trees and execution of bulk earthworks
- Clearance of any accumulated vegetation after the completion of bulk earthworks.
- Bulk earthworks, shaping, trimming and grading of the Site to formation levels, cutting into the hillsides to depths where foundation conditions are capable of supporting the major plant and buildings, and forming the remainder of the platform by placing and compacting excavated material. Excess material should be used on site where possible to build bunds to protect the site from surface and stormwater runoff and assist with mitigating sound transmission to nearby residents. Excess site materials to be disposed of in designated soil disposal areas as approved by the Project Manager .
- Slope stabilisation and protection works as required.

- Earthworks related to underground services, including water distribution, sewerage and septic tank, fire main loop and hydrants, drains for stormwater, telephone and local power supply.

The Contractor is responsible for all excavation, filling and backfilling, including importing fill, exporting and disposing of spoil and final trimming of the platform as required. The suitability and standard of compaction required for any structural filling shall be as defined by the detailed geotechnical investigation and shall follow relevant local or international standards. Reforming of any existing slope batters may be required to ensure a satisfactory factor of safety is achieved, as defined by the results of the detailed geotechnical investigation and testing. The minimum factors of safety for slope design shall be as follows:

Static - 1.5

Seismic - 1.1 or a maximum total horizontal displacement for slopes NOT supporting structures of 150mm.

The Contractor shall ensure that siltation, runoff and erosion of soils on the site is adequately controlled and in compliance with the approved environmental plans. Vehicle tracking control shall be used at all vehicle and equipment exit points from the site to prevent sediment exiting the limits of construction of the project site. Vegetation shall be established on all bare cut/fill slopes and on unsurfaced areas of the Site. Earthworks and spoil disposal shall be carried out in a manner to minimise erosion and siltation.

Top soil shall be considered to be the surface layer of undisturbed land no less than 30 cm and no greater than 50 cm deep. Top soil and sub soil shall be stockpiled within areas designated for soil disposal. The Contractor shall propose for the Project Manager's approval the designated areas for soil disposal. Top soil stockpiled within designated areas shall be separated, not mixed with other non-compatible materials, and properly identified. This material shall be used for rehabilitation at the end of the construction phase. The sub soil shall be reinstated first then covered with the top soil to a depth between 30 and 50 cm.

## 3.3 Drainage

The requirements for maximum levels of residual contaminants as defined in the IFC Performance Standards and EHS Guidelines and the Environmental and Social Management Plan shall be complied with for all fluids discharged from the Plant.

The effluent water disposal systems shall consist of a storm water system, oily water system and a sanitary sewer system. The Contractor shall prepare a design report to document the proposed design concepts for all drainage systems for review and approval by the Project Manager before commencing with the detailed design.

Process condensate from the Power Plant or condensate from the SGS shall not be disposed of via the stormwater drainage system.

### 3.3.1 Design for Surface Water Flooding

The Contractor shall undertake an analysis of potential flooding for the Power Plant Site and for the cross country pipeline routes as well as any impacts the development of the Site will have on adjacent properties.

The basis of the analysis shall be on a 100-year annual return interval rainfall. The Contractor shall use the metrological data provided by the Employer and supplement it with further publicly available data to provide the best summary of rainfall conditions on the Site.

The Contractor shall provide adequate drainage systems to capture rainwater potentially flowing onto the Power Plant site from surrounding areas (including areas which are not part of the Site) and safely divert stormwater flow away so that the Power Plant site is protected from flooding and potential damage. Note that this requirement is to be complied with at all

times during the Contract (i.e. not just for the finished Plant, but also throughout construction so that all construction works are protected).

Flooding of streams during heavy rainfall may entrain debris. Design of the reinjection pipeline shall make provision for these conditions.

The Contractor shall provide a Flood Design Report for Project Manager's approval which details the analysis. This report shall include a copy of all referenced data.

The Contractor shall also incorporate in their design and project planning the data and findings as presented in the document titled "Indirect Peak Discharge from Tropical Storm Erica" as provided for Supplementary Information.

### 3.3.2 Surface and Storm Water

The surface and storm water drainage system shall be designed to collect surface water from springs and existing creek beds as well as storm water from building roofs (overflow volumes not first captured and stored for use as domestic water), finished surfaces, in ground fire hydrants pits and other areas which could reasonably be expected to collect stormwater. Appropriate slope drainage, drainage ditches and culverts under roadways shall be provided to assure adequate drainage and control of surface and storm water runoff around the project site. All drainage shall conform to applicable local standards and regulations. Under no circumstances shall process effluents, contaminated or foul water be discharged directly into the storm water drainage system.

The site drainage shall be designed for the maximum peak rainfall as obtained from the meteorological data of the area, which shall, in any case, not be less than 80 mm/hr for a 30-minute duration, and shall be based on appropriate flood return periods which shall not be less than 1in 10 years for open drains and 1 in 25 years for closed/pipe drains and outfalls. Surface run-off shall be calculated using the Rational Formula Method.

Site layout and falls shall be set out to ensure that storm water flows away from built-up areas and buildings do not become inundated if rainfall in excess of the design rate occurs. Surface runoff originating from the plant shall be collected by pipes, ditches or otherwise controlled for disposal. Where drainage pipes are to be used, they will typically have a gradient sized for a velocity not less than 0.75 m/s for self-cleansing with an upper limit of 3.0m/s. The pipe materials shall be consistent with the condition or characteristic of the site such as septicity, soil properties, etc. and the manholes, pipes and fittings shall comply with appropriate local or international standards. Where open drains are to be used, adequate measures shall be incorporated for pedestrian and vehicular safety and crossings where applicable. Drainage pipes laid on steep slopes shall terminate with a tee section at a rip rap apron or at a designed energy dissipater. Intercepting ditches shall be provided to protect embankments from erosion.

Where necessary to meet storm water quality requirements, either during construction or operation, water shall be collected and stored to allow settlement of suspended solids before disposal. In this regard, the maximum acceptable turbidity of the discharge to the environment shall be 50 NTU.

The site is subject to groundwater emerging as natural springs. This water shall be collected, conveyed, treated and discharged in a similar manner as stormwater across the project site.

Storm water shall be directed to natural discharge points/channels.

### 3.3.3 Contaminated (Oily and Chemical) Water

Contaminated water comprising of the following shall be connected to the contaminated water drainage system:

1. Wash-down water from process areas within the buildings
2. Rain-water or wash-down water from externally located plant and equipment with or without bund walls for containment of contaminates

3. Wash down water from areas provided with bund walls for containment of contaminates within the buildings

4. Contaminants include gasoline, diesel fuel, oil, grease, hazardous chemicals and any other environmentally detrimental substance.

5. Containment of contaminates shall be in place for the duration of the project, including temporary measures during construction as well as permanent facilities for the plant and site.

Contaminated fill material shall be classified as unsuitable and disposed of as directed by the Project Manager.

All process equipment and plant with chemical storage shall be provided with concrete bund walls for containment of spillage in accordance with relevant standards and good practice. Floors shall be sloped towards a sump to facilitate removal of any contaminate spillage. Sump shall be connected to the contaminated drainage system through a lockable valve which shall remain shut during normal operation and shall be opened to allow discharge of rain or wash down water into the contaminated drainage system.

Under no circumstances shall clean storm water or foul water be discharged into the contaminated drainage system. The Contaminated water drainage system shall comply with relevant local or international standards.

Wash water from the chemical storage facility floor and emergency eyewash stations may contain chemical concentrations higher than those acceptable for discharge into the stormwater drainage system. The Contractor shall provide a pre-treatment system to reduce the chemical levels that may occur in this effluent prior to tie in to the contaminated water system. The pre-treatment facility shall achieve an effluent quality that is compliant with the requirements of the relevant local regulation and international standards.

All contaminated water, including that from the chemical pre-treatment facility, shall be collected and passed through an oil/water separator prior to discharge into the storm water drainage. The oil/water separator shall separate oil from water such that the quality of effluent from the separator is suitable for discharge into stormwater drainage. The oil/water separator shall be provided with efficient means of removing oil including access for maintenance requirements. The oil/water separation system shall include instrumentation connected to the DCS to advise operators of any malfunction of the system including oil containment high and high-high levels.

Materials for contaminated water pipes outside the building shall be consistent with the condition or characteristic of the site such as septicity, soil properties, external loading, abrasion etc, and shall be laid at appropriate depths taking into consideration loading that the pipe will be subjected to; this shall be a minimum of 1.2 m to the crown of the pipe under roads and 0.9 m elsewhere. Where this is not possible, a protective slab of reinforced concrete may be required over the pipe.

Where drainage pipes are to be used, they will typically have a gradient sized for a velocity not less than 0.75 m/s for self-cleansing. Manholes shall be provided with galvanised mild steel step irons where the depth is greater than 0.6m. The inner surfaces of manholes shall be rendered with cement/sand mortar and the base shall have benching to falls. Manhole covers shall be heavy-duty in trafficked areas or where heavy external loading is anticipated, and medium-duty elsewhere. The covers shall be painted with bituminous paint.

All pipes and fittings, manholes, covers and step irons shall comply with the relevant local or international standards. The Contractor shall provide an oily waste water discharge system that collects storm water and process water spillage from maintenance facility floor drains, equipment drains, turbine / generator area, lube oil system drains and transformer bays. All such discharge sources shall be directed to an oil/water separator prior to tie-in to the storm water system.

### 3.3.4 Plant Waste Water

Foul water discharge from kitchen, toilets, wash hand basins and showers shall be discharged into a foul water drainage system. Foul water drainage shall comply with the guidelines and requirements of relevant codes and standards of international and local authorities having jurisdiction and required as defined in the Interface Schedule. Under no circumstances shall process effluents, storm water or contaminated water be discharged into the foul water drainage system.

The velocity of flow in the pipes shall not be less than 0.75 m/s for self-cleansing, with an upper limit of 3.0 m/s. Flow in closed sewer pipes should not be full bore and should be designed for a maximum of 2/3 full at maximum flow.

Flows should be determined as recommended in applicable local standards and regulations or where these are incomplete, then the International Plumbing Code shall be used. The plant sanitary sewer shall be connected to a package sewerage treatment plant and field drains. This package plant can also be used for the construction waste water treatment. Leach beds shall be located with due regard to the environment, local codes and regulations for such installations. The sewer shall connect the plumbing from all occupied areas. The treated effluent discharge from the treatment plant shall flow by gravity to the absorption bed (leach field) to be located within the Site area as allocated. Where they are required, soak-pits shall be suitably sized taking into consideration the permeability of the soil into which the effluent is to be discharged. They shall be located with due regard to environment, water pollution and existing amenities/services, and shall comply with the local codes and regulations for such installations.

Sewer piping shall have a gradient sized for a minimum velocity of 0.6 to 0.75 meters per second for self-cleaning. Septic tank and effluent field drain systems shall be sized and have capacity sufficient to meet the nominated occupancy of the station and in accordance with the local codes and regulations for such installations. Chemistry Laboratory drains shall be collected for pre-treatment prior to disposal.

### 3.3.5 Liquid Geothermal Effluents

All geothermal liquids shall be disposed of to either brine reinjection or to condensate reinjection. The choice of which is appropriate depends on the state of the liquid being disposed of; cold aerated liquids to go to condensate reinjection, hot unaerated liquids to brine reinjection.

### 3.3.6 Existing Well Cellar Drainage

The contractor shall design and retrofit cellar drainage to the standard required within this Specification for all existing well cellars involved in the project in order to prevent the accumulation of stormwater and surface run off within the cellars.

## 3.4 Raw Water

### 3.4.1 Supply and Storage

Raw water shall be taken from the interface point as defined in the Interface Schedule. Pipework from the interface point to the Plant shall, as far as practical, be buried. The piping shall be installed within the land boundaries as defined.

The Interface Schedule provides details of the raw water source. The Contractor shall construct a suitable intake structure at this point, and provide a suitable pump station to supply water to the raw water storage facility at the Power Plant. The intake shall be provided with a quick removable inlet strainer and isolation valve(s), to facilitate regular maintenance.

Piping and equipment from the intake structure to the raw water storage shall be sized to provide the required flow, with 30% surface blockage of the inlet strainer to achieve the worst case of the following plus 10%;

1. flow required to fill the raw water storage volume within 3 days, or
2. flow required to fill a single Unit empty cooling tower basin within 8 hours if wet evaporative cooling is used, or
3. flow required for fire-fighting in accordance with the standards, or
4. flow required for the largest raw water demand during maintenance activities.

Piping shall be buried, with above ground sections only as required at the intake and discharge points.

Raw water shall be stored in a tank which can be a dedicated tank, or within a portion of the fire tank in a manner that does not allow for dedicated fire water to be used for general operational purposes and still allows the fire tank to comply with relevant standards.

In addition to the volume required for firefighting this tank shall be sized to provide for the following storage for general use;

a. 250m³ for Employer's reserve requirements for general use, plus

b. amount to fill a single Unit empty cooling tower basin or

c. amount required to undertake the largest single volume use for operation / maintenance activities

Contractor shall install a water flow meter in the supply line immediately before it discharges into the tank / tanks.

Level in the tank shall be continuously monitored by the DCS, using an ultrasonic level transmitter.

An overflow shall be built into the tank to safely discharge overflow to the nearest natural water course, in the event of level control failure.

### 3.4.2 Plant Requirements

Reticulation around the Plant shall be designed to provide suitable operating pressure (water head) at the point of connection/consumption which shall, in any case, not be less than 2bar.

All pipes and fittings shall be heavy duty, galvanized mild steel to ASTM A53 or other applicable local or international standard. Alternatively, HDPE may be used for sections of pipework that are buried.

Sufficient outlets complete with isolating valves, couplings (to disconnect the hoses) and permanently installed heavy duty hoses/hose reels shall be provided so that raw water can be delivered to any point within the Plant. Hoses shall be limited to 30m in length.

## 3.5 Domestic Water Supply, Storage and Treatment

### 3.5.1 General

Domestic water shall be supplied to all relevant areas of the Plant, including;

- Operations Building sanitary systems
- Visitor and Education centre sanitary systems

The plant shall be sized to provide adequate domestic water for up to 10 people per day. The water uses to allow for shall include, but are not limited to, the following:

- Washing
- Cleaning
- Showers
- Toilets
- Kitchen

Storage of domestic water shall be sufficient for a 2-week supply without makeup.

Domestic water for construction shall be provided by temporary potable water supplies.

### 3.5.2 Water Source and Treatment

The operations building and turbine hall roofs shall be used as required to provide the primary source of rain water for processing, with the raw water supply as a backup.

A suitable water treatment plant to comply with Government of Dominica standard for the requirements of domestic water shall be installed. The plant shall avoid or minimise the use of chemical treatment where practicable. For disinfection, the Employer's preference is for ultra violet light with intensity and tube degradation monitoring

### 3.5.3 Plant Requirements

Reticulation around the Plant shall be designed to provide suitable operating pressure (water head) at the point of connection/consumption which shall, in any case, be not less than 2bar.

All pipes and fittings shall be heavy duty, galvanized mild steel to ASTM A53 or other applicable local or international standard. Alternatively, HDPE may be used for sections of pipework that are buried.

## 3.6 Retaining Walls

Where retaining walls are required, they shall be constructed of reinforced concrete. Gabion walls or cemented stone masonry shall only be used for non-critical applications, where if they slump or fail shall not compromise any Plant or pipelines. They may therefore be used alongside roads or at the edge of the wellpads (away from wellheads). They shall not be used around main plant areas such as at the Power Plant, Cooling Tower, Separator Stations, etc.

The minimum factors of safety shall be as follows:

Overturning - 1.5

Sliding - 1.5

Bearing - 3.0

Allowance shall be made for vehicle surcharge and likely equipment loadings. Retaining walls are to be designed for seismic loading as specified. Walls are to include appropriate stormwater/flooding protection from scour/washout as appropriate.

The reinjection pipe route between WW-01 and WW-R1 currently includes a section which traverses a steep hillside upstream from the football field in Trafalgar. This section is approximately 110m long that includes potential slip zones, but will require the pipeline and access to be benched into the slope. This benching may require the use of retaining walls and slip mitigation measures to accommodate the appropriate track across the slope.

## 3.7 New Roads, Parking and External Finishes

The roads and parking shall be designed to the applicable Dominica standards for public road design and construction or other applicable international standards. The pavement shall be designed to support all likely traffic loading during construction and shall take into consideration the CBR / strength of the existing or improved sub-grade and other applicable soil properties.

Maximum grade shall be 15 per cent. Carriageway widths shall be a minimum of 5 m and shall have a minimum cross-fall of 2.0 per cent. Roads outside of these requirements require approval of the Project Manager.

Appropriate barriers shall be provided to demarcate areas to which traffic shall be restricted.

Footpaths shall be provided and laid to local or international standards.

While determining the internal road network, as a minimum, the following roadways shall be considered and constructed accordingly:

- The main access driveway to the Power Plant
- To all rollup doors to access workshop areas
- Access to the main equipment on the Wellpad and SGS
- Access to the Operations Building and up to all entrances of the Power Plant building
- To the Visitor and Education Centre
- Access to any parking lots

Parking spaces adjacent to the Operations Building for a minimum of 10 vehicles shall be included as a minimum. Parking spaces adjacent to the Visitor and Education Centre shall be provided for one medium sized tour coach and 5 cars.

Drive-through turnarounds shall be provided for fire lanes and for delivery trucks. Such trucks shall be able to turn around and exit the plant without backing up or passing directly through their delivery point locations.

Suitable all-season access shall be provided for maintenance equipment, including (but not limited to) shipping container delivery trucks, mobile cranes, fork lifts, personnel lifts (“cherry pickers”) and boom trucks.

The cooling tower basins shall have paved aprons wide enough to prevent saturation of the ground surrounding the basins as a result of drift losses from the tower, but in no case less than 3m.

### 3.7.1 Upgraded Access Road

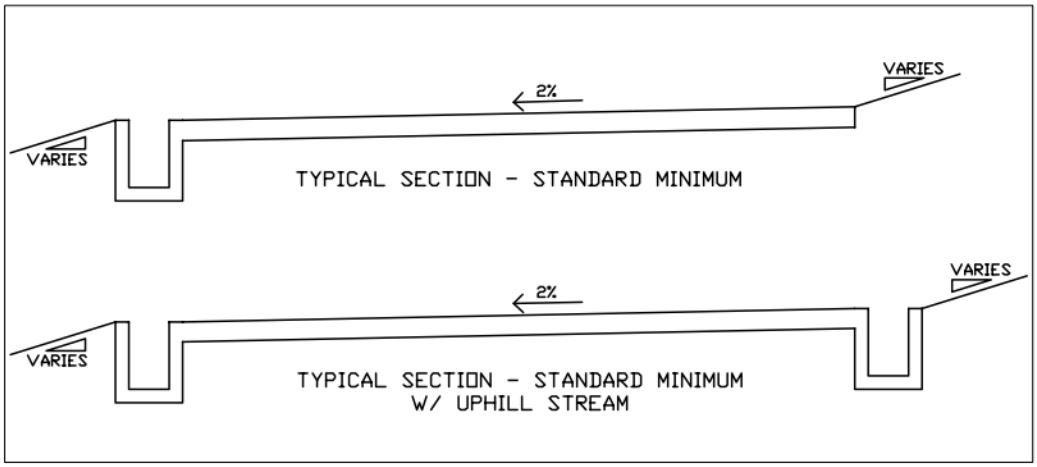
Contractor shall provide suitable roadway upgrades to approximately 625m of access road from Laudat to the existing well pad site as indicated in the GIS extract figure below. The road shall be constructed to a minimum width of 5m to accommodate the anticipated construction and vehicle traffic to the site. Efforts shall be taken to straighten the alignment and reduce grades of the road where practical.




Public road upgrade extents.

The road shall have a concrete surface and cross-section designed for the anticipated traffic loading for the design life of the road. Concrete section shall not be less than 150mm thick and laid upon an appropriately designed subgrade section. Stormwater drainage meeting the requirements of this specification shall be collected to prevent flooding of roadway and adjacent properties, and discharged appropriately. Drainage facilities shall include concrete-lined roadside channels on either or both sides of the roadway as appropriate to convey stormwater and creek flows. Typical sections are shown in the Figure below. Where roadside channels cross existing driveways, concrete bridges shall be installed to maintain access. Starting from the north end of the road the typical sections apply as follows (chainages are approximate & subject to field adjustments):

- Chainage 0 to 100m - does not need channels on either side of road due to constrained width (section not shown in Figure).
- 100 to 200m - standard minimum typical section.
- 200 to 380m - standard minimum w/ uphill stream
- 380 to 530m - standard minimum typical section (includes 25m section of off-street parking at crest of hill – no channels needed)
- 530 to 625m - does not need channels on either side of road due to constrained width (alongside fenced pond up to wellpad entrance)




The road shall be upgraded to provide an all-weather surface and adequate drainage throughout the construction phase of the project. Contractor shall remove and make good any permanent works damaged by construction activities.

Contractor shall take full precautions to protect the road, edgings, buildings or other features (both within and adjacent to the project limits) from damage by roadway works. Any damage which does occur, shall be made good.

Contractor shall protect the completed work from damage and from dropping other materials during the remainder of the construction period. Do not use the completed work as a building platform or for material storage.

## 3.8 Re-Vegetation of Road Corridors and General Site Areas

The Contractor shall provide landscaping and re-vegetation of the site including all un-paved areas within the Plant in harmony with the local environment.

Sign at main gate shall be placed in a small landscaped area including shrubbery and lighting.

Soil shall be analysed and appropriate supplementary additions such as compost, fertiliser etc. shall be provided as appropriate for all species planted.

Landscaping shall be approved by the Project Manager.

The Contractor shall establish grass and shrubs as appropriate on all fill slopes, disposal areas, exposed areas of structural fills, pipe benches, and on cut slopes to provide against erosion. Topsoil previously stockpiled from the preparation of earthworks shall be cleared of deleterious material and respread wherever possible. Material to be compacted with a light roller to a minimum thickness of 150 mm.

Areas to be re-vegetated shall be planted using locally occurring grass, vegetation, plants and trees, primarily native species. The Contractor shall provide a list of species for review by the Employer Representative. Where possible plants shall be sourced locally to ensure they are the local varieties of each plant species. Local knowledge and input from an experienced specialist should be used to select the correct vegetation and planting procedures.

Planting shall preferably be carried out at the beginning of a rainy season and the Contractor will be required to adjust his works programme accordingly. Planting can, and should, be carried out at the same time as Plant construction in order to protect exposed soils from erosion as soon as possible to minimise soil loss and environmental damage. In exceptional circumstances, grassing works will be allowed during the Defects Liability Period for the Plant, but the Contractor should expect consequent extended Defects Liability Periods for these areas of the Plant.

Final earthwork re-vegetation stabilization is achieved when all ground disturbing activities at the site have been completed, and uniform vegetative cover has been established with an individual plant density of at least 70 per cent of pre-disturbance levels, or equivalent permanent physical erosion reduction methods have been employed. These measures shall be included in the revegetation plan submitted to the Project Manager for their review.

In the case of ground cover plants, the lateral shoots shall be spread out well around the plant as far as shape permits to encourage outward growth.

Climbing plants shall be positioned with the root ball touching the wall/fence, and shoots angled towards the structure to be climbed. Where appropriate, climbing stems shall be lightly trained to climbing frames. All containers, labels, canes and ties shall be removed unless otherwise instructed.

The Contractor shall maintain (water, weed, prune, fertilise) the planting for 6 months after completion of the Works. The Contractor shall re-plant any grass or shrubs which die or otherwise fail to establish until such times as a satisfactory ground cover is achieved, and shall ensure that all planting is in a healthy condition at the end of this period.

## 3.9 Signage

All health and safety related signs, shall be in pictorial form and worded in English. All other informational signs shall be in English only. Where appropriate, reflective signs shall be provided. All signage shall be in accordance with the relevant local or international regulations and shall be approved by the Project Manager prior to installation.

All signs shall be in engraved aluminium except lit signs which shall be in Perspex of the colour approved by the Project Manager. Matching stainless steel screws or rivets shall be used as necessary.

Signs shall be provided to indicate visitor entrance to the Plant and visitor and employee parking.

# 4. Structural Requirements

## 4.1 Structures

The following criteria, standards and loadings will be applied to the civil and structural design of the project:

Design Methods: The design method used shall be consistent with the loading code and material codes that are used. Where the Ultimate Strength, or Limit State, approach is adopted the material codes used shall be Limit State based. Load cases and combinations shall take due account of the relationship between intensity of earthquake loading, wind speed and return period.

Loads and Forces:

Dead Load - The dead load to be assumed in design shall consist of the weight of the structure being considered plus equipment permanently fastened to or supported by the structure.

Live Load - The live load shall be that stipulated by the applicable code used for the design of the structure, but shall not be less than the following:

1. Operations Building 5 kPa
2. Ground floors 12 kPa
3. Adjacent to structures 12 kPa
4. Laydown areas - determined by the weight of the components and requirements for handling and installation.

Impact and Vibration - For structures carrying live loads which induce impact, the live load shall be increased sufficiently to provide for the dynamic effects of the impact component. Machine impact and vibrations and dynamic loads as provided by the equipment manufacturer shall be factored as appropriate to be consistent with the adopted design philosophy. Structures shall be designed to preclude resonant vibration induced by machine dynamic loads. Deflections shall be controlled to meet equipment supplier criteria.

## 4.2 Seismic Design Specification

The Contractor shall engage a specialist seismic engineer who shall be responsible for all aspects of the seismic design of the Facilities. The specialist seismic engineer shall have the following experience as a minimum:

- Relevant experience and capabilities in previous similar roles
- Familiarity with design codes requiring ductile behaviour
- Experience in analytical modelling of the seismic interaction between structures and any large equipment contained within them
- Familiarity with design procedures for equipment containing brittle components such as porcelain insulators and porcelain bushings
- Familiarity with the seismic design and testing of mechanical and electrical equipment
- Practical experience with the current Dominican standards.

All buildings and structures and portions of structures shall be designed and constructed to seismic demands produced by earthquake forces coming from any direction.

The seismic design requirements for all structures, plant, piping and other systems shall be based on the more stringent requirements of the local building code or ASCE 7-16, “Minimum Design Loads for Buildings and Other Structures” as modified herein.

For the purpose of establishing seismic loads, plant structures shall be considered with an Occupancy Category of III, “Power Generating Structures”. Site specific spectral response acceleration parameters shall be derived for the local building standards if available or from the procedures of ASCE 7-16. The seismic design for seismic events up to those defined by the design response spectrum shall ensure that all plant (eg buildings, structures, mechanical and electrical plant) performs as follows:-

1. An immediate and safe shut-down of all plant and equipment takes place.

2. Control equipment critical to the continuation of the safe shut-down remains operational during and after the event.

3. Damage to buildings, plant and equipment is limited to that which can be repaired sufficiently quickly for the generation of electricity to resume safely within 30 days.

4. The building structures shall continue at all times to provide adequate weather protection to prevent environmental damage to susceptible plant and equipment.

5. An adequate factor of safety against the collapse of any buildings and/or equipment which would endanger personnel is maintained.

6. Potential costs of repair or replacement and the duration of inability to generate electricity after a large seismic event have been minimised.

7. Structures, plant, components and equipment should be detailed in such a manner that in the event of seismic loading in excess of the design earthquake, catastrophic collapse shall be avoided either by means of ductility, energy dissipation, reserve capacity, or some other demonstrated means. Designs shall consider a hierarchy of failure mode in the event of seismic overload.

8. Design for vertical response shall be considered.

9. For short-period structures and equipment, the design spectral acceleration shall be taken as the maximum value represented by the spectrum for the particular soil.

10. For equipment which when combined with its mounting and foundation system have period less than 0.06s, the seismic loadings interpreted from the design spectra may be taken as the peak ground accelerations (PGA).

11. The lateral coefficient used shall not in any event be less than 0.60 g for non ductile electrical insulator.

12. The requirements for design, detailing and construction of ASCE 7-16 shall be satisfied.

    a. Maximum Considered Earthquake ($MCE_R$) to be 2475 years return period

    b. PGA = 0.6g

    c. Spectral response acceleration parameters for to be $S_s$= 1.57g and $S_1$=0.47g.

Provision shall be made for:

13. Avoidance of weak storeys

14. Allowance for additional loading due to P-delta effects

15. Horizontal regularity - i.e an appropriate distribution of lateral load resisting elements so that the centre of mass and centre of rigidity are reasonably proximate. Lateral load resisting elements shall, where possible be distributed

around the perimeter of the building rather than concentrated near the centre, so as to maximise the torsional resistance of the structure.

16. Accidental eccentricity. Allowance shall be made for additional torsional building loads resulting from the centre of inertial loading and centre of rigidity deviating from the calculated locations.

## 4.3 Wind Loads

Proper provision shall be made for stresses caused by wind, both during erection and after completion of the structure.

Wind loads for buildings and structures shall be determined in accordance with ASCE 7-16. “Minimum Design Loads for Buildings and Other Structures” by taking into account that the site is on a hurricane prone region. Puerto Rico May wind data shown in the table below may be used in the absence of local data. The risk category III shall apply to this project.

Table of Basic Wind Speeds

| Risk Category | Basic Wind Speed |
|---|---|
| I | 160 mph (72 m/s) |
| II | 170 mph (76 m/s) |
| III | 180 mph (80 m/s) |
| IV | 190 mph (85 m/s) |

A minimum basic wind speed as defined in ASCE 7-16 of shall be used, taking to account the wind direction and local topographical effects including:.

- Basic wind speed specified in the local building code if available.
- Available wind data from site or nearby weather station, taking into account the length and quality of records, averaging time, anemometer height and terrain exposure.

The philosophy adopted in setting the design wind velocity and loadings shall be consistent with loadings and design factors used for other aspects of the plant.

## 4.4 Foundations

Foundations for all buildings, structures, tanks and miscellaneous equipment pads shall be selected and designed based on the combinations of superimposed loads, and the strength and character of the supporting material as determined by the geotechnical site surveys and testing programs. In general, all equipment shall be supported by adequately designed foundations (pad, raft or strip and/or piles as appropriate). Specific equipment requirements such as weights, anchorage requirements, static or dynamic loading criteria, potential for differential settlement or any special recommendations by equipment manufacturers shall be incorporated in the design of foundations.

The Contractor shall take into account possible subsidence on the ground as a result of geothermal fluid draw down and shall also design the foundations of the Plant to take into consideration potential differential settlement as follows:

- Turbine pedestal: 10mm differential settlement across the pedestal width and length respectively. Provision for shimming the rotating plant bearings or other means of O&M mitigation shall be provided.
- Turbine hall structure: 30mm differential settlement at one corner of the turbine hall.
- Cooling tower basin: 10mm differential settlement across the cooling tower basin length
- SGS separator and scrubber foundations: 5mm differential settlement across the foundation diagonal.

The turbine, generator and electrical annex shall not experience discontinuous changes in levels of foundations. The cooling tower could be allowed to change level relative to the turbine / generator and electrical annex as long as the design of interconnections allows for this.

The cooling tower and its basin shall not experience discontinuous changes in levels of foundations.

For equipment inside buildings, the foundation plinth shall project at least 150mm above the floor slab for housekeeping reasons. Foundation plinths for the turbine and generator shall be isolated from the adjacent floor slabs by perimeter joints.

Foundations for transformers shall be constructed of reinforced concrete. Spill containment shall be provided for all oil-filled transformers and as required by applicable codes and regulations plus an additional 30 % freeboard for rain water. Fire and blast walls between oil-filled transformers and adjacent structures and equipment shall also be provided and in compliance with applicable codes, but with a minimum 3 hour fire rating.

Crushed basalt aggregate shall be placed in the bund for fire-quenching purposes. The aggregate shall have a nominal size of 40mm.

All cables within the bund shall be protected from the aggregate. Any cables that pass through the aggregate or bund wall shall be installed in conduit which shall rise above the bund top level height. Any bund penetrations shall be adequately sealed to prevent the leakage of oil.

The bunds of the transformers shall be connected to the oil/water separator system.

All foundations shall be designed to withstand the maximum dead and live loads, overturning moments and horizontal loads together with the specified factor of Safety.

### 4.4.1 Sub Base Excavation

Where poor soils are encountered they shall be excavated and replaced with competent material. Appropriate measures shall be taken to ensure the stability is maintained by de-watering with pumps as necessary.

### 4.4.2 Piling and Ground Anchors

When piles are adopted to support plant over soft sub-surface material, the system shall be designed and installed to accommodate any consequences of future settlement of the soft material. Appropriate flexibility shall be provided in services and pipework which traverses the interface between rigidly founded structures and surrounding material that may be susceptible to settlement. Ground anchors must be designed with sufficient corrosion protection for their design life.

The design loading capacity of anchors and piles shall be confirmed by appropriate loading tests. The Contractor shall maintain accurate records of all anchor and pile installation.

### 4.4.3 Tank Foundations

Cylindrical vertical tanks should be supported on a suitable foundation consisting of a ringwall or a mat foundation on well-compacted structural fill or other alternative compliant with the applicable codes and standards.

### 4.4.4 Foundations and Structures for Mechanical and Electrical Equipment

Foundations and other structures of reinforced concrete or structural steel shall be provided for the following mechanical and electrical equipment.

#### 4.4.4.1 Turbine/Generator Foundations and Pedestals

The turbine generator foundations and pedestals shall be reinforced concrete based on the turbine manufacturer's recommendations and general arrangement requirements. Seismic isolation joints shall be provided between the foundation and adjoining floor slab. The ground floor slab shall be reinforced concrete slab +200 above grade on compacted fill to engineered standards. Each turbine generator pedestal shall be constructed using a single pour to avoid the creation of unnecessary and structurally compromising joints.

#### 4.4.4.2 Auxiliary Equipment

Items such as pumps, compressors, heat exchangers, standby generators and other mechanical equipment shall be supported on structural concrete mats or slabs founded on suitable bearing material designed in accordance with these design criteria and to the relevant internationally recognised engineering standards approved by the Project Manager.

#### 4.4.4.3 Electrical Equipment

All items of electrical equipment such as transformers, switchgear and miscellaneous equipment shall be supported on structural concrete slabs inside oil bunds where applicable and founded on suitable bearing material. Cable trenches shall have pre-cast concrete removable covers sealed to prevent ingress of oil or water.

#### 4.4.4.4 Outdoor Buildings Structures and Platforms

Plant located externally shall be supported on structural concrete structures. All surfaces that may be adversely affected by exposure to process related emission and fluids shall be protected using an appropriate synthetic or epoxy system to the approval of the Project Manager. Operating and maintenance platforms shall be in hot dip galvanised structural steel.

### 4.4.5 Concrete

Structural concrete includes all reinforced concrete and any concrete required for the strength, durability, or stability of any building, foundation or other structure.

All structural concrete shall be designed and constructed to the latest version of ACI 318. Concrete mixes are to comply with ACI 211.

All structural concrete shall have a characteristic compressive cylinder strength of 30 MPa or higher at 28 days. The Contractor shall determine an appropriate strength margin above the characteristic compressive strength specified above, in order to ensure that not less than 95 per cent of all strength test results fall above the specified characteristic strength based on a sample of at least 40 tests made from different batches of concrete.

Concrete shall be sampled and tested in accordance with internationally recognised codes and standards, and the test results shall be submitted at least weekly to the Project Manager.

All concrete shall be designed to take account of the corrosive ground and air environment and the requirement for dense durable concrete suitable for the required working life. Sulphate resisting concrete shall be used wherever geothermal fluid is in continuous contact and shall include cooling tower basins, cold wells, rock muffler structures and foundations, geothermal fluid sumps and similar. Concrete for water retaining structures shall be designed to meet the requirements of an internationally recognised code and shall generally have a cylinder strength of 40 MPa at 28 days.

Concrete to be placed on the ground shall have the site prepared with a hard fill bearing layer overlaid by an impervious moisture membrane.

All concrete shall be properly protected and maintained during the curing period.

Curing membranes, sprinkler application of water and ponding shall be acceptable as appropriate for the curing of concrete.

Reinforcement for structural concrete shall be in accordance with the material requirements outlined in the relevant local or international standards.

#### 4.4.6 Concrete Masonry and Brick Masonry

The design and construction of concrete masonry and brick masonry shall be in accordance with relevant codes and standards. All concrete masonry shall be reinforced and filled with grout

Unreinforced masonry infill panels are not acceptable unless than they are tied as brick veneer to structural walls in either timber or reinforced concrete and are in accordance with the Dominican or any internationally recognised Seismic Design Code.

#### 4.4.7 Concrete Batching Plant

Contractor shall consider the need for a site based concrete batching plant during delivery of the Facilities. Contractor shall determine the required size to facilitate concrete pours during delivery of the Facilities. Contractor to satisfy itself on the site batching plant requirements and whether other local batching plants are available for the construction work and continuous pour requirements.

## 4.5 Structural Steel

All structural steel shall be designed and constructed to the latest version of AISC LRFD codes, or a similar approved international code.

Steel shall be supplied in accordance with the material requirements outlined in the relevant ASTM specifications. Welding shall be performed in accordance with the relevant AWS specification. All welds shall have designated structural classification.

Surface protection against corrosion shall be applied to steel structures as required by the Corrosion Control Report..

## 4.6 Structural Aluminium

Supporting structures to be constructed in aluminium shall be designed and fabricated in accordance with the relevant codes and standards. Alloys shall be appropriate for proposed service and be durable.

## 4.7 Stainless Steel

Any supporting structures constructed from stainless steel shall be designed and fabricated in accordance with the relevant codes and standards. Material selection and design details shall be appropriate for their intended use and environment, shall minimise any failure due to stress corrosion or fatigue, and shall avoid galvanic corrosion when in contact with carbon steel.

## 4.8 Plant Support Structures

Support structures shall be designed to resist vertical and horizontal, seismic, wind and normal operating loads. The strength and stiffness of the supports shall be compatible with the supported plant or pipe work, its flexibility and degree of restraint,

under all design conditions. Relative deformations due to thermal, seismic and other lateral load conditions shall be accommodated without over-stressing the support or associated plant. The support structures and foundations shall be designed to minimise vibration.

## 4.9 Pipe Support and Pipe Rack Loads

All pipe supports and pipe racks shall be designed to include the weight of all pipelines, valves, fittings, insulation, and the weight of contents during test or normal operation whichever is greater. Pipe supports and pipe racks shall also be designed with capacity to handle all lateral and vertical thermal loads imposed by guides and anchors from the piping system. In no case shall pipe racks or supports be designed for an imposed load of less than 2 kPa.

## 4.10 Platforms

Adequate access, laydown and withdrawal areas shall be provided to allow ready maintenance of the Plant without unnecessary dismantling of adjacent plant to gain access. All items of plant that are to be operated, adjusted, inspected or maintained shall be readily accessible and arranged to facilitate inspection and removal. Platforms shall be provided where necessary to allow access. Where access for operational inspection is required on an infrequent basis only, fixed ladder access to the platform is acceptable. Where operational access is required on a frequent basis, or where maintenance access is required, stair access to the platform shall be provided.

Galleries, platforms and stairways shall be designed generally for a load of 5 kN/m$^2$ or a concentrated load of 4.5 kN but where loads in excess of this are likely to be imposed during operation or maintenance, the Contractor shall make due allowance for the increased loads in the design. Particular care shall be given to their rigidity.

All the necessary supports from the floors, buildings and foundations shall be provided under this Contract.

Galleries and platforms around plant subject to significant thermal expansion or movement shall be designed to allow for such expansion or movement and to provide adequate access to both hot and cold plant.

Platforms and galleries shall have a minimum width of 850 mm clear passageway and shall be enclosed by toe boards and hand-railing on both sides. In cases where there is a space not exceeding 200 mm on one side of a passageway hand-railing need be supplied for the opposite side only, however a toe board shall be provided on both sides. The minimum headroom on platforms and galleries shall be 2100 mm.

All aspects of platforms, stairways, ladders and other access ways shall comply with the requirements of US code OSHA CFR-29 or similar approved internationally recognized standard unless otherwise stated.

All platform gratings in external locations shall be fibre reinforced plastic and the Contractor shall follow the guidelines and principles contained in the Fibreglass Grating Manufacturers Council (FGMC) ASCE Prestandard (see www.acmanet.org/fgmc/asce_standard.htm). All other gratings shall be hot dip galvanised expanded metal or chequer plate as appropriate.

## 4.11 Roading, Bridges and Wellpads

### 4.11.1 Roading and Bridging General

All roading and road bridges, whether new or upgraded, shall comply with relevant local or international standards. Roads and bridges shall be designed for use by the general public and project.

The design loading for roads and bridges shall be the worst case of;

- Heaviest possible load of plant or equipment brought on site by the Contactor or by Employer plus a 10% margin, or
- BM100 loading in accordance with RSNIT-02-2005.

The design vehicle shall be a single prime mover with trailer 19m long x 3.5m wide. Axle loadings shall be confirmed by the Contractor as suitable for the roads and bridge crossings prior to any transport being undertaken.

The Contractor is required to provide a Road and Bridge Design Report which details all aspects of the proposed design, including standards adopted, layout drawings, material selection etc.

Bitumen sealing on paved roads shall comply with relevant Dominica standards or other international standards. A bitumen wearing course shall be provided on the road bridge.

The roads and parking shall be designed to the applicable Dominica standards for public road design and construction or other applicable international standards. The pavement shall be designed to support all likely traffic loading during construction and the Employer's drilling operations and shall take into consideration the CBR /strength of the existing or improved sub-grade and other applicable soil properties.

### 4.11.2 Integration to Existing Road Drainage

Where existing drainage along the main site access road necessarily joins or interacts with new drainage for the Plant, the Contractor shall undertake all work to complete such integration. This is especially required around the Power Plant site, where the drainage system of the Power Plant will need to join with main site access road drains.

### 4.11.3 Maintenance of Existing Road Drains

If any activity undertaken by the Contractor causes damage or impedes the intended flow in the existing main site road drains, the Contractor shall, within 2 days, undertake the necessary repairs or maintenance to correct that impact and restore the operation and condition of the drains to that which they were at the commencement of the site works.

## 4.12 Gorge Pipe Bridge

### 4.12.1 Design Purpose

The Contractor shall provide a reliable, economic and easily serviced bridge structure is required to enable the pipeline to span at least 85m to fully cross the main gorge above Trafalgar Falls.

### 4.12.2 Site Selection

The bridge site has been selected after consideration of several alternatives on the basis that this site has significantly lesser span than other potential sites further downstream in the wider part of the gorge, and it has a suitable topography to enable the pipeline to be configured with a fall across the bridge, and suitable pipeline arrangements at each end. Reliance has been made of Lidar topographic survey data and a general inspection of the gorge site conditions. The selected site has not been closely investigated on the ground. Geotechnical conditions for suitability of foundations and cable anchorages have been assessed on the basis of observations at rock exposures within the gorge area. Specific drilling at the selected anchorage and foundation locations has yet to be undertaken. It is expected that this drilling will provide information for the detailed design of foundations and anchorages.

### 4.12.3 Bridge Preliminary Design Philosophy

The bridge site is in a location that has limited access for construction materials and equipment, and is in a region where specialist construction equipment is scarce. One end of the bridge (north) will have vehicle access from the Dominica road network, whilst the southern end will have walking access only from Wotten Waven. The design has been based on proven typical remote site pedestrian/cycleway bridge configuration and detailing. Such bridges have been constructed in remote locations where vehicle access to sites is limited, and much of the assembly is carried out by hand or with the use of winches, and utilising workers skilled at working at height from harnesses. Key construction stages will require the use of a helicopter,

such as stringing cables and delivery of heavy materials. The design is such that components can be fabricated and delivered in pieces that are within the lifting capacity of a relatively small helicopter (ie typically 1000-1500kg capacity).

The design utilises the simple structural form of a draped steel cable suspension bridge that offers ease of construction with minimal mechanical plant requirement, generous construction tolerances, and relatively low maintenance. The bridge design incorporates catwalks each side of the pipeline to facilitate foot access during construction and for future pipeline inspection and maintenance.

### 4.12.4 Design Loadings

The concept design has been based on the following design loads (un-factored).

1. Dead Load: 1.4 kN/m (decking, beams, transoms & cables
2. Pipeline (including fluid): 1.6 kN/m
3. Live Load: 12 kN (10 persons)
4. Wind Load: Based on 80m/s wind velocity
5. Earthquake Load: 0.6G

### 4.12.5 Structural System

The concept structural system consists of the following:

1. Primary support: Draped catenary main cables (two 36mm diam steel cables, one each side) with a 9.4% sag:span ratio.
2. Cable anchorage: Ground anchors and/or grouted rock bolts (depth to be determined from investigative drilling) with concrete anchor block and cable attachment and adjustment hardware.
3. Secondary support: Steel bar hangers from main cables with adjustable hardware supporting steel CHS transoms at 8.0m spacing
4. Access Deck: Steel PFC beams spanning between transoms and steel grate access decking.
5. Lateral support: Horizontal catenary cables (40mm diam) each side with connector cables at 8.0m spacing
6. Lateral anchorage: Ground anchors and/or grouted rock bolts, concrete anchor block with cable adjustment hardware.
7. Cable support towers: Steel CHC columns with flanged and bolted connections (to facilitate material transport and site assembly) with cross bracing and transoms.
8. Tower foundation. Concrete pad with micro-piles (depth and configuration to be confirmed by investigative drilling)

### 4.12.6 Construction Methodology

The methodology for the construction of this bridge is significantly influenced by the site logistics and access. As much as possible, materials should be pre-fabricated off site into components that can be lifted into position by hand or with the assistance of a helicopter. It is assumed there will be vehicle access to the north (TR) end of the bridge but no vehicle access to the TL end. A helicopter of 1000-1500kg lift capacity will be necessary to transport plant items and components to

the south (TL) bridge end on the opposite side of the gorge from the road access point. The construction will be predominantly by hand assembly, except for lifting of heavy components by helicopter.

Construction of the bridge will require persons with skills in fully suspended access who are capable of working from harnesses on suspended cables to assemble hangers, transoms and decking. Strict safety procedures and certified equipment will be necessary for this part of the work. Construction of anchorages will require drilling equipment suitable for the rock type and that can be either hand carried or flown by helicopter to the TL end of the bridge.

The recommended construction sequence is as follows:

| | Task | Method |
|---|---|---|
| 1 | Confirm site set-out and clear trees and ground vegetation at tower, and anchor locations | Hand vegetation clearance |
| 2 | Strip foundations and excavate for tower and anchor blocks | Hand and mini-excavator |
| 3 | Drill for rock bolts and micro-piles for main cable anchors, lateral anchors and tower foundation | Light weight drilling rig |
| 4 | Install rock bolts/anchor bars and micro-piles | Cement grouting |
| 5 | Form and pour concrete tower foundations | Concrete delivered by helicopter to TL end |
| 6 | Assemble steel towers | Hand assembly on ground |
| 7 | Erect towers on foundation pads and fit tower stays | Winches or helicopter lift |
| 8 | Sling main cables over towers and connect to anchors | Helicopter lifting |
| 9 | Fit hangers, transoms, deck beams and decking | Suspended working from main cables (progressing out from TR) |
| 10 | Install horizontal catenary cables and connector cables | Helicopter lifting, hand assembly (working from main deck) |
| 11 | Installation of pipeline | Incrementally launched from |
| 12 | Adjust main cable and lateral cable tensions to set bridge in correct line and level | Hand adjustment and winch. |

## 4.13 Architectural

Buildings and parts of buildings and exterior equipment shall be designed and constructed to have a clean, uncluttered and harmonious appearance and be of a cost effective design in keeping with their function.

Attention shall be given to local building styles and building techniques. While these are not to be inappropriately used or copied, the design of buildings shall sensibly reflect and be empathetic to such local styles and techniques.

In selecting exterior building materials and construction details, account shall be taken of the long term weathering effects of the local climate and of the need to minimised ongoing maintenance costs.

In planning and detailing spaces within buildings account shall be taken of local preferences.

Design of the buildings shall maximise the use of natural lighting.

### 4.13.1 Finishes

All internal and external finishes shall be designed and installed to ensure durability and safe performance for the life of the plant. This shall include allowance for environment, movement, moisture, ventilation and wear. Specific consideration and measures shall be made to account for the presence of $H_2S$ gas in the atmosphere.

All surfaces that may be adversely affected by exposure to process related emission and fluids shall be protected using an appropriate synthetic or epoxy system to the approval of the Project Manager.

### 4.13.2 External Cladding

External cladding shall be designed and installed to provide a complete weatherproof enclosure of all the internal spaces. Special attention shall be paid during design and construction to the weather proofing of roofs, wall openings for windows, doors, vents, etc.

Attention is drawn to the noise reduction requirements specified elsewhere and to the need for sound attenuating construction to be carefully detailed and installed without gaps that allow sound bridging. Special attention shall be given to the construction under metal roofs to ensure that noise criteria are met in the rooms directly under such roofs.

Walls and roof shall be thermally insulated and/or continuously vapour sealed as required to economically maintain specified internal temperatures and avoid condensation.

### 4.13.3 External Wall Cladding

Exterior wall cladding for the turbine generator building shall be made of profiled sheet aluminium. Materials shall only be supplied by well-established manufacturers who can provide well researched technical information on their products and, in particular, on the long term durability of the protective coatings. Profiles shall be factory formed, not rolled on site. The thickness of the base metal shall be appropriate for the spans and live loads involved and also take into account any special maintenance loads and shall not be less than 0.7 mm thick.

Exterior plastering shall be 3 coat work and must be carried out by skilled tradespersons. Plaster shall only be mixed using high quality cement and clean sharp borrow pit or river sand, gauged with hydrated lime or proprietary additives in accordance with the manufacture’s recommendations. Mixes shall be graded from stronger to weaker between coats in order to avoid cracking.

### 4.13.4 Roofs

Metal roofing shall be made of profiled sheet aluminium. Roofing materials shall only be supplied by well-established manufacturers who can provide well researched technical information on their products and in particular on the long term durability of the protective coatings. Profiles of metal roofing shall be factory formed, not rolled on site. The thickness of the base metal shall be appropriate for the spans and live loads involved and also take into account any special maintenance loads and shall not be less than 1.0 mm thick.

Roofing sheets shall be supplied with colour matched flashings, and rainwater disposal goods made from material of appropriate gauge. Roofs shall be coordinated in pitch and colour to provide a harmonious appearance. Membrane roofing systems, such as synthetic rubber or liquid membranes shall not be used without prior approval and then only in situations where such systems are shown to be more appropriate than metal roofing.

All metal roofing shall be securely fixed to purlins through ridges only at centres recommended by the manufacturer and approved by the Project Manager. Special attention must be paid to ensure the effectiveness of fixings close to roof verges.

Overflow systems must be designed from all gutters.

Downpipes shall be directed into the raw water collection system or the storm water disposal system as appropriate.

Adequate provision is to be made for safe roof access from within the power house building for maintenance purposes and access to any outdoor services. Defined walkways on the roof shall be allowed for to prevent damage to the roof cladding. A safety arrestor system shall be provided for in the design.

The Contractor shall consider the impacts of the Hurricane Proofing and Measures report prepared by the Employer on the design of roofing.

### 4.13.5 Windows and Louvres

Windows and louvres shall be fabricated from powder coated aluminium alloy extrusions of approved manufacture suitable for use in a geothermal area.

Louvres shall be fitted with stainless steel (or other permanent material requiring no maintenance) mesh to prevent the entry of insects and animals of size 10mm in diameter or greater.

Louvres shall be placed to maximise the natural prevailing wind direction to achieve required ventilation without allowing wind gusts to enter, uncontrolled or diffused, into the enclosed spaces.

Powder coating on aluminium extrusions shall be carried out by an experienced firm with a well-equipped spray booth. The coating shall have a uniform film thickness which shall not be less than 80µm. The coating shall be a selected colour and shall comply with the relevant local and international standards.

Large scale and detailed shop drawings of all windows shall be prepared in advance of manufacture and shall be reviewed by the Project Manager before fabrication commences.

Window articles, fabrication techniques, fixings, gaskets and sealants shall all be chosen to meet a combination of the maximum design wind load and the maximum design rainfall for the site without significant air or water leakage.

All window and louvre frames shall be suitably detailed to accommodate the predicted seismic movements.

Windows shall not be provided for electrical rooms, DCS cabinet rooms, store rooms and similar sensitive equipment rooms. This is to prevent a broken window from allowing ingress of rain as well as hydrogen sulphide gas.

### 4.13.6 Doors

Doors shall be of sufficient size to allow for removal and/or replacement of even the largest system components within the buildings. High-quality materials and finishes of durable industrial quality shall be provided.

All roll-up doors shall be the best available galvanised steel roll-up type and motorised, with interior opening controls and adjacent personnel door. Roll-up doors shall provide truck access to the maintenance areas.

All personnel access doors shall be fire rated, flush faced, provided with heavy-duty hardware and subject to the Project Manager's review and approval before manufacture. Fire rated doors shall be provided to maintain fire ratings where required by the Fire Protection Report.

Emergency exit doors shall have panic-release hardware which provides immediate means of escape from inside while maintaining external security.

Doors to sensitive equipment areas including switchgear rooms. DCS panel rooms, HMI control rooms, instrument store rooms and similar shall have personnel air lock entries with self-closing hardware. Air lock entries shall have dual doors with a minimum distance between doors of 2m. These doors shall seal against elastomer seals to prevent the ingress of hydrogen sulphide gas.

### 4.13.7 Floor Finishes

If no particular finish is required to meet other considerations specified, the Contractor shall allow for dust-free, power floated concrete finish with hardening additive and painted with two epoxy coats of two pack Master Seal 180 (or similar approved) applied to the manufacturer's specifications.

All electrical and control room shall have durable floor tiles installed to prevent the buildup of dust.

The Operator Control Room (OCR) shall be finished with an approved anti-static hard wearing tiled vinyl manufactured and installed to recognized standards.

Medium voltage switchgear rooms shall have their floor tiles rated to withstand the loadings of loaded circuit breaker removal trollies.

The switchgear rooms shall be flat with a maximum 3mm deviation from the floor's design level.

### 4.13.8 Drywall Partitions

Proprietary aluminium framed drywall construction shall generally be used for internal partitions. The Contractor may propose an alternative mode of dry wall partition on condition that they are durable and suitable for their intended uses throughout the design life of the plant.

Boards shall be manufactured and selected according to relevant codes and standards.

Interior linings shall be chosen for fire rating, noise, thermal and moisture control.

Drywall partitions shall be installed with a low maintenance finish.

### 4.13.9 Ceilings

Ceilings shall be installed in the following areas:

- Offices

- Toilets
- Washrooms
- Kitchens
- Control Rooms
- Switchgear rooms
- Other areas as appropriate

Ceiling space shall have access for services.

Ceiling systems shall be designed to meet the specified seismic design requirements and have a satisfactory appearance.

In office areas and similar locations fibrous plaster acoustic tiles are acceptable when installed in a well-designed proprietary one way braced grid system. Rails shall be powder coated. Tiles shall be rebated to sit below the grid. In service areas an exposed 2-way grid system with unrebated tiles is acceptable.

Ceiling heights shall be a minimum of 3m above floor level

#### 4.13.10 Stairs and Ramps

Stairs may be steel or concrete framed, seismically separated and provided with balustrades and handrails to meet local building code requirements.

As a minimum a balustrade shall be at least 900mm above the pitch line of the stair shall be installed on the open sides(s) of any stair. At least one handrail shall be provided on narrow stairs and two handrails on wider stairs. Going and tread dimensions shall ensure easy use of the stair and shall be uniform throughout.

Excessively long flights shall be avoided; normally two flights shall be provided between floors. The maximum height rise of a flight of stairs shall be in accordance with the relevant international and local standards governing staircase design.

Treads shall be surfaced to suit adjacent floor finishes.

Ramps shall be no steeper than 1:12, with landings at every 750 mm rise in height and sides of ramps protected as necessary. Floor finishes shall be treated with non-slip finishes.

#### 4.13.11 Painting

All masonry walls, structural steel, sheet metal, uninsulated piping and casing, pipe racks and supports, stacks, mufflers etc. shall be painted with an appropriate coating approved by the Project Manager.

## 4.14 Buildings and Support Facilities - General

The Contractor shall provide all buildings and support facilities required for a complete, fully functional, modern geothermal Power Plant.

The Contractor shall design and build all required buildings in accordance with the national and local codes of the Government of Dominica, and building permits issued by authorities having jurisdiction. Where national codes do not exist, recognised international codes shall be used. Approval from the Employer’s engineer shall be sought on the use of international codes.

Building materials, components and construction methods shall be suitable to ensure that the buildings and structures continue to fulfil the required functions for a period of not less than 50 years, with normal maintenance.

### 4.14.1 Visitor and Education Centre

The Contractor shall supply a building / facilities to cater for groups of approximately 20 people so the Employer can host external stakeholders during the Plant's operation following Operational Acceptance. The building may also be used during future Plant planned maintenance activities to house additional shut-down personnel, and permitting requirements.

The building's design shall comply with the requirements of this specification and include:

- Covered shelter for arriving at the building in a minivan
- Indoor reception area for all visitors for reporting purposes
- Presentation room and facilitates to allow for presentation to visitors – including projector, sound system, screen, and seating to be supplied under this contract.
- Kitchen facilities and seated eating area including tables and seating to be supplied under this contract. This can be included within the presentation room.
- Separate toilets and wash hand facilities for male and female.
- Landscaping / parking area

# 5. Mechanical Requirements

## 5.1 Standards

Use of Codes and Standards other than those published by Institutions from the following list shall require approval from the Project Manager.

The key design standards for piping and pressure vessels shall be the current edition of the following standards as at 1 June 2018.

| | |
|---|---|
| **ASME B31.1** | **Power Piping** |
| ASME B31.3 | Process Piping |
| ASME II | BPVC, Section II, Materials |
| ASME V | BPVC, Section V, Non-destructive Examination |
| ASME VIII | BPVC, Section VIII, Rules for the Construction of Pressure Vessels (Division 1 and 2) |
| ASME IX | BPVC, Section IX, Welding and Brazing Qualifications. |
| | |
| ASME A13.1 | Scheme for the Identification of Piping Systems |
| ASME B1.20.1 | Pipe Threads, General Purpose |
| ASME B1.1 | Unified Screw Threads |
| ASME B1.13M | Metric Screw Threads |
| ASME B16.5 | Pipe Flanges and Pipe Fittings |
| ASME B16.9 | Steel Butt Welding Fittings |
| ASME B16.10 | Face-To-Face and End-To-End Dimensions of Valves |
| ASME B16.11 | Forged Fittings, Socket-welded and Threaded |
| ASME B16.20 | Metallic Gaskets for Pipe Flanges |
| ASME B16.21 | Non-metallic Flat Gaskets for Pipe Flanges |
| ASME B16.25 | Butt-welding Ends |
| ASME B16.28 | Wrought Steel Buttwelding Short Radius Elbows and Returns |
| ASME B16.34 | Valves – Flanged, Threaded & Welding End |
| ASME B16.36 | Orifice Flanges |
| ASME B16.47 | Large Diameter Steel Flanges |
| ASME B16.48 | Line Blanks |
| ASME B16.49 | Factory-Made Wrought Steel, Buttwelding Induction Bends for Transportation and Distribution Systems |
| ASME B18.2.1 | Square and Hex Bolts and Screws |
| ASME B18.2.2 | Square and Hex Nuts |
| ASME B36.10M | Welded and seamless wrought steel pipe |
| ASME B36.19M | Stainless Steel Pipe |
| ASME B73.1 | Horizontal End Suction Centrifugal Pumps for Chemical Process |
| ASME B73.2 | Vertical In-Line Centrifugal Pumps for Chemical Process |
| ASME/HI 9.6.2 | Centrifugal and Vertical Pumps for Allowable Nozzle Loads |
| ASME Z49.1 | Safety in Welding and Cutting |
| ASNT SNT-TC-1A | Personnel Qualification and Certification Recommended Practise |

| | |
|---|---|
| API 5L | Specification for Line Pipe |
| API RP 5LW | Recommended Practice for Transportation of Line Pipe in Barges and Marine Vessels |
| API 6A | Specification for Wellhead and Christmas Tree Equipment |
| API 6D | Specification for Pipeline Valves (Gate, Plug, Ball, and Check Valves) |
| API 598 | Valve Inspection and Testing |
| API 599 | Metal lug Valves – Flanged, Threaded and Welding Ends |
| API 600 | Steel Gate Valves – Flanged and Butt-Welding Ends, Bolted and Pressure Seal Bonnets |
| API 601 | Metallic Gaskets for Raised Face Pipe Flanges and Flanged Connections (Double Jacketed Corrugated and Spiral Wound) |
| API 602 | Compact Steel Gate Valves – Flanged, Threaded, Welding and Extended-Body Ends |
| API 603 | API Corrosion-Resistant, Bolted Bonnet Gate Valves – Flanged and Butt-Welding Ends. |
| API 609 | Butterfly Valves: Double Flanged, Lug- And Wafer- Type |
| API 610 | Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries |
| API 620 | Welded Steel Storage tanks |
| API 650 | Low Pressure Steel Storage Tanks |
| API 920 | Prevention of Brittle Fracture of Pressure Vessels |
| API RP551 | Instrument Installation Practice |
| | |
| ASTM A36 | Specification for Structural Steel |
| ASTM A53 | Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-coated Welded and Seamless |
| ASTM A105 | Forgings: Carbon Steel for Piping Components |
| ASTM A106 | Specification for Seamless Carbon Steel Pipe for High-Temperature Service |
| ASTM A182 | Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service |
| ASTM A193 | Alloy Steel & Stainless Steel Bolting Materials |
| ASTM A194 | Carbon & Alloy Steel Nuts |
| ASTM A216 | Steel Castings for Fusion Welding and High Temperature Service |
| ASTM A217 | Specification for Steel Castings, Carbon, Suitable for Fusion Welding for High Temperature Service |
| ASTM A234 | Pipe Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevate Service |
| ASTM A283 | Specification for Low and Intermediate Tensile Strength Carbon Steel Plates |
| ASTM A312 | Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes |
| ASTM A350 | Standard Specification for Carbon and Low-Alloy Steel Forgings |
| ASTM A403 | Standard Specification for Wrought Austenitic Stainless Steel Pipe Fittings |
| ASTM A370 | Standard Test Methods and Definitions for Mechanical Testing of Steel Products. |
| ASTM A488 | Practice for Steel Castings, Welding Qualification of Procedures and Personnel |
| ASTM A516 | Specification for Pressure Vessel Plates, Carbon Steel, for Moderate and Lower Temperature Service |
| ASTM A703 | Specification for Steel Castings, General Requirements, for Pressure Containing Parts |
| ASTM C533 | Standard Specification for Calcium Silicate Block and Pipe Thermal Insulation |
| ASTM C547 | Standard Specification for Mineral Fibre Pipe Insulation |

| | |
|---|---|
| ASTM C553 | Standard Specification for Mineral Fibre Blanket Thermal Insulation for Commercial and Industrial Applications |
| ASTM C585 | Standard Practice for Inner and Outer Diameters of Rigid Thermal Insulation for Nominal Sizes of Pipe and Tubing (NPS System) |
| ASTM C1136 | Standard Specification for Flexible, Low Permeance Vapor Retarders for Thermal Insulation |
| ASTM C1393 | Standard Specification for Perpendicularly Orientated Mineral Fiber Roll and Sheet Thermal Insulation for Pipes and Tanks |
| ASTM E165 | Practice for Liquid Penetrant Inspection Methods |
| ASTM E709 | Practice for Magnetic Particle Examination |
| | |
| AWS A2.4 | Standard Symbols for Welding, Brazing and Nondestructive Examination |
| AWS A3.0 | Standard Definitions including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting and Thermal Spraying |
| ANSI/AWS A5.5 | Specification for Low Alloy Steel Covered Arc-Welding Electrodes |
| ANSI/AWS A5.17 | Specification for Bare Mild Steel Electrodes and Fluxes for Submerged Arc-Welding |
| ANSI/AWS A5.18 | Specification for Carbon Steel Filler Metals for Gas Shielded Arc Welding |
| ANSI/AWS A5.20 | Specification for Carbon Steel Electrodes for Flux Cored Arc Welding |
| AWS D1.1 | Structural Welding Code |
| AWS QC1 | Standard for AWS Certification of Welding Inspectors |
| AWS Z49.1 | Safety in Welding, Cutting and Allied Processes |
| | |
| ANSI/FCI 70-2 | Control Valve Seal Leakage |
| | |
| AWWA D100 | Atmospheric Tanks |
| AWWA C207 | Steel Pipe Flanges for Waterworks Service |
| | |
| BS 3958 | Thermal Insulating Materials |
| BS 5970 | Code of Practice for Thermal Insulation of Pipework and Equipment |
| | |
| ISO 5752 | Metal valves for use in flanged pipe systems – Face-to-face and centre-to-face dimensions |
| ISO 2858 | End-suction centrifugal pumps |
| ISO 15156 | Materials for use in $H_2S$ Environments |
| | |
| MSS SP-79 | Socket-Welding Reducer Inserts |
| MSS-SP-83 | Carbon Steel Unions Socket Welding and Threaded |
| MSS SP-97 | Integrally Reinforced Forged Branch Outlet Fittings |
| | |
| NACE MR0175 | Materials for use in $H_2S$ Containing Environments in Oil and Gas Production, Parts 1 to 3 |
| | |
| OSHA | US Occupational Safety and Health Authority – Regulations for Platforms and Access |
| | |
| SSPC SP-10 | Near White Blast Cleaning |
| SSPC-SP-30 | Weld Through Inorganic Zinc Primer |

| | |
|---|---|
| WRC 107 | Local Stresses in Spherical and Cylindrical shells due to External Loadings |
| WRC 297 | Local Stresses in Cylindrical shells due to External Loadings on nozzles |
| WRC 537 | Precision Equations and Enhanced Diagrams for Local Stresses in Spherical and Cylindrical Shells |

## 5.2 Pipe Specifications

The Contractor shall develop and provide pipe specifications for all services. In addition, a complete line list is to be provided identifying design, operating and test values for temperature and pressure for each pipe line. Each specification shall be given an identifying alphanumeric code to match the designation within the pipeline numbering scheme. Each piping specification shall include the process fluid, design code, design conditions, corrosion allowance, wall thickness requirements and details of all components to be used within the piping system, including a pipeline branch table. Identification codes for additional pipe specifications shall be created as and when required.

All piping and pressure vessels shall be designed for the full project life. In any cases where this life is not expected to be achievable, that fact shall be noted on the relevant drawings, along with the expected life.

The minimum corrosion allowance for carbon steel shall be 3 mm. The minimum corrosion allowance for stainless steel shall be 0.5 mm. Corrosion allowances shall be noted on the piping specification sheets.All carbon steel pipe and fittings delivered to the site shall have a suitable corrosion resistant coating to allow the pipe and fittings to be stored outside without weather protection for up to six months without corrosion damage.

Pipework sizing shall be based on pressure drop calculations to suit equipment requirements, available fluid pressures and to minimise pumping costs.

Pipework and equipment shall be sized for the maximum transient flow rates (maximum operating conditions) that can occur in the pipeline. The minimum difference between the normal and maximum transient flow for design purposes shall be 10 per cent.

The instrument air receivers and any other carbon steel components in contact with instrument air shall be acid pickled and passivated before commissioning of any part of the instrument air system. The piping and vessels shall be thoroughly dried after pickling and passivating.

All drains for two-phase, steam, condensate and brine to be minimum DN40 and all vents for two-phase, steam, condensate and brine to be minimum DN25. All drains clearance shall be provided to enable rod-out (hot-tap) of a plugged valve.

Instrument root valve tappings shall be a minimum of 25mm.

All sample connections shall be at least 25 mm nominal diameter and shall have a roddable isolation valve.

The following pipeline flow velocities shall not be exceeded.

| Fluid | Maximum Velocity |
|---|---|
| Steam – Main steam lines | 40 m/s |
| Steam – first 100m from the separator discharge (scrubbing line) | 25 m/s |

| Fluid | Maximum Velocity |
|---|---|
| Steam – Other lines | 50 m/s |
| Two Phase | 30 m/s |
| Brine | 2 m/s |
| Water and oil | |
| Pump suction and drain lines | 2 m/s |
| General service | 3 m/s |

All pipework shall be designed for applicable ambient conditions, gravity loads, wind loads, thermal loads, seismic loads, discharge reactions, dynamic time-force reactions, effect of supports, anchors and terminal movements/loads.

Where GRP or HDPE piping is installed below ground, indicator signs shall be installed at each end of the pipe and at each change in direction to show where the pipe is located. Pipe shall be installed at least 700 mm below grade. A signal strip with integral metal wire shall be placed over the entire buried length of the pipe, 100 mm above the pipe, during backfilling operation to enable the pipe to be remotely located later.

## 5.3 Piping Design

### 5.3.1 General

Normal gravity load cases for steam, two phase and compressed air piping shall be calculated for contents with specific gravity of the contents at design conditions. Gravity load cases for all other services shall assume the pipe to be full.

Design pressures shall be the maximum pressure required for the operating conditions determined from the process design plus 2 bar or plus 10 per cent of the maximum operating pressure, whichever is the greater. Pressure load calculations shall be made using the allowable stress of the material at maximum design temperatures.

The design temperature shall be the saturation temperature at the design pressure.

All piping shall be designed for full vacuum.

Thermal loads and stresses shall be determined by assuming expansion from the ambient temperature stated in the Schedule of Interfaces to the design temperature. Where piping design requires the consideration of combinations of hot and cold piping as a result of normal operational isolation, cold pipes shall be considered to be at the minimum ambient temperature. Piping shall be analysed for all possible combinations of hot and cold configurations that may be caused by valve line-ups and other operations.

Wind loads shall be considered for external piping, vessels and high structures. Wind load shall not be assumed to occur concurrently with seismic load.

Where piping is supported from buildings or structures the effect of elastic response on increases in seismic acceleration shall also be considered.

The layout and design of piping systems and their connection to plant, equipment and structures shall be such that adequate provision is made for seismic deformations. Piping supported from different structures shall be provided with adequate flexibility to accommodate the maximum calculated out of phase differential deflections between each structure at the level of support while maintaining code compliance.

Only static seismic loads shall be considered. Pipe support spacings shall be selected to ensure that resonance will not occur.

Fluid transient loadings shall be determined for piping subject to such loading, and the effects included in the stress analysis, support design and location of pressure relief devices.

Pipe restraints connected to the ground shall be assumed to be rigid.

The pipe materials shall be specified by the Contractor which shall indicate what piping materials are to be used for each plant service. The following table shall give an indication for the Contractor.

| Pipe Service | Location | Material |
|---|---|---|
| Condensate Cold Temperature | Condensate System | Glass fiber reinforced plastics (GRP) or 316L stainless steel. |
| Steam Hot Temperature | Steam System | Carbon Steel |
| Brine Hot Temperature | Brine System | Carbon Steel |
| ORC working fluid | ORC | 316L stainless steel |
| Water cooling | Condensing steam plant or ORC | Glass fiber reinforced plastics (GRP) or 316L stainless steel. |

### 5.3.2 Pipe Stressing

As a minimum requirement, any piping system which meets any of the following criteria shall be computer analysed for code compliance:

1. Pipes, DN 50 and larger whose design temperature is greater than 250°C
2. Pipes, DN 100 and larger whose design temperature is greater than 200°C
3. Pipes, DN 200 and larger whose design temperature is greater than 150°C
4. Pipes, DN 300 and larger whose design temperature is greater than 90°C
5. Any pipes DN 500 and larger
6. All GRP piping systems DN 150 and larger
7. All DN 80 and larger lines connected to rotating equipment
8. All DN 150 and larger lines connected to tankage

All computer analysis shall be carried out using Bentley AutoPIPE or Intergraph Caesar II pipe stress software. ASME B31.1 will used except in the following selected applications:

- Fibreglass piping will be designed to BS 7159 using the stress intensification factors from ISO14692
- Other non-metallic piping will be design to ASME B31.3

For piping systems not meeting the above criteria, or being designed for lower temperatures or pressures, judgement shall be used as to when a computer analysis, hand analysis, or no analysis shall be performed. This judgement shall be based on piping configuration, temperature, and allowable reactions on equipment.

Loads shall be assumed to be applied to the pipe in the following sequence:-

- Gravity
- Pressure
- Temperature
- Seismic or wind or other occasional loading

The following are acceptable boundaries for starting and terminating pipe stress analysis problems.

- Equipment nozzles
- Structural anchors or penetrations which provide three force and three moment restraints
- Consecutive supports on a straights run of pipe, one of which restrains in three orthogonal directions, and the second of which restrains in directions lateral to the pipe.
- A branch pipe whose moment of inertia is less than one-tenth of the run pipe. Where the moment of inertia of a branch pipe connected to a run pipe is less than one-tenth the moment of inertia of the run pipe, the branch pipe can be treated as an individual segment with an anchor at the branch point.

A Pipe Stress Analysis report shall be prepared and delivered to the Project Manager for each piping system. Each report shall include, as a minimum, the following:

1. Introduction
2. System Description – characteristics, special or particular features
3. Design Criteria
4. Description of Analysis
5. Modelling Assumptions
6. Results of Analysis
7. Appendices containing:
8. Supporting calculations
9. Drawings as appropriate (layouts, isometrics, P&IDs)
10. Data on components as appropriate (valves, instruments, flexible connections etc)
11. Piping specifications
12. Pressure & temperature load case plots

13. Model node point diagrams

14. Model input listing (comprehensive listing including setup or execution parameters)

15. Model output result files (including support loads, displacements, internal forces and moments and code compliance stresses)

Soft copies of all stress analysis models and results shall be provided to the Project Manager.

All branch piping connections on two phase production piping (excluding small bore start up lines) shall be at 45 degrees unless pipe stress requirements preclude their use.

### 5.3.3 Piping Layout

Piping shall be arranged so that full access is provided for the maintenance of equipment and so that removal or replacement of plant can be achieved with the minimum dismantling of piping.

All pipework shall be carefully set out and installed to ensure that clear access is maintained to valves, strainers, vents, instruments, plant and through all access ways. Piping shall be routed so it is not accessible for walking upon. Where this is not possible piping shall be adequately supported for the additional live loading.

All valves, strainers, instruments and items requiring operation or maintenance shall be easily accessible from ground or permanent safe working platforms. Valves shall not be installed in the interior of piping bundles.

All pipework shall have, as appropriate, automatic or manual vents and drains. All horizontal pipework shall be graded to provide for draining and venting as appropriate. Piping shall generally be graded to drain in the direction of flow. Non-condensable gas piping shall be free draining with no low points requiring separate drainage. Relief valves and vents shall be piped to discharge in safe locations. Overflows and drains shall be piped to discharge to the nearest convenient drain. Additional vents and drains shall be provided for hydro testing. These shall be plugged with a threaded plug on completion of testing.

### 5.3.4 Overpressure Protection

Over pressure protection shall be provided in accordance with code requirements on all pressure vessels and on all pressure pipes which are not designed to withstand maximum possible process pressures. Each specification break shall be separately protected to meet design code requirements. Where a section of the protected pipe can be isolated, the unprotected section shall be assessed to determine whether it needs to be separately protected. Several pipes of different pressure ratings connected together with no isolation valve or similar in between shall be considered as one system and protection is required on one pressure class provided the pressure ratings of the other classes of pipe cannot be exceeded.

Valve and rupture discs shall be set in accordance with Code requirements. Tank venting capacities shall be designed in accordance with API RP 2000.

Rupture discs shall be the reverse buckling type with a scored surface to give a bursting tolerance of +/-5 per cent and shall be capable of withstanding a pulsating service of 15000 cycles up to 85 per cent of disc rated pressure. The disc shall also be able to withstand full vacuum pressure. In addition, the bursting disc assembly shall be designed to allow pre-torqueing in the workshop prior to installation of the assembly in the pipe. Bursting discs shall be provided with PTFE inserts for both the inside and the outside surface. Disc holders shall be provided with safety devices to prevent incorrect mounting in the line.

### 5.3.5 Pressure Vessel and Pressure Piping and Equipment Certification

The Contractor shall comply with all current Dominican regulations and requirements for the design, design verification, fabrication and fitness for service assessments for all pressure vessels, pressure piping and relief devices.

In the absence of specific Dominican regulations relating to pressure equipment Contractor shall adopt ASME B31.1 for power piping, ASME BPVC Section VIII DIV 1 for pressure vessels. Consistent similar codes for other equipment shall be used.

The Contractor is required to determine all applicable Dominican regulations in force at the time of the Contract and shall ensure compliance with these regulations.

Where required by Dominican regulations, pressure piping shall be independently verified by a third party certified for such work.

Pressure vessel designs shall be independently verified by an approved third party prior to the construction of the pressure vessels. The contractor shall submit details of the proposed design verifier to the Project Manager for review and approval.

All pressure vessels, pressure piping and relief devices must be inspected, tested and certified prior to livening. Any costs associated with the attendance of regulatory personnel, nominated representatives or certified third parties for design review, inspection, testing and operational witnessing shall be paid by the Contractor.

All pressure vessels shall have certified nameplates in compliance with both the design code and current Dominican certification requirements.

### 5.3.6 Pipeline Draining & Venting

Condensate drain pots shall be provided on steam lines in appropriate locations to drain condensate during start up and normal operation. Each condensate drain pot shall have a manually operated low point drain of DN 50 size and a steam trap assembly for condensate removal .

Where drains discharge into a header, means shall be provided to confirm the correct operation of trap assemblies without shutting down the balance of the drain system.

Manual high point vent valves and low point drains shall be provided as required for gas venting and warm through purposes. Adequate venting capacity within the Power Plant shall be provided to ensure the steam mains remain heated and clear of non-condensate gas accumulations following a station shutdown. All vent and drain valves shall be fitted with master/martyr (master/slave) dual valve combinations to allow replacement of the martyr (normal operating) valve on-line.

Venting and drain provisions for hydrostatic testing shall be provided.

### 5.3.7 Pipe Supports

Piping shall be supported, anchored or guided to prevent excessive sagging, bowing, bending or movement of pipework under normal, seismic or wind loading conditions. Allowance shall also be included for ground settlement as a result of seasonal variation in ground water levels and any post construction settlement.

Use of springs, constant force supports and other adjustable supports shall be minimised. Limit stops incorporating a gap (non-linear restraint) are preferred in place of snubbers.

Pipe shoes shall be utilised for insulated pipe and shall be long enough to accommodate linear pipe expansion. All pipe support components in direct contact with the pipe shall be of materials compatible with the pipe material. Clamp-on

supports shall be used for alloy pipe. Supports and break-out flanges should be located to assist in installation and minimise temporary supports during overhauls.

Pipe spans for larger piping shall be designed to ensure that the natural period of the piping system is less than 0.1 seconds.

Pipework shall be supported immediately adjacent to all valves and equipment items which are not separately supported.

Pipe supports shall be carefully located to minimise and maintain within code requirements pipework stresses and deflections resulting from gravity, thermal, wind, seismic, and other loads likely to be imposed on the pipework.

#### 5.3.8 Isolation

Provision shall be made in the design for safe piping and equipment isolation. The method(s) used shall be appropriate for the specific application, considering line size, accessibility, etc. Suitable methods include:

- Isolation valve and downstream piping drop-out spool piece
- Double block and bleed
- Spectacle blind
- Slip blind
- Drop out spool where isolation not permitted due to pressure relief system integrity

## 5.4 Steel Pipes

#### 5.4.1 General

The pipe shall be manufactured by an API, ASME or ASTM approved facility. The approval shall be current and documents supporting the approval shall be submitted to the Project Manager prior to manufacture.

The pipe sizes shall be selected from commercially, readily available and cost effective standard sizes.

The following types of pipes are acceptable subject to application and Project Manager’s approval:

- Seamless (SMLS) pipes
- Electric Resistance Welded (ERW) pipes
- Submerged Arc Welded (SAW) pipes

Spiral welded pipes shall not be used.

Stainless steel pipe shall not be manufactured or fabricated with carbon steel pipe.

Carbon steel pipes shall be manufactured to API 5L-Grade B, or approved equivalent.

Stainless steel pipes shall be manufactured in accordance with the requirements of ASTM A312.

All pipes with the same diameter and pipe wall thickness shall be manufactured to the same Standard.

Pipes equal to or greater than DN 100 shall be manufactured in double random length of approximately 12 m.

Circumferential weld joints (jointers) are not permitted.

### 5.4.2 Pipe Tolerances

Dimensional tolerances shall be in strict accordance with the relevant standards.

### 5.4.3 Pipe Ends

Pipes DN 50 and smaller shall be furnished with plain ends, cut square.

Pipes larger than DN 50 shall be furnished with bevelled ends conforming to ASME B16.25 or API 5L as applicable.

Flame cut bevelled ends are not permitted.

### 5.4.4 Inspection and Testing

The inspection, sampling and testing of the pipe as required by the applicable Specifications shall be conducted by an independent third-party testing authority (the Inspector) approved by the Project Manager but engaged by the Contractor. All reports, and test certificates shall be forwarded to the Project Manager by the Inspector.

The Project Manager shall have the right to conduct any other non-destructive tests in addition to the tests undertaken by the Inspector.

The Contractor shall provide reasonable space, labour, and equipment for handling the pipe during any additional testing the Project Manager carries out in accordance with this clause.

The Contractor shall give the Project Manager a minimum of four weeks advanced notification in writing of the scheduled inspection or test so that the Project Manager may make arrangement to witness the same. The Contractor shall afford the Project Manager and/or his representatives total access to all parts of the manufacturer's facilities where work is being done on the pipe order.

If any item or portion thereof fails under tests to give the required performance, such further tests as are considered necessary by the Project Manager shall be carried out by the Contractor and the whole cost of the repeated or extra tests shall be borne by the Contractor.

### 5.4.5 Product Chemical Analysis

Chemical analysis on each heat shall be made and shall conform to the chemical composition of the material specified. The report shall be submitted to the Project Manager.

Two pipes from each lot shall be analysed for their chemical composition. The results of the analyses shall be submitted to the Project Manager.

If analysis of any one of the tests does not conform to the chemical composition of the pipe material specified, then further analysis shall be made on another two pipes of the same lot. Each of which shall conform to the requirements specified. If either pipe fails to meet the material specification, the Project Manager shall have the right to reject all pipes of the affected lot.

### 5.4.6 Hydrostatic Test

Every length of pipe, without exception, shall be hydro tested in accordance with the relevant standard.

All sizes of seamless pipe and all welded pipes under DN 450 shall be held under the calculated pressure for at least 5 seconds.

Welded pipes DN 500 and larger shall be held under the calculated pressure for at least 10 seconds.

### 5.4.7 Radiography

Seam welds on all welded pipe shall be 100 per cent radiographed.

### 5.4.8 Additional Requirements

The following are additional inspection requirements for pipes to be performed by the Contractor or its designated testing authority.

- 25 per cent dimensional check, per shipping lot, per size, type and requisition before shipment;
- 25 per cent end finish and surface finish check per shipping lot, per size, type, and requisition before shipment;
- 100 per cent check on quantity, packaging, marking and loading for shipment.

### 5.4.9 Repair of Injurious Defects

If the rejection rate exceeds 5 per cent at the Project Manager’s final inspection for defects as defined in the appropriate Standard and this specification, the Project Manager shall be entitled to refuse acceptance of production. Disposal of rejected pipe shall be the Contractor's responsibility.

Repair procedure for defective pipes shall be subject to approval by the Project Manager and shall be made in strict accordance with the appropriate Standard. Repaired pipes shall undergo repeat NDT in accordance with the applicable Standard and this Technical Specification, at the Contractor’s cost. If further defects are found after the initial repair, the pipe length shall be rejected.

Repair of weld seams in SAW or ERW pipe is prohibited at the construction site.

### 5.4.10 Marking and Coding

Marking and coding shall be in accordance with the applicable Standard.

All items shall be paint stencilled on the outside surface of the pipe. This shall be performed on a clean pipe surface and before any anti-corrosion varnish is applied to pipe.

No die stencilling (hot or cold) shall be permitted.

In addition to the requirements of the relevant standard the following items shall also be paint stencilled on the outside surface on each pipe:

- Heat Number
- Weight per Unit Length
- Length
- Pipe Nominal Diameter, Wall Thickness and Grade

- Joint Number
- Purchase Order Number

Summary tally sheets shall be maintained showing heat or cast number, joint number, pipe joint weight per unit length of each joint. Summary tally sheets shall list joint numbers consecutively for each diameter of pipe regardless of heat or cast numbers.

#### 5.4.11 Mill Certificates

Mill Certificates for all pipes shall be supplied to the Project Manager.

Mill Certificates shall contain all mandatory and supplementary information as required the relevant Standard.

## 5.5 GRP Piping

GRP piping shall be of the reinforced thermosetting resin type manufactured by the filament wound process using a thermosetting resin reinforced with fibreglass.

The piping shall be designed to either:

1. BS 7159: Design and Construction of glass reinforced plastic (GRP) piping systems for individual plants or sites, and for areas not covered by BS 7159, BS 4994: Design and Construction of Vessels and Tanks in Reinforced Plastics, or

2. ISO 14692: Petroleum and Natural Gas Industries – Glass-Reinforced Plastics (GRP) Piping – Parts 1, 2, 3 & 4.

In addition, sections of piping which are buried shall comply with the requirements of AWWA M45: Fibreglass Pipe Design or ISO/TS 10465 Underground Installation of Flexible Glass Reinforced Pipe.

Evidence of the design basis (allowable strain for BS 7159, qualified pressure for ISO 14692) will be required to support the piping design.

If BS 7159 is used for the piping design, stress intensification factors and flexibility factors may be derived from ISO 14692.

Buried pipework shall be laid bedded in and back filled with clean sand of a depth recommended by the manufacturer but not less than 300 mm. Special care shall be taken with the sub-base beneath trenches for GRP pipework to ensure that the piping is installed in cut material. Where this is not possible, all materials used shall be structural fill compacted to ensure that differential settlement causing potentially damaging shear forces on the buried pipework is avoided. Great care is to be taken when back filling to ensure that stones and other sharp objects are excluded from the back fill material and that compaction equipment is not allowed to impact on the pipe.

Where GRP pipework is installed above ground it shall be suitably supported in accordance with manufacturer's requirements and protected from damage from impact or other accidental causes. Pipe joints shall be made only by suitably qualified and experienced tradesmen to a procedure to be approved by the Project Manager.

GRP piping should generally be buried in order to provide for maximum protection from mechanical damage.

All valves and other inline components shall be supported without relying on the pipework support system.

Jointing and repair procedures for GRP and HDPE piping shall be developed by the Contractor and included in the plant maintenance manuals. Special tools for the repair of the piping during the life of the Plant shall be supplied.

Transitions between stainless steel and GRP shall be accessible and above grade. Manway access shall be provided to all cooling water piping 600mm diameter and greater. The manway(s) shall be installed with suitable backing plates to reduce the impact on hydraulic losses in the piping system.

## 5.6 Pipe Fittings

Fittings for DN 50 and larger shall be butt welded. Butt-welded fittings shall be specified with a wall thickness to match the mating pipe. Where there is a change in pipe size or pipe specification, the wall thickness shall be specified for the thicker wall pipe and the smaller end shall be machined to the correct thickness.

Pipes less than DN 50 shall use socket weld fittings (butt-weld fittings may be used for stainless steel piping).

Threaded fittings may be used for DN40 and smaller pipes but their use shall be minimised as much as possible to avoid potential leak problems. Threaded fittings may be used for pressure tappings. Threaded connections shall not be seal welded. Where screwed or threaded connections are used, there shall be at least 2 threads left on the male component when the connection is completed.

Unless specifically approved, fittings with integral flanges shall not be used.

Forged fittings shall be specified in preference to fabricated fittings. Fabricated 45 degree and 90 degree stab-in type branch connections with reinforcing plates may be used if local stresses are checked. Special consideration shall be given to large diameter branch connections. All fabricated branch connections shall meet code requirements and all fabricated branch connections where the branch is equal to or larger than 50% of the run diameter shall be analysed using FEA.

### 5.6.1 Pipe Bends

A standard long radius pipe elbow shall have radius 1.5 times the diameter of pipe (1.5 D).

Longer radius bends (3D, 4D) shall be supplied with 1D neck length.

Each bend shall have factory machined bevelled ends at each end.

Double Mitre bends shall not be used unless the angle is such that the distance between butt joints on the inner curve of the pipe elbow would be less than 100mm or 5 x wall thickness.

Fabricated multiple-mitre bends, more commonly known as ‘Lobster Back’ bends, are not acceptable.

No other fabricated bends shall be used without the approval of the Project Manager.

### 5.6.2 Ends

All butt welding fittings shall be furnished with bevelled ends conforming to ASME B16.25.

Flame cut bevelled ends are not permitted.

The ends of butt welded fittings shall match the wall thickness of the specified pipe schedule.

All socket welding fittings shall be furnished with ends conforming to ASME B16.11.

### 5.6.3 Flanges, Gaskets and Seals

Weldneck flanges shall generally be used on pipes DN50 and larger.

Socket welded flanges shall be used in pipes DN40 and smaller. Threaded flanges shall not be used unless otherwise approved.

Raised face flanges shall generally be used up to and including ASME Class 300.

Ring Type Joint (RTJ) flanges shall be used on all high pressure (ASME 600 and above) piping, except that orifice flanges in this service shall be raised face.

The following flanges shall not be used:

- Reducing welding neck flanges
- lap joint flanges

Stud bolts shall be used on all flanges, except for connection to special equipment.

Flange bolting patterns shall be in accordance with the following requirements

- Up to DN 600 ASME B16.5
- DN650 and greater with temperatures greater than 100 degrees C ASME B16.47 Series A
- DN650 and greater with temperatures ≤100°C AWWA C207

Spiral wound gaskets shall be made from non-asbestos material. These gaskets shall have type 316 metal winding and inner ring, carbon steel centring ring and flexible graphite filler material.

Compressed fibre (non-asbestos) gaskets may be used for flanges where the temperature of the fluid is less than 100 degrees.

Teflon (PTFE) tape shall be used for sealing all screw joints.

Neoprene rubber may be used for all low temperature, less than 60 degrees C, fittings.

Soft iron ring gaskets shall be used on all RTJ flanges.

### 5.6.4 Inspection and Testing

The inspection, sampling and testing of the pipe fittings as required by the applicable Specifications shall be conducted by an independent third-party testing authority (the Inspector) approved by the Project Manager but engaged by the Contractor. All reports and test certificates shall be forwarded to the Project Manager by the Inspector.

The Project Manager or his representative shall have the right to conduct additional non-destructive tests by ultrasonic, electromagnetic, radiography, visual, and/or other means.

The Contractor shall provide reasonable space, labour, and equipment for handling the pipe during any additional testing the Project Manager carries out in accordance with this clause.

The Contractor shall give the Project Manager a minimum of four weeks advanced notification in writing of the scheduled inspection or test so that the Project Manager may make arrangement to witness the same. The Contractor shall afford the Project Manager and/or his representatives total access to all parts of the manufacturer's facilities where work is being done on the pipe order.

The following are additional inspection requirements for pipe fittings and flanges to be performed by the Contractor or his designated testing authority.

1. Fittings
    a. 25% dimensional check, 10% weight per shipping lot, per size, type and requisition before shipment;
    b. 25% end finish and surface finish, check per shipping lot, per size, type, and requisition before shipment;
    c. 100% check on quantity, packaging, marking and loading for shipment.
2. Flanges
    a. 25% check on finish per shipping lot, per size, type, and requisition;
    b. 25% check on dimensions per shipping lot, per size, type, and requisition;
    c. 100% check on marking, packaging, loading procedure and quantity.

If any item or portion thereof fails under tests to give the required performance, such further tests as are considered necessary by the Project Manager shall be carried out by the Contractor and the whole cost of the repeated or extra tests shall be borne by the Contractor.

The Project Manager shall be entitled to refuse acceptance of production if the rejection rate exceeds 5 per cent

**5.6.5 Product Chemical Analysis**

Chemical analysis on each heat shall be made and shall conform to the chemical composition of the material specified. The report shall be submitted to the Project Manager.

One pipe fitting from each lot shall be analysed for its chemical composition. The results of the analyses shall be submitted to the Project Manager.

If analysis of the test does not conform to the chemical composition of the material specified, then another test may be made on another pipe fitting from the same lot. If the second test fails again, all of the fittings from the same lot shall be rejected.

One tensile test shall be done on one representative specimen per lot of fittings.

One flattening test shall be done on one representative fitting per lot of fittings.

**5.6.6 Proof Test**

The following are additional testing requirements for pipe fittings to be performed by the Contractor or his designated testing authority.

1. Fittings

a. 1% proof test (minimum of one), per size, and type as required by the Standard. Check per shipping lot and requisition before shipment.

#### 5.6.7 Radiography

All seam welded fittings shall have their welds radiographically examined throughout their entire length in accordance with Article 2, ASME Section V with acceptance limits in accordance with ASME Section VIII, Division I.

#### 5.6.8 Repair of Injurious Defects

Repair procedure to defective fittings shall be subject to approval by the Project Manager and shall be made in strict accordance with the appropriate Standard.

#### 5.6.9 Marking and Coding

All items information listed below shall be paint stencilled on the outside surface of the pipe fitting. This shall be performed on clean fitting surface and before any corrosion varnish is applied to the fittings (if applicable).

Flange markings shall be as per the relevant code.

No die stencilling (hot or cold) shall be permitted.

Information paint stencilled on the outside surface of each pipe fitting shall include:

- Heat or Cast Numbers
- Bend radius where applicable
- Bend angle where applicable
- Pipe Nominal Diameter, Wall Thickness and Grade.
- Tally number
- Contractor’s Purchase Order Number.

Tally number shall be consecutive beginning with the number 1 for each type of fitting of the same diameter and wall thickness.

#### 5.6.10 Mill Certifications

The Contractor shall supply Mill Certificates and test reports for all pipe fittings supplied.

Records of temperature of hot forming and heat treatments, as well as records of wall thickness of hot formed bends, shall be provided to the Project Manager.

## 5.7 Pressure Vessels

#### 5.7.1 Design Requirements

Pressure vessels shall conform to design, fabrication, testing and inspection requirements of ASME Section VIII Division 1.

Pressure vessels shall be designed to ensure that the maximum allowable working pressure (MAWP) of the vessel is limited by the vessel shell and not by the vessel nozzles.

All vessels in steam service shall be designed for full vacuum.

A minimum 3 mm corrosion allowance shall be applied for all carbon steel vessel designs. A minimum 0.5 mm corrosion allowance shall be applied for all stainless steel vessel designs.

All vessel nozzles less than 8” diameter shall be Schedule 160.

For purposes of seismic load calculations, the water level in all vessels shall be assumed to be in the normal operating condition.

Surfaces where erosion may occur are to include design features for mitigation, for example wear plates or additional wear allowance.

Gaskets shall be spiral wound.

### 5.7.2 Materials

All materials shall be certified and shall be traceable to, and be accompanied by, applicable mill certificates. The mill certificates shall include material composition and mechanical properties test results.

Reinforcing pads and nozzle necks which are fabricated from plate shall be of the same material as the vessel shell or head to which they are attached.

### 5.7.3 Fabrication

No opening shall be located over welded joints.

Longitudinal welded joints shall not be located behind any plate or obstruction which prevents inspection of the weld. Circumferential welded joints shall clear support ring welds by at least 75 mm.

Wherever possible, reinforcing pads for nozzles and other attachments shall not be located over longitudinal or circumferential welded joints. If this is unavoidable, the welded joint shall be ground smooth and 100 percent radiographed for the entire length of weld to be covered, plus 75 mm on each side.

Circumferential welds shall be so located that visual inspection can be made with all internal equipment in place.

All connections shall be trimmed flush with the inside surface of the vessel (except for instrument bridle connections or where internal piping is specified.)

Exposed edges of manhole and nozzle necks shall be rounded at the inside surface of the vessel.

A complete dimensional check of each vessel shall be made by the Contractor before hydrostatic testing to ensure conformance with the dimensions and orientation specified on the construction drawings, and to the tolerances required by ASME Section VIII.

### 5.7.4 Radiography

All butt welds in vessel shells, heads, nozzles, manways, and all other pressure retaining components shall be 100% radiographed (RT-1) per ASME code Section VIII Division 1. All other welds shall be magnetic particle inspection (MPI) or dye penetrant tested.

### 5.7.5 Documentation

#### 5.7.5.1 Drawings and Documentation for Approval

The Contractor shall submit documentation for review by the Project Manager as noted below.

- All drawings which are required for the fabrication of the pressure vessel
- Fabrication schedule including the Contractor internal milestones (to be updated monthly)
- Welding procedure specifications (WPS) and procedure qualification records (PQR) per specification
- Heat treatment procedures
- Non destructive examination and testing procedures
- Quality Assurance documentation
- Test certificates
- Material certificates
- Final Documentation

Quality Assurance (QA) documents are a deliverable item. The Contractor shall approve them, then present them to the Project Manager. Each page of each document submitted shall be clearly identified with the Employer's name, the contract numbers, the equipment description and specific identification, and the Contractor's name and address. Each individual document shall be legible.

Documents that have been submitted with a previous shipment shall not be duplicated. However, a statement shall be furnished to the Inspector itemizing, by document, the documents previously furnished for each item of equipment and the date of that previous submittal.

The Contractor shall supply pdf soft copies of the documentation as well as a total of two bound, reproducible copies in A4 size of the QA Report for the pressure vessels and all equipment supplied to them by any Sub-Contractor. Larger drawings (A1 to A3) shall be neatly folded to A4 dimensions. These Reports shall contain, as a minimum, the following (as applicable to the specific vessel design, fabrication method and NDT requirements):

- Certificate of Design Verification (if applicable to the country of manufacture)
- Certificate of Inspection (issued by an inspection body accredited by ASME as an Authorised Inspection Agency)
- As Built Drawings
- Manufacturer's Data Report for Pressure Vessel
- Certificate of Compliance for Fabrication and Inspection
- Hydrostatic Testing
- Hydrostatic Test Procedure
- Calibration Certificates (Gauges and Recordings)
- Hydrostatic Test Result (Pressure Recording Charts)
- Calculation Sheets, if applicable
- Postweld Heat Treatment Records
- Photograph or Pencil Rubbing Copy of the Vessel Name Plate
- NDE Testing Results

- Radiographic Tests
- Ultrasonic Tests
- Magnetic Particle Tests
- Dye Penetrant Tests
- Reinforcing Pad Air Tests
- Mill Certificate of Materials
- Pressure Vessel Heads Inspection Report
- Pressure Vessel Plates Inspection Report
- Welder Certificates
- WPS and PQR Records
- Painting Procedures and Records

### 5.7.6 Inspection, Testing and Shipping

#### 5.7.6.1 Third Party Inspection

The Contractor shall comply with all inspection requirements of the relevant Standards, the country of use and, if applicable, the country of manufacture.

The Contractor shall engage an independent third-party Inspector to witness testing processes for Pressure Vessels.

The inspection and testing must be performed to a verified ITP using verified drawings for the pressure vessel concerned.

The Contractor shall provide for the Inspector to have access to all drawings, calculations, repair procedures and all other documentation as necessary for him to perform his duties.

#### 5.7.6.2 Other Non-Destructive Examination

The following non-destructive examination is required on the attachment weld of all nozzles.

- The root pass shall be examined by liquid penetrant after back gouging to sound metal.
- The surfaces of the completed weld shall be liquid penetrant examined both inside and outside.
- When access for backwelding from the inside is not possible, the root pass shall be made with a TIG or MIG process. The root pass and the outside surface of the finished weld shall be liquid penetrant examined.

#### 5.7.6.3 Hydrostatic Testing of Pressure Vessels

Pressure vessels shall be shop hydrostatic tested. Test pressure shall comply with ASME Code Section VIII, Division 1, Paragraph UG-99 (c) requirements.

When pressure vessels contain a baffle (dividing) plate the entire vessel shall be completely filled with water and hydrostatically tested at the same time. The baffle plates shall be subject to a separate hydrostatic test at lower pressure as specified on the drawings or datasheets.

All gaskets used by the Contractor for hydrostatic testing shall be replaced with new gaskets prior to shipment.

#### 5.7.6.4 Service Bolts

Service bolts furnished by the Contractor shall NOT be used in testing or shipping the vessel.

#### 5.7.6.5 Cleaning

Prior to final inspection and hydrostatic tests, the inside and outside of the vessel shall be cleaned and free from all slag, loose scale, dirt, weld splatter, pieces of metal, oil, rubbish, etc. After the final hydrotest, the vessel shall be dried and cleaned thoroughly, both internally and externally. No welding is permitted on the vessel after hydrotesting or after stress relieving.

#### 5.7.6.6 Tell-Tale Holes

All welded attachments provided with tell-tale holes shall be tested prior to hydrostatic test. Leak tests of reinforcing pads shall be performed by procedures in accordance with ASME Code, Section V. The welds of each pad or segment shall be given an air-and-bubble solution pressure test before hydrostatic testing the vessel.

The tell-tale hole test pressure shall be at least 1.0 barg, but shall not exceed 1.3 barg. Test holes shall be left open but filled with corrosion inhibiting grease after the hydrostatic test and prior to shipment.

#### 5.7.6.7 Gaskets

Gaskets used for hydrostatic testing shall be dry or coated with graphite. The use of shellac, glue compounds or lead, etc., with gaskets shall not be permitted.

#### 5.7.6.8 Test Instruments

The Contractor shall furnish calibrated test instruments, fill and pressure pumps, air compressor and tie-ins necessary to successfully perform the above hydrostatic and leak tests on the completed vessel.

#### 5.7.6.9 Witnessing

The above tests shall be witnessed by the Inspector. The Project Manager reserves the right to witness and approve or to waive approval of the above tests.

#### 5.7.6.10 Preparation for Shipment

No vessel shall be released for shipment without the approval of the Project Manager.

## 5.8 Atmospheric Vessels

Atmospheric vessels shall be designed, fabricated, inspection and tested in accordance with standard engineering practise for tanks. The design shall be consistent with the allowable stresses and stress combination methods as used in ASME VIII. All atmospheric vessels (except mini flash tanks for process drains etc.) shall be designed for the maximum design flows.

### 5.8.1 Materials

All Materials shall be certified and shall be traceable to, and be accompanied by, applicable mill certificates.

### 5.8.2 Welding

All welding shall be in accordance with AWS D1.1.

All gas cuts shall be ground smooth and all sharp edges shall be rounded.

Qualification papers for each welder shall be provided to the Project Manager.

### 5.8.3 Inspection and Shipping

Prior to final weld and dimensional inspection the inside and outside of the vessel shall be cleaned and free from all slag, loose scale, dirt, or weld splatter. All welds shall be visually inspected for defects.

No vessel shall be released for shipment without the approval of the Project Manager.

## 5.9 General Valve Requirements

All valves shall be arranged so that the handwheel or lever moves in a clockwise direction to close the valve. The face of each handwheel or lever shall be clearly marked with words “open” and “close” and shall be provided with an arrow to indicate direction for opening and closing. Valves shall not be fitted with the stems below the horizontal. An indicator shall be fitted to each valve and each extended spindle to clearly show the position of the valve. The position and orientation of valve stems for all valves DN 80 and greater shall be shown on the piping design drawings.

No thrust from the valve shall be transmitted to extension spindles, and valve pedestals shall not be mounted directly on floor plating. Chain operators shall not be used without prior approval of the Project Manager.

Where desirable to protect valve rising spindles against ingress of dirt, or where the position of the valve may create a hazard to operators when the spindle is extended, suitable covers shall be provided.

Hand wheels and gear reducers shall be sized to permit operation of valves without using hand wheel spanners with the full pressure differential and with the force applied to the handwheel not exceeding 250 N. All valves DN 300 and above shall be provided with gear reducers.

As far as practicable, maintenance or replacement of wearing parts shall be able to be accomplished with the valves in situ.

All valves of similar size and type shall be from the same supplier and directly interchangeable.

The internal diameter of all isolating valves shall match that of the connecting piping.

In the case of all welded-in valves, the stub ends of the valves shall project from the valve body a sufficient length to ensure that the welding process will not affect the valve seats.

Gate, parallel slide and globe valves shall be the OS & Y external screw rising spindle type.

Valve packing shall not contain asbestos or lead. A gland packing grease nipple shall be provided for valves of DN 80 and above.

Valve selection and materials shall be appropriate to the fluid and operating conditions to ensure long life, maintainability and, where applicable, minimum pressure drop. They shall be well proven in similar service.

Gate valves, unless specially modified, shall not be used for throttling. Welded end valves shall not be used for control valves.

### 5.9.1 Valves for Steam and Condensate Service

Materials shall be in ASTM A216 WCB carbon steel, with body seat rings, stem and bushings in 13 per cent Cr steel, or equivalent.

Isolating valves above DN 200 shall have:

- “Flexi-wedge” gate or parallel slide type
- Body and disc seats trimmed in Stellite 6 and 8 respectively
- Integral drain
- Bypass DN 25
- Back seating

Isolating valves DN 200 and below shall have body seats trimmed in Stellite 6 on wedge gate, parallel slide or globe valves.

For all steam valves there shall be a differential hardness of 50 Brinell between fixed and moving seats, with the harder material on the fixed seats.

Butterfly valves shall be high performance butterfly triple offset eccentric disc valve, double flanged type, metal torque seated, two-way axial thrust bearings, designed for full bi-direction flow and shut off. Gear operated. Vanessa valves are preferred. All other applicable requirements as given above shall also apply.

### 5.9.2 Valves for Cooling Water Service

Process valves normally operated as part of start-up and shut down shall be provided with electric or pneumatic actuators. All other main isolating valves shall be provided with an approved means of mechanical operation.

Materials - all wetted parts shall be AISI 316L stainless steel or rubber coated suitable for duty.

### 5.9.3 Valves for Brine Service

Valves for brine service shall be selected having regard for the problems associated with silica deposition.

For valve sizes larger than DN200, through-conduit slab gate valves shall be used. These valves shall comply with the latest edition of API 6D. Through-conduit gate valves shall have:

- Seat ring and disc hardfaced with Stellite 6
- Stem from 17-Chromium 4-Nickel stainless steel precipitation hardened to RC 33 minimum
- Facility to replace all valve parts, including the seat rings, without removing the valve from the line
- A DN50 flanged wedge gate valve to allow draining of fluid from the body during operation
- All stainless steel to be Grade 316 (Grade 304 is not acceptable)

### 5.9.4 Power Operated Valves

All power operated valves shall be controlled by electrical signals. Mechanical power required for valve operation may be electric motor, compressed air or hydraulic fluid. The equipment shall be of proven design and reliability. All actuators shall have:

- A handwheel for opening and closing the valve which shall be automatically de-coupled when the valve is being power operated.
- A mechanical valve position indicator mounted where it can be easily read from the local operating position.
- Instrumentation as required

The actuators shall be suitable for opening and closing each valve against the relevant differential pressure plus a minimum of 30 per cent extra torque to overcome sticking which may occur due to deposition within the valve body.

Control valves shall be sized to operate between no more than 70 per cent open at the normal flow, or 80 per cent open at the maximum flow, whichever is greater, and no less than 40 per cent open at the normal flow. Proposed deviations shall be subject to Project Manager's approval.

Where necessary, shaft bearings shall have lubricating nipples installed to allow on-line bearing lubrication using standard pressure lubricating equipment.

The Contractor shall ensure that the relevant vendor provides acoustic trims and/or other accepted means, as required, to reduce vibrations and noise during valve operation to acceptable levels for long-term valve durability and contractual noise limits.

The Contractor shall ensure that the relevant vendor states any requirements on pipe and piping layout for optimum operation of the type of control valves offered.

The valves offered for liquid service shall have a smooth flow path in order to minimise the risk of deposition of solid materials that may be carried with the fluid.

All electronics, accessories and attachments shall be suitable for vibrations generated by fluid flowing through the valves.

Lubrication nipples shall be installed on the top and bottom shaft bearings of all rotary valves.

Control valve seats shall be replaceable.

### 5.9.5 General Control Valve Requirements

Various standard control valves styles may be used, including butterfly, rotary ball and globe. Any proposed style shall be confirmed by the manufacturer as being suitable for the intended service. Special proprietary designs may be used, subject to Project Manager's approval, for specific applications such as low-noise emission. Such special designs shall still be "manufacturer standard" equipment.

Modulating valve actuators shall have:

- A speed of response to meet with requirements of the control loop in which they are connected.
- A positional accuracy which is repeatable within the limits required for the control loop in which they are connected.
- The capability of following the input signal accurately, over a widely varying range of set points. Difference between signal and valve position shall be no more than 3% under dynamic conditions.
- Valve position indicators shall be Westlock manufacture or similar approved by Project Manager.

Except where specifically permitted, the actuation time for valves from the fully open position to the fully closed position and vice versa shall be not greater than 20 seconds.

### 5.9.6 Control Valve Actuators

All valve actuators shall be sized to exceed the breakout torque requirement for the control valve under closed conditions where the differential pressure across the valve is a maximum.

Control valves shall be supplied with a hand wheel to open, close or position the valve manually either during normal operation or in an emergency. The hand wheel shall be capable of use for checking the shaft/stem of the valve for sticking. Hand wheel design for the valve shall be manufacturer's standard.

The hand wheel shall be suitably sized to provide sufficient mechanical advantage to enable the valve to be opened or closed easily against its full rated pressure. Means shall be provided to render the mechanical mechanism inoperative while the actuator is in service using an electric motor. Bevel gear operated hand wheels shall be provided with a shear pin for over-torque protection.

In the event of control signal failure to the valve, the actuator shall not impair the manual operation of the valves. This may be achieved by providing means to disengage the actuator manually while manually operating the valve.

### 5.9.7 Electric Actuators

Electric valve actuators may only be provided for valves in non-throttling open/close type service. Electric actuators shall be Rotork IQ or similar approved by the Project Manager. Control signals shall be via 4-20mA current loop with valve status feedback via serial, fibre optic connected communications.

Modulating electric actuators may be used with the Project Manager's prior approval only.

### 5.9.8 Pneumatic Actuators

Pneumatic Actuators may not be used on control valves greater than DN400 without first seeking and gaining approval from the Project Manager. Such approval may only be given if the Contractor clearly demonstrates that;

- Pneumatic actuators proposed are suitable for the task, in that the operating / process / mechanical requirements are well within the capability of the proposed actuator
- Pneumatic actuators proposed have a track record in similar service
- There are operational and/or maintenance benefits from the avoidance of more systems

Actuators may be of the piston or diaphragm types to suit particular service requirements.

Diaphragm actuators shall be sized to permit full valve stroking against 120 percent of the maximum process differential pressure and spring tension with a 0.2 to 1 bar or 0.4 to 2 bar gauge air signal to the actuator diaphragm.

Valve supply pressures for diaphragm actuation shall normally not exceed 2.4 bar gauge.

Piston Actuators, where used shall be sized to operate at a normal operating pressure of 5.5 bar gauge down to a minimum operating pressure of 3.85 bar gauge, with a signal pressure range of 0.2 to 1 bar or 0.4 to 2 bar gauge.

Actuators shall continue to operate satisfactorily across the full range of process conditions.

### 5.9.9 Solenoid Actuators

Solenoid operated valves may be used on valves up to DN 80. Valves shall move to the safe position in the event of the loss of power supply. Valves shall be mounted such that the coil is vertical and with the coil on top of the valve.

### 5.9.10 Filters and Strainers

Filters and/or strainers shall be installed to protect critical system components. Strainers shall be provided on the suction of all pumps with the exception of the condenser hotwell pumps and hydrocarbon pumps.

All filters and strainers shall be installed in accessible positions to allow easy cleaning and removal. Isolating valves shall be installed adjacent to each filter/strainer. Drain valves shall be fitted to each filter/strainer body.

### 5.9.11 Steam Traps

Piping arrangements shall be set up to minimise the requirements for steam traps. Steam traps shall be of cast or forged steel construction. Traps shall be sized for the condensate maximum quantity and minimum differential pressure. Care shall be taken to ensure the steam traps discharge to atmosphere or discharge into open channel flow sections of condensate headers to avoid potential cavitation and hammering. Within the Power Plant all discharges from steam traps shall be piped either to the cooling tower or to the condenser as appropriate.

Each trap shall be installed with isolation valves each side of the trap assembly, together with a strainer, check valve, manual bypass and a blowdown valve. Steam traps assemblies shall have a common geometry to allow ready maintenance and interchange ability.

Thermodynamic steam traps shall not be used.

## 5.10 Pumps

Horizontal shaft centrifugal process pumps shall comply with the requirements of API 610. Particular attention shall be paid to the selection of pumps and their materials of construction for the specific application.

Horizontal shaft pumps shall be either horizontal split casing or back pull out.

Vertical shaft centrifugal process pumps shall comply with the requirements of API 610, unless specific approval for deviation is given by the Project Manager, which approval will not be unreasonably withheld. In approving variations from the API specification, the Project Manager will take due consideration of the reasons for the variations as proposed by the Contractor.

Pumps shall be capable of operating continuously over their full operating range without overheating, cavitation, excessive noise or vibration, surging or instability when operating in single or in parallel with other pumps. Pumps shall be selected for maximum efficiency at the design condition and shall have a head/flow curve that rises steadily from rated flow to shut off. Pumps shall either be installed with a flooded suction or shall be self-priming.

Pumps shall be supplied with oil flooded bearings and self-oilers. Oil reservoirs and housings that enclose moving lubricated parts such as bearings, shaft seals, highly polished parts, instruments, and control elements shall be designed to minimize contamination by moisture, dust, and other foreign matter during periods of operation and idleness

Pumps shall be selected with a pump suction specific speed of less than 10,000

Mechanical seals shall be used on all pumps. Seals shall be self-flushing with process fluid wherever possible.

Pumps and motors above 15kW shall be coupled and assembled on a common base.

All pumps, with the exception of the hotwell pumps, shall be specified with a 10 per cent flow margin above the design flow as set out on the process flow diagram. Pumps shall be selected with impellers trimmed such that the head of the pump, with a full size impeller, could compensate for a 10 per cent increase in dynamic head at the process design flowrate for the pump.

Hotwell pumps shall be specified with a margin of at least 5 per cent on total dynamic head (TDH) above the head required to meet the worst case duty condition specified (generator limit at unity power factor) under dirty pipe conditions.

Pumps shall be installed with an adequate NPSH margin to ensure that the pump operates without cavitation over the full range of flows and suction level conditions. For continuous duty, pumps driven at no more than 1500 rpm are preferred. All pumps shall be close coupled without gearboxes.

All pump bearing housings, shall be fitted with surfaces suitable for the fitting of portable vibration sensing transducers.

All equipment shall be designed to permit rapid and economical maintenance. Major parts such as casing components and bearing housings shall be designed and manufactured to ensure accurate alignment on reassembly.

## 5.11 Shop and Field Welding

### 5.11.1 General

These Clauses describe recommended practices and establishes the minimum mandatory requirements for all shop and field welding of equipment, components, pipe fittings and pipes in piping system and pressure vessels.

These requirements also apply to welds attaching lugs, brackets and other non-pressure parts in piping systems.

It supplements the welding and welder qualification requirements of ASME B31.1and ASME Boiler and Pressure Vessel Code (BPVC).

Compliance with these Employer's Specification and approval of welding procedures, welder qualifications and non-destructive examination (NDE) method does not relieve the Contractor of his responsibility and obligation to provide quality welds which are suitable for the intended purpose and in compliance with the codes.

The Contractor shall prepare detailed welding specifications for each piping classification. The specifications shall set out the WPS to be used, welding rod requirements, inspection and testing requirements. The specifications shall be submitted to the Project Manager for review.

### 5.11.2 Abbreviations

PQR - Procedure Qualification Record

WPS - Welding Procedure Specifications

NDE - Non-destructive Examination

SAW - Submerged Arc Welding

SMAW - Shielded Metal Arc Welding

GMAW - Gas Metal Arc Welding

GTAW - Gas Tungsten Arc Welding (TIG)

PWHT - Post Weld Heat Treatment

FCAW - Flux Cored Arc Welding

WQR - Welder Qualification Records

### 5.11.3 Filler Materials and Controls

The Contractor shall submit for the approval of the Project Manager his plan for the storage and handling of welding consumables.

Filler material for welding shall be compatible with the base material and shall comply with those specified in the ASME Boiler and Pressure Vessel Code Section II, Part C for Welding Rods, Electrodes and Filler Metals.

Filler material for carbon and low alloy steel shall be selected so that the principal elements in the deposited weld metal has the same nominal composition as the base metal.

Filler materials for welding low carbon austenitic stainless steel shall be low carbon type.

Austenitic stainless steel filler metal used shall contain 5 to 9 percent ferrite in the finished weld.

Low hydrogen type electrodes shall be used for SMAW except that E6010 electrodes may be used for high penetration welds. The finished weld shall have approximately the same strength as the base material.

If jointing of dissimilar metals or special materials is required, the Contractor shall submit details of the filler electrodes, the composition of the base materials and filler electrodes, together with the WPS for approval.

Finished welds from automatic welding processes, especially SMAW, shall not derive any principle elements from any flux used. The flux shall be neutral and the principle elements shall be derived from the solid filler wires used in the process.

All welds shall be made with at least two passes unless otherwise approved.

Fluxes shall be used according to the manufacturer's recommendation.

Filler wires in specification AWS A5.2 shall not be used when the GTAW process is used.

AWS electrode classes E6012, E6013, E6020, E7014, E7020, E7024 shall not be used for any pressure retaining or load bearing welds. E7028 may be used in flat and horizontal position welding, contingent upon procedure qualification and joint configuration, and prior approval.

Welding rods, electrodes and filler metals shall be stored in a locked, weathertight, clean and dry enclosure which is kept at a temperature above ambient dew point, usually between 15 °C and 40 °C. The materials shall be stored on perforated wooden shelves away from the walls and floor of the enclosure to avoid contact with condensing moisture. The materials shall be identified at all times and shall be separated to prevent removal of the wrong material.

Storage and atmospheric exposure limits of low hydrogen electrodes for shielded metal arc welding shall comply with the requirements of AWS D1.1 Section 4 and the electrode manufacturer's storage instructions.

Filler materials in the following conditions will be considered damaged and shall not be acceptable for use.

- Materials that are damaged or pitted.
- Electrodes which are dirty, damp, contaminated with oil.
- Electrodes with flux separated from the wire.
- Bare and flux cored wires with rusts which cannot be removed by light sanding.
- All flux-cored electrodes contaminated with oil or water.
- Electrodes which have exceeded atmospheric exposure limits.

Bare and flux-cored wire that becomes dirty may only be used if cleaned and restored to a bright surface prior to use.

Welders shall not be issued with or allowed to carry more than one type of electrode or filler metal at any one time except that when a qualified welder is specifically assigned to make a weld involving two processes.

Unused welding rods shall be returned and stored in the proper storage area for welding electrodes. Damaged electrodes as defined above shall be discarded.

For field welding, electrodes shall be stored in vented portable hot boxes beside the welder with a controlled temperature to suit the type of electrode being used.

### 5.11.4 Welding Procedure Specification, Performance Qualification Record and Welder Qualification

Welding Procedure Specifications (ASME Form QW-482 or equivalent) and Procedure Qualification Records (ASME Form QW-484 or equivalent) shall conform to the requirements of ASME Section IX and the requirements of this specification. These documents shall be submitted for the Project Manager's review.

Only welders or welding operators qualified to the appropriate fabrication code shall be employed for welding work and they shall be requalified prior to commencement of work.

Welding Procedure Specifications (WPS), Procedure Qualification Records (PQR) and Welder Performance Qualifications (WPQ) (ASME Form QW-484 A or B, or equivalent) shall be submitted to the Project Manager for review at least two weeks prior to the commencement of production welding. Only the appropriate WPS and PQR required for the job shall be submitted.

A representative weld map showing the WPS for each type of joint to be made and the type of base materials for each type of application shall be submitted to the Project Manager for review.

Welding shall not commence until all documents have been reviewed and approved by the Project Manager.

Each welder shall be assigned a unique identification number for the duration. The Welder identification number shall be recorded for each weld completed.

Requalification is exempt only on the discretion of the Project Manager and when the Contractor can produce documents to prove that the qualified welder or welding operator has been engaged in the same welding procedure within the preceding 6 months.

Welders or welding operator's qualifications shall be certified by a recognised independent authority and subject to any requirements of the local inspection authority. All charges associated with welding qualifications shall be to the Contractor's account.

Procedure Tests for all welding processes shall be qualified using the same welding consumables and fluxes as will be sued in the production welds. For the following processes or base materials, a change from one manufacturer's consumables or flux to that of another manufacturer, or a change of type or grade from the same manufacturer, shall require requalification:

- Carbon steel materials subject to PWHT with impact test requirements
- Duplex stainless steels
- Nickle alloys
- Submerged Arc Welding (SAW)

### 5.11.5 General Welding Requirements

Fabrication drawings shall use AWS welding and NDE symbols to show where welding is required, type of weld, welding process examination method, etc.

Welding terms and definitions shall be in accordance with AWS.

Safety measures in accordance with ASME Z49.1 requirements shall be implemented to protect welders and operators involved in welding and cutting of steel.

Welds not conforming to approved WPS shall be rejected.

Welding may be performed using one or combinations of the following processes:

- Shielded Metal Arc Welding (SMAW)
- Manual and Automatic Gas Tungsten Arc Welding (GTAW)
- Automatic Submerged Arc Welding (SAW).

Other welding process, such as Gas Metal Arc Welding (GMAW), Manual Submerged Arc Welding, and Flux Cored Arc Welding (FCAW) shall not be used unless otherwise approved by the Project Manager.

SAW shall be performed in multiple layers with each layer not exceeding 12 mm thick. Flux and filler material used shall be of the same type, grade and manufacturer as those used for the Procedure Qualification Record.

Peening is not permitted.

Full penetration seal welds shall be used on all joints which are exposed to process fluids or gases, require special cleaning (pickle and passivation), or require protective coating or lining. Permanent backing rings or bars are not permitted.

All joints welded on both sides, except those with a root pass deposited by the gas tungsten arc welding (GTAW) process, shall have the root of the weld on the second side removed to sound metal before welding from that side. The Contractor inspection procedure shall be included in the WPS to ensure metal soundness after gouging and cleaning.

Unless the welding area is protected by a proper wind shield, welding shall not be done when air draught or wind velocity os greater than 8 km/hr for GTAW and 16 km/hr for SMAW.

Welding shall not be performed when the metal temperature is below 10°C or when the air humidity is 100 Per cent. Welding shall not be permitted on wet surfaces.

Parts to be joined by welding shall be fitted, aligned, and held in position by bars, jacks, clamps, or other mechanical fixtures during the welding operation. Use of welded temporary attachments are not permitted except under exceptional circumstances and require the Project Managers approval. If approved by the Project Manager, all tack welding and welding of temporary attachments shall be performed using approved WPS and qualified welders.

Tack welds and temporary attachments shall not be permitted on austenitic stainless steels or corrosion resistant materials.

Any temporary attachments approved by the Project Manager shall be the same as the base material. These and tack welds shall be removed after welding (avoid removing base material) and the attachment area ground smooth and flushed with the surrounding surface. The affected area shall be visually examined except that for low-alloy, martensitic stainless or precipitation hardened stainless steels it shall be examined by magnetic particle or liquid penetrant examination techniques as applicable.

Welding procedures for austenitic stainless steel shall be designed to minimise sensitisation.

Welding procedures for austenitic stainless steel shall be qualified with the requirements of ASTM A708.

Wherever possible, starter pads shall be used to avoid arc strikes on the base metal. Any arc strikes shall be ground smooth and faired into the surrounding surface and the affected area shall be examined by liquid penetrant or magnetic particle inspection techniques as required.

Defects which reduce the design minimum section thickness (corrosion allowance included) shall be referred to the Project Manager. Repair may be made with the same type of electrode or filler wire that would be used for the root pass.

Grinding of completed welds is to be performed only to the extent required for NDE, including any in-service examination, and to provide weld reinforcement within the requirements of the fabrication Code. If the surface of the weld requires grinding,

care shall be taken to avoid reducing the weld or base material below the minimum required thickness. Grinding below the minimum wall thickness shall require repair welding to restore the lost base metal thickness.

Pressure retaining welds on pressure vessels shall be 100 per cent radiographed. All other welds on the pressure vessel shall be either magnetic particle or dye-penetrant tested.

The Contractor shall be responsible for all costs relating to weld inspection, repair welding, retraining and requalification of welders or welding operators.

**5.11.6 Weld Joint Preparation**

Tools used on austenitic stainless steel or non-ferrous materials shall not be used on carbon or low alloy steels and vice versa. Alumina grinding wheels shall be used on austenitic stainless steels and non-ferrous materials.

Weld joint preparation may be made by machining, grinding and thermal cutting provided the prepared weld joint surface shall be uniformly smooth, free of all loose scale and slag accumulation and ground back to bright metal finish where flame cut.

Oxy-fuel shall not be used to cut stainless or non-ferrous steel.

If preheating is specified for welding it shall also be applied to the material prior to thermal cutting.

Prior to welding, the surfaces up to 25 mm from the edge of the welding groove for ferrous material and 50 mm for non-ferrous and stainless steel materials shall be clean and free from oil, rust, scale, slag, grease, paint, and other foreign material which is detrimental to welding.

If required, prepared weld joints may be protected from corrosion by the use of a weld through inorganic zinc primer meeting the requirements of SSPC-Paint 30.

**5.11.7 Weld Repairs**

Weld repairs/rework shall be made before any required PWHT. Repair work after PWHT shall require further PWHT.

Unacceptable discontinuities shall be completely removed by chipping, gouging, grinding or other authorised methods (for the type of material being repaired) to clean, sound metal, and the excavated area shall as a minimum be visually examined to assure complete removal. The width and profile of the excavated area shall provide access for re-welding. The ends and sides shall have a gradual taper from the base of the excavation to the surface of the base metal.

Weld repairs shall be made using the same WPS used for the original weld, or other approved welding procedure.

The repaired areas shall be re-examined using the same inspection method which detected the original defect.

Only two attempts will be allowed to repair any one defective area. If defects are detected after the second attempt, further repairs shall not be allowed and the defective weld and heat affected zones shall be completely removed.

**5.11.8 Thermal Treatment**

Preheating, heating and cooling rates, post-weld heat treatment temperature and holding times at specified temperature shall be in accordance with the applicable fabrication code and WPS. PWHT specified in the WPS shall adhere to steel supplier's recommendations and shall be approved by the Project Manager.

PWHT for pipes shall be performed using four recording thermocouples on DN 250 and larger pipes. These shall be placed as close as possible to the weld but no more than 25 mm away from it, at 12 o'clock and 6 o'clock on one side of the weld

and at 3 o'clock and 9 o'clock on the opposite side. Pipes DN 200 and smaller only require two thermocouples, one at 12 o'clock and the other at 6 o'clock on the opposite side of the weld.

Batch PWHT shall include hot and cold zones using at least 4 recording thermocouples on the weld.

Temperature recording charts shall be used with all recording thermocouples and shall have a suitable scale that is large enough for calculating accurately the heating rate, holding time and cooling rate.

PWHT records shall be maintained with all other QA records relating to the particular welded joint.

The Contractor shall submit to the Project Manager for review, a method for protecting threads and gasket surfaces against excessive oxidation during heat treatment.

### 5.11.9 Non Destructive Examination (NDE)

#### 5.11.9.1 General Requirements

NDE methods, acceptance criteria, and additional general requirements shall be in accordance with the applicable fabrication code.

Visual examination shall be by personnel certified to AWS QC1 requirements. All other NDE shall be by personnel qualified to Level II or Level III requirements of SNT-TC-1A of the American Society for Non-Destructive Testing.

Visual examination shall be performed before other NDE.

#### 5.11.9.2 Visual Examination

The examination procedures shall be in accordance with the requirements and methods specified in ASME Code, Section V.

Surfaces of all finished welds shall be visually inspected.

#### 5.11.9.3 Magnetic Particle Examination

The examination procedures shall be in accordance with the requirements and methods specified in ASME Code, Section V, Article 7.

Base material 25 mm on each side of the weld shall also be included in the examination of welds.

The evaluation of results and the acceptance criteria shall be in accordance with ASME Code, Section VIII, Division 1 or 2, whichever is applicable.

#### 5.11.9.4 Liquid Penetrant Examination

The examination procedures shall be in accordance with the requirements and methods specified in ASME Code, Section V and this specification.

At least 5 percent of the first pass and 5 percent of the final pass of welds on austenitic stainless steels and non-ferrous materials shall be examined by liquid penetrant techniques.

Sulphur and chloride content of penetrant materials shall meet the requirements of Paragraph T-644 of Article 6, Section V of ASME Code, regardless of the type of material to be examined.

Base material 25 mm on each side of the weld shall also be included in the examination of welds.

The evaluation of results and the acceptance criteria shall be in accordance with ASME Code, Section VIII, Division 1 or 2, whichever is applicable.

#### 5.11.9.5 Ultrasonic Examination

Ultrasonic examination is required for all welds after PWHT of material 50 mm and greater in thickness.

The examination procedures shall be in accordance with the requirements and methods specified in ASME Code, Section V.

Base material 25 mm on each side of the weld shall also be included in the examination of welds.

The evaluation of results and the acceptance criteria shall be in accordance with ASME Code, Section VIII, Division 1 or 2, whichever is applicable.

#### 5.11.9.6 Radiographic Examination

The examination procedures shall be in accordance with the requirements and methods specified in ASME Code, Section V.

Radiographic examinations required shall be done in accordance with the requirements of the appropriate fabrication code and shall comply with the acceptance criteria of that code.

Radiography shall be conducted upon 100% of circumferential butt welds on pressure piping. For pipe size DN 450 and smaller, the whole circumferential butt weld shall be examined. For pipe size DN 500 and larger, a minimum of 375 mm of circumferential butt weld shall be examined for each quadrant. One of these quadrants shall be at the bottom of the pipe. In addition the first two welds by each welder shall be 100 per cent radiographed.

When radiographic examination shows a defective weld requiring repair, two additional welds performed by the same person shall be examined. If either of these shows a defective weld requiring repair, a further two welds shall be examined and if defects continue to show up then all the welds performed by that person shall either be replaced or examined and repaired as necessary. The welder or welding operator shall be retrained and re-qualified before being allowed to perform further work. The Employer reserves the right to prohibit further work by that person.

Radiographic examination not required by the fabrication code but required by this specification shall be in accordance with the requirements of ASME Section V. The results shall comply with the reference acceptance criteria.

The Contractor shall be responsible for the safe handling and storage of all radioactive sources used for non destructive examinations. The Contractor shall submit for the Project Manager’s review his plan for storage and handling which shall comply with governmental requirements and best trade practice.

Where spot radiography is required, as specified in ASME Code, Section VIII, Division 1, paragraph UW 52, the welds selected for examination shall represent each WPS on the piece of equipment inspected.

The evaluation of results and the acceptance criteria shall be in accordance with ASME Code, Section VIII, Division 1 or 2, whichever is applicable.

The Contractor shall provide a suitable air conditioned dark room facility and digital densitometer for use by the inspector and access shall be granted for use by the Employer and the Project Manager.

### 5.11.10 Documentation

The Contractor shall submit for approval a proposed weld recording procedure that demonstrates the traceability of all matters relating to the welds and shall maintain complete records for all the welds performed. The Project Manager and Employer shall have access to this documentation during the course of the work.

All repairs shall be fully documented including the following details:

- Location and orientation of defect
- Nature of defect and means of detection used
- Repair work actually performed
- NDE performed and post-repair results obtained

Originals and copies of all WPS, PQR, welder's certification, NDE examination results, and all other documentation required by this specification shall be retained by the Contractor until the work is completed. At the completion of the work, 2 copies of all the documents, other than radiographic films where the original films only are required, shall be systematically filed, bound and delivered to the Project Manager.

## 5.12 Pipe Installation

### 5.12.1 Handling and Storage of Materials and Plant

The Contractor shall follow manufacturer’s lifting and handling data and shall ensure that the craneage and handling of all plant, pipes and equipment is carried out in a safe and workmanlike manner.

Physical separation of different materials shall be enforced and each batch of materials shall be marked in such a manner that it can be related to the Manufacturer's Test Certificate and Delivery Advice Note.

All fittings, expansion compensators, flanges, valves, instruments, filters, gaskets, bolts, control panels and other mechanical plant shall be stored under ventilated cover unless otherwise specifically allowed by the Project Manager

All carbon steel pipe and fittings delivered to the site shall have a suitable corrosion resistant coating to allow the pipe and fittings to be stored outside without weather protection for up to eight months without corrosion damage.

All items listed above shall be stored above grade on material pallets, racks or dunnage such that they may drain.

Electrodes shall be stored in hermetically sealed containers as supplied by the Manufacturers. Once such containers have been opened, electrodes shall be stored so as to avoid absorption of moisture. Any electrodes exposed to moisture in any way shall be scrapped.

Protective coverings of pipe bevels shall not be removed until immediately prior to preparation for welding.

All gaskets shall be stored flat on their own backing plate which shall not be removed until immediately prior to final installation in the pipeline.

All pipe coating materials shall be stored in covered well ventilated stores and handled in such a manner as to prevent damage or contamination which would make them unsuitable for use. Any such material which shows evidence of contamination or deterioration while in the Contractor’s custody due to weathering or any other cause, shall be rejected.

### 5.12.2 Stacking and Storage of Pipes

Line pipe shall be stacked clear of the ground and be adequately protected against damage to pipe or coating, and against accidental rolling. Suitable padding shall be provided between pipe tiers.

The number of tiers in a stack shall not exceed safe limits for the diameter and wall thicknesses of the pipe and the type of coating. Particular attention shall be paid to large diameter thin walled pipe. The ends of pipe stacks shall be adequately blocked to prevent any movement.

Pipes shall not be nested.

### 5.12.3 Pipe Handling

The Contractor shall provide and maintain in good repair all necessary lifting equipement suitable for handling line pipe, pipeline fittings, valves and equipment without damaging bevelled ends, coatings and linings.

End protectors shall remain in place until immediately prior to use.

Line pipe whether bare or coated shall not be rolled or dropped, nor allowed to strike any objects which may damage the pipe.

Calliper hooks shall be properly padded with brake lining. End hooks shall be malleable iron or faced with nickel; shall be smooth faced and shall properly fit the curvature of the inside of the pipe. Where end lifting hooks are used, spreader bars shall be provided for the lifting chains or ropes. In the case of pipes having end caps, the pipes shall be lifted using nylon, canvas or rubber lined slings.

Coated line pipe shall be lifted, lowered or suspended by special end hooks or by wide non-abrasive belt slings of rubber or canvas.

The use of tongs, bare pinch bars, chain slings, pipe hooks without proper padding, ropes, chains or wire cables or any such other handling equipment shall not be permitted.

Coated pipe shall not be permitted to come into contact with ground which could be injurious to the coating. Stepping or walking on coated pipe shall also not be permitted.

All lifting equipment shall have sufficient capacity and reach to lift pipes completely clear of obstacles so as to avoid causing damage to the pipe and its coating. Dragging the pipe along the ground shall not be permitted.

### 5.12.4 Transportation of Materials and Equipment

The Contractor shall take precautions to ensure that no damage is caused to line pipe or other materials during loading, hauling and unloading.

Line pipe and other materials shall be transported on vehicles in a suitable manner. Truck bolsters for handling bare or coated pipe shall be well padded and shall be of suitable width and shape to distribute the pressure on the pipe and pipe coating. Suitable padding shall be provided between layers of pipe. The height of the stack on the vehicle shall not exceed limits appropriate to the pipe diameter and type of coating as recommended by the Pipe and/or Coating Manufacturer.

On completion of loading, pipes and all other items shall be adequately secured with chains and come-alongs in such a manner as to prevent damage to the pipe and coating during transportation. The chains shall be suitably padded where they make contact with the pipe.

### 5.12.5 Stringing of Pipe

Pipes shall be strung only on ground which has been cleared, and where necessary, graded. The Contractor shall ensure that the pipe is strung for the proper placement of pipe, size, weight and grade.

Coated pipe shall not be placed directly on the ground but shall be placed on sand bags or padded skids.

Any damage to the pipe or coating caused during handling, transportation, stacking, storage and stringing, shall be repaired by the Contractor.

Valves, flanged fittings or other equipment with finished surfaces shall be placed on skids to prevent the finished surface from coming into contact with the ground.

### 5.12.6 Pipe Bends

Standard long radius pipe elbows shall be used to make bends in the pipeline unless noted otherwise in the drawings.

Each cut elbow shall have one factory machined bevelled end. That is, each standard pipe elbow cannot be used to make more than two bends in the pipeline.

No other fabricated bends shall be used without the approval of the Project Manager.

### 5.12.7 Alignment of Welded Joints

Each joint shall be aligned such that the offset between the internal surfaces does not exceed the following:

- < 10 mm wall; +/- 1.00 mm
- 10 mm > wall < 13 mm; +/- 1.25 mm
- > 13 mm wall; +/- 2.00 mm

Pipe diameter changes within a pipe specification, using reducing tees or pipe reducers, may require chamfering of the internal circumference of the fitting to adjust the wall thickness to meet the above alignment criteria. Chamfering shall comply with the requirements of the relevant design code.

Wherever possible line-up clamps shall be used for aligning pipe ends. Line-up clamps shall remain in position until completion of the root pass.

On no account shall strips, plate sections or cleats be attached to the pipe for alignment purposes. Where fittings prevent the use of line up clamps, the work shall be set up, properly spaced and supported, and tack welded.

### 5.12.8 Installation of Pipeline Components

The Contractor shall field check all dimensions before preparation of any pipe spools in the shop or field. All fittings including valves and expansion joints shall be positioned in accordance with the drawings and fitted in accordance with the Manufacturer's Specifications and shall be protected at all times from weld splatter, undue heat, dirt and any pressure, force or deflection in excess of Manufacturer's Specification.

Flanges shall be installed with the bolt holes straddling the vertical centreline of the pipe.

When flanges are to be welded into a line the second flange of the pair shall be tacked in position. The alignment and rotation shall then be checked before final welding begins. Where flanges connect to valves, expansion joints or other fittings, a similar procedure shall be adopted. The fitting shall be installed and the flanges bolted up before the final joint is tacked and welded. Where such fittings are not available at the time of pipeline construction the Contractor shall fabricate a spacer piece equal in thickness to the fitting face to face dimension and, bolt this into the line in place of the fitting. The Contractor shall site verify the bolt hole alignment of all flanges already installed before welding mating flanges.

All valve stems shall be adequately protected with grease at all times to avoid corrosion.

Valves in piping are to be located so as to be operable from the normal working areas and platforms. Handwheels shall be orientated accordingly. No valve shall be installed with its operating spindle gland below the horizontal centre line so as to

avoid dirt entering the gland and to ensure complete drainage. Butterfly valves shall not be installed with the valve shaft in the horizontal without the written approval of the Project Manager.

Valves installed in “site-run” piping shall be located so as to be easily accessible from ground level or from walkways and platforms. Such valve locations shall also be subject to the written approval of the Project Manager.

Butt and socket welded valves shall be in the closed position when welded into pipelines and shall remain closed until the valve has returned to ambient temperature.

All flanged surfaces and grooves shall be clean, dry and unmarked prior to make-up. Gaskets shall be new, clean and free from defects. Stud bolts shall have a full, continuous thread and be long enough to extend a minimum two full threads beyond each nut when tight.

Nickel based anti-seize compound shall be used on the threads of all flange bolts and all exposed threads shall be liberally coated with high temperature grease after installation.

Exposed portion of holding down bolts on concrete pads and plinths for supports, anchors and equipment shall be greased and covered before casting into place.

Exposed ends of instrument connections shall be plugged.

### 5.12.9 Installation of Compensators / Expansion Joints

All expansion joints shall be hydrotested to 1.5 times the design pressure in the factory before shipment and shall be provided with test certificates demonstrating compliance.

Expansion joints shall not be installed until line testing including hydrostatic testing has been successfully completed on the line section. The expansion joints shall then be installed in the line with cold pull set within ± 1 mm of the length shown on the drawing, and the welds on either side of the compensator shall be 100 per cent radiograph tested. Expansion joints shall be installed in the positions shown on the drawings.

Extreme care shall be taken in setting up the pin angle which shall be within ± 0.2 degrees of the angle shown on the drawings. The Contractor shall demonstrate the accuracy of the setting to the Project Manager before welding the compensator into place.

The angle of the single incline support between the compensators shall be checked and set within ± 0.2 degrees of the angle shown on the drawing. The Contractor shall demonstrate the accuracy of the setting to the Project Manager before welding the compensator into place.

### 5.12.10 Buried Pipes

All buried steel pipes shall be adequately protected against corrosion by approved Denso tape, Polyken tape or other equivalent system. The Contractor shall submit the proposed system and procedures for site application for approval. The protective coating shall be applied preferably in the factory prior to stringing the pipes along the pipe route except that site joints shall be wrapped insitu. There shall be at least 25 mm overlap when wrapping around pipes.

All protective coatings shall be applied and inspected in accordance with the Manufacturer's specification.

The bed where the buried pipe is to be installed shall be filled with a layer of sand or stone free soil. Backfill shall be free of sharp objects and stones. If need be the pipe shall be covered with a polythene sheet.

Where non-metallic piping is installed below ground, indicator signs shall be installed at each end of the pipe and at each change in direction to show where the pipe is located. Pipe shall be installed at least 700 mm below grade. A signal strip

shall, with integral metal wire shall be placed over the entire buried length of the pipe, 100 mm above the pipe, during backfilling operation to enable the pipe to be remotely located later.

Buried non-metallic pipework shall be laid bedded in and back filled with clean sand of a depth recommended by the manufacturer but not less than 300 mm. Special care shall be taken with the sub-base beneath trenches for non-metallic pipework to ensure that the piping is installed in cut material. Where this is not possible, all materials used shall be structural fill compacted to ensure that differential settlement causing potentially damaging shear forces on the buried pipework is avoided. Great care is to be taken when back filling to ensure that stones and other sharp objects are excluded from the back fill material and that compaction equipment is not allowed to impact on the pipe. Where above ground pipework is non-metallic material, it shall be suitably supported in accordance with manufacturer's requirements and protected from damage from impact or other accidental causes. Pipe joints shall be made only by suitably qualified and experienced tradespersons to a procedure to be approved by the Project Manager

Jointing and repair procedures for non-metallic piping shall be developed by the Contractor and included in the plant maintenance manuals. Special tools for the repair of the piping during the life of the Plant shall be included with the Special Tools.

#### 5.12.11 Cold Pull

Where cold pull (cut short) shall be used, pipe shall be at ambient temperature when cold pull measurement and set up is undertaken.

All work on supports and shoes between adjacent pipe anchors, including grouting and painting, shall be completed prior to the application of cold pull to the superimposed pipe.

Cold pull shall be set up within +/- 1mm of the required gap length and shall be made only after the pipe has been supported. Temporary supports may be used to hold up the pipe during cold pull.

#### 5.12.12 Identification

Identification bands shall be painted on all finished piping in accordance with PB-03-75-94, Section 7 - Painting and Inscriptions on Piping. Bands shall be applied either to the finished painted pipe or the insulation cladding as appropriate. The identification bands shall be applied at regular intervals and to both sides of any wall or floor penetration.

## 5.13 Equipment Installation

#### 5.13.1 Installation Requirements

All installation of mechanical equipment shall comply with the manufacturer's installation instructions, construction Drawings and Specifications as applicable, and shall be subject to the Project Manager's approval.

Unless otherwise specified, all equipment such as vessels, tanks, and pumps shall be set in line to true horizontal and vertical planes.

Connections with gaskets shall be tightened up evenly all around to ensure uniform stress and a tight seal over the entire gasket surface. Final tightening shall be to the recommended torque using a calibrated torque wrench.

#### 5.13.2 Equipment Storage and Preparation for Installation

Equipment shall be stored in a clean and dry environment in its original shipping crates, or with original shipping protectors, until it is prepared for installation.

All equipment shall be thoroughly checked internally and externally for cleanliness, presence of foreign matter and any internal stays and bracing used for shipping. Greasy surfaces shall be washed with suitable non-flammable solvent and wiped dry. All shipping braces and stays shall be removed prior to installation of any equipment unless they are required for installation. In any case, they shall be removed prior to the use of any equipment. Check and tighten bolts if necessary, in case they have come loose during shipment.

All plant in storage shall be inspected regularly. Unless specified otherwise, rotating plant shall be rotated once every week, whether in storage or installed on its permanent mounts.

Bearing housings, gear reducers and any other lubricated parts of equipment shall be filled with flushing oil containing a rust inhibitor.

Any deterioration such as rust or physical damage as a result of shipment or storage prior to installation shall be reported to the Project Manager with proposed remedial action to correct the deterioration or damage.

Temporary covers to pump connections, pipe ends and the like shall be left in place for as long as practicable.

### 5.13.3 Craneage and Handling

The Contractor shall ensure that the craneage and handling of all plant and equipment is carried out in a safe and workmanlike manner. Manufacturer's lifting instructions shall be adhered to, including the use of all proper lifting and jacking points.

All lifting operations shall be conducted with adequate supervision. For specific lifting operations, such as installation of major plant items, the Contractor shall prepare a special lift procedure for review by the Project Manager.

### 5.13.4 Workmanship

Adjustable spanners shall not be used without Project Manager’s approval. Correctly-sized spanners and tools of an appropriate quality shall be used. Chain hoists and similar shall be certified.

Where special tools are provided with an item of equipment, they shall be used as intended, maintained and secured by the Contractor until handed over to the Project Manager in as-new condition.

When welding is carried out adjacent to rotating or other special equipment, that Plant shall be protected from weld splatter by suitable non-flammable covers. Under no circumstances shall welding current flow through rotating equipment or equipment containing electronics.

### 5.13.5 Tolerances

Unless otherwise required by the Plant item manufacturer, the following tolerances shall be achieved as a minimum:

| | | |
|---|---|---|
| Baseplates, etc. for | Height | ±1.0 mm |
| rotating equipment | Level | ±0.25 mm/m |
| | | max 1.0 mm |
| Baseplates, etc. for | Height | ±1.0 mm |
| static equipment | Level | ±0.50 mm/m |

| | | |
|---|---|---|
| couplings | axial gap | 0.25 mm |
| | angular & parallel<br>measured on coupling hub | ∅100 mm shaft: 0.05 mm<br>∅150 mm & above: 0.10 mm |
| Flange faces, general | all sizes | 1 mm parallel across face<br>1 mm unrestrained axial |
| | bolt hole offset, all planes | 1.0 mm |
| Flange faces, for<br>connection to<br>fixed nozzles | all sizes<br><br>bolt hole offset | 0.25 mm parallel across face<br>0.25 mm unrestrained axial<br>0.5 mm |

### 5.13.6 Stationary Equipment

#### 5.13.6.1 Foundations

As soon as practicable but not less than one week prior to the installation of an item of equipment, the Contractor shall check the dimension accuracy of the foundations.

The Contractor shall ensure all bolt boxes and tubes are plugged with sacking or similar material to prevent the ingress of foreign matter. Similarly, holding down bolts shall be well greased over the exposed threaded portion. Parts of the anchor bolts to be cast in concrete or grout shall not be greased.

#### 5.13.6.2 Preparation

Prior to placing equipment on the plinth or foundation, all bolts on the equipment shall be checked and tightened if necessary, in case they have come loose during shipment.

Any items removed by the Contractor to facilitate dimensional accuracy checks shall be replaced and not removed again until it is ready to install equipment on the foundation.

The bearing surfaces for all equipment shall be thoroughly cleaned prior to installation of the equipment.

#### 5.13.6.3 Installation

Once the equipment has been placed, the base shall be shimmed up by means of stainless steel plates and shims until the equipment is plumb and level at the proper height as specified in the drawings.

All tolerances in alignment and levelling, and the quality of work for each class and stage of work and piece of Plant shall be subject to the Project Manager's approval.

No grouting shall be made until the level, plumb, and alignment of the equipment has been reviewed and approved in writing by the Project Manager.

Grout shall be non-shrink and mixed and poured in accordance with the manufacturer's instructions. Any formwork required to contain the grout shall produce a neat and tidy finish to the cured surface. Air release holes shall be used as required when placing grout under large flat surfaces. As far as practicable, exposed edges shall be chamfered.

After the grout has cured, all holding down bolts shall be tightened to the correct torque. Documentation shall be provided for each piece of equipment that records holding down bolt torque.

#### 5.13.6.4 Piping Connections

All pipe flanges connecting to stationary equipment shall be correctly aligned such that no additional forces or moments other than weight loads from the attached piping shall be applied to the equipment nozzles during tightening of the flange bolts.

All such connections shall be inspected and approved by the Project Manager prior to installation and tightening of flange bolts.

In no case shall the piping 'spring' on release of the flanged bolts, unless cold pull has been specified on the construction drawings.

### 5.13.7 Rotating Equipment

#### 5.13.7.1 Foundations

As soon as practicable but not less than one week prior to the installation of an item of equipment, the dimensional accuracy of the foundations shall be confirmed.

The Contractor shall ensure all bolt boxes and tubes are plugged with sacking or similar material to prevent the ingress of foreign matter. Similarly, holding down bolts shall be well greased over the exposed threaded portion. Parts of the anchor bolts to be cast in concrete or grout shall not be greased.

#### 5.13.7.2 Preparation

Prior to placing equipment on the plinth or foundation, all bolts on the equipment shall be checked and tightened if necessary, in case they have come loose during shipment.

The support surfaces for all equipment shall be thoroughly cleaned prior to installation of the equipment.

#### 5.13.7.3 Installation

The Contractor shall ensure there are free passages to priming connections, cooling water supply to bearings, lubrication piping to bearings, stuffing box jackets and sealing glands of all horizontal and vertical rotating plant.

Once the equipment has been placed, the base shall be shimmed up by means of stainless steel plates and stainless steel shims until the equipment is plumb and level at the proper height as specified in the drawings. Where used, jacking screws shall be backed off before the holding-down bolts are tightened.

All work, including alignment and tolerances, shall be in accordance with the manufacturer's installation instructions, construction Drawings and Specifications as applicable.

All tolerances in alignment and levelling, and the quality of work for each class and stage of work and piece of plant shall be subject to the Project Manager's pre-approval.

No grouting shall be made until the equipment has been levelled, plumbed, and aligned by Contractor and reviewed and approved in writing by the Project Manager.

After the grouting has cured, the Contractor shall tighten all holding down bolts. No piping is to be connected until after grouting and final tightening of holding down bolts.

Prior to giving approval for final coupling of rotating equipment, if requested by the Project Manager, the Contractor shall break all flanged piping connections to the driven equipment and demonstrate the flange set up tolerances are within specification.

All couplings on rotating equipment shall be uncoupled for direction of rotation checks.

#### 5.13.7.4 Seal Packing

The Contractor shall check all stuffing boxes for sufficient rings or packing and for tightness of packing gland draw-up nuts. Packing lubrication shall be checked for cleanliness and supply. Additional lubricant of the same type as the original shall be added if required.

Drains from stuffing boxes, casing vents, etc., shall be run neatly to the nearest convenient drain, or as otherwise shown on the drawings.

#### 5.13.7.5 Oil and Lubricants

The Contractor shall provide all lubricants and greases for the protection during shipment and first filling of equipment of Site including flushing oils where necessary.

The Contractor shall ensure that the oil and lubricant quantities in the equipment are in accordance with the manufacturer's instructions.

Only oils and lubricants recommended by the manufacturer and approved by the Project Manager shall be used.

The Contractor shall furnish a complete schedule of recommended oils and other lubricants, for all components of the plant. It is preferred that a single supplier be selected for all lubricants and that all lubricants are readily available in Dominica.

The number of different types of lubricant shall be kept to a minimum. The schedule of lubricants shall be incorporated in the Operating and Maintenance Manuals.

#### 5.13.7.6 Piping Connections

All pipe flanges connecting to rotating equipment shall be correctly aligned such that no additional forces or moments are applied to the equipment nozzles during tightening of the flange bolts.

In no case shall the piping 'spring' on release of the flange bolts, unless cold pull has been specified on the construction drawings.

### 5.13.8 Final Inspection

The Contractor shall open, or make accessible for inspection any item of equipment as required by the Project Manager, prior to the equipment being placed in operation.

During commissioning the Contractor shall provide manpower to carry out maintenance type work as required under the Project Manager's directions.

### 5.13.9 Documentation

The Contractor shall provide documentation for each item of equipment to document all alignments and checks carried out. Where applicable, the information shall include:

- Packing checks
- HD bolt torque
- Final coupling alignment
- Connection alignments
- Bearing oil brand/grade
- Bearing oil levels

The draft documentation shall be available at the commencement of the job, and will become part of the as-built information upon completion.

## 5.14 Insulation and Cladding

The insulation system comprises total enclosure of the piping system with insulating material which is to be protected by suitable weatherproof aluminium cladding. The Contractor is responsible for the material supply and installation.

Insulation materials for piping and vessels shall be non-corrosive and suitable for application to steel surfaces.

Insulation fitted to stainless steel shall be chloride free.

Alternative equivalent materials and application methods may be proposed by the Contractor, but shall be used only with prior written approval of the Project Manager.

### 5.14.1 Materials

The following systems shall be used for insulation of piping and equipment:

| Service | Location | Material |
|---|---|---|
| Piping system, normally hot | Cross-country | Rigid calcium silicate |
| Piping system, normally hot | Fenced plant area, top of pipe within 1.5m of grade | Rigid calcium silicate |
| Piping system, normally hot | Fenced plant area, top of pipe >1.5m above grade | Rigid calcium silicate |
| Piping system, normally cold | - | As for hot pipe, but painted underneath |
| Vessels, normally hot | - | Fibreglass |
| Vessels, normally cold | - | Painted under Fibreglass |

All materials shall be new.

The Contractor shall submit full details of the proposed insulation system(s) (materials, fixings and accessories) to the Project Manager for review and approval within 30 days of Commencement Date. The submittal shall include the manufacturer's data sheets or technical literature showing compliance with the applicable codes and this Specification.

#### 5.14.1.1 Calcium Silicate

Calcium silicate or equivalent rigid, impact-resistant material approved by the Project Manager, shall be supplied in preformed sections to BS 3958: Part 2. It shall be suitable for use at temperatures up to 317°C with a thermal conductivity not higher than 0.07 W/mºC at 150°C mean temperature.

#### 5.14.1.2 Cladding

Insulation material shall be clad with aluminium sheet to AA 5005 H14 or approved equivalent. The cladding thickness shall be 0.9mm with a plain surface finish.

Thicker material may be required for cladding fittings, flanges, valves and miscellaneous equipment.

Provision shall be made to prevent electrolytic action between the cladding and dissimilar metals.

The cladding exterior shall be coated with a factory-applied colour coating of Dark Forest Green in order to blend into the natural environment and reduce visual intrusion. The colour coating shall be resistant to the geothermal environment, solar radiation and weathering for at least 10 years. The Employer will confirm the proposed colour scheme prior to Contract Commencement. Full details of the proposed colour coating system, shall be submitted to the Project Manager for approval within 30 days of Commencement Date.

#### 5.14.1.3 Removable Insulation Boxes

Removable insulation boxes shall be used on flanges, valves and access points requiring inspection and maintenance. The boxes shall have fibreglass blanket or equivalent fillers with aluminium cladding to contain the loose fibres. Strengthening ribs shall be used on large surfaces, and drain holes shall be drilled in the bottom of each box at the lowest point.

The boxes shall be in two or more parts with the insulation fixed to the box parts for easy removal and replacement.

The parts shall be fixed together with quick release toggle clips. Where insulation boxes overlap pipe insulation, the gaps shall be sealed with a suitable sealant.

The tops of the boxes shall be sloped for drainage.

#### 5.14.1.4 Wire

Wire shall be a minimum of 1.6 mm diameter galvanised steel.

#### 5.14.1.5 Bands

Banding material shall be 316 stainless steel 12 mm wide, 0.5 mm thick for all pipe sizes greater than DN400, and 12 mm wide, 0.4 mm thick for all pipe sizes DN400 and smaller.

#### 5.14.1.6 Fittings and Component Jackets

All elbows, tees, caps and other components shall be provided with pre-formed, shop or field fabricated aluminium cladding.

#### 5.14.1.7 Screws

Screws shall be Type 316 stainless steel pan head or hex head or hex head slotted self tapping sheet metal screws not less than 2.5 mm by 19 mm long.

#### 5.14.1.8 Clips

“S” clips shall be 316 stainless steel and either be pre-formed stainless steel clips or field fabricated. The clips shall, and be at least 19 mm wide and 0.5 mm thick.

#### 5.14.1.9 Sealing Compound

A high temperature, non-shrinking, flexible silicone sealant shall be used for sealing joints, edges, and penetrations in jacketing. Sealing of cladding shall use G.E. Silicone or approved equal. The colour of the silicone shall match the colour of the aluminium cladding as closely as possible and shall be resistant to ultra-violet radiation.

#### 5.14.1.10 Pop Rivets

Blind pop rivets shall be Monel or 316 stainless steel, with both shaft and rivet head made of the same material. Minimum size is 4 mm diameter by 8 mm long.

#### 5.14.1.11 Handling and Storage

All insulating materials shall be delivered to the site and stored in a safe, dry place with appropriate labels and/or other product identification. Manufacturer's storage instructions shall be followed.

The Contractor shall make himself familiar with the manufacturer's handling data and shall ensure that the handling of all material is carried out in accordance with those instructions.

Insulating materials must be kept dry and free of water at all times. If any insulation material becomes wet the Contractor shall not install such material. Should any insulation material already installed become wet, the Contractor shall remove said material and replace with new materials.

### 5.14.2 Piping

#### 5.14.2.1 General

Any piping which is normally cold shall be completely painted in accordance with this Specification prior to the application of insulation and cladding.

All cladding shall be installed commencing at low points and working uphill, irrespective of the fluid flow direction.

Lifting lugs, clips and hangers shall be left free of the lagging and cladding

All gaps due to metal protrusions through insulation such as pipe shoes, anchors, lugs, drain valves, etc. shall be clad and sealed with suitable sealing compound. All cut-outs resulting from protrusions will be made as close as possible to the fitting (3 mm maximum clearance) to minimise heat loss and to provide a neat appearance. The Contractor shall install material on the pipeline such that the insulation forms a continuous coating.

All bands shall be drawn up by mechanical tightening devices, and the ends shall be secured by suitable mechanical fasteners of a form which will permit a flat joint to be made.

#### 5.14.2.2 Straight Pipe Insulation

Insulation shall be applied to clean, dry, bare or painted pipe using staggered joint construction, and shall be secured in place with galvanised wire at 300 mm centres. However, each section shall have at least two wires. The wires shall be tightly twisted and ends embedded into the pipe insulation.

On vertical pipes, DN 300 and larger, insulation material shall be positively supported at regular intervals by insulation supports fixed to piping with stainless steel bands. The supports shall not extend beyond the insulation layer. This spacing shall not exceed 5.0 m of vertical rise starting at 0.3m into a vertical run. An insulation support shall be installed a distance away from any flange equal to the bolt length plus 75 mm.

#### 5.14.2.3 Straight Pipe Cladding

Aluminium cladding shall be applied with circumferential and longitudinal seams beaded and lapped as shown on the drawings. Cladding shall be secured in place with bands or as specified. Longitudinal seams shall be placed near the bottom of the pipe with overlap in the direction to shed water. The riveted joints shall alternate on successive sections of cladding, 20 mm left and right of the bottom centre line. The longitudinal seams shall be weatherproof along the entire length of the jacket. For vertical and incline pipes, the longitudinal seam shall be sealed with a suitable sealant to water-proof the seal.

Aluminium cladding shall be pre-rolled to the requisite diameter, including capillary break crimping. These may then be sprung over the pipe and the longitudinal seam fastened with pop rivets or screws. The Contractor shall ensure the cladding is pulled tight against the insulation material.

Longitudinal seams shall be located parallel to the centreline of the pipe. Seams shall have screws or rivets at 150 mm maximum spacing.

All insulation cladding penetrations such as clips, supports, etc. shall be clad and sealed with sealing compound to prevent entrance of moisture and water. Sealant should be applied over all screws and rivets to prevent leakage onto the insulation.

Bands should be used in strategic places. On vertical or inclined piping, bands on permanent jacketing shall be maintained in position with screws.

Circumferential joints should be left free to allow for thermal expansion movement. These joints should have suitable allowance in the length of overlap for thermal expansion and should not have sealant applied to them.

All vertical or inclined piping shall have circumferential seams overlapping downward to shed water and moisture.

Insulation must be clean and dry prior to installation of cladding.

#### 5.14.2.4 Bends

Bends shall be formed into lobster backs with segments no larger than 100 mm on the inside radius. Each segment shall include capillary breaks. All joints shall be sealed with a suitable sealant.

Inspection ports shall be provided through the insulation and cladding at selected pipe elbows as specified in the drawings or directed by the Project Manager.

#### 5.14.2.5 Insulation Adjacent to Flanges

Insulation adjacent to flanges shall be installed in a manner to permit removal of flange bolting without damage to the insulation. The insulation shall be stopped short of the flanges by a distance equal to the stud or bolt length plus 25 mm on each side of the flange. The flanges shall be covered with a removable insulation box.

#### 5.14.2.6 Valves and Special Fittings

Custom made insulation boxes shall be fitted to all valves and special fittings.

The upper part of valve gland packing shall be left un-insulated.

#### 5.14.2.7 Terminus Bevels

Metal terminus bevels shall be provided wherever insulation is terminated on piping. Pipe cladding shall be bevelled at 45°. Edges shall fit under the adjacent pipe covering jacket.

#### 5.14.2.8 Penetrations

Pipe insulation shall be extended without interruption through walls or other piping penetrations.

### 5.14.3 Vessels

#### 5.14.3.1 Insulation Installation - Sidewalls

Vessels shall be insulated with fibreglass.

Insulation shall be supplied in blanket form. Insulation shall be applied to a clean, bare, dry surface using staggered joint construction, and shall be secured in place with galvanised wire at no greater than 250 mm centres. However, each insulation section shall have at least two wires. The wires shall be tightly twisted and ends embedded into the insulation.

On irregular surfaces, blanket insulation shall be applied to fit snugly around surfaces and secured with galvanised wire.

#### 5.14.3.2 Insulation Installation - Heads

Insulation for vessel heads shall be installed to fit snugly, with all joints butted together. Insulation shall be bevelled to prevent “V” - shaped voids between pieces. Insulation sections shall be secured using specified banding material attached to float rings from which they shall extend radially and be secured to the anchor ring. Spacing at anchor ring shall not exceed 300 mm on centres.

#### 5.14.3.3 Cladding Installation - Sidewalls

Flat plain aluminium cladding 0.9 mm thick shall be used and all longitudinal seams shall be lapped a minimum of 75 mm and shall be secured in place with specified bands. All circumferential seams shall be lapped 75mm. “S” clips shall be installed at a maximum spacing of 600 mm on centres to support sheets in circumferential laps.

Lock seams shall be used on vertical laps for flat metal and no screws shall be used.

Insulation must be clean and dry prior to installation of cladding.

#### 5.14.3.4 Cladding Installation - Heads

Flat plain aluminium cladding 0.9 mm thick shall be applied to the heads. Sections shall overlap to shed water and be secured with sheet metal screws on 100 mm centres. Sections shall overlap shell cladding by approximately 100 mm on vertical vessels and shall be secured with stainless steel bands. Each band shall have two band loops made of the same material to keep the band from slipping down. Loops shall be located 180 $^{0}$ apart and secured with two sheet metal screws each. All laps shall be sealed.

Insulation must be clean and dry prior to installation of cladding.

#### 5.14.3.5 Care of Work

The Contractor shall ensure that his work force does not walk on, or otherwise load the aluminium cladding so as to cause permanent damage.

The Contractor shall make good any such damage.

#### 5.14.3.6 Inspection and Testing

The Contractor shall provide the Project Manager with an installation programme, and fully cooperate with the Project Manager to permit regular inspections to be carried out after each stage of the work.

Cladding shall not be installed until the insulation has been inspected by the Project Manager.

The Contractor shall provide samples of any materials used to the Project Manager for testing, upon request.

#### 5.14.3.7 Maintenance Recommendations

The Contractor shall provide the Project Manager with a summary of manufacturer's and installer's recommendations for inspection and treatment of the insulation to ensure the initial performance of the material will be maintained. Where applicable this will include methods for repair and replacement to be adopted should damage occur during service or overhaul of the piping or equipment.

# 6. Electrical Requirements

## 6.1 General Electrical Requirements

### 6.1.1 General

The major components within the electrical scope of work are shown on the conceptual single line diagrams, which show the Employer's indicative requirements and which are subject to verification and detailed design by the Contractor.

The electrical system shall be designed to meet all requirements of the Dominica Generation Code.

The electrical system shall be designed to operate reliably and safely under both normal and emergency conditions. Control and protection logic shall incorporate all reasonable levels of intelligence and redundancy. The system shall be fully integrated at all voltage levels and interfaced with the DCS to provide optimum control and monitoring capabilities, including bus voltages, breaker and MCC states, feeder and load currents and major individual loads. Interface points shall be extended to all voltage levels and priority equipment to provide a coherent system.

All critical support systems (pumps, fans, compressors, DC systems etc) shall be fed from the Unit and/or common services boards. The voltage and capacity of these boards shall be determined during detailed design. The expected voltage of critical equipment is LV AC and therefore the critical feeders shall have direct supply from the emergency diesel generator unit. Normal feed to the boards shall be via the LV switchgear. The concept shall be to provide a means of safe, orderly shutdown of major equipment following a Power Plant trip. Turbine-generator lube oil and turning gear, facility lighting, life support systems, fire protection and related systems shall be included in the critical list of equipment. The emergency system shall be available on a continuous basis.

Electrical and mechanical interlocks shall be applied throughout the entire system to ensure a safe operating environment and to prevent mal-operation and plant damage. MV Circuit breakers shall be electrically interlocked with associated isolators and isolators shall be electrically interlocked at least with associated earth switches. Control systems for circuit breakers and motors shall include manually operated switches and indicators that override all automated functions. Status indication and alarms shall be provided in each scheme to notify the operator of equipment status.

All switchgear and motor control centres shall be located within environmentally controlled spaces.

The Contractor shall employ standard equipment where possible, which provides optimum levels of convenience and economy, but does not compromise safety, reliability or efficiency. The basic design philosophy shall provide the most effective measures to ensure high reliability and low maintenance.

Ratings given in the drawings provided are indicative only. The Contractor shall determine actual ratings for review by the Project Manager during the detailed design phase.

The electrical installation shall provide safe and reliable means of transmitting generated power to the MV transmission system, and to the station auxiliary power supply system under all anticipated operating conditions. The electrical system shall be simple to operate and maintain and shall be provided with the degree of redundancy which will permit the plant to meet its guaranteed availability.

The electrical equipment shall be designed on the basis of power system studies that shall include the following as a minimum:

1. Load flow studies
2. Short circuit fault duty calculations
3. Motor starting studies

4. Electrical protection studies
5. Transient stability studies under steady and transient state conditions
6. Projected voltage impulse levels due to lightning or switching operations
7. Voltage profiles
8. Harmonics analysis
9. Earthing studies

All studies shall be undertaken under a number of scenarios that shall include the most onerous operating and environmental conditions expected during the life of the plant. Load flow studies shall include equipment loadings and system voltage levels, and short circuit studies shall include both 3 phase and phase to earth fault studies, all under the most onerous conditions. All study reports shall include conclusive requirements for equipment and detail design. All such studies and calculations shall be submitted as comprehensive reports for review by the Project Manager before commencement of the detail design of those systems.

The electrical protection study reports shall be submitted for approval by the Project Manager and shall comprehensively explain all aspects of all protection systems. They shall include protection philosophy, relay and instrumentation diagrams, protection relay types and functionality, CT and VT rating calculations, cable burden calculations, scheme descriptions, protection settings and performance descriptions, internal relay and scheme logic diagrams, and protection relay programme information. This information will be reviewed by the Project Manager, DOMLEC and other authorities.

The insulating and dielectric materials used in all electrical equipment shall be non-toxic and shall not contain compounds that are persistent and hazardous environmental contaminants, such as polychlorinated biphenyls (PCBs) or asbestos.

The plant shall be suitable for the ambient conditions as defined including the site altitude.

The Contractor shall provide drawings defining the electrical classifications throughout the Plant. Such classifications shall include considerations of the presence of $H_2S$, reference 6.1.11.

### 6.1.2 Electrical Supply

#### 6.1.2.1 Operating Voltages

The operating voltages for the plant and their nomenclature are defined as follows for the purposes of this specification.

| Description | Abbreviation/ Nomenclature | Voltage Level | Frequency | Comment |
|---|---|---|---|---|
| Medium Voltage | MV | 11kV | 50Hz | |
| Low Voltage (AC) | LV | 415V (3phase) | 50Hz | Nominal low voltage |
| DC Voltage | 110V | 110V | DC | Application specific |
| DC Voltage | 48V | 48V | DC | External communication systems |

| | | | | |
|---|---|---|---|---|
| DC Voltage | 24V | 24V | DC | Plant control systems |

#### 6.1.2.2 Supply Arrangements

For each Unit, auxiliary power will be supplied via a MV/LV transformer.

For each Unit, a LV Auxiliaries Switchboard shall supply Unit low voltage loads.

A LV Common Service switchboard shall be configured such that it can be fed from all Unit auxiliary switchboards with interlocked feeder circuit breakers.

The LV Essential Service switchboard shall be able to be fed by an emergency diesel generator in a situation where one or more units is off and the MV transmission voltage is not available.

The LV Essential Service switchboard is to include feeders to the LV supplies within the MV switchboards, SGS power distribution and any other equipment requiring essential power for the safe operation of the plant.

The SGS LV supplies shall be derived from the LV Common Service board.

### 6.1.3 Construction Power Supplies and Supplies to Employer's Facilities

Construction power for the site shall be provided by the Contractor via silenced diesel generator(s).

### 6.1.4 Operating Voltages for Equipment

The electric equipment shall be designed for operation at the following voltages:

| Item | Voltage | System | Freq. |
|---|---|---|---|
| Motors less than 200 kW | LV | 3 phase, 3 wire | 50 Hz |
| Motor operated valves | LV | 3 or 1 phase, 3 or 2 wire | 50 Hz |
| Non-process motors less than 0.5 kW | LV | 1 phase, 2 wire | 50 Hz |
| Motor control circuit | LV | 1 phase, 2 wire | 50 Hz |
| Lighting system | LV | 3 or 1 phase, 3 or 2 wire | 50 Hz |
| Welding outlets | LV | 3 phase, 4 wire | 50 Hz |
| General service socket outlets | LV | 1 phase, 2 wire | 50 Hz |

| Item | Voltage | System | Freq. |
|---|---|---|---|
| AC Supplies for instruments and shutdown circuits | LV | 1 phase, 2 wire, ex UPS | 50 Hz |
| Tripping & closing high-voltage and medium-voltage CB's and relays | 110V | 2 wire | DC |
| DC motors | 110V | 2 wire | DC |
| Low-voltage switchgear, CB's and relays | 110V | 2 wire | DC |
| DCS Inputs and Outputs | 24V | 2 wire | DC |

All systems shall include solid earth

### 6.1.5 Deviations and Variations in Supply Voltage

During normal operation, the voltage at equipment terminals shall not deviate from the equipment nominal voltage by more than 5 per cent under steady-state conditions. All loads shall be balanced such that the negative phase sequence components of voltage and current, at any point in the system are minimised.

During starting or reaccelerating of a motor, either alone or in a group, the voltage at the motor terminals shall not vary more than +10 per cent, -10 per cent from nominal voltage. Transient voltage variations occurring at switchgear busbars during motor or group motor starting/acceleration shall be such as to maintain a voltage at all other equipment terminals of at least 90 per cent but not more than 110 per cent of equipment nominal voltage. Voltage variations and deviations shall have no detrimental effect on plant operations.

Other voltage deviation limits on feeder circuits are:

- Motor cables at full load — 2.5 per cent
- Lighting circuits, i.e., from LV distribution board to furthest lighting fixture — 2.5 per cent
- Feeders to instrument supply equipment — 1 per cent

The following criteria shall apply with respect to transient voltage depressions or interruptions such as those arising as a consequence of system short circuits or disturbance from the MV system:

1. Voltage depressions resulting in equipment terminal voltages down to 80 per cent of equipment operational voltage shall not affect plant operations.

2. Voltage depressions resulting in equipment terminal voltages below 80 per cent of equipment operational voltages for a duration of not more than 0.2 seconds shall, on voltage restoration, result in the instantaneous re-energisation of critical equipment.

3. Voltage depressions resulting in equipment terminal voltages below 80 per cent of equipment operational voltage for a duration of between 0.2 and 2 seconds shall, on a voltage restoration, result in a sequential re-energisation of all critical equipment automatically.

4. Voltage depressions resulting in equipment terminal voltages below 80 per cent of equipment operational voltage for a duration exceeding 2 seconds shall result in the starting of the emergency diesel generator. If the normal source of supply has not been restored by the time the generator has achieved acceptable voltage and frequency, then changeover to the generator source shall be automatic. Thereupon, essential supplies shall be sequentially re-energised by automatic means. Resetting of supplies to normal voltage after tripping to emergency diesel generator supply shall be manually initiated.

On instantaneous or sequential re-energisation of equipment, the voltage at equipment terminals shall not be less than the manufacturer's minimum recommended equipment operational voltage.

Equipment having special requirements with respect to variations in voltage level and/or waveform shall be provided with a power supply that is adequately power conditioned with no interruptions.

### 6.1.6 Supply Waveform

Electrical loads having non-linear characteristics so as to produce voltage and current waveform distortion of a magnitude detrimental to the lifetime or performance of Plant electrical equipment shall not be utilised unless appropriate measures are taken to render harmless the effects of such distortion, e.g. by power conditioning, isolation transformers, etc.

Harmonic voltage distortion at any point in the electrical systems within the Plant shall, in any event, not exceed the following limits:

| Switchgear Busbar Supply Voltage | Total Harmonic Voltage Distortion | Individual Harmonic Voltage Distortion | |
|---|---|---|---|
| | | Odd | Even |
| LV | 3% | 2% | 1% |
| MV | 3% | 2% | 1% |

Equipment that produces a sustained direct current component in the alternating current power supply system shall not be utilised.

Harmonic voltages and currents which may be induced in the Dominican supply system from the Plant shall be less than the limits recommended by the relevant IEC standards (as specified in the Dominica Transmission and Distribution Supply Code).

### 6.1.7 Voltage Control

The plant generator output shall ensure the following:

1. That the phase currents at all connection points are sufficiently balanced to limit negative sequence voltages to less than 1per cent,

2. That their contribution to voltage harmonic distortion at their points of connection is less than 3 per cent, and

3. That voltage dips caused by occasional motor starting shall be limited to 5 per cent below normal voltage at any connection point.

### 6.1.8 Power Station Power Models

The Contractor shall provide the plant details required to develop a plant model sufficient to undertake power system modelling. The model shall include the block diagrams, parameters and details for the following:

1. Generators (impedances, inertia etc.)
2. Prime-mover
3. Governor
4. AVR & Power System Stabiliser

The plant models shall be provided in Laplace representation block diagram form. The models shall follow typical power system modelling practice, as outlined by the IEEE, for example “IEEE ST421.5-2005 IEEE Recommended Practice for Excitation System Models for Power System Stability Studies”. The Contractor shall liaise with DOMLEC to provide models that are compatible with DOMLEC systems and existing information and models.

During commissioning the Contractor shall undertake tests and comparisons and provide a Station Model Verification Report to demonstrate that the model information provided represents the physical plant installed. The report shall demonstrate:

1. AVR response (off-line and on-line)
2. PSS response
3. Governor response (off-line and on-line)
4. Stable plant behaviour
5. Response comparisons between the plant model and the physical plant

The Contractor will provide an electronic copy of the power system plant model and the test data captured during the tests.

### 6.1.9 3 Phase Rotation and Phase Disposition

In general, phase rotation shall be per IEC standards unless noted otherwise. The phase vectors of all voltages shall be in accordance with the relevant Dominica standards. Metal-clad switchgear and transformers will be arranged to facilitate uniform phasing. Incoming and outgoing phases will be identified (as viewed from the front), as phase A, B, and C, left to right and top to bottom, or front to back, as applicable. All bus bars and out-going feeders and circuits shall be colour coded in accordance with Dominica requirements.

The Contractor shall confirm the requirements of the Dominica grid and comply with the specific requirements.

### 6.1.10 System Earthing

The existing DOMLEC 11kV system is solidly earthed.

System earthing for individual systems shall be as follows:

| System Voltage | Earthing |
|---|---|
| MV | Resistance earthed |
| LV | Solidly earthed |
| 110 V DC | Solidly earthed |
| 24VDC | Solidly Earthed Negative (Single connection) |

### 6.1.11 Environmental Considerations

$H_2S$ may be present around the site at concentrations up to 5 ppm. Concentrations above 0.3 ppm are unacceptable for exposed copper conductors, and concentrations down to 0.1 ppm have adverse effect on silver-plated connectors and conductors. Rapid tarnishing of these and other materials occurs in this atmosphere. Consequently:

MV & LV switchgear, electrical and electronic equipment shall be located only within air-conditioned rooms or enclosures supplied with air under positive pressure from which the H2S has been removed. The only exceptions to this are:

1. Individual items of instrumentation equipment which are directly necessary for Plant process control / monitoring or safety systems with only a single function (i.e. measuring pressure) and having an IP rating of IP65 (to IEC 60529) or better. Note that process instruments, especially “general purpose” instruments such as pressure and temperature measurement shall be provided in IP67 form. Exceptions to this will be accepted on a case by case basis by prior approval from the Employer, where it can be demonstrated that there is no “off the shelf” instrument available to perform the requirement measurement. Instruments with LCD displays shall be equipped with 316SS plate steel rain / solar hoods to prevent direct solar damage.

2. TEFC electrical motors

3. Support / auxiliary equipment which is not directly or indirectly necessary for Plant process control / monitoring or safety system (i.e. non-emergency lighting fixtures, PA and communications systems, access and security systems) in which case it is acceptable to supply the highest IP rating enclosure available per equipment item / type, but not less than IP55.

No equipment including bus-bars, links, terminals, fittings, circuit breakers, contactors, relays, contacts and the like, is to be made in whole or in part of silver, nickel-silver, copper, phosphor-bronze, brass or other copper or silver alloy, unless hermetically sealed or tin plated to a minimum thickness of 0.002 mm, or otherwise suitably permanently plated or coated. Cadmium plating shall not be used for any purposes including screws and fastenings. The only exception to this is where such prohibited materials (e.g. silver) are part of a manufacturers standard design for a piece of equipment which cannot be varied (proof of this may be required) and where that piece of equipment is protected by locating within air-conditioned rooms or enclosures supplied with air under positive pressure from which the $H_2S$ has been removed

All circuit boards shall be effectively conformal coated to class 2 of IEC 61086, with Humiseal 1A33 (or approved equivalent), epoxy encapsulated or be tinned and lacquered. The conformal coating shall be applied to both sides for protection against hydrogen sulphide, humidity, condensation and air-borne contaminants. The conformal coating shall be inert to attack from fungi, bacteria, atmospheric conditions, and shall have proven suitable and stable properties for at least 15 years’ maintenance-free service under the conditions specified.

MV insulators shall be suitable for very heavy pollution level according to IEC 60815.

Although some equipment may be located in temperature controlled air conditioned areas, it shall be rated for continuous operation without the benefit of the temperature control without detrimental effects on the equipment. Maximum design temperature shall be based on the maximum ambient temperature plus all temperature rises that can occur as a result of heat gains, flows and dissipations that may affect the installation area.

## 6.2 Transformers

### 6.2.1 General

This section of the specification states the requirements for the design, manufacture, and testing of MV / LV DyN11 Auxiliaries transformers (outdoor, oil immersed type)

The auxiliary and SGS transformers shall have the following general characteristics:

| **Type:** | **Outdoor, oil-immersed, three phase, double wound type.** |
|---|---|
| Standard: | The transformers shall conform to the requirements of IEC 60076. |
| Cooling: | ONAN |
| Rating: | Transformers shall be sized in accordance with the relevant duty. |
| Duty: | The transformers shall be suitable for continuous operation on the electrical systems and under the site conditions described in this specification. |

### 6.2.2 Service

The auxiliary and SGS transformers will be used to supply power to the LV loads. The transformers shall be designed to cope with the worst case static and motor starting loads imposed.

### 6.2.3 Electrical Requirements

Electrical Characteristics shall be as follows:

Impedance Voltage:

Transformer impedances shall be optimised to limit fault levels as necessary and to minimise cost. Voltage regulation under worst case motor starting or other load step conditions shall not exceed those requirements specified elsewhere in this specification.

Voltage Tappings:

Auxiliary Transformers: Off circuit (OCTC) ±5 per cent in 2.5 per cent steps (5 tap positions)

Insulation Level:

The insulation level of the windings shall be in accordance with IEC 60076 and the service conditions specified elsewhere in this specification.

External Short-Circuit Withstand

The ability of all windings to withstand the thermal effect of external short circuits shall be demonstrated as per IEC 60076-5. The duration of the current used for the calculation of the thermal ability to withstand short-circuit shall be 1 second for the generator and 3 seconds for the auxiliary transformers.

### 6.2.4 Auxiliary Transformers Bunding

The Unit auxiliary transformers shall be separated by concrete blast walls from buildings and from neighbouring transformers within 50 m. The blast walls shall be cantilevered reinforced concrete walls at least 150 mm thick extending higher than the upper most bushings on the transformer and 1m horizontally past the horizontal straight line trajectory from the transformer to other transformers or building walls not able to resist explosion debris. The blast walls shall be anchored in concrete foundations.

The Contractor may offer dry type transformers for Employer approval in which case the requirements for bunding and oil handling and containment would not apply.

A reinforced concrete containment having a volume sufficient to hold the total oil volume normally held by the transformer and conservator plus 20 per cent shall be provided. The volume shall include granite rock so that a total oil spill is below the rock level in order to mitigate fire conditions. The bund volume shall allow for the rock volume.

The containment shall be provided with a connection to the oily water separation system via a system designed to allow the drainage of storm water but to retain the oil spill within the bund. This shall be achieved by a simple decanting system to allow bund water to drain to the storm water system. There shall be no moving parts for the decanting system. Oil expanding plugs shall not be used. Operators shall be able to view the liquid level in the bund and then decide to open a valve to the main oily water separator.

The transformers shall be provided with an automatic water deluge fire protection system except in the case of dry type transformers. Contractor shall provide a suitable fire protection system for dry type transformers.

Manual fire alarm pull stations shall be located in the transformer yard area.

### 6.2.5 Core and Windings

Core

The core shall be insulated from all structural parts, and shall be capable of withstanding a test voltage to core bolts and to the frame of 2500 volts rms for one minute. Cores shall be of the 3 limb type.

Internal Earthing Arrangements

All metal parts of the transformer, except those electrically connected to the windings, shall be maintained at earth potential. Fortuitous contact shall not be relied upon.

### 6.2.6 Cooling System

Cooling shall be by means of radiators attached to the tank walls for transformers greater than 1 MVA rating.

If transformers are equipped with separate radiators they shall be tested for leaks by the same methods as used for the transformer tank, and shall withstand full vacuum.

### 6.2.7 Accessories

| | |
|---|---|
| Name plates: | Stainless steel plate giving information required by IEC 60076-1. Stainless steel plate showing location and function of all valves, vents, cocks, and plugs to be provided for Unit auxiliary transformers. |
| Earthing Facilities: | Two separate earthing paths shall be provided for each item of equipment. |
| Tap Position Indicator: | Local indicator to be clearly readable from ground level. |

### 6.2.8 Current Transformers

Current transformers, including neutral CTs, complying with IEC 61869 shall be provided as indicated on the relay and instrument diagrams or as otherwise determined during detailed design.

Each current transformer shall be supplied with a device to prevent overvoltage occurring between the secondary terminals in the case of inadvertent open circuiting. Secondary wiring shall be terminated on approved shorting terminal blocks located in the main protection relay cabinet.

### 6.2.9 Transformer Oil

Insulating oil shall be inhibited oil to Class 1A of BS 148 and shall be PCB and sulphur component free. Oil used for filling at site shall be provided by the transformer manufacturer complete with guarantee of chemical composition.

## 6.3 Switchboards

### 6.3.1 General

This section of the specification states the requirements for the design, manufacture, and testing of:

1. MV Switchboards
2. LV Switchboards/MCCs
3. LV Distribution Panels

### 6.3.2 Degree of Protection

Unless otherwise stated enclosures shall have the following minimum IP ratings

1. Outdoor
    - IP65
2. Indoor (Inside climate controlled, air purified switch rooms)
    - IP41
3. Distribution sections (with external doors open and escutcheons closed)
    - IP4X
4. Internal (with internal doors and escutcheons open and covers removed)
    - IP20

### 6.3.3 Indoor Switchboards

The floor of a switchroom is not considered to be part of the enclosure. The bottom of the switchboard shall be closed off, sealed, dust and vermin proofed.

Indoor switchboard enclosures shall only be installed in climate controlled, air purified switch rooms.

Indoor enclosures shall have a folded construction, utilizing cold rolled 2mm (minimum) zinc annealed sheet steel painted RAL 9001.

Indoor enclosures shall be assembled on minimum 100 x 50 mm galvanised steel channel base suitable for direct fastening to a concrete or steel floor.

### 6.3.4 Outdoor Switchboards

No switchboards will be installed outdoors other than medium voltage ring main units specifically designed for outdoor installation in harsh environments.

### 6.3.5 Busbars

Busbars shall be:

1. Fabricated from hard drawn high conductivity tinned copper bar of constant cross-section for the complete length of the switchboard.
2. Fully insulated throughout their lengths, including tee-off connections and joints between adjacent busbar chambers and shall be able to receive future extension pieces.
3. Suitably rated for the normal current carrying capacity and fault rating of the switchgear
4. Fully fault rated up to the point of attachment of the protective devices in the cells, completely enclosed in an earthed metal chamber.
5. Made with a bolted assembly which is of a type tested design suitable for the fault level and current rating specified.

The design of the busbar system shall permit future extensions at both ends of the switchboard and in order to accommodate this feature, busbar ends are to be predrilled and fitted with removable caps, and covered by external removable steel plates.

For bolted connections, high tensile stainless steel bolts and nuts with locknuts and Belleville washers shall be used. Spring washers and nylon locknuts will not be acceptable.

The maximum continuous temperature rise of busbars at the nominal rated current shall be 20°C.

Busbar supports shall be fabricated from rigid, non-hygroscopic insulating material.

Number, location and method of installation of busbar supports and bracing for multiple busbars shall be in accordance with the type tested design for the fault level and duration specified.

The phasing of busbars shall be identified by colour-coded insulation the length of each bar. Plastic tape will not be accepted. Busbars shall be positioned so that the arrangement is always red/white/blue from front to back or from top to bottom when viewed from the front of the switchboard.

Neutral busbars shall be identified by black coloured insulation along the length of each bar.

Low Voltage MCCs shall have a neutral busbar provided for the full length of the MCC, insulated from the MCC frame and located in a convenient position for termination of external neutral cables.

Form of segregation of the LV switchboards shall be Form 4A, type 3.

### 6.3.6 Wiring

All control wiring, CT & PT terminal points shall have easy access for maintenance.

Covers shall be included over wiring terminals to afford an IP20 level of protection from accidental touching by personnel when the main board doors are opened for maintenance.

### 6.3.7 Locks

Individual switchboard cubicles shall be provided with lockable handles and the key for each of these locks shall be different from all the other keys provided. Each cubicle shall, however, be able to be opened by a master key which can open every cubicle on each board. A lockable wall mounted key cabinet with a glass front shall be provided and installed in a location to be agreed with the Project Manager on site.

Facility shall be provided to allow locking of circuit breakers in the isolated position, locking of earth switches in the closed position, and for locking of busbar and circuit shutters in the closed position.

Each contactor cubicle shall incorporate an isolating device lockable in the isolated position from outside the cubicle. Under normal conditions it shall not be possible to open the cubicle door unless the isolator is open.

### 6.3.8 Protection Relay Control System Interface

All protection relay information and data shall be made available in the DCS. A data communication system shall be employed to facilitate this. Time dependant data shall be time stamped to the same time base as the DCS time clock.

### 6.3.9 Indication and Metering

Meters and transducers shall be provided in accordance with the appropriate Relay and Instrumentation Diagram as a minimum. Ammeters and voltmeters shall be selectable between all three phases. Current and voltage on all three phases, power factor, kilo-watt hours and kilo-VAR hours shall be measured continuously and input to the DCS for trending and display.

Transducers shall comply with IEC 60688 to accuracy class 0.5.

Transducer and indication current circuits shall have voltage limiters or similar installed to protect transducers under system fault conditions and protect CT circuits from open-circuit failure of measuring instruments or indicating meters.

Transducer voltage circuits shall be protected by suitably rated fuses in each line.

Circuit breaker positions shall be indicated per breaker compartment using LED lamps.

### 6.3.10 Arc Fault Containment

The design of the switchboard shall minimise the risk of initiating arcing faults by the use of phase separation barriers, shrouding, insulation etc particularly within each cubicle.

The line side of the Circuit Breaker/Fuse Switch shall be designed or provided with covers to protect personnel from the effects of arc flash when the module is isolated and the line side terminals are still live. These covers shall be fitted with the appropriate warning labels, i.e Maximum voltage behind the covers and the need to isolate elsewhere prior to removing the cover.

The minimum arc flash protection inside the module shall provide a Hazard Risk Category 1 for protective clothing (NFPA 70E-2012) with a maximum Incident Energy of 16.74J/cm2 calculated by IEEE 1584-2002.

Arcing faults shall be confined to a single functional unit within the enclosure. Venting of hot gases and arc products shall be directed away from the front of the enclosure by suitably designed internal ducts. Emergency pressure relief vents shall be incorporated in the enclosure design to prevent failure of doors or covers due to internal over pressures during arcing faults. The arc fault rating shall be maintained for mounting within a switchroom of limited ceiling height

An arc flash study in accordance with NFPA 70 E and IEEE 1584 shall be performed for the MV and LV systems. The studies shall be submitted along with the native files to the Project Manager for review.

### 6.3.11 Earthing

All metal parts of the switchboard, other than current carrying parts shall be continuously bonded and earthed.

Each cubicle shall be provided with hard drawn tinned copper earth bars of minimum 30x10mm rectangular section, and which shall connect to all equipment and panel work within the enclosure. The earth bar shall extend the full length of the switchboard.

Pre-drilled holes and fasteners for terminating screens shall be provided for all incoming power cables.

Earth switches shall be provided for earthing incoming or out-going circuits. Facilities shall also be provided to enable earthing of the busbars.

Earth switches shall have a peak fault making capacity and fault withstand capacity appropriate to the duty.

## 6.4 MV Switchboards

### 6.4.1 Medium Voltage Circuit Breakers

All circuit breakers of the same type shall be identical in arrangement and those of the same current rating shall be interchangeable.

Each MV circuit breaker shall be fitted with an operation counter operated from the mechanism. Closing mechanisms shall be of the trip free type. Trip circuit supervision shall be supplied on MV circuit breakers.

Vacuum circuit breakers shall be fitted with surge arrestors to prevent transmittal of voltage spikes upon switching, unless the Contractor can demonstrate that the equipment offered is spike-free.

Each complete circuit breaker together with its auxiliary switches and operating mechanism shall be arranged on a withdrawable carriage to permit full accessibility for maintenance purposes and as a means of isolating the circuit. Interlocks shall be provided to prevent incorrect or unsafe withdrawal, insertion, operation, or earthing. Shutters shall be provided to automatically cover the busbars when circuit breakers are withdrawn.

A carriage switch shall be provided in the fixed portion of the switchgear to be operated by the circuit breaker carriage to control interlocking and remote indication and to show when the circuit breaker is in the 'service' or 'isolated' position.

An approved circuit breaker lifting device of suitable section and robust construction shall be provided for each switchboard for the movement of circuit breaker carriages into and out of the stationary portion of the cubicle.

### 6.4.2 MV Circuit Breaker Control Arrangements

Circuit breakers shall be controlled as follows:

1. locally at the switchgear panels

2. The 11kV grid interconnection switchboard shall be controlled and monitored remotely from the existing DOMLEC Control Room via the DOMLEC supplied RTU cabinet. Control commands shall be via hardwired controls between the RTU and the switchgear. Monitoring of all switchgear discrete and analogue signals shall be via discrete and 4-20mA connections between the RTU and the switchboard's protection relays and transducers. IEC 61850 interface may be used for monitoring purposes only. The Contractor shall allow 800mm X 800mm of RTU cabinet space within the grid connection switchboard room.

3. The Unit switchboards shall be controlled and monitored remotely from the DCS Operator Interface located in the OCR. Control commands shall be via hardwired controls between the DCS and the switchgear. Monitoring of all discrete and analogue signals shall be via discrete and 4-20mA connections between the switchboard's protection relays and the DCS. IEC 61850 interface may be used for monitoring purposes only.

4. In addition to space for the free standing RTU panel the Contractor shall allow an additional 800mm X 800MM panel space for the DOMLEC supplied fibre terminations and communications panel. This fibre panel shall be used for the 11kV protection signalling and other fibre communications requirements as described in the Interface Schedule.

Each auxiliary plant circuit shall have a 'Local-Off-Remote' selector switch mounted on the appropriate switchboard. In the 'Local' position the circuit shall be controlled from the switchboard. In the 'Remote' position the circuit shall be controlled remotely.

There shall also be a Local circuit breaker operating switch with "Open" and "Close" commands. Remote tripping shall be required by other protection circuits.

### 6.4.3 MV Circuit Breaker Control System Interface

Circuit breakers shall be monitored by the DCS and DOMLEC and the following signals shall be provided as a minimum.

1. Circuit Breaker Control in "Local' or "Remote" mode
2. Circuit breaker open, closed, and tripped status indications
3. Circuit breaker commands for open and close.
4. Earth Switch open and closed indications
5. Circuit breaker earth switch position
6. Circuit breaker fault indication
7. Circuit Breaker line currents and bus voltages
8. Protection relay status information including power supply faults.

The above information shall be provided via potential free discrete contacts to the DCS for remote monitoring and supervision. Analogue information shall be provided from a digital protection relay with a serial interface to the DCS, with the exception that trip signals and protection interlocks shall be hardwired. The DCS shall also provide hardwired "open" and "close" control commands to the breakers via hard wired contacts i.e not via IEC61850 control commands. The IEC61850 communications interface shall connect all relays to the DCS and DOMLEC for the purposes of monitoring relay and breaker status, currents, voltages and similar breaker signals.

### 6.4.4 MV Circuit Breaker Requirements

The MV switchgear shall comply with IEC 62271. The switchgear shall comprise single busbar, indoor, metal clad, air insulated, draw out, segregated switchgear cubicles, vacuum circuit breakers and front panel mounted control, instrumentation, protection, metering, and DCS transducer facilities.

The switchboard as a whole unit shall comply with IEC 62271-200 and shall be capable of sustaining without damage, the electrical and mechanical stresses produced by the determined fault conditions. The rated insulation level of the switchgear across the isolating distance shall be as defined in IEC 62271

Means shall be provided to prevent arcing damage when switching inductive loads.

Separate compartments shall be provided within each tier for:

- MV switchgear
- Busbars
- Cable terminations, earth switches and cable-side CTs and VTs
- LV/ELV protection, control, metering and communications equipment.

Switchboards shall be designed and type tested in accordance with IEC 62271-200. Type tests shall be submitted to the Employers Representative.

The ceilings of the switchroom shall be at least 3000mm above floor level. Gas discharge tunnels shall be provided if the ceiling height is insufficient to dissipate arc fault gases without danger to personnel. For simplicity, it is preferred that gas discharge tunnels are not vented to the outside of the switchroom.

The enclosure design shall incorporate the following features:

1. Ability to extend from either end by at least one tier. In order that this can be effectively used, each switchboard shall be placed in the switchroom so that one tier can be added to either end and still leave spare space for normal personnel access and maintenance clearance / access.
2. Bottom entry for cables, with minimum 5mm aluminium gland plates, un-drilled.
3. Ability to close switchgear doors with CBs in the service, test or isolated positions and with earth switches in either the open or closed position.
4. The opening of enclosure doors or intended access points will not expose personnel to any voltages above 110V and shall maintain IP2X.
5. All live parts above ELV (to earth) and which are accessible when the doors are open, shall be shrouded and marked with warning labels.
6. Arc fault explosion vents in accordance with the type tested design.
7. Fully closed at the top and the bottom.

Each MV functional unit shall be installed in a separate tier. All equipment associated with an individual functional unit shall be accommodated in the respective tier.

Only cables associated with a functional unit may enter the cable termination chamber of that functional unit. Under no circumstances shall cables from other functional units pass through the cable termination chamber of that functional unit.

A separate compartment for LV/ELV control, monitoring, protection and indication is to form part of each panel.

All LV and ELV contactors, relays, instruments and other similar items shall be arranged so that they may be removed and replaced with complete safety when the associated MV circuit is de-energised but the other MV circuits on the rest of the switchboard are energised.

Auxiliary switches shall be rated in accordance with their duty; spare switches shall be rated at not less than 10 A at 110 V DC.

Busbars shall be rated to include for one additional tier of load where that additional tier load is based on the worse case of the in-service tiers.

A portion of the MV switchboard (i.e. CB2, CB3, CB4, CB5, CB6, CB7 and CB8) will form part of DOMLEC's 11kV grid network and DOMLEC will thus need to remotely switch and monitor the status of these 11kV breakers. DOMLEC owns and operates a fibre network for the control and monitoring of its hydro stations (including the Laudat hydro station). DOMLEC will install a fibre from the Laudat hydro station to the MV Switchroom RTU panel to facilitate the control and status monitoring of the 11kV switchboard and the status of the plant.

## 6.5 LV Switchboards

The switchgear as a whole shall be capable of sustaining without damage, the electrical and mechanical stresses imposed by fault conditions in accordance with IEC 60439. The switchboards, and the individual components thereof shall be type tested by a recognised short circuit testing authority in accordance with the above rating and copies of test certificates proving this rating shall be submitted.

The switchgear shall comprise single busbar, indoor, metal clad, air insulated, segregated switchgear cubicles; air circuit breakers, isolators, moulded case circuit breakers and contactors; and front panel mounted control, instrumentation, protection, metering, and DCS transducer facilities.

Individual cells shall be non withdrawable and equipped with Socomec (or approved equivalent) visual load break switches as well as a separate circuit breaker. The load break switch will be used to provide O&M staff with the visual break safety requirement.

Each switchboard shall be equipped with tinned copper phase, neutral and earth busbars. The neutral busbar shall have a current rating not less than half that of the phase busbars.

Circuit breakers shall comply with IEC 60947 supplied with an on/off mechanically operated position indicator shall be incorporated and facilities shall be provided for padlocking the isolation devices in the 'off' position.

All LV switchboards greater than 250A rated capacity shall be capable of future extension at either end without modification. Space for two tiers of switchboard of spare, un-occupied space shall be provided at each end of each switchboard (through the placement of the switchboards in the switchrooms and the size of the switchrooms) for a future switchboard extension. One spare circuit breaker, fully equipped, with a rating equal to the largest used circuit breaker, shall be installed in each switchboard. A further single spare circuit breaker, fully equipped, with a rating equal to the median of all used circuit breaker, shall be installed in each switchboard.

Busbars for each switchboard shall be rated to include for a 20% margin above the peak load of the board. The peak load as calculated for the sum total of all connected loads operating at 100%.

The form of separation for low voltage electrical switchgear, cabinets and panels to IEC 61439-1 shall be as follows:

| | |
|---|---|
| Switchboards ≥ 250A | Form 4a |
| Motor Control Centres | Form 4a |
| Distribution Panels <250A | Form 1 |
| Variable Speed Drive Enclosures | Form 2a or 2b |

Miniature or moulded case circuit breakers shall be designed and tested in accordance with IEC 60157 and supplementary requirements of this specification. They shall be suitable for use over the full range of expected voltage variation as specified in IEC standards.

They shall be suitably rated for both the continuous and short circuit loadings of the circuits they are protecting under all service and atmospheric conditions stated in the specification and ensure that correct discrimination is maintained between main and sub-circuits.

For three phase circuits the miniature circuit breakers shall be of the three pole type; for single phase circuits they shall be of the single pole type and, for dc circuits they shall be of the double pole type.

Where miniature circuit breakers are used in circuits containing inductive loads, eg operating coils, it is essential they are suitable for satisfactory operation in the circuit in which they are used and due account is taken of the circuit time constant.

All miniature circuit breakers shall be provided with an auxiliary contact(s) for remote indication of circuit breaker operation.

Miniature circuit breakers shall be mounted in such a manner so as to give easily visible indication of breaker position and shall be grouped and spaced according to their function in order to facilitate identification and easy replacement.

Withdrawable LV air circuit breakers shall be used for all incomer circuits to facilitate isolation requirements. This shall include the LV bus section breakers, diesel generator breaker and essential services feeder breaker.

### 6.5.1 Doors and Covers

Hinged doors shall be provided where access is necessary to the inside of the switchboard for normal inspection, operation or maintenance. This includes cable zones.

Doors shall be constructed with double returned edges and additional stiffeners where necessary to prevent distortion. All doors shall be installed on stainless steel lift-off hinges. Doors shall be arranged to open by at least an angle of 110°. Positive stops shall be provided to ensure that doors cannot open so far that they will come into contact with adjacent equipment and cause damage.

All doors for individual modules, cable zones, distribution boards, etc shall be fixed with 8mm square shaft quarter turn fixings with a square shaft operator slotted for use with a flat screw driver.

The number of catch points for doors shall be sufficient to maintain the IP rating of the door seal and the arc flash rating.

Bolted removable covers shall be provided where access to the inside of the switchboard is required for major repairs.

Locating pins shall be installed on the fixed portion of the switchboard to facilitate installation of covers with handles provided on all covers over 1200 mm high.

All doors and removable covers shall be provided with gaskets consisting of neoprene covered foam rubber. Gaskets shall be securely retained in a recess within the door or cover. Gaskets shall bear on a flat sealing surface at least as wide as the gasket.

Bolted removable gland plates fabricated from minimum 5 mm thick aluminium plate shall be provided at the bottom of each cabling zone.

### 6.5.2 Condition Monitoring

Design of the switchboard enclosures shall facilitate condition monitoring by infra-red thermal inspection equipment.

For this the following features shall be provided;

- Door interlock defeat on each module

### 6.5.3 Incomer Circuit Breakers and Bus Tie Switches

Incomer circuit breakers shall comply with the requirements of IEC 60947-2, and be withdrawable.

Circuit breakers shall;

1. Be capable of interrupting the maximum prospective short circuit current.
2. Have digital protection/metering relays incorporating metering, alarms and fully adjustable overcurrent and earth leakage protection with a communication link to the DCS to convey all dynamic information to the DCS.
3. Be constructed so that should the circuit breaker be closed when an effort is made to withdraw it the Unit shall trip before the main contacts start to separate. Similarly, if an attempt is made to rack in a breaker when it is closed it shall trip itself before the main contacts meet.

### 6.5.4 Motor Control Centres

Motor circuits shall be fed from appropriately sized contactor arrangements for each specific duty. All contactors shall have MCCB protection on the primary (bus) side as well as Socomec load break switches on the incomers to the cells. Dedicated control power transformers shall be installed in each non-latching starter compartment.

Enhancements such as MCCB type primary breakers with selectable electronic protection modules and associated central processor units may be offered. Final selection shall be determined and approved by the Project Manager.

Each MCC shall be equipped with a lockable incoming main circuit breaker for disconnect purposes.

Motor Starters shall have Type 2 co-ordination to comply with IEC60947-4.

Spare starters and feeder breakers shall be furnished and mounted in each MCC assembly for future use as follows:

- At least two spare starters per tier rated at the highest rating of the tier's installed starters. The Project Manager shall approve the spare starter's capacity prior to construction.
- Two– 300 mm spare cells

Motor starters shall include the following for each motor circuit.

1. Socomec visual load break switch or approved equivalent.
2. Moulded case circuit breaker.
3. Overload and fault protection. For all motors, a digital motor protection relay with current transformers and phase failure relay function shall be supplied. These shall be of approved type and be operated by saturating type current transformers. The relays shall be interfaced to the DCS via a communications link to permit all dynamic information to be conveyed to the DCS.
4. Ammeter for all motors (may be incorporated in motor protection relay display)
5. Amber lamp to indicate 'fault' condition and red and green lamps to indicate 'running' and 'stopped' conditions respectively.
6. Clean auxiliary contacts as necessary for remote operation and indication.
7. Stop-Start controls integrally mounted
8. All internal wiring, terminal boards, fuses, locks, equipment for terminating cables
9. 'Local-Off-Remote' selector integrally mounted

### 6.5.5 Contactors

Contactors for motor starting duties shall be of two types: electrically operated latched contactors and electrically held contactors. No important or essential plant items may use the electrically held type.

Vacuum contactors may be accepted subject to the provision of evidence to the Project Manager's satisfaction that they will not cause wave chopping in excess of that which motors manufactured to IEC60034-1 will tolerate.

All contactors shall be of robust design and shall be rated for full voltage starting squirrel cage type motors.

### 6.5.6 Distribution Panels

LV AC power for plant lighting, small power and miscellaneous loads shall be provided by distribution boards located in the main switchgear room and throughout the Power Plant.

Panels shall be rated for the projected fault duty and shall be protected from $H_2S$ corrosion by a combination of suitable IP ratings, judicious use of materials and air filtration.

Distribution boards shall be manufactured to IEC 61439-3 with provision for incoming lockable isolation, and shall utilise clearly labelled circuit breakers for all connected loads.

A minimum of five pad lockable "lock dogs" shall be supplied for miniature circuit breaker isolations within each distribution board in a sealed bag.

A minimum of 20 per cent spare circuit breakers shall be provided on each panel for future use.

Each DB shall be provided with a document pocket to house the DB service schedule for ease of operational use.

## 6.6 DC and UPS Systems

### 6.6.1 Description

A single phase AC UPS system shall be provided to operate common critical control system components including the DCS operator interfaces, and any other similar critical plant. A single system shall be provided for one or more Units, however, the UPS system shall be designed so that feeds can be individually isolated to each Unit.

The DCS panels including the power supplies, processor cards, input/output cards, network switches and similar shall have the DCS power supplies fed with a "raw" single phase AC supply as well as 110V DC. The 110 V DC shall be derived off the Unit 110 V DC battery system. The power supply voting units shall provide a potential free contact to the DCS in the event of one or both of the incoming supplies failure.

The Unit 110 V DC system shall be used for operation and control of circuit breakers, auxiliary switchgear and protection relays.

A 110V DC independent battery bank per generating unit shall be provided; each bank shall supply its connected load independently. The separate battery banks shall have a DC bus connector so that either bank can supply the normal operating loads of both units in the event that one bank is out of service for maintenance.

Each Unit's 110 V DC system shall provide power for each Unit's turbine generator emergency lube oil pump (if required) and other critical equipment as applicable to the plant offered.

The LV three phase standby emergency diesel generator shall also be used to supply all emergency loads, essential loads including DC and UPS Systems.

All battery banks shall be supplied with equipment / tools to allow the Employer to undertake load testing of the batteries. The tools shall include a portable battery discharge test rig.

### 6.6.2 Uninterruptible Power Supplies

The UPS systems shall be sized to feed the plant critical loads related to work station computers, communications/telemetry equipment and related equipment.

There shall be a single UPS system for the Power Plant, MV Switchroom and SGS.

The UPS system will comprise multiple UPS sub-systems or modules operating in parallel, arranged to provide N+1 redundancy for the Plant. Thus it shall be possible to take one UPS sub-system off line whilst still providing full UPS supplies to the connected equipment. Each sub-system shall consist of a rectifier/charger/inverter section, dedicated battery, bumpless static transfer switch and external maintenance bypass switch.

The UPS system output shall feed a dedicated essential AC distribution panel and shall be rated to carry actual connected load plus 20 per cent. Battery capacity (ampere hour rating) shall be determined by detailed engineering.

Input to the UPS system shall be provided from two sources; the LV essential supply and a non-essential supply to allow either supply to be taken out of service whilst still maintaining supply to the UPS system. Bumpless transfer to and from each AC source and the battery shall be ensured via the static transfer switch. The inverter output shall be maintained in synchronism with the AC source.

Transfer to and from “bypass” mode shall also be bumpless and require specific sequence switching. “Bypass” mode shall be visually indicated on the local UPS panel and the operator interface in the OCR.

An external maintenance switch shall be provided to enable isolation of the UPS for maintenance, with no interruption to the load.

Full UPS system (including transfer switches) status, input and output conditions and loads and fault conditions shall be signalled to the DCS.

Basic requirements and ratings shall be as follows:

| **Characteristics** | **Value** |
|---|---|
| Output Voltage | LV 1 phase or 3 phase + N |
| Power factor | 0.7 to 1 (within kW rating) |
| Regulation | |
| Balanced load | ± 2 per cent maximum |
| 50 per cent unbalanced load | ± 3 per cent maximum |

| Characteristics | Value |
|---|---|
| Phase displacement | |
| Balance load | ± 10 |
| 50 per cent unbalanced load | ± 30 |
| Nominal Frequency | 50 Hz |
| Hold up time | 4 hours |

### 6.6.3 UPS System Batteries

Each battery shall be the “maintenance free” deep-cycle type. The battery shall be designed for a life expectancy of at least 10 years, an average emergency duty frequency of four times a year being assumed.

All battery cells shall be numbered consecutively and each terminal shall be marked to show polarity.

Failure of one cell in any one battery shall not affect the overall performance of the system. Batteries shall be mounted on multi-tier racks braced to withstand earthquake forces. Racks and mountings shall be designed to allow easy inspection and replacement of individual cells.

### 6.6.4 110V Battery Chargers

The Contractor shall supply dual battery chargers for each DC system suitable for maintaining a float charge in the battery banks while supplying the 110 V DC Unit and common loads together with additional capacity sufficient for recharging the battery at the end of a discharge period. The charging system shall be able to recharge the battery banks to a capacity which permits one emergency plant shutdown sequence (e.g. turbine trip and simultaneous loss of AC power) within 1 hour after an emergency plant shutdown sequence has occurred (and discharged the batteries).

Chargers shall be identical in design and rating and shall be capable of parallel operation. One charger shall be in service whilst the other shall be in standby mode. Switching between service and standby mode combinations shall be selectable by the operator to be manual or automatic.

The chargers shall be of the automatic constant voltage type to be supplied from the Essential Services board. The output voltage of the chargers shall be adjustable through +/-10%. Ripple content of output shall not exceed 2%,

The charger output voltage regulation range shall not exceed plus one or minus four percent of the nominal constant float charger voltage or exceed a maximum in excess of battery manufacturer’s recommendations when connected to the load and operating under any combination of the following conditions:

- Frequency variation of 50 Hz + 5 percent.
- Rated input AC voltage variation of + 10 percent.
- Output between 0 and 100 percent of rating.

Each float charger is to incorporate an overcurrent limit to ensure that the charger rating cannot be exceeded by the application of DC loads.

Each charger shall include at least the following instrumentation and indicating facilities:

| | |
|---|---|
| Red/Green | on off indicating lamps for the incoming AC supply and alarm to DCS on loss of supply |
| Voltmeter | incoming AC supply |
| Voltmeter | DC output voltage and with remote indication to DCS |
| Ammeter | with offset zero to register charge/discharge currents |
| Charger Fail/ Low Volt Relays | with flag indication and 2 contacts for remote indication to the DCS |

An earth fault detector with flag indication and remote alarm contacts shall be provided to detect earth faults on either the positive or negative pole of the DC system.

Charger status and fault conditions shall be signalled at the operator interface.

### 6.6.5 110 V Batteries

Each battery shall be the “maintenance free” deep-cycle type. The battery shall be designed for a life expectancy of at least 10 years, an average emergency duty frequency of once four times a year being assumed.

All battery cells shall be numbered consecutively and each terminal shall be marked to show polarity.

Failure of one cell in any one battery shall not affect the overall performance of the system.

Batteries shall be mounted on multi-tier racks braced to withstand earthquake forces. Racks and mountings shall be designed to allow easy inspection and replacement of individual cells.

### 6.6.6 Power Plant Battery Duty

Batteries shall be sized in accordance with IEEE 485 "Recommended Practice for Sizing Batteries for Power Plants". With the battery charger disconnected, each battery bank shall have sufficient capacity to supply the connected normal DC load for 10 hours; or to supply the power requirements for projected emergency duty periods (e.g. turbine trip and simultaneous loss of AC power) plus normal DC load for an additional 3 hours, whichever criteria is more onerous. In addition, an ageing factor of at least 25 per cent shall be applied plus at least 20 per cent contingency for load growth.

### 6.6.7 DC Switchboards

The LV AC UPS and 110 V DC Switchboards shall be a multi-unit type comprising incoming isolators, outgoing circuit breakers and all required equipment as necessary.

The switchboard as a whole shall comply with IEC 61439 and shall be capable of sustaining without damage the electrical and mechanical stresses imposed by fault conditions.

DC switchboards shall be equipped with one set of positive and negative main busbars.

The busbars are to be of tinned copper conductor, rigidly supported and fully insulated throughout their lengths, including tee-off connections and joints between adjacent busbar chambers. The busbars are to be fully rated throughout.

The switchboards shall utilise clearly labelled circuit breakers for all connected loads. Circuit breakers on respective boards shall be identical in arrangement and those of the same current rating shall be interchangeable. All the DC circuit breakers shall be two pole type.

DC motor starters shall comply with IEC 61947 and shall incorporate a multi-step starting resistance with automatic progressive cut-out of the resistance steps on a time graded basis. All essential DC motor starters will be of the mechanically latched type.

Each motor starter or other feeder circuit shall form an individual compartment in which the main and control circuit cables are terminated. Access to these terminations shall be arranged so that it is independent of access to any other circuit compartment. The lube oil motor starters (if required) shall be designed so that the motor DC supply shall not trip for an emergency run down of the rotating plant. In this case the DC supply shall run to destruction.

Cable ways and access to terminals shall be generously proportioned to allow for ease in installing main and control cables.

## 6.7 Electric Motors

All motors shall be in accordance with IEC 60034 and IEC 60072 and unless otherwise specified, shall be suitable for continuous operation.

All motors larger than 35kW and are required for black starting the Facility shall be provided with VSDs. This is due to the capacity constraints of the Dominica grid.

All motors shall be suitable for DOL starting. Where VSD drives are used the associated motors shall have their winding insulation rated for VSD drive use and an insulated bearing and shaft earthing brush shall be fitted to all motors in the size range recommended by the manufacturer. The kW rating to be to IEC standard frame sizes.

All motors shall be rated IP55 TEFC, except for the Cooling Tower Fan drives which shall be IP56. Drain plugs, accessible in the motor service position, shall be provided at a low point on all motors and their associated coolers to permit drainage of any condensation. Enclosures shall be cast iron or steel plate. Aluminium is not permitted. All motors shall be factory fitted with IP66 rated termination boxes.

Main conductor and slot insulation shall be non-hygroscopic and in accordance with Classes F of IEC 60085, with Class B temperature rises.

Should motors use grease lubricated rolling element bearings they shall be provided with readily accessible grease nipples and a grease dump.

The motor shall have 1.0 service factor, and all motors shall be rated for not less than 115 per cent of the requirements of the driven equipment when operating under design requirements. Motor windings shall be rated for continuous operation, and the temperature rise shall not exceed 40°C.

Motors for applications requiring continuous operation (and their spares) shall be Class IE-3- Premium Efficiency per IEC 60034-30. Motors in intermittent service in non-critical equipment may be standard efficiency Class IE-1 per IEC 60034-30.

Motors shall be capable of operating continuously at rated output at any frequency between 46.5 and 52.5 Hertz and at any voltage within ten percent (10 per cent) of the nominal value, capable of starting with terminal voltage eighty percent (80 per cent) of nominal, and designed to operate for a period of not less than five (5) minutes at a voltage of twenty-five percent (25 per cent) below the nominal value and at normal frequency without injurious overheating.

AC motors rated more than 1 kW and all dc motors shall be provided with anti-condensation heaters.

Motors rated 5 kW and above but less than 50 kW shall be provided with thermistors in each stator winding. Motors rated 50 kW and above shall be provided with RTD temperature sensors in each stator winding and include at least one spare RTD per winding. Motors rated 200 kW and above shall be provided with 100% redundant bearing and stator temperature RTD's.

All motors rated at 50 kW and above shall be fitted with vibration monitoring studs on both drive and non-drive end bearings.

All motors larger than 5kW shall have oversized power cable termination boxes provided.

Motors fitted with temperature monitoring devices such as RTDs, thermistors and similar shall have these signals brought out via separate instrument junction boxes on the motor.

## 6.8 Variable Speed Drives

### 6.8.1 General Requirements

The VSDs shall be designed to operate under the nominated ambient conditions and are to incorporate reliable modern equipment selected to provide a minimum service life of 30 years. Temperature rise limits are to be based on a maximum ambient temperature of 50 degrees C.

VSDs shall be capable of controlling all phases of power to asynchronous 3 phase AC motors. As a minimum, the VSDs shall have a high degree of immunity to RF interference, high overload capability, inbuilt motor protection and soft stopping capability.

The product is to be from a standard range, which can be demonstrated as having provided a number of years of service.

VSDs shall have the requirements and ratings as follows:

| **PARAMETER** | **UNITS** | **SPECIFICATION REQUIREMENT** |
|---|---|---|
| **DESIGN** | | |
| Design Code (IEC) | | The device is designed, built and tested on the basis of EN 61800-2, EN61800-3, EN 61800-5-1 and EN 60204-1<br>IEC 60204 - Electrical equipment of industrial machines/machinery<br>IEC 60529 - Degrees of protection by enclosure<br>IEC 61800-3 - Electromagnetic compatibility<br>IEC 60721-3-3 - Class 3C2 & 3S2 Classification of environmental conditions<br>IEC 68068-2-3 - Basis environmental testing procedures |
| **PERFORMANCE** | | |
| Maximum Input Voltage | V | > 425 |
| Output Frequency Range | Hz | 0 – 50 |

| | | |
|---|---|---|
| Efficiency | % | > 97 (at rated current and nominal supply voltage) |
| Input Displacement Power Factor | DPF | > 0.97 at all loads > 15% |
| Total Current Harmonic distortion | THDI | < 5% when considered in combination with either of the following:<br><br>Active Front End<br><br>Sinus Filter<br><br>External Harmonic Filter |
| Sound pressure level | dB(A) | < 76 at 1 metre |
| EMC (IEC) | | EMC Immunity - IEC 1004-2; IEC 1004-3; IEC 1004-4; IEC 1004-5; IEC 1004-6.<br>EMC Emission - EN 61800-3, 2nd environment, category C3.<br>IEC 60721-3-3 Class 3C2 and 3S2: Classification of environmental conditions |
| **MECHANICAL** | | |
| Design | | Floor-standing enclosure |
| Cooling | | Forced |
| Noise | | < 65 dBA |
| Mechanical vibration | | According to IEC/EN 60068-2-6 1.5mm at 3 to 10 Hz, 0.6g at 10 to 200 Hz (3M3 according to IEC/EN 60721-3-3) |
| Shock | | According to IEC/EN 60068-2-27 4g for 11ms (3M2 according to IEC/EN 60721-3-3) |
| Operation temperature | 0C | 0 0C … +45 0C |
| Ingress Protection degree | | IP41 (Inside Switchrooms) |

| | | |
|---|---|---|
| Humidity | % | Class 3K3 in accordance with IEC/EN 60721-3-3/ no condensation, max 95% relative humidity |

### 6.8.2 Control and Communication

The drives shall have industry standard serial communications capability. The control system shall be capable of controlling and monitoring all of the drive features specified in this document via this interface. This excludes the emergency stop requirements.

The drive shall provide a digital input for emergency stopping (disabling the drive). Strong preference will be given to drives with a SIL rating of 2 or greater on this input.

The drive shall have the ability to monitor the following operating parameters via the communication ports.

1. Motor Power
2. DC Link Current
3. DC Link Voltage
4. Line Voltage
5. Motor Voltage
6. Motor Current
7. Motor Torque (Accuracy to be provided)
8. Motor Speed
9. Drive operational Status.

The drives shall provide both a thermal model overload and RTD or thermistor motor temperature monitoring.

The drive door mounted data display shall have the ability to store a backup set of drive parameters so that in the event of drive failure a current set of parameters is ready at hand.

## 6.9 Earthing

### 6.9.1 General

Earthing studies shall determine earth potential rise (EPR), step and touch voltages and safety of the Power Plant site area, and all interconnected metallic structures such as steam and water pipelines. The earthing study design report shall include the studies, and the designs to demonstrate compliance with IEEE Std 80 for the Power Plant site area, and all interconnected metallic structures and be submitted for review by the Project Manager. The Contractor will undertake overall earthing system tests according to IEEE Std 81.2 to confirm that the Power Plant site area and all interconnected metallic structures are earthing safe.

Earth resistivity tests shall be performed prior to commencing earthing system design sufficient to provide design parameters.

The Contractor shall use modelling software (such as CDEGS) to model and prove the earth system for the entire installation.

The Contractor shall design the earthing connections for the various items of electrical plant within the Plant to comply with the relevant Dominica standards/codes, including the Dominican Generation Code and Transmission, Distribution and Supply Code. For example, the Contractor shall determine if the generator star points are bonded to earth via a neutral earthing resistor, or by some other means.

The Plant earthing system to be provided under this contract shall comprise a main earthing busbar strategically routed through the site so as to provide the lowest resistance path from the earthed equipment to ground. The system shall be interconnected to all electrical plant both inside and outside the Power Plant and MV Switchroom buildings, and to steam and water piping passing into and out of the area.

The primary (below ground) earthing system shall comprise bare stranded, annealed, tinned copper wires of sufficient cross section to withstand worst case fault currents for at least 1 second, exothermically welded in a grid pattern, supplemented with appropriately sized ground rods as necessary. Where copper conductor is exposed to the atmosphere it shall be PVC insulated and/or protected with heat shrink sleeving.

The Contractor shall supply and install earth bond connections from the main earth grid to all non-current carrying metalwork supplied under this Contract, including, but not limited to, generators, transformers, switchgear, motor control centres, control boards, cubicles, metal conduit, cable trays, armoured cables, switch boxes, marshalling cubicles, motors, metal tanks, cladding, hand and guard rails, stairs, ladder, gratings, reinforcing steel connections brought out of concrete, structural steel, fences and metal-work shown to be necessary as a result of the Contractors touch and step voltage calculations and to prevent transferred potentials or limit them to safe levels.

An instrument / control system “clean” (no noise) earth bus bar shall be provided. This shall be bonded directly to the main plant earth system separate from all power equipment earths. This bus bar shall be clearly marked with it’s function.

### 6.9.2 Earthing Resistivity Testing

In order to provide data to enable the electrical earthing design, the Contractor shall undertake earth electrical resistivity tests.

The resistivity tests shall be by the “Wenner 4” electrode method. Two sets of tests shall be carried out along two axes 90 degrees apart at each site, with electrode spacings as follows:

- 0.5m, 1m, 5m and at every additional 5m up to 50m (a total of twelve (12) spacings)

The test probes shall be located a minimum of 10m and preferably a greater distance away from metallic objects or ground electrodes or wells. The results shall be reviewed for correctness and repeated if necessary to achieve a sensible result set before leaving each site.

Tests shall include recording of meteorological & geotechnical data including:

1. Soil type and ground surface type
2. Air temperature and humidity
3. Ground temperature
4. Weather conditions at time of test and noting of any recent rainfall

The Contractor shall provide a detailed test methodology plan for approval prior to testing including:

a. Planned test equipment/ test set
b. Test method and information
c. Results sheet to be completed

Tests shall be carried out by experienced personnel with the lead person having at least 5 years’ experience of earth resistivity testing. The name of the company and the person and his/ her CV shall be provided with the tender schedule.

Tests shall be carried out in the driest period possible and results provided to the Project Manager with a commentary on any issues or particular notes for each site within the timeframe specified in this Contract.

### 6.9.3 Earthing of Reinforcing Steel

All reinforcing steel, concrete foundations, and piles shall, wherever possible, be used to form earthing electrodes for the earthing system. In particular, the main reinforcing bars for the turbine hall foundations including the rotating equipment plinth shall be used to form a robust earthing system. Reinforced concrete foundations shall have their earthing connections brought out via 316 SS Wricon connections or similar approved. Turbine hall foundation earth connections shall be brought out at no less than every 8m.

### 6.9.4 Lightning Protection System

The Contractor shall provide lightning protection systems for all buildings, cooling towers, and any other structures which could act as a path to ground for lightning.

The lightning protection system shall be designed and installed in accordance with IEC 61024 and the design calculations submitted for review by the Project Manager. Lightning conductors shall be made from high conductivity aluminium and they shall follow the most direct route to earth to ensure the safe conduction of the discharge.

The system shall include but not be limited to the following:

1. Air Terminations at the highest point on the highest structure
2. Down Conductors and Fixings
3. Lightning event counter
4. Test Joints
5. Earth Electrodes independent of the station earthing grid

## 6.10 Cabling

### 6.10.1 General

This specification covers the requirements for provision of MV, LV, instrumentation and communication cables for the Plant.

All power, earthing, control, instrumentation and communications cabling shall be tinned along their entire lengths during manufacturing and not just tinned at the terminations.

### 6.10.2 Definition

| Item | Definition |
|---|---|
| Power Cable | Low voltage (600 V or less) cable and medium voltage (5,000 - 15,000 V) cable. |
| Control Cable | Single or multi-conductor cable used at relatively low current levels or used for intermittent operation to change the operating status of project equipment. Low current levels include single phase AC and DC currents up to 10 amps continuous. |
| Instrument Cable | Low level signal cable operating at 50 V and less, generally transmitting low level, under 1 amp, information. |

| | |
|---|---|
| Thermocouple Extension Wire | Low level signal cable operating at 50 V and less, used for temperature transmission from thermocouples |
| Data Highway Cable | Data communication cable which provides the interconnection between the remote locations of the various control systems. |
| Coaxial Cable | Shielded, single-conductor cable with special electrical characteristics used for accurate transmission of small signal information. |
| Trixie Cable | Single-conductor cable with two concentric shields having special electrical characteristics used for the accurate transmission of small signal information. |
| Communications Cable | Low level signal cable used as interconnecting cable between components of a communications system |
| Lighting cable | Low voltage power cable used for indoor lighting including receptacles and miscellaneous small power. |
| Capacity | The current-carrying capability of a wire or cable, expressed in amperes. |

### 6.10.3 Basis of Design

In general, the design of installed wire and cable shall be based on a maximum ambient air temperature of 40°C, soil temperatures are 25°C and continuous conductor temperature of 90°C.

All medium and low voltage power cables shall be Class B concentric or compacted stranded tinned copper construction in accordance with ASTM B8 or equivalent IEC standard.

Control and instrument cable shall be Class B concentric or compacted stranded tinned copper in accordance with ASTM B8 or equivalent IEC standard.

Cable splices are not allowed, except where specified in junction boxes and specifically approved by the Project Manager. Cables shall be rated for the type of raceway system in which it is installed.

pH of the soil or ground water shall be considered as being 5.0;

### 6.10.4 Procedures

In order to assure that power cables will operate within their design temperature limits, the cables will be sized in accordance with the following general sizing procedures:

1. Determine the maximum current for the load served. This includes both intermittent and continuous duty loads.
2. Multiply this current by appropriate factors such as service factor, overload factor, etc.
3. Apply proper dating factors for installation configuration, soil resistivity, and ambient temperatures and determine cable size from IEC 60364-5-52
4. Determine maximum volt drop is within limits
5. Verification of the withstand capabilities of cable under short-circuit conditions.

All cable sizing calculations shall be submitted for review by the Project Manager.

### 6.10.5 Sheath, Serving and Insulation Material

The outer sheath of cables shall include; a fire retardant and additives to enable the cable to resist attack by termites and/or $H_2S$. Such chemicals shall not be carcinogenic.

All cables installed outdoors shall be either installed in conduit or shall be armoured with galvanised steel wire.

The outer sheath of 600 V power cables and low voltage control cables shall be black. The outer sheath of medium and high voltage cables shall be red.

The following minimum information shall be embossed marked on the surface of the cable at regular intervals not exceeding 1m intervals over the entire length of the cable:

1. Manufacturer's name
2. Number of cores
3. Temperature rating
4. Insulation material
5. Sheath material
6. Year of manufacture

Insulation and jacket thickness for all power cable shall be in accordance with ICEA standards for the voltage rating of the insulated conductor. Insulation materials shall be cross-linked polyethylene (XLPE) or polyvinyl chloride (PVC). Jacket materials shall be chlorosulfonated polyethylene (Hypalon), chlorinated polyethylene (CPE), or polyvinyl chloride (PVC). Jackets materials shall include a fire retardant.

Insulation and jacket thickness for all control cable shall be in accordance with ICEA standards for the voltage rating of the insulated conductor. Insulation materials shall be XLPE. Jacket materials shall be Hypalon, CPE or polyvinyl chloride (PVC). Jackets materials shall include a fire retardant.

Insulation materials for instrument cable shall be PVC or XLPE and jacket materials shall be Hypalon, CPE or polyvinyl chloride (PVC). Jackets materials shall include a fire retardant.

Sheath materials shall provide the following protective features

1. Sheath material shall not suffer deterioration in the presence of all conditions and compounds commonly found in clay, sand and soils;
2. Sheath material shall remain colourfast when buried in soil;
3. Sheath material shall remain colourfast when exposed to direct sunlight;
4. Sheath materials shall not suffer significant deterioration when exposed to solar radiation, such that its primary functions are diminished during the cable life.

### 6.10.6 Power Cables

Unless otherwise stated, all conductors for Power cables shall be annealed, high conductivity electrical tinned grade copper material to comply with BS 6360:1991, IEC 60228 and IEC 60270.

All cables feeding loads other than instrument or lighting and receptacle loads shall be classified and applied as power cables and rated in accordance with IEC 60287. This includes cables supplying small single phase fractional horsepower motors in 240 V AC systems.

For motor circuits, the cables shall have a current carrying capacity at least equal to 115 percent of the full load current rating of the motor after application of the appropriate cable derating factors and shall be dependent on the maximum conductor temperature recommended by the cable manufacturer.

The short circuit rating of main cables shall be based on the expected fault level of the switchboards. Transient conductor temperatures shall not exceed those ratings recommended by the cable manufacturer.

The time rating, under short circuit conditions, of the cables shall be determined by the total operating time of the complete protection system.

The steel wire armouring of cables shall be solidly earthed at both ends of each cable via appropriate steel wire armour glands. The armouring shall not be used as an earth continuity conductor for electrical bonding purposes.

### 6.10.7 **MV Power Cables**

MV cables shall have an electrically continuous metallic screen of tinned copper wires provided under the cable sheath grounded to earth.

Where the cable core screens are inadequate to meet the earth fault current specified, a metallic layer of adequate cross-sectional area shall be included in the design applied over the screen. The metallic layer shall be constructed of annealed high-conductivity tinned wires.

### 6.10.8 **LV Power Cables**

Cables rated for 600/1000 V shall be used on the LV AC, 110 V AC and 110 V DC systems.

Cable conductors shall comprise tinned copper with a minimum conductor size of 2.5 mm2 cross sectional area.

All LV multi-core cables shall include an earth conductor.

### 6.10.9 **VSD Motor Cable**

To minimise the likelihood of electromagnetic interference (EMI) motors controlled by Variable Speed Drives (VSD) shall be connected by specialist multicore XLPE tinned copped braid shield and foil screen VSD cable. VSD cable sizes over 4mm2 shall be constructed with multiple symmetrical earthing conductors producing a balanced cable.

VSD cables shall be terminated as recommended by the cable manufacturer using specialist EMC glands

### 6.10.10 **Inspection and Testing**

The tests shall consist of manufacturer’s standard factory tests and those tests required by the Standards, using calibrated equipment to known standards. The Project Manager shall reserve the right to inspect the testing at the manufacturer’s works.

**XLPE Cable Routine and Sample Tests**

The cable Routine Tests shall be performed sequentially, as per BS 6469:1990, IEC 60060, IEC 60502 and IEC 60811: The tests shall also include:

- Conductors and screens - all appropriate tests according to IEC 60270

- Insulation thickness
- Non-metallic sheath thickness

### 6.10.11 Control Cables

Control cables shall be rated for 600 V with tinned copper conductors. The use of copper sheathed cables will not be permitted.

Core colour coded to comply with IEC requirements.

The following lists the minimum cross sectional areas required:

- Motor control circuits: 1.5 mm2
- Current Transformers: 2.5 mm2
- Panel internal wiring: 1.5 mm2

### 6.10.12 Instruments Cables and Wiring

Wire and cables for 4-20 mA electronic instrument installation shall be single pair not less than 1.5 mm2 tinned copper conductors with PVC insulation, twisted, with individual screen comprising aluminium tape (100% coverage), Mylar tape separators and drain wire, covered by an extruded PVC inner sheath, galvanised steel wire armour (SWA), and overall PVC jacket.

Instrumentation cable shield will be aluminium/Mylar tape with an 18AWG stranded copper drain wire.

Thermocouple extension wire shall be selected to be compatible with the instruments to which it is connected. Important parameters include wire type eg: "EX" for Type E, conductor material, temperature range and limits of error. Insulation materials shall be EPR or XLPE and jacket materials shall be Hypalon or CPE. Thermocouple extension wire shield shall be aluminium/Mylar tape with an 18AWG stranded copper drain wire. Thermocouple terminal blocks, where used, shall be of the compensated type.

Coaxial and Triaxial Cable shall be selected to be compatible with the systems to which it is connected. Special vendor installation requirements shall be adhered to.

### 6.10.13 Optical Fibre Cable

The optical fibre shall be loose buffered tube cable complete with termite shield and strength member, suitable for direct burial. No paper fillers shall be used. Outer jacket to state manufacturer, type, number of fibres, year of manufacture and sequential length.

A minimum of 100 per cent over capacity in the number of fibres and not less than four fibres per cable shall be available on completion of commissioning in each cable.

Fibre-optic cables shall be:

1. Suitable for outdoor use - UV, water, fungus and rodent resistant
2. Suitable for the wide operating temperature ranges of the site
3. Include a 900 µm tight buffered coating on each optical fibre for environmental and mechanical protection

Outdoor fibre cable shall be armoured with armouring suitable for installation adjacent to power cables direct buried and on cable trays in plant areas.

The fibre-optic cable shall be supplied in continuous lengths suitable for the cable lengths specified on schedules. No field splicing of the cable shall be allowed except at designated termination points.

Suitable, fire retardant fillers shall be used in the interstices of the fibres (Interstitial filling).

Optical Time Domain Reflectometer (OTDR) tests shall be carried out to check that the length of run indicated by the test matches the installed length. Any losses associated with termination shall be within cable manufacturer's specification and a maximum attenuation index for all fibres shall be 3.3dB/km. A test report shall be submitted to the Project Manager for approval prior to formal handover.

All terminations shall be made with either epoxy-based or hot-melt adhesives. Dry termination or quick crimp connector methods shall not be used.

### 6.10.14 Cable Installation

#### 6.10.14.1 General

A combination of cable ladder systems, buried cable routes and underground cable ducting shall be provided to route the cabling, taking into account aesthetics, maintenance access to other equipment, and environmental considerations. Above ground conduit based systems shall not be used without the express approval of the Project Manager. To facilitate cable pulling and installation to the bottom of switchgear, a cable trench with non-conductive, non-flammable checker plate covers shall be provided.

Within the Plant area cables shall be routed on cable ladder. Deviation from this requirement shall be with the approval of the Project Manager. Cable entry into switchgear shall be via bottom cable entry.

Ten percent spare space shall be available in all cable support systems on each cable route upon completion of the Facilities.

Cables run external to the Power Plant fence boundary shall be direct buried. Where cables are run beneath roads or access ways, they shall be run within concrete enclosed PVC ducts and the concrete enclosure shall be designed for the expected mechanical loads. Cables shall not be direct buried where the surrounding ground temperature exceeds 30°C.

Cable pulling shall be undertaken using suitable rollers, supports and other equipment to avoid damage during pulling. In particular cable manufacturer's recommended minimum bending radius and maximum pulling tension shall not be exceeded. Particular care shall be taken with fibre optic cables, the installation pulling force shall be monitored using appropriate instrumentation at all times during cable installation, and shall not exceed the manufacturer's recommendation. The Project Manager shall be provided with evidence at the completion of each fibre optic cable installation that this requirement has been complied with.

Cable ladder passing vertically through floors or platforms shall be protected with a concrete kerb or metal kick-plate at the floor level.

Where required for the purpose of fire protection, ladder passing through floors or walls shall have a suitable fire seal at the opening.

Cables shall be laid in the ladder in neat, parallel runs. Each cable installed in the ladder shall be in the same relative position with regard to the ladder, throughout the run.

Single core power cables shall be kept in Tri-foil groups with proprietary clamps.

Control cables may be laid to a depth not exceeding the depth of the cable ladder and to a maximum of 65 mm at any point in a ladder run. Care shall be taken to ensure that the permissible ladder loadings are not exceeded.

Cables contained in cable ladders, conduits or cable ducts shall be continuous with no splices permitted between loads and supply locations.

#### 6.10.14.2 **Cable Segregation**

Cables of different usage, voltage and classification shall as far as possible be physically separated in accordance with IEEE 422, however the following requirements must be complied with unless otherwise approved by the Project Manager.

Where cableways consist of two or more levels of cable ladder, power cables are to run on the higher level and control and instrumentation cables on the lower level.

Where high voltage cables are installed on ladder or in ducts then the ladder or duct shall be a separate, dedicated cable support system.

Control and instrumentation cables are to be segregated into two physically separated groups as follows:

1. Control cables used for intermittent operation of devices, indication and alarms.
2. Low level analogue signals typically 4-20 mA and low level digital signals.

A minimum distance of 300 mm shall be kept between all sound or telephone cables and any other cable except when cable paths cross at right-angles, and where run with low level analogue or digital control cables.

Earthing cables shall be segregated from all other cables such that should an earth conductor be damaged by a high earth fault current, no damage will result to other cables.

Control and instrumentation cables shall not be run in the same cable ladder with medium voltage cables under any circumstances.

#### 6.10.14.3 **Conductor Segregation**

Conductors used for AC and DC circuits shall not be carried in the same multi-conductor cable.

Instrumentation signals shall not be run in the same cable as those required for driving electrical loads such as solenoid valves, power supplies and similar.

Separate cables shall be provided for control and annunciation and power circuits.

#### 6.10.14.4 **Cable Ladder**

Marine grade cable ladder shall be used to support above ground cables. All cable ladders shall be aluminium except around or approaching within 15m of a wet cooling tower. Cable ladder on the cooling tower and approaches shall be proprietary 316 stainless steel or fibre reinforced plastic.

Individual cable exits off cable ladder shall be protected in conduit up to the terminal equipment.

Threaded hanger rods/nuts/washers shall be 316 stainless steel. Concrete anchors shall be chemical (epoxy resin). Welding of cable ladder supports to structural beams is not permitted. Proprietary clamping systems shall be used.

Cable ladder runs are to be continuous and made from manufactured bends risers, tees and fittings where practicable.

Cable ladders shall be installed such that the cables are completely surrounded by the ladder. This means that the bending radius of the cable cannot be more than the bending radius of the ladder that it is in. This is particularly relevant when riser bends are site manufactured or sets are too sharp or do not have enough stages in them.

When bends and risers are made on site they shall use manufactured hinges and fittings and consideration shall be given to the rung locations to provide adequate support for the cables.

Allowance must be made for expansion joints in long runs of ladder (this allowance must consider the cable expansion and contraction also).

Cable ladders directly exposed to sunlight shall be fitted with peaked aluminium covers. This cover must be secured in place at a maximum spacing of 1200mm.

Power cables may be installed in multiple layers providing that de-rating factors are determined in accordance with the appropriate standard and applied to the installation. Cable size calculations are to be based on this configuration allowing for multiple circuits.

Small power cables equal or less than 4mm² can be installed bunched up to a maximum of three layers.

Control cables can be bunched in up to a maximum of three layers.

Air lines on the ladder are to be considered as control cables, but bunched separately to the cables.

Where cable ladder is affixed to removable items of plant the cables installed on the ladder shall have an additional loop of excess cable to allow the ladder to be removed.

Small diameter low voltage and control cables (up to 40 mm OD) shall be fixed to the cable ladder by cable ties. Larger diameter cables shall be secured by double cable ties crossed over diagonally at each fixing point. Black nylon UV resistant cable ties shall be used where the cable tie is exposed to ultra violet light, direct sunlight or is used under cable ladder covers that are exposed to direct sunlight.

#### 6.10.14.5 **Underground Ducting Systems**

All below ground cables within the Power Plant fence boundary shall be run in conduit. Below ground cables shall only be used with the approval from the Project Manager. Above ground cable ladder routes shall be provided.

Conduit runs shall be straight; no bends are permitted. At every change of direction, a concrete vault shall be installed. Underground conduits shall be installed to the same specification as direct buried underground cables (see paragraph 6.10.14.7). Conduits shall be temporarily plugged with proprietary polystyrene plugs immediately after installation, which shall only be removed when cables are installed. Once all cables have been installed, conduits shall be sealed (at both ends).

These underground concrete vaults shall be at least 1000 mm wide, 1500 mm long and 1500 mm deep or a manhole of minimum 1200 mm diameter and 1500 mm deep with a minimum wall and cover thickness of 100 mm. Vaults shall be pre-cast before installation to a standard design. They shall have “soft-spots” which can be punched out for installation of conduits. Vaults in trafficable areas shall be rated to withstand such loads. All vaults shall be provided with a low point sump and soakage drain. All vaults shall have a concrete slab cover that is sealed with silicon sealant to the vault walls to provide waterproofing. Vault covers shall have a minimum of four (at each corner) cast-in galvanised steel lifting hooks which are flush with the cover top surface. Conduits shall be sealed to vault walls to provide a waterproof seal. Vaults shall be bedded on the bottom and all sides with 100 mm of clean sand.

Conduit and associated fittings shall be high impact strength PVC. All conduits shall be jointed/sealed using an appropriate solvent. In the case of underground conduits this solvent shall be applied before placing the conduit in the trench.

Flexible conduit shall be used wherever there is a connection between two items where one of the other items is subject to movement of vibration. Where flexible conduit is required, a product from the Anamet Anaconda (or approved equivalent)

range with a stainless steel inner sheath shall be used. Stainless steel glands from the same manufacturer that specifically match the conduit shall be used.

All conduits shall be adequately sized so that any cable can be withdrawn and replaced at a later date.

All underground cable systems shall be fire sealed to a minimum of 2hour rating where they entry or leave any building, structure or cable vault to prevent the spread of fire.

#### 6.10.14.6 **Above Ground Conduit**

In cases where above ground conduits are permitted by the Project Manager, the Contractor shall provide draw-in junction boxes where necessary for this purpose at maximum 10 metre intervals and at all changes of direction. Above ground conduits shall be adequately supported to ensure conduits do not sag. Conduits 32 mm and smaller shall be supported at centres not exceeding 500 mm.

Conduit bends in conduits above 32 mm in size shall be made from pre-formed sections. Bends in conduits 32 mm and below shall be made using appropriate sized bending springs. Conduits bends shall be selected be to ensure cable manufacturer's recommended minimum bending radii are not exceeded.

Conduit exposed on walls or ceiling shall be run parallel to or at right angles to the building lines and shall be located so that it will not interfere with apparatus and other services. Conduit runs shall be grouped and attached to an approved hanger system, or to a solid surface. Where conduits are run in a group the spacing shall be such that all conduits are accessible for maintenance or removal.

Conduits shall be fastened to a wall or structure by clamping to Unistrut channel spacers with heavy two hole 316 Grade stainless steel spacer saddles which shall be screw fastened at both sides of the conduit at a maximum spacing of 2m. All support brackets and racks shall provide for an increase of at least 100% in the number of conduits initially supported.

#### 6.10.14.7 **Direct Burial**

Any direct buried cables shall be buried to a depth of at least 1000 mm. Good trade practice in regard trench preparation, bedding, materials and cover shall be followed to ensure damage does not occur during installation or service. Trenches may be hand or machine dug providing the finished open trench provides two clean sides and a clean even bottom. The cable bedding material shall be clean sand that is sieved to remove sharps and any objects greater than 5 mm diameter. The bedding material shall be at least 200 mm below and above cables in depth. Bedding material shall be compacted using a mechanical vibrating compacter before backfilling. Backfill material may be the removed spoil providing it is free from rocks, else fresh backfill material shall be used. Backfill material shall be compacted using a mechanical vibrating compacter before placing the warning strip. The remaining backfill material shall then be placed and be compacted using a mechanical vibrating compacter. Additional backfill material shall be added as required to provide an even (with adjacent ground level) finish. Backfill material shall have thermal resistivity properties that are commensurate with the Contractor’s cable rating calculations.

Concrete slabs shall be placed over these cables at a depth of 800 mm (directly over the bedding material) and a 100 mm wide polythene warning strip shall be buried at 300 mm. The location of the cable shall be clearly identified above ground with permanent concrete maker posts or slabs marked “buried cable beneath” at intervals of 10 m and at every change of direction.

Where there is existing thermal features or risk of thermal features in the ground at or near to where cables are proposed to be buried, the Contractor shall supply concrete culverts to protect the cables from geothermal fluids.

### 6.10.14.8 **Fire Rated Penetrations**

Where cables and cable ladders pass through fire rated walls, floors or ceilings, penetration gaps shall be back filled with a UL listed fire-stopping compound. A suitable range of compounds is the “Flamesafe” products from IPC (or approved equivalent). Where cable installation is “permanent” but may be subject to movement or vibration, sealing shall be achieved with a material that sets but remains flexible. All fire stopping installations shall meet or exceed the fire rating of the wall, floor or ceiling through which it passes.

### 6.10.14.9 **Cable Glanding**

All cables shall be glanded at point of entry to equipment.

Glands shall be 316 stainless steel for all steel wire armoured cables, nylon or aluminium elsewhere.

All motor, instrument and control equipment shall be factory fitted with termination boxes and entries to suit steel wire armoured cable glands. Conduit entries, except where required for flexible connections and unarmoured cables, shall not be used, nor shall any adaptors to accommodate steel wire armour cable glands.

Termination of flying leads within site fitted termination boxes is not acceptable.

Maximum permitted tolerance between glands and gland plates/termination boxes/any other surfaces to which glands are attached, is 2 mm (diameter) for glands 50 mm diameter and larger, 1 mm (diameter) for glands less than 50 mm in diameter.

Cable glands shall be suitable for the cable provided.

Glands for termination of cables to equipment shall match or exceed the IP rating of the equipment. Gland shrouds shall be fitted to all glands.

Glands for extruded solid dielectric insulated cables (PVC, XLPE) shall be of the compression type and as specified in BS-EN 50262.

All glands shall be provided with an earthing tag or equal facility. Glands for armoured or screened cables shall be provided with an integral heavy duty earthing lug capable of carrying the full earth fault current for a period not less than 1 second without deterioration.

### 6.10.14.10 **Conductor Termination Fittings**

Conductor fittings for terminations shall be of a type recommended by the cable manufacturer as suitable for the service involved. They shall include all sealing compounds and sleeving used and selected to suit the service temperature conditions under which the cable is to operate.

Cable conductor fittings shall be of the compression type or mechanical shear-bolt type. Compression fittings shall be specifically matched to suit cable conductor dimensions. Fittings shall comply with IEC 61238-1 and shall be rated to suit conductor load transfer and fault capacity ratings.

Mechanical shear-bolt connectors shall be correctly suited to conductor size and load transfer capacity and fault ratings. Fittings shall comply with IEC 61238-1 for mechanical and aging behaviour.

Outdoor conductor lugs shall be blank types, to prevent core conductor water ingress. Blank type compression ferrules shall be used wherever practicable, to provide core longitudinal water-blocking properties. The lugs shall also have heat shrink provided to cover the lug shank and at least 15mm of conductor insulation.

For control and instrument terminations the Contractor shall provide boot lace or pin lugs for cage clamp terminals. All other terminals shall be pre-insulated boot lace, non-lip blade or spade type terminals.

#### 6.10.14.11 Cable Identification

All conductors shall be uniquely identified at terminations. Cable end sleeves shall be colour coded as follows:

1. AC (3-Phase) Red, white, blue for A, B, C, black for neutral, green for ground,
2. AC (1-Phase) Red and black (black for neutral)
3. 110 V DC Red sleeve and “plus” ferrule for positive, black sleeve and “zero” ferrule for zero, and white sleeve plus “negative” ferrule for negative
4. 24 V DC White sleeve and plus ferrule for positive, black sleeve and zero ferrule for zero, and black sleeve and negative ferrule for negative

#### 6.10.14.12 Cable Marking

Cable numbers shall be fastened at both ends of every cable. Cable numbers shall be Grafoplast yellow with black lettering or etched stainless steel type, in accordance with cable schedules. Alternative cable marking systems shall be to the approval of the Project Manager. Cable numbers shall be installed inside cubicles where possible.

Where cables pass through penetrations and both sides of the penetration cannot be viewed from the same location then cable marker identification shall be installed on both sides of the penetration.

Where the cable number is exposed to sunlight then black nylon UV resistant cable ties shall be used to attach the cable number to the cable.

#### 6.10.14.13 Core Numbers

All control cable cores are to be fitted with numbered ferrules in accordance with the schematic diagrams or connection tables. The numbers shall be pre-printed on slip-on white ferrules; self-adhesive tape numbers shall not be accepted.

All spare cores are to be labelled with the number of the cable. They shall be left at their maximum lengths for possible replacement of any other conductors in the cable. Each spare conductor shall be neatly coiled and then taped to the conductors being used.

#### 6.10.14.14 Testing

All cables shall be tested for continuity, identification and insulation. All medium voltage cables shall be field voltage tested after laying at a level recommended by the cable manufacturer. Power and control cables shall be tested with a 1000 V megger while instrument cables shall be tested with a 500 V megger. Test records shall be provided to the Project Manager.

Cable manufacturers must provide positive evidence that the cable they are supplying passes the Vertical Flame Test and Cable Tray Fire Test (both oily-rag and gas-burner tests) in accordance with ICEA S-68-516 and IEEE 383. The test data must be certified by an independent agent.

## 6.11 General Electrical Equipment

The Contractor shall install all electrical equipment in accordance with equipment manufacturers and supplier’s guidelines and requirements.

Manufacturer’s’ representatives shall inspect and approve the installation and testing of the generator, the exciter/AVR and the 11kV switchboard prior to energisation.

The Contractor shall connect temporary power supplies to all anti-condensation heaters as soon as equipment is installed on site.

The Contractor shall provide temporary supplies to all battery chargers and ensure all battery banks receive a refreshing charge within 90 days of delivery. A capacity discharge test shall be made on each battery bank.

Construction power supplies and installation shall be installed and maintained in a safe condition in accordance with basic rules for good working practice.

The Contractor shall ensure that prior to installation of any equipment which requires protection by filtered, $H_2S$ free, “clean air”, the systems to provide this “clean air” are fully operational. To achieve this, temporary power supplies may be required.

### 6.11.1 Hazardous Areas

Electrical equipment located within any defined hazardous areas shall be selected to comply with the area and temperature classification of the flammable agent therein. The protection technique employed to achieve this shall be in accordance with IEC requirements.

### 6.11.2 Vibration and Seismic Resistance

All equipment as well as its foundations and equipment holding down assemblies shall be designed to withstand seismic forces in accordance with the requirements of Section 4.2.

### 6.11.3 Gaskets

Gasket materials shall be suitable for the environmental conditions and for the duty. Materials which are not protected by impregnation are to be adequately treated with an approved fungicide. Sleeving and fabrics treated with linseed oil or linseed varnishes shall not be used.

### 6.11.4 Electrical Equipment Labels

All electrical equipment shall be provided with labels or name plates in accordance with requirements stated elsewhere in this document, giving any identifying name, type or serial number, together with information regarding the rating, nominal voltage and current and the like, under which the item of plant in question has been designed to operate.

All electrical equipment labelling shall follow the Employer’s standard.

Panel mounted components shall be labelled with a function description. All apparatus within cubicles shall be labelled with either a complete description of the function or a non-ambiguous code relating to the circuit diagrams. The English language shall be used throughout.

Bold danger and warning notices shall be displayed where the removal of covers exposes live voltage above extra low voltage. These labels shall be red lettering on yellow background. They shall be of adequate size and be easily readable.

Exterior electrical equipment labels shall be permanently attached to each item of the Plant by industrial, high temperature sealant. Self-adhesive labels shall only be used for interior panel equipment identification. The inscription shall be either a complete description of the function of the item or an unambiguous code relating to the drawings.

Labels shall be made of corrosion resistant material, such as laminated plastic. Embossed stainless steel labels shall be used where plastic is unsuitable for the environment. Plastic labels shall be engraved with black lettering on a white background unless otherwise stated; stainless steel labels shall be etched or engraved and painted

### 6.11.5 Locks

Locking facilities shall be provided generally as follows:

1. Control position selector switches in all positions provided.
2. Marshalling, operating and terminal kiosks or cubicle access doors and panels.
3. MV and LV circuit breakers and contactors in isolated position, and
4. Outdoor panels, in which case the lock components shall be stainless steel.

Separate keying common for MV, LV and instrument services shall be provided. Details of the proposed keying system shall be provided for review by the Project Manager.

### 6.11.6 Anti-Condensation Heaters

Any major items of electrical equipment or panels which are liable to suffer from internal condensation due to atmospheric or load variations shall be fitted with heating devices suitable for electrical operation at 240 V ac, 50 Hz, single phase of sufficient capacity to prevent condensation. The electrical apparatus so protected shall be designed so that the maximum permitted rise in temperature is not exceeded if the heaters are energised while the apparatus is in operation.

Electrical supplies for anti-condensation systems shall be separate (separate cable and protection / isolation) from the main power supply to the equipment in which they are fitted. Warning labels shall be affixed to all such equipment to alert maintenance personnel that there are two (or more) points of electrical supply to be isolated for safety.

### 6.11.7 Indicating Lamps

Indicating lamps fitted to the fascias of switch and instrument cubicles or panels shall be clearly discernible when illuminated under general lighting levels of 400 lux. High intensity LED type shall be used. Neon type lamps shall not be used.

Lamps shall be easy to remove and replace from the front of the panel by manual means not requiring the use of extractors.

The rated lamp voltage shall be at least 25 per cent in excess of the auxiliary supply voltage for AC and DC.

Lenses shall be glass or plastic in standard colours red, green, blue, white, and amber. Indication colours shall be subject to the approval of the Project Manager.

Five spare LED’s of each type and colour used shall be supplied.

### 6.11.8 Control Switches, Push Buttons

Control switches for electrically operated circuit-breakers shall be of pistol grip type arranged to operate clockwise when closing the circuit-breakers and anti-clockwise when opening them. They shall be designed to prevent accidental operation and interlocked to prevent two successive operations in the "close" direction (i.e. they must be turned to the trip position before initiating a closing operation).

Other apparatus shall be operated using shrouded push-buttons or handles of the spade or pistol grip type. All push buttons except for special "emergency stop" use shall be of the non-retaining type made of non-hygroscopic material, non-swelling and fitted to avoid any possibility of sticking.

"Emergency Stop" push buttons shall be of the red rotate to reset type. They shall be adequately protected against accidental operation.

All control switches shall be provided with labels to give clear indication as to the direction of each operation.

### 6.11.9 Electrical Instruments

All electrical instruments and meters are to comply with IEC 60051 and IEC 60414 and, unless otherwise specified, shall be of industrial grade quality.

All indicating and recording instruments shall be of the flush mounted pattern with dust and moisture proof cases complying with IEC 60068 classification 20/40/04, or rack mounted in a cubicle with a clear perspex door. Rack mounted instruments are preferred. Dimensions shall be in accordance with IEC 61554, with a preferred size of 144 x 144 mm for outdoor equipment and 92 x 92 mm for indoor equipment.

Instrument dials in general shall be white with black markings and should preferably be reversible where double scale instruments are specified. Scales shall be of such material that no peeling or discolouration will take place with age. Wherever possible, instruments shall be provided with a readily accessible zero adjustment.

### 6.11.10 Enclosures

All enclosures, including terminal boxes, junction boxes, control panels, local/field control stations, shall be designed for ease of operation and maintenance and shall have spare space for future instrumentation, piping, tubing and cabling with glanded cable entries. The minimum spare provision shall be 20 per cent.

Cable entry shall be from below via earthed aluminium gland plates. Gland plates shall be pre-drilled or punched off site to match the glands to be fitted and shall be a minimum of 5mm thick. Sufficient spare holes shall also be included to ensure no additional holes have to be drilled at site. Spare holes shall be plugged/capped with stainless steel blanks to provide the same IP level as the enclosure. By exception, additional holes may be drilled on site after prior approval by the Employer.

All used (i.e. with cable) entries shall be installed using appropriate cable glands with an IP rating (as determined by IEC60529) equal to or higher than the enclosure itself.

All enclosure support stands and brackets shall be via hot dipped galvanised steel. If Unistrut brackets are provided then these shall be 316SS material.

All enclosures shall be of proprietary manufacture with type testing certification for IP rating by an independent, quality assured, testing laboratory.

No on site drilling of holes in the enclosure shall be permitted.

Enclosures inside air conditioned rooms shall be to IP41 or better. If required by the internal components' heat dissipation the enclosures shall be well ventilated top and bottom through vermin proof louvres with a gauze screen attached to a frame and secured to the inside of the louvre opening. Divisions between compartments within the enclosure shall be perforated to assist air circulation.

All fastenings shall be integral with the panel or door and provision made for locking. Access doors or panels shall be glazed where instruments are required to be viewed as part of regular operation.

Enclosures shall be provided with a LV single phase switched socket outlet of approved manufacture and type. Fuses for this circuit shall be mounted within the cubicle. Protection, metering, and control panels shall have a 60 W equivalent, LV 1ph AC LED light fitting with safety cover. The light shall be mounted at the top of the enclosure and controlled by a door activated switch.

The cubicle and panel functions shall be prominently displayed on a permanent label mounted on the outside of the cubicle or panel.

For all outdoor enclosures the installation shall include the following features:

1. IP65 rated, and manufactured from 316 stainless steel.
2. The door securing mechanism shall ensure the IP rating is retained indefinitely despite repeated opening/closing of the door. It shall be lockable and use permanent handles rather than require a special tool.
3. Domed or sloping roof and drip lip manufactured from 316 stainless steel
4. A hot dipped galvanised steel stand affixed to a concrete plinth to support the enclosure such that the base of the enclosure is at least 500 mm clear of the finished surface.
5. Cables glanded through pre-drilled gland plate in bottom of enclosure.
6. If they contain anything other than terminals and where any of the contained equipment has an IP rating less than IP65, they shall be continuously purged with clean instrument quality H2S free air and shall have at least two over-pressure relief devices. Instead of the instrument air purge Contractors may provide thermostatically controlled enclosure space heaters sized that in the event of the thermostat failing energised the heater element shall not cause an internal temperature rise of more than 5 deg C.

#### 6.11.10.1 **Terminals**

Low voltage AC circuits shall be segregated from other circuits and associated terminals shall be fitted with non-flammable transparent plastic covers to prevent accidental contact with live parts. They shall have warning labels with red lettering mounted in a conspicuous position.

All control and instrument wiring shall use terminals incorporating a disconnection plug or blade switch for isolation. Each core shall be assigned to a separate isolation terminal. No more than two cores shall be terminated in any one terminal. Enclosures shall have at least 10 per cent spare terminals and enough extra space on mounting bars for another 20 per cent terminals. Sufficient length of spare wiring shall remain to allow any core to be transferred to any other terminal in the same rack.

Terminals shall be numbered sequentially, beginning at the top or left side of the row. Numbered markers shall be used with each terminal block, and the row shall be marked with a group number.

Auxiliary components shall be mounted in appropriate terminal blocks on the terminal rails.

Terminal boards shall be spaced not less than 100 mm apart. For relay panels, they shall be mounted at the sides of the cubicle, and set obliquely towards the rear doors to give easy access to terminations and to enable ferrule numbers to be read without difficulty.

Studs of stud type terminal boards shall be locked in the base to prevent turning and all connections shall be made on the front of the terminal board using lock nuts or lock washers. Where crimped type terminations are provided at least two sets of crimping tools must be supplied for each installation.

Terminals shall be of the insertion clamp type incorporating captive pressure screws which do not bear directly on the wire but on a serrated clamping plate. The pressure screws shall have an inherent locking feature.

Where connections are to be made between the multicore cables supplied and telephone type multicore cables, then the terminals shall comprise a stud or clamp type terminal for the multicore cable and a soldered tag for the telephone cable joined by a withdrawable insulated link. These terminals shall also be provided with facilities for the insertion of test probes on both sides of the link.

The use of terminals as junction points for wires which are not required in the associated cubicle shall be avoided wherever practicable.

### 6.11.10.2 **Small Wiring**

All panel wiring, secondary control wiring in circuit breakers, motor starters, control gear and other similar equipment shall be colour coded. Installation shall be in accordance with the IEC standards.

Wiring shall be carried out in a neat and systematic manner with cables supported clear of the panels and other surfaces at all points to obtain free circulation of air.

The wire used for panel wiring shall have tinned copper conductors conforming to the requirements of IEC 60228. The conductors for bus and power wiring shall have a cross section area of not less than 2.5 $mm^2$ and for other wiring not less than 1.5 $mm^2$ and be of not less than seven strands. Multi-pair cables shall have tinned copper conductors of not less than 1.5 $mm^2$ laid in twisted pairs. Wiring diagrams must indicate wire markings which shall comply with the requirements of IEC 60446.

Adequate slack wire shall be provided to allow for one re-stripping and re-connection at the end of each wire.

All wires shall be fitted with numbered ferrules of approved type at each termination. The ferrules on wiring directly connected to circuit-breaker trip coils, tripping switches, etc., shall be of a colour, preferably red, different from that of the remainder and marked "trip".

No wires shall be teed or jointed between terminal points.

All metallic cases of instruments, control switches, relays etc., mounted on or in cubicles, steel or otherwise, shall be connected by means of PVC covered coated tinned copper conductors to the nearest earth bar.

# 7. Control and Instrumentation System Requirements

## 7.1 Overview

The plant control and instrumentation system shall provide a safe, reliable, efficient and essentially automatic system for coordinated control and monitoring of the Power Plant and SGS in all modes of operation.

The Contractor shall be responsible for the suitability of all the control and instrumentation equipment supplied for both local and remote operation of the Facility as specified and for its suitability for the site conditions described in this specification.

## 7.2 Control System Design Philosophy

The OCR shall contain operator facilities for control and monitoring of the entire Power Plant, the SGS and the MV Switchgear. The OCR shall contain the operator desk with HMI, printers, fire panel monitoring, site access control, communications (telephone and VHF radio) and similar operator facilities.

A Distributed Control System (DCS) with computer based operator workstations shall be used for the supervision and monitoring of the Facility, including the run-up, synchronising, loading and shutdown.

If necessary where the uniqueness of a control system element makes this unavoidable, separate control systems may be provided. The only elements considered to fall into this category are the Functional Safety System (FSS), automatic voltage regulator (AVR), synchronising equipment, governor controls and machinery protection. These shall be interfaced to the main DCS using Ethernet, or where that is unavailable, serial connections and where necessary, hardwired connections. These separate controls systems shall be considered to be part of the DCS, and the term DCS is used hereinafter to collectively refer to them and all the requirements stated hereinafter for the DCS shall equally apply to these separate control systems.

## 7.3 Control Desk

All DCS HMI work stations shall be installed in the OCR on a suitably designed control desk(s) acceptable to the Project Manager. The desk(s) shall also incorporate other facilities such as the emergency trip panels and a telephone console. The desk(s) shall be ergonomically designed and be the centrepiece of the OCR. A modular approach to construction shall be adopted which permits segregation of workstations to suit assigned operational responsibilities for different sections of the plant. The control desk design shall provide generous workspace for plant operators.

## 7.4 Control and Monitoring Functions

The system shall permit data acquisition and control functions to be performed at various plant area locations while providing the capability to monitor and control the distributed functions from the HMI. The DCS shall be flexible enough so that it can be configured to a wide range of process requirements at the loop and component level by software configuration changes only.

The DCS functions shall include but not necessarily be limited to the following:

1. Condenser Hotwell level control and monitoring
2. Cooling tower cold basin level control and monitoring
3. Condensate injection flow control and monitoring
4. Circulating water and cooling tower control and monitoring
5. Turbine generator tripping
6. Turbine run-up, synchronising, loading and shut-down controls and monitoring

7. Gas extraction system controls and monitoring
8. Electrical parameters and generator controls and monitoring
9. All control, status monitoring and alarm requirements of the SGS
    a. Pressures and temperatures
    b. Separator and scrubber level controls
    c. Brine pump station supervision
    d. Reinjection well flows, pressures and alarms
10. All control and monitoring of the MV Switchgear
11. Auxiliary equipment operation
12. Electrical protection alarms
13. Revenue metering recording
14. Computed based operator interface
15. Alarm management and event recording system
16. Trip disturbance logging system
17. On line Trending subsystem
18. On line performance calculations
19. Operation and production reporting
20. Plant Data Historian

## 7.5 System Integrity

The Contractor's system and equipment shall be designed to comply with the following general criteria:

1. No single fault shall cause the complete failure of the DCS. However, such fault shall be alarmed.
2. No single fault shall cause the protection system to operate spuriously or cause the protection system to become inoperative. However, such fault shall be alarmed.
3. No single failure of any system, equipment or power source shall interrupt or disrupt any system function. However, such failure shall be alarmed.
4. No single failure shall cause any controlled equipment to change status except as specifically described in the Contract.
5. No communication links failure shall render forced outage of the Facility. However, such failure shall be alarmed.
6. For redundancy provisions of equipment, no single fault within the DCS shall cause the failure of the duty equipment and at the same time cause the standby equipment to be unavailable. With duty equipment in service, any failure within the DCS that causes the standby equipment to be unavailable shall be alarmed to the operator.
7. No failure within the Contractor's system or wiring shall impose any earth path for any power source provided.
8. Alarms and trips shall remain active in manual and automatic modes. Exceptions to these requirements are:
    a. In cases of a failure of a single system input transducer (not a multiple measurement transducer) or of an input module serving only that transducer, a system response to the failure will be allowable. All such failures, however, shall be alarmed.

b. In cases of processor or a control system failure, where a single control system has been specified to serve without a backup, a system response consisting of locking the output or a shutdown of running equipment may be allowable. All such failures, however, shall be alarmed.

c. In cases of power source failure, or a logic failure, the system shall produce a pre-designed and predictable failure mode. All such failures shall be alarmed.

9. The DCS shall incorporate comprehensive self-checking facilities and adequate test facilities, so that internal faults can be detected within the systems and provide alarms prior to any resulting disturbance to the process.
10. The alarm system provided shall be in accordance with the criteria described elsewhere in this specification.
11. The system's controller and power supply modules shall be in a redundant configuration and shall be hot swappable with no interruption to system control
12. The system's I/O modules shall be hot removable and replaceable with disruption in control only to those I/O associated with an individual module

## 7.6 System Failure Modes

The DCS shall be designed to react in a predictable manner to certain system failures, as generally described herein. General cases of failure mode are described in the following paragraphs.

1. Upon system logic failure, as detected by system diagnostics, the system shall transfer to its backup. If the backup does not exist, or is unavailable, the outputs shall fail to a predictable status and shall enable any manual shutdown facilities that are appropriate to provide orderly shutdown of equipment. Generally, outputs shall hold the status existing prior to the failure.
2. Upon system logic power supply failure, or system I/O power supply failure, the system shall transfer to its backup. If the backup does not exist, or is unavailable, the outputs shall fail to a de-energised state, which shall be designed to produce minimum disruption of operation.
3. Upon failure of driving power to a controlled device which is running, the system shall react in a predetermined manner, either to command a restart of the equipment upon power resumption, or to cycle the logic to a status requiring equipment shutdown. In either case, the system shall command a start of any backup equipment without waiting for any process deterioration.
4. Upon interruption of a logic sequence caused by failure of controlled equipment, or by equipment not being available to allow the completion of the sequence, the logic system shall automatically reset itself, and shall automatically reset controlled equipment to a safe and predictable condition. Once the sequence has been interrupted, such conditions shall be alarmed and the logic system shall not resume the sequence unless it is re-initiated by operator's action.
5. It shall be possible to hot swap out controller modules without interruption to system integrity.
6. Any failures described above shall not affect the protection and reliability of the generating units and associated major process equipment.

## 7.7 Plant Protection

Trip signals shall be derived as directly as possible from the initiating device. Wherever possible, pending trip conditions shall be alarmed at the operator interface.

Safety functions as identified in the FSS defined in clause 7.8 shall be implemented and verified in accordance with IEC61511.

For each Unit, an emergency trip panel shall be provided in the OCR on the control desk equipped with hardwired trip button for emergency tripping of the Unit. The emergency trip function shall be hardwired and bypass all DCS systems. The emergency trip button shall be monitored by the DCS such that all trip actuations are recorded.

Unless otherwise specified or agreed, trip devices must be reset before plant is permitted to restart.

All trips shall be alarmed and trip sequences recorded at the operator interface.

Sequence of events monitoring and alarming via the DCS will be performed on all station protection relay actuations.

DCS control nodes shall be equipped with dual power supplies, redundant control processors, and a redundant local area network.

The DCS shall be designed to ensure that the plant reverts to a safe state upon failure of any individual plant item or power supply, and that the operator is notified of the failure. The following means may be used to ensure a "safe" state:

1. Automatic switching to a standby device or power supply
2. Shutdown of the affected plant
3. Locking of the DCS at the settings prevailing immediately prior to the failure

During fault conditions, common mode voltages, transients, and other system disturbances may occur and the Contractor shall state in design documents the maximum voltages between input terminals and earth that can be tolerated without disturbing the operation of the equipment and without causing electrical damage. Full details shall be given of any protective equipment being provided to minimise the effects of such disturbances.

## 7.8 Functional Safety Systems

This section outlines the requirements for the design and delivery of Functional Safety Systems (FSS) associated with the Plant. FSS's are those systems that provide key protection against significant hazards, where a "significant hazard" means a hazard that is an actual or potential cause or source of:

4. Serious harm; or
5. Harm (being harm that is more than trivial) the severity of whose effects on any person depends (entirely or among other things) on the extent or frequency of the person's exposure to the hazard; or
6. Harm that does not usually occur, or usually is not easily detectable, until a significant time after exposure to the hazard.
7. Adequate design, maintenance and operation of FSS's are required to accepted international practice standards for unattended systems and also to comply with the Employer's Safety, Health and Environment requirements. In particular, the following standards shall apply;
8. IEC 61508 (all parts) - Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems (E/E/PE, or E/E/PES).
9. IEC 61511 (all parts) - Functional safety - Safety instrumented systems for the process industry sector.

It is expected that the HAZOPs (refer section 1.6.9.10) shall be pre-cursors to the FSS work, in so far that the HAZOPs shall identify those systems which are safety critical and which must, therefore, be considered under the FSS analysis.

Throughout the development of functional safety requirements, the 'As Low As Reasonably Practicable' (ALARP) principle shall be applied. Risks shall be shown to be ALARP, i.e. reduced where it is practicable to do so. ALARP can be demonstrated when the cost of further risk reduction is grossly disproportionate to the benefit gained. Any identifiable residual risk to human life will not be accepted.

### 7.8.1 Identification of FSS

The identification of necessary FSS's should be undertaken using a clear, robust, systematic and transparent process. This shall be the responsibility of the Contractor and shall be arranged, prepared, facilitated and recorded by that party. The process used shall be at the discretion of the Contractor, but shall include the following key steps:

1. Definition of the Plant safe operating envelope during normal conditions;
2. Identification of Plant mal-operations and other initiating events that may lead to a hazardous condition;
3. Determination of margins between the safe operating envelope and the hazardous condition;
4. Identification of the operational controls that have to fail to challenge the FSS;
5. Consequence assessment of the hazardous conditions developed to determine which are significant;
6. For each significant hazardous condition, a statement specifying the FSS which protects against it.

It should be noted that FSS implementation should not be a first resort. Alternative designs should also be considered that remove or reduce the hazard without the need for intervention.

The FSS is not necessarily a single item. All components within the system that are required to form a full line of defence against the hazard shall be part of the FSS. For example, if a valve requires closure in the event of a high pressure signal, the pressure detector, relay, solenoid and valve would all form part of a single FSS.

### 7.8.2 Justification of Adequacy

Following identification of FSS's, the Contractor shall review each FSS to demonstrate their adequacy to fulfil the safety role identified. Input to the review by the Employer's personnel, particularly the operations staff shall be sought by the Contractor. This review shall include, but not be limited to:

1. A review of defence in depth – showing levels of operational failures required before the FSS is challenged and that a single failure cannot result in a dangerous condition;
2. Conformance to relevant national and international design standards;
3. Demonstration of system reliability (including to the appropriate SIL level for instrumented systems);
4. Confirmation that the design meets the FSS design philosophy;
5. Recovery and remediation requirements following FSS operation (including confirmation that systems that will be required to investigate and correct the fault and bring the Plant back on line will still be available following the trip);
6. Assessment of the risk to personnel during operation and demonstration that this meets the Employer's risk acceptability model as laid out in the Employer's risk management framework.
7. If, during this review process, a shortfall is identified in the designed system, changes shall be made either by revising the system to ensure a more robust system, additional system(s) added or reviewing the design to remove or reduce the hazard potential.

### 7.8.3 Design

It is a fundamental requirement of the FSS that the components and devices for such systems have a high degree of integrity and ability to operate on demand. FSS's may be active instrumented systems that trip the plant in a given situation, active mechanical systems that prevent the mal-operation escalating into a hazard (e.g. relief valves) or they may be passive protection (e.g. physical barriers separating equipment from personnel). Where practicable, design options for FSSs should be in accordance with the following hierarchy:

1. FSSs must be capable of independent, automatic operation to bring the plant to a safe state without any intervention required. Independent, in this context, means that they shall be systems separate from the Plant normal operational control systems and should not be challenged except in the fault condition.
2. FSSs should not, as far as practicable, share field input devices, control hardware, power supplies or final control devices with the associated Plant control systems.
3. Following activation of FSSs, return to normal operation must only be achieved through manual intervention via a controlled start-up procedure which incorporates the requirement for diagnosis and rectification of the original fault.
4. Analogue transmitters shall be used in preference to level, flow or pressure switches. This will enable effective monitoring and discrimination between transmitters. Loop failure detection is to be incorporated for each instrument loop.

### 7.8.4 Risk Matrix

The project risk matrix to be used to assess the level of acceptable risk for the design of the FSS's shall be as follows or as agreed with the Project Manager:

| Severity \ Likelihood | **Unlikely (Category 1)** Not likely to occur in the life of the facility. May occur in one of several like facilities. | **Remote (Category 2)** Likely to occur once in the life of the facility (e.g., once every 50 years). | **Occasional (Category 3)** Likely to occur more than once in the life of the facility (e.g., once every 10 years). | **Frequent (Category 4)** Likely to occur several times in the life of the facility (e.g., once yearly). |
|---|---|---|---|---|
| **Negligible (Level 1)** **Operating Personnel** : Superficial injury. **Public** : No impact. **Environmental** : Hazardous process fluid contained. **Equipment** : Minor equipment damage and negligible downtime (<1 day). | **1** | **2** | **2** | **3** |
| **Marginal (Level 2)** **Operating Personnel** : Minor injury. **Public** : No impact. **Environmental** : Small release of hazardous process fluid. **Equipment** : Minor system damage and downtime (>1 day). | **2** | **4** | **6** | **6** |
| **Critical (Level 3)** **Operating Personnel** : Severe injury. **Public** : Exposed to accident. **Environmental** : Uncontained release of hazardous process fluid. **Equipment** : Major system damage and downtime (>10 days). | **3** | **6** | **7** | **8** |
| **Catastrophic (Level 4)** **Operating Personnel** : Death. **Public** : Exposed to threatening accident. **Environmental** : Large, uncontained release of hazardous process fluid. **Equipment** : Extensive facility damage and extended downtime (>90 days). | **4** | **7** | **8** | **9** |

| | | | | | |
|---|---|---|---|---|---|
| **7 to 9** | Unacceptable Risks Risk reduction mandatory | **3 to 6** | Transitional Risks Consider risk reduction if costs are not excessive | **1 to 2** | Tolerable Risks No risk reduction required |

## 7.9 DCS Functional Design Description

The DCS shall provide integrated facilities for supervision of the Power Plant, SGS and MV switchgear from a control desk in the OCR.

Prior to commencement of configuration of the DCS, the Contractor shall prepare and submit for the approval of the Project Manager a comprehensive Functional Design Description (FDD) of the DCS.

The FDD shall contain a comprehensive description of the system configuration and system functions. The FDD shall include a description of operator interface display philosophy including display organisation, display symbol standards, colour schemes, graphic layouts, and operator keyboard sequences and control sequences.

The FDD shall include a detailed description of the alarm management system including tag naming convention, functionality of annunciation, prioritisation, acknowledgement, filtering and recording of alarms.

The FDD shall include preliminary descriptions of all major control logic supported by logic diagrams.

The FDD shall include a description of the DCS interface signals with the MV switchgear.

The FDD shall be updated during the course of the project to be ultimately incorporated in Operating and Maintenance Manuals for the DCS.

## 7.10 DCS Architecture and Hardware Requirements

### 7.10.1 System Availability and Reliability

The DCS shall be of modular design, with a fault tolerant, redundant architecture such that the failure of one section will not affect the operation of other sections of the equipment. The reliability of each constituent part of the system, and the system as a whole shall be such as to meet the overall plant performance criteria. This shall be achieved by suitable levels of redundancy on the equipment. Critical instruments shall be configured to eliminate single point of failure (e.g. terminate instrumentation for redundant equipment on separate I/O cards). There should be no process change resulting from the failure of a controller.

The availability of the DCS shall be not less than 99.99 percent for the first year of service after final acceptance. Availability is defined as the DCS not being the limiting factor in running the Power Plant at NCR

### 7.10.2 Grounding of Control and Instrumentation Subsystems

Grounding of the DCS and instrumentation equipment shall follow good industry practice and be such as to ensure that equipment operates reliably, safely and without damage in the presence of large electrical disturbances such as occur in power generation plant. A separate grounding system for DCS and instrumentation systems shall be established. This shall be isolated from the power system earthing except for a single point connection.

### 7.10.3 Electrical Noise

The system performance shall not be affected by electro-magnetic or radio frequency interference up to 3 V/m and according to IEC 60255-22.

In order to minimise the effects of generated or radiated electrical noise the following shall be provided:

1. The DC power and signal cables shall not run parallel or in close proximity to AC power cables
2. Proper earthing techniques shall be utilised

3. Proper cable shielding shall be utilised
4. Visual Display Units shall not be installed in strong magnetic fields
5. The primary AC power source shall be noise free

### 7.10.4 Vibration & Environment

In addition to the seismic requirements set out in Clause 6.11.2 the DCS hardware shall withstand shock and vibration up to 200 Hz/0.25 g and according to IEC 60255-21.

All DCS hardware modules shall have a conformal coating to a G3 level.

### 7.10.5 Controller Modules

Digital multi-function controllers shall be microprocessor based and be able to control, manipulate, acquire data, and communicate with other controllers and devices via the data highway. Controllers shall be mounted in the system cabinets and shall not in general be field mounted.

The multi-function controllers shall be distributed throughout the various system cabinets and partitioned for maximum reliability. Each multi-function controller shall support on-board diagnostics, with on-board LED indicators defining processor status.

As a minimum, the multi-function controllers shall support the following:

1. High speed processing - analogue and digital loops shall be processed at a user tuneable rate of ten (10) times per second or faster
2. A full range of pre-configured algorithms (function blocks) that can be used to implement control strategies in a "connect-the-block" manner
3. Logic to be capable of freely mixing analogue and sequence logic
4. Capable of executing user-defined functions not included in the standard function block library
5. Capable of executing any combination of the above functions simultaneously in a given multi-loop controller
6. Capable of peer-to-peer communications with every other module in the system
7. Capable of on-line tuning of PID algorithms and other parameters

Multi-function controllers shall be configured in a “Primary/Hot-Standby” configuration and there shall be no single point of failure in the system architecture.

The use of redundant multi-function controllers shall enable the system to be modified on-line without interrupting the execution of control logic by the primary multi-function controllers.

### 7.10.6 System I/O Modules

The I/O modules shall be able to support process signals from various types of sensors and contact devices without requiring external or auxiliary signal conditioning devices. Provision shall be made for calibrating all analogue inputs other than thermocouples using a special calibration program.

Inputs shall be fully optically isolated and shall be able to withstand test voltages between the inputs and the internal electronics and between the inputs and the earth of 1500 Vrms 50 Hz for one (1) minute (ANSI/IEEE Standard C37.90).

Signal conditioning including linearisation and scaling to engineering units shall be provided with a minimum of 12 bit analogue to digital (A/D) converter, and a minimum of 10 bit digital to analogue (D/A) converter.

Surge, overcurrent and reverse polarity protection shall be provided.

Each I/O card within the system shall be monitored for proper operation. The system shall alarm indicating the card failure, (e.g. run down, transfer to manual, etc.).

Standard input and output signal types shall include the following:

| | |
|---|---|
| Analogue Input | 4 to 20 mA with individual A/D conversion. The system shall be capable of supplying the 24 V DC loop power for 4 to 20 mA 2-wire or 3-wire transmitters. The system shall also be capable of accepting voltage inputs within the range of -10 V DC to +10 V DC. The choice of field or system power shall be user selectable for each point. Inputs shall be via a low-pass filter to reject high frequency interference. Common mode noise rejection shall be a minimum of 110 dB at 50 Hz. Normal mode rejection shall be a minimum 60 dB at 50 Hz. Accuracy shall be ±0.2 per cent of full span or better. The system shall have HART pass-through functionality. |
| Analogue Output | Capable of driving 600ohm standard or up to 750 ohms total loop resistance at 4 - 20 mA. The system shall be capable of supplying the 24 V DC loop power. The choice of field or system power shall be user selectable for each point. The system shall also be capable of providing a user selectable default output state for each individual point in the event of an error. Accuracy shall be +0.2 per cent of full span or better. Analogue setpoint outputs maybe implemented using HART or Fieldbus protocols. |
| Digital Input | Capable of receiving 24 V DC as input with selectable filtering from 2 to 20 millisecond. Inputs shall be high impedance type (IEC 60255-4 Class III ).<br><br>Each digital input shall be individually fused. |
| Digital Output | Isolated contact rated at 125 V DC, 3 A and 240 V AC and user selectable as normally open or normally closed, momentary or maintained. The system shall also be capable of providing a user selectable default output state for each point in the event of an error.<br><br>Each digital output shall be individually fused. |
| RTD Input | Capable of receiving 100 ohm platinum resistance temperature detectors (RTDs) inputs directly. Lead length compensation for 3-wire RTDs shall be provided. |
| Thermocouple Input | Capable of receiving all types of thermocouple inputs directly. Cold junction reference compensation and open circuit detection shall be provided. Millivolt input ranges of -100 to +100 mV and 0 to +100 mV shall also be provided. Thermocouple reference junction temperature compensation shall be provided. The thermocouple reference junction temperature compensation value shall be available for display to the operator and shall have alarm limits. |

| | |
|---|---|
| Pulse Input | Capable of receiving square wave or contact input of 1-10 volts and a pulse rate of up to 25 kHz. |
| FieldBus Communications Interface | Capable of providing network communications to field devices such as motorised valve actuators and other selected instrumentation. |

Analogue input modules shall scan, process, filter, linearise and convert to engineering units the non-linear analogue inputs such as thermocouples, RTDs and analyser inputs. For flow devices they shall have the capability of provide square root functions where square root function not carried out in the transmitter. The scan rates shall be in all respects adequate to support required control and calculation functions

The Analogue output modules shall send continuous domain scaled control signals to valve actuators.

All digital inputs and outputs shall be processed by the DCS processing capability which shall provide comprehensive facilities for boolean, and sequence logic functions for processing of these inputs and outputs. The input scan rates shall be in all respects adequate to provide the required alarm, protection, indication, and event recording functions.

Redundant I/O for critical loops and also for duty/standby drives and shall be via different I/O modules to avoid common mode failure. Thus I/O for a duty drive and I/O for a standby drive shall be connected to different I/O modules so that failure of any I/O module will only affect the duty or the standby drive, not both.

### 7.10.7 General I/O Requirements

The I/O modules shall be able to:

1. Communicate the current values of all inputs (analogue and digital) and display them at any operator and/or engineering work station
2. Perform automatic diagnostic testing to identify failure and errors and report such failure via the operator's and/or engineering work station

Field cables shall not terminate directly onto electronic circuit boards.

All field terminals shall include disconnects to facilitate isolation of field equipment from DCS electronics for commissioning and fault finding purposes.

For each analogue input and output, two terminals plus screen shall be provided.

For digital inputs, a minimum of two terminals terminal for each digital input shall be provided. Terminals supplying outgoing field power shall be individually fused.

### 7.10.8 Spare Capacity

The DCS shall have spare capacity after the Facility is fully commissioned as follows:

1. Multi-loop controller – 50 per cent of total processing capacity per module.
2. I/O – 20 per cent of I/O per process control unit.
3. Cabinet space for expansion – 25 per cent.
4. All spare I/O shall be active and wired to terminations.

The DCS shall allow for system expansion through the addition of controllers, operator work stations and I/O modules while the system is on line.

### 7.10.9 DCS Network Communications

A dual redundant network shall be used to transmit data. Both networks shall be in continuous operation.

Fibre optic cable shall be used between DCS cabinet/equipment, data highway and remote I/O cabinets.

The communication network protocol shall include error correction code and protective action to assure high transmission reliability.

Failure at any station or device shall not affect the normal operation of other stations or the communication system.

Error detection shall be provided to ensure that accepted messages are the same as what was sent, and that neither noise nor hardware failure can cause erroneous data to be incorporated into the message received.

The communication system shall be provided with continuous self-diagnosis, quick failure alarm, and correct protective action functions.

The local area network shall be master-less and shall eliminate catastrophic single point failure.

Specific devices such as motorised valve actuators may be interfaced to the DCS via networked communications, provided that the communications network is redundant and that operator interface performance for controls and device monitoring is not compromised by slow network performance.

### 7.10.10 DCS Cabinets

All DCS modules, modular power systems and terminations shall be mounted in cabinets utilising a standard rack mounting system. The cabinets shall be able to accommodate either top or bottom cable entry. The cabinets shall provide front and rear doors to provide easy access for installation and maintenance of power systems and mounting assemblies.

### 7.10.11 DCS Power Supply Arrangements

The DCS power supplies for the I/O, processor and communications equipment shall be powered off a “raw” single phase AC supply as well as a 110V DC battery supply fed from the Unit battery DC supply DB. The two supplies shall be fed into a voting unit which shall provide the equipment power for the DCS. A failure of either the raw or DC supply shall provide a potential free alarm contact monitored by the DCS.

These redundant power supplies shall be provided to power process control modules and field termination devices. The power supply output voltages shall be well regulated and not fluctuate more than ± 1 per cent with input voltages of 240 V AC ± 10 per cent.

### 7.10.12 System Clock

A standard, 24 hour clock shall be provided for DCS reference.

Type GPS, IRIG-B output, rack mounted, with backup battery

Quantity 1 set

Output IRIG-B timing pulse, interfaced with plant DCS and wall mounted 24 hr clock unit, in the OCR

All the Facility control system components, systems, sub-systems which have a time based aspect to their data, shall be time synchronised with the DCS system clock.

## 7.11 DCS Standard Software Capability

### 7.11.1 Control Algorithms

The software used for the configuration, control and monitoring of the DCS shall be the DCS vendor's standard licensed software. Programming and commenting of the DCS whether by SFC's, ladder or other means shall be in English language. Configuration and application software shall be comprehensively commented to allow the Employer to make minor adjustments of the software during the DCS design life.

The selection of control functions on the active modules shall be accomplished by configuring "function blocks". These function blocks are generic software control algorithms that can be used to perform specific tasks.

As a minimum, the standard function library shall support the following functions:

1. PID loop control
2. Controller reset anti-wind-up
3. Direct and reverse controller output selection
4. Cascade, ratio and bias control
5. Automatic adjustment of tuneable parameters based on an external input signal
6. Ability for setpoint to track a process variable based on an external input or internal logic signal
7. Ability for controller output to track a specified input, based on an external input or internal logic signal
8. Ability for controller to be selected to manual or automatic mode either from operator work station or from local faceplates where specified

### 7.11.2 HMI Design Philosophy

Full graphical display screens are required. The graphics shall be designed and implemented according to the ASM Consortium graphics and alarm standards. The system software shall be designed such that the operator shall always have access to any display from the screen. The screen displays shall include but not be limited to:

1. A main display for plant overview
2. Area displays for each main plant system and SGS system
3. Group displays for designated control and indication loops
4. Alarm and events displays
5. Trend displays
6. Dynamic presentation of analogue signals, status and alarm indications
7. Process variables, set points and outputs in both graphic and numeric values, with engineering units and control mode
8. Time tags for all alarms and events on the alarm and events displays
9. System capability diagram
10. Operator interface functions shall include but not be limited to:
11. Secure access to the system by password access or other mechanism approved by the Project Manager
12. The ability to select any type of display, by either, dedicated function keys, display menus, display selection points on displays

13. Scrollable pull-down menus of the displays, accessible by the work station and including a reasonable number of last pages which were displayed
14. Plant controls by selecting plant items via graphic or tabular displays and operator sequence via “pop-up” window, and two step “Select then Confirm” sequences
15. The ability to select any item for manual control in such a way that no other operator can interfere (except for viewing purposes). After having engaged an item in this way, the item shall be released either manually or automatically (after expiry of a certain time)
16. Setpoint thresholds for allowable control ranges (configurable only by the engineer)
17. Other dynamic function buttons essential to run the process
18. Other select buttons to link with other displays
19. Alarm management facilities
20. Training Mode facilities to permit operator training with simulated plant.

### 7.11.3 Alarm & Event Recording System

A comprehensive alarm and event management system shall provide facilities for annunciation, prioritisation, acknowledgement, filtering and recording of plant alarms. The detailed alarm and event philosophy shall be to the approval of the Project Manager.

Comprehensive alarm and event notification shall be provided by:

1. Alarm and events record, for display and printing on demand
2. Visual annunciation on screen
3. Audible annunciation
4. Capture of operator actions on separate event log display
5. Alarms shall be categorised into the following priorities:
    a. Urgent – Alarms that require immediate attention e.g. personnel safety, major plant integrity faults, loss of grid, environmental breach
    b. Low – Priority – Alarms that require investigation e.g. standby, started, high pressure, etc
6. Events – Operational activity e.g. duty pump changeover, set point change by operator, perimeter gate opened, change of state of alarm inhibited points.

“First-up” alarm logic shall be included to ensure that alarm flood situations do not mask the reporting of primary alarm conditions

The alarming sequence shall be:

1. Alarm Notification
2. Acknowledgment
3. Return to Normal Notification
4. Acknowledgment
5. Unacknowledged alarms shall be presented in the following ways:
    a. A flashing plant symbol on a process graphic display
    b. An entry in the alarm list displayed on a system alarm display

c. An entry in a ‘recent alarms’ window on each display.

Alarms may be acknowledged by selecting a flashing object in any of the above and depressing the acknowledge key upon which the object shall cease flashing. Alarm acknowledgement will automatically silence the audible alarm.

An audible alarm will sound if an unacknowledged alarm exists and no operator entry occurs within 10 seconds of the alarm occurring.

It shall be possible to segregate alarms from different parts of the plant to different operator stations according to plant groupings, e.g. Unit alarms, SGS alarms.

Alarm conditions may be applied to both measured and calculated analogue and status points shall include:

1. Over-range and under-range
2. Deviation
3. Rate of change
4. Change from normal state
5. Transmitter failure.
6. Alarm filtering by time delays for both digital and analogue alarms.

Time-stamping: All low resolution alarms and events shall be time stamped to 1.0 second time resolution. A high resolution sequence of event recording facility shall be provided for up to 100 selected inputs for which status changes shall be time stamped to 5 millisecond accuracy by input modules or IEC61850 connected protection relays time synchronised with the GPS clock. This shall include all trip initiating signals. In addition, all other potential trip initiating alarm condition shall be time stamped to 0.1 seconds.

In addition to plant alarms and events, operator actions such as controls, tag state changes, alarm inhibits shall be logged in the event list. The events shall be time-stamped and include month, day of the week, hour, minute, and second

Alarm acknowledgment shall be configurable for either a particular operator station or system-wide. It shall be logged to the alarm and event list stating the date, time, alarm tag number and other descriptions required to show the status or attributes of each alarm.

The analogue alarm functions shall include, but not be limited to, the following features, each configurable on per analogue point, and calculated point basis:

- High and low alarm limits and adjustable incremental alarm limits, either fixed or as a function of another system point,
- High and low transducer range limits
- Significant change increment alarm limits
- Alarm dead bands
- alarm suppression conditions

The Contractor shall assign tags, alarm descriptions, and alarm groups to the alarm system. All tag names and descriptions shall be unique and shall conform to a consistent tag naming convention.

### 7.11.4 System List Displays

In addition to the system alarms display, the system shall provide the following displays of points name according to the following categories.

1. Event list display - chronological list of all alarm occurrences, operator entries, changes of state with date and time of event.
2. Exceptions summary - list of points with transducers out of range or with input discrepancy alarms conditions, or alarm inhibit

### 7.11.5 Trend Recording

The system shall be equipped with a flexible trend recording system which will provide facilities for real-time trending of analogue data. Each trend display shall be capable of plotting at least five analogue variables against a common time axis in separate colours. Status points may also be assigned to trend graphs to assist in monitoring analogue parameters in presence of other plant conditions.

The system must be able to handle short term and long term trend recording. Short term trending would typically include analogue variables sampled every 1 second for a period of 15 minutes. Long term trending would typically include variables sampled at half hour intervals for a period of seven days. Both the sample interval and the storage period must be configurable. The system must accommodate at least 40 pre-configured trend definitions and displays. In addition a further 20 trends must be able to be configured by the operator whilst the system is on line. It shall be possible to select any point for trending

#### 7.11.5.1 Data Logging & Historical Storage

Data logging features shall be provided for both routine logging of selected parameters and disturbance logging initiated by defined status (i.e. trip) events.

Routine logs shall be fully configurable in terms of, sample interval, points to be assigned to the log the period of the log record, and archiving arrangements. Typically, data measured at regular intervals shall be stored for periods of 8 hours, 24 hours, and up to 7 (seven) days before being archived or printed out automatically. Logs may also be printed on demand. At the end of each logging period, the log shall be transferred to an archive storage area. Disk storage shall be provided to provide up to one year archived historical data. The exact details of all log functions and output formats shall be proposed by the Contractor and subject to the Project Manager’s approval.

### 7.11.6 High- Resolution Disturbance Logging

A High Resolution log facility shall be provided for fault analysis purposes and shall permit the capture of high resolution plant analogue and digital parameter measurements immediately before and after defined disturbance events such as turbine trip, line trip, or other plant trip. Event data shall be extracted from event storage held in protection relays and other intelligent electronic devices (IEDs). The exact details of all disturbance log functions and output formats shall be proposed by the Contractor and subject to the Project Manager’s approval.

### 7.11.7 System Capability Chart

The system shall be able to display the stability limits of the generator and the present output coordinates. The output shall be in vector format.

### 7.11.8 Calculations

The DCS shall provide a facility for on line calculations to be configured and to be executed in real time in order to provide derived points and on-line performance calculations. The calculations shall be on an instantaneous and continuous basis and shall be available for inclusion in any display or report and for archival in the historical storage and retrieval system. Calculations shall be able to be configured using a simple calculations control language which can be implemented without the need for a specialist programmer.

Calculations shall support all basic arithmetic functions, plus support time averaging and integration. Data quality propagation shall be supported so that data from transducers out of range is flagged in error and the results of dependent calculations are also flagged as in error.

As a minimum, the following on-line performance calculations shall be implemented:

1. Steam conditions, based on temperature and pressure measurements with corrections to account for steam quality and entrained gas as appropriate. Steam quality and entrained gas shall be included in the calculation algorithm as a factor to enable updating to suit changes in SGS performance
2. Total correction factor to correct to guarantee conditions
3. Plant and unit steam rates (measured and corrected)
4. Plant and Unit brine rates and temperatures
5. Power generated
6. Power consumed
7. Power exported, NDC
8. Contracted turbo-generator net and gross steam rate (kg/kWh)
9. As Commissioned Unit T/G net and gross steam rate (kg/kWh)

The Contractor shall incorporate the applicable portions of the ASME Steam Tables into the software. This shall include but not be limited to enthalpy, entropy, steam and water specific heats, densities and viscosities over the range 0-20 bara with up to 15 °C superheat at 0.1 bar increments.

### 7.11.9 Reports

The system shall have a flexible system for creating, displaying, and printing reports. The prime sources of data for such reports will be:

1. Live process data
2. Derived process data
3. Data from historical records
4. Data from manipulations of data extracted from historical records.

The report package must be capable of allowing operations and plant production reports to be configured easily to allow for changing operations management requirements. These reports must be fully definable by the user and be able to be configured without the aid of specialist software engineering assistance.

All reports shall be available for display, print out on demand, print out at selected times of day or week.

The following reports shall be configured and installed in the system by the Contractor:

1. Trend log
2. Trip log
3. Shift report
4. Unit Performance report
5. Daily, weekly, and monthly reports
6. Unit statistics log

Reports shall be configured and implemented by the Contractor. The final format of all reports shall be to the approval of the Project Manager.

Each log shall store up to 48 samples of 100 measured or calculated variables sampled at a user selectable interval as selected via the keyboard. Log shall be able to be viewed via an operator display and printed on demand or at a user defined interval. The log shall include the measured variables grouped in systems according to their tag number.

The samples for each point shall be printed in a vertical column with the units appearing at the top of the column on each page. It is expected that up to 18 columns can be accommodated across each page thus requiring 6 pages for a full day's log with half-hourly samples or 3 pages with hourly samples.

### 7.11.10 Off System Historian

In addition to any in-built data historian functionality required to comply with the requirements as stated, the Contractor shall provide and “off-system” (ie not part of the DCS internal network and able to operate separately) historian. This shall be a Microsoft SQL server based historian with the following features;

1. Plant data analysis and reporting providing: trend analysis, process data reporting, real-time process control monitoring
2. Publication of trends and reports to a web server
3. Publication of report of Microsoft Word and Excel formats

The historian shall be provided on a standalone PC, the hardware for which shall be rack mounted into the DCS cabinets. An integrated keyboard, mouse and screen (within the cabinet) shall be provided for system maintenance. This PC shall be interfaced with redundant communication links to each pair of DCS data servers. The PC shall be provided with a hardware based firewall and network interface to allow it to be connected to the Employer’s business network (connection to be made by the Employer).

Adequate communication, processing and storage capacity shall be provided to allow capture of all measured plant data and all control outputs at a sample rate not less than the scan rate of the DCS, for a period not less than one year. Means shall be provided to archive data to the Employer’s business systems.

### 7.11.11 High Resolution Trip Log

A trip log (or sequence of events recorder) shall be automatically generated on the occurrence of any Power Plant trip and key trips from the MV Switchgear. This log shall include pre-trip and post trip data to assist in ascertaining the cause of the Power Plant trip. The trip log shall consist of a high resolution event log of critical digital points which clearly indicates the reason for the plant trip and the sequence of events leading to the plant trip. The trip log shall also include 10 minutes of pre-trip data and 5 minutes of post trip data, data which is to include operator control actions and critical operating process analogue values. The trip log shall also include a limited number of analogue points at 1msec resolution. The signals to be recorded (from IEC61850 connected protection relays) shall be:

1. Frequency, current, voltage and power for each unit
2. Frequency, current, voltage and power for the station

### 7.11.12 Shift Report

This report shall normally be created automatically at the end of each 8-hour shift. It shall contain the following information:

1. Summary of alarms and selected status changes, i.e. all points entering or leaving alarm condition and those selected points changing state together with the time of occurrence and limits.
2. Summary of current alarms.

3. Summary of operator commands.
4. Summary of any hardware or software failures, e.g. peripheral device faults, data link failures, etc.
5. The energy output (MWh) of each unit over each half-hour of the shift.
6. The maximum instantaneous demand (MW) for each half-hour of the shift.

### 7.11.13 Station Daily and Weekly Reports

This function shall produce automatically daily and weekly reports. Daily information shall include at least the following accumulated average or integrated data for the unit:

1. Electrical generation, unit auxiliary consumption, station and site auxiliary consumption and steam consumption.
2. Turbo-generator heat rate.
3. Plant heat rate.
4. Plant operation data, e.g. number of starts, plant load factor, plant availability factor.

The weekly report shall contain similar information for a seven-day period ending on a Sunday at midnight.

The Contractor shall propose content and format of the reports to the Project Manager for review and comment. Upon receipt of comments, the Contractor shall then prepare draft reports in the DCS and forward these for review and comment. Final reports shall then be submitted by the Contractor for final approval.

### 7.11.14 Training Facilities

The DCS shall provide specific facilities to support the training of operators.

This training mode may be able to be selected on any HMI either in the OCR or field based HMI’s.

In training mode, the full HMI functions shall be able to be exercised at a training level and software shall be included to simulate plant start-up, shutdown and other control and alarm sequences. In training mode, the user shall be able to make realistic use of a wide range of operator facilities with absolute certainty that he is restrained by the system from being able to interfere in any way with the operation of the plant and from being able to alter any of the operational (i.e. non-training) data or setups.

Whenever an HMI is in training mode, there shall at all times be a clear indication to the operator that training mode has been selected so that this is clearly distinguished from normal operational mode. All events and alarms arising from training mode shall be excluded from the system alarm and event lists.

### 7.11.15 Cyber Security

The DCS shall comply, to a bronze level as minimum, with the requirements of the WIB report M 2784-X-10, version 2.0 as published in October 2010 or an alternative security system for approval by the Project Manager. The Contractor shall provide the necessary certification to demonstrate that this is the case.

The DCS shall include facilities for cyber security and intrusion protection by means of firewalls and other appropriate mechanisms. Remote access to network configuration, logic configuration, display development or any other internal controller function shall not be permitted. Firewalls shall be included between the plant DCS and any hierarchical control systems including the Employer’s Local Area Network.

### 7.11.16 Remote Web Client

The DCS shall be configured with the necessary hardware to allow a remote web browser to securely access the power plant DCS control system to monitor and control the plant remotely. The remote web view shall be fully graphical and shall be capable of connection with Windows, IOS and Android based devices.

The remote web view shall have equivalent functionality as the local DCS HMI and shall be capable of continuous monitoring without time-limit restrictions.

The remote view connection shall be via a secure firewalled VPN with user authentication and encryption as necessary to comply with clause 7.11.15 Cyber security requirements.

### 7.11.17 Engineering Maintenance Functions

The engineering work station (EWS) shall be provided to allow the following functions:

1. Configure, maintain and trouble-shoot all components of the DCS system.
2. Development of all DCS databases
3. Calibration of field mounted smart transmitters
4. Project documentation modification

The EWS may operate on the DCS network or in stand-alone mode. The EWS shall be “hot-pluggable” into the DCS network, so that it can be connected and disconnected from the DCS network without any detrimental effect. DCS network connection points shall be provided in the OCR.

The EWS shall be protected from unauthorised access by means of logon access with password which is unique to the EWS.

The EWS workstation shall utilise identical hardware to the main operator stations.

The EWS shall be supplied as a portable unit, with its own mobile desk unit which incorporates all EWS hardware. All the hardware shall be secured to the desk so that the desk can be safely moved. Means to coil up, protect from damage during transport and temporarily secure power and communication cabling (to connect the EWS to a power supply and the DCS network) shall be included in the desk.

### 7.11.18 Software Modifications and Upgrades During Warranty

The Employer reserves the right to undertake minor modifications to the software configuration of the system during the warranty period without voiding the terms of any warranty. A procedure shall be developed and agreed by the Project Manager for approval and documentation of all modifications carried out by the Employer during the warranty period.

Provision shall be included to provide and implement any upgrades in supplied licensed software during the warranty period. This shall include the labour required to install and commission the upgrade, including any re-testing.

Calibration of field mounted smart transmitters

Project documentation modification

Software required for the configuration of the system shall be supplied as part of system and shall include but not be limited to: HMI configuration software; DCS programming software, communications configuration, smart device configuration software and any other utility software required to monitor or configure any equipment.

Facilities for automatic generation and archiving of backup system configuration and the ability to restore from backup archives shall be provided. On completion of commissioning, the Contractor shall handover backup copies of all system

software and configuration data bases to the Employer. The procedures for back and restoration shall be comprehensively documented and the Employer's staff shall be trained in restoration procedures.

#### 7.11.19 Software Licenses

The Contractor shall take out on behalf of the Employer and transfer to the Employer any necessary licences required for the use of all software supplied with the system. Such licenses shall be valid for the lifetime of the system without further license payments payable by the Employer. Where licenses include a licensed database capacity (no of tags, size of historian etc) a minimum of 20 per cent spare licensed capacity shall be available at the completion of commissioning.

#### 7.11.20 Maintenance Support Arrangements

The DCS equipment shall have an established support base in Dominica or within the Caribbean region and the manufacturer shall have a proven track record in supporting Power Plant control systems through their life. The selected technology shall be proven in service but in the early stages of its life-cycle.

## 7.12 Human Machine Interfaces

For each Unit and for the Common systems, Human Machine Interface functions shall be provided via at least four flat panel colour high resolution Liquid Crystal Displays (LCD) with a minimum diagonal size of 52 cm. Each HMI shall have a resolution of at least 1920 by 1080 pixels. The screens shall be of non-glare armoured glass and shall be flicker free.

Each HMI shall be able to control and monitor any Unit's systems.

Each HMI shall include a keyboard with dedicated keys for regularly used process control functions such as Alarm Acknowledge, and selection of key display pages. In addition, keys in a QWERTY layout shall be provided to facilitate alphanumeric data entry. A robust cursor positioning device such as an optical track ball or approved alternative shall be included.

Normally, two of the HMIs for each Unit will be used for Power Plant related functions and one HMI will normally be used for supervision of related SGS functions. Typically, one HMI would be reserved for alarm management functions but all displays will have equal functionality.

An additional HMI shall be provided as an engineering workstation dedicated for engineering configuration and training. The engineering workstation shall be used primarily for system maintenance, engineering and configuration functions but is also to be available for normal operator work station functions and shall be functionally equivalent to the other HMIs.

The HMI workstations shall interface via I/O servers connected to a redundant local area network to processor based plant control units where all plant control algorithms and logic shall be implemented.

#### 7.12.1 HMI Performance

A display shall be fully displayed on the screen within one second of selection. Information displayed on the screen shall not be more than 1 second old.

All control actions shall be completed at the field equipment within one second of completion of operator control entry. All critical plant control actions shall require a two-step confirmatory operator entry sequence prior to transmission of a control command. Field responses to control actions shall be updated on the HMI screen within two seconds of completion of operator entry.

Each HMI workstation shall be microprocessor based and shall be able to provide all regular system functions whilst achieving the above performance requirements with at least 50 per cent spare processing capacity.

Failure of any HMI workstation shall not affect the operation of the remaining HMIs. Neither shall it affect the operation of the plant.

The HMI workstations shall be served by redundant servers operating in a “primary/hot-standby” configuration and interfacing to the plant I/O system. Servers shall be sized by the Contractor but when fully configured and commissioned shall contain at least 50 per cent free storage memory after storage of system software and data, displays, historical data, and all other software required for the system.

At least two backup, standard, removable media shall be supplied for redundant storage and retrieval of historical and trend data, system software, and system configuration files.

Tape drives and floppy disk drives are NOT acceptable as backup devices given the site environment.

### 7.12.2 Printers

Two industry standard non-impact printers shall be provided. These shall be desktop mounted in the OCR on suitable furniture provided by the Contractor and acceptable to the Project Manager. Printers shall use American standard paper sizes and shall include bulk paper feeders.

1. Two online (main and backup) multicolour printers for printing of reports, incident logs, and system configuration. These printers shall be high resolution colour laser jet suitable for printing A3 and A4 paper sheets from separate sheet trays.

Printers shall operate without sound hoods in a quiet control room environment and printer noise level shall not exceed 47 dBA at distance of 1 metre from printer.

Sufficient ink/toner cartridge set(s) for reasonable use of each printer suitable for one year's operation of the Power Plant shall be supplied with the equipment. Printers shall use American standard paper sizes.

All logs and other files for printing be spooled to disk, for printing on demand. Each printer shall be able to be accessed via any operator work station.

## 7.13 Instrumentation

### 7.13.1 General

All instrumentation systems and documentation shall comply with the relevant requirements of the ISA Standards.

Instrument transmitters providing continuous analogue or sampled data to the DCS shall be provided for monitoring, display, control and alarm requirements and similar. Transmitters shall be monitored at the input card level to monitor and alarm for broken wire or transmitter out of range alarms. The use of discrete instruments such as switches shall not be used without the approval of the Project Manager.

The Contractor shall co-ordinate, calibrate, and set all the transmitters, controllers, recorders, indicators, switches, relays and alarms and shall provide the Project Manager with tabulation of recommended settings, and complete manufacturer’s data and site test reports. A tabulation of settings as commissioned shall also be provided.

Instruments using mercury shall not be used.

All instrumentation used shall have an established support base for Dominica through which technically competent service arrangements for full backup and support can be provided.

Local indication shall be displayed in SI units on Liquid Crystal Displays or gauges.

### 7.13.2 Location

All instruments (with integral displays) and gauges shall be easily readable from operating platforms or floors and in general readable from the most accessible location. Where information from local instruments is critical to an operation, the instrument or gauge shall be visible from the point of normal operation. Instruments shall be located at typical head height for ready access.

### 7.13.3 Redundancy

Redundancy for sensors and controls shall be provided to meet the design availability requirements for the Plant.

Installed spare sensors shall be provided where it is not possible to replace a failed sensor without an overhaul of equipment (eg. stator windings).

Three sensors shall be provided where an automatic control is dependent on the sensor and an operator cannot be reasonably expected to operate the control manually with or without the sensors. Redundant sensors shall be provided for critical functions.

Multiple sensors shall be used in instances where a single sensor cannot be expected to provide an average true value because of conditions or where a single instrument cannot cover the expected range.

Redundancy, where required, shall be complete. This means that everything including root valves, impulse lines, bridles, cables, DCS input/output cards etc. shall be completely independent between the redundant sensors.

### 7.13.4 Hazardous Areas

All instruments located within any defined hazardous areas shall be selected to comply with the temperature classification of the flammable agent therein. The protection technique employed to achieve this shall be in accordance with IEC requirements.

### 7.13.5 Transmitters and Transducers

Analogue measurements from process plant and electrical power supply systems for remote indication and control purposes shall generally be transmitted as 4-20 mA dc output signal. “Smart” transmitters using the HART protocol shall be used wherever available. HART signalling may be used to supplement 4-20mA signalling.

Transmitters and transducers shall be solid state electronic devices suitably designed for the location and services required.

All transmitters utilised for process plant analogue measurements shall include an integral local output indicator, scaled 0-100 per cent (in SI units), for use as an operator check of signal.

The output from all transmitters and transducers shall provide isolation to withstand a test voltage of 2000 V r.m.s. 50 Hz for one minute (IEC 255-4 Class III). This isolation shall be between input and output and earth.

Non-electric signals of plant instrumentation and control shall not be connected direct to control room equipment.

Transmitters and transducers shall be grouped into cubicles where possible.

### 7.13.6 Instrument Mounts

Electronic instruments shall not be directly mounted to process piping or vessels, except where the nature of the instrument’s design leaves no alternative to direct mounting. Electronic instruments shall be mounted on hot dipped galvanised pipe stands either bolted to structures or concreted into the ground. In the case where instruments are mounted on a pipe stand

concreted into the ground, the cable from the instrument shall be run within the pipe stand into the ground and clear of the concrete, in other words the pipe stand shall also act as a conduit. The top of the pipe shall be sealed with a waterproof flexible mastic once the cable has been installed and a plastic cap fitted over the top.

### 7.13.7 Installation

Remote mounting of RTD sensors from their associated converters (to 4-20 mA) shall be avoided in preference to mounting the converters directly in the RTD sensor head. Where remote mounting is unavoidable, the interconnecting cable shall be temperature compensating 4 wire cable and shall be kept as short as possible. Cable specification and colour codes of cores shall be to IEC60584. Note; Direct connection of RTDs or thermocouples to DCS I/O cards is allowed where the DCS supports this.

The steel wire armouring of the instrument cables shall be solidly earthed at both ends of each cable via appropriate steel wire armour glands. The armouring shall not be used as an earth continuity conductor for electrical bonding purposes.

It is permitted to group single pair cables into a multi-pair cable. If this method is employed, the multi-pair cables shall have the same specification as the single pair cable (as described above) except that in addition to each pair being individually screened, there shall also be an overall screen. The joining of individual single-pair cables to a multi-pair cable shall be done within a steel IP65 junction box. Individual screens from single pair cables shall be bonded only to the corresponding screen in the multi-pair cable. Exposed twisted pairs (i.e. without screens) lengths shall be kept as short as possible. The overall screen of the multi-pair shall not be connected to anything in the junction box.

Cables shall enter junction boxes via IP65 armoured glands fitted to an aluminium gland plate in the bottom of the box. The gland plate shall be factory fitted and included in the IP rating. The gland plate shall be earthed in the immediate vicinity of the junction box to the plant electrical earth system.

AC power and instrument signal wiring shall be separated by a minimum spacing of 100 mm in all cases, and shall not under any circumstance be run in the same wireway.

Wiring between terminals shall be point-to-point and free from wire splicing and T connections.

### 7.13.8 Gauges

Instruments dials and scales shall be white with black markings. Ranges and marking shall comply with EN837. All instrument dials shall be at least 100 mm diameter. Dial ranges shall be selected to be consistent with the normal operating conditions. All instruments shall be provided with rear calibration access.

### 7.13.9 Flow Measurement

#### 7.13.9.1 General

Flow shall be preferentially measured by either differential pressure, Doppler, vortex shedding or mag-flow techniques. Doppler flow measurement may be considered for flow measurement of individual pump flows and measurement of brine and condensate flow in the SGS. Vortex flow meters may be considered for non critical steam flow measurement in the SGS, except for the main steam flow meter required for Performance Testing.

Primary flow elements shall be readily accessible for maintenance or calibration and shall be stamped with the tag number and correct installation direction, both of which shall be clearly visible whilst installed.

The Contractor shall provide instrument hook-up drawings for review by the Project Manager prior to construction.

All flow meter installations shall comply with all aspects of the applicable standards and manufacturers' requirements, in particular the upstream and downstream straight pipe lengths.

#### 7.13.9.2 Differential Pressure Flow Measurement

Differential pressure measurement shall be used for steam flow measurements. Differential pressure measurement shall employ electronic transmitters in conjunction with a venturi tube, pitot tube, or orifice plate.

Measurement of the main steam flow to the turbine shall be by a factory calibrated venturi. If two or more steam lines are employed, then a venturi and associated instruments, shall be provide in each steam line. Performance Testing of the Plant shall be carried out using this calibrated venturi meter. The venturi meter and its installation shall provide accuracy of 0.5 per cent or better.

Where pressure and temperature compensation is required in conjunction with differential pressure (flow) measurement, the electronic transmitters employed for differential pressure measurement shall be multi-variable types that simultaneously measure differential pressure, line pressure and temperature using HART signalling as well as 4-20 mA. The location of temperature sensors shall be determined so as not to affect the accuracy of flow measurement. The transmitters shall correct for line pressure and temperature and shall output mass flow rate as the base 4-20 mA signal. The measured pressure and temperature shall be transmitted simultaneously using digitally superimposed signals. Differential pressure instruments shall be capable of taking full line pressure on one side only without damage or loss of calibration.

The design and installation of all primary differential pressure measurement devices shall comply with ISO5167 or the ASME equivalent. Orifice plates, venturi tube throats and flow nozzles shall be ANSI 316L stainless steel. Vent and drain holes shall be provided in orifice plates to prevent the build-up of vapour pockets in liquid service pipes and condensate in vapour service pipes. Differential pressure primary elements in hot liquid services shall be under sufficient hydrostatic head to prevent flashing at the lowest pressure point in the element outlet.

Steam measured with a pitot tube shall be installed in a “hot-tap” isolation assembly that shall allow the safe removal of the pitot tube without shutting down the steam line.

#### 7.13.9.3 Magnetic Flow Measurement

Mag-flow tube and transmitter electronics shall be kept separated. Mag flow tube installation shall comply with all aspects of the manufacturer’s requirements, in particular the upstream, and downstream straight pipe lengths.

#### 7.13.9.4 Ultrasonic Flow Measurement

Ultrasonic flow measurement may be considered as an option for flow measurement of individual pump discharge flows and water flows in other large diameter pipelines. The sensor heads shall not be direct buried and sufficient access shall be provided to the heads to permit their replacement in the future if required. The cables between the sensor heads and the transmitter shall be easily removable and replaceable. Ultrasonic flow instrumentation is generally not preferred and shall only be provided with the written consent of the Employer.`

### 7.13.10 Level Measurement

#### 7.13.10.1 General

Suitable bosses, stub pipes and isolating valves shall be provided on all tanks and vessels where level measurements are required.

An external level bridle shall be provided wherever turbulence or other undesirable conditions are present to enable representative and stable level measurements to be made. Where a level bridle cannot be incorporated, a stilling well shall be provided for this service.

Particular care shall be taken in the selection of level gauges and transmitters for the SGS, considering the potential for silica deposition which interferes with instrument operation. Preference shall be given to instruments which use indirect contact techniques and also have proven track record in SGS service.

Bridles shall be fitted with process isolation valves, a drain valve and a fill/vent valve as a minimum. Where more than one instrument is fitted on a bridle, each instrument shall be individually isolatable where practical.

Level transmitters and switches shall be mounted external to the tank or vessel, and fitted with isolation, drain, vent or fill valves to permit on load testing.

Glandless level instruments using magnetic coupling between the float and output device shall be protected against the accumulation of magnetic deposits where present in steam or water by a flexible waterproof hood or other accepted means. These devices shall only be used for local indication and not for DCS level indication and control

Ultrasonic level measurement techniques shall only be used in vessels or sumps completely open to atmosphere and where there is no surface foaming of the measured liquid.

Care shall be taken, when using hydrostatic head or differential pressure meters to measure levels, that suitable compensation is allowed for the density difference between the HP and LP legs, or when the external pipe is partly filled with condensed liquid and vapour.

#### 7.13.10.2 Main Condenser Level Measurement

Condenser level measurement requires special attention. The Contractor shall submit details of the proposed device(s) for approval by the Project Manager.

#### 7.13.10.3 Sight Gauges

For scrubber, steam separator and main condenser level indication, locally mounted liquid level sight gauges shall be provided. Such gauges shall use a hi-visibility interlocked bar-graph indicators magnetically coupled to a float. All floats shall be suitable for the process conditions.

### 7.13.11 Pressure and Differential Pressure Measurement

Pressure transmitters shall be able to withstand 50% over-range without damage. Differential pressure transmitters shall also be capable of taking full line pressure on one port with the other port isolated, without damage.

Pressure and differential transmitters shall be “smart” transmitters and be compatible with the HART protocol.

Accuracy shall be 0.25%, or better, of calibrated span. This includes the combined effects of linearity, hysteresis and repeatability. The stability shall be equal or better than ± 0.25% of upper range limit, for 12 months.

All pressure tapping points shall be on the horizontal centre line of main pipes which are not vertical. Pressure tappings shall not be placed in inaccessible positions.

All steam service transmitters shall be provided with pigtails. Pigtails shall be factory manufactured from 316 stainless steel.

Gauges shall be fitted with a 316 stainless steel gauge valve to which a 316 stainless steel plug and a 316 stainless steel bleed valve has been fitted.

For pressure transmitters, a 316 stainless steel two valve manifold (which allows a test gauge to be fitted to bleed port) shall be fitted.

All differential pressure transmitters shall be fitted with 316 stainless steel 5-valve manifolds. Impulse lines from the manifold to the process connection shall be kept equal in length and at the same level throughout.

Pressure instruments shall comply with the requirements of EN837, including the precautions relating to instruments with high pressure gases for all gauges scaled up to and over 60 bar. All pressure tappings on piping and vessels in gas or vapour service rated ASME300 or greater shall be fitted with reduced bore orifice connections. Instruments shall be capable of withstanding the piping design pressure at their tapping points.

Instruments measuring pulsating pressure shall be suitable for the duty with suitable protection measures if required.

Where the process fluid is corrosive or is subject to particulates, appropriate measures such as the use of diaphragm seals, shall be taken to prevent any impurities from affecting transmitter and transducer.

### 7.13.12 Pressure Gauges

Pressure gauges shall contain 316 stainless steel internals, with 100 mm minimum diameter face. The gauge housing shall be 316 stainless steel, oil filled, fitted with a shatter-proof glass face plate and suitable for installation outdoors. Unless otherwise specified, the pressure gauge shall be the bourdon tube type with an accuracy of 1.0% full scale deflection or better.

Each gauge shall be ranged such that, in normal operation, they are working at about 75% of their full range. Units shall be given in metric (bar, mbar). The graduations on the dial shall be black against a white background. The graduations shall span at least 75% of the face.

The gauge shall be fitted with a ½" NPT process connection at the bottom of the casing and it shall have overpressure blowout protection at the back of the gauge.

The body and seats of the gauge valves shall be fabricated in 316 stainless steel.

Direct mounting of gauges is acceptable, however, the effects of process piping vibration, fluid temperature and also the visibility of the gauges from normal working platforms must all be analysed. Considering all of these factors, it may be necessary to remote mount some gauges to comply with these Employer's Requirements.

### 7.13.13 Temperature Measurement

Temperature measuring primary elements for distant reading shall be resistance thermometer devices (RTD) up to 150°C and thermocouples above 150°C as follows:

1. DIN 43760: platinum resistance thermometer elements
2. ANSI/MC.96.1: chromel/alumel thermocouples (type K).

RTDs may be used at higher temperatures subject to their availability and Project Manager's approval.

Thermowells and temperature measuring equipment shall be fitted in positions to suit the operation and testing of the plant.

Mineral-insulated metal sheathed thermocouples shall be thoroughly dried out before installation, and the insulation resistance value shall be not less than 2 megaohms before the cold seal is made.

Suitable thermocouple or resistance thermometer assemblies shall consist of the primary element and a connection block which shall be mounted in the connection head. The Project Manager will consider exceptions to this on a case by case basis where specialised applications require direct connections from the elements. The base of the connection head shall be at least 75 mm clear in all directions of pipe lagging and shall be arranged to avoid excessive temperatures at the head assembly.

Temperature instruments with electric contacts shall be fitted with contact terminals. Pointer-operated contacts shall not be used.

Glass thermometers shall not be used as permanent instruments. Thermowells shall generally be downstream of pressure instrument connections. Plant efficiency and performance check thermowells shall be supplied in addition to the normal operation thermowells. Each additional performance check thermowell shall be fitted with a removable plug. Thermowells shall be installed in threadolets unless otherwise specified or agreed.

Thermowells shall generally be of the quick response type and insertion lengths shall be appropriate to the process measurement location. Tapered thermowells are generally preferred for ease of insertion and strength. Calculations shall be provided to confirm for each thermowell in a high flow or high pressure situation, that the selection of material and thickness of walls is adequate to withstand forces applied to the thermowells by process fluid flow and vortices.

### 7.13.14 Chemical Analysis Equipment

For conductivity or pH measurement, in-line pipe measurement shall be of the immersed electrode type, and dip type for open vessels. The measurement electrode, reference electrode and temperature compensation shall all be contained in the same probe.

### 7.13.15 Vibration Analysis Equipment

Permanently installed continuous vibration analysis instrumentation shall be provided for the turbine, generator, hot-well pumps, cooling tower fans, liquid ring vacuum pumps and all motors over 150kW, plus other specific requirements as stated elsewhere.

A single system which integrates all of the sensors from the various items of equipment is required.

The system shall be interfaced to the DCS via a high speed communication link that provides full access to all the data in the vibration monitoring system. Any critical trip signals shall also be hard-wired trip circuits.

### 7.13.16 Detection of Failure of Duty Pumps

On/Off and start-up of back-up equipment shall generally be determined via discharge flow or pressure monitoring. Motor control circuit energised status shall be used where discharge condition monitoring is inappropriate.

### 7.13.17 Hydrogen Sulphide Monitoring

$H_2S$ monitors shall be provided within the Plant in low points both indoors and outdoors such as hotwell pump pits and other areas where $H_2S$ may accumulate. The monitors shall include local alarms for alarming unsafe personnel access situations shall be monitored by the respective plant DCS systems and shall be used to trigger an $H_2S$ alarm. A continuous reading of $H_2S$ levels from each monitor shall be logged and trended on the DCS.

## 7.14 Instrument Air Supplies

### 7.14.1 Filter Air Regulators

Air filter/regulator sets shall be provided as required to supply the required air pressure for control signals and actuators. The regulators shall be pre-set to the required supply air pressures. The regulators shall be suitably sized to ensure they do not restrict the flow of air to the actuator necessary to achieve specified valve stroke times.

Pressure gauges with appropriate range and 50 mm dial shall be supplied integral to I/P transducers, positioners and filter regulators as required to indicate air pressure on each regulator output, supply air pressure and control signal air pressure. Gauges shall be stainless steel, rated to IP65, robust in design and liquid-filled.

I/P transducer (when required to be mounted on the actuator) and positioner shall be supplied ready mounted on the actuator complete with all interconnecting tubing.

### 7.14.2 Instrument Valves

All connecting lines between tapping points and instruments, transmitters or test points shall have not less than two isolating valves. One valve shall be the root valve, the other shall be an instrument quality, 316 stainless steel ball valve. This second valve shall be located as near as possible to the root valve. This second valve shall be known as the instrument isolating valve. The instrument isolating valve shall be located such that the temperature on the valve does not exceed 60°C.

For all pressure measurement applications, the root valve shall be a gate valve to API 602.

Blowdown valves are required in the connecting lines to all transmitters and instruments used on water and steam services. These valves shall be in addition to instrument manifold valves. They shall be mounted at the lowest point of the impulse line from the instrument isolating valve to the instrument manifold.

Root valves shall be capable of being locked in the fully open or fully closed position. Valves shall be fitted with indicators to clearly show the position of the valve. All root, isolation and blowdown valves shall have valve labels in permanent materials.

### 7.14.3 Instrument Pipework and Fittings

All instrument tubing and fittings shall be ANSI 316 seamless austenitic stainless steel, ½" minimum.

Where movement can occur in the process pipe due to thermal expansion or severe vibration (that could affect the transmitter operation or lifespan), an appropriate degree of flexibility/isolation between the root valve and the instrument shall be included, the first 1 m (minimum, more if the amount of movement requires a longer length) section of instrument impulse line shall be formed from flexible tubing. This flexible tubing shall be ½" (minimum) flexible metal hose of appropriate pressure and temperature rating. Where flexible tubing is used, the transmitter end of the tubing shall be solidly secured to a non-moving structure.

Instrument connections shall be of the same base material and schedule as the process line to the isolation valve. A Swagelok (or equal) tube socket weld union shall be provided at the isolation valve to convert to standard stainless steel instrument tubing with compression connectors.

Instrument tubing wall thickness shall be based on normal commercially available wall thickness appropriate to the pressure and temperature of the particular service.

Pipework shall be routed to ensure all compression fittings are accessible and comply with the manufacturer's instructions.

Blowdown pipes shall be included in the connecting pipework to each transmitter or pressure switch, for all steam services and for all other services in which corrosion products, suspended solids etc., may block the instrument connecting pipework. Blowdown connections to a suitable drain shall be made at a point as close to the transmitter as practicable, while ensuring that the transmitter will not be damaged by overheating.

Pipework and tubing shall be neatly run and suitably supported in a manner such that no air pockets or traps can occur. If either is unavoidable then the Contractor shall provide a suitable drain or vent valve which shall be easily accessible from a floor, permanent platform or walkway. Instrument piping used on liquid services shall be self-venting to the main, while non-condensing gas and vapour instrument lines shall be self-draining to the main. Instrument piping containing condensable vapour shall not be less than 10 mm actual bore from the tapping point to the inlet of the instrument isolating valve, to avoid the formation of a liquid lock.

All pipe ends for compression type couplings shall be prepared using the coupling maker's specialised tools and techniques.

Instrument tapping points on piping or surfaces which are subject to continuous or intermittent deposition of solids shall have an access opening for “rodding” out deposits across the tapping point. The means of access shall conform to the piping or vessel design standards.

Each pipe shall be identified by individually numbered metal tags or ferrules spaced not more than ten metres apart.

Adequate junction boxes shall be provided for the termination of multi-tubes including spare tubes. All tubes shall be fitted with numbered ferrules at each termination. At points of interconnection between tubing where a change of numbering cannot be avoided double ferrules shall be provided. Such points shall be clearly indicated on schematic diagrams. Labels shall be fitted to junction cubicles to identify each group and each individual tube.

Pipe connections to gas sampling apparatus shall be capable of easy internal cleaning. Suitable provisions shall be made to facilitate such cleaning.

## 7.15 Valve Actuators

### 7.15.1 General Requirements

Actuator housings shall be a standard watertight enclosure to IP66 rating. Additional requirements are stated elsewhere.

All valve and actuator assemblies shall be integrated and tested by the valve manufacturer.

The assembly of the valve and actuator shall be designed such that critical parts cannot become disengaged by vibration. Shaft keys or splines used to connect them shall be positively locked with grub screws or similar means. Use of press fits or adhesives for this purpose is prohibited.

Valve position indication shall comply with the following requirements:

1. A graduated mechanical indicator shall be mounted on the shaft of the valve to give clear local indication of the actual valve position.
2. Each modulating control valve shall be provided with limit switches for fully open and fully closed position and continuous position detection from 0-100% open. These conditions shall all be connected to the DCS.
3. Each open/close control valve shall be provided with limits switches for fully open and fully closed position. These conditions shall all be connected to the DCS.
4. The accuracy of the valve position transmitter shall be equal to or better than 1% of span, including the effects of hysteresis, linearity, dead-band and mechanical couplings.
5. Control valve position indicators shall be Westlock manufacture or similar approved by the Project Manager. These shall be non contact magnetically coupled 4-20mA indicators.

Handwheels shall comply with the following requirements:

1. Control valves shall be supplied with a hand wheel to open, close or position the valve manually either during normal operation or in an emergency. The hand wheel shall be capable of use for checking the shaft/stem of the valve for sticking. Hand wheel design for the valve shall be manufacturer’s standard.
2. The hand wheel shall be suitably sized to provide sufficient mechanical advantage to enable the valve to be opened or closed easily against its full rated pressure. Means shall be provided to render the mechanical mechanism inoperative while the actuator is in service using an electric motor. Bevel gear operated hand wheels shall be provided with a shearpin for over-torque protection.
3. In the event of control signal failure to the valve, the actuator shall not impair manual operation of the valves via the handwheel. This may be achieved by providing means to disengage the actuator manually while manually operating the valve.

Actuators shall be finished with a minimum of one coat of primer and two coats of epoxy paint suitable for the prevailing site conditions, including ambient hydrogen sulphide. The proposed paint specification shall be submitted to the Project Manager for review. Refer also to Clause 1.15.3.

### 7.15.2 Motorised Valve Actuators

Electric actuators shall be Rotorq IQ type or similar approved by the Project Manager. Electric valve actuator power supply shall be LV 3 phase 50Hz.

Electric valve actuators shall be provided with integral contactors, motor thermal cut-out and anti-condensation heaters.

Actuators shall include an integral, dedicated field cable termination compartment separate from the actuator electrical equipment. This field termination compartment shall be dust and water resistant to at least IP68. Electric valve actuators shall include a serial communications interface for communications with the DCS. The communications interface shall be utilised for status, and diagnostic reporting. Control of the actuator shall be via 4-20mA control signal.

A lockable “remote/off/local” selector switch shall be supplied on each actuator along with “open”, “stop” and “close” local control pushbuttons. The “stop” pushbuttons shall provide overriding control, even if the “open” or “close” pushbuttons are operated and remain depressed. Remote signalling to the DCS of the Remote/Off/Local selector status is required.

The mechanism shall be designed to prevent over-running or jamming and shall be fitted with limiting devices capable of accurate and fine adjustment. Torque limiting or other devices shall be provided to prevent damage to the mechanism in the event of the valve jamming.

Reversing contactors and limit switches used for actuator control shall be robust and of proven reliability by both type test and commercial operation. Solid state switching may be accepted where conditions permit. Actuators shall be provided with “inching” capability.

### 7.15.3 Pneumatic Valve Actuators

Volume booster devices and quick exhaust valves are acceptable where necessary to achieve required stroke times. For all control valves calculations shall be provided to demonstrate that the required stroke times can be achieved.

The actuator casing shall withstand pressure equal to 150 percent of spring range. Actuator springs shall be carbon steel fully enclosed in a metal housing and stamped or colour coded for identification of characteristics. Spring compression rate tolerance shall not exceed 5 percent and they shall be ground flat on each end to minimize cantering.

In the opening direction, the actuator shall engage an adjustable stop before the valve plug reaches its travel limit. The stop shall have sufficient area to absorb the maximum force of the actuator.

Positioners shall comply with the following requirements:

1. “Smart” digital positioners shall be used, and shall support HART communications over 4-20mA signalling for both position feedback and position setpoint
2. Electro-pneumatic converter accuracy shall be 0.25%, or better, of calibrated span. This includes the combined effects of linearity, hysteresis and repeatability. The stability shall be equal or better than ± 0.25% of upper range limit, for 12 months.

Positioners shall be mounted separately from the control valves where the possibility of high vibration from the valve exists, in order to avoid calibration drift or damage as a consequence of vibration.

# 8. Buildings and Site Services

## 8.1 Building and Support Facilities

### 8.1.1 General

The Contractor shall design and build all required buildings and support facilities in accordance with Dominica standards, national and local codes and building permits issued by authorities having jurisdiction.

The main buildings or structures required are;

1. Turbine Generator Building(s), including a separate unitised electrical annex. The annex per unit can be housed within the turbine/generator building. Unitised arrangement is required to provide risk mitigation in the event of fire or similar risks.
2. Separate MV Switchgear Building for the housing of the 11kV switchgear used for the 11kV grid interconnections and to be used primarily by DOMLEC staff.
3. Operations Building, including;
    a. Plant Room
    b. Operator Control Room
    c. Office
    d. Workshop
    e. Fire Pump House
    f. Laboratory and Testing Room
    g. Stores
4. Temporary Building(s): Contractor's construction worker accommodation.

All structures shall be designed using internationally recognised standards to remain safe, operational and withstand hurricane conditions experienced in Dominica. The standards used, design measures taken to address these risks shall be detailed in the Civil and Structural Design Report.

All building floors shall be tiled with hard wearing tiles suitable for 20 year duration. Provide 5% spare tiles as part of the building handover requirements.

### 8.1.2 Turbine Generator Building

The Contractor shall provide a fully functional turbine - generator building including all Plant and personnel requirements for the operation and maintenance of the Plant.

The turbine generator building shall be a custom-designed structure to protect the equipment from weather particularly the wind loadings and potential for wind borne objects– a suitable structure shall be provided for each unit. The structure shall allow for dismantling and servicing the equipment housed in the shelter or building. Laydown areas for generator rotor, turbine rotor, spare rotor shall be provided. These specific laydown areas shall be identified in the design reports. In particular, sufficient space shall be available for operations such as removal of the generator rotor without the need to dismantle or penetrate any external walls. An overhead crane of adequate capacity and clearance to allow removal of various equipment parts for repair, maintenance, and replacement of the turbine generators and auxiliary plant shall be provided.

Auxiliary lifting beams, monorails and other permanent lifting facilities shall be provided to enable all necessary maintenance activities to be undertaken on the Plant.

Roller shutter doors for plant and equipment access and removal, personnel access doors, staircases and building ventilation shall be provided.

The Turbine Generator Building shall have a minimum of two means of personnel egress. The entire area shall be designed to provide safe operating conditions for maintenance personnel and clear means of egress in case of fire or other emergencies.

The building design shall incorporate provision for adequate natural ventilation.

### 8.1.3 Operations Building

A stand-alone Operations Building will serve as the main building for typical Operation and Maintenance activities, including operation of the Plant.

The building shall have at least the following rooms and facilities. When not specified, the Contractor shall ensure that the area provided is sufficient for the specified application. All rooms shall have a sufficient number of double socket single phase outlets and LAN outlets.

Noise measured within the offices whilst the Plant is operational shall not exceed NC40.

| Room | Minimum Area Required ($m^2$) |
|---|---|
| Reception Area | 20 |
| Managers Office | 16 |
| Meeting Room | 50 |
| Records Storeroom | 16 |
| Operator Control Room | 50 |
| Janitorial Room | 10 |
| Plant Room | To suit |
| Washrooms | To suit |
| Lunch room and kitchen | 60 |
| Workshop | 200 (nominally 20 x 10) |
| Stores | 200 (nominally 25 x 8) |

#### 8.1.3.1 Plant Room

The plant room shall provide adequate room for the air-conditioning and ventilation plant required to service the entire Facilities. The air conditioning system shall be used for both control of air quality and for humidity control of the air.

The room shall house at least the following:-

- Pre-filtration and activated carbon filtration to ensure removal of hydrogen sulphide ($H_2S$) from air supplied to rooms in the Operations Building.
- Air conditioning chiller, condensers and air conditioning units
- Supply and return air fans
- Supply and return air dampers

#### 8.1.3.2 Office

An open plan office shall be provided for the administration of the Facility.

#### 8.1.3.3 Reception Area

This shall be suitable for a single receptionist to receive and control movements of visitors to the Plant and complete with the following furniture.

- Modern style reception desk complete with three drawers
- Ergonomic chair for reception desk
- Additional chairs for four visitors

#### 8.1.3.4 Operator Control Room

The Operator Control Room (OCR) shall have clear visibility through double glazed windows to the Power Plant and also the main access gate where practicable.

The OCR shall be adequately sized to contain all the OCR requirements relating to the operation of the whole of the Plant including Power Plant, SGS and Switchroom.

The OCR shall be provided with generous desk space for the normal control and operation of the plant, including sufficient room for the laydown and use of log books, operating manuals and other documentation that may be used in the normal course of operating the Plant. Printers shall be located on separate desks from the main operator desk.

Noise levels within the OCR shall not exceed 52 dBA (SPLA) measured at each work station.

The OCR shall be equipped with hardwearing, anti-static floor tiles.

The OCR and office area shall be designed to include an EMF suppression system such that plant personnel will be shielded from high voltage EMF emissions emanating from plant switchgear and bus duct apparatus where these electrical items are located closer than 10m to any point in the OCR. Contractor shall demonstrate that EMF emissions measured within the OCR shall be less than 5 microtesla.

The OCR shall have at least two separate means for personnel egress.

The OCR shall have windows for natural lighting located so that these do not provide glare or reflections onto the operators and the operator workstations respectively.

#### 8.1.3.5 Managers Office

An office complete with furniture shall be provided immediately adjacent to the reception area. A window shall be included to provide a general view of the Power Plant.

Furniture shall be matching in style and colour and comprising;

- Executive desk of minimum size 1800mmL x 800mmW x 750mmH; completed with three drawers, natural colour.
- Ergonomically designed chair
- 3 drawer filing cabinet
- bookcase, natural colour
- round meeting table complete with four chairs

### 8.1.3.6 Meeting Room

A meeting room complete with tables, chairs and accessories shall be provided suitable for meetings of a minimum of 10 people. The meeting room shall be located such that access is readily available to the lunchroom / kitchen and the washroom / toilet facilities. A storage cupboard, whiteboard and fixed projector screen shall be provided.

### 8.1.3.7 Records Storeroom

A room suitable for storage of records that is easily accessible from the Open Plan Office. The room shall include book shelves sufficient for the handover documentation plus 20% spare capacity.

### 8.1.3.8 Open Plan Office

An open plan office shall be provided complete with 20 single phase outlets and 20 LAN outlets connected to the Employer's Business LAN. Furniture for 5 workstations shall be provided. Each workstation shall comprise a standard three drawer desk, an ergonomically designed chair and a bookcase. Each workstation shall be within open partitions.

### 8.1.3.9 Washroom and Toilet Facilities

Male and separate female toilet and washing/changing facilities shall be provided in the Operations Building for the use of the maintenance staff. Facilities to be provided shall include at least the following:-

| | Male | Female |
|---|---|---|
| Locker room/changing facility | 5 | 5 |
| Shower | 1 | 1 |
| hand basins with hot and cold taps | 2 | 2 |
| hot air hand drier | 2 | 2 |
| paper towel dispenser | 2 | 2 |
| soap dispenser | 2 | 2 |
| Urinals | 2 | - |
| Toilets | 1 | 2 |

### 8.1.3.10 Lunchroom and Kitchen

Kitchen and lunchroom facilities suitable for use by at least 10 people shall be provided. The room shall be provided with storage cupboards, table and chairs, bench, sink, with hot and cold taps, hot water heater, stove including oven and two microwave ovens. It shall be to a commercial catering standard.

### 8.1.3.11 Furniture Standard

All furniture shall be constructed to a high quality industrial standard, using solid timber. It shall be finished with a durable laminate surface which is scratch, stain, heat resistant. Edges shall be finished with hard PVC wearing rigid edging. Office and meeting room chairs shall be ergonomically designed, constructed with durable foam, high quality fabric, robust swivel and five castor wheels. Lunchroom chairs shall be of robust construction and easily cleaned.

### 8.1.3.12 **Workshop**

A Workshop with a concrete slab floor shall be provided. The room shall provide areas to store supplies and tools, and work space for equipment maintenance, instrumentation and electronic components for maintenance purposes. The Contractor shall supply suitable maintenance equipment in the workshop complete with electrical, pneumatic and other service connections as required.

The Workshop room will be sized to allow for maintenance of pumps, actuators, valves, motors as well as with fabrication facilities for normal plant maintenance including a welding bay, robust work benches, hoists and lifting beams as required.

It shall be equipped with;

- Two separate, motor driven garage type roller doors. These shall be lockable from the inside.
- One steel skinned pedestrian door, lockable from the outside.
- Lighting to 500 lux, switched in two banks
- Automatic louvre extract fan, sized to provide two complete air changes per hour
- Fire/smoke detection system. The welding bay shall be equipped with an air extract system to preclude interference with the room fire detection system.

A concrete, bunded wash-down concrete slab shall be provided adjacent to the workshop building to allow wash down of Plant equipment during maintenance activities. This shall be sized sufficient to maintain the water blasting of turbine diaphragms, rotor and similar. This will include a contaminated water containment system as described elsewhere in this Specification.

The Workshop shall be provided with at least five utility stations to supply compressed air and water for maintenance purposes within the workshop. The utility stations shall also supply 240 V single phase outlets for small hand tools and three phase welding power outlets. A safety shower and eye wash station shall also be provided in the workshop.

The floor of the workshop building shall be sealed to control the generation of concrete dust from the floor. The floor shall be hardened to reduce damage on the floor when heavy items of plant are placed on the floor.

The minimum height of the workshop shall be 6m.

The concrete slab shall extend outside at least 2m in front of the roller doors and shall be sloped down to road grade.

### 8.1.3.13 **Stores Area**

The stores area may be included within the Workshop and make use of the Workshop height and roller door access, but it shall be separately lockable.

Suitable steel shelving shall be provided that covers at least 33 per cent of the available floor area. The top shelf shall be 2m from floor level.

### 8.1.3.14 **Main Workshop Equipment**

The scope and size of the Workshop equipment, specified herein, shall be the minimum acceptable and the Contractor shall ensure that the workshop is sufficiently equipped to carry out the emergency maintenance and repair of plant without utilising the need of sophisticated equipment and highly specialised tradesmen.

All machines and equipment shall be rated to operate on the LV system complete with all controls and starters ready for operation.

In addition to the special machines and tools to be provided the Contractor shall provide a full complement of hand tools, work benches, vices, measuring instruments and inspection equipment including but not limited to those specified.

Each machine shall be complete in all respects, including driving motors, starters, push button control, low voltage lighting units with transformers etc., and supplied with a comprehensive set of spare parts.

All necessary guards to afford protection from electrical apparatus and moving parts of machinery shall be provided. The guards shall be of approved design and shall be fitted with inspection doors where necessary.

The Contractor shall provide all machines with adequate tool storage cabinets and stands. The necessary containers shall be provided for mixing cutting fluid (suds) and the collection of waste material swarf and chippings.

The Contractor shall provide all necessary clamping arrangements where not included in the various machine tools standard equipment.

The Contractor shall equip the mechanical workshop with a comprehensive set of tools and accessories including those listed as follows:

- lathe
- drill press, radial arm type, minimum 3HP, 24”
- milling machine
- sheet metal bender
- steel cut off machine
- MIG welding bay - complete
- Hand tools
- Small power tools.
- Other tools, equipment, lubricants and wash bays (Contractor to provide list)

The sizes, quantities and capacities quoted are the minimum acceptable, actual sizes and capacities shall be based on the requirements of the Facility.

#### 8.1.3.15 **Electronics Workshop & Electronics Storeroom**

This shall be used for the calibration of field instruments and control equipment. The room shall have internal access to a storeroom that will be used for the storage of electronic spare parts for the plant and electronic test equipment.

The workshop shall be provided with at least 10 single phase power outlets and four instrument air supply outlets. The workbench shall also include a 110V DC, 24V DC variable voltage current limited instrument power supply rated to 10A.

The Contractor shall equip the electronics/instrument workshop with all tools required for the maintenance of the Facility’s instrumentation.

The supplied equipment and tools shall be of the highest quality and provided with full instructions and supporting technical literature.

### 8.1.3.16 **Laboratory and Testing Facility**

A well testing laboratory shall be provided to facilitate the Employer's sub-surface and well testing of geothermal samplings including analysis of CW water (e.g. general "wet" sample analysis). It shall be a standalone or a suitable annex to the Operations Building.

The laboratory shall consist of a room of area 12$m^2$ which shall include a fume cupboard and a stainless steel benches.

Four 220V single phase RCD protected electrical outlets shall be provided together with four LAN outlets connected to the Employer's business systems.

A manufacturer's standard fume cupboard complying with Dominican Health and Safety regulations shall be provided in the laboratory room. This shall be equipped with domestic water, drains and electrical supplies.

The fume cupboard shall be mechanically ventilated to the outside.

The laboratory shall be provided with opening windows to the outside.

The floors in the laboratory shall be finished with swept corners to the walls and corners so that dirt cannot accumulate. The floor shall be finished with a hard wearing, chemical resistant, vinyl or similar flooring material designed for a wet laboratory environment which extends up the sweep corners to 100mm above floor height. A central floor drain shall be provided in the laboratory room.

An eye wash station shall be provided within the laboratory.

A site laboratory shall be provided for analysis of geothermal fluids (water and gas) and water from the circulating cooling water system. The equipment supplied shall be sufficient only for some important analyses required for ongoing monitoring, including:

pH, sodium (Na), calcium (Ca), chloride (Cl), sulphate ($SO_4$), boron (B), bicarbonate ($HCO_3$), silica ($SiO_2$), carbon dioxide ($CO_2$) and hydrogen sulphide ($H_2S$), ammonia ($NH_3$) and bacterial analyses.

For comprehensive analyses, samples will be sent to a commercial laboratory.

Aspects of layout are as follows:

- Dimensions: 4 x 3m
- Benches: on two sides of room. Chemical resistant surface.
- Storage: drawers and cabinets beneath bench.
- Non-hazardous chemicals above bench.
- Acids and flammable liquids in appropriate safety cabinets, under bench.
- Electrical sockets on panel around bench.
- Fume cupboard at bench level. External venting with light and power.
- Sink. Hot and cold water. Chemical resistant with swan-neck faucets.

The following laboratory equipment and chemicals shall be provided by the Contractor:

**Laboratory Equipment**

| Item |
|---|

| |
|---|
| Portable pH/mV meter (e.g. Orion brand), AC/DC with two buffer manual calibration |
| pH electrode (x 2) |
| Visible spectrophotometer (325 – 800 nm), with 1 cm cuvettes |
| Flame photometer (for sodium) |
| Ammonia Gas-Sensing Electrode |
| Portable magnetic stirrer (with 2 x stirrer bee and retriever) |
| Water Distiller |
| Hot plate |
| Small Incubating Oven |
| Digital thermometer (x 2) |
| Turbidimeter for cooling water and sulphate |
| 500g x 0.01g balance |

**Chemicals (all analytical grade, AR)**

| Analysis/Use | Item | Quantity |
|---|---|---|
| pH | pH buffer solutions (pH 4, 7, 10) | 500 ml |
| Chloride (high) | Silver nitrate, AR | 100 g |
| | Potassium dichomate, AR | 100g |
| | Potassium chromate, AR | 500 g |
| | Sodium chloride, AR (100 g) | 100 g |
| Silica | Ammonium molybdate, AR | 250 g |
| | Concentrated sulphuric Acid, AR | 1 l |
| | Ammonium hydroxide solution, AR (28%) | 1 l |
| | 1000 ppm silicon standard, AR | 500 ml |
| Others | Zinc acetate, AR | 100 g |
| | Calcium carbonate, AR | 100 g |
| | Concentrated nitric Acid, AR | 1 litre |
| | Concentrated hydrochloric Acid, AR | 1 litre |
| | Sodium hydroxide pellets, AR | 1 litre |
| | Ammonium chloride, AR | 250 g |
| | Mannitol, AR | 500 g |
| | Sodium tetraborate, AR | 250 g |
| | Bromothymol blue (1% w/v in 95% ethanol | 100 ml |
| | Eriochrome Black T Indicator, AR | 25 g |
| | EDTA (AR) | 500 g |
| | Iodine 0.1N, AR | ampoule for 1 litre stock solution |
| | Sodium thiosulphate 0.1N, AR | ampoule for 1 litre stock solution |
| | Sodium starch glycollate, AR | 100 g |

**General Laboratory and Sampling Equipment**

| Analysis | Item | Quantity |
|---|---|---|
| Glassware | 100 ml beaker | 10 |
| | 500 ml beaker | 5 |
| | Distilled water wash bottles | 2 x 500 ml |
| | Measuring cylinders | 2 x 100, 2 x 500 ml |
| | Volumetric flasks | 50, 100, 200, 500 m) |
| | Graduated pipettes | 1, 2, 5, 10, 20, 25, 50 ml. Two of each |
| | glass screw-cap bottles (e.g. Schott) | 2 x 500, 2 x 1000 litre |
| | Pipette dispensing bulbs | 2 |
| Plasticware | Disposable droppers | 3 ml, box of 500 |
| Filtration | 50 ml disposal syringes (luer -slip) | pack of 50 |
| | 0.45 micron 45 mm cellulose filters (Millipore or Sartorius) | pack of 100 |
| | Filter holder (Millipore) | 4 |
| | spare filter holder o-rings | pack of 10 |
| Sampling | Portable sampling separator rated to operating WHP. For collection of separated brine and steam samples from a two-phase pipeline. | custom made |
| | 316 SS condensing/cooling coil (6 m), with flexible SS reinforced teflon hose | custom-made |
| | tools (pipe wrenches, adjustable wrenches etc). | |
| | plastic dipper | 2 x 1 litre |
| | 500 ml plastic, screw-cap sample bottles | 100 |
| | 100 ml plastic, screw-cap sample bottles | 200 |
| | 250 ml plastic, screw-cap sample bottles | 200 |
| | 30 mls glass screw-cap sample bottles | 100 |
| | Rotoflo gas sampling bottles, 250 ml. | 10 |
| Other | Petrifilm culturing plates | various for sulphur oxidising bacteria |
| Safety | Eye glasses | 3 |
| | Latex gloves | box of 50 |
| | Ear muffs | 3 |
| | Lab Coats | 3 |

### 8.1.4 Electrical Annex

The electrical annex shall be suitably located within the turbine generator building and shall be sized to include at least the following, including provisions for future expansion:

- 11kV generator breakers and 11kV unit transformer breakers.
- 110V DC protection and tripping supplies for the 11kV and 415V unit switchboards and the DC emergency oil pump. This battery room shall be naturally ventilated to the outside
- Electrical protection relays, power metering and synchronisation panels.
- Unit DCS panels
- 415V unit and common services switchboards.
- Relay and protection panels
- Communications equipment
- DCS hardware and DCS marshalling panels
- Governor, vibration and similar cubicles
- DC chargers. These shall not be installed within the same room as the battery banks.
- UPS systems

With the exception of cable galleries and battery rooms, all areas of the annex shall be air conditioned, the incoming air being treated to remove hydrogen sulphide ($H_2S$) and other contaminants in order to meet the environmental controls and air treatment requirements set out in this Specification. The electrical annex shall be sealed to minimise leakage of treated air. This includes cable or piping exits as well as doors.

This electrical annex shall have no windows. Normal personnel access shall be via a double door air locks, with minimum distance between the airlock doors of 2m. At least two means of personnel egress shall be provided. The equipment access door shall be normally closed and be fitted with emergency exit “push bar” handle to facilitate easy egress from the room.

### 8.1.5 MV Switchroom

The MV Switchroom building shall be suitably located adjacent to the turbine generator building and will include at least the following:

- Electrical switching and protection relay equipment for the main 11kV switchboard. This switchboard shall be operated and maintained by DOMLEC after Commissioning.
- Battery room for the 110V DC protection and tripping supplies. Alternatively, a 110V DC feed from each of the Unit battery supplies may be used to supply the MV Switchroom. The dual feeds shall be connected via suitably rated diodes to then supply the 11kV switchboard.
- SCADA, RTU, and metering equipment.
- Cable galleries to accommodate incoming/outgoing 11kV cables. The incoming 3 x 11kV circuits from DOMLEC’s network will be via 11kV underground cable. The 3 x 11kV circuits will be constructed by DOMLEC and will also be terminated into the switchgear by DOMLEC. The Contractor shall designate an underground cable route for the construction and access of the cables by DOMLEC.

The MV Switchroom floor shall be tiled to eliminate concrete dust.

The room shall be designed to provide safe operating conditions for maintenance personnel.

The switchroom design and location shall include space for a potential future upgrade to connect the plant to the DOMLEC network at 33kV. Accordingly, the switchroom design shall accommodate additional space for the following requirements:

- A 33kV switchboard (5 circuit breakers; two line incomers, one bus section breaker and two transformer feeders).
- Protection/control equipment associated with 2 x 11 / 33kV transformers.
- Cable galleries to accommodate incoming and outgoing 33kV cables.

Sufficient space shall be provided outside for the future 11 / 33kV 9MVA transformers, 33kV landing gantry and surge arresters.

### 8.1.6 Perimeter Fencing

The Contractor shall provide and install a new heavy duty, hot dipped galvanised, 2.4 m high, chain link fence around the site. The fence shall be topped with three-strand barbed wire. As a minimum, three widely-spaced gates shall be provided comprising a 7.0 m wide main gate and two 5.5 m wide emergency gates. The emergency gates shall be fitted with a locking system which can be only opened from within the fenced area.

Where equipment, tanks or buildings are vulnerable to vehicle traffic, crash posts shall be provided. Posts that would interfere with maintenance and overhaul requirements shall be removable. Fixed posts shall be DN 150 hot dipped galvanised steel pipe, set 900 mm in concrete, concrete filled, painted and projecting 1.2 m above grade. Removable posts shall be DN 150 hot dipped galvanised steel and painted pipe, projecting 1.2 m above grade in a hot dipped galvanised steel sleeve set in concrete extending 900 mm below grade. Galvanised steel continuous crash guards shall be provided along buildings where building cladding is in proximity to vehicular traffic areas.

### 8.1.7 Employer Project Site Offices

The Contractor shall provide the following facilities and hand them over to the Project Manager within 60 days of Effective Date for the entire duration of the Contract up to and including Commissioning.

The project site office shall be a portable office building or 40’ container based offices, each to a high standard of internal fit-out complete with:

1. Open plan office suitable for 8 Employer personnel
2. Separate meeting room for eight people complete with table and chairs
3. Separate document storage area complete with 10m2 of shelving.
4. Complete internal wiring at 240 V 50 Hz; at least 8 double socket outlets to Dominican standard.
5. A 5 kVA UPS (supplied by Contractor) wired to selected and labelled socket outlets (5 of)
6. Fluorescent lights to adequately illuminate all areas
7. Ethernet wiring to 10 outlets (data and communication) wired to a central point adjacent to the UPS
8. External lights
9. Reversible A/C heat pump system for heating and cooling capable of maintaining the area between 21 and 25 DegC and 50 to 60 per cent relative humidity
10. Separate male and female toilets with hand basin in an enclosed area serviced by an extractor fan
11. Small kitchenette with bench & sink and space for microwave and small under-bench refrigerator
12. Microwave oven, water dispenser.
13. Office desks and chairs.
14. Filing cabinets.

The Contractor shall be responsible for the following:

- Connection to a reliable construction site power supply, availability >95% during working hours
- Provision of septic tank system suitably sized for use by 8 people on a continuous occupation basis.
- Connection of toilets to septic tank system
- Connection to water supply (non-potable) for toilets & basins. Provide primary filtration system.
- Maintenance and cleaning of building structures and fixed fittings up to and including Commissioning.
- Removal of temporary facilities after Commissioning.

## 8.2 Vehicles for Maintenance Activities

The following vehicles shall be supplied to ensure that all plant and materials may be safely and efficiently moved as required for all maintenance and repair activities. These equipment movements shall include transport via the public and private road network.

As applicable, the Contractor shall ensure that equipment provided is certified to relevant local or international standards.

The site layout shall include a suitable under cover parking location for the vehicles specified in these sub clauses.

### 8.2.1 One hoist truck

A diesel hoist truck with a flat bed of at least 4m equipped with an hydraulically actuated hoist. The truck shall be capable of hoisting steamfield valves, piping, pumps and similar equipment for maintenance activities. Minimum hoist capacity shall be two tonnes. It shall be fully licensed for use on Dominica roads.

### 8.2.2 Fork Lift

The Contractor shall provide an electric fork lift suitable for stacking and moving spare parts in the store as well as for moving loads within the Power Plant area for maintenance activities. The forklift capacity and height shall be suitable for all duties associated with the plant, but as a minimum the forklift shall be capable of lifting 3.0 tonnes to a stacking height of 3.5 metres.

The fork lift truck shall be designed for use in narrow aisles and shall be able to operate within the provided stores stacking areas.

It shall use an electric drive and shall preferably have a Dominica based service agent.

### 8.2.3 Boom Lift

The Contractor shall provide a self-powered / self-motive boom lift for maintenance personnel, which has the following capabilities;

- Height reach – 15m
- Outreach – 8m
- Lift weight - 200 kg
- Swing - 360 degrees
- Platform size – to safely accommodate two people including structurally designed safety harness attachments

It shall use an electric drive and shall preferably have a Dominican based service agent.

## 8.3 Fire Protection

### 8.3.1 Introduction

The facilities at Dominica are remote and have limited effective external fire brigade, and this plant is therefore required to be self-sufficient in regards to fire fighting. Fire protection systems shall be simple in concept, easy to maintain and be supported by spare parts and maintenance procedures designed to be carried out by local maintenance staff.

The fire protection system and associated equipment shall comply with NFPA codes and Government of Dominica requirements.

In general, the design shall comply with NFPA. Where differences exist between the Dominican standards and the NFPA Standards, the Contractor shall choose the more onerous requirement. Any contradiction or uncertainty shall be raised to the Project Manager.

The applicable Codes, Standards and Regulations are listed below.

**Applicable NFPA Standards**

The most recent edition of the following NFPA Codes standards shall apply:

NFPA 10; Standard for Portable Fire Extinguishers

NFPA 11, Standard for Low-, Medium-, and High-Expansion

NFPA 12, Standard on Carbon Dioxide Extinguishing Systems

NFPA 13, Standard for the Installation of Sprinkler Systems

NFPA 14, Installation of Standpipe and Hose System

NFPA 15, Standard for Water Spray Fixed Systems for Fire Protection

NFPA 16, Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems

NFPA 17, Standard for Dry Chemical Extinguishing Systems

NFPA 20, Standard for the Installation of Stationary Pumps for Fire Protection

NFPA 22; Standard for Water Tank for Private Fire Protection

NFPA 24: Installation of Private Fire Service Main and Their Appurtenances

NFPA 70: National Electrical Code

NFPA 72: National Fire Alarm and Signalling Code

NFPA 850: Fire Protection for Electric Generating Plants and High Voltage DC Converter Station

NFPA 1961; Standard for Fire Hoses

NFPA 1963; Standard for Fire Hose Connection

In this section the acronym VESDA is used to describe any listed aspirating high sensitivity smoke detection system that has service support in Dominica.

### 8.3.2 Design Report

At an early stage in the design of the buildings the Contractor shall provide a comprehensive Fire Protection report prepared by a qualified (to Dominica Standards and NFPA) fire engineer to demonstrate means of compliance with this specification, local fire protection codes, and any additional requirements of the Employer's insurance assessors.

The report shall take into account means of escape and protection for personnel and both active and passive fire protection measures that will be fulfilled in the design in order to adequately protect the Employer's investment.

The report shall include layout drawings demonstrating the hazard occupancy classification on each area, and determine the sprinklers application based on hazard occupancy classification in compliance with NFPA and local standard.

The report shall be reviewed by the Project Manager and comments incorporated in the fire protection measures before further design work is undertaken.

Prior to installation of the fire protection system, all design documentation shall be submitted by the Contractor to the local fire department (or the authority having jurisdiction) for review and approval. All resulting requirements and recommendations from such review shall be incorporated into the design by the Contractor. The revised design documentation shall be resubmitted for final approval. The final approval shall be demonstrated to the Project Manager.

### 8.3.3 Fire Pump House

A separate fire pump house shall be provided to house fire pumps for the Plant. Adequate access shall be provided for maintenance and operation of the pumps in side. The pump house shall be fully enclosed with roofing to allow covered operating and maintenance access.

### 8.3.4 Fire Separations

The buildings shall be divided into fire compartments by the use of fire rated walls, doors and sealing around penetrations.

The layout of fire compartments shall follow structural concrete walls where possible. All fire walls shall be strong enough to resist impact from normal activities in the compartment.

All fire separations shall be rated 2 hour or greater. Fire doors shall be to a Standard acceptable to the Project Manager and fitted with automatic closers.

Cable and pipe penetrations through fire walls shall be sealed by fire pillows where above ground floor level and sand barriers where in trenches below ground floor level. Cable penetrations through fire rated floors shall be fitted with intumescent fire collars or other approved proprietary fire proofing system.

### 8.3.5 Fire Alarm System

A single addressable fire alarm system shall be provided for the Plant, it shall be of an approved type supported in Dominica by a stockist of spare parts and with specialist installation and servicing skills. It shall be supplied with sufficient technical information and spare parts to enable any experienced industrial electrical fitter to carry out routine service and replace components for any single fault. Annual surveys will be carried out by appropriately qualified staff from outside Dominica if required, who shall also offer fire alarm maintenance training for electricians.

Specific requirements include:

1. The fire alarm control panel shall be located in the OCR.
2. The fire alarm control panel shall be provided with 24 hours back-up power supply which in turn shall be supplied from the Power Plant UPS and shall be able to be tested monthly.

The fire alarm control panel shall display the following system functions, as a minimum:

- System Status
- Power On
- System Activation/Alarm
- Zone
- Fire Pump Running

Manual alarm call points shall be break glass type complete with signage approved by the Project Manager. Manual alarms shall be installed at each fire exit.

VESDA shall be provided with collection points covering the risk areas identified, but not necessarily the whole room. Generally a single detection tube can be considered to cover 5 m either side of the tube. Inlet orifices shall be spaced no more than 10 m apart.

Single smoke beam detectors shall be installed in workshops at high level to provide early warning of fire when the workshop is unattended; multiple beam coverage is not required.

Gas detection shall be provided appropriate to the type of gas that may be devolved from the batteries.

Battery room ventilation shall be via natural ventilation which shall preclude the build-up of hydrogen gas within the room and ceiling space.

The annunciation panel shall be provided in the OCR which indicates the relative location of each fire detection system within the Plant.

### 8.3.6 Fire Water Supply

The Contractor shall supply bulk storage of raw water as required to ensure adequate reserved capacity for the fire suppression systems in accordance with NFPA guidelines recognising that the raw water supply may be unavailable for periods of time. The Contractor can use the storage available in the raw water storage tank, as long as systems are included in the Plant to guarantee that the assumed volume of water required from this storage area for firefighting is available at all times, regardless of plant maintenance or abnormal plant operations. If this requirement cannot be met and /or there is insufficient storage capacity from this, then additional dedicated bulk storage tanks shall be provided.

The minimum storage required shall be able to provide fire water for a minimum of 2 hours for any of the following, whichever is greater:

- The largest fixed fire suppression system demand, or
- Any fixed fire suppression system demands that could reasonably be expected to operate simultaneously during a single event. e.g., turbine underfloor protection in conjunction with other fire protection systems in the turbine area, or adjacent transformers which are not adequately separated, or
- Hose stream demand in accordance with NFPA 14 section 7.10.1

A location for any bulk storage tanks along the route from the supply terminal point to the main Site may be proposed by the Contractor that will allow the natural ground elevation to provide the appropriate water supply pressure requirements at the Power Plant.

Water shall be delivered at the pressure required to meet the hydrant performance.

Two sets of fire pumps shall be provided; a diesel powered set as an emergency stand-by pump and an electric powered set as the duty fire pump.

Fire pumps shall be started automatically on drop in fire service mains pressure. An electric jockey pump shall be provided to maintain a system pressure against minor leakage or thermal expansion volume changes.

Pump sets shall include a dedicated control system, pressure relief valves to prevent over heating under zero flow conditions and to ensure fire main pressures remain below equipment maximum working pressure. All pump sets and controllers shall comply fully with NFPA 20 requirements.

### 8.3.7 Hydrants

A combined underground fire water ring main shall be provided using welded steel pipe or HDPE. The ring main shall be run outside the buildings so as to provide hydrant stand points within 15 m of each fire exit, and to supply sprinkler and deluge systems within the buildings.

Hydrants shall be provided outside and inside buildings (including cooling tower and all auxiliary building for chemical storage, workshop, store, etc.) at a maximum separation of 60m.

The cooling towers shall be equipped with fixed monitors at strategic locations to provide firefighting cover for the entire cooling tower structure.

The ring main shall be divided into at least 4 sections of similar length by maintenance isolating valves. Fire suppression feeds from the pumps' main shall be arranged so that supply to all suppression systems is maintained should any one section of ring main be out of service.

Hydrant stand pipes shall be DN 100 and hot dip galvanised to 600 mm below ground. All hydrants shall be dry barrel type, rated to provide minimum 114$m^3$/hr and shall be U.L listed and/or FM approved. Hydrants shall be self-draining type, and shall include a 0.6m x 0.6m deep area under each hydrant filled with gravel. Hydrants shall be located between 1m and 2m from edge of the road shoulder or curb. Where a shoulder or curb is not provided, hydrants shall be located between 1.5m and 2m from the edge of the road.

Outdoor hydrants shall be equipped with an outdoor hydrant box equipped with fixed hose racks for personnel to provide quick application for fire suppression and equipment protection. Hose racks shall be equipped with at least 30m of double jacket hose with hose diameter 2.5 inch, and adjustable spray nozzle, in total capable delivering 56.7 m3/hr at 6.9 bar. Firefighting hoses shall be sufficiently long to provide overlapping fire protection zones from adjacent fire hydrants.

Inside buildings, hydrants shall be provided with a hose rack and double jacket hose at least 30m in length, diameter 1.5 inch and adjustable spray nozzle, in total capable delivering 22.7 m3/hr at 4.5 bar.

The hydrant ring main shall be sized (in conjunction with the fire pumps if required) to deliver 10 l/s each to the 3 most hydraulically remote hydrants, plus water flow for a number of the most remote sprinklers as per applicable NFPA 13 requirement, with a minimum residual pressure of 6.9 barg with any one section of the fire main out of service and the largest single suppression system operating.

All hydraulic calculations shall be done using recognised fire protection software and the calculation records shall include coordinated node diagrams and NFPA format detail printouts.

### 8.3.8 Fire Suppression Systems

#### 8.3.8.1 Water Based

Manually operated water deluge systems shall consist of a nozzle array to provide direct impingement coverage of all parts of the risk and shall be operated manually by a ball valve from a safe distance. The ball valve shall have signage approved by the Project Manager and be fitted with a micro-switch connected to the fire alarm system to raise the alarm if the valve is operated. Automatically operated water based suppression systems shall be operated by a listed deluge valve triggered by sprinkler heads mounted on DN 15 pipe work.

Automatic sprinklers shall be installed to NFPA 13 or other standard specifically approved by the Project Manager. Sprinkler application rate shall be as per reference standard hazard occupancy classification, head spacing between 3 m and 4 m, with no more than 12 $m^2$ coverage per head. Pipe sizing shall be determined by full hydraulic calculation.

Sprinkler and deluge heads shall be selected to provide appropriate discharge patterns and shall utilise glass tube frangible elements offering an RTI of no more than 50 $m^{-1}s^{-1}$.

Water sprinklers shall not be used for electrical switchrooms, DCS cabinet locations and other sensitive electrical equipment areas.

#### 8.3.8.2 Foam Flooding

High expansion foam flooding system shall be used in the areas containing flammable liquid drum storage which has flash point below 38°C.

#### 8.3.8.3 Gas Flooding

Due to health and safety concerns, in-cabinet flooding is preferred over room flooding systems. Gas flooding agents shall be selected to have minimal effect on the Employer’s personnel exposed to a discharge. Gas used for flooding shall be;

- Free from poisons
- Free from CFC elements
- Free from Halon elements
- Is a nonconductive gas
- Has an ODP (ozone depleting potential) and GWP (global warming potential) values of zero

Recharge of the selected gas must be readily available in Dominica or a backup charge of gas shall be provided which can be used to easily render the gas suppression system operable.

Gas flooding controls shall incorporate warning signs and discharge delays if the space is occupied, and relief venting to ensure proper gas distribution.

Where drainage is a problem or where a suitable enclosure exists, automatic gaseous extinguishing systems may be used to replace sprinkler protection of cable installations. Care must be taken to provide sufficient relief vents to ensure that gaseous extinguishing distribution completely covers all cables.

Cable galleries/plenums and cable tunnels shall be provided with an early warning fire detection system (VESDA) which shall be used to trigger the fire suppression systems in those areas.

#### 8.3.8.4 Hand Held Equipment

Fire Extinguisher types and sizes shall be limited to those able to be serviced in Dominica by the Employer's personnel. Fire extinguisher service equipment manuals and spare parts shall be provided. Water and foam extinguishers shall be stainless steel. $CO_2$ extinguishers shall hold 5 kg of $CO_2$.

### 8.3.9 Buildings and Visitor and Education Building

The Plant buildings have the following fire risks that are required to be protected:

- Workshops / Machinery Room (Manual Alarm, smoke beam detector, $CO_2$ and foam extinguishers)
- Electrical and DCS panel rooms (Manual alarm, VESDA, handheld $CO_2$ extinguishers)
- MV Switchroom (Manual alarm, VESDA, handheld $CO_2$ extinguishers)
- Outdoor fuel storage tanks (foam water system, manual alarm),
- Offices, kitchen rooms etc. (Manual alarm, room coverage automatic sprinkler system)
- Plant rooms (Manual alarm, room coverage automatic sprinkler system, $CO_2$ and foam extinguishers)
- Visitor and Education Building (Manual alarm, room coverage automatic sprinkler system, $CO_2$ and foam extinguishers)
- Chemical storage unit ($CO_2$ and foam extinguishers)
- Toilets and washrooms (Manual alarm only)
- Stores (Manual Alarm, smoke beam detector, $CO_2$ and foam extinguishers)
- Steam or hydrocarbon turbine and generator lube oil skids and valve control oil skids: manual alarm, smoke beam detector, $CO_2$ and foam extinguishers.
- Turbine and generator rotating plant: manual alarm, $CO_2$ and foam extinguishers.
- Hydrocarbon storage, piping and vessels: manual alarm, gas detection, fixed sprinkler or deluge systems, fixed hydrant monitors as appropriate

### 8.3.10 Training on Fire Protection Systems

The Contractor shall provide comprehensive training on the fire protection equipment to the Employer. This shall include the following training:

- Use of handheld fire extinguishers
- Starting and stopping of the electric and diesel fire water pumps
- Use and handling of the fixed fire monitors
- Use and handling of the fire hose reels and nozzles
- Statutory, routine testing requirements for the fire fighting system

## 8.4 Shower and Eye Wash Stations

Combination shower / eyewash stations shall be provided wherever chemicals are stored or used, including battery room(s). At a minimum, shower /eyewash stations shall be provided adjacent to chemical injection equipment, cooling tower chemical injection equipment, chemical bulk storage tanks and all battery rooms in the Plant.

Each station shall have foot pedal actuation for eye wash, manual pull ring for emergency shower release. Water supply pipework shall not be exposed to direct sunlight.

Each shower / eyewash stations shall be independently alarmed to notify others in the OCR via the DCS when an eyewash station is used.

## 8.5 Utility Air Stations

Utility stations consisting of two DN 20 compressed air outlets, complete with ball valves, shall be provided at suitable locations throughout the plant for maintenance activities; one near each turbine generator, two near the cooling tower / air cooled condenser, and five within the maintenance workshop area.

## 8.6 Ventilation and Air Conditioning

### 8.6.1 General

Clean filtered air is required to protect electrical and control equipment as defined in this specification. This air is considered an essential plant service. A redundant system shall be provided. Redundancy shall include electrical supplies, fans, filters, filter media and control systems. It shall be possible to take one “half” of the system off-line for maintenance whilst still providing 100 per cent of the air requirements with the other “half” of the system.

The ventilation and air conditioning systems shall be complete in all respects and fully operational before any electrical equipment is installed in the areas that the systems are intended to condition. Any necessary temporary supplies required to achieve this objective shall be the responsibility of the Contractor.

Ventilation and air conditioning design must allow for at least 15 per cent additional plant capacity above the design requirements.

All designs must allow for the filtration/purification of air from toxic gases such as Hydrogen Sulphide ($H_2S$) where spaces are occupied by humans and/or where Hydrogen Sulphide in the atmosphere may affect the integrity of the equipment and/or installations. Concentrations of 0.3ppm of $H_2S$ are unacceptable for exposed copper conductors, while concentrations of 0.1 ppm of $H_2S$ have adverse effects on silver-plated connectors and conductors.

All fasteners for the air handling units, filter units and condensing units shall be stainless steel or approved by the Project Manager.

### 8.6.2 Design Conditions

Rooms with occupancy shall be supplied with fresh air according to the NIOSH standards.

In spaces defined as ‘Maintained’, air is to be maintained as follows:

For human occupancy, minimum oxygen level will be 19.5 per cent. Other gaseous and chemical levels are as to be defined by National Institute for Occupational Safety and Health (NIOSH) and specifically for $H_2S$, Recommended Exposure Limit of: 10 ppm (15 mg/m3) for 10-minute exposure

For equipment integrity, maximum $H_2S$ levels of 0.1 ppm.

Spaces with Maintained air must be pressurised to a 15 Pa differential to prevent entry of non-maintained air. This shall be achieved by room design including double door air-lock personnel access, complete surround elastomeric door seals, sealed ceiling construction such as polystyrene insulated aluminium skinned refrigeration panel and similar design techniques.

| Room | Occupancy | Design Conditions | Air quality |
|---|---|---|---|
| Control Room | 6 occupants | 21°C to 25°C temperature<br>50 to 60% relative humidity | Maintained and $H_2S$ Scrubbed |
| DCS panel rooms, Electronic Workshops and Electronics Storeroom | 2 occupants | 21°C to 25°C temperature<br>50 to 60% relative humidity | Maintained and $H_2S$ Scrubbed |
| Offices, Meeting Rooms, Training Rooms | Varies up to 12 people | 21°C to 25°C temperature<br>50 to 60% relative humidity | Maintained |
| Lunchroom, kitchens, canteens | Varies up to 12 people | 21°C to 25°C temperature<br>50 to 60% relative humidity | Maintained |
| Cable Space Rooms | Nil | | Natural ventilation only |
| All rooms containing electrical equipment | Up to 4 people intermittent use | 21°C to 25°C temperature<br>50 to 60% relative humidity | Maintained and $H_2S$ Scrubbed |
| Battery Rooms | Nil | 24°C to 26°C temperature<br>50 to 60% relative humidity | Natural ventilation only |
| Mechanical Workshop | 6 occupants | Vented to outside via separate ducting | Forced ventilation |
| Laboratory | 3 occupants | 24°C to 26°C temperature<br>50 to 60% relative humidity<br>Vented to outside via separate ducting | Maintained |

| Room | Occupancy | Design Conditions | Air quality |
|---|---|---|---|
| Chemical storage Areas | Nil | Vented to outside via separate ducting | Ventilated only – 1 air change per hour |
| Ablution Areas | | Areas to be exhaust ventilated to the equivalent of 25 litres per second for each WC or Urinal. | Maintained at negative pressure. |
| Emergency Generator space | | To be mechanically ventilated to maintain a maximum of 35 degree exhausting air temperature | |

### 8.6.3 Air Handling and Filter Units

The air handling units shall include panel type pre-filters with EU5 media.

Filters shall also be provided to remove $H_2S$ to the levels specified. These filters shall be protected by the pre-filters.

The filter media shall be readily available in Dominica where possible. A local supplier shall be located by the Contractor or alternatively minimum levels of operational spares shall be nominated for the Project Manager's review.

Each filter shall be provided with magnahelic type filter pressure drop manometers and differential pressure switches providing alarms in the case of clogged filters.

The filter section and coil sections shall be selected for a maximum face velocity of 2.4 metres per second.

All filter media shall have a minimum lifespan of two years.

Return air shall be ducted from all rooms except the battery room.

The return air is to be ducted to the inlet plenums of each air filter unit to ensure the return air as well as the incoming air is filtered by the $H_2S$ filtration system before entering the air handling units.

Provide motorised control dampers in the fresh air inlet and return air connections to each air filter unit. Dampers shall be configured to open only when the respective unit is in operation.

### 8.6.4 Ductwork and Accessories

Ductwork shall be galvanised steel at least 1.2 mm thick treated for operation in corrosive environments.

Rectangular section ducts shall be manufactured in accordance with DW/144 or SMACNA specifications. Ductwork hangers and supports and their installation shall also be to DW/144 or SMACNA standards.

Ducts shall be installed to have as few joints as possible. Where there are changes in direction, fabricated fittings with directional vanes shall be used. Diagonal runs across building spaces are to be avoided. As much as possible, ducts shall be installed in corners or near structural elements of buildings.

Dampers used to control air flow in branches or to supply and return grilles in building spaces and shall be constructed in accordance with DW/144. Combination smoke and fire dampers shall be used to control fire and smoke movement through ductwork and shall be interfaced with the fire alarm and detection system and shall be controlled through the fire alarm control panel. Combination smoke and fire dampers shall comply with the appropriate National Fire Protection Agency (NFPA) requirement and shall be factory manufactured, with a fire rating as specified in the Fire Protection Report and shall be certified by the Underwriters Laboratory Inc. (UL). Fusible link dampers shall have a temperature rating of 72°C. Damper properties such as leakage ratings shall meet 2000 International Building Code. (i.e. minimum leakage rating of Class 2). Generally, damper characteristics such as leakage coefficients, pressure loss coefficients, fire rating etc. shall be submitted as part of the information for approval. All combination smoke and fire dampers shall also have the direct capability to respond to high temperatures should there be high temperatures in the duct(s) but no signal through the fire alarm panel.

All motorised smoke/ fire dampers shall include micro-switches or potentiometers to provide independent confirmation of the open or closed position of the dampers.

Manual test switches shall be provided on the mechanical control panel with indicating lights for proving the operation of the dampers independently of the automatic fire alarm interlocks.

### 8.6.5 Refrigerant

All air conditioning plant shall be selected to operate on R410a only.

### 8.6.6 System Control and Monitoring

The system control equipment shall;

- Respond to inputs from a variety of sensors to maintain requirements.
- Shut down all fan operation in response to smoke or fire detection systems
- Monitor indoor and outdoor temperatures, humidity levels, static pressures and provide system responses.
- Control mechanical equipment elements such as dampers, motors, pumps and heat exchangers.

Control equipment, links and software shall be to ASHRAE standards.

The system shall be programmed such that there is a changeover from duty to standby and vice versa for each piece of air-conditioning and ventilation equipment every 24 hours with each unit running as the duty unit for alternate 24 hour periods.

The system control equipment shall be interfaced to the DCS for the purposes of full remote monitoring and control of the ventilation and air-conditioning systems.

As a minimum, the monitoring shall include:

- Plant in operation
- Set points of controllers for temperature, humidity, flowrate.
- Actual measured temperatures, humidities, air flowrates, fan speeds, duct static pressures, critical in room static pressures, filter pressure drops
- Fault indication for plant and automatic changeover of duty/ standby plant.
- Alarms for systems operating out of control limits.

- Status of fire alarm interlocks with plant.
- Status of all electric smoke/ fire dampers.

All rooms provided with positive pressure ventilation shall have Magnahelic differential pressure gauges installed near personnel access ways to confirm the maintenance of positive pressure.

## 8.7 Building Electrical System, Lighting and Small Power

### 8.7.1 General

Suitable light fixtures, power outlet sockets and switches with associated distribution and lighting boards shall be provided for illumination and miscellaneous power supply in all areas.

Each lighting fitting and power outlet shall be suitable for the respective location and degree of hazard in which it is installed.

All equipment and wiring shall comply with Government of Dominica requirements or where these do not exist then to applicable international standards.

### 8.7.2 Power Outlet Sockets

All rooms and corridors except toilets, changing rooms and washrooms shall have single phase combination socket outlets to allow the use of 230V British style plugs and meet the relevant Dominica standard rated not less than 10 amps at intervals not greater than 5 m along the walls for cleaning and maintenance purposes. These shall be additional to outlets required for building services, operational and general equipment requirements.

Stores, workshops, turbine / generator area, unloading bay areas and rooms containing relays and switchgear shall have 10A rated single phase and three phase socket outlets rated not less than 60 amps at intervals not exceeding 10 m along the walls and 0.5 m above workbenches in workshops. These shall be additional to outlets required for building services, operational and general equipment requirements.

All items of outdoor plant shall have one single phase and one three phase socket outlet installed at a convenient junction box within 20 m of it.

All single phase sockets shall be protected by Residual Current Devices (RCDs) with a 30mA threshold. Single phase outlets may be grouped together under a single RCD, though in any case, at least one RCD shall be provided for a maximum of four outlets.

Power sockets located outside shall be IP65 rated when in use or not in use. The Contractor shall propose the fitting type for approval by the Project Manager to ensure compatibility with the Employer’s equipment.

Each power socket shall be provided with an engraved label with the identification tag of the circuit breaker feeding that socket. Labelling shall be in accordance with the labelling specification.

The Contractor shall provide at least three 60A rated portable power boxes with three phase leads and plug connections suitable for the socket outlets installed by the Contractor. These power boxes shall be provided new to the Project Manager and will be used for normal outage and maintenance power requirements. The three phase power box lead shall be at least 20m long and rated for the 60A.The power boxes shall provide a minimum of 6 single phase non RCD socket outlets, 4 RCD single phase outlets and two three phase outlets.

### 8.7.3 Lighting Sources

Lighting fittings shall be of the following types:

- High bay, flood lighting and general yard area - LED preferred, High Pressure Sodium (HPS) if not possible by LED
- Control rooms, switchrooms, and office areas - LED (glare control may be required).
- Stairways, ladders, local lighting (at process equipment etc) - LED preferred, fluorescent where LED not suitable
- Roading and general outdoor - LED preferred, High Pressure Sodium (HPS) if not possible by LED
- Exit lighting - LED

### 8.7.4 Luminaire Design

Luminaires shall comply with the following design requirements:

All Luminaires

- Fluorescent fittings shall be fitted with electronic ballasts and 'extra-long life' 20,000 hours lamps. These shall not be used in areas with rotating plant i.e workshops, turbine hall and similar.
- Luminaires subject to vibration shall be fitted with anti-vibration dampening

Luminaires installed external to offices and switchrooms

- IP65 rated
- Low copper content corrosion resistant body
- LED luminaires shall have 50,000 hour average rated life at L70 and fitted with a thermal management system. Stainless steel clips, screws and hardware
- LED Luminaires shall be designed to perform to IEC 62471, IEC 62717 and IEC 62722
- HPS luminares shall be in accordance with IEC 60662
- All HPS fittings to have external ignitors and thermal cut-outs fitted to the ballasts

### 8.7.5 Lighting Levels

Indoor lighting levels shall be in accordance with BS 8206 and the following average Lux levels:

| | | |
|---|---|---|
| 1. | Entrance halls and reception area | 200 |
| 2. | Corridors and stairs | 100 |
| 3. | Offices, meeting rooms | 400 |
| 4. | Laboratories | 400 |
| 5. | Computer workstations | 350 |
| 6. | Control rooms | 400 |
| 7. | Relay and switchgear rooms | 400 |
| 8. | Workshops and stores | 400 |
| 9. | Work benches | 500 |
| 10. | Unloading bays | 150 |
| 11. | Turbine and Generator pedestals | 400 |
| 12. | Toilets, changing, wash rooms | 150 |

Outdoor lighting shall be in accordance with BS 5489 and the following minimum Lux levels:

| | | |
|---|---|---|
| a. | General (except as below) | 30 |
| b. | Roadways | 5 |
| c. | Walkways | 10 |
| d. | SGS (Note 1) | 30 |
| e. | Security fence lines | 5 |
| f. | Raw Water | 30 |

*Note 1 –Lighting to be provided for the illumination of walkways, platforms and/or maintainable equipment*

### 8.7.6 Lighting Control

All outdoor lights shall be on day light sensor automatic light level control with manual override.

Lighting in control rooms shall be arranged with multiple circuits so that individual rows of fittings can be controlled. Additionally, the lights shall be fully dimmable.

Toilets, changing and washroom lighting shall be controlled by an ultrasonic/PIR occupancy sensors fitted with manual override control.

Lighting contactors shall have normally closed contacts so that the lights fail ‘ON’.

### 8.7.7 Emergency Lighting

Two emergency lighting systems shall be provided:

Exit Lighting

Adequate emergency lighting shall be provided to enable safe exit from the plant on failure of the primary lighting system. Internally illuminated “/EXIT” signs shall be provided at emergency exit doorways. Lighting shall comply with NFPA 101 and the applicable local Dominican standard.

Exit lights shall have an internal battery whose charge is automatically maintained by the mains power supply. Upon failure of the mains, each battery shall maintain a minimum of 1 hour power supply. Alternatively, Contractor may offer a central, independent battery system to supply the emergency exit lights. Circuits from the independent battery system shall be designed so that no single failure of a circuit breaker or other Plant failure shall affect no more than one emergency light.

Exit lights shall be always maintained “on”.

Strategic Lighting

Lighting sufficient to enable safe continued operation of the plant shall be wired independently from less important lighting circuits, and connected so that supply may be taken over by the emergency diesel generator upon mains failure.

Strategic lighting circuits shall encompass as a minimum the OCR, MV Switchroom, electrical annex, main turbine /generator area, general lighting to enable safe exit of personnel from the site, and any plant which requires manual operation or monitoring.

The strategic lighting system shall be supplemented with mains-charged battery lighting in the OCR to provide a minimum lighting level of 100 lux upon simultaneous mains and diesel generator failure.

All emergency lights supported by a battery shall be controlled by a specialist timed testing facility for emergency lighting discharge testing. An emergency lighting test facility shall be fitted to each switchboard that supplies an emergency lighting circuit.

#### 8.7.8 Luminaire Numbering and Labelling

Luminaires shall be allocated a unique light number shown on a luminaire list and location diagram. The list shall identify the type of fitting and location details.

Each luminaire shall be provided with a label with the light number and the circuit breaker feeding that light. The label is to be affixed to the bracket used to mount the plug base or on the steel near the base. Labelling shall be in accordance with the labelling specification.

## 8.8 CCTV and Access Control

#### 8.8.1 General

The Contractor shall be responsible for the design, supply, testing, installation, and commissioning of a Closed Circuit Television (CCTV) Surveillance System. This shall consist of a number of CCTV Field Installations. Each Camera Field Installation (CFI) shall consist of:

- Camera and zoom lens with accessories
- Fixed cameras – adequate number / position to get full coverage
- Housing
- Support pole or other structure as appropriate
- Communication links.

In addition, control and monitoring equipment shall be provided at the OCR and the remote operator room to control and monitor all the CFIs.

#### 8.8.2 Functional Requirements

##### 8.8.2.1 CCTV Locations and Coverage

CFIs shall be provided to ensure complete (100%) coverage of the following:

- MV Switchroom
- Entrance point / gates to Power Plant and Wellpad and SGS
- Operator Control Room
- Turbine/generator plinth and operating platform
- Electrical annex
- The entire gas extraction plant (technology applicable)
- The entire cooling tower / air cooled condenser including the plume
- The entire turbine oil system

- Production / injection equipment within the SGS, including vent station and plume

#### 8.8.2.2 Image Quality

Each CFI shall provide the following image quality:

- At the furthest required viewing distance (to provide the required coverage) or at the maximum optical zoom setting, a person in height of 1.6 m shall fill the vertical axis of the image
- At the furthest required viewing distance and at the maximum optical zoom setting, the image stability of a stationary object in the field of view, shall be such that it's apparent movement or shake does not exceed 3per cent of the monitor's diagonal viewing area measurement in any direction.
- At the maximum zoom the image quality shall permit the facial recognition by the authorities of potential intruders.

These requirements shall be met during the day or night time and for average wind conditions as defined.

#### 8.8.2.3 Camera Specification

Each CCTV camera shall comply with the following:

- Highlight compression shall be utilised to minimise the effect of bright spot light sources "washing out" the picture
- Facility to automatically increase sensitivity under night lighting conditions to effect the required image quality performance.

#### 8.8.2.4 Lens Specification

Each CCTV lens shall comply with the following:

- The lens shall have automatic iris control. Preference is given to be able to switch remotely to manual iris control in addition to the automatic iris control, but this is not essential
- Digital zoom may not be used. Use of tele-converters or optical extenders is prohibited
- All the optical elements of lens shall be glass or similar approved
- The iris shall automatically close in the event of a power failure to the CCTV system
- The lens shall be designed to prevent flare from indirect sunlight outside the field of view at all zoom settings.

#### 8.8.2.5 CCTV Housing

Each CCTV housing shall comply with the following:

- Provide a minimum IP66 ingress protection to IEC 60529
- A sunshield shall be provided over the housing containing the CCTV equipment, designed to minimise the amount of heat build up in the enclosure due to solar radiation, and to shade the lens. The sunshield shall not impinge on the field of view of the CCTV when it is at minimum zoom setting. Each housing and sunshield shall be designed to ensure that the internal temperature of the housing does not exceed the manufacturers recommended maximum continuous operating temperature of any hardware components contained within it.
- Thermostatically controlled anti-condensation heaters shall be included in the enclosure to ensure that condensation shall not occur within the housing;

#### 8.8.2.6 Power Supply

All CCTV systems shall be powered from UPS sourced supplies for a minimum of two hours hold up time.

#### 8.8.2.7 Mounting Requirements

Where standalone poles are required for a CFI, these poles shall be the swing-down type, allowing the CCTV unit to be lowered to ground level without use of additional tools or equipment. Otherwise the maintenance access requirements stated elsewhere shall apply.

#### 8.8.2.8 Control/Data Interface Requirements

The Contractor shall provide a means for video and control signal transmission between the OCR and each CFI. Fibre optic cabling shall be used for the physical layer and an IP network shall be used for the network layer.

All video and control signals shall be bought back to the OCR. The Contractor shall provide an IP video switching matrix to interface the CFI video signals to monitors. This matrix shall be sized to allow for a 100% increase in video signal connection both in bandwidth and simultaneous IP connections. This matrix shall be sized to allow for a 100 % increase in video outputs to monitors. This spare capacity is to cater for the connection of further CFIs provided by others.

The video matrix shall be controlled through unified operator interfaces. One operator interface shall be provided at the OCR and one accessed remotely.

Via the operator interface, the operator shall be able to select video sources, route them to a video sink (monitor) and control each CFI. The operators shall be able to configure up to ten sequences; each sequence shall allow various video sources, to be sequentially scrolled on any particular monitor in a repeating loop.

The video matrix shall be able to simultaneously display from one to at least four video sources on each monitor.

Two monitors shall be provided. Each monitor shall be a wall mounted minimum 40” LED unit. Note that these units shall be monitors only and shall not be able to receive broadcast television.

#### 8.8.2.9 Recording

A hard disc based recorder shall be provided to record all video inputs (included spare as identified) simultaneously. Images shall be captured from each input at a rate of 1 frame per second. The recorder shall store up to 2 week’s worth of images.

Operators shall, via the operator interfaces, be able to playback the recorded images to the monitors.

The recorder shall also be able to save the recording to a recordable DVD or flashdrive as MPEG-2 files. This recording process shall be controlled via the operator interface.

#### 8.8.2.10 Maintenance Requirements

CCTV equipment shall be designed to facilitate planned and breakdown maintenance with the minimum of equipment and in the shortest time. CCTV equipment shall not require more than two field visits annually for routine maintenance.

### 8.8.3 Site Access Control

#### 8.8.3.1 General

The Contractor shall be responsible for the design and supply of a secure, tamper proof manual locking main access gates to the Facilities.

Separate gates shall be supplied for vehicle and pedestrian access.

The main gate shall be the same general design and height as the surrounding fence and shall be a slide type action rather than a swing action. The gate shall be for vehicle access only.

Weather protection shall be provided over the pedestrian access gates to shelter personnel as they pass through the access way.

Adequate lighting complying with the requirements of this specification shall be provided by the Contractor that automatically activates at the site entrance. Lighting should provide adequate lux levels for the CCTV covering the gate area.

## 8.9 Communications System to Site

### 8.9.1 Fibre Connection General Description

The Contractor shall provide an IP based telephone system. This shall include, IP handsets, IP switches and cabling infrastructure.

#### 8.9.1.1 IP Telephone System Facilities

Telephones shall be provided as follows;

- OCR, one per Unit station, one per Common station
- one per switchgear room,
- one per meeting room
- one per office
- one per workshop
- one per laboratory
- one per Visitor and Education Centre

The telephone central IP control and communication system shall be provided from a UPS sourced power supply.

Telephone cabling from the handsets to the telephone central IP control and communication system shall be shielded CAT 6 cable.

### 8.9.2 Employers LAN

To facilitate the addition of a business system network by the Employer, the following infrastructure shall be provided by the Contractor.

Ethernet outlets, connected by fibre cables and fibre/copper converters, and connectivity to a central point in the Plant, nominally in the OCR, but to be confirmed by the Employer, shall be provided as follows;

- OCR, three per Unit station, three per Common station, but no less than six in total
- one per switchgear room,
- two per meeting room
- two per office, unless overriding requirements are stated in section 8.1
- one each per lunchroom / kitchen / two per workshop
- two per laboratory

- one per reception

At the central point where the Cat 6 cables terminate, the Contractor shall provide;

- A 4U 19” rack suitable for mounting Ethernet switches (switch to be provided by Employer)
- Power rail with at least four outlets of single phase power supplied from UPS system

Location of Ethernet outlets to be agreed with the Employer.

# 9. Site Inspection, Testing and Commissioning

## 9.1 General

The Contractor shall develop an inspection, testing and commissioning plan to cover all activities undertaken by the Contractor and its subcontractors on the Site. The plan shall include comprehensive inspection, test, check-out, start-up, Precommissioning and Commissioning procedures with reference to the applicable item of equipment being tested, equipment used, the standards and method of testing, and shall include a proposed test schedule with dates consistent with the detailed critical path schedule required by paragraph 1.2.1 of the Specification.

The details of the Guarantee Tests are given in Appendix 8 –Guarantee Tests.

A detailed procedure document shall be developed, issued and approved for all testing and inspection activities at site. The testing and inspection procedure document may be created to cover the entire Facilities or individual procedure documents may be provided for the various different sub systems and individual tests.

Before any testing is undertaken the procedure covering that part of the testing shall have been approved.

The procedure document shall, as a minimum, include:

1. Adequate information to the Employer with regard to the requirement of the Employer’s operation and maintenance personnel as well as with regard to communication with the DOMLEC dispatch centre for the agreed electrical load profile required during Pre-commissioning and Commissioning.
2. Information to the Employer of the use of components which are to be introduced into the Facilities on a temporary basis for commissioning, testing or operating purposes.
3. Indicate the anticipated programme for the tests, the arrangement and form of the tests, requirements regarding import of power and related calculations, log sheets, duration, control periods, readings to be taken and number of observers required, calibration data, instrumentation data, records, frequency of measurement.
4. Explicitly state the industry codes and standards that will be used, the instrumentation required, the form of the expected results, the anticipated time duration of the Test, and the anticipated number of Employer's operating personnel required to assist the Contractor in the conduct of the test.
5. With respect to the Precommissioning Tests and the Commissioning Tests (including Guarantee Tests), the procedure and test plan shall also include the list of pre-operational and operational test items and their schedules.

The Plant will be divided into systems, and checkout, start-up and testing is to be done on a system by system basis. Individual test procedures for each system shall be developed and issued to the Project Manager for review. These procedures shall include a detailed CPM chart and associated Gantt chart showing the sequence in which checkout, start-up and testing activities will occur. The procedures shall include shutdown sequences for normal and emergency situations. A simplified flow chart shall also be provided in sufficient detail to allow training and planning of start-up procedures. Key roles and responsibilities shall be identified.

The Contractor shall maintain a written record that logs the execution of the checkout, start-up and testing activities. This log shall be continuously available to the Project Manager on Site and shall be delivered to the Project Manager on completion of testing. The Contractor shall also develop, during the course of the checkout, start-up and testing activities, full base line performance and maintenance data (including clearances, machine vibration characteristics, control setting etc).

The Contractor shall not close up any plant prior to Precommissioning without the approval of the Project Manager. Where piping is broken down as part of the testing and inspection procedures, the Contractor shall confirm the integrity and leak tightness of the system after reinstatement.

As part of start-up, the Contractor shall develop a concise defects administration system, to be agreed upon by the Project Manager, to streamline any defects liability claims that may arise.

The Employer's operations staff shall be included in the Contractor's commissioning and start-up team to enable on the job training and familiarisation of the operational requirements of the Plant. The Contractor shall be responsible for the overall commissioning of the Plant and shall instruct the Employer's operational staff accordingly. The Contractor shall have completed the training schedule for the Employer's operations and maintenance staff in sufficient time to ensure that they are fully conversant with the requirements of the Plant before the beginning of commissioning and start-up activities.

The Employer's operational personnel will be provided to the Contractor without charge. The use by the Contractor of these personnel shall not constitute Completion as set out in the General Conditions.

The following describes the minimum Precommissioning, start-up and other tests required to confirm compliance with the requirements of this Contract. Additional inspections and tests may be required by the Project Manager as necessary to confirm that the performance of any system meets the requirements of this Contract.

## 9.2 General Inspections

The following lists typical inspections and tests that, amongst others, are to be undertaken:

1. Inspection of buildings and plant set out coordinates
2. Inspection and testing of virgin, disturbed and engineered soils
3. Inspection and testing of finished road works
4. Inspection of prepared ground and /or reinforcing steels for structural and civil works
5. Inspection and testing of prepared concrete mixes
6. Inspection and testing of finished concrete work and grouting
7. Inspection and testing of driven piles
8. Inspection of fabricated structural steel work
9. Testing of painting on all steel works
10. Electrical and instrument loop testing
11. Electrical system functional testing
12. Tests recommended by manufacturers to check for damage in transit (e.g. transformer impact recorders, electrical insulation tests, etc) and correct assembly
13. Verification of bolt torque settings on structural, mechanical, and electrical equipment
14. Contact resistance of bolted and crimped joints (ductor) tests
15. Inspection and testing of building, construction and plant materials for compliance with specifications, code and data sheets
16. Inspection of pipes, pipe alignment, levels and pin angle settings of angular compensators on pipe lines.
17. Inspection and testing of pipe and fittings joints
18. Inspection of pipe support type, size, gap settings, offsets and inclination
19. Inspection of valve and other in-line equipment type, size and tag numbers
20. Inspection of thermal insulation type and thickness and cladding seals
21. Inspection of pumps, turbines, compressors, generators, air conditioning equipment and other machinery delivered to site

22. Inspection of vessels and other fabricated items.
23. Inspection of machinery alignment
24. Inspection, radiography and other non-destructive testing of welds
25. Inspection, pressure test and leakage test for vessels and piping systems
26. Inspection and testing of equipment rotation, balance and vibration.
27. Inspection and torque testing of bolted connection
28. Welder qualification tests

## 9.3 Walk-downs

### 9.3.1 Preparation

Before initial system operation, the Contractor shall guide the Project Manager on a walk down of the system to verify that the system is completely installed in accordance with the “Issued for Construction” (IFC) design, this walk down shall show that all gauges, thermometers, instruments, valves, orifices, drains, vents, etc. are installed and all blinds removed in accordance with the P&IDs. Pipe supports and hangers shall be checked against the piping drawings. Hand operated valves shall be fully stroked and checked for clean stem threads. Motor operated valves shall be stroked, and torque and limit switches set. Air and hydraulic operated valves shall be stroked, positioners set and limit switches adjusted. All equipment shall be tagged in accordance with the design documentation.

Valve, piping, and mechanical equipment line-ups shall be demonstrated to the Project Manager as being in accordance with the agreed start-up procedures and manufacturer's requirements.

Electrical cables shall be neatly installed and clipped to cable ladder or tray as appropriate. Ground connections shall be complete. Motor control centres, control panels, instrument cubicles, etc shall be clean and secure.

A punch list shall be generated for the system as part of the walk down process. This punch list will record items still to be completed or corrected from the construction phase of the work.

### 9.3.2 Safety

During the commissioning and start-up period, the Contractor shall ensure that procedures are implemented for the safe execution of the testing, commissioning and start-up procedures, with particular attention to any ongoing construction activities on the Site.

The Contractor shall prepare a plan that covers at least the following and shall submit the plan for the approval of the Project Manager:

1. Lock out and tag out procedures for electrical, instrumentation, control and mechanical devices
2. Vessel entry, access and close up
3. Installation and removal of pipeline blinds
4. Access control to hazardous areas

Where plant and equipment needs to be maintained in a live condition in order to facilitate testing of commissioning, access by all personnel to that plant and equipment shall be limited to only those people required for the testing and commissioning and this access shall be controlled; personnel shall be required to sign into a controlled area around the plant and equipment and this sign-in process shall inform the personnel of all hazards and provide clear indication of all precautions required to be followed. Personnel shall be required to sign out when leaving the controlled area.

## 9.4 Precommissioning

### 9.4.1 Site Testing

#### 9.4.1.1 Hydrostatic Testing

The Contractor shall notify the Project Manager at least 28 working days before hydrostatic testing and shall arrange for government agency and insurance inspectors and other representatives to witness the test as required, and shall confirm to the Project Manager the intention to conduct testing by further notice 7 days prior to testing.

The Contractor shall submit the test procedure to the Project Manager for review. The test procedure is required to be in English to comply with local standard for hydro testing. The procedure shall include all safety actions and planning. This test procedure shall include any need for testing of pressure vessels required to meet governmental certification requirements.

For two-phase piping (except wellpad branch lines) and steam piping, 100% RT and in-service test will be accepted instead of hydrostatic testing.

Safety valves shall be blanked off prior to testing. Pressure gauges, transmitters and other items that could be damaged shall be removed or isolated prior to test. Valves may be left in place only in the fully open position; they may not be used in closed position to serve as hydrostatic test boundaries. Blanking plates (spectacle blinds) are required at test boundaries. The test procedure shall include marked up schematic and, as appropriate arrangement drawings to describe the above provisions.

Test pressure shall be as recommended by the manufacturer. A calibrated test gauge shall be used. The test shall consist of a pressure decay test (no less than one hour at nominal test pressure) and a visual leak inspection to the satisfaction of the Project Manager and insurance representative.

#### 9.4.1.2 Steam Blowing

Prior to steam blow, any steam line safety valves shall be tested for proper lifting and reclosing pressure. Test certificates by a reputable testing agency shall be submitted to the Project Manager.

When steam blowing is conducted, the Contractor shall ensure the affected area is kept clear of no essential personnel and routinely measure and record the noise level.

Before flowing steam to any process equipment for commissioning, the piping shall be cleaned as a minimum in a 2-step process. Step 1 shall be a physical removal of construction debris from accessible areas. Step 2 shall be a high-velocity, thermally cyclic steam blow using target plates as the means of determining final acceptance. The Contractor shall furnish all target plates, temporary piping jumpers, spool pieces, blinds and temporary supports and strainers. Control valves, orifices, check valve flappers, venturi flow meters and other items that may impede high velocity flow or trap debris or be damaged shall be removed prior to initial steam blow.

As a minimum, steam blows shall be performed on all steam pipelines to the steam turbine, gland steam system, lines to the steam jet ejectors and on any other steam distribution lines and shall be completed before steam is admitted to equipment. Each line shall undergo at least three blows of at least one hour duration each with several hours cool down between blows to ensure temperature cycling and maximum cleaning. The final blow shall be at system conditions which result in a disturbance factor of at least 1.5 times the disturbance factor at maximum continuous rating, where the disturbance factor is given by:

Disturbance Factor = $(W^2 \times V)$ [blowing]/$(W^2 \times V)$ [design]

Where:

W = Mass flow rate V = Specific volume

For the sections of main steam supply piping between the scrubber and the turbine, or separator and heat exchanger, to confirm adequate cleanliness at the end of the final cleaning blow, target plates shall be exposed to the steam flow for consecutive individual periods of 5 minutes. The target plates shall be of polished brass, 20 mm wide by 6 mm thick and with a length of greater than 85 per cent of the pipe diameter and shall be exposed normal to the flow of the steam. The criteria for acceptance shall be that on three consecutive exposures, the targets, examined over their full length, shall have no pit marks greater than 0.5 mm in diameter and no more than 6 pit marks between 0.1 mm and 0.5 mm in diameter.

The detailed procedures for steam blowing and for manufacturing, using and inspecting target plates shall be a matter for agreement between the Project Manager and the Contractor.

Should it be impractical for a particular section of steam pipework to be cleaned by steam blowing then the Contractor shall submit to the Project Manager a proposed system of cleaning and inspection that ensures the entire system cleanliness is not compromised in any way.

Boroscope inspection of first stage steam turbine fixed and moving blades shall be conducted by the Contractor prior to final acceptance.

The Contractor shall notify the Project Manager of the time, duration and expected noise levels at least one week in advance of steam blows and shall ensure the safety of all personnel and property during the steam blows. Hearing protection shall be provided as necessary.

#### 9.4.1.3 Working Fluid system

All equipment that will contain the working fluid for shall undergo a leak test in accordance with the relevant accepted code. The Contractor shall submit details of the code the leak test shall be undertaken to within the ITP plan for approval by the Project Manager.

#### 9.4.1.4 Lubricating and Control Oil Systems

All systems and components of the lubricating and control oil systems must be thoroughly cleaned and flushed in accordance with the manufacturer's requirements and the requirements set out below. The lubricating oil system and all associated piping, miscellaneous valves and equipment and the entire system which supplies and returns oil from the bearings, controls, and associated equipment shall be cleaned using a high velocity flushing procedure.

Prior to the oil flushing operation, the oil reservoir tank must be thoroughly cleaned and any contamination that may have accumulated during shipping and installation must be removed.

By-passes shall be installed around all bearings, control system components and other parts requiring lubrication/ control oil to prevent any foreign particles from being deposited in the bearings or any sensitive areas during the flushing operation.

The Contractor shall supply all temporary flushing equipment, temporary piping and flexible hoses between the temporary piping and the piping and equipment to be flushed, temporary lubricating oil reservoir of adequate run back capacity, oil heaters and external oil circulating pumps if required and the labour required to install and operate all the equipment.

The Contractor shall provide a full flow duplex flushing filter capable of filtration to 5 micron particle size. An adequate number of replacement filter elements for the oil flush shall be supplied. The Contractor shall supply a heater capable of raising the temperature of the flushing oil to approximately 50ºC to be sustained for the duration of the oil flushing.

Each line and item of equipment of the lubricating and control oil systems shall be flushed for a continuous period of at least 48 hours or the minimum required in accordance with manufacturer's requirements (whichever is the greater) with flushing oil having a viscosity of approximately 100 SSU at 50ºC.

Oil flushing must be continued until no visible contamination remains in the lubricating and control oil systems using the patch test method. The Contractor shall obtain approval from the Project Manager before removing bearing oil piping bypasses, reinstating the permanent connections, and flushing oil through plant bearings.

After completion of the oil flushing operation, the system shall be completely emptied of the flushing oil. The oil reservoir tank interior shall be thoroughly cleaned before refilling with oil.

#### 9.4.1.5 Instrument and Utility Air Systems

Compressors and driers shall be commissioned as required by the manufacturer. The setpoint and flow capacity of each pressure relief device shall be checked.

Before pressurising the compressed air distribution system, all piping and tubing shall be blown clear. Main headers shall be blown to atmosphere individually with the installed air receiver at an initial pressure of at least 7 bar. Pipe and tubing to individual instruments, actuators and controllers shall be blown clear by disconnecting air lines at each device.

#### 9.4.1.6 Ventilation and Air Conditioning Systems

The testing & commissioning procedures for the ventilation and air conditioning systems shall be to CIBSE and or ASHRAE guides.

#### 9.4.1.7 Main Cooling Water System

If a wet evaporative style cooling tower is used this section shall apply. Where accessible, the main cooling water system shall be cleaned manually prior to first fill with clean water. Particular attention shall be paid to removing debris from the cooling tower ponds and wind-blown and similar debris from inside buried piping. The system, including the condenser, shall be thoroughly inspected in the presence of the Project Manager prior to final closure. The system shall then be filled via the cooling tower pond, with the cooling tower pond outlet screens in place prior to commencing filling.

The Contractor shall demonstrate to the satisfaction of the Project Manager that the main cooling water circuit is clean and condenser nozzles and distribution trays are clear prior to start up.

After a period of operation of the cooling water system for not less than one week, the condenser shall be opened in the presence of the Project Manager and checked for and cleared of, construction debris

#### 9.4.1.8 Auxiliary Cooling Water

Prior to flushing, all heat exchangers are to be by-passed. All piping, including dead legs, shall then be washed through with clean water. Heat exchangers shall be visually inspected internally in the presence of the Project Manager and cleaned on the tube side by jetting with clean water.

#### 9.4.1.9 Fire Protection System

All fire protection system shall be tested in accordance with applicable NFPA, local, and other requirements identified by project specifications.

Testing shall be conducted by experienced personnel, and witnessed by the Project Manager, local authority (Fire Department), insurer as appropriate.

All piping shall be flushed and hydrostatically tested in accordance NFPA 14 chapter 11. Prior to formal testing, all operating parts shall be functionally tested to verify proper operation, both individually and as a system.

Testing of water flow alarm devices, supervisory switches, fire detectors, etc. shall be included in the circuit test, between the devices and Fire Alarm control panel terminal. Devices shall be actuated and resistance checks made at the junction box to verify the integrity of end of-line devices and wiring.

The Contractor shall provide a test report as follows:

1. Suitable for issue to the Employer, Local Authority, Insurance Company.
2. A “Certificate of Completion” after formal testing and acceptance of system by the Employer which identifies the building area, system type and function, project number, date etc.

#### 9.4.1.10 **Pumps**

Pumps shall be thoroughly checked and the written results submitted to the Project Manager prior to putting into service. Piping shall be thoroughly flushed to remove welding slag and debris. Temporary suction screens shall be installed as required. Bumping motors to check rotation shall be done with the coupling disconnected. Coupling alignment shall be checked against manufacturer's recommendations and submitted in written form to the Project Manager. Mechanical seal lines shall be thoroughly cleaned and flushed. Bearing lubrication shall be checked and filled to the manufacturer's instructions. If possible, pumps shall be rotated at least one revolution by hand to check for mechanical interference.

Alignment shall be checked with pumps unbolted from piping and also bolted to piping, with the Project Manager present. After a few brief running periods, pump and motor bearing vibration shall be checked in the vertical, horizontal and axial directions and the results submitted to the Project Manager.

#### 9.4.1.11 **Instrumentation & Control**

The instrumentation and all control systems shall be fully tested as a prerequisite to main plant commissioning. The Power Plant DCS shall be used as an essential tool in the main plant commissioning activities. During this phase all the input, output and control functions of the DCS shall be comprehensively tested from the operator interface through to primary elements. The requirements of WIB report M 2784-X-10 to the bronze level for testing and commissioning shall be complied with / incorporated into the DCS testing and commissioning.

It is however recognised that the SGS, which is reliant on the Power Plant DCS for control, is likely to be completed and ready for testing prior to the central DCS system in the Power Plant being ready. If this is the case, the Contractor shall provide temporary operator workstation(s) as hardened laptop(s) loaded with the final HMI software for the SGS in order to be able to fully control and monitor the SGS.

Before a system is put into service, instrumentation calibration and loop checks shall be completed and written results given to the Project Manager. The Contractor shall use trained personnel to perform all instrumentation calibration to include but not be limited to: field transmitters, valves, local controllers and control units, electrical relay testing and calibration and all electrical interlock checks to include but not be limited to motor permissive circuits. Test equipment shall be supplied by the Contractor.

Instruments of accountability used to measure steam, emissions etc., shall be calibrated and checked at no less than 5 points (e.g. 0,10,40,80,100 percent of full scale). Other control, transmitting and recording instruments shall be calibrated and checked at no less than 3 points.

Self-actuated pressure and temperature regulators shall be checked and set in the field after they have been permanently installed. Thermowells shall be checked for conformance to specifications with regards to materials of construction, length and proper installation location. Float-type devices shall be checked in place. Conductivity, pH and other analysers shall be calibrated according to the manufacturer's recommendations.

The Contractor shall perform loop checks to verify that the loop functions as designed. A loop is defined as two or more devices acting in unison for a single control function, such as the DCS and a pressure transmitter.

### 9.4.1.12 Lifting Plant Load Tests

All Lifting Plant shall be tested in accordance with the requirements of the specific standard to which they have been designed and manufactured. As a minimum these tests shall include minimum part load, full load and overload testing using certified test weights. The overload test shall be at least 125% of the safe working load of the Lifting Plant. The Contractor shall also demonstrate that inching, traversing and other operational requirements of the Lifting Plant meet the performance requirements of the duty.

### 9.4.1.13 Circuit Breakers

Circuit breakers shall be given a visual inspection.

Tests (according to breaker type) shall include, but not be limited to, megger, DC over potential (vacuum integrity, dielectric level etc), time travel analysis, minimum trip voltage, mechanism check, contact wipe, circuit integrity, cell to breaker alignment, mechanical operation, lug tightness, contact resistance, insulation resistance and other tests appropriate to the type of breaker.

### 9.4.1.14 Isolators and Earth Switches

Manual operation of isolators and earth switches shall be subject to operational tests to confirm contact pressures, contact resistances, simultaneous operation of all phases and the ease of operation.

Checks shall be made on interlocks, local and remote indications and operation of auxiliary contacts.

Earth switches shall be tested to confirm the opening and closing sequences and checks shall be made on interlocks, indications and manual locking devices.

### 9.4.1.15 Current and Voltage Transformers

The magnetisation characteristic of all current transformers shall be checked as necessary to identify the current transformers with reference to the manufacturer’s design curve and to determine the suitability for its intended duty.

All current and voltage transformers shall be checked for polarity, phasing and ratio.

### 9.4.1.16 Surge Arresters

General inspection shall be carried out to verify the condition and satisfactory mounting of the arrester, earth connections and electrodes.

### 9.4.1.17 Earthing System

Tests shall be made on the effectiveness of the bonding and earthing which will include conductivity tests on selected joints, on the main earthing system, and at the connections to equipment and structures. Checks shall also be made on precautions taken to avoid corrosion attack on the earthing system.

Test probes at approximately 300 and 600 metres separation will normally be required to effectively test the earthing system. The use of transmission line conductors may be used to simplify these testing procedures.

The earth resistance shall be measured during the installation and on completion as follows:-

Of each earth rod after driving

Of the earth grid after completion and backfilling of the trenches

Of each group of earth rods or earth point after completion of the connection from the test link terminal

The completed switchrooms / power stations according to IEEE 81.2. The test method is suitable for testing extended earthing systems and is via off-frequency current injection test into the earth grid from a remote location and measurement of EPR and touch/step voltages. It is usual to make use of a de-energised transmission line to undertake this test. In the absence of an available transmission line for remote current injection the Contractor shall run an insulated cable to a remote location to facilitate the injection of current.

The tests shall be carried out by a method and with equipment agreed by the Project Manager. All tests are to be witnessed and the equipment and method used, recorded with the test results.

#### 9.4.1.18 **AC Switchboards**

General inspection shall include checks on interlocking, changeover arrangements and the interchangeability of components.

Point to point wiring continuity checks on all control circuits to confirm agreement with design drawings. Operational check of all meters, relays, instruments, alarms and trips.

Insulation tests shall be carried out with a 1kV test set.

#### 9.4.1.19 **DC Supply Equipment**

Tests shall be carried out on the batteries and chargers to confirm the charger ratings and adjustment, the battery and charger alarm systems and battery capacity.

The open-circuit cell voltages of the batteries when fully charged shall be recorded.

The insulation to earth of the complete DC installations shall be tested.

#### 9.4.1.20 **Protective Relaying and Control Equipment**

1. Mechanical Inspection

All panel equipment is to be examined to ensure that it is in proper working condition and correctly adjusted, correctly labelled and that cases, covers, glass and gaskets are in good order and properly fitting.

2. Schemes

Sufficient tests shall be performed on the relays and protection schemes to:

a. Establish that the equipment has not suffered damage during transit
b. Establish that the correct equipment has been supplied and installed
c. Confirm that the various items of equipment have been correctly interconnected
d. Confirm performance of schemes designed on the bases of calculation, e.g. differential protection
e. To provide a set of figures for comparison with future maintenance values allowing the condition of the equipment to be determined

3. Secondary Injection

Secondary injection shall be carried out on all AC relays, using voltage and current of sinusoidal wave form and rated power frequency to confirm satisfactory operation and range adjustment.

The polar characteristics of all distance protections shall be recorded at a minimum of 30 degree intervals.

For circulating current protection employing high impedance voltage operated relays, the points of injection for relay voltage setting tests shall be across the relay and stabilizing resistance.

The fault setting for the type of protection is to be established by secondary injection, where it is impracticable to ascertain this value by primary injection. Injection is to be made across the appropriate relay bus wires with all associated relays, setting resistors, and CT's connected.

4. Primary Injection

Primary current injection tests are to be carried out by the Contractor and the methods employed for a particular installation are to be agreed with the Project Manager.

Tests are to be carried out as follows:-

a. Local primary injection to establish the ratio and polarity of current transformers as a group, care being taken to prove the identity of current transformers of similar ratio.
b. Overall primary injection to prove correct interconnection between current transformer groups and associated relays.
c. Fault setting tests, where possible, to establish the value of current necessary to produce operation of the relays.

5. DC Operations

Tests are to be carried out to prove the correctness of all DC polarities, the operating levels of DC relays and the correct functioning of DC relay schemes, selection and control switching, indications and alarms. The correct functioning of all isolation links and fuses shall also be checked.

6. On Load Tests

In view of the hazards inherent in these tests, they shall be carried out under the direct supervision of the Project Manager.

An operation and stability test shall be carried out for on load commissioning.

Tests for restraint shall be carried out to prove the characteristics of protective systems with directional characteristics.

On load checks shall be made after the protective gear has been placed in service to ensure that all connections and test links have been replaced and test leads removed, as well as to confirm the integrity of the current transformer circuits. Where necessary voltage readings shall be taken at the terminals on each relay to ensure that loop connections between the relays are complete. Special attention shall be paid to broken delta voltages and residual current circuits where zero voltage or current respectively may not be proof of the completeness of the circuit.

#### 9.4.1.21 **Transformers**

Site installation and final assembly of generator and auxiliary/ SGS supply transformers shall follow manufacturers' specified procedures and be witnessed by the Project Manager.

All test results shall be jointly reviewed by the third party, Contractor, the Project Manager and manufacturer's representative.

#### 9.4.1.22 **Generator**

After generator dry out, the following tests shall be carried out;

1. High voltage tests on the stator and rotor at 80 per cent of Plant MV test levels.

2. Open and short circuit characteristics.
3. Phase and balance of terminal voltage.
4. Shaft voltage measurement.
5. Temperature rises on load.
6. Rotor earth fault detection.
7. Winding resistance
8. MV test
9. PD test
10. Excitation system dynamic performance including manual follow control, response to step changes, under and over excitation limiters, power system stabiliser response, parameters at operating limits and rectifier diode failure detection.
11. Test all protection functions with temporary settings (if required)

#### 9.4.1.23 Motors and Motor Starters

Motors shall be subject to an insulation resistance measurement. Phase rotation checks shall be carried out. Temperature and vibration transducer operation shall be verified (if fitted).

For each motors starter, verify proper contactor operation, contact alignment and lug tightness. Install and record ampere rating of all thermal overload relays. Functional tests before operation on load.

#### 9.4.1.24 VTs and CTs:

For all CTs, ratio, polarity, burden, saturation, ratio, phase angle error, magnetisation, knee point voltage and megger tests shall be conducted.

For all VTs, ratio, polarity, ratio, phase angle error, magnetisation, knee point voltage and megger tests shall be conducted.

#### 9.4.1.25 Power and Control Cables

Insulation resistance tests shall be carried out with a duration of one minute and at a voltage not less than 1000V. Glands and terminations shall be checked for conformity with the Specification.

In addition, the following tests shall be carried out on the Generator XLPE cables:

1. High voltage test generally as per Clause 6.1 IEC 60840.
2. Voltage (dc) test of 10 kV maximum for one minute on anticorrosion covering in accordance with Clause 5 IEC 60229. This test shall be carried out after the cable laying but before jointing and back filling above concrete slabs.
3. After completion of the installation, all sheath insulation shall be tested in accordance with Clause 5 IEC 60229.
4. The insulation resistance of the cable shall be checked before and after the high voltage test on the cable.

5. The core resistance shall be measured and the value corrected to 20°C in accordance with Clause 5 of IEC 60228.

#### 9.4.1.26 **Panel Wiring**

Insulation resistance tests at 1000V AC for one minute are to be carried out on all protection, control, alarm and indication circuits to ensure that wiring is in satisfactory condition.

Visual inspection shall be made on cable glands, cable jointing, fuse or circuit-breaker ratings and small panel items, such as indicating lamps. Static equipment which may be damaged by the application of test voltages shall have the appropriate terminals short-circuited.

Inter-relay, inter-unit and cubicle wiring carried out at site is to be checked to the appropriate circuit and/or wiring diagram. This may be done by using bells or buzzers or DC voltage supplied from the station battery may also be used. Where it is found necessary to effect site modifications to the secondary wiring, copies of the appropriate schematic and wiring diagrams shall be suitably marked as agreed with the Project Manager before the circuit is commissioned.

Loop resistance measurements shall be made on all current transformer circuits. Separate values are required for current transformer and lead resistances and all measurements are to be recorded on lead resistance diagrams.

#### 9.4.1.27 **Communications Equipment**

Tests shall be comprehensive and shall demonstrate that the overall performance satisfies every requirement specified.

The tests to be carried out shall be: -

1. Physical inspection unit testing and demonstration of diagnostic aids as appropriate of all equipment in standalone mode.

2. System testing of supply equipment.

3. System testing of OPGW equipment for teleprotection, speech, SCADA, and data channels.

4. System testing of telephone equipment.

5. System testing of teleprotection equipment to plant.

#### 9.4.1.28 **Miscellaneous Plant and Systems**

Any other system not specifically mentioned within this section shall be thoroughly cleaned and flushed before being put into service. Similarly, any other plant not specifically covered within this section shall be tested and commissioned in accordance with manufacturer's recommendations and the requirements of Commonwealth of Dominica and Standards.

#### 9.4.1.29 **SGS Additional Requirements**

During the operation of any item of the SGS, whether on-line or otherwise, at any time when under the supervision of the Contractor, the Contractor shall ensure that all plant is regularly checked for overheating, noise, vibration and any other checks or tests specified or required or which could have been reasonably required by the manufacturer of specific items of the SGS.

All piping systems shall be visually checked for leaks, clogged pressure gauges, interferences, excessive vibration and other abnormal conditions.

Pipping support systems shall be checked over the range of operating conditions (thermal growth) to ensure that the supports perform as required and that pipes are supported correctly at all times.

Temporary cone-type pump suction strainers shall be checked periodically for clogging. These strainers shall be kept in service during initial operation and shall be cleaned as required to minimise pressure drop due to clogging. Whenever plant is shut down due to strainer clogging, the strainer shall be cleaned immediately to ensure availability of the plant. New gaskets shall be installed after each cleaning operation should the design so require. After initial operation, when strainer fouling no longer occurs, and the Project Manager's approval has been obtained, the temporary strainers shall be removed from the piping permanently. Spacers shall be furnished and installed where these strainers are removed.

After a period of operation of the SGS system for not less than one week after completion of steam blows, the SGS vessels, condensate drain pots, dirt traps or any other low point where materials could accumulate, shall be opened up, inspected and cleaned out.

## 9.4.2 Functional Testing

### 9.4.2.1 General

The Contractor shall develop and submit for the Project Manager's approval, a detailed procedure for functional testing of the SGS as a sub-set, and for the Plant as a whole. Such procedures shall include but not be limited to the following plant items and systems. In carrying out these functional tests, all interlocks and safety mechanisms shall be completely tested and verified as operating correctly. All redundant functionality shall be tested through deliberate removal of the duty systems from operation to ensure standby/backup systems automatically take over the function.

### 9.4.2.2 SGS

1. Compressed air system
2. LV switchgear
3. Transformers
4. Separator level control including emergency dumping
5. Pressure control & venting system
6. Wellhead flow control valve trimming
7. Operation up to full (MCR) flow

### 9.4.2.3 Plant

1. Station battery systems (load test required)
2. Uninterruptible power supplies (including demonstration of bump-less transfer via the static switch)
3. Emergency diesel generator (factory load test may be acceptable, subject to the Project Manager's approval)
4. LV switchgear
5. MV switchgear
6. Transformers
7. Main generator
8. Auxiliary cooling water systems
9. Compressed air system

10. Main cooling water system, including cooling tower (if applicable)
11. Condenser and NCG extraction system
12. Chemical dosing systems
13. Steam turbine / Binary Turbine
14. Protection relays and associated circuit breakers
15. Motive fluid system including air cooled condenser (if applicable)
16. SCADA remote monitoring and control (as applicable) by DOMLEC

Successful completion of all functional tests including witnessing by the Project Manager is a prerequisite for synchronising the generator.

### 9.4.3 Pre-Synchronisation Tests and Inspections

Following successful completion of the Functional Testing, and prior to the first synchronisation of each turbine generator, the Contractor shall carry out the following Pre-Synchronization Tests and Inspections:

1. Automatic voltage regulator setting and adjusting in stand-still condition, and with the generator running at full speed and no load;

2. Demonstrate stable operation of the turbine over a range of 95% to 105% of rated speed in an open circuit mode followed by an overspeed trip test.

3. Open circuit tests on the generator.

4. The Contractor, the Project Manager and DOMLEC shall verify that all protection level settings for all the schemes are as mutually agreed.

5. The Contractor, the Project Manager and DOMLEC shall verify that all communication interfaces meet Dominican Generation Code requirements.

Once the above tests have been completed and after the Project Manager has issued a Pre-Synchronisation Test Completion Certificate, the turbine generator shall be synchronized to the grid system.

### 9.4.4 Post-synchronisation Tests

#### 9.4.4.1 Turbine Trip Test

Each unit of the Plant shall be required to demonstrate its ability to withstand a turbine trip from 25%, 50%, 75%, NCR and MCR. The unit shall be loaded to and stabilised at the requisite load and the turbine then manually tripped. The unit shall be required to shut down safely to a standby condition following such trip.

#### 9.4.4.2 Load Rejection Tests

Each unit shall be load rejection tested by opening the generator circuit breaker at loads of 25%, 50%, 75%, NCR and at MCR. The full load rejection test shall be conducted at power factor of 0.80 lagging at MP2. Each unit shall demonstrate that it can remain operational at house load following such a load rejection, supplying station loads only.

Loss of the grid connection shall result in the Plant continuing to generate to match “islanded” or “house” load, maintaining all necessary systems such that it may be resynchronised to the external grid without the need to stop generating. Electrical protection systems shall be designed and co-ordinated with the grid protection such that the Plant systems are as stable as possible for grid events while adequately protecting the plant, enabling the Plant to either “ride through” or trip to house load for low level grid events.

Following a trip to house load the operator will have the choice of initiating a safe and orderly shutdown of the plant, or "Hold at House Load" for up to 2 hours until grid power is re-established and then re-synchronising.

#### 9.4.4.3 **Reactive Capacity**

The operator shall have the choice of operating in power factor control mode, reactive power control mode or voltage control mode. In power factor control mode, the power factor shall be maintained by the continuous automatic control of the generator excitation and shall be demonstrated at 0.80 lagging and 0.95 leading at full load. In reactive power control mode, the reactive power shall be maintained by the continuous automatic control of the generator excitation and shall be demonstrated at a lagging VAr level of 60 percent of MW rating and a leading VAr level of 31 percent of MW rating subject to any limitations imposed by DOMLEC. Voltage limits shall be tested between +10% and -5% of generator nominal voltage subject to any limitation imposed by DOMLEC.

The Contractor shall demonstrate the capability of each Unit to operate stably for a minimum of one hour at rated voltage and frequency as follows:

| | |
|---|---|
| NCR | 0.95 leading power factor |
| NCR | 0.80 lagging power factor |
| MCR | 1.00 power factor |
| | |
| NCR | Export 60% of MW rating |
| NCR | Import 30% of MW rating |
| | |
| NCR | +10% of nominal generator terminal voltage |
| NCR | -5% of nominal generator terminal voltage |

## 9.5 Commissioning

### 9.5.1 Guarantee Tests

Following successful completion of the tests in Section 9.4.4, tests to measure the Guaranteed Net Delivered Capacity will be carried out to the requirements set out in Appendix 8 of the Contract Agreement.

### 9.5.2 Reliability Test

After the Guarantee Tests for performance are completed and accepted, reference Section 9.5, there shall be a Reliability Test of 30 days. Successful completion of this test is a prerequisite to Operational Acceptance.

Each Portion of the Facilities shall be operated in accordance with the dispatch requirements of the Employer for a continuous period of thirty (30) days without the need for maintenance intervention. The Reliability Test will include a period of seventy-two (72) hours continuous operation at not less than 95 per cent of the NCR capacity of the unit. During this test, the Employer will make best endeavours to dispatch the Plant at NCR, but grid limitations may in fact limit the ability to

dispatch at NCR for the full 72-hour period. Therefore, all time periods of reductions in the dispatch level below NCR due to restrictions imposed by the Employer or others, will be considered as if the Plant was instead operating at NCR for the affected periods.

The acceptance criteria for the Reliability Test are as follows:

Day 1 to 10

Not more than two (2) availability failures which cause a reduction in available capacity of greater than 0.3 MW and have a duration of greater than three (3) hours and 30 minutes. Total Availability Failures shall not exceed five percent (5 per cent).

Failure of the test during this period requires the test to start again as at day one (1).

Day 11 to 20

Not more than two (2) availability failures which cause a reduction in available capacity of greater than 0.15 MW and have a duration of greater than three (3) hours and thirty (30) minutes. Total Availability Failures shall not exceed five percent (5 per cent).

Failure of the test during this period requires the test to start again as at day eleven (11).

Day 21 to 30

Not more than two (2) availability failures which cause a reduction in available capacity of greater than 0.15 MW and have a duration of greater than two hours. Total Availability Failures shall not exceed five percent (5 per cent).

Failure of the test during this period requires the test to start again as at day twenty one (21).

### 9.5.3 Demonstration Tests

During the Commissioning of Portion B and prior to Operational Acceptance, the following tests shall be carried out.

#### 9.5.3.1 Reliable Operation of Both Units Simultaneously

The Contractor shall demonstrate that the Plant (comprising, but not limited to, all the equipment between the production wellhead, the reinjection wellpads and the grid connection point, and encompassing the two electrical generating Units) shall operate safely and reliably.

In case there is not sufficient steam available from WW-P1 to achieve GNDC for both Units simultaneously, a demonstration test shall be undertaken at the highest net deliverable capacity possible from both Units simultaneously with the steam available, provided that there is no venting of steam from the steam vent system in this case.

In case there is sufficient steam available from WW-P1 to achieve GNDC for both Units simultaneously, this demonstration test shall be undertaken while GNDC are achieved for both Units simultaneously, and venting of excess steam is permitted in this case.

This test to demonstrate that the Plant can operate safely and reliably shall be carried out over a 6-hour consecutive time period, the timing of which shall be agreed with the power purchaser (DOMLEC) but it shall occur during a time period when demand on the grid is expected to be at the commonly occurring mid-week maximum. In the event it is not possible to operate both Units simultaneously at GNDC during this test, firstly one unit and then the other shall be operated at its guaranteed net deliverable capacity during this test, while the other Unit shall operate at whatever highest generation value is possible as constrained by the steam available from WW-P1 or by the maximum demand on the grid.

#### 9.5.3.2 Noise Levels

The noise tests testing to confirm that the Facilities meets the Contract and Environmental Permit requirements shall be carried out by a noise specialist employed by the Contractor and approved by the Project Manager. This shall take the form of a noise survey conducted at a representative number of locations around noise-producing items and at the boundaries defined in the Interface Schedule.

Measurement shall be in accordance with ISO 1996 Acoustics-Description and Measurements of Environmental Noise, Parts 1, 2 and 3. The total and impulsive adjustments described in Part 2 shall apply to the measured level. The sound level meters shall comply with the requirements of IEC Publication 651:1979 Sound Level Meters, for type 1 instruments, using the time weighing “F”.

#### 9.5.3.3 Hydrogen Sulphide $H_2S$ Concentration

Ambient air H2S concentration levels both inside and outside the Site at ground level, and emission concentration of H2S from the cooling tower stacks shall be measured to confirm that the Plant meets the Contract and Environmental Permit requirements.

The H2S tests shall be carried out at locations and times as agreed between the Contractor and Employer.

#### 9.5.3.4 Demonstration of MCR operation

Demonstration tests to measure MCR output for each Unit shall be carried out over a 6 hour consecutive time period. This test shall be carried out for each Unit with the Plant operating at MCR conditions as indicated by the Contractor.

The purpose of the test shall be to establish the MCR output of the plant. There shall be no liquidated damages applied for this demonstration test.

## 9.6 Tests at the end of the Defects Liability Period

Commencing not earlier than three weeks prior to the expected completion of the respective Defects Liability Period, each Portion shall be thoroughly inspected by the Project Manager in the presence of the Contractor to determine that no untoward degradation or deterioration has occurred. This inspection shall include internal inspection of the turbine and of any other machinery or plant that the Project Manager may require. Should the Contractor fail to attend this Test, any results shall be accepted by the Contractor as correct.

# 10. Steam Gathering System Specific Requirements

## 10.1 Introduction

This section details the specific requirements for the Steam Gathering System (SGS), for both the overall SGS concept design and the specific design features of individual items of plant.

## 10.2 Concept Design

A preliminary conceptual layout has been prepared for the SGS. This is intended to illustrate to the Contractor the Employer's expectations for the SGS design.

The Contractor shall develop and have complete responsibility for its own design for all elements of the SGS. The Contractor's design may vary from the concept design provided that it shall remain consistent with the Contract and Employers' Requirements.

In general, the level of automation, control and monitoring equipment shall correspond to the needs of unmanned operation where the SGS will be normally operated under both normal and emergency operation. However, operation personnel will always be on site during SGS start-up.

To confirm that the Employer's intent for the SGS is implemented correctly, the Contactor shall submit a SGS Design Intent Report (DIR).

## 10.3 Employer's Provision of Wells

The production well and condensate injection wells have been drilled previously and are available to the Contractor from the Commencement Date.

All permanent production and injection piping on the wellpads shall be laid out to allow vehicle access, isolation, testing and drilling rig work-over of any well. Where future wells are identified, the piping shall be laid out to permit drilling of new wells without disrupting production of the existing wells. The Contractor shall provide a section of piping of at least 15 m length immediately downstream of the wellhead to be flanged to allow removal for drilling rig access to carry out well workovers, etc. without the requirement to cut the pipe.

## 10.4 Modifications to Employer's Wells

### 10.4.1 Safety Grating

The Contractor shall install fibre reinforced plastic grating around the wells within the well cellars. The grating shall be flush to the ground level and shall not present a tripping hazard. Grating shall be in two pieces per well so that each piece can be lifted out of place and put to one side using mobile lifting equipment provided under the Contract to allow access to the well cellar. The grating shall extend to within 150mm of the well piping. Grating shall be suitable for normal personnel loading only (i.e. not trafficable) as per standards for stairways or walkways. A permanent sign shall be affixed flush to each grate with the maximum allowable loading.

### 10.4.2 Braces

The Employer's wellheads are presently unbraced. Braces shall be fitted to all wellheads as to restrain the lateral movement of the wells from seismic, thermal, or hydraulic (hammer) induced loads. These braces shall extend over the grating and shall be easily removable to allow for the grating to be removed. Braces shall be designed to restrict movement of the upmost part of the master wellhead valve or upper wellhead piping to no more than 10mm in any direction when the wellhead is operating at normal temperature.

## 10.5 Design Criteria

The Contractor is required to prepare their own piping specifications in accordance with this Specification.

### 10.5.1 Scale Allowances

Allowances shall be made for pipeline diameter reduction and increased roughness due to silica scale deposition where appropriate. Minimum allowances shall be:

1. Two-phase production fluid pipelines — 3 mm scale thickness of 3 mm roughness
2. Steam pipelines — no scale thickness, 0.1 mm roughness
3. Brine pipelines — 5 mm scale thickness of 5 mm roughness

Two-phase pipeline sizing and layout shall consider the avoidance of slug flow conditions over the required operating range. The Contractor shall advise any operating conditions which may be expected to result in slug flow occurring.

### 10.5.2 Corrosion Allowances

Contractors shall provide a minimum of 3mm allowance for corrosion on all carbon steel two phase, brine and steam lines. Stainless condensate lines shall have a minimum of 0.5mm corrosion allowance.

### 10.5.3 Pipeline Sizing and Pressure Drop Criteria

Piping pressure drop calculations shall be based on industry-recognised methods.

The preferred method for two-phase steam/water flow is that of Harrison (Harrison R. F., ”Geothermal Two-Phase Pipe Flow“, DSIR Chemistry Division Wairakei Geothermal Circular, September 1977. Also, Freeston D. H. et al, ”Utilisation of Geothermal Energy: Two-Phase Flow Studies“, New Zealand Energy Research and Development Committee, Report No. 95, September 1983.).

Two phase pipelines shall be designed, wherever practicable, to operate in annular flow regime (refer to Freeston et al, NZERDC report #95)

Piping and equipment shall be sized for the maximum transient flow rates that can occur in the pipeline.

Adiabatic flow should be assumed in the calculation of two phase pressure drop, unless specific calculation requirements dictate otherwise.

### 10.5.4 Thermal Expansion

Piping shall be designed so as to maximise the use of natural flexibility to absorb thermal expansion. Horizontal expansion loops are preferred for accommodating expansion.

### 10.5.5 Pipeline Rating

Two phase pipelines shall be designed to withstand impulse loads associated with unsteady (slugging) two phase flow.

### 10.5.6 Separator Design

Refer to Lazalde-Crabtree, “Design Approach of Steam-Water Separators and Steam Dryers for Geothermal Applications” (1984) for an acceptable design approach for the steam separators.

Inlet piping shall be arranged to provide a smooth and continuous flow path and achieve fully annular or dispersed two phase flow at the separator inlet.

Where two phase flow enters a pipeline the entering flow shall be arranged to sustain its momentum and minimise disruption to the flow already in the pipeline.

## 10.6 Production Wellpad

### 10.6.1 General

Flanged wellhead master and side valves will be part of the finished wellhead constructed by the Employer. The interface to the Employer's wellheads is defined in the Interface Schedule.

The Contractor shall be responsible for the design, supply and proper installation of the SGS pipework, flanges, gaskets, bolts and nuts to the master and side valves of each well designated for connection. The Contractor shall also be responsible for operating the well once it is handed over by the Employer. The Contractor shall provide a person experienced in the operation of master and side valves of geothermal wells / geothermal facilities and the Contractor must submit details of this experienced person to the Employer together with detailed wellhead operating procedures before they operate any well. The Contractor shall not use the master or side valves to control or vary the flow of fluids from or into the well.

A bleed line facility shall be provided at the wellhead by the Contractor, running to an atmospheric flash vessel, to be used for safe bleed-off of gas and/or production fluid. The atmospheric flash tank shall drain to the sump. The tank shall be sized to allow sufficient warm-up from a well(s) on the pad.

A valved bypass line around the wellhead master valve shall be provided by the Contractor. This shall be used to balance the pressure on both sides of the wellhead master valve before it is opened.

All side valves shall also have a second valve installed on a master/martyr basis, such that the outer valve is the one normally used to control any flow, with the inner valve only being operated under a no-flow condition.

### 10.6.2 Wellhead Support and Thermal Growth

Wellheads shall be adequately laterally restrained by a support extending over and above the well cellar. Design and construction of these supports, including foundations, shall be the responsibility of the Contractor. The support shall be of bolted construction to allow for its complete removal to pad level during a well work-over. This support is required to take the thrust load of discharging fluid as well as thermal, seismic and wind loads imparted onto the wellhead via the pipe work. This support shall accommodate the wellhead thermal growth as provided in the Interface Schedule.

All pipelines connected to a wellhead shall be designed and supported with due allowance for vertical thermal growth of the wellhead.

The SGS piping shall be designed for wellhead thermal growth as provided in the Interface Schedule.

### 10.6.3 Atmospheric Flash Tanks (AFT)

A "full-flow" atmospheric flash tank shall be included as part of the SGS. It shall be vertical cylindrical steel construction with a tangential two-phase inlet and a brine outlet via a weir box.

The "full-flow" AFT shall be sized based on no less than the maximum connected capacity of the Emergency Dump Valves, rupture discs or wells.

### 10.6.4 Wellpad Sump

The Employer's existing sump at WW-P1 shall be used to serve as a holding pond for brine emergency retention; a reservoir of fluid for use in field operations; and a collection point for other drain fluids. The Contractor shall line the existing sump. The contractor shall confirm the amount of operation time allowed in the existing sump if the brine injection system is not in service. The Contractor shall increase the size of the sump to provide the required fluid storage holdup time.

The wellpad sump shall be equipped with a permanent pump facility to allow the cold sump contents to be pumped into the condensate reinjection line to the WW-03 injection well.

## 10.7 Two phase Pipelines

Production pipelines refer to all pipework used from the wellhead to transfer two phase fluid to the Separator.

### 10.7.1 General Layout and Routing

Routing of production pipelines shall be such that they are free-draining, either to the separator or back to the wellhead. There shall be no low points in the lines. Any drain valves shall be located and arranged to permit access for operation and unblocking.

### 10.7.2 Pressure Rating

The pipelines and fittings from the wellheads to any isolation valves which can be isolated from the centralised pressure relief devices located on the steam system shall be rated for maximum wellhead shut in pressure taken from the well connected to that isolatable system.

### 10.7.3 Line Sizing

The Contractor shall undertake sizing of the production pipelines using the data provided in this Specification and Interface Schedule. Two phase piping shall be sized at 100% of the flows from the connected wells, and to avoid the slug flow regime at the indicated flow rates.

### 10.7.4 Pipe Supports

Adequate support shall be provided to sustain thrust loads from two-phase slug flow. Supports shall also be provided to account for water filled pipelines during hydrotesting or similar integrity tests.

### 10.7.5 Isolation and Flow Control Valves

The wellhead branch pipeline shall be fitted with a flow control valve. The flow control valve shall be used for throttling of the well output from 0 to 100% on a continuous operating basis. The flow control valve shall be motorised (MCV).

The flow control valve shall be sized at no more than 70% of full capacity at normal flow, or 80% of full capacity at maximum flow, whichever is greater. The.

The flow control valve shall not be located in the flanged section of wellpad piping which is removed for well work-over, but shall be as close as possible downstream.

The flow control valve design shall have the following characteristics:

1. It shall be resistant to deposition, scaling and erosion damage.
2. It shall have a flow characteristic suitable to provide good control of well output.

3. It shall have low pressure drop in the fully-open position.
4. It shall be a vee-notch type valve

Control valves used for primary steam system pressure control (steam vent valves) are considered to be special-service valves and shall be sized based on the specific system requirements.

Various valve styles can be used, depending on the fluid service and the control service (modulating vs. on-off control). Acceptable styles are butterfly, high performance butterfly, segmental rotary ball/plug and globe. Any proposed control valve style must be confirmed by the equipment vendor as being suitable for the intended purpose.

Special proprietary valve designs may be used for specific applications, such as low noise valves or steam venting. Such valves must have a proven track record in geothermal service, or must be verified as having suitable design details for such service.

#### 10.7.6 Instrumentation and Other Connections

Refer to the Employers' concept design P&IDs for the minimum instrumentation required. All electronic instruments shall remote indicate on the Power Plant DCS. The full status of all actuated valves shall remote indicate on the Power Plant DCS and full remote control of such actuated valves from the Power Plant DCS is required. Motorised valves shall include integral local controls to open and close the valves and select local or remote (DCS) operation.

A chemical tracer injection and sampling system shall be provided to allow the two-phase flow of the production well two-phase line to be measured; the Employer will provide an outline of the technique to be employed on request. Suitable connections shall be provided to allow chemical tracer injection and downstream sampling for well mass flow and enthalpy determination.

Suitable connections shall be provided by the Contractor on the production lines to allow liquid and vapour samples to be taken.

Pressure tappings shall be installed at the wellhead and upstream of the production isolation valve.

## 10.8 Steam Separator

#### 10.8.1 General

The production fluid shall be fed from the production well to the steam separator.

#### 10.8.2 Separator Inlet Piping

If the production fluid piping is required to rise up to the separator inlet then the final bend shall have a minimum radius of 3D, where D is the nominal inlet pipe diameter.

#### 10.8.3 Separator Vessel

##### 10.8.3.1 Design

The Contractor shall undertake full design of the separator vessel. The separator shall be of an existing, Employer approved design used in geothermal or relevant industrial or power generation service.

The preferable design shall be vertical, skirt-mounted, bottom steam outlet, cyclone Webre type with a scrolled/lemniscate two-phase inlet and a tangential brine outlet from the steam drum. A 3D bend shall be used for the final entry to separators. Brine flow from the steam drum to the injection system shall be through a loop seal.

The separator vessel shall be designed to ensure that the maximum allowable working pressure (MAWP) of the vessel is limited by the vessel shell and not by the vessel nozzles.

The separator design shall provide for:

1. High steam quality in broad range of steam loads, beginning from the zero flow rate
2. Convenient plant layout with minimised building height requirements.

The separator efficiency shall be greater than 99.97%, defined as follows:

a. Separator Efficiency = 100 x Separated Brine Flow / (Separated Brine Flow + Brine Carryover Flow),
b. where the Brine Carryover Flow is the flow of brine that passes through to the steam line. This may be estimated by measuring the Total Chloride Flow from the downstream scrubbing system (condensate drain pots and scrubber) and applying the following equation:

    i. Brine Carryover Flow (t/h) = Total Chloride Flow (g/hr) / Chloride in Separated brine (g/t),

Designs shall be resistant to the effects of scaling and other solid debris deposition which characterise geothermal applications, and shall facilitate periodic cleaning of such deposits as may occur.

The Contractor shall show that their design shall operate satisfactorily during steam system pressure variations during normal operation and, in particular, shall meet the steam quality limits during periods of declining steam system pressures.

Pressure relief for the separators shall be provided.

A chemical sampling point shall be located at the separator outlet.

#### 10.8.3.2 **Monitoring and Control**

Refer to the Employers' concept design P&IDs for the minimum instrumentation required. All electronic instruments shall remote indicate on the Power Plant DCS. The full status of all actuated valves shall remote indicate on the Power Plant DCS and full remote control of such actuated valves from the Power Plant DCS is required.

Level tappings on separators shall be designed to avoid false indications caused by brine vortices, etc.

Particular care shall be taken in the selection of level gauges, level switches and level transmitters, considering the potential for silica deposition which readily interferes with instrument operation. Preference shall be given to instruments which have proven track record in SGS separator service. Unproven instruments for this type of service shall not be used.

The separator shall be equipped with a brine dump system designed to provide emergency level control of a high-high separator water level. The dump system shall consist of a 2 x 100% emergency dump control valve (EDV), upstream isolation valve and discharge piping running to the separator atmospheric flash tank. The system shall be sized for the design separator brine flow. The EDV shall fully open in the event of the separator high-high level being activated. The EDV shall be actuated to permit a daily automatic valve stroking sequence to be carried out in order to confirm correct valve operation, any failure shall be alarmed. Valve actuators shall be pneumatic or electric.

The Contractor shall provide a bypass manual dump valve around the EDV complete with isolation and drain facilities to facilitate the maintenance and temporary removal of the EDV

### 10.8.4 Water Drums

#### 10.8.4.1 Design

The water drums, where required, may be integral or separate to the separator vessel.

The drum or inlet piping design shall make provision to collect any major debris which may be carried through from the production wells and piping.

A means of venting non-condensable gases to the steam system shall be provided, as small quantities of these will be carried into the drum with the incoming brine flow.

#### 10.8.4.2 Water Drum Inlet Piping

No isolation valve is required in the brine pipeline between the separator and water drum.

During transient steam system pressure declines (within the steam system pressure control band), the separator pressure can fall below the water drum pressure. The resulting brine flashing and back-flow into the separator can result in reduced outlet steam quality. If necessary to guarantee separator outlet steam quality, a suitable system shall be provided in the water drum inlet line to prevent this flashing and back-flow. A check valve is not an acceptable device due to risk of mal-operation due to fouling. An example of a suitable system is a piping loop seal sized so that:

- The height of the loop is greater than the expected pressure differential between the separator and water drum - i.e. the separator will not flood.
- The rate of head gain of an element of brine due to its vertical velocity down the loop is not less than the rate of head loss due to the separator pressure reduction - i.e. the brine in the down-flow section of the loop will not flash.

#### 10.8.4.3 Monitoring and Control

Refer to the Employers' concept design P&IDs for the minimum instrumentation required. All electronic instruments shall remote indicate on the Power Plant DCS. The full status of all actuated valves shall remote indicate on the Power Plant DCS and full remote control of such actuated valves from the Power Plant DCS is required.

Level tappings on vessels shall be designed to avoid false indications caused by brine vortices, etc.

Particular care shall be taken in the selection of level gauges, level switches and level transmitters, considering the potential for silica deposition which readily interferes with instrument operation. Preference shall be given to instruments which use indirect contact /measurement techniques and also have proven track record in SGS brine drum service. Unproven instruments for this type of service shall not be used.

During normal operation, a level is maintained in the water drum and is controlled by the variable speed drives at the pump station. In the event of an abnormal high level in the brine drum, the brine dump system shall provide emergency control. The EDV shall automatically close when the level has dropped to an acceptable level.

## 10.9 Steam System and Pipelines

### 10.9.1 Line Sizing

Steam piping shall be designed for a minimum of 110 % NCR design steam flowrate at normal operating pressure up to the steam vent system, and 110% NCR design steam flowrate to the Power Plant.

The lines shall be sized with due consideration of maximum pipeline steam velocity. The maximum pipeline steam velocity for general service shall be as specified elsewhere in this Specification. Main steam lines shall be sized to avoid superheating

the steam due to pressure drop (i.e. velocity should be limited). The absolute maximum steam velocity shall generally be limited to 0.3 Mach.

Common equipment shall be designed to meet the specification requirements and take into account that the Units shall be capable of operating simultaneously at NCR.

### 10.9.2 Steam System Design Pressure

The steam system shall be designed to withstand the pressures resulting from the range of normal and upset (trip of Power Plant from full load state to no load state) operating conditions without requiring operation of pressure relief devices.

### 10.9.3 Steam System Pressure Relief

Overpressure protection for the entire steam system between the separator production fluid inlet lines and the Power Plant steam turbines shall be provided by pressure relief devices located directly on the separator outlet steam lines upstream of any isolation valves. This shall be the centralised pressure relief. Sizing of these relief devices shall take into account any need for relief of the full two phase separator inlet flow at piping design pressure conditions. The total relief capacity provided shall not be less than 105% design steam flow plus associated brine flow.

Rupture discs shall be used. These shall be rated to provide sufficient busting pressure margin of at least 10% over the maximum operating pressure.

The rupture discs shall be the reverse buckling type with a scored surface. The rupture disc and disc holder shall be designed for assembly in the workshop and it shall have safety features to prevent incorrect mounting of the disc in the holder. A safety device shall also be provided to prevent incorrect installation of the assembly in the pipe.

Rupture disks shall be fitted with lockable isolation valves between the rupture disk and the process piping. This is to facilitate the on-line replacement of the rupture disk. The Contractor shall provide sufficient rupture disks to allow a single rupture disk to be replaced at any time. Isolation valves shall have chain and padlocking facilities. Typically the burst rupture disk shall be isolated until such time that the Plant can be shut down to allow the rupture disk to be replaced..

The relief device settings should be in accordance with the relevant system design pressure and piping/equipment design codes.

### 10.9.4 Steam Vent System

#### 10.9.4.1 General

As part of the steam pressure control a steam venting system is required to discharge excess steam to atmosphere in a controlled and environmentally-acceptable manner. The steam venting system shall consist of a number of vent control valves (pressure control valves) connected to the steam header which pass steam to steam silencers or rock mufflers.

#### 10.9.4.2 Vent Control Valves

Multiple pressure control valves (PCV) shall be provided to operate under split-ranged steam pressure control in order to give adequate performance over the full range of vent flows. The number and capacity of these PCVs, along with provision of isolation valves and pipe manifolding, shall permit any one valve to be taken out of service for maintenance while the remaining operative PCVs still provide a total vent capacity of at least 105% of design steam flow – allowing for two units operational at NCR conditions.

Design and selection of PCV types shall take into account vibration and noise resulting from operation over the range of vent flows, in addition to the required control performance characteristics. PCV valves shall be pneumatically or hydraulically actuated.

The PCVs shall be of a type in which the line pressure assists it to open.

#### 10.9.4.3 Steam Vent Piping

The vent piping from the steam header to the control valves, and from the control valves to the silencers shall be arranged to be free-draining to avoid risk of condensate slugs.

A continuous steam bleed flow is required to ensure the piping is maintained hot.

Acoustic insulation of the vent valves and vent piping shall be provided, if necessary, to meet the noise restrictions specified in this Specification.

#### 10.9.4.4 Steam Silencers

A minimum of two above-ground steam silencers or rock mufflers shall be provided, each sized for the full capacity of all its connected vent control valves.

Any silencer shall be able to be taken out of service while maintaining the rest of the SGS and Power Plant on line, though possibly at reduced load. The acoustic performance of the silencers shall be such that the noise restrictions specified in this Specification and permits relating to noise restrictions.

The Power Plant may be required to run for extended periods at 25% load. The steam vent system shall be deigned to vent the required volume of steam for extended periods of time to achieve a Power Plant output of 25%.

The location and design of the silencers shall take into account the potential for accumulation of non-condensable gases in the steam system, and the need to minimise the risk of steam clouds drifting over the Power Plant, transmission lines and access roads - i.e. they shall not be located up-wind of key facilities or operator areas.

The silencer design, materials and construction shall:

1. Minimise the risk of corrosion
2. Ensure condensate drainage
3. Provide for internal inspection and drain clearing
4. Provide low maintenance requirements
5. Facilitate any maintenance which may be required.
6. Minimise thermal stress damage

#### 10.9.4.5 NCG Emissions

The ground level concentrations of hydrogen sulphide ($H_2S$) dispersed from the steam silencers and other sources of NCG discharge (e.g cooling towers) shall meet the requirements of the Schedule of Environmental Compliance Norms and shall additionally not exceed 3 mg/m3, measured at a height of 1.5 m above ground level.

The Contractor shall calculate dispersion of $H_2S$ for the steam silencer plume using recognized methods. If required by environmental control authorities, the Contractor shall prepare a dispersion model for the steam silencers or rock mufflers, incorporating the non-condensable gas discharge, and provide a report to the Employer describing the anticipated ground level gas concentrations under all operating and atmospheric conditions. The Employer will provide topographical and meteorological data which it has available to assist the Contractor in the preparation of the model. Dispersion modelling shall be undertaken using screening data and the results shall be interpreted by a qualified dispersion modelling person through comparison of screening data results with Employer-provided meteorological information.

During performance testing of the SGS, the Contractor shall measure the ground level concentrations of NCG's and take appropriate action where concentrations are above agreed acceptable levels.

### 10.9.5 Steam Purity

In-service steam purity (composition) at the inlet to the turbine shall be measured as follows:

1. by sampling from ASME design isokinetic steam sample probes supplied by the Contractor and permanently installed in the steam line downstream of the scrubber and analysing for the impurities. For the purposes of SGS performance validation, the Contractor shall provide facilities to carry out isokinetic steam sampling at a suitable location upstream of the Power Plant at the steam scrubber

### 10.9.6 Steam Quality

For the measurement of steam quality (dryness) at the power plant inlet a throttling calorimeter shall be used.

### 10.9.7 Steam Quality and washing

A steam scrubber or demister is to be provided upstream of the steam flow measurement device and the turbine inlet.

Provision for potential future condensate washing of the steam shall be provided upstream of the scrubber. Space at the Power Plant shall be provided to retrofit wash water pumps and associated fittings and pipework.Steam washing system shall be a 2 * 100% with regards to any pumps required to provide the supply. The supply system may be a common system with the turbine blade washing system. The system shall be selectable as either fixed manual flow or automatically flow matched to the steam flow based on an adjustable % rate.

Adequate isokinetic (ASME style) sample points shall be provided to sample steam coming from the SGS and for monitoring the performance of the steam scrubber.

The amount of wash water allowable is limited to 2% of mass of steam volume to the scrubber.

### 10.9.8 Steam Scrubbing System

The steam scrubbing system will include at least 2 condensate drain pots followed by a steam scrubber/demister. Condensate drain pots shall be provided at least every 50m

Drain pots shall be designed using the criteria specified by Lee (Performance Tests of the Condensate Drain Pots at Wairakei, NZ Geothermal Workshop 1982)

The condensate drainpot(s) will provide first-stage removal of separator brine carryover and shall be located between the separator and the scrubber. The drainpots shall have steam traps suitably sized for maximum expected carryover flows and accessible for sampling and flowrate measurement, in order to measure separator performance.

The steam scrubber (steam-water separator/scrubber or demister vessel) shall produce an outlet steam dryness of 99.98 per cent during normal operation and, in conjunction with washing if required, shall deliver outlet steam impurities as required by Appendix 8 to the Contract Agreement. This performance shall be achieved over the full range of anticipated normal interface steam conditions defined in the Interface Schedule. Under upset conditions, including the stated SGS transients, the scrubber outlet steam impurities shall be no more than ten times the values listed above.

Connections shall be provided for measuring pressure and for sampling steam at the steam inlet and outlet.

The scrubber vessel shall be of a design that has proven performance in geothermal service. The vessel shall not employ vane or mesh type demisters, but shall instead rely on cyclonic action, impingement, gravity and/or other mechanisms. The vessel internals shall be robust and resistant to the effects of incoming slugs of water. The vessel shall be constructed to

avoid internal plugging due to scaling and to facilitate cleaning. Stainless steel internals for vane or mesh type demisters shall not be used.

Automatic level control and drainage shall be provided. Condensate discharged from the scrubber or demister shall be directed to the flash vessel, cooling tower basin or other suitable location depending on the power plant technology. The scrubber surge capacity and the condensate handling system shall be capable of handling the peak flows resulting from an incoming slug carryover.

Construction shall be from ASTM A516 Grade 70 steel or alternative approved by the Project Manager.

The scrubber underflow shall be readily accessible for sampling and flow measurement, in order to assess separator efficiency.

### 10.9.9 In-line Condensate Removal and Venting

The design of steam scrubbing pipeline sections will require lower steam velocity to allow entrained condensate droplets to settle on the pipe wall and drain to the bottom of the pipe for disposal via condensate drain pots.

The steam flow for this section of piping is as specified elsewhere in this Specification.

Piping drains and also drain pots equipped with drain valves and steam trap assemblies shall be provided as necessary to facilitate line drainage and to avoid risk of liquid slugs during start-up, normal operation and upset conditions. In particular, suitable drainage provisions shall be made to allow the SGS to be kept on hot stand-by with no steam flow to the Power Plant.

High point vents shall be provided as necessary to allow piping to be kept hot particularly for start-up and stand-by operation.

### 10.9.10 Monitoring and Control

Refer to the Employers' concept design P&IDs for the minimum instrumentation required. All electronic instruments shall remote indicate on the Power Plant DCS. The full status of all actuated valves shall remote indicate on the Power Plant DCS and full remote control of such actuated valves from the Power Plant DCS is required.

### 10.9.11 Steam Pressure Control

An automatic Steam Pressure Control System (SPCS) shall be provided to maintain the separator operating pressure characteristics, both the absolute pressure and the rate of pressure decline, within design limits. This is to minimise the risk of steam quality reduction, brine carry-over and separator flooding which can otherwise result from normal and upset operating conditions. Examples of such operating conditions include production increases and decrease from the production well and load pick-up and shedding by the Power Plant.

The SPCS shall be part of the Power Plant DCS.

The SPCS performance must therefore be matched to the steam system and separator design parameters. Additional required performance features of the SPCS are:

1. Storage volume of the steam and two-phase piping systems will be relatively small for this project. Hence, system pressure response to operating changes will be fast, and the SPCS shall be similarly fast acting to maintain stable control.
2. Venting of steam to atmosphere shall be minimised (minimised means no visible steam discharge), particularly under normal operation. This shall be achieved through automatic adjustment of the motorised wellhead flow control valves.
3. Steam pressure limits as required by the Performance Guarantee shall be maintained.

4. Increasing steam pressure shall be controlled by venting steam to atmosphere independently of load.
5. Declining steam pressure shall be controlled by first by reducing atmospheric venting and secondly by decreasing Power Plant load. The turbine governors shall be equipped with steam pressure control to prevent the turbine from decreasing the interface steam pressure below an acceptable and adjustable margin (initially 0.2 bar) below the steam pressure set point.
6. The SPCS shall achieve maximum use of available steam for generation, rather than it being vented.
7. The control shall remain stable under normal and upset operating situations.

Control valves used for primary steam system pressure control (steam vent valves) are considered to be special-service valves and shall be sized based on the specific system requirements.

## 10.10 Condensate Injection System and Pipelines

### 10.10.1 General

Condensate from the Power Plant and SGS shall discharge into common condensate systems.

The Employer has designated a specific well for condensate injection. Refer to the Interface Schedule and the concept design P&IDs.

To avoid corrosion of the carbon steel well casing, the condensate pH shall be maintained between 5 and 7.5.

If cooling tower blowdown is required then this shall be taken from the discharge of the hotwell pumps.

Vent valves are to be provided at high points to vent air at start-up. Drain valves shall be provided at low points to allow the piping to be drained.

Condensate pipelines are to be constructed from 316 stainless steel pipe to minimise corrosion.

### 10.10.2 Wellhead Support and Thermal Growth

Requirements are as per the Production Wellpad

### 10.10.3 Design Basis Flow and Line Sizing

The condensate injection line shall be sized for economic pressure drop at the normal full load injection flow from the Power Plant, taking account of the parasitic electrical cost of pumping. If possible the piping shall be sized for gravity injection.

### 10.10.4 Instrumentation and Monitoring

Refer to the Employers' concept design P&IDs for the minimum instrumentation required. All electronic instruments shall remote indicate on the Power Plant DCS.

## 10.11 Drains

All drains, with the exception of small bore (25mm diameter or less) start up drains, from all equipment, vessels, condensate drain pots etc. in the SGS shall be either routed to the local sump, where there is a system for the sumps to be drained / transferred to the condensate injection system,

The drainage point selected in each case shall depend on achieving the required flow under gravity to drainage point, and ensuring the destination is suitable for the liquid. Cold, oxygenated fluids shall only go to the condensate injection system, hot deoxygenated fluids shall only go to the brine injection system.

## 10.12 Brine Pipelines

Brine pipelines refer to all pipework used to transfer brine. The pipelines running from the separation plant / power plant to the reinjection wellpads is referred to as reinjection cross country line. The lines from the wellpad header to the wellhead are referred to as well branch lines.

### 10.12.1 General Layout and Routing

The brine line shall be free-draining to the injection wellheads where possible. Any drain valves shall be located and arranged to permit access for operation and unblocking.

The Employer has designated specific wells for brine injection. Refer to the Interface Schedule and the concept design P&ID drawings.

The brine injection system shall be designed to operate under all normal operating conditions with a process fluid temperature of no less than the temperature specified in Section X, Appendix 8 of the Contract anywhere in the system.

Pipeline corridor widths shall be restricted to the minimum necessary for the pipelines plus construction and maintenance. All construction activity is to be confined within these corridors in order to minimise disturbance to the surroundings.

Preferably locate the pipelines on the inner (uphill) side of a pipe bench cut into sloping ground to take advantage of generally better soil conditions. However, consider locating the pipeline on the outer edge in cuttings through unstable soils, where the risk of cut slopes slumping onto the line is high.

Where practicable, elevate the pipeline corridor approximately 1.5m above steamfield access and public road level to provide protection from vehicle impact. Where this is not possible, or where the pipeline corridor must rest at road level, provide guard-rail protection in vulnerable locations, such as on the outside of road bends or where width is restricted.

Where practicable, pipelines shall cross under, rather than over, access roads. Where the pipeline crosses under the road, the crossing needs to be rated for vehicle traffic. If the crossing passes under wellpad access roads then the crossing shall be rated for the weight of the drilling rig.

For pipe crossings over roads, a minimum vertical clearance of 8 m shall be provided on roads that require drilling rig access and 5m clearance on roads that do not require rig access, unless otherwise approved by the Project Manager. Where possible, no parts of the pipeline or support structures above the foundation are to be closer than 2m to the edge of the running surface of roads. Should this not be possible, a guardrail shall be installed to protect the pipeline or support structure.

Where practicable, pipe routing shall aim to minimise the number of expansion loops required by using natural changes in direction.

Where possible, pipe expansion loops shall be horizontal to minimise vulnerability to seismic action, liquid slug flow and low points.

Expansion loops shall be graded with the back leg in the same gradient as the pipeline, and the side legs horizontal.

### 10.12.2 Penstock location criteria

The section of the pipe route between the Power Plant and the river crossing/car park location contains an existing DOMLEC penstock. The brine pipeline including insulation and pipe supports shall include the following design and construction criteria:

1. It be constructed at least 1.2m from the existing penstock to provide penstock maintenance and inspection access.
2. The brine pipeline shall be constructed on the side of the penstock opposite the existing access road (i.e the non road access side). The Contractor shall construct any brine pipeline civil works, benches and access requirements to facilitate the pipeline installation.
3. It is imperative that the construction activities do not interfere with or damage the existing timber penstock. The Contractor shall conduct a construction methodology risk workshop with the Employer for this specific section of the pipe route which shall include a temporary penstock transportable steel shroud, scaffolding (or similar) to protect the penstock from inadvertent damage. This construction methodology shall be approved by the Employer prior to commencement of construction in this area.
4. The preferred above ground height of the reinjection piping assembly must be greater than or equal to 1.2m above grade measured to BOP.
5. Any expansion loops shall maintain the clearances described in items 1) and 4) above.
6. Where the brine pipeline crosses over the penstock this shall be achieved at right angles to the penstock in order to minimize the zone of vertical clearance constraints.

### 10.12.3 Pressure Rating

The brine pipelines and fittings shall be rated to withstand the static pressure of a full line should the Employer's master valve on any associated downstream injection well be closed, plus any operating pressure up to the maximum which could occur before any centralised pressure relief devices operate.

### 10.12.4 Line Sizing

The line shall be designed to run fully flooded so as to achieve the maximum pressure at the wellhead and therefore maximise the reinjection flow that the well can accept. Line size calculations shall take into account the fouling likely to occur in the lifetime of the plant and shall adopt suitable roughness and scaling factors to accommodate this.

The line shall be sized to accommodate the maximum expected brine volume being sent for injection.

The minimum brine pipeline sizes have been determined by the Employer as indicated below.

| IP Chainage | Line Size | Description |
|---|---|---|
| WW-P1 Separator to Upstream of Bridge | DN 300 | Cross-country reinjection line starting from WW-P1 Separator Pad to Bridge |
| Bridge | DN 250 | Pipe bridge (80m length) |
| Downstream of Bridge to IP/405 | DN 250 | Cross-country reinjection line to WW-01 Injection Pad |
| IP/405 to IP/580 | DN 250 | Cross-country reinjection line to WW-R1 Injection Pad |

The Contractor shall undertake a complete design using the current well output data provided by the Employer to determine if any line size needs to be increased above the minimum. The reinjection cross-country line shall be sized based on 100% of

the separated brine flow. The injection well branch lines shall be sized for the maximum injection well capacity. Refer to Employers Interface Schedule for the well capacities.

### 10.12.5 Injection Wellpad Isolation and Flow Control Valves

The injection branch line to each well shall be fitted with a hand operated isolation gate valve (“branch line isolation valve”) to permit local isolation of the well. The isolation valve shall be located as close as possible to the junction with the main injection line, to avoid leaving a dead-leg with potential for silica deposition. It shall not be located in the flanged section of the wellpad piping which is removed for well work-overs.

In addition to the isolation valve, each injection branch line shall also be fitted with a separate motor operated butterfly flow control valve (MCV), located on the wellpad. The MCV shall be used for throttling of the flow to each well from 0 to 100% on a continuous operating basis. The MCV shall also be used for reverse flow protection. Closure time shall take due consideration of potential for water hammer, and if necessary limit stroke times to minimise this.

### 10.12.6 Brine pipeline Instrumentation and Other Connections

The brine pipeline and reinjection wellpad instrumentation and control shall be as generally shown on the P&IDs.

The separator water drum shall have dual redundant stand pipes and associated dual level transmitters for the separator level control. A high level of brine in the separator water drum shall initiate a trip of the separator EDV to dump brine to the power plant AFT.

Suitable connections shall be provided to allow chemical tracer injection and downstream sampling for well mass flow determination, as well as injection chemistry monitoring.

### 10.12.7 Brine Pump Station

The brine pump system shall consist of a 2 x 100% brine pump arrangement and provide full pumping redundancy and shall be sized based for 120% of design separator brine flow. The brine pumps shall be operated by separate VSDs to control brine drum level while managing parasitic load at off design conditions. The pump station shall include full isolation of individual pumps for maintenance purposes as well as required check valves, pressure instrumentation and similar.

The pump shall be able to operate satisfactorily and safely over the range of flow conditions; avoiding risk of flashing and vapour column collapse, particularly during transient events.

### 10.12.8 Flashing, Transients and Water Hammer

Care shall be taken to minimise the risk of water hammer in the brine pipelines. Possible protection measures, if required, include:

- Limiting speed of operation of actuated isolation and throttling valves.
- Minimising the risk of creating two-phase conditions between single-phase legs which could subsequently be collapsed by changing system flows or pressures. Where necessary, backpressure control systems shall be installed to maintain system pressures above saturation.
- Avoiding injection of cooler single phase liquid into piping where two-phase conditions exist.

### 10.12.9 Draining and Dead Legs

Piping dead legs shall be avoided, or at least minimised, as these promote deposition of silica scale.

All piping shall be able to be fully drained, in order to protect against silica buildup of shut-in lines. Brine piping shall free drain to the Power Plant sump or to the reinjection wells.

### 10.12.10 Injection Wellpad Sumps

The WW-01 injectivity curve indicates that it will be able to accept brine at 0 barG pressure. All content of the cross-country reinjection line upstream of WW-01 pad shall be designed to free drain into the WW-01 Injection well. The Contractor shall confirm the sump volume requirement and provide the required sump capacity as required. The sump shall have an additional 20% freeboard allowance. The Contractor shall line the sump at the reinjection wellpad WW-01 location and provide a local AFT for the purposes of safely discharging brine from the wellpad rupture disks. The sump and wellpad piping at WW-01 shall be equipped with portable diesel sump pump facilities to enable the sump contents to be easily pumped into the local reinjection well. Contractor to provide the potable pump and all the required piping and isolation valves for this functionality.

At WW-R1 injection wellpad, the contractor shall provide a lined sump to drain the full content of the cross-country reinjection line downstream of the WW-01 injection pad branchline including the WW-R1 wellpad piping. The Employer's existing sump at WW-R1 shall be used for this purpose. The Contractor shall confirm the sump volume requirement and provide the required sump capacity as required. The sump shall have an additional 20% freeboard allowance. The sump and wellpad piping at WW-R1 shall be equipped with portable diesel sump pump facilities to enable the sump contents to be easily pumped into the local reinjection well. Contractor to provide all the required piping and isolation valves for this functionality. The same portable pump provided for WW-01 pumping shall be used at WW-R1.

### 10.12.11 Wellpad instrumentation, monitoring and control

Refer to the Employers' concept design P&IDs for the minimum instrumentation required. All electronic instruments shall remote indicate on the Power Plant DCS.

Brine and condensate reinjection wellpad instrumentation shall include the following:

1. flow measurement for each wellpad
2. Wellhead pressure.
3. Reinjection branch-line pressure

Instrument transmitters shall have local displays of the process variables. The transmitters shall be connected to the Power Plant DCS for operator monitoring via dedicated, armoured fibre optic communications with VHF radio backup communications facilities. The fibre optic cable may be clipped to the reinjection pipeline insulation between the reinjection pads and the Power Plant. Public, cellular communications shall not be used.

The wellpad branchline motorised control valves shall be provided to allow remote trimming of flow control to each reinjection well. At the WW-01 wellpad location the maximum allowable wellhead pressure is 20 Barg. Local pressure control of the wellhead pressure shall be provided by means of the wellhead pressure transmitter and the local motorised control valve.

Local transmitters shall be supplied via battery backed DC supplies in order to provide at least 24 hours of wellpad monitoring in the event of local wellpad mains power loss.

Tapping points for additional temporary instrumentation shall also be provided for the following:

a. Wellhead pressure gauge
b. Reinjection line temperature. This shall include the 316 SS thermowell.
c. Reinjection line pressure gauge

### 10.12.12 Wellpad power supplies

The local wellpad power supplies shall be derived by the Contractor off the local DOMLEC 415V networks including local tariff meters. The Contractor shall provide all the necessary electrical facilities including power supply surge arresters and protection and statutory permissions to provide the wellpad power supplies. A minimum 6 way, single phase distribution board shall be provided at each wellpad location within an IP65, 316SS enclosure.

Each wellpad distribution board shall provide a lighting supply for the wellpad. The lighting shall be manually operated. Contractor to provide sufficient lighting facilities to enable the safe operation of local valves and monitoring of wellpad instrumentation.

The Contractor shall make provision for a three phase socket to be provided at each wellpad location for the potential connection of a “plug-in” emergency diesel generator including mechanically interlocked change over switches. The generator will be provided by others.

The local wellpad motorised actuators shall be supplied from a battery backed DC voltage supply to ensure continuity of actuator service during periods when the DOMLEC 415V AC supply is not available. The holdup time for the actuator DC supply shall be at least 24 hours. The local battery charger and batteries shall be housed within a naturally ventilated reinforced concrete bunker type hut. The hut’s floor, walls and roof shall be constructed from concrete and it shall be fitted with a galvanised steel door with secure padlock locking facilities. The hut shall be located at least 300mm above any potential hurricane flood level. The DC battery bank shall be equipped with isolation and test facilities to enable six monthly battery discharge tests to be easily conducted.

## 10.13 Utilities

### 10.13.1 Compressed Air

Compressed instrument air for the SGS shall be derived from the Power Plant compressors.

In addition to the air receivers fitted with pressure relief facilities in the power plant, local air receiver(s) to serve SGS equipment shall be supplied. Air supply piping to the air receiver(s) shall be equipped with non-return valves to prevent the power plant air consumers drawing on the SGS air receiver in the event of failure of the air compressors and associated system. Receiver capacity shall be sufficient to permit continued operation of the SGS systems for a minimum of 15 minutes under upset conditions following loss of supply from the Power Plant.

In the case of loss of supply from the Power Plant, the air pressure measured at the end of the 15 minute period shall be not less than 4 barg, and not less than the pressure at which control valves trip to their loss of air failure mode.

# 11. Power Plant General Requirements

Irrespective of the Power Plant technology, the Contractor shall comply with these Power Plant general requirements.

The Units' component parts shall generally be interchangeable to facilitate site O&M and all spares provided shall be able to be used on any Unit.

The following Mechanical and Electrical requirements shall apply to each of the two Units.

## 11.1 Mechanical Requirements

### 11.1.1 Turbine Critical Speed

The critical speeds of the turbine and generator shall be sufficiently removed from the normal operating speed to avoid any adverse effect on the operation of the Unit over the range of 94% to 115% of rated speed. The Contractor shall provide calculations to demonstrate this range of speeds and the relationship to the critical speeds of the combined machine.

### 11.1.2 Turbine Vibration

Vibration shall be minimised by good design and by the adoption of high standards of balancing of both components and rotating assemblies during manufacture.

Except where otherwise detailed the vibration amplitude of rotating plant when measured on the bearing housings under steady state conditions shall not exceed the middle values of the bands designated "brauchbar" (satisfactory) in ISO 10816 for the class of machine concerned.

Turbines and generators shall be installed with velocity transducers or accelerometers on all bearing housings. The transducers or accelerometers shall measure x & z direction vibration on all housings and y direction (axial) vibration on thrust bearings. Vibration limits for turbines and generators shall comply with the relevant sections of API 612 and API 546 respectively. Design and installation of vibration monitoring equipment shall comply with the requirements of API 670.

The natural frequencies of the rotating blading shall be sufficiently removed from the operating frequency of the machine. Campbell diagram(s) shall be provided to demonstrate this requirement.

Continuous vibration monitoring equipment shall be provided for turbines, generators, gearboxes, hotwell pumps and motors, auxiliary cooling water pumps, cooling tower fans and liquid ring vacuum pumps and motors as a minimum. Equipment shall be Bentley-Nevada 3500 series or Project Manager approved equivalent. All vibration signals shall be brought to a monitoring panel located in the electrical annex and also showed in the HMI and SCADA in the Control Room to ease the visual display of the vibration data by the Plant Operators. The panel in the electrical annex shall provide relay access for hook up of spectrum analysing equipment. Summary indication and alarm signals shall be connected to the OCR.

The vibration of any such radiating surface shall not exceed the following:

| Frequency (Hz) | Amplitude Peak-to-Peak (µm) |
|---|---|
| 5 | 115 |
| 10 | 58 |
| 25 | 23 |

| | |
|---|---|
| 50 | 12 |
| 100 | 6 |

For intermediate values of frequency, the amplitude limit shall be obtained from the graph having both values plotted on logarithmic scales.

Should vibration levels exceed the above limits, or such other limits as may be designated elsewhere in this Specification Employer's Requirements, then the Contractor shall reduce the vibration to within the defined limited by methods acceptable to the Project Manager.

Provision shall be made for the reduction of vibration transmitted to covers, cladding, platforms and structures.

### 11.1.3 Bolt Tightening

All bolting 50 mm diameter and larger shall be arranged for hydraulic tightening or bolt stretching using heating elements. The required tightening equipment shall be provided by the Contractor as part of the special tools.

Bolting for diaphragm supports and similar that are within the working fluid path shall not be of hardened material.

### 11.1.4 Bearings (Turbine & Generator)

All main bearings shall be provided with sight flow indicators to allow a positive check to be made for oil flow through the bearings. Bearing metal temperature and indications and alarms shall be provided.

Gauges shall be supplied so that bearing wear can be readily ascertained.

Bearings shall be electrically insulated to prevent the flow of shaft eddy currents. Test blocks shall be provided for connection of meters or instruments to positively test insulation levels. Earthing brushes shall be provided on the shaft.

### 11.1.5 Turbine Rotor

Discs, if required, shall be integral with the rotor forging. The turbine rotors of each Unit shall be identical and interchangeable.

### 11.1.6 Gearbox

If the Contractor's design requires a gearbox it shall comply with the following requirements.

#### 11.1.6.1 Gearbox requirements

- Design, manufacture, shop inspection, and delivery to site of reduction gearboxes (if required) with associated sole-plates and anchor bolts, and all auxiliary items as required.
- Supply of shaft couplings, with guards, for both the turbine and generator, including co-ordination of detailed engineering.
- Supply of slow-speed barring gear and controls, including motor starter. Contractor may offer the barring gear and barring motor mounted directly off the turbine shaft depending on the manufacturer's design. The gearbox shall incorporate a barring gear capable of rotating the combined turbine, gearbox and generator shafts. Jacking oil shall be provided if required. The barring gear shall be automatically engaged when turbine zero speed is detected and

shall automatically disengage when the turbine accelerates above barring speed. A means to manually bar over, start and stop, engage and disengage the barring gear shall be provided.

- In addition to the barring gear, emergency hand barring, that is readily accessible and easily operated by one person shall be provided.
- Supply and mounting of external shaft-driven lubricating oil pump on the gearbox to meet the flow and pressure required. Contractor may instead provide redundant electrically driven pumps in addition to the emergency DC pump.
- Provision for mounting of vibration sensors .
- Provision of temperature sensors, and the supply of gearbox mounted local temperature gauges
- Provision of acoustic enclosure if required
- Provision and delivery of all spare parts required for commissioning and 2 years operation
- Provision of documentation as specified.

The gearbox shall be designed to ensure long life in continuous baseload operation to meet the duty requirements. The gearbox design and manufacture shall conform to ANSI/AGMA standard 6011-J14 . The gearbox shall be of proven design on previous projects of a similar power and speed range.

A shaft driven lubricating oil-pump is shall be incorporated into the gearbox, however other means of oil lubrication supply can be submitted to the Employer for approval.

The gearbox casing shall be horizontally split at the shaft centreline to facilitate maintenance. Parting screws and locating dowels shall be provided to simplify removal and reassembly of the top cover during maintenance. The complete gearbox and the removable top-section shall be provided with lifting lugs for handling during shipping, installation and maintenance. Fabricated gearbox casings shall be stress relieved before machining.

Means shall be provided to allow the complete drainage of oil from the casing for maintenance. Connection of any casing-mounted auxiliary equipment shall not entail drilling or bolting through the casing. Fully sealable hatch covers shall be provided to allow inspection of gear teeth and lubricant delivery without removal of the top cover.

The gear shafts shall include suitable seals to prevent escape of lubricant and ingress of contaminants.

The number of teeth of pinion and gear shall be selected to avoid a predominant wear pattern. The gear train and shafting shall be designed to avoid critical speeds or excitations at any harmonic of 50Hz when operating at normal speed. The pinion and gear teeth shall be ground to the quality level specified in the AGMA standard as a minimum requirement.

A suitable sole-plate complete with levelling screws shall be provided for grouting into the foundation. Anchor bolts, washers and nuts shall be provided for bolting to the foundation pad. Suitable dowels or positioning blocks shall be provided for installation after final alignment with both turbine and generator.

#### 11.1.6.2 **Shaft Couplings**

A suitable coupling shall be provided to connect the turbine to the gearbox high speed shaft. This coupling shall be capable of accommodating radial and axial displacement between the turbine and gearbox shafts between cold and normal operating temperature conditions.

Where the coupling requires pressurised oil lubrication this shall be combined with the gearbox lubrication system so that only one interface point is required in both oil supply and return piping. The coupling shall incorporate suitable seals to avoid leakage of the coupling oil. An oil drain sight glass shall be provided for the coupling drain.

A solid coupling shall be used to connect the gearbox to the generator. An integral flange shall be provided on the gearbox output shaft to mate with a similar flange on the generator Matching coupling bolts or pins shall be provided by the gearbox supplier. A template shall be provided to the generator supplier to ensure that the correct fit of generator shaft end to gearbox shaft end is achieved

The gearbox supplier shall co-ordinate detail engineering and dimensioning of the coupling connections with both the turbine and generator suppliers. If any parts of the couplings are required to be precision-fitted to the turbine and/or generator shafts those parts shall be delivered to the turbine and/or generator supplier for final machining and assembly before shipment.

### 11.1.6.3 **Gearbox Lubricating Oil System**

A common lubrication system will supply lubricant to the turbine, gearbox and generator bearings.

Oil will be supplied to defined terminal connections at the gearbox. Distribution of oil to bearing surfaces and the gear mesh shall be incorporated into the design of the gearbox. Internal oil piping shall be manufactured from 316L stainless steel tubing.

Drainage of oil from the gearbox will be by gravity. Sight glasses shall be provided in all oil drains for positive confirmation of oil flow. A suitable magnetic trap shall be provided by others, to remove metallic particles.

The main lubricating pump for the turbine-generator set shall be provided, attached to, and driven by, the gearbox.

### 11.1.6.4 **Gearbox Instrumentation**

A machinery protection system will be installed for the complete turbine-gearbox-generator set in accordance with the API 670 standard. Instrumentation as listed below for monitoring shaft/bearing vibration, gearbox casing vibration and bearing temperature monitoring shall be installed in accordance with API 670. The gearbox shall be provided with robust mounting attachments compatible with the probes types supplied.

Four wire RTD probes shall be provided with drilled passages to achieve satisfactory thermal indication of bearing temperatures.

Mounting brackets shall also be provided for separate instrument junction boxes for vibration and temperature transmitters

The junction box shall be rated at no less than IP65 according to IEC 60529

The following minimum instruments shall be provided:

| Item | Description |
|---|---|
| **1** | Gearbox input shaft (DE) bearing accelerometer |
| **2** | Gearbox input shaft (NDE) bearing accelerometer |
| **3*** | Gearbox input shaft (DE) X & Y proximitor probes |
| **4*** | Gearbox input shaft (NDE) X & Y proximitor probes |
| **5** | Gearbox input shaft (DE) bearing metal temperature transmitter. |
| **6** | Gearbox input shaft (NDE) bearing metal temperature transmitter. |
| | |
| **7** | Gearbox output shaft (NDE) bearing accelerometer |
| **8** | Gearbox output shaft (DE) bearing accelerometer |
| **9*** | Gearbox output shaft (NDE) X & Y proximitor probes |
| **10*** | Gearbox output shaft (DE) X & Y proximitor probes |
| **11** | Gearbox output shaft (NDE) bearing metal temperature transmitter. |
| **12** | Gearbox output shaft (DE) bearing metal temperature transmitter. |
| **13** | Gearbox casing accelerometer |

| Item | Description |
|---|---|
| * Note | For use when white metal journal bearings are proposed. |

#### 11.1.6.5 Acoustic hood

If required to meet the specified maximum sound pressure level, a suitable acoustic enclosure shall be provided. It shall be possible to easily dismantle and reassemble any such enclosure for maintenance purposes.

External surfaces of the gearbox shall be painted in machinery enamel according to the manufacturers standards to meet the environmental conditions

#### 11.1.6.6 Testing

The following acceptance tests will be carried out on-site:

- Power loss testing by measuring heat transferred to the lubricating oil as described in the AGMA standard.
- Vibration and Noise level tests as noted in the AGMA standard
- Verification of proper operation of gearbox, oil pump and turning gear.
- Functional test of all instrumentation
- Verification of conformity of submitted component documentation to the specifications.

### 11.1.7 Shaft Revolution Indicator

An uncovered area of the shaft shall be provided to enable motion of the shaft to be visually checked. This area of the shaft shall be marked so as to facilitate the use of a stroboscopic tachometer.

### 11.1.8 Lubricating System

The following equipment shall be factory assembled on a lube oil skid. The main oil pump may be driven from the turbine shaft in which case it will not be included in the factory assembled lube oil skid.

Main Oil Pump

| | |
|---|---|
| Type | Centrifugal pump |
| Quantity | 1x100 per cent main shaft driven or 2x 100 per cent AC Motor driven, per Unit |

Auxiliary Oil Pump (if required)

| | |
|---|---|
| Type | Centrifugal pump, AC motor driven |
| Quantity | 1 per Unit |

Jacking Oil Pump (if required)

| | |
|---|---|
| Type | Plunger pump |
| Quantity | 1 per Unit |
| Driving Method | AC motor driven to be supplied from the essential services board |

Emergency Oil Pump

| | |
|---|---|
| Type | Centrifugal pump |
| Quantity | 1 per Unit |
| Driving Method | DC Motor Driven |

Oil Cooler

| | |
|---|---|
| Type | Shell and tube |
| Quantity | 2 x 100 % per Unit |

Oil Filters

| | |
|---|---|
| Type | Cartridge |
| Quantity | 2 x 100 % per Unit |

Oil Tank

| | |
|---|---|
| Number | 1 per Unit |
| Capacity | Sufficient for a minimum of five minutes retention time between oil entering and leaving the tank |
| Material | carbon steel with epoxy internal coating, or stainless steel |
| Heater | Thermostatically controlled sufficient to maintain minimum oil temperature as required by the turbine supplier but not less than 40°C when the turbine is shut down. |
| Level Indication | Level alarm on high and low oil level |

Lube Oil Purifier

| | |
|---|---|
| Type | Centrifuge or coalescing filter |

| | |
|---|---|
| Quantity | 1 x 100 % per Unit (if centrifuge) or 2 x 100% per Unit (if coalescing filter) |
| Driving Method | AC motor driven (for centrifuge type) |
| Installation | Recirculating on main oil tank |

Vapour Extractor

| | |
|---|---|
| Type | Blower |
| Quantity | 1 per Unit |
| Driving method | AC motor driven |

The system shall be provided with sampling points on supply pipes, before and after filters and on each return line to the tank.

In the case of loss of electrical power, the system shall minimise the potential for turbine and generator bearings being damaged during rundown and barring operations.

### 11.1.9 Control System

After an initial manual line up of isolation valves (which are defined as valves not normally opened or closed during plant start/run-up or shut down but are only operated during maintenance to isolate plant for safe service/removal), all sequences required for the normal run-up and shut down of the turbine generator shall be performed semi-automatically, including generator synchronisation. The run-up sequence shall include starting auxiliary plant, all necessary pre-start permissives, ramp to speed, synchronise and ramp to pre-set load. The sequence shall include a series of hold points for plant stabilisation, to clear alarms and at critical stages of the start-up sequence to permit operator confirmation of plant operating status prior to proceeding to the next stage of start-up.

The Turbine control system and instrumentation system shall provide a safe, reliable, efficient and essentially automatic system for coordinated control and monitoring of the rotating T/G assembly.

The turbine shall be provided with an electronic governor controller. The requirements for this governor are as follows:

Speed Governor:

| | |
|---|---|
| Type | Electro-hydraulic to IEC 60045-1 |
| Quantity | 1 per Unit |

Operating Modes: the following shall be provided:

- Generated power output control including an operator adjustable dead-band,
- Speed/frequency control effective under part or full loads which including an operator adjustable dead-band, and
- Inlet pressure control, which shall be automatically selected and deselected to maintain a minimum operator adjustable inlet pressure. Power output or speed/frequency control shall normally be the primary mode.

Governor Control Valve:

Quantity 1 per inlet pipe per Unit

Valve stroking Daily to 50% valve opening where only one valve is provided

Emergency Governor (Overspeed Trip)

Type Triple redundant systems, Bently Nevada or similar approved

Quantity 1 set per Unit

Emergency Stop Valve

Quantity 1 per inlet pipe per Unit

Valve stroking Daily to 50% valve opening where only one valve is provided

### 11.1.10 SGS Pressure Control Requirements

The steam pressure control system shall be implemented in the DCS, and will use both the turbine governor valves (in the Power Plant) and the steam vent valves (nominally in the SGS) to provide tight, modulating control of steam supply pressure to the plant. The key indicative characteristics of this control scheme are as follows:

- Under integrated modulating control, the governor valves will normally operate to maintain SGS steam supply pressure at setpoint. The steam vent valves at the steam vent station have a positive setpoint offset above the governor control setpoint, and will therefore only operate to vent excess steam when the governor encounters another load limitation (e.g. MW limit, including as a result of plant load reduction) or the governor valves are fully open. This will be the normal control mode for the plant, to minimise steam venting.
- Slower acting controls will adjust geothermal fluid supply from the production wells, by modulating selected wellhead control valves, in response to a steam shortfall or excess.
- It shall also be possible to operate with the governor on fixed load control and steam pressure controlled by modulation of the steam vent valves. Under this mode of operation, the governor shall still monitor steam pressure and respond to a pressure decline by limiting load once the steam vent valves are closed, utilising the Vent Stations and also the turbine governor. Under normal operations the vent valves shall be closed, but shall open to control positive steam pressure excursions (e.g. after a Power Plant load reduction). The Turbine Governor in conjunction with the main unit steam valves shall be used to sustain steam pressure in the situation where insufficient steam is available.

### 11.1.11 Air Compressors and Compressed Air System

The instrument and utility air systems shall provide filtered, compressed air to the utility air header and filtered, dried and oil free compressed air to the instrument air header.

The instrument air header shall distribute air to pneumatic instruments and valve actuators. The utility air header shall distribute air to hose connections, pumps and filters throughout the Facility.

Two (2) 100 per cent air cooled oil-free rotary screw type electric driven compressors shall provide compressed air to the instrument and utility air systems. The capacity of the system shall meet all Power Plant control, utility air, and instrument air needs, and in addition the requirements for the SGS.

Air shall pass through filtration equipment before the compressors to minimise damage to the compressors from dust and particulate matter and to remove $H_2S$. A visual means to indicate the remaining $H_2S$ filtration capacity shall be provided.

Both compressors may be required to be in service during periods of high utility air demand. Air receiver(s) shall be provided with sufficient storage capacity to supply the Power Plant for 10 minutes of purge and general air demand and as much air as is necessary to safely shut down the Power Plant, in the event of failure of the air compressors. In this event, the air pressure measured at the end of the period shall be not less than 4 barg, and not less than the pressure at which control valves trip to their loss of air failure mode. No allowance shall be allowed for the volume of the distribution piping and the SGS air receiver in the calculation of the volume of the air receiver(s).

Air receivers shall be coated internally to prevent corrosion.

The air from the air receiver shall pass through a coalescing pre-filter. Following the pre-filter, the utility air shall branch off and the instrument air shall be sent to a dryer/filter.

After filtering the utility air shall flow through a pressure control valve and into the utility air header. The utility air header pressure control valve shall close automatically on low instrument air header pressure to conserve instrument air in an emergency. The stand-by air compressor shall start automatically as required to maintain adequate instrument air pressure.

Instrument air shall pass through automatic regenerating, adsorption type dryers. Air supply from the dryers and after filters shall meet ISA requirements for instrument air quality and shall have a moisture dew point not greater than -40°C. Two air dryers, each of 100 per cent capacity shall be provided.

The Compressed air system shall operate automatically with duty and standby plant starting and stopping according to air demand. The installation shall provide for local control and monitoring by the DCS. Controls shall include local primary-secondary control and shall be capable of alternating primary compressors. Trouble alarms that will be monitored by the DCS include HP air temperature and compressor shutdown alarms for each compressor. Instrument air header pressure shall also be monitored by the DCS.

Compressors and associated equipment shall be located within the turbine generator building.

## 11.2 Electrical Requirements

### 11.2.1 Main Generator and Exciter

The following requirements shall be provided per Unit.

#### 11.2.1.1 General

The generator shall be enclosed with either air to air or air to water cooling. Makeup generator enclosed air shall be via an $H_2S$ filter and its rating and characteristics shall comply with the requirements of all relevant parts of IEC 60034 except where modified by this specification.

The generator shall comply with;

1. the Dominican Generation Code,
2. able to supply its rated output at rated frequency and rated power factor for a voltage range of ±10 per cent at the generator terminals,
3. able to supply its rated output at rated voltage and rated power factor at a frequency which may vary between 51 Hz and 48 Hz,
4. able to supply rated output over the power factor range 0.85 lag to 0.95 lead,

The generator shall withstand an overload of 50 per cent rated current for not less than 15 seconds at rated voltage. The generator temperature shall have attained a value corresponding to rated load.

The short circuit ratio shall be based on the no load excitation current at rated generator voltage and the short circuit excitation current at rated generator current. It shall be not less than 0.5 and shall be not less than allowed by IEC 60034 3.

Synchronous reactance (saturated, design value) shall be between 150 and 200 per cent and be based on the short circuit excitation at rated generator current and the no load excitation at the rated generator voltage.

Generators shall be of the cylindrical rotor type, totally enclosed and shall meet the requirements of IEC publication 60034 unless otherwise specified herein.

The generators shall be supplied complete with all necessary accessories including, but not limited to, stator resistance temperature devices, generator air cooler, shaft earth brushes, complete brushless excitation system, automatic voltage regulator (AVR), manual voltage regulator, AVR potential and current transformers, neutral earthing cubicle, star point to neutral earthing cubicle connection, surge arresters and capacitors, local and remote instrumentation and special tools.

The generators shall be connected through suitably fault rated 11kV generator circuit breakers (GCB1 and GCB2) to the 11kV switchboard. The GCBs shall be fault rated to IEEE C37.013 using the applicable DC offset component from the generator data.

#### 11.2.1.2 Technical Characteristics

1. Rating — Continuous
2. Output — Generators MVA rating shall match or exceed the turbine MW output under all operating conditions divided by the rated power factor
3. Power factor — 0.85 lag - 0.95 lead
4. Frequency — 50 Hz
5. No. of poles — 2 or 4
6. Speed — according to number of poles

7. Voltage, Nominal 11,000 V
8. Voltage, Rated as per IEC 60034-3 clause 4.6
9. No. of phases 3
10. Insulation Class F
11. Temperature rise Generator and exciter temperature rises are not to exceed values specified in IEC 60034 as measured by a minimum of 6 resistance temperature devices embedded in the stator slots and stator core where it is anticipated the maximum temperatures will occur. In addition, rotor temperature shall be measured by an approved method.
12. Connection Star
13. Excitation method Brushless excitation
14. Connection Direct or gearbox coupling to turbine
15. Stator casing Enclosed to class IP54 of IEC 60034-5.

#### 11.2.1.3 **Abnormal Operating Conditions**

The generator shall be capable of withstanding the following abnormal operating conditions without harmful deformation of the windings or shafts, and without significantly reducing the fatigue life of the generator:

1. A sudden short circuit when at rated load and 105 per cent voltage, maintained for three seconds at the terminals of the generator.
2. Temporary loss of synchronisation at full load (pole slip or out of step).
3. High speed single and slow speed triple pole re-closing of the high voltage switchgear following system faults, with the generator connected to single or multiple outgoing circuits.
4. Negative sequence current, up to 10 per cent of continuous rating, subject to the combined currents not exceeding the base MVA rating of the machine, continuously.
5. Phase to earth fault at the terminals of the generator for the length of time required for the machine to come to rest and excitation off.

#### 11.2.1.4 **Stator**

Access shall be provided for inspection and maintenance as per the manufacturer’s specified maintenance requirements.

Stator windings shall be corona-free at operating voltage.

Each stator winding phase shall be provided with 2 winding temperature detectors of the resistance temperature type, and core temperature measurement devices in accordance with manufacturer standards which are continuously monitored by the DCS. In addition, 100% spare winding temperature detection and core temperature measurement devices shall be installed and wired out to terminal boxes. The detectors shall be mounted where the highest temperatures are to be expected.

Anti-condensation heaters shall be fitted near the end windings of the stator to prevent condensation in the casing whilst the generator is shut down. The heaters shall be low temperature or strip type, to maintain the stator winding temperature 3°C

above ambient temperature. Controls shall ensure that the heaters are connected when the generator is not operating and disconnected when the generator is operating.

#### 11.2.1.5 Rotor

Rotors shall be made of one solid forging and designed to have a large margin between the critical and running speeds under normal operating conditions.

The rigidity of the rotor body along the pole axis and along the windings axis shall be equalised as far as is possible to avoid double frequency vibration being transmitted to the foundations and associated equipment.

In the choice of material for the winding and in the design and manufacture and fitting of the coils, every precaution shall be taken to avoid deformation or the occurrence of earth faults in the windings during service. The packing blocks used in the rotor windings shall be entirely suitable for the high temperatures and mechanical forces experienced in the rotor.

Radial perforation of the end shields for purposes of ventilation is not permitted.

#### 11.2.1.6 Cooling System

Generators shall be enclosed air cooled to Code IC W37 A81 or IC 01 61 of IEC 60034-6 via a closed circuit air path.

Oxidising catalytic filters shall be incorporated in cooling air circuits to eliminate any harmful effects of $H_2S$ on the generator and ancillary equipment. External, pre-filter elements shall be provided to remove larger, air borne contaminants prior to the oxidising catalytic filters. A dehumidifier shall also be provided to extract moisture from cooling air during shutdown periods. A humidity meter shall be provided to allow monitoring of the moisture content.

Temperature detectors shall be mounted on the inlet and outlet of each cooler to measure cooling air temperature. Each cooler shall be equipped with a cooling water flow switch and water leakage detector complete with alarm contacts wired to the DCS.

#### 11.2.1.7 Terminals

The joint faces at the end of each bushing, and at the connections to the stator winding, shall be platinum, palladium, or gold alloy plated. The joints between the bushings and the cables shall be bolted.

#### 11.2.1.8 Excitation System

The excitation system shall be a brushless type.

All rotating components shall have the ability to withstand overspeeds of up to 120 per cent of nominal.

At rated AC supply voltage and frequency the excitation systems shall be capable of delivering continuously, within rated temperature rise, any value of field current from zero to 110 per cent of the field current required by the generator at its maximum continuous capability and rated power.

The exciter/voltage control system shall function as an integrated system and perform reliably throughout the entire design operating range. The automatic voltage control shall be designed so that the system operation remains stable under all operating conditions.

All static equipment shall be cooled by natural circulation.

The excitation system shall be capable of an excitation ceiling voltage of 1.6 p.u. on base excitation voltage that produces rated generator stator voltage at rated generator active power output and rated power factor.

#### 11.2.1.9 **Pilot Exciters**

A shaft driven, permanent magnet 3 phase synchronous generator shall be provided as the source of input voltage to the rotating exciter. It shall be air cooled with Class F insulation, continuously rated for the required main exciter input without exceeding the temperature rise permitted in IEC 60034.

An excitation transformer may be offered as an alternative to a pilot exciter. Excitation transformers shall be of the dry type, naturally cooled, with non-hydroscopic Class F insulation, complying with the requirements of IEC standard 60726, and constructed of $H_2S$ resistant materials. They shall be provided with temperature monitoring alarms and shall be housed with the Generator VTs or alternatively in a separate cubicle.

#### 11.2.1.10 **Main Exciter and Rotating Rectifier**

The exciter shall be cooled using a closed circuit air path system. The air path may be an integral part of the generator cooling system provided that no contamination from either system is possible.

Monitoring systems shall be provided to detect rotating rectifier bridge arm failure and excitation failure.

#### 11.2.1.11 **Field Suppression**

Field suppression shall be achieved by an exciter field switch and discharge resistor.

Operation shall be possible from the operator interface and the excitation control panel.

#### 11.2.1.12 **Field Flashing**

The Contractor shall provide, if necessary, field flashing equipment utilising the 110 V dc supply to energise each generator field on start-up. Note: not required for brushless generator

#### 11.2.1.13 **Voltage Regulation**

A continuously acting fast response automatic voltage regulator of proven design shall be supplied to control the output of each main excitation system. The AVR shall be equipped with a power system stabiliser (PSS). 100% redundancy shall be provided in the AVR so that failure of one AVR does not affect operation.

Each AVR shall have the following technical characteristics:

1. Shall be able to operate over a range of ± 10 per cent generator output voltage

2. It shall maintain the generator terminal voltage within ± 0.5 per cent of its setpoint value between no load and full load over the frequency range 47 - 52Hz.

3. It shall restore the voltage to within ± 0.5 per cent of its setpoint value within 10 seconds of a transient change.

4. By adjustment of the voltage setting device, it shall control the generator terminal voltage over the range of ± 10 per cent of its nominal value, when operating at its maximum continuous rating at rated frequency and power factor.

5. When the generator, driven at rated speed and voltage under no load conditions, is switched onto a symmetrical load equal to 35 per cent of rated current at a power factor of 0.4-0.9 lagging, the initial voltage drop shall be limited to 10 per cent of rated voltage and the voltage shall recover to at least 95 per cent of rated voltage within 1.5 seconds.

6. The AVR shall be capable of preventing excessive overvoltage during overspeed conditions following the sudden loss of load. The voltage shall not rise above 115 per cent of normal 3 seconds after shedding full rated MW load at the rated power factor with a normal speed rise.

The AVR shall have the following operational features:

1. It shall have the facility for optional electronic manual control from the operator interface, and changing to and from auto control when the machine is generating.

2. Provision shall be made for automatic follow-up to ensure smooth changeover from automatic to manual control. The follow up equipment shall operate so that if the automatic voltage regulator trips, the manual excitation control shall hold the field current to the value existing prior to the trip.

3. The AVR shall automatically change over from the primary to secondary automatic regulator on failure of the reference voltage circuit, failure of the power supply to the AVR, overload of the AVR, or any other AVR fault in the primary regulator.

4. It shall ensure equal and stable sharing of reactive load when machines are run in parallel. It shall be equipped with quadrature droop control.

5. It shall be suitable for operation in conjunction with automatic synchronising equipment.

6. Excitation current limiting to prevent operation outside of safe operating limits.

7. Self-diagnostic features to allow rapid diagnosis of faults.

8. Protective device with two alarm contacts to prevent the regulator going to ceiling voltage on loss of generator terminal voltage signal in the event of generator excitation voltage transformer fuse failure.

To facilitate testing of AVR performance after installation, accessible terminals shall be provided for the following signals :

- Stator voltage - one phase
- Stator current - one phase
- Main exciter control and other signals necessary to test the performance of the AVR.

#### 11.2.1.14 **Rotor Earth Fault Detection and Telemetry System**

Systems shall be provided for monitoring of rotor current, voltage, and temperature from the operator interface. Rotor current may be derived from directly measured exciter current. Rotor temperature shall be derived from rotor current and voltage measurements.

Equipment of an approved type shall be provided to detect a rotor earth fault and alarm to the DCS.

#### 11.2.1.15 **Current and Voltage Transformers**

Current transformers and voltage transformers shall comply with IEC 61869. Metering and protection transformers and systems shall be as a minimum as indicated on the Relay and Instrument Diagram and meet the requirements of the specification. The ratio, class, accuracy and output of the metering and protection transformers required shall be determined by the Contractor and calculations shall be provided to the Project Manager for review.

VT circuits shall be protected by HRC (high rupture capacity) fuses. Fuses shall be clearly identified and easily accessible.

#### 11.2.1.16 **Generator Surge Protection**

Surge diverter assemblies shall comply with IEC 60099 and IEC 60071 and shall be suitable for protection of the generator windings under the specified conditions. Each surge diverter shall be fitted with a surge counter.

#### 11.2.1.17 **Earthing Transformer**

Each generator shall be provided with an earthing cubicle constructed of heavy gauge primed and painted galvanised sheet steel or aluminium suitable for floor mounting. The cubicle shall contain a single-phase earthing transformer with its primary connected between generator neutral and earth and its secondary shunted by a resistor.

The transformer shall be dry or cast resin type with Class H non-hygroscopic insulation and shall be readily accessible for maintenance.

Means of isolation of the equipment from the neutral conductor shall be provided and a suitable cable sealing box shall be provided for termination of the neutral conductor.

The primary of the transformer shall be shunted by a surge diverter of approved type.

The design of earthing transformers and matching resistors shall be based on the following parameters:

1. Maximum earth fault current (transformer primary) at 100 per cent voltage must not exceed 5 amps.

2. Rated primary voltage shall be chosen to ensure that even on generator over-voltage under field forcing, the transformer core will be working at relatively low flux densities to avoid any possibilities of ferro-resonance. The flux density may be 50 per cent -60 per cent of knee point flux density.

3. One minute kVA rating - rated primary voltage times maximum earth fault current under overvoltage conditions.

The magnitude of the earth fault current shall be measured by a time delay voltage sensing relay shunted across the transformer secondary resistor.

The neutral earthing equipment shall be suitable for a 60 second duty cycle.

### 11.2.2 Control System Interfaces

The following interface signals (as a minimum requirement) shall be supplied to the DCS.

1. Stator winding temperature
2. Stator core temperature
3. Rotor earth fault alarm
4. Excitation Voltage (analogue)
5. Excitation Current (analogue)
6. Rotor temperature (measured or derived – analogue)
7. Rotating rectifier bridge arm failure
8. Excitation failure
9. Field breaker control signals and status indication
10. Voltage regulator control signals
11. Rectifier overcurrent

12. Loss of trip circuit
13. Loss of AC and/or DC power supply
14. AVR mode of operation auto/manual
15. Under excitation limit operation
16. Over excitation limit operation
17. Voltage limit operation
18. CB fail protection with isolation switch
19. Bearing temperatures
20. Phase currents
21. Line voltages
22. Air temperature

### 11.2.3 Protection & Metering System

The following requirements shall be provided per Unit.

#### 11.2.3.1 Description

The protection system shall comply generally with the Relay and Instrument Diagrams. Protection of all Units shall be coordinated with the MV system.

#### 11.2.3.2 Technical Characteristics

Relays may be offered as individual or combination devices incorporating more than one function. However protection devices providing mutual backup shall be placed in different groups.

Relays shall have sufficient setting ranges to cater for all conceivable instrument transformer characteristics, discrimination requirements, and sensitivities to fault conditions.

Relays shall be modern digital devices with redundant data communication link to the DCS to facilitate the transfer of all dynamic and fault data. All time based data shall be time stamped to the same basis as the DCS.

Each relay shall be clearly labelled with relay type and descriptive function. Relays shall be installed and wired in switchgear in accordance with applicable standards and industry practice. Relay and metering potential circuits shall be segregated and individually protected by fuses or MCCBs. Primary and secondary trip circuits (DC) shall be segregated. Primary trip circuits, high priority trip circuits and relay power supply circuits shall be segregated. Circuit protection devices shall not be included in relay trip circuits. DC control power circuits shall be the only schemes employing circuit protection.

The generator protection shall include duplicate/redundant protection of different manufacturer each having as a minimum:

1. Overall Differential protection (87U)
2. Generator Differential protection (87G)
3. Stator ground fault protection (95per cent and 100per cent schemes) (59GNG/27TNG)
4. Generator field protection (64F)
5. Reverse power protection (32G)
6. Over-excitation protection (24G)

7. Loss-of-field protection (40G)
8. Pole slip/Out of Step protection (78G)
9. Negative sequence current protection (46G)
10. Phase-to-ground overcurrent protection (51TNG)
11. Voltage controlled overcurrent protection
12. Under voltage protection (27G)
13. Overvoltage protection (59G)
14. Under/over frequency protection (81G)
15. Overfluxing (V/Hz) protection
16. Phase fault backup protection (21/50P/51P)
17. Inadvertent energisation protection (synchronism check) (50/27G)
18. VT fuse-loss indication/protection (60G)

An overall differential protection scheme (87) shall be implemented across the generator. Current transformers for this scheme shall be located as close as possible to the star point of the generator and the incoming generator circuit breaker on the MV Switchboard. In addition, all requirement of the Dominican Generation Code shall be complied with.

Schweitzer (SEL) and Beckwith protection relays shall be used for generator protection (duplicate/redundant).

As a minimum the unit auxiliary transformer protection shall consist of:

a. Phase-to-ground overcurrent protection (50G/51G)
b. Phase fault protection (50P/51P)

As a minimum, MV switchgear protection shall include:

- Overcurrent and earth fault protection relays installed to provide time and instantaneous overcurrent relay and ground overcurrent protection (Device 50/51).
- Distance protection on circuit breakers that connect to DOMLECs 11kV network (CB3, CB5 & CB7) (Device 21P/21G).

LV switchboard protection shall include:

1. Motor Feeder Protection by means of phase and ground overcurrent protection containing overcurrent direct- trip devices with both long-time, short time and instantaneous elements and ground overcurrent trip device.
2. The long-time unit shall have adjustable pickup and time-delay capabilities, with the settings allowing for coordination with the thermal characteristics of the motor.
3. The instantaneous trip element shall have adjustable pickup and provide short-circuit protection by tripping the motor breaker in the event of a short-circuit in the motor or feeder.
4. Motor Control Centre Feeder Protection by means of phase overcurrent protection consisting of low voltage air circuit breakers containing overcurrent direct-trip devices with adjustable long-time and short time trip elements;
5. The long-time delay unit shall be set to pick up at a value higher than the expected full load current and less than the rated current carrying capacity of the cable, with sufficient time delay to coordinate with the maximum overload device setting in the motor control centre.
6. The short-time delay unit shall be coordinated with the maximum instantaneous setting in the motor control centre.

7. Feeder Protection by means of: combination motor starters, combination contactors, and branch feeder circuit breakers Housed in individual cubicles. each cubicle to be provided with moulded case circuit protection, contactor and all required ancillaries
8. For motor loads fed from motor control centres, overcurrent protection shall be provided by motor circuit protectors (MCP). The magnetic elements of the MCPs shall be set to provide short-circuit protection for both continuous and intermittent duty motors.
9. For non-motor loads, protection shall be provided by moulded case circuit breaker with magnetic and thermal overload trips

The plant systems shall be designed to limit fault current to safe levels while providing adequate sensing current for protective relay systems. The protection system shall be designed to provide the optimum level of personnel safety, continued equipment operation and fault sensing devices to assist personnel in locating and repairing faulty equipment.

The protection equipment shall consist of proven, self-diagnosing, electronic type relays with complementary functions and sufficient redundancy to ensure that faults are detected and cleared without disruption to unaffected supplies. The scheme shall incorporate overlapping zones of protection with principal plant items provided with back-up protection in addition to the primary protection.

#### 11.2.3.3 MV System Protection Interface

The Unit protection system shall be designed and installed to coordinate with DOMLECs 11kV network protection system. The interconnection 11kV cables shall be provided and installed by DOMLEC together with over current, earth fault, distance and differential protection. The differential protection CTs at the Site shall be provided and installed by Contractor.

#### 11.2.3.4 Trip Circuit Supervision

Trip circuit supervision shall be provided on all MV and LV incoming circuit breakers. Breaker status lamps (red) shall be connected in the trip coil circuit; loss of DC to trip circuits shall be alarmed at the operator interface. Trip circuit supervision shall function independent of whether the associated circuit breaker is open or closed.

#### 11.2.3.5 Design Review

A complete short circuit and relay co-ordination study shall be submitted in conjunction with the detailed relay and control drawings and protective device settings for review by the Project Manager and DOMLEC before implementation.

#### 11.2.3.6 Under-voltage Protection

Under-voltage relay schemes shall be provided in all voltage levels for alarm and/or trip functions. Relays shall be applied in a manner that monitors and/or protects connected loads, and especially motors.

#### 11.2.3.7 Instrument Transformers

Instrument transformers shall be of sufficient output, and appropriate metering or protective class to cater for the application.

Unless otherwise agreed voltage transformers shall be withdrawable and of the core type. They shall be epoxy resin encapsulated and comply with IEC 61869. They shall be provided complete with LV fuses, limiting resistances and isolating safety shutters which shall cover the sockets on the fixed portion. Ground straps shall be fixed to each VT carriage that effectively grounds the MV side when in the withdrawn position.

Both leads of all current transformers shall be brought to terminals in the instrument panel where any neutral point shall be made off. Provision shall be made for primary injection testing. Current transformer circuits shall include terminal blocks with

shorting links to allow the transformers to be short circuited when loads are disconnected. CTs requiring neutrals to be grounded shall be connected in only one position, preferably at the shorting terminals.

### 11.2.4 Synchronising Arrangements

The following requirements shall be provided per Unit.

The Contractor shall provide automatic and manual synchronising facilities and associated check synchronising permissive relays to enable synchronising to be selectable either at the generator circuit breakers (GCB1 and GCB2) or at the bus tie circuit breakers (CB2 and CB8) in the case that the Units are running on house load. The requirement is that in the event of a momentary or short duration transmission line outage the Units will trip to house load and maintain at synchronous speed to enable a rapid reconnection of the Units to the transmission line once the fault has cleared.

The synchronising shall be available both as an auto-synchronising process (following breaker selection), and a manual synchronising process. The manual synchronising meters and controls shall be located in a discrete panel provided in the scope of this contract. The auto synchronising process shall be initiated via the operator command to the DCS.

The automatic synchronising equipment shall work in conjunction with the governor and voltage regulator devices to achieve synchronism with system voltage and frequency before initiating a circuit breaker closing signal. It shall feature adjustable time delay settings to compensate for the circuit breaker closing time. At the instant of circuit breaker closure, voltage matching shall be better than 1 per cent peak to peak and phase matching better than 2.5 per cent.

'Synchronising in progress' and 'synchronising unsuccessful' signals shall be provided to the operator interface. The synchronising unsuccessful signal shall be a time-out alarm having adjustable time delay. Once timed out, synchronising will not occur until a new close command is issued.

Independent synchronism check circuits shall be provided to inhibit circuit breaker closure if voltages and frequencies are not within prescribed parameters.

#### 11.2.4.1 Check Synchronism

Where an MV or LV circuit breaker can be closed onto a potentially live circuit fed from another source a check synchronising relay shall be provided to inhibit circuit breaker closing should the different systems not be synchronised.

### 11.2.5 Revenue Metering System

The following requirements shall be provided per Unit.

As a minimum it shall include:

1. Main and backup revenue metering per Unit in accordance with the requirements of the Dominican Generation Code.
2. Revenue metering transducers (CT’s and VT’s), to IEC 61869
3. Revenue metering cabling, marshalling cubicles or junction boxes between the metering transducers and the revenue meters, to IEC 62053.
4. Standalone revenue metering panel per Unit that is dedicated to the main and backup metering equipment, which will be inspected and sealed by DOMLEC (System Operator) in accordance with the Dominican Generation code.

The Contractor shall determine the CT and VT ratios and their specifications based on the expected plant capacity output and to meet the requirements of the specification. The metering CT’s and VT’s shall be class 0.2, the meter class 0.2, and the overall error to match the revenue metering. The loads applied to the CT’s and VT’s shall be such that the CT and VT burden is within the limits required to achieve CT and VT accuracy and confirmed by CT and VT test certificates.

#### 11.2.5.1 Revenue Meters

The metering system shall consist of programmable, electronic multifunction units and all associated components. The metering units shall directly interface with the plant DCS. Metering functions shall include, but not be limited to: kWh, kVarh, kW, kVar, instantaneous demand and totalising outputs. Bi-directional registration shall be available as default programming setup. The meters shall be capable of displaying the above parameters as well as displaying and recording all time-of-use and end-of-interval values, logging, storing and printing to hard copy all recorded data on a reconfigurable spreadsheet format.

| | |
|---|---|
| Type | Electronic, multi-function, programmable |
| Quantity | 2 sets, main and check, 3 phase, 3 wire |
| Functions | kW, kVAr, kWh, kVArh, demand, start/end of period, and others as available from manufacturer |
| Features | Programmable, LCD display, auto-logging, data interface capable, user settable security code, on line testing and calibration, block interval demand calculation, cumulative demand calculation, demand peaks measurement, non-volatile memory for storage of data, firmware, and operating parameters; alarm outputs for meter fault and voltage signal failure to plant monitoring system. |
| Accuracy | Class 0.2 |

### 11.2.6 Generator Circuit Breaker System

The following requirements shall be provided per Unit.

#### 11.2.6.1 Description

Each generator shall be connected to a suitable MV generator circuit breaker that connects to the MV switchboard as indicated on the single line diagram. Connections to instrument transformers and surge capacitors (if required) shall be provided as indicated on the generator and transformer relay and instrument diagram or as determined during detailed design.

#### 11.2.6.2 Generator Circuit Breaker

The Generator Circuit Breakers (GCB1 and GCB2) shall be housed indoors and shall be rated for generator synchronisation duty, interruption of maximum rated generator load current and interruption of maximum projected sub-transient fault current including the asymmetrical DC offset component.

The circuit breaker shall be metal-enclosed and operated by a charged spring. Circuit breakers may be either free standing or mounted in line with bus ducts provided ease of maintenance is not compromised. Operating mechanisms shall have sufficient energy storage to enable a close-open sequence after loss of auxiliary power. Indication of circuit breaker status and operations counter shall be clearly visible on the circuit breaker face panel.

The switchgear shall comply with IEEE C37.013 and shall be capable of sustaining without damage, the electrical and mechanical stresses produced by the specified fault conditions. The rated insulation level of the switchgear across the isolating distances shall be as defined in IEC60694 and IEC 62271.

An approved means shall be supplied for earthing incoming and outgoing circuits and the bus bars through the circuit breaker. Adequate mechanical interlocks shall be provided to ensure that the bus cannot be livened while the earth switches are closed and the earth switches cannot be closed on to a live bus. Copies of test certificates proving that the earthing device complies in full with IEC 62271 shall be submitted.

GCB fail (to trip) protection will intertrip the relevant MV CBs and Generator protection shutdown system, including generator excitation.

GCB status shall be indicated locally with LED lamps.

A GCB position status discrepancy alarm shall be raised at the DCS in the event of the GCB Open and closed status indications not following exclusive OR logic within the allowable transition time.

### 11.2.7 LV Systems

#### 11.2.7.1 Plant Control Circuits

All contactor circuits will be used to control motor drives or heaters and normal control of turbine/generator auxiliary motors and heaters will be through the DCS. Individual start/stop facilities shall be supplied at the switchgear to allow manual start/stop of the drives.

Local “Emergency Stop” pushbutton stations shall be supplied and installed under this contract and will be mounted adjacent to each motor. The STOP pushbutton shall be of the “stay-put” type mounted local to the motor, and shall function in all modes of control circuit operation for safety reasons.

Motor control circuits shall be supplied with a three position ‘Local-Off-Remote’ selector switch on the switchboard. START and STOP controls shall be provided on the switchboard. The STOP pushbutton for maintenance purposes, shall be of the ‘stay-put’ type similar to the STOP switch mounted local to the motor.

With the selector switch in the ‘Remote’ position, the circuit shall be controlled manually or automatically by the DCS. In the ‘Local’ position the circuit shall be controlled only from the switchboard.

The status of the ‘Local-Off-Remote’ selector switch shall be monitored by the DCS for indication to the operator. The selector switch shall provide an alarm and indication at the operator interface when not in the “Remote” position.

Fixed cells shall also incorporate a separate test feature which will enable full operation of the cell without operation of the load.

Where duplicate or multiple drives are provided for duty/standby operation, functionality shall be included in the DCS to interchange or rotate the order of operation of the drives.

### 11.2.8 Emergency Diesel Generator

#### 11.2.8.1 Description

A diesel powered generator set shall be provided to ensure electric power supply sufficient to enable the Facility to be shut down safely in the event of loss of transmission grid connection. This is described as the emergency diesel generator.

The emergency diesel generator shall be housed indoors. A purpose built containerised set is acceptable.

The capacity of the emergency diesel generator shall be capable of meeting the operational demands for essential services and services required during extended periods of maintenance when power is not available from the grid back feed, including;

1. 100% of all Plant ventilation and air-conditioning plant load,
2. All normal and emergency Plant (including Stores, Workshop, Laboratory, office space) lighting so that the lux levels specified are maintained,
3. All motor and generator anti-condensation heaters,
4. 100% of rated charging capacity for Power Plant and MV Switchgear DC system for tripping & protection supplies
5. 100% of rated capacity for Plant UPS system(s).

6. Operation of turbine barring gear and any required lube oil system
7. Normal operation of fire detection systems
8. Normal operation of Plant communication systems
9. Normal operation of Plant security / access control systems
10. SGS motorised valves.
11. any other services required to permit the Plant to be maintained in a safe condition and ready to be re-started with a minimum of delay once start-up power is re-established.

A minimum 10 per cent additional margin shall be added to the calculated capacity to determine the final rating for the emergency diesel generator.

The emergency diesel generator shall be arranged to feed the LV Essential Services secure board.

The emergency diesel generator system shall include protection and controls that are compatible with the main plant equipment and provide safe, reliable operation.

Synchronising equipment shall be provided to allow connection of the emergency diesel generator to the LV Common Services board while the switchboard is live, to allow the generator to be tested under load.

The emergency diesel generator set shall be fully self-contained and inclusive of speed and voltage controls. It shall be the manufacturer's standard model, well proven in similar service and rated for use in the project ambient environment and elevation.

The emergency diesel generator shall be designed to auto-start on loss of system power. Adequate sensing and protective devices shall be included to facilitate a fully automatic start and connection to the LV Essential Services board. Selection of either auto or manual start shall be provided to the plant operator; however, when manual mode is selected an appropriate alarm shall notify the operator of this status.

The status of the emergency diesel generator (running, starting, fault, ready to start etc.) and the status of all selector/mode switches (auto/manual etc.) shall be reported to the DCS.

#### 11.2.8.2 **Performance Requirements**

Performance requirements shall be as follows:

| | |
|---|---|
| Prime mover | Diesel engine of proven design and adequate rating |
| Voltage | LV |
| Power factor | 0.8 lag |
| Governing and voltage control | ANSI/IEE Standard 446 |
| Noise | 85 dBA if unenclosed. May exceed 85dBA if enclosed in a cell, in which case the noise outside of the cell must not exceed 85dBA |
| Maximum rotational speed | 3000 rpm |
| Overspeed withstand | 120 per cent |
| Underspeed withstand | 95 per cent |
| Cold start time | 10 seconds max |
| Fuel | Commercially and locally available automotive grade diesel fuel |

#### 11.2.8.3 **Maintenance**

The diesel engine shall be supplied by a manufacturer who preferably has a fully accredited Dominican service agent and can guarantee field support of the unit.

The diesel engine shall preferably offer unit exchange features for replacement of major sub-assemblies with minimum down-time. Special consideration shall be given to ease of removal and replacement of fuel injectors, fuel pumps and all filters and other components requiring regular maintenance.

#### 11.2.8.4 **Fuel System**

Bulk fuel storage shall provide for two weeks at maximum normal rated output of the generator, plus a day tank for 8 hours continuous maximum normal rated output.

The bulk fuel storage tank shall be located conveniently for filling by road tanker. The fuel system shall be complete with automatic transfer pump, level monitoring and alarm and pump control switches. The status of all alarms, levels, pumps operation etc. shall be reported to the DCS.

All fuel supply equipment shall comply with NFPA 30 “Flammable and Combustible Liquids Code”.

#### 11.2.8.5 **Starting System**

The diesel engine starting system shall employ batteries with sufficient storage for at least 4 aborted and one successful start. The recharging of batteries or air supply shall not be reliant on sources outside of the emergency diesel generator itself and its associated systems.

#### 11.2.8.6 **Cooling System**

The emergency diesel generator shall be supplied complete with its own cooling and heat rejection system. This shall comprise a water cooling circuit for oil, engine jacket, generator and, if required, charge air cooling. Heat rejection shall be via a radiator to be supplied with the engine. The radiator shall be generously sized and include a 20 per cent fouling margin. Installation of the emergency diesel generator and its radiator shall be such as to ensure an adequate flow of fresh air for cooling and engine aspiration.

# 12. Steam Condensing Turbine Power Plant Specific Requirements

## 12.1 General

The following requirements apply to steam condensing steam turbine technology. The steam condensing turbine Power Plant shall consist of two independent and identical Units, in order to provide a modular solution.

The following requirements shall apply to each of the two Units.

The equipment and components of each Unit shall be identical and interchangeable between the two Units.

## 12.2 Steam Power Plant Mechanical

The following requirements shall be provided per each Unit.

### 12.2.1 Description

The steam turbine shall be a condensing machine complete with all necessary auxiliaries, complying with the requirements of IEC 60045-1 for steam turbines driving generators for electrical power services.

The turbine shall normally operate with constant steam supply pressure however there may be circumstances under which the steam supply pressure will not be constant and the turbine will be required to operate in pressure control mode. The turbine shall have a proven history of satisfactory operation with geothermal steam and that materials are selected to effectively eliminate corrosion risk and provide long-term, low maintenance, reliable service.

The turbine shall be complete with all protective devices including as a minimum the independent overspeed trip devices, bearing failure protection device, radial bearing vibration protection device, low vacuum trip device, turbine drain system and one set of casing over pressure protection devices.

A complete lubricating oil system shall be provided complete with necessary, fully redundant oil pumping capacity including as necessary shaft, AC and DC motor driven pumps, two 100 per cent capacity oil coolers, two 100 per cent capacity oil filters, one main oil reservoir, one oil purifier, all required supply oil and drain line piping. Drain trays or equivalent containment shall be provided under all lube oil system equipment. The lubricating system shall be so arranged as to ensure safe run down of the steam turbine without damage to bearings on loss of all normal electrical supplies

The Contractor shall also supply one complete barring gear system, one complete gland sealing steam system, all instrumentation (both local and remote) and one set of special tools.

### 12.2.2 Design Life

Design features and material selection shall minimise the effects of scaling, corrosion, erosion and fatigue over the design life whilst minimising the need for spares.

### 12.2.3 Steam Strainers

Basket type steam strainers to the turbine manufacturer’s recommendation shall be provided on each inlet leg upstream of the emergency stop valve. Provision for measurement of differential pressure across the strainers shall be made.

### 12.2.4 Drains and Vents

The turbine shall be fitted with generously sized casing and inter-stage drains. Particular attention shall be provided to the removal of water from the lower pressure stages of the turbine in order to minimise the effects of erosion.

Drains from the turbine casing, steam piping after the stop valves and valve spindle leak-offs shall be returned to the condenser. Drains from parts of the plant that are operating at or near main steam pressure and which need to be operated when the turbine is started shall be fitted with two valves in series, the upstream one for isolation and the downstream one for control. The upstream (isolating) valve shall have welded joints and the downstream (control) valve shall be flanged. Steam traps shall not be used for these drains unless unavoidable. Casing drains shall be fitted with removable erosion protection wear inserts. Drain orifice plates shall also be easily removeable and replaceable.

Provision shall be made for the monitoring of casing drains, both to ensure that they are operating and to take samples of drain water for chemical analysis.

### 12.2.5 Steam System

The following requirements shall be provided per Unit.

#### 12.2.5.1 Description

The Power Plant steam system shall be designed in accordance with ASME B31.1 Power Piping. The steam system shall be designed to safely handle slug flows of water from the SGS into the Power Plant, which may occur on rare occasions under upset conditions. These may represent up to 10 per cent by weight of the total flow from the SGS. The system shall also be designed to provide for adequate drainage of condensate and moisture under start up, normal operational and upset conditions.

In the case of steam flash plant, specific requirements shall include a steam scrubber or demister.

In the case of an Organic Rankine Cycle power plant, the use of a steam scrubber or demister is optional, however suitable measures shall be taken to detect excessive brine carry over from the separator. Adequate condensate pots with automatic level control and drainage shall be provided in the main steam line between the separator and Power Plant inlets.

#### 12.2.5.2 Steam Flow Measurement

Venturi flow meters shall be installed in the main steam pipework. These devices shall be connected to the DCS and shall be used for measurement and recording of steam flow during normal operation of the Power Plant and during Performance Testing. These meter(s) shall record the total steam from the SGS to the Power Plant.

Steam flow to the auxiliary steam system shall also be measured such that the steam flow to the turbine can be determined independently to allow for individual plant item performance monitoring purposes.

#### 12.2.5.3 Auxiliary Steam System

Auxiliary steam for start-up and operating steam jet ejectors (if used) and gland sealing steam shall be taken from the main steam supply inside the Power Plant. The gland sealing and NCG extraction systems shall be designed to allow short term pressure transients, where the main steam pressure falls below normal by up to 0.5 bar, without tripping the turbine.

### 12.2.6 On Line Turbine Blade Washing

Equipment shall be provided to allow regular on-line washing of steam turbine blading for removal of scale deposits.

Water shall be sourced from the Hotwell or other water source subject to Project Manager's approval. The system shall comprise two 100% pumps together with piping, valves, spray nozzles and control valves as necessary to allow the safe on-line cleaning of the turbine. It may be a common system with the steam scrubber washing system.

The system shall be selectable as either fixed manual flow or automatically flow matched to the steam flow based on an adjustable % rate.

### 12.2.7 Safety Features

Steam turbine trips shall be initiated by the following events as a minimum:

1. Emergency Manual (local, control room initiation)
2. Overspeed (redundant electronic)
3. Insufficient condenser vacuum
4. Excessive vibration/rotor axial position
5. Differential expansion – Subject to review as part of HAZOP/FSS
6. High water level in scrubber or demister vessel
7. High condenser water level
8. Generator protection trip
9. High turbine exhaust hood temperature
10. Low inlet steam pressure for a sustained period of time (this is to protect the SGS). Too rapid separator steam decline risks brine carryover into the downstream steam system. The governor controls shall prevent the rapid fall of separator steam pressure.
11. High bearing temperature – Subject to review as part of HAZOP/FSS
12. Low lube oil supply pressure
13. Insufficient condenser vacuum unloading functionality shall be provided.

### 12.2.8 Gland Seal System

Gland Steam Seal Flow Regulator

| | |
|---|---|
| Type | Automatic |
| Quantity | 1 per unit |

Gland Exhaust Fan (if required)

| | |
|---|---|
| Type | Centrifugal |
| Quantity | 2 x 100 per cent per Unit |
| Driving method | AC motor driven |

Gland Steam Condenser (if required)

| | |
|---|---|
| Type | Direct contact |
| Quantity | 1 per Unit |

Sealing glands shall be accessible without having to remove the turbine top casing. Glands shall be designed to prevent the deposition of silica and chlorides in the glands.

If a gland steam condenser is used, it shall be direct contact and shall be provided with a bypass to the main condenser to allow the gland steam condenser to be isolated and shut down during normal turbine operation without impacting gland extraction operation.

### 12.2.9 Condenser

The following requirements shall be provided per Unit.

#### 12.2.9.1 Description

The Contractor shall supply one direct contact steam condenser per Unit in accordance with HEI specifications. The Condenser shall be designed to reject the thermal load from the geothermal fluid and to minimise the dissolved gas content in the condensate exiting the condenser hotwell. Condenser performance curves shall be provided by the Contractor.

Sampling connections shall be provided for water leaving the condenser and gas cooler in the discharge pipework from the hotwell pumps.

Pressure test connections (plugged) and test thermowells shall be provided at all main fluid inlets and outlets, with connections to check the pressure gradient across the condenser.

The condenser shall be equipped with level control facilities to prevent the hot well pumps from cavitating due to insufficient NPSH requirements.

#### 12.2.9.2 Internals

Internals shall be free-draining and self-cleaning and shall avoid fouling and clogging from any foreign material or deposit build-up.

The condenser shall be designed to enable the Plant to be operated at part load with only a single Hotwell pump in operation.

A sparger shall be provided at each point of discharge into the condenser where impingement damage could occur.

Suitable screens or other provisions shall be included, if required, at the condensate outlet nozzles to prevent damaging foreign matter from reaching the hotwell pumps. Vortex breakers shall also be provided, if required by the design.

#### 12.2.9.3 Maintenance Provision

Any internals such as nozzles or diffusers required to be removed for maintenance shall be designed for ease of removal and replacement and, together with any associated tools, shall be capable of fitting through the access manholes.

#### 12.2.9.4 Materials

Materials for wetted parts shall be:

Shell: Solid ANSI 316L stainless steel, or low carbon steel clad internally with ANSI 316L stainless steel

Nozzles, internals and piping: ANSI 316L stainless steel

Non-wetted parts may be constructed of other materials suitable for the service requirements.

### 12.2.10 Gas Removal System

The following requirements shall be provided per Unit.

#### 12.2.10.1 Description

A hybrid two stage gas removal system shall be provided. The system shall comprise multiple independent trains in parallel. The requirement is for two trains each of 100% full output.

It shall comprise of;

- first stage comprising steam jet ejectors as two 100% duty, and
- last stage comprising one 100% duty liquid ring vacuum pump and one 100% standby steam jet ejector plus
- associated inter- and after-condensers and coolers draining to the main condenser or cooling tower as appropriate, and associated auxiliaries.

Alternatively,

The system shall be designed to extract non-condensable gases from the main condenser gas cooler section and to discharge the gas into the cooling tower plume above the fan level.

The system shall be so arranged to ensure the continued operation of the system in the event of a failure of any one active component.

The gas removal system shall be designed to maintain condenser vacuum above the turbine trip limit under all operating conditions including transients in steam pressure as set out in the Schedule of Interfaces and Employer Obligations.

Gas removal system shall be equipment with sufficient automation to permit full remote start-up and shut down without operator intervention in the field.

#### 12.2.10.2 Liquid Ring Vacuum Pumps

The operating speed of liquid ring vacuum pumps shall preferably not exceed 500 rpm. Belt drives shall not be acceptable for speed reduction. Speed reduction gear units shall have self-contained oil lubrication and lubricant cooling systems.

Pump design shall be proven in geothermal service.

Metallic components of the liquid ring vacuum pumps in contact with water or the non-condensable gas shall be from ANSI 316L stainless steel or approved equivalent.

A complete seal water supply and separator system shall be provided for each pump, including all necessary instrumentation, controls and test ports. Each pump shall have a warning alarm on low seal water flow, followed by a pump trip upon extra low flow.

If air bleed valve is required for startup of pumps, operation of this shall be fully automatic

#### 12.2.10.3 Steam Jet Ejectors

Steam jet ejectors shall be designed in accordance with HEI standards for steam jet vacuum systems. Nozzles shall be replaceable for maintenance and to permit changes of the duty requirement if the non-condensable gas content of the steam should change.

The ejectors shall be constructed of ANSI 316L stainless steel or approved equivalent.

Note: ejectors are likely to require lagging to comply with noise limits

#### 12.2.10.4 Inter and After Condensers

Inter and after condensers shall be designed in accordance with HEI standards.

They shall be designed to withstand a full vacuum.

If loop seals are employed, these shall be equipped with clean-out ports.

The inter and after condensers shall be equipped with access ports and levels gauges. Spray nozzles and other components requiring removal for maintenance shall be designed for ease of removal.

Material of constructions shall be 316L (316 acceptable for components that are not welded).

#### 12.2.10.5 Non-Condensable Gas Disposal

Non-condensable gas from the last stage of the gas removal system shall be piped to the cooling tower for disposal by dispersion into the fan plumes. The gas discharge system shall be designed to ensure good mixing of the gas with the tower plume in order to provide for good dispersal of the gas.

Gas shall be piped to each of the cooling tower cells and discharged above the fans. The gas discharge ports into each cell shall be provided with actuated isolating valves and spectacle blinds. The actuated isolation valve shall automatically isolate the flow to each cell upon tripping of the associated fan.

Gas flow shall be monitored in the DCS.

The gas disposal system shall be designed to allow full flow with any one cooling tower cell isolated.

NCG system shall be designed with sloping piping to prevent pocketing of fluids. The riser up the cooling tower shall be equipped with a drip leg and u-seal drain to the cooling tower basin.

#### 12.2.10.6 Auxiliary Cooling Water (ACW) Supply

The ACW system shall be designed so that, in addition to all other loads, a single (i.e. the duty pump) ACW pump is sized to provide all the water requirements to operate all trains simultaneously.

### 12.2.11 Hotwell Pumps

Multiple canned type, vertical, direct driven centrifugal or mixed flow pumps with a combined duty of 100 per cent shall be provided to extract cooling water and condensate from the condenser Hotwell and return it to the cooling tower. The pumps shall be rated such to meet the plant requirements under all operating conditions. The pumps shall conform to API 610.

The pumps shall be complete with check valves, isolation valves, bearing and seal water filtration equipment and all other necessary auxiliaries.

Maintenance access for the pumps shall be provided by electric powered lifting facilities including any necessary specific overhead crane.

#### 12.2.11.1 Materials

All metallic components in contact with the pumped fluid shall be of ANSI 316L stainless steel or equivalent as a minimum.

#### 12.2.11.2 Pump Speed

The pumps shall run at fixed speed, which shall not exceed 1000 rpm. The first shaft critical speed shall be at least 20 per cent above normal running speed.

#### 12.2.11.3 Reverse Flow

The pumps shall be designed to avoid damage in the event that they are driven in a reverse direction as a result of reverse flow through the pump arising because of check valve failure.

The check valves shall be of the balanced non-slamming type to minimise water hammer effects on pump stop.

#### 12.2.11.4 Bearings and Seals

Mechanical seals shall be provided

Process water shall be used for seal and bearing lubrication. Water for bearing and seal lubrication shall be filtered to 2 micron or better. Flow sight indication shall be provided on all supplies (eg floating ball or similar).

The pump thrust bearing shall not be used to absorb thrust from the motor.

#### 12.2.11.5 Casing and Impeller Size

The pump casing and impeller shall be sized together to allow for an increase or decrease in pump head at design flow of at least 10 per cent by a change of impeller.

#### 12.2.11.6 Provisions for Wear

The shaft shall be fitted with replaceable sleeves at the seals and bearings.

Replaceable wear rings shall be installed on both the bowl of the pump and the impeller

#### 12.2.11.7 Vortex Suppression

Unless a double suction impeller pump design is used, a vortex suppressor shall be fitted to the suction. It shall be designed to reduce eddies and entrance losses, thus reducing vibration, noise and wear.

#### 12.2.11.8 Minimum Flow Recirculation

The minimum flow recirculation shall be automated and shall stop recirculation when the flow through the pump exceeds the minimum flow requirement. The system shall alarm when the discharge pressure from the pump exceeds the head at which minimum recirculation flow should be operational.

#### 12.2.11.9 Pump Protection

Two velocity transducers shall be provided on the top bearing housing only for each pump, 90° apart, for vibration monitoring.

Alarms shall be provided for the following events as a minimum:-

- Excessive vibration
- Low flow

High motor current

Pump trips shall be initiated by the following events as a minimum:-

Excessive vibration

Less than minimum flow for defined time

Seal flush failure

Motor protection

Condenser low level

### 12.2.12 Wet Cooling Towers

The following requirements shall be provided per Unit.

#### 12.2.12.1 Description

One mechanical induced or forced draft cooling tower per generating Unit shall be provided to dissipate the heat rejection load, including the main condenser, gas extraction system condensers, the turbine unit auxiliary cooling load and any other heat loads from the Power Plant. The cooling tower shall comprise a number of cells modularised such that one complete cell, including the associated NCG dispersion system but excluding the basin, can be taken out of service for safe cleaning or maintenance whilst the balance of the cells remains in operation.

The cooling tower shall be designed in accordance with the Cooling Technology Institute (CTI) standards.

The tower structure shall be constructed using materials with a demonstrated life under similar conditions at least equal to the design life.

The cooling tower shall be equipped with heavy-gauge, clog-resistant splash or film fill, high efficiency mist eliminators which hold drift losses to less than 0.002% of the inlet water flow. The air path shall be designed to minimise air pressure drop, water drift and splash and the tower shall operate without vibration or flutter.

The tower basin shall be designed with sufficient free board above the normal operating level to enable the condensate disposal to re-injection system to be shut down for up to 5 hours without overflowing the basin.

The tower design shall avoid or make adequate provision to mitigate the effects of plume recirculation or interference which may occur from the proximity of other buildings and/or as a result of variable wind conditions.

#### 12.2.12.2 Fill and Drift Eliminators

The fill shall be heavy gauge PVC, low clog, straight/vertical fluted, film pack of minimum thickness **after forming** of 0.38 mm, to minimise risk of fouling due to biological material, sulphur deposits or ambient dust.

The fill shall include an upper protection layer of heavy gauge PVC to protect the film pack against the direct impingement of water jets.

High efficiency mist eliminators and splash eliminators shall hold drift losses to less than 0.02 per cent of the design mas flow.

The fill material shall have a maximum temperature limit that is compatible with all operating conditions of the plant, including dry shut down and subject to solar heat gain.

Timber or asbestos fill packs will not be acceptable.

.All fasteners and hardware shall be ANSI 316L stainless steel.

Water risers and distribution pipework shall be manufactured from fibre reinforced plastic, HDPE, ANSI 316L stainless steel or equivalent.

Load bearing supports within or around the perimeter of the tower shall be above the water level.

External surfaces of the tower shall be resistant to deterioration from ultra-violet light.

#### 12.2.12.3 **Fire Resistance and Tower Wetting**

All materials used in the tower shall have an NFPA fire combustibility rating of less than 25. Fire protection for the cooling tower shall comply with NFPA 214 and Section 8.3 Fire Protection.

#### 12.2.12.4 **Water Distribution System**

Nozzles shall be threaded to permit easy removal for cleaning of the nozzles and the distribution pipework. Cleanout provisions shall be made at the end of all headers and distribution pipework with removable end caps to allow easy flushing and cleaning.

The design of the water distribution system shall allow for 90 per cent of the plan area of the cell to receive a water flow within 5 per cent of the average flow. The water flow shall not deviate by more than 10 per cent from the average at any portion of the plan area.

Valves shall be provided to allow flow equalisation.

#### 12.2.12.5 **Outlet Screens**

The outlet from the cooling tower basin shall be provided with two rows of screens sized and arranged so as to permit on-line changing and cleaning of screen elements without limiting the operation of the Power Plant. The screens shall be fabricated from 316 stainless steel as a minimum. Suitable lifting beams, runway and overhead lifting equipment are to be provided with a cleaning apron area draining into the main effluent drainage system. A hose and hose point is to be provided adjacent to the screen area to provide for wash water from the raw water system.

Stop-logs shall be provided to enable the basin outlet to be isolated to allow access to cooling water components without the need to drain the basin.

The primary basin level transmitter shall be located upstream of the screens and differential pressure alarms provided across the screens.

Screens shall be sized with mesh or hole sizes suitable to prevent fouling of condenser spray nozzles.

#### 12.2.12.6 **Access and Safety**

A stairway and a caged fire escape ladder shall be provided at opposite ends of the cooling tower for access to the fan deck, including handrails and toe boards on the stairway and fan deck. Lighting shall be provided on the stairway, ladder, fan deck and around the tower.

Each cell shall have a lift-off access hatch in the fan deck floor and a ladder leading down to a landing at the drift eliminator level. Each landing shall have a lift-off hatch for entry to the top of the water distribution level.

Fan cylinders shall have easily removable external hatches of sufficient size to permit removal of all mechanical equipment and components. An access catwalk shall be provided.

The fan deck shall be capable of supporting fan components, driving motor, gearing and shafting during overhaul. Maintenance facilities and necessary equipment shall be provided to allow the fan, gearbox and motor to be removed and lowered to ground level.

All access doors shall be easily openable from inside the tower.

### 12.2.12.7 **Fans and Drives**

Fans shall be balanced, multi blade, manually-adjustable pitch (with indexing), manufactured from corrosion resistant material with airfoil profile. Fan tip speed and air velocity shall be such as to ensure operation within the allowable noise limits. The airfoil surface of the blades shall have a smooth surface without any protrusions.

Low noise fans shall be provided by the Contractor.

Motors and the gearboxes shall include vibration transducers to provide continuous condition monitoring, alarm and trip functions to the DCS. In addition, temperature sensors shall be fitted to the gearboxes to allow for maintenance measurement as required of gearbox temperature.

Fan, gear, drive shaft and motor shall be mounted on a unitized base designed and constructed to prevent misalignment of the drive train and fan within the stack under all operating conditions. The base and any associated structural members shall be ANSI 316L stainless steel. The drive shaft shall be ANSI 316L stainless steel or carbon fibre, and shall be provided with flexible couplings. Support and attached structures shall be designed to avoid blade passing frequency harmonic excitation.

Belt drives are not acceptable.

Gear boxes shall have an oil level sight glass, fill line, vent line, drain line, a low level switch and grease fittings connections all located outside the fan stack for convenient maintenance access. External oil pumps will not be acceptable. Gear boxes shall have a minimum AGMA service factor of 2.0 and be designed for the life of the plant; bearings shall be designed for a minimum L10 life of 100,000 hours. Adequate lubrication shall be automatically provided for windmilling.

Fan stacks shall extend at least 2.1m above the deck, to minimise potential for personnel exposure to hydrogen sulphide discharges.

Fan motors shall be sized to handle the highest cold-weather ambient air density without overload, when blades are pitched for the design airflow capacity.

### 12.2.12.8 **Basin Cleaning**

The basin is to be provided with a drainage sump suitable for use with a submersible or similar pump provided by the Contractor for emptying the basin for cleaning of the basin. A hose point is to be installed adjacent to the basin to supply water for wash down purposes.

The drainage pump shall be capable of handling sludge and is to be provided with all fittings and motor starter equipment necessary for connection to a sludge removal truck. The truck will be provided by others.

A bunker shall be provided for the collection and air drying of sludge removed from the basin. Total bunker size shall be 12 m3 with a plan area of no less than 12 $m^2$. The bunker shall incorporate a removable canopy to protect the bunker from rain whilst the sludge is drying. Isolatable drainage shall be provided from the bunker to the Power Plant’s thermal pond.

The design shall cater for disposal of water and sludge by truck also. Any permanent connections installed to allow connection of temporary hoses to the trucks shall be adequately protected against any potential collision damage.

Basins of adjacent cooling towers shall be interconnected with suitable valves to allow the filling of one basin from the other after maintenance or cleaning.

#### 12.2.12.9 Basin Overflow

The basin shall have a built-in overflow immediately above the design level. The overflow discharge shall be piped to the production wellpad sump. No isolation shall be fitted to the overflow discharge. Actual discharge flow via the overflow shall be visible from the immediate surrounding area.

#### 12.2.12.10 Chemical Treatment System

A chemical treatment system shall be provided to maintain water chemistry in the water systems within required limits as specified by the various equipment and system manufacturers and designers.

Chemicals will be metered into the hotwell pump discharge. Cooling water monitoring equipment shall be provided for duplex continuous sampling of pH through a sample line from the cooling water system. Chemical injection shall be controlled continuously by the duplex continuous pH sample. Remote high/low pH alarms will be provided. The continuous sample line will have a flow switch with remote indication and will automatically deactivate the chemical injection if sample flow ceases.

The chemical treatment system shall also include biocide and dispersant chemical injection pumps, metering a solution into either the hotwell pump discharge or the cooling tower basin. Provision for shock dosing shall also be included.

Chemical treatment with sodium hypochlorite or chlorine shall not be used.

### 12.2.13 Cooling Water Systems

The following requirements shall be provided per Unit.

#### 12.2.13.1 Description

The Contractor shall provide a complete cooling water system including cooling tower and auxiliary cooling system as required. The main cooling water system will serve as the cooling water supply for the steam turbine direct contact condenser. The auxiliary cooling water supply pumps shall supply the gland steam condenser (if required), drains flash vessel, gas extraction system condensers, liquid ring vacuum pumps, lube oil system coolers, generator air coolers (if water cooled) and air compressors (if water cooled).

The thermal load extracted by the main cooling water system and the auxiliary cooling water system shall be rejected by the cooling tower.

The cooling water system shall be unitised and capable of handling the full cooling load of the steam turbine condenser plus 100 per cent of the maximum auxiliary plant heat load. This requirement must be met over the full operating range and all modes of the Power Plant, with a reasonable allowance made for fouling of the tower fill material.

Excess condensate shall be returned to the SGS for injection.

The cooling system make-up water system shall be sized such that a cooling tower basin can be refilled from the raw water supply in approximately 24 hours after cleaning.

#### 12.2.13.2 Auxiliary Cooling Water Supply

Two 100 per cent duty auxiliary cooling water (ACW) supply pumps (one operating, one stand-by) shall be provided to supply cooling water to the various auxiliary requirements.

The pumps' casings and impeller shall be sized together to allow for an increase or decrease in pump head at design flow of 10 percent by change in impeller.

The ACW supply pumps shall be single-stage, electric motor-driven centrifugal pumps, to API610, or approved equivalent. All wetted parts shall be of AISI 316L stainless steel or approved equivalent.

The pumps shall be provided with check valves to enable the standby pump to be left ready to start automatically on duty pump stop or failure.

The stand-by pump shall start automatically on low ACW system pressure.

Duplex strainers shall be provided downstream of the pumps.

#### 12.2.13.3 **Piping**

The system piping shall be constructed of glass reinforced plastic (GRP), AISI 316L stainless steel or high density polyethylene (HDPE).

Buried pipework shall be GRP, HDPE or approved alternative.

### 12.2.14 Steam System Drains

All steam system drains upstream of the turbine main stop valve(s), including the steam scrubber drain underflow shall be routed to the cooling tower basin or condensate sump and shall be discharged and condensed in a dedicated Auxiliary Flash Tank (AFT). Particular attention shall be paid to safety in the design of the system. An alternate drain to grade shall be provided to allow checking that drains are not blocked. A suitable means of condensate collection and atmospheric discharge shall be provided.

All steam system drains downstream of the main stop valves shall be routed to the condenser or other location as approved by the Project Manager.

### 12.2.15 Condensate Reinjection

Surplus condensate/cooling water shall be disposed of from each unit's cooling water circuit by injection to the common condensate injection well. The injection supply shall be taken from the hotwell pump discharge and piped to the SGS interface point.

Control shall be modulating, based on the cooling tower basin level. A valved bypass around the level control valve shall be provided to allow on-line maintenance of the level control valve.

A condensate injection pumping system shall be provided, if required, in order to achieve the necessary interface pressure. Adequate pump capacity and redundancy shall be provided to cater for the full range of plant operating and climatic conditions. Pumps shall be ANSI 316SS and suitable for the condensate service.

Portable equipment and permanent connections shall be provided to enable water to be pumped directly from the cooling tower basin to the condensate injection system for planned shut downs when draining of the cooling tower is required.

The pH of the condensate shall be adjusted and controlled automatically to ensure that the pH remains within the limits specified in the Interface Schedule.

A condensate sump shall be provided adjacent to the Power Plant for the temporary collection and storage of condensate. The sump shall be sized to accommodate 24 hours of condensate at NCR. Pumps shall be provided to empty the sump into the condensate injection system. These may be the same pumps as used for condensate injection.

# 13. Organic Rankine Cycle Power Plant Specific Requirements

## 13.1 General

Organic Rankine Cycle (ORC) technology for the Power Plant shall comply with the specific requirements in this section of the Specification. The Organic Rankine Cycle Power Plant shall consist of two independent and identical Units in order to provide a modular solution.

The following requirements shall apply to each of the two Units.

The Equipment and Components of each Unit shall be identical and interchangeable between the two Units.

## 13.2 Power Plant Mechanical

The following requirements shall be provided per Unit.

### 13.2.1 Description

The ORC Unit shall use steam and brine from the SGS separator.

The ORC Unit shall be the Contractor's standard design and it shall consist of the turbine and generator as well as the train of heat exchangers complete with all necessary auxiliaries.

The ORC Power Plant shall normally operate with constant thermal load. However, there may be circumstances under which the thermal load will not be constant and the ORC Power Plant will be required to operate in partial thermal load.

The ORC Unit shall have a proven history of satisfactory operation within the geothermal applications and that materials are selected to effectively eliminate corrosion risk and provide long-term, low maintenance, reliable service.

### 13.2.2 Power Plant Design Life

Design features and material selection shall minimise the effects of scaling, corrosion, erosion and fatigue over the design life whilst minimising the need for spares.

The ORC Unit shall include a minimum interval for planned seal replacements of five years of continuous operation.

### 13.2.3 Turbine

The turbines shall comply with the recommended requirements of API 612 (Steam Turbines - Special-Purpose Applications) in the case of axial flow turbines, or API 617 (Axial and Centrifugal Compressors and Expander-Compressors) in the case of radial flow turbines, and API 614 (Lubrication, Shaft-sealing and Oil-control Systems and Auxiliaries).

The Contractor's design shall eliminate or minimise the likelihood of resonant frequency issues for the wheel/blade arising from nozzle passing, and rotor dynamic vibration.

The ORC Turbine shall be provided with a comprehensive machinery protection system. Details of the system shall be submitted during design review. Turbine vibration monitoring probes and bearing temperature RTDs are to be included. The Contractor shall identify where their design does not comply with the mandatory and recommended requirements of API 670 (Machinery Protection Systems).

A complete lubricating oil system shall be provided complete with necessary, fully redundant oil pumping capacity including as necessary shaft, AC and DC motor driven pumps, two 100 per cent capacity oil coolers, two 100 per cent capacity oil

filters, one main oil reservoir, one oil purifier, all required supply oil and drain line piping. Drain trays or equivalent containment shall be provided under all lube oil system equipment. The lubricating system shall be so arranged as to ensure safe run down of the ORC turbine without damage to bearings on loss of all normal electrical supplies

The Contractor shall also supply one complete barring gear system, all instrumentation (both local and remote) and one set of special tools.

The following requirement shall be applied to the turbine equipment.

#### 13.2.3.1 Strainers

The Contractor shall provide the Turbine filters and strainers with the following requirements:

The ORC turbine filter shall be design to increase the turbine lifetime avoiding the introduction of external bodies in the turbine inlet and to ease operation and maintenance of the binary power plant.

The ORC turbine filter shall be in accordance with the turbine manufacturer's recommendations.

The ORC turbine filter shall be provided on each inlet leg upstream of the emergency stop valve.

Provision for measurement of differential pressure across the filters shall be provided if required.

The Contractor shall provide the following filters and strainers with the following requirements:

1. Feed Pump Suction Filter

   Basket type strainers upstream the Feed Pump shall be provided in accordance with the feed pump manufacturer's recommendation.

   Provision for measurement of differential pressure across the strainers shall be made.

2. ORC Drain System strainers

   ORC Drain System strainers shall be provided.

3. Other minor ORC strainers

   Other minor ORC strainers shall be provided.

#### 13.2.3.2 Safety Features

ORC turbine trips shall be initiated by the following events as a minimum:

1. Emergency Manual (local, control room initiation)
2. Overspeed (redundant electronic)
3. Low vacuum
4. Excessive vibration/rotor axial position
5. Differential expansion – Subject to review as part of HAZOP/FSS
6. High working fluid level in scrubber or demister vessel
7. High condenser working fluid level in the turbine

8. Generator protection trip
9. High turbine exhaust hood temperature
10. High bearing temperature – Subject to review as part of HAZOP/FSS
11. Low lube oil supply pressure

### 13.2.4 Heat Exchangers

The Heat Exchangers shall operate on a continuous basis, apart from periodic maintenance shutdowns.

Heat exchangers shall be arranged to allow for easy drainage during maintenance inspections, in-situ inspection and chemical cleaning. Design and fabrication of heat exchangers shall be in accordance with TEMA standards.

The Contractor shall determine heat exchanger configurations to:

1. Achieve cost-effective conversion of the heat in the geothermal fluid
2. Meet plant performance requirements
3. Provide an overall plant layout that fits within the available site area and affords ready access to main equipment for O&M of the plant.

Consideration shall be given to the material selection suitable for the various fluids that will contact the shell and the tube for the various heat exchangers.

Heat Exchangers design shall avoid the possibility of flow induced vibrations in heat exchanger tubes.

The Contractor shall propose the following main heat exchangers, as they determine appropriate:

1. Pre heaters

   The preheater shall be required to preheat the binary cycle working fluid using cooled geothermal fluid after it leaves the vaporiser. Preheated working fluid will then be supplied to the evaporator.

   The preferred configuration shall be for a TEMA type BEM or BFM arrangement. Geothermal fluid shall be on the tube side. The shell shall be of carbon steel, and tubes and tube sheet shall be duplex stainless steel Type 2205 or better. Tubes shall be expanded into the tube sheet, and seal welds shall be used to ensure a high degree of leak-tightness.

   The Contractor shall advise on the design strategy for achieving the required duty, e.g. use of low fin tubes, proposed variations to material selections, finishing etc.

   The Contractor shall state the hydrocarbon and geothermal fouling factor in $m^2$.K/W that they intend to use for heat exchanger thermal design, which shall be based on the Contractor's previous experience.

   The preheater unit shall be installed with slight fall to facilitate draining of geothermal fluid for maintenance.

2. Evaporators

   The evaporator shall be required to fully preheat and vaporise the ORC working fluid using high temperature geothermal fluid that will be supplied from the gathering system. Once vaporised and demisted, the working fluid vapour will be fed to the turbine.

The preferred configuration shall be for a Kettle type unit (TEMA Type BKM), with expansion bellows integral to the shell. Geothermal fluid shall be on the tube side. The shell shall be of carbon steel, and tubes and tube sheet shall be duplex stainless steel Type 2205 or better. Tubes shall be expanded into the tube sheet, and seal welds shall be used to ensure a high degree of leak-tightness.

The Contractor shall advise on the design strategy for achieving the required duty, e.g. use of low fin tubes, proposed variations to material selections, finishing etc.

The Contractor shall state the hydrocarbon and geothermal fouling factor in $m^2$.K/W that they intend to use for heat exchanger thermal design, which shall be based on the Contractor's previous experience.

The Contractor shall supply the knockout pot for separation of geothermal fluid NCGs after the vaporizer, if required.

3. Recuperators

The Recuperator shall be required to desuperheat the ORC working fluid at turbine exhaust by heat transfer in a shell and tube heat exchanger with cool ORC working fluid from the condenser.

The preferred configuration for the recuperator is a two tube pass shell, fixed tube sheet (TEMA Type BXN). The shell, tubes and tube sheet shall be of carbon steel. Tubes shall be expanded into the tube sheet.

The Contractor shall advise on the design strategy for achieving the required duty, e.g. use of low fin tubes, proposed variations to material selections, finishing etc. The Contractor shall state the fouling factors in $m^2$.K/W that they intend to use for recuperator thermal design, which shall be based on the Contractor's previous experience.

Heat exchangers will process geothermal fluids and due to the possibility of geothermal scale formation, the heat exchanger shall be designed for routine mechanical cleaning (rodding and/or water jetting), and the periodic chemical cleaning.

Where possible the length of the heat exchangers shall be limited to 12 metres in order to facilitate easy delivery.

The ID of tubes shall not be less than 20 mm.

Surfaces exposed to geothermal fluids including tube and tube plate shall be duplex stainless steel 2205 or better.

### 13.2.5 Working Fluid Pumps

The Contractor shall supply 2 x 100% working fluid feed pumps, to operate in a duty/standby configuration. Change over between the duty and standby pumps shall be selectable by the operator on the plant control system HMI.

The hydrocarbon working fluid pumps shall be vertical shaft, multistage, mixed flow, can pump, designed, manufactured and tested in accordance with API 610. Particular attention shall be paid to the selection of pumps and their materials of construction for the specific application.

The drive motor shall be close coupled to the pump shaft. Thrust loads from the pump shall be absorbed by thrust bearing(s) within the pump, and not transferred to the drive motor.

Pumps shall be capable of operating continuously over their full operating range without overheating, cavitating, excessive noise or vibration, surging or instability when operating in single or in parallel with other pumps. Pumps shall be selected for maximum efficiency at the design condition and shall have a head/flow curve that rises steadily from rated flow to shut off. Pumps shall either be installed with a flooded suction or shall be self-priming.

Pumps shall be supplied with oil flooded bearings and self-oilers.

Pumps shall be selected with a pump suction specific speed of less than 15,000 as a preference – the Contractor will confirm the specific speed value following detailed design for review during design review.

Double mechanical seals shall be used on all pumps. The mechanical seals and sealing technique must not allow any leakage of the working fluid and be based on Contractor's previously proven experience in binary applications. Shaft seals shall follow API 682 (ISO 20149) and be tandem seals with a standard pressurized barrier fluid seal flush Plan 53B. Pumps and motors above 15 kW shall be coupled and assembled on a common base.

Pumps shall be installed with an adequate NPSH margin to ensure that the pump operates without cavitating over the full range of flows and suction level conditions. For continuous duty, pumps driven at no more than 1500 rpm are preferred. All pumps shall be close coupled without gearboxes.

All pump bearing housings, shall be fitted with surfaces suitable for the fitting of portable vibration sensing transducers.

All equipment shall be designed to permit rapid and economical maintenance. Major parts such as casing components and bearing housings shall be designed and manufactured to ensure accurate alignment on reassembly.

Working fluid feed pumps shall be operated by VSD to control vaporiser working fluid level while managing parasitic load at off design conditions.

The Contractor shall consider the possibility to install the condensate pump (1 x 100% per unit) including interconnecting piping, control and manual isolation valves, instruments, etc., assuming pumping into the brine line ahead of the preheater or to a separate storage tank for recovery.

### 13.2.6 Air Cooled Condensers and Auxiliary Cooling Systems

Each Unit shall include independent condensers and cooling systems to facilitate independent, modular Units.

The Contractor shall provide Air Cooled Condensers. In this condenser technology selection the Contractor shall consider the Power Plant space limitations.

The condenser shall be equipped with level control facilities to prevent the working fluid pumps from cavitating due to insufficient NPSH requirements.

The Air Cooled Condenser (ACC) shall be based on the Contractor 's standard design.

The Contractor shall state the air and hydrocarbon fouling factors in $m^2$.K/W that they intend to use for condenser thermal design, which shall be based on the Contractor's previous experience.

Fan drive assemblies shall be designed and fabricated to provide sustained accurate alignment. Adjustment of alignment, tension and replacements of drive belts shall be easily carried out.

Each condenser shall comprise sufficient bay numbers for the required load including design margin. The DCS shall provide the ability for individual ACC fans to be switched on or off in order to manage parasitic loads as the unit operates at various loads; the fans shall be selected so as to not adversely impact NCG dispersion.

The condenser shall be an induced or force draft air cooled heat exchanger. The fan motor and drive assembly shall be mounted below the air cooler tube bundles, to permit replacement of drive components from the ground with suitable lifting equipment. Fans shall mount in the plenum chamber above the tube bundles and shall be selected to avoid resonant vibration of the fan assembly and the surrounding air cooler structure.

Fan motors shall be controlled by VSDs and all fans in a row shall operate at the same speed.

Fans shall control the condensate pressure to achieve optimum plant net power production.

The condensers/air coolers for the motive fluid shall be designed, manufactured and tested to ASME standard as the minimum requirement. The tubes shall be aluminium finned carbon steel arranged in a one-pass configuration. Any deviation from this standard shall be to the written approval of the Project Manager.

The Contractor shall use low noise fans in the construction of the ACC.

The ACC shall be provided with an automatic air purge system to vent trapped air while avoiding loss of hydrocarbon working fluid.

The following documentation shall be provided for all air-cooled heat exchangers:

1. Noise data sheets
2. Fan performance curves
3. Belt drive design
4. Weld quality documentation including welder qualifications, welding procedures used,
5. Weld procedure qualification records, documentation for welders qualifying to the procedures used, copies of any NDT undertaken
6. All heat exchangers shall undergo a sensitive leak test to a recognised code that must be submitted for approval to the Employer prior to testing.

The external auxiliary cooling water system shall guarantee the heat removal of the generator coolers and other auxiliary thermal loads if required.

Cooling water flow shall be guaranteed by two 100 per cent duty circulating Auxiliary Cooling Water (ACW) supply pumps at fixed speed.

The heat shall be transferred to the cooling water by two 67 per cent heat exchangers and discharged with fin fan dry coolers equipped with fans.

The cooling water system shall be a close circuit and clean water make up, and blow down shall be provided.

Fans shall start and stop by the DCS to regulate dry cooler outlet temperature.

The pumps' casing and impeller shall be sized together to allow for an increase or decrease in pump head at design flow of 10 percent by change in impeller.

The ACW supply pumps shall be single-stage, electric motor-driven centrifugal pumps, to API610, or approved equivalent. All wetted parts shall be of AISI 316L stainless steel or approved equivalent.

The pumps shall be provided with check valves to enable the standby pump to be left ready to start automatically on duty pump stop or failure.

The stand-by pump shall start automatically on low ACW system pressure.

Duplex strainers shall be provided downstream of the pumps.

### 13.2.7 NCG Extraction System

The following requirements shall be provided per Unit.

All NCG extraction equipment shall be fabricated from 316L stainless steel or better.

The gas extraction system shall be designed to:

- be flexible to allow for changes in the NCG content. All venting equipment shall be conveniently arranged for maintenance and operation and be accessible from platforms or floors.
- Vent the NCG and discharge at a suitable height. The NCG discharge shall be fully dispersed with the air, shall not cause elevated gas concentration at ground level or any areas occupied during operation and maintenance, shall comply with health and safety standards and meet The Employer's environmental requirements.
- The NCG discharge shall be liquid-free. The discharge piping shall be fabricated from 316L stainless steel and/or FRP.
- Distribution shall be located at a suitable location to ensure adequate dispersion.
- NCG piping shall be sloped to avoid pocketing wherever possible.
- Where local low points cannot be avoided, drains with loop seals shall be provided.

Sample ports shall be provided for sampling non-condensable gases.

### 13.2.8 Hydrocarbon working fluid

The hydrocarbon working fluid process design, handling and storage facilities shall be designed to address the hazardous nature of the working fluid. Local Dominican and relevant international standards shall be adhered to.

Hydrocarbon storage facilities shall be designed to ASME Boiler and Pressure Vessel Code Section VIII (Div 1). The Contractor shall obtain all required approvals for the use of hydrocarbon working fluids on Site.

### 13.2.9 Hazardous Area Requirements

The Contractor shall provide drawings defining the electrical classifications throughout the Facilities. Such classifications shall include considerations of $H_2S$.

Electrical equipment located within any defined hazardous areas shall be selected to comply with the area and temperature classification of the flammable agent therein. The protection technique employed to achieve this shall be in accordance with the IEC 60079 series of standards.

The immediate area surrounding the equipment which contains the working fluid is a hazardous area, and all equipment within the hazardous area shall be rated Ex 'd' or Ex 'i' for safety purposes.

Wherever possible, Ex i shall be used as the protection method in order to minimise disruption to maintenance. Where Ex i is used, care shall be taken to ensure the segregation of Ex cables and terminals from non Ex cables and terminals is strictly adhered to. Where the Contractor proposes an alternative method, this shall be agreed with the Employer.

Hazardous area drawings and classification information shall be submitted with the design report.

# Part 2 - Employer's Requirements

Section VII - Employer's Requirements

# 3. Interface Schedule

# Interface Schedule

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# 1. Introduction

The Contractor shall contribute to maintaining the Interface Schedule, based on this document, for the duration of the Contract. The Employer will retain overall control, but will require the Contractor to provide information to maintain an up-to-date schedule.

The Interface Schedule identifies both physical and “soft” interfaces (e.g. provision of design information), in sufficient detail and with sufficient breakdown to allow effective interface management by the applicable parties.

The Interface Schedule includes the following details for each interface point as appropriate:

- Reference
- Title
- Location (by reference to drawing)
- Physical parameters or definition
- Party responsible for making the connection
- Date by which the interface is to be ready (connected to/information provided)

The Contractor shall submit the information as required to fully define each interface such that the other interested parties have sufficient information to execute their works in a timely manner and without rework. The Contractor is fully responsible for the accuracy of the information they provide. The Contractor shall submit an initial update to the schedule within 28 days of the Effective Date.

# 2. Interface Schedule

The interface schedule below defines the interface details between the Employer, the Contractor and DOMLEC.

The following abbreviations are used:

- E - Employer
- C - Contractor
- D - DOMLEC

| Item | Interfaces | Interface Detail | | | | |
|---|---|---|---|---|---|---|
| | | Details | Clause | Location | Affected Parties | Responsible Party |
| **1.** | **Civil & Structural** | | | | | |
| 1.1. | Right of Access to the Site | N/A | 3.1.1 below | Site | E/C | E |
| 1.2. | Main Access to Site | Contractor to upgrade / maintain | 3.1.2 below | Site | C/E | C |
| 1.3. | Stormwater drainage disposal | Discharge from stormwater collection system to natural feature | 3.1.3 below | Site | C/E | C |
| 1.4. | Foul water disposal | Discharge from wastewater treatment system to site leach field | 3.1.4 below | Site | C/E | C |
| 1.5. | Laydown / Spoil | Area indicated within Site for laydown and spoil | 3.1.5 below | Site | C/E | C |
| 1.6. | Site Boundary | Site boundary | 3.1.6 below | Site | C/E | E Defines for C to work within |
| **2.** | **Process / Mechanical** | | | | | |
| 2.1. | Two phase, design data | Piping terminal points | 3.2.1 below | Site | E/C | E provides data for C design |
| 2.2. | Two phase, construction | Piping terminal points | 3.2.1 below | Site | C/E | C connects to E wellhead |
| 2.3. | Reinjection, design data | Piping terminal points | 3.2.2 below | Site | E/C | E provides data for C design |
| 2.4. | Reinjection, construction | Piping terminal points | 3.2.2 below | Site | C/E | C connects to E wellhead |
| 2.5. | Raw water supply | Raw water supply location and permit | 3.2.3 below | Site | E/C | E |
| 2.6. | Raw water supply | Raw water intake structure and supply to site | 3.2.3 below | Site | C/E | C |
| **3.** | **Electrical** | | | | | |

| Item | Interfaces | Interface Detail | | | | |
|---|---|---|---|---|---|---|
| | | **Details** | **Clause** | **Location** | **Affected Parties** | **Responsible Party** |
| 3.1. | Connection to DOMLEC Grid | DOMLEC to install transmission underground cables up to the interface points. Interface at the Power Plant switchgear outgoing connection busbars. | 3.3.1 below | Site and DOMLEC Transmission | D/C | D |
| 3.2. | Construction power supply | Contractor to provide diesel generators for construction. | 3.3.2 below | Site | C | C |
| 3.3. | Injection wells power supply | Contractor to interface to local DOMLEC 415V distribution network. | 3.3.3 below | Site | D/C | C |
| **4.** | **Communications / Control & Instrumentation** | | | | | |
| 4.1. | DOMLEC fibre and communications | DOMLEC fibre patch panel | 3.4.1 below | Site | C/E/D | D |
| 4.2. | 11kV Switchgear controls and supervision | SCADA interconnect between DOMLEC RTU panel and site 11kV grid connection switchgear | 3.4.2 below | Site | C/D | D |
| 4.3. | IP Telephones | Termination point for IP PABX extensions including testing and commissioning | 3.4.3 below | Site | E/C | C |
| 4.4. | Fibre link for DCS remote supervisory communications | Design, installation, testing and commissioning | 3.4.4 below | Site | E/C | C |
| 4.5. | Remote CCTV interface | Fibre connections for the DGDC remote CCTV monitoring | 3.4.5 below | Site | E/C | C |
| **5.** | **Noise** | | | | | |
| 5.1. | Plant boundary | Location of noise limits | 3.5.1 below | Site | E/C | C |

# 3. Interface Details

## 3.1 Civil and Structural

### 3.1.1 Right of Access to the Site

Access to the Site including proposed Laydown areas is as shown on the General Project Plan drawing. In accordance with the General Conditions of Contract, Employer shall provide access to and possession of the Site.

### 3.1.2 Main Access to Site

Main access to the Site will be via the upgraded roadway that the Contractor shall provide. Suitable roadway upgrades to approximately 625m of access road from Laudat to the existing well pad site as indicated in the GIS extract figure below.

The indicative area for main access to the Site is indicated on the preliminary Bid drawings.

### 3.1.3 Stormwater Disposal

Stormwater from the Facilities shall be drained to discharge into the Site and surrounding environment and natural waterways without the concentration of flows and in compliance with the requirements of the Employers Requirements.

### 3.1.4 Foul Water Disposal

Foul water from the Facilities shall be treated (as required to comply with the Employers Requirements) and then shall be discharged within the Site via a leachfield. Contractor to design acceptable locations.

The indicative area for Foul Water Disposal is indicated on the preliminary Bid drawings.

### 3.1.5 Construction Laydown Area

Space required by the Contractor for construction laydown and temporary topsoil / cut material laydown shall be managed as required by the Contractor within the Site extent indicated on the drawings, specifically the areas labelled “Proposed Laydown Area & Spoil”.

### 3.1.6 Site Boundary

The project Site Boundary is defined in Appendix B. Site Boundary

The pipeline corridor for the cross-country brine line shall be 5m either side of the pipeline IP points stated in Appendix B. Site Boundary unless noted otherwise on the drawings.

## 3.2 Process/Mechanical

### 3.2.1 Production Well: WW-P1

The data in this section 3.2.1 indicates the expected process output of the production well and construction interface at the production well WW-P1. Well production curves are presented in Appendix A to this document.

The location of WW-P1 is indicated on the drawings.

### 3.2.1.1 Process Data at Production Well

| Item | Well WW-P1 | Unit |
|---|---|---|
| 1. **Fluid** | Steam, Brine & Geothermal Gases | |
| 2. **Mass Flow** | | |
| 2.1 Two Phase Maximum | 100 | kg/s |
| 2.2 Two Phase Flow – Operational – NCR | 90 | kg/s |
| 3. **Enthalpy** | | |
| 3.1 Normal – NCR | 1,060 | kJ/kg |
| 3.2 Long term | 1,200 | |
| 4. **Pressure** | | |
| 4.1 Operating pressure at wellhead wing valves-NCR | 6.0 | bara |
| 4.3 Maximum non-operating (shut-in) | 55 | barg |
| 5. **Non Condensable Gas (NCG) in Brine, Steam and NCG flow** | | |
| 5.1 Separation Pressure (SP) – Employers Concept Design | 5.5 | bara |
| 5.2 Design NCG – NCR | 0.5% | Weight percent @ SP |
| 5.3 NCG Range | 0 – 3% | |
| 6. **Composition of NCG** | | |
| 6.1 Carbon Dioxide ($CO_2$) | 94 - 96 | Percent weight in dry gas |
| 6.2 Hydrogen Sulfide ($H_2S$) | 3 - 5 | |
| 6.3 Nitrogen ($N_2$) | 1 - 2 | |
| 6.4 Hydrogen ($H_{2)}$ | 0 - 0.1 | |
| 6.5 Methane ($CH_4$) | 0 - 0.1 | |
| 6.6 Ammonia ($NH_3$) | 0 - 0.1 | |
| 7. **Impurities in separated brine (note 1)** | | |
| 7.1 Separation Pressure (SP) – Employers Concept Design | 5.5 | bara |
| 7.2 Sodium | 1800 – 2000 | ppm weight in brine @ SP |
| 7.3 Potassium | 270 – 300 | |
| 7.4 Calcium | 60 – 70 | |
| 7.5 Silica | 540 – 580 | |
| 7.6 Boron | 40 – 45 | |
| 7.7 Chloride | 3200 – 3500 | |
| 7.8 Sulphate | 20 – 25 | |
| 7.9 TDS | 6000 – 6500 | |
| 8. **pH** | | |
| 8.1 Steam Condensate | 6 – 6.5 | pH @ 25 $^oC$ |
| 8.2 Brine | 6 - 8 | |

.

*Note 1: Using normal & long term enthalpy and 13/6 & 15/6 reservoir data*

### 3.2.1.2 Mechanical Characteristics of Interface

| Item | Well WW-P1 | Unit |
|---|---|---|
| 1. **Wellhead Location** (Note 1) | | |
| 1.1 Northing | 1,695,567 | mN |
| 1.2 Easting | 679,461 | mE |
| 1.3 Elevation (Wellpad) | 549.5 | mASL |
| 2. **Wellhead Design Pressure** | 116 | barg |
| 3. **Wellhead Design Temperature** | 323 | $^{o}$C |
| 4. **Thermal growth** | 300 | mm |
| 5. **Master Valve Nominal Size** | 300 | mm NB |
| 6. **Master Valve Pressure Class** | 900 | |
| 7. **Wellhead Pipe Material** | Carbon steel | |
| 8. **Interface Connection** | Top Flange of Well Master Valve and wing valves (RTJ to ASME B16.5) | |

*Note 1: Location information shall not be relied upon for design. Contractor to survey all wells to confirm location.*

### 3.2.2 Injection Wells

The data is this section 3.2.2 indicates the indicative well injectivity. Well curves are presented in Appendix A to this document.

The pH figures are the required pH ranges that the Contractor must achieve at each well through the design of the Plant in order to ensure the injection wells are not compromised.

#### 3.2.2.1 Data for Brine and Condensate Injection Wells

| **Item** | **Well WW-03** | **Well WW-01** | **Well WW-R1** | **Unit** |
|---|---|---|---|---|
| 1. **Fluid** | Condensate (@40 ° C) | Brine (@ 160°C) | Brine (@ 160°C) | |
| 2. **Injection Capacity** | | | | |
| 2.1 Injectivity | 53 | 11.4 | 2.5 | kg/s-bar |
| 2.2 Capacity at 0 barg | 60 | 16 | 0 | kg/s |
| 2.3 Capacity at 10 barg | - | 29 | 4 | |
| 2.4 Capacity at 20 barg | - | 41 | 27 | |
| 2.5 Capacity at 30 barg | - | - | 48 | |
| 3. **pH** | | | | |
| 3.1 Range | > 5 | 6 - 8 | 6 - 8 | |
| 4. **Pressure** | | | | |
| 4.1 Maximum non-operating (shut-in) | 55 | 20 | 55 | barg |
| 4.2 Minimum operating pressure (at wellhead) | Full vacuum | Full vacuum | Full vacuum | |
| 4.3 Maximum operating pressure (at wellhead) | WW-P1 steam relief pressure plus static head to WW-03 | Design must result in pressure not greater than 20 barg at 190 Deg C.<br><br>Must not be greater than 18.9 barg at 160 Deg C.<br><br>Must not be greater than 17.5 barg at 120 Deg C. | WW-P1 steam relief pressure plus static head to WW-R1 | |

### 3.2.2.2 Mechanical Characteristics at Interface to Injection Wells

| Item | Well WW-03 | Well WW-01 | Well WW-R1 | Unit |
|---|---|---|---|---|
| 1. **Wellhead Location** (Note 1) | | | | |
| 1.1 Northing | - | 1,694,864 | 1,694,334 | mN |
| 1.2 Easting | - | 678,302 | 677,321 | mE |
| 1.3 Elevation (wellpad) | 543 | 241 | 178 | mASL |
| 2. **Wellhead Design Pressure** | 116 barg down to full vacuum | 116 barg down to full vacuum but well limited to 20 barg | 116 barg down to full vacuum | |
| 3. **Wellhead Growth** | 50 | 50 | 50 | mm |
| 4. **Master Valve Nominal Size** | 250 | 250 | 300 | mm NB |
| 5. **Master Valve Pressure Class** | 900 | 900 | 900 | |
| 6. **Wellhead Pipe Material** | Carbon steel | | | |
| 7. **Interface Connections** | Top Flange of Well Master Valve and wing valves (RTJ to ASME B16.5) | | | |

*Note 1: Location information shall not be relied upon for design. Contractor to survey all wells to confirm location.*

*Note 2: The Bid Bills of Materials (BOM) provided in drawing RZ042100-BM-DRG-0010 includes the piping estimates for the main cross-country brine reinjection route as indicated on drawings RZ042100-ME-DRG-0110 through RZ042100-ME-DRG-0120 inclusive. The BOM does not include piping, pipe fittings and pipe supports required within the reinjection wellpad perimeters at WW-01 and WW-R1.*

### 3.2.3 Raw Water Supply

This raw water section applies to the water required for construction supply and permanent supply for the Facilities.

#### 3.2.3.1 Raw Water Analysis

The Employer will provide analysis of the spring water. This will be made available to the Contractor.

#### 3.2.3.2 Stream Data at Interface

Raw water for construction and permanent works shall be drawn from a naturally occurring spring located at higher elevation above the site as indicated in the table below. The Employer will provide confirmation of the stream data prior to Contractor mobilising to site .

The Employer shall be responsible for obtaining the permit to use the water for construction and permanent works. The Contractor shall be responsible for the design, execution and completion of the raw water intake structure and piping required to transfer to Site.

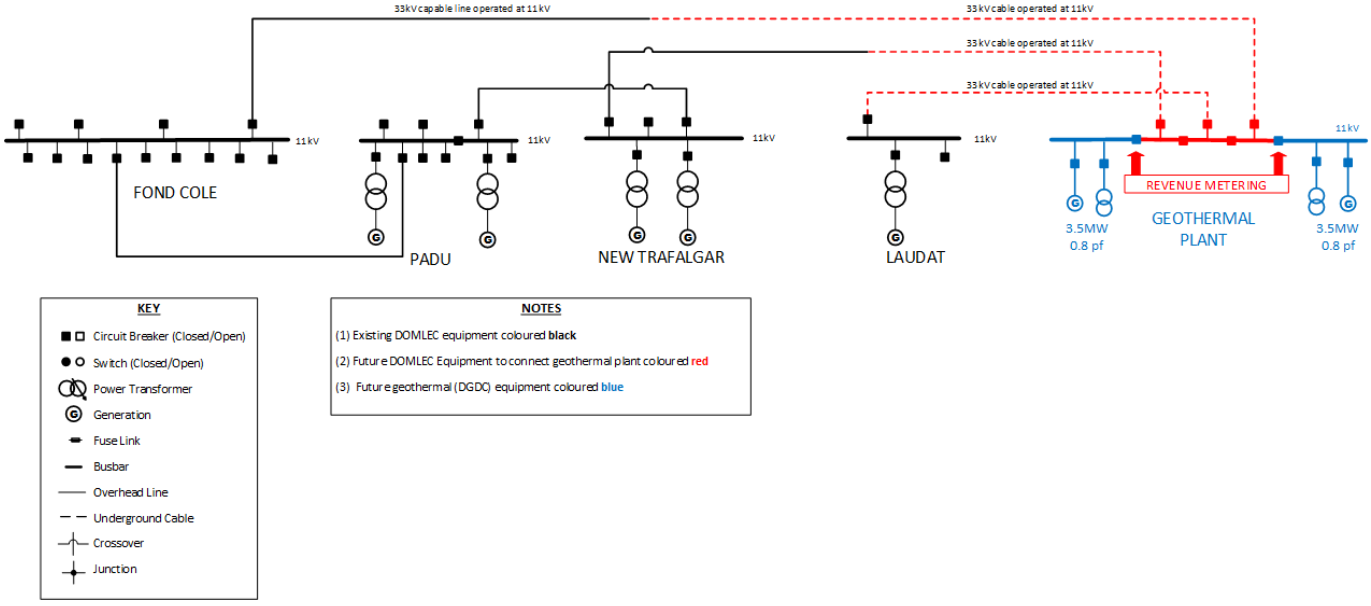
| Item | Natural Spring | Unit |
|---|---|---|
| 1. **Raw Water Source Location** | | |
| 1.1 Latitude | 15°19'58.20" | N |
| 1.2 Easting | 61°19'34.22" | W |
| 1.3 Elevation | 623 | mASL |
| 2. **Water take limits** | | |
| 2.1 Daily | 10,000 | Litres |
| 2.2 Monthly | 200,000 | Litres |
| 2.4 Maximum instant | 5 | Litres/s |

## 3.3 Electrical

### 3.3.1 Connection to DOMLEC Grid

DOMLEC will design, install, test and commission the 11kV transmission lines and terminate them on the busbars of the Site 11kV main interconnect switchboard. The transmission lines will be via three separate circuits installed underground from the Laudat Power Station and into the Site 11kV interconnect switchboard.

The transmission lines will service the "New Trafalgar" , "Fond Cole" and "Laudat" circuits. The figure provided below indicates the connection arrangement of the geothermal power plant within the DOMLEC grid.




Once the Contractor's MV switchroom and associated switchgear are ready for connection to the transmission lines, the Contractor will coordinate with DOMLEC for DOMLEC to install the underground cables into the switchgear and for DOMLEC to terminate, test and commission the interconnection.

### 3.3.2 Construction Power Supply

Contractor provided diesel generators.

### 3.3.3 Brine Reinjection Wells' Power Supply

The point of connection shall be the DOMLEC local revenue metering enclosure and fuse links located at each wellpad site boundary. Contractor shall be responsible for requesting connection from DOMLEC.

## 3.4 Communications

### 3.4.1 Fibre and communications panel

DOMLEC shall provide and install a fibre and communications panel within the 11kV switchroom on Site. This includes the fibre cable between the Laudat Hydro-station and the fibre communications panel. The point of connection between this panel and the Contractor's services shall be the fibre bayonet fittings located within the DOMLEC fibre and communications panel. This panel shall be the fibre interface panel for the following services:

1. RTU communications' fibre connections to the DOMLEC RTU panel.

2. 11kV electrical protection signalling for the differential and other electrical protection for the three grid interconnection circuits.

### 3.4.2 Communication Interface between the 11kV switchgear and DOMLEC RTU panel

DOMLEC will provide and install an RTU panel with discrete interfaces to control and supervise the 11kV grid interface switchgear. The interface points for the RTU field connections to switchgear and relays shall be the outgoing field terminals within the DOMLEC supplied and installed RTU panel.

### 3.4.3 IP Telephones

The Site telephone PABX system provided by the Contractor shall be connected via fibre connections to the Dominica public telephone system. The point of connection shall be the local Dominica public telephone connection panel at the Laudat location.

### 3.4.4 DCS Remote Supervisory Data connection

The DCS remote supervisory point of connection shall be the local Dominica public internet connection panel at the Laudat location.

### 3.4.5 Remote CCTV data connection

The CCTV remote supervisory connection shall be the local Dominica public internet connection panel at the Laudat location.

## 3.5 Noise

### 3.5.1 Plant Boundary

The physical interface location for Plant noise measurements for guarantee purposes shall be the Site extent as indicated on the drawings.

# 4. Ambient Conditions

The following data is a summary of the Owner's metrological data (after excluding bad or missing data rows).

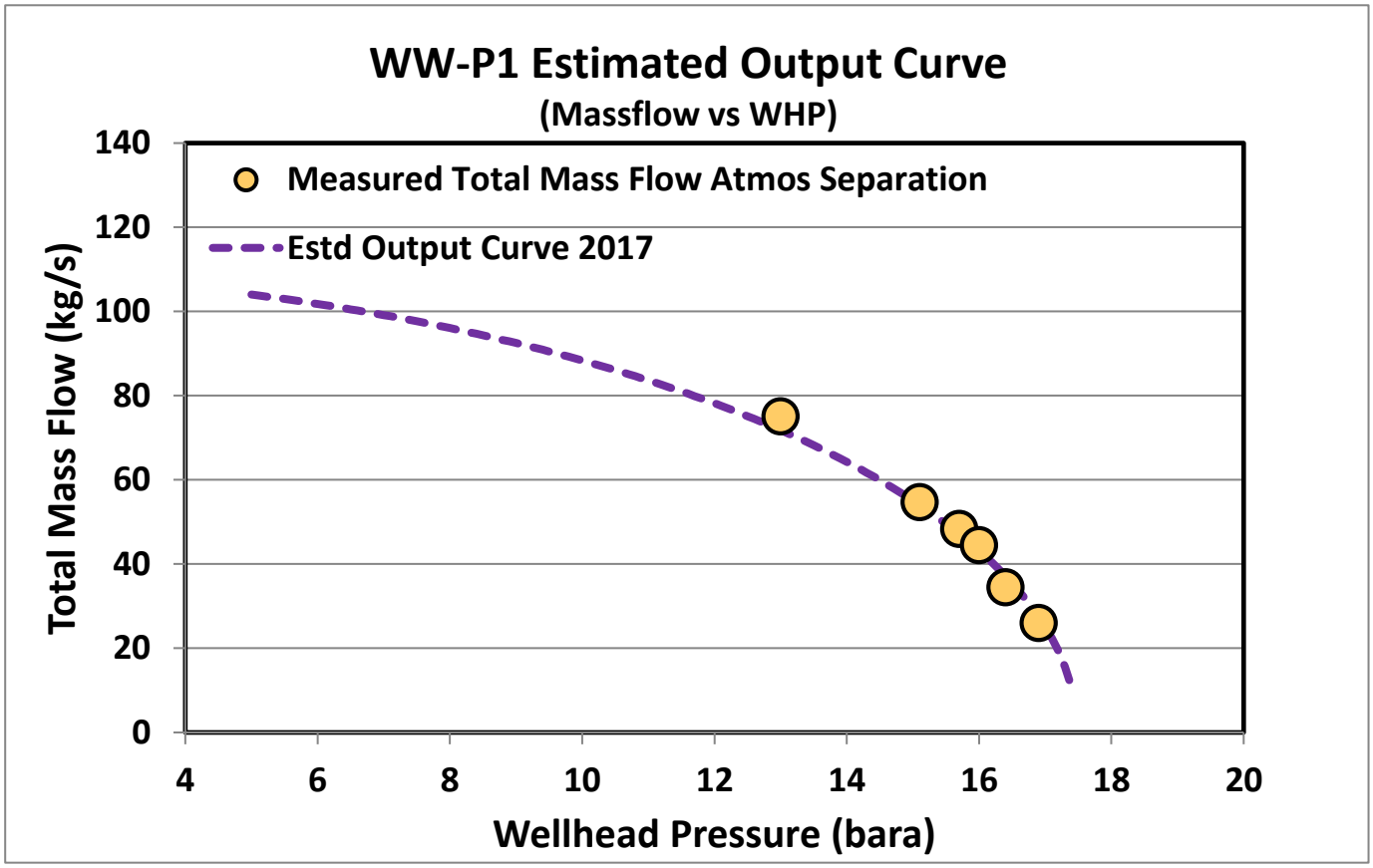
| | Value | Units |
|---|---|---|
| 1. Dry Bulb Temperature | | |
| Range (Minimum to Maximum) | 16 to 29 | °C |
| Average | 22 | °C |
| 5th percentile | 19.6 | °C |
| 95th percentile - NCR | 24.6 | °C |
| 2. Wet Bulb Temperature | | |
| Range (Minimum to Maximum) | 13 to 23 | °C |
| Average | 19 | °C |
| 5th percentile | 17.4 | °C |
| 95th percentile – NCR | 21.1 | °C |
| 3. Barometric Pressure | | |
| Average - NCR | 950 | mbar |
| Range (minimum to maximum) | 940 to 1090 | |
| 4. Rainfall (note 1) | | |
| Maximum | 190 | mm/day |
| Average | 10 | mm/day |
| 5. Average Relative Humidity | | |
| Average | 82 | % |
| 6. Wind Speed (see wind rose information below), Note 2 | | |
| 7. Seismic | | |
| Horizontal Seismic Coefficient | This shall be determined in accordance with the Employers Requirements. | |
| 8. Altitude of Power Plant Site Above Sea Level | ~560 | mASL |

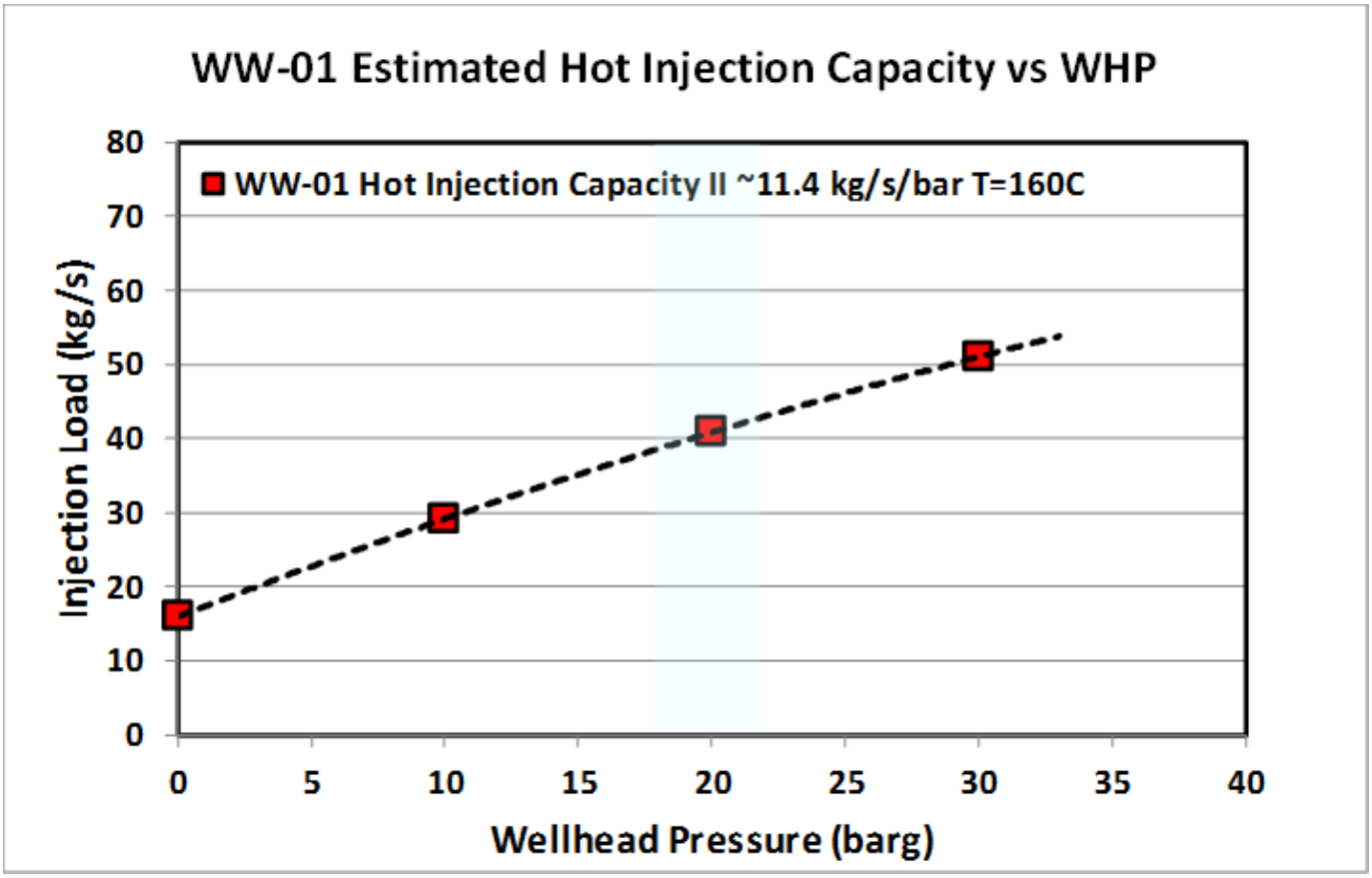
*Note 1: Please also refer to the weather data in Erika Study - Indirect Peak Discharge from Tropical Storm Erika.*

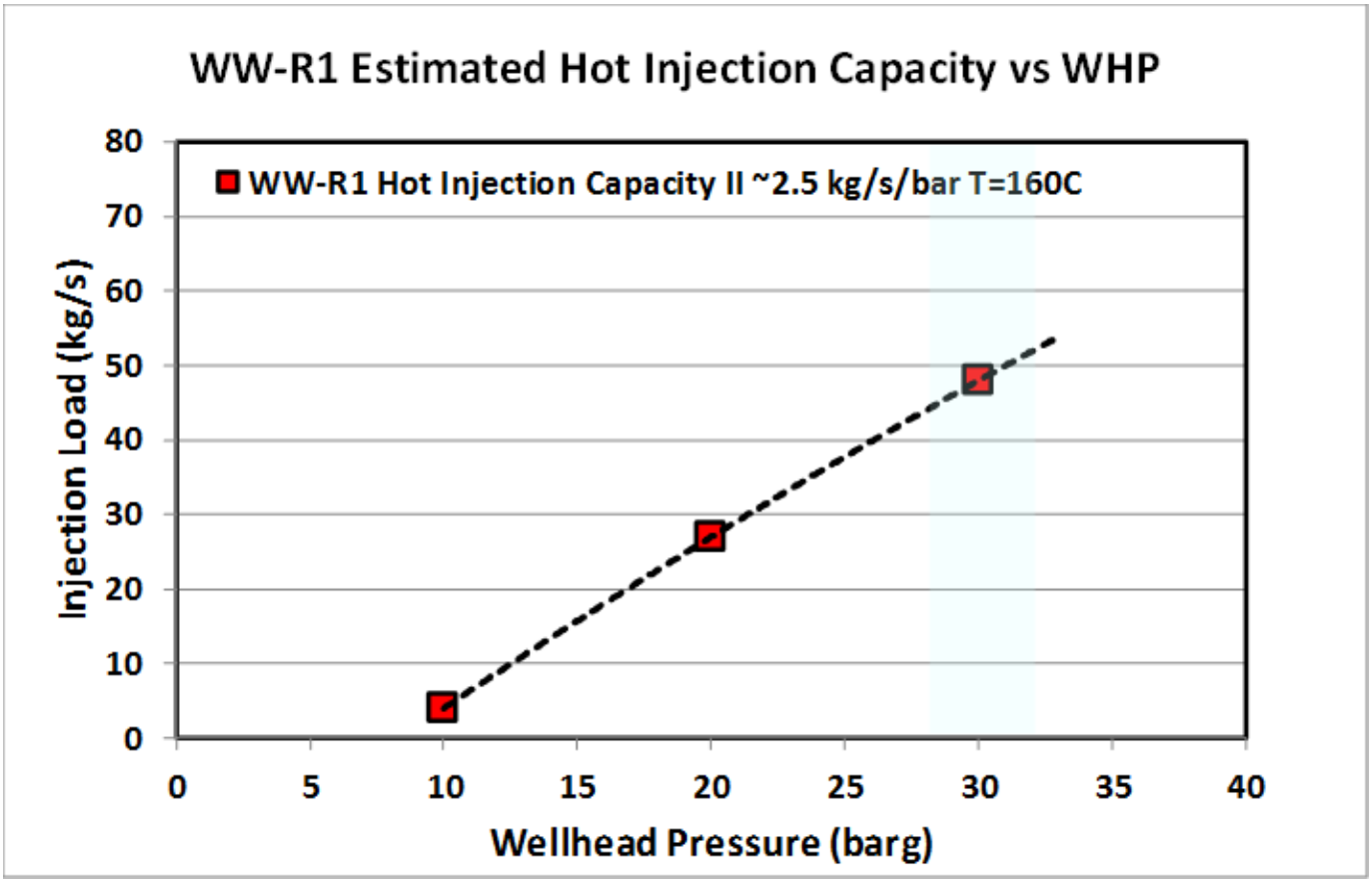
*Note 2: Contractor to note requirements for hurricane strength wind design requirements as outlined in the Specification.*

| Wind Direction and Speed | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Wind Speed (m/s)** | **E** | **N** | **NE** | **NW** | **S** | **SE** | **SW** | **W** | **Total** |
| 0-5 | 0.63% | 0.15% | 0.38% | 0.14% | 0.16% | 0.33% | 0.49% | 0.16% | **2.44%** |
| 5-10 | 5.91% | 0.22% | 1.85% | 0.17% | 0.59% | 2.69% | 0.30% | 0.30% | **12.02%** |
| 10-15 | 15.87% | 0.15% | 4.03% | 0.06% | 0.47% | 5.24% | 0.08% | 0.07% | **25.98%** |
| 15-20 | 19.31% | 0.07% | 4.57% | 0.01% | 0.20% | 4.48% | 0.02% | 0.01% | **28.66%** |
| 20-25 | 13.95% | 0.02% | 2.93% | 0.00% | 0.06% | 2.37% | 0.00% | 0.00% | **19.35%** |
| 25-30 | 6.36% | 0.01% | 1.23% | 0.00% | 0.01% | 0.90% | 0.00% | 0.00% | **8.51%** |
| 30-35 | 1.88% | 0.00% | 0.33% | 0.00% | 0.00% | 0.23% | 0.00% | 0.00% | **2.45%** |
| 35-40 | 0.38% | 0.00% | 0.05% | 0.00% | 0.00% | 0.05% | 0.00% | 0.00% | **0.48%** |
| 40-45 | 0.06% | 0.00% | 0.01% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | **0.08%** |
| 45-50 | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | **0.01%** |
| 50-55 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | **0.00%** |
| 55-60 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | **0.00%** |
| **Total** | **64.35%** | **0.62%** | **15.39%** | **0.39%** | **1.50%** | **16.31%** | **0.90%** | **0.55%** | **100.00%** |

# Appendix A. Well Curves




WW-01 Estimated Hot Injection Capacity vs WHP
WW-01 Hot Injection Capacity II ~11.4 kg/s/bar T=160C
Injection Load (kg/s)
Wellhead Pressure (barg)
0
10
20
30
40
50
60
70
80
0
5
10
15
20
25
30
35
40


WW-R1 Estimated Hot Injection Capacity vs WHP
WW-R1 Hot Injection Capacity II ~2.5 kg/s/bar T=160C
Injection Load (kg/s)
Wellhead Pressure (barg)
0
10
20
30
40
50
60
70
80
0
5
10
15
20
25
30
35
40

# Appendix B. Site Boundary

The following table summarises the project Site Boundary.

Refer to the following drawings for locations of the Site Boundary Nodes defined below:

- RZ042100-GN-DRG-0002
- RZ04200-ME-DRG-0100

| Site ID Point | Northing (mm) | Easting (mm) |
|---|---|---|
| PP-01 | 1 695 465 928 | 679 512 139 |
| PP-02 | 1 695 476 713 | 679 521 007 |
| PP-03 | 1 695 489 085 | 679 510 839 |
| PP-04 | 1 695 510 603 | 679 489 310 |
| PP-05 | 1 695 526 003 | 679 462 042 |
| PP-06 | 1 695 548 327 | 679 440 977 |
| PP-07 | 1 695 567 521 | 679 428 691 |
| PP-08 | 1 695 569 355 | 679 428 073 |
| PP-09 | 1 695 577 021 | 679 429 775 |
| PP-10 | 1 695 589 663 | 679 429 338 |
| PP-11 | 1 695 608 769 | 679 424 524 |
| PP-12 | 1 695 640 421 | 679 447 481 |
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# Part 2 - Employer's Requirements

Section VII - Employer's Requirements

# 4. DGDC Occupational Health & Safety Management Plan

Dominica Geothermal Development Company Limited
*Powering a New Generation...*

# Dominica Geothermal Development Company

## 7MW Geothermal Power Plant Project

## Occupational Health & Safety Management Plan

August 2018

Dominica Geothermal Development Company Limited
*Powering a New Generation...*

| | |
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# 1. Introduction

The Dominica Geothermal Development Company Ltd (DGDC) will develop and manage the operations of a geothermal power plant in the Roseau Valley, Dominica. The Project comprises the construction, completion, testing, commissioning, ownership and operation of geothermal wells, steam gathering and injection system, power plant with nameplate capacity of approximately 7MW and connection to the electrical grid.

This Occupational Health and Safety (OHS) Management Plan will assist DGDC staff to achieve a safe and healthy workplace for employees, Contractors and all those to whom DGDC has a duty of care over the life of the Project.

## 1.1 Purpose of the OHS Management Plan

The purpose of this OHS Management Plan is to:

1) Provide the OHS policies and systems applicable for the Project.
2) Outline the responsibilities for management of OHS activities of the various Project participants.
3) Provide the framework for the execution of all OHS activities.

The OHS Management Plan has been developed in line with the requirements of Dominican Legislation, World Bank, and International Good Practice (defined as the Occupational Safety and Health Administration [OSHA[1]]).

As the Project progresses, the OHS Management Plan will be revised and updated annaully. This process is designed to ensure that all parties involved in the Project team are aware of the latest methods and procedures in place.

## 1.2 DGDC OHS Policy & OHS Management Systems

Safety management is of paramount importance to DGDC, who is committed to developing and applying safe systems of work for its own work and for its projects. The DGDC OHS policy is defined in DGDC-OHS-002 Safety Policy & Commitment.

The Safety Management System and associated Safety Manuals define the procedures and actions within which all staff are required to work to ensure the Health and Safety Policy is implemented effectively. This includes:

- Actions to achieve a safe and healthy workplace.
- Actions to make sure activities undertaken are conducted in an environmentally responsible manner.
- Actions to adopt safe working practices at all times in all areas.
- The framework is based on the following principles:
  A. Philosophy – Safety will not be compromised. We expect safety leadership and accountability from everyone.
  B. Practice – Our safety standards are practiced in every project and geography.

[1] OSHA is the standard applied in this part of the world for countries that don't have a recognised HSE legislation.

C. People and Partners – We respect our people and empower them to think and adapt to make informed safety decisions.

D. Performance Improvement – We use knowledge, we learn, we improve to practice safety by design.

## 1.3 OHS Management Team

The main participants involved in the management of OHS activities for this Project are:

- Dominica Geothermal Development Company Ltd Board who are responsible for setting Policy and safety reporting.
- Owner's Team for the construction and operation of the Project. The Owner's Team comprises the following:
  - DGDC Project Manager, who is responsible for the overall health and safety management of the Owner's Team.
  - DGDC Safety Officer.
  - Owner's Engineer (Jacobs) Site Project Manager and site based staff.
  - Owner's OHS representative, who will be appointed by the Agence Francais de Developpement (AFD) to train DGDC staff and oversee implementation of OHS management systems.
- Engineer, Procure, Construct (EPC) Contractor who shall be responsible for the the safe design and construction of the Facilities. At site, the EPC Contractor will oversee all health and safety related activities.
- Operations & Maintenance Contractor(s), who are responsible for all health and safety related activities at site during the operational phase of the Project.

## 1.4 Key Performance Indicators

To encourage good OHS practices at site, the DGDC Team has set the following performance indicators and targets for the Project:

| Party | Indicator | Target |
|---|---|---|
| DGDC Team | Recording and monitoring of OHS performance | 1. Lost Time Injuries = 0<br>2. LTI frequency rate = 0<br>3. Medical Treatment Injuries = 0<br>4. Motor vehicle incidents = downward trend<br>5. Environmental Incidents = 0 |
| | Pro-active measures to maintain site OHS | 1. Weekly OHS walk downs – actions to be cleared prior to next walk down<br>2. OHS Audits – Audit actions addressed as planned.<br>3. OHS observations– minimum of 5 observations per month. |
| EPC Contractor | Recording and monitoring of OHS performance | 1. Lost Time Injuries = 0<br>2. LTI frequency rate = <0.5<br>3. Medical Treatment Injuries <25 over life of project |

| Party | Indicator | Target |
|---|---|---|
| | | 4. Motor vehicle incidents = downward trend<br>5. Environmental Incidents = 0 |
| | Pro-active measures to maintain site OHS | 1. OHS Inductions = 100% prior to starting on site. PPE issued.<br>2. Twice daily / semi continuous for the EPC Safety personnel OHS walk downs – actions to be cleared prior to next walk down.<br>3. OHS Audits – Audit actions addressed as planned.<br>4. OHS observations – Using observations – closing actions as agreed. |

# 2. Applicable Safety Regulations

The EPC Contractor, the DGDC Team, and any other project participant must comply via their respective OHS Plans with the relevant safety regulations as described below:

## 2.1 Statutory Regulations

- The principal statutory safety regulations[2] applicable to the Project in Dominica are:
- Employment Safety Act (No. 3 of 1982)
- Factory and Machinery Rules
- Noxious and Dangerous Substances (Control) Act, 1981 (No. 4 of 1982)
- Commonwealth of Dominica Constitution Order 1978 (S.I. No. 1027 of 1978) [consolidated version]
- Accidents and Occupational Diseases (Notification) Act, Chap. 89:51 (Act No. 29 of 1952) (Cap. 108 of 1961)
- Employment of Women, Young Persons and Children Act (L.f. 5 of 1938) (Chap. 90:06)
- World Bank Environmental, Health, and Safety (EHS) Guidelines.

### 2.1.1 Employment Safety Act (No.3 of 1982)

The Employment Safety Act is the principal piece of legislation in Dominica, which has the following objectives:

- Ensure the safety and welfare of workers in the construction industry.
- Protect the welfare of the general public within and around the immediate vicinity of the construction site.
- Promote harmonious employer-employee relationships in the construction industry.

It does this by specifying a number of requirements as listed below. These are provided for by this OHS management plan as noted:

1) Construction Safety and Health Management Control
   - Composition of safety committee
   - Specific safety policies
   - Penalties and sanctions for violation of safety and health rules
   - Education, training and orientation of workers
   - Proper waste disposal
2) Construction Safety and Health Program
   - Shall be executed and verified by the EPC Project Manager

[2] As identified by the International Labour Organisation: Occupational safety and health country profile: Dominica

- Shall be submitted to Bureau of Working Conditions which may approve, disapprove or modify according to existing laws, rules and regulations
- The cost of implementing the Construction Safety and Health Program shall be integrated in the Project cost

3) Safety Personnel
   - EPC shall have a full time safety officer (IOSH) as a minimum.
   - EPC shall provide additional safety officer(s) as required by Dominican Legisilation.
   - EPC shall provide one safety officer for every 10 items of heavy equipment.
   - Each subcontractor shall have their own qualified safety officer.
4) Personnel Protective Equipment
   - Every employer shall, at his own expense, furnish his workers with protective equipment for eyes, face, hands and feet, lifeline, safety harness, protective shields and barriers whenever necessary by reason of the hazardous work process or environment.

     As defined in DGDC-OHS-031: Personal Safety Equipment
5) Emergency Occupational Health Personnel and Facilities
   - EPC shall provide competent emergency health personnel within the worksite duly complemented with adequate medical equipment, supplies and facilities based on the total number of workers.
   - Ensure accessibility to the nearest hospital.

     As defined in DGDC-OHS-038: Emergency Procedures and DGDC-OHS-026: Contractor and Construction Safety
6) Construction Safety Signage
   - Construction safety signage must be provided to warn the workers and the public of the hazards existing in the workplace.
   - Signage shall be posted at strategic locations in the language understandable to workers.
   - Signage should be maintained in good condition.
7) Construction Heavy Equipment
   - Certification from the accredited organization for both equipment and operators.
   - Routine inspection and maintenance.

     As defined in DGDC-OHS-017: Plant, Systems and Equipment
8) Construction Safety and Health Reports
   - Monthly Construction Safety and Health Report (Summary of monthly health and safety committee meetings, accidents and investigations, and periodic hazard assessments and its remedial measures)
   - Major accidents or dangerous occurrence– notify DGDC Project Mananger without undue delay and local legislation within 24 hours.

- As defined in DGDC-OHS-039: Incident/Accident Reporting

9) Workers Welfare Facilities

- Adequate supply of safe drinking water.
- Adequate sanitary and washing facilities.
- Suitable living accommodations for workers.
- Separate sanitary, washing and sleeping facilities for men and women.

  As defined in DGDC-OHS-026: Contractor and Construction Safety

# 3. DGDC OHS Management

## 3.1 DGDC Responsibilities

The OHS responsibilities of the DGDC cover the following two distinct areas of management control:

1) Management of OHS risks that affect DGDC personnel and non-DGDC personnel (suppliers, subconsultants, etc).
2) Obligations and accountabilities of the Owner's Team - as defined in the contract scope of work between DGDC and the EPC contractor.

### 3.1.1 DGDC Responsibility to its People and Suppliers

In undertaking the work as the Owner, DGDC will manage immediate and longer term risks associated with the execution of the Project that affect its staff and persons within its care and control. The DGDC responsibility for the health, safety and security of DGDC staff and subcontractors includes:

- Consideration of travel and local off-site hazards.
- Developing Job Safety Environment Analysis for carrying out site inspection and monitoring duties.
- Participation in incident investigations, safety meetings, toolbox talks and the like.
- Complying with DGDC corporate safety reporting requirements.
- Providing visible leadership on safety matters, without detracting from the EPC Contractor's prime responsibility for the site.
- The legislation applicable to the work being undertaken.
- The management of OHS will be monitored, audited and reviewed to identify trends, measure conformance and drive continual improvement.
- Formulating a Safety Committee for the Project.

All non-DGDC personnel will be required to:

- Intervene and stop any unsafe acts or work practices observed
- Undertake all required minimum required training sessions
- Follow their supervisors' instructions with respect to OHS on the site
- Immediately report all actual and potential hazards, injuries and incidents to their supervisor
- Keep their amenities and work areas clean and tidy
- Comply with reasonable instructions given for the purpose of OHS
- Use personal protective clothing and equipment provided by their employer, and use it as instructed
- Not wilfully or recklessly interfere with or misuse anything provided for OHS on the site
- Not wilfully place at risk the health and safety of any person on the site

- Not wilfully injure one's self
- Behave in a manner that does not put any person or property at risk.

### 3.1.2 Obligations of Owner's Team

This OHS Management Plan recognises the EPC Contractor's accountability for site OHS, which includes but is not limited to security, entry control, induction, hazardous substance management, operating equipment standards of compliance, competency of all personnel and training, waste and environmental protection, PPE, incident reporting, emergency response, hazard identification, safe work practices , medical facilities, traffic control, authority liaison and compliance.

DGDC has responsibility to ensure that the EPC contractor is adhering to its responsibilities by:

- Conducting site OHS inspections (at least weekly). The criteria used in this inspection will be critical controls focussed and based on DGDC significant risk standards applicable to the phase of the Project.
- Conduction of site safety observations on a frequent basis. Outcomes from the safety observation process will be reported back to the EPC Contractor and filed on the Project record.
- Reviewing the EPC Contractor's construction hazard analysis, risk assessment and risk register carried out for any part thereof for its scope of works.
- The results of safety observations, audits and reporting will be monitored to identify any trends.
- The following regular communication vehicles are expected to be used at the Project by the EPC Contractor.
  - Tool box meetings
  - Weekly safety coordination meetings
  - OHS site committee meetings
  - EPC Contractor's progress and incident reporting
  - DGDC will participate in site OHS coordination and committee meetings, and will be involved in the investigation and reporting of incidents.

## 3.2 Owner's Team Roles

The key drive to the success of the OHS Plan is the commitment, involvement and accountability of Management and the Project team. The DGDC Project Manager and Safety Officer will oversee all Project health and safety related activities which will include, as a minimum, the following:

- Proactively instill a strong safety culture for all site-based operations and personnel.
- Reviewing, implementing and monitoring performance against the EPC Contractor's OHS Plan and DGDC Safety Manual. DGDC shall monitor the activities of the EPC Contractor and any other third parties to ensure that the requirements of any health and safety plan, and / or any relevant health and safety regulations are enforced.
- Review and provide comments to the safety procedures that are being carried out by the EPC Contractor on an ongoing basis.

- Regular auditing of the EPC Contractors' health and safety related activities and follow through with the EPC Contractors on any findings and remedial actions.
- Cooperation with the EPC Contractors and any other third party to ensure that the requirements of any health and safety plan, and / or any relevant health and safety regulations are enforced.

The OHS roles and responsibilities of the Owner's Team personnel are as follows:

### 3.2.1 DGDC Project Manager

The DGDC Project Manager is ultimately accountable for the OHS results of the Project and is the owner of this Plan. He is responsible for ensuring that all personnel are aware of the contents of the Plan and has an obligation to:

- Provide visible leadership on safety matters for the Project.
- Ensure active line engagement in the OHS program.
- Comply with DGDC corporate safety reporting requirements and monitor KPIs.
- Convene the OHS Safety Committee.
- Monitor the EPC Project Manager and team to ensure they have achieved appropriate OHS management practice and mitigation of risks.
- Ensure all appropriate statutory appointments are made under Dominica Law.
- Coordinate with the Owner's Engineer to ensure compliance of the EPC Contractor with contract and legal requirements.
- Take action to intervene and correct where performance of the EPC Contractor is substandard Monitor the Owner's Engineer OHS obligations on the project.
- Ensure that appropriate resources are are allocated to effectively manage OHS requirements.

### 3.2.2 Safety Officer

The Safety Officer reports directly to the Project Manager and will work alongside the Owner's OHS representative to establish effective OHS systems and processes. He/She will receive support from the Owner's Engineer and Owner's OHS representative, prior to and during construction of the project, to undertake the following roles and responsibilities:

- Build a safety culture founded on a principle that safe projects are successful projects and all injuries are preventable.
- Risk assessment and job planning aimed at elimination of hazards prior to work commencing.

- Ensure compliance with occupational health, safety, security and environmental regulations and policies, while respecting the rights of others and their cultural differences.
- Coordinate the implementation of the Project OHS plans provided by the EPC Contractor to ensure compliance of the contract requirements.
- Review and amend where needed the OHS plans to ensure compliance and best practice.
- Conduct regular site inspections and audits and ensure that the results are reported in a timely manner.
- Participate in incident/hazard report investigation and reporting.
- Ensure the EPC Contractor report all incidents.
- Work with the DGDC team to collate and report accident/ incident statistics to the Project Manger.
- Arrange first aid training, treatment and maintenance of first aid facilities, in consultation with the Project Manager, as required for the DGDC and those subcontractors performing works directly for DGDC.
- Identify requirement for first aid qualified personnel in field (ratio) and qualification and training matrix.
- Monitor the activities in ensuring that the EPC Contractor fulfils its OHS obligations.
- Conduct monthly procedural compliance audits e.g. Working At Height, Confined Space Entry, permits to work etc.
- Participate, develop, coordinate and conduct Job safety enviromental analysis (JSEA)/hazard analysis and accident/incident prevention programmes for the Owner's Team.
- Supervise the safety performance of the Owner's subcontractors.
- Participate in, and ensure the reviews of the EPC Contractor's Permit-To-Work, Hot Work, Confined Space, Scaffold Erection/Inspection systems.
- Monitor and audit all significant high risk tasks for compliance.
- Participate in the Owner's Safety oversight visits in consultation with the Owner's Engineer.
- Liaise with statutory authorities and Owners Shareholders on safety matters as required.
- Liaise with DGDC staff on community safety issues.
- Interface in the field with the Owner's Engineer, the EPC Contractor, and the workers, during the daily site works activities to oversee that safe work practices are being implemented on site.
- Attend Safety Committee Meetings and ensure that minutes are prepared either by the Owner's Engineer or the EPC Contractor as required.
- Ensure the Owner's Engineer's records are up to date and maintained on the Project filing system.
- Display and distribute notices and information on OHS issues.

### 3.2.3 Owner's Engineer Site Project Manager

The Site Project Manager is responsible for implementing and monitoring the performance of the requirements of this OHS Management Plan by undertaking the following:

- Demonstrate OHS leadership by actively promoting OHS as a priority for all persons on Site.
- Arrange regular and frequent audits and inspections of the EPC Contractor and their sub-contractors and report findings to the Contractor and Owner.
- Conduct safety observations on a weekly basis. Ensure Owner's Engineer team conducts safety interactions and report findings to the EPC contractor and the Owner.
- Record findings in a register maintained by the Safety Officer and Site OHS representative.
- Ensure all Owner's Engineer staff and visitors are adequately trained and resourced to undertake their roles.
- Ensure that any incidents are investigated appropriately for the level of severity and reported in a timely manner to the Owner and Owner's Engineer senior management.
- Attend the regular OHS Safety committee meetings of DGDC and the EPC Contractor.
- Ensure that safety in design technical reviews are completed in a professional manner and to applicable standards.
- Ensure Job Safety Analyses are developed in consultation with the Owner's Enginere site team for all work activities where OHS risks identified in the risk register require management controls.
- Ensure Owner's Engineer project staff comply with the corporate travel-safety system.

### 3.2.4 Owner's OHS representative

The Owner's OHS representative will be appointed using grant funding from the AFD. The OHS representative will support DGDC to meet its obligations by providing in-country leadership and assistance to DGDC in the implementation of their OHS policies. The key roles and responsibilities include:

- Update and expand on the basic set of operational health and safety (OHS) policies and procedures.
- On-the job training of DGDC staff, and in particular the Safety Officer, to include:
  - The OHS policies
  - Safety inspections
  - Permit-to-work systems
  - Hazard identification and assessment
  - Role of DGDC staff during the construction in reviewing the EPC Contractor's safety performance
  - Incident reporting and incident investigation
  - Safety inductions to DGDC operated sites (main and site office).
- Prepare and deliver a project induction for Owner's Engineer and persons under Owners Engineer's control.
- Monitor the EPC Contactor preparation of the site health and safety file.
- Attend site for one week per month to continually train the Safety Officer and observe implementation of policies.

- Carry out audits and inspections of the EPC Contractor and their sub-contractors and report findings to the Contractor and the Owner.
- Review Safety Observations register.
- Attend the regular OHS Safety committee meetings.
- Contribute to incident investigations.
- Provide OHS reports as required by DGDC Project Manager.

### 3.2.5 Project Team Members

The responsibility for application of the OHS Plan rests with all employees within the Project. All staff assigned to the Project shall become familiar with the OHS Plan and implement the Plan requirements relevant to their role.

It is the responsibility of everyone associated with the Project to ensure that:

- They work in accordance with Project Plans and procedures to ensure safe and effective designs and execution plans are developed.
- They draw to the attention of the Project Manager any deficiencies, either in this procedure or in their instructions and guidelines, which could result in inadequate safety considerations being applied.
- They bring to the attention of the Project Manager, any feature which could affect the safety of the plant or facility so that all reasonable precautions can be taken to eliminate it.

# 4. EPC Contractor OHS Management

## 4.1 Responsibilities

With respect to the EPC Contractor's safety performance, the areas of focus will be on the safe design and construction of the Plant. At site, the EPC Contractor will oversee all health and safety related activities which will include the following:

- Proactively assist DGDC to instil a strong safety culture for all site-based operations and personnel.
- Assist DGDC in reviewing, implementing and monitoring performance against the EPC's OHS Plan. DGDC shall monitor the activities of the EPC and any other third parties to ensure that the requirements of any health and safety plan, and applicable health and safety regulations are enforced.
- Review and provide comments to DGDC with respect to site health and safety procedures under the EPC Contract on an ongoing basis and as may be specifically requested by DGDC from time-to-time.
- Review and provide feedback, including suggested actions and remedial measures, to DGDC with respect to any site health and safety issues that might arise from time-to-time.
- Conduct regular audits of the EPC health and safety related activities and follow through with the EPC Contractor's management on any findings and remedial actions.

The EPC scope, methodology and recording of its health and safety support services are included in Table 1.

Table 1 – Health and Safety Support Services

| Requirement | Methodology | Records |
|---|---|---|
| Proactively instil a strong safety culture at site, including review and provide comments to the DGDC. | Weekly management walkdown | Weekly site walkdown report |
| | Weekly and monthly meetings | Weekly and monthly minutes of meetings |
| | Special hazard identification and alerts | Correspondence<br>Reviews of Method Statements/Risk Assessments |
| | DGDC Team weekly meeting | minutes of meeting |
| | Stop work orders for significant infringements | Correspondence and e-mails |
| Reviewing, implementing and monitoring performance of the Contractor's against the OHSplan, including audits. | Site surveillance | · Safety Observation Reports<br>· Daily safety electronic diary<br>· Weekly and monthly reports |
| | Safety Audits | Audit Reports |
| | EPC weekly safety meeting attendance | EPC minutes of meeting |

Table 1 – Health and Safety Support Services

| Requirement | Methodology | Records |
|---|---|---|
| Review and provide feedback / advice on site health and safety issues | Accident investigation | Accident investigation analysis and recommendations |
| | Incident investigation | minutes of meeting |

## 4.2 Safety in Design

### 4.2.1 Overview

Safety in design refers to the design processes aimed at 'designing out' or reducing hazards that arise from the manufacture, delivery, construction, operation, maintenance, decommissioning and demolition of physical assets. Hazards can be to the environment or to the community - although it is safety hazards (i.e. to people) that tend to receive the most attention.

Wherever a project may be undertaken, the individual and the company undertaking a design have a duty of care (ethical if not statutory) to demonstrate that the safety of the design in terms of constructability, use, maintenance and eventual decommissioning/demolition has been considered and that the risks have been eliminated or minimised. This duty cannot be demonstrated without a traceable record of risk assessment, corrective actions and records of design close-out.

There are many responsibilities for designers which are contained in various statutes, professional associations' codes plus those provided in various supporting codes and design standards. Specific responsibilities are detailed in various statutes however the responsibilities generally include:

- Designers must ensure that design related hazards associated with the manufacture/ assembly/ construction and the operation/ use are identified before exposure to the hazard.
- Designers must ensure, to the extent that they have control over the design, that any risks to the health and safety of any person or the environment that are a result of the design, are eliminated, or where this is not reasonably practicable, minimised.
- Designers must report to the client, in writing, on the health and safety aspects of the design identified above. The level of detail to be provided in the report must be commensurate with the degree of risk.

The use of appropriate tools and techniques will assist in hazard identification and risk assessment, based on the type of asset and the nature of the expected hazards. Some typical tools include:

- Hazard Identification (HAZID)
- Hazard Analysis (HAZAN)
- Hazard and Operability Studies (HAZOP)

Safety in design procedures reveal assumptions (or blind spots) in the mind of the designer about how a facility might be constructed or used in operation (including misuse). As such, it is essentially a group activity, heavily reliant upon the experience of others.

- It's a requirement during the design phases to record information about hazards that have been identified and the actions taken or required to be taken to control risks. This information must be passed to the Project Manager so those involved in later stages of the asset lifecycle can be made aware.

Safety issues identified during the investigation and planning of a project should be reviewed to determine whether they can be eliminated or reduced through design. Where risks cannot be mitigated or eliminated, they should be included in relevant and appropriate documentation requiring future users to comply with any identified control measure that is necessary to safely use the asset. The guiding principle for the Project is that the designer shall be able to demonstrate that risks have been reduced to As Low As Reasonably Practicable (ALARP). ALARP refers to a risk level that is tolerable only if further reduction is impracticable or if its cost is grossly disproportionate.

Risks are inherent to any human activity and cannot always be eliminated. The safety in design process for this Project is therefore to be based on sound risk management practice that is based on the systematic identification of hazards and their associated causes in order to define the extent and likelihood of the potential loss. This shall be used to prioritise and assign appropriate actions or treatments appropriate to the level of risk. These treatments shall then be used to reduce the risks to the Project.

The design philosophy shall be based on:

1) Elimination and prevention of hazardous incidents, as far as is practicable to:
   - Ensure the installations are designed to nationally recognised safe standards or Good Practice
   - Provide safe working conditions for construction and operations personnel
2) Mitigation of the effects, should a hazardous incident occur to:
   - Minimise the potential or frequency of hazardous events
   - Control or mitigate the consequences of the hazards, including impacts to the environment
   - Define the requirements regarding asset protection, ensuring they are duly taken into consideration
3) Emergency response, including escape, evacuation and rescue in the event of an incident.

DGDC, through the Owner's Engineer, will monitor the works of the EPC Contractor, to see that a Safety in Design process is applied in the design of the power plant and associated works. It should be noted that neither the EPC Contract nor the Technical Specification present or impose specific requirements on the EPC Contractor for Safety in Design.

### 4.2.2 Applicable Standards

All work carried out in relation to the Project shall be in accordance with the applicable Dominican and recognised International Standards.

## 4.3 Health and Safety File

It is required that the EPC Contractor collects all relevant Health and Safety documentation for the Project into a single compilation (often referred to as a Health and Safety 'file' or 'dossier'). This is then passed to the Owner/ Operator at the handover to commercial operation to ensure those parties associated with the future operation are fully briefed with all relevant information to control potential health and safety risks.

DGDC will monitor the compilation of the EPC Contractor's health and safety file, for input into the Project documentation.

Consideration will be given to including information about each of the following where they are relevant to the health and safety of any future use, operation, maintenance, construction work or demolition:

1) A brief description of the work carried out.
2) Any residual hazards which remain and how they have been dealt with (for example surveys or other information concerning asbestos; contaminated land; water bearing strata; buried services etc.).
3) Key structural principles (for example, bracing, sources of substantial stored energy – including pre- or post-tensioned members) and safe working loads for floors and roofs, particularly where these may preclude placing scaffolding or heavy machinery there.
4) Hazardous materials used (for example lead paint; pesticides; special coatings which should not be burnt off etc.).
5) Information regarding the removal or dismantling of installed plant and equipment (for example any special arrangements for lifting, sequencing or other special instructions for dismantling etc.).
6) Health and safety information about equipment provided for cleaning or maintaining the structure.
7) The nature, location and markings of significant services, including direct buried cables; gas supply equipment; fire-fighting services etc.
8) Information and as-built drawings of the structure, its plant and equipment (for example, the means of safe access to and from service voids, fire doors and compartmentalisation etc.).
9) Information and reports required to demonstrate the plant has been safely designed.

The level of detail should allow the likely risks to be identified and addressed by those carrying out the future operations and maintenance work.

## 4.4 Safe work controls

### 4.4.1 Procedures and training

Safe work procedures and training modules have been developed and apply to the control of safety and environment risks on the Project. They include:

| Control | Location/Source |
|---|---|
| Safe Work Method Statements | EPC Contractor |

| | |
|---|---|
| Travel Planning | OE Travel procedure |
| Driver Training and Safe Work procedure | As required |
| OE Staff Project Induction | As required, by Site OHS Rep |
| EPC Contractor Site Induction | EPC Contractor |
| Hazard identification and reporting | Safety Observation Reports |
| Permit System | EPC Contractor |
| Working at height Training | EPC Contractor |
| Confined space training | EPC Contractor |

### 4.4.2 Job safety enviromental analysis

In the execution of the work, the EPC Contractor will be required to produce construction methodologies and JSEA's. DGDC will monitor and review these methodologies and JSEA's.

Any sub-consultants are required to prepare a job safety environmental analysis and if necessary health and safety and or environmental work procedures that are relevant to their scope of work where risk requires management control. The Project Manager shall review these documents prior to commencement of work for conformance with DGDC project OHS objectives, legislative requirements and contractual requirements.

### 4.4.3 Personal protective equipment

The EPC contractor shall, at his own expense, furnish his workers with protective equipment for eyes, face, hands and feet, lifeline, safety harness, protective shields and barriers whenever necessary by reason of the hazardous work process or environment.

As defined in DGDC-OHS-031: Personal Safety Equipment

### 4.4.4 Hazardous materials management

The EPC Contractor will be required to maintain a site register for all hazardous materials and dangerous goods. Material Safety Data Sheets must be available. If DGDC staff require to bring onto site any substances defined as hazardous they will be required to comply with the EPC Contractor approval process before taking the substance onto the site. Also as defined in DGDC-OHS-020: Hazardous Substances

### 4.4.5 Site access and security

The EPC Contractor controls the site access and security. DGDC staff will comply with these requirements.

- Entry is restricted to only authorised persons
- Prior approval may be needed prior to accessing the site
- No vehicles will be allowed on site unless they have appropriate authorisation from the EPC Contractor and the driver is inducted and appointed in writing by the DGDC Project Manager

### 4.4.6 Plant and equipment management

The only equipment DGDC will have management control over will be the light vehicles provided for transport of DGDC staff. A light vehicle operating JSEA procedure and training package will be developed. All designated drivers are required to sit for the training. The key controls processes for light vehicle operation include as defined in DGDC-OHS-025: Excavations and Shoring and DGDC-OHS-017: Plant, Systems and Equipment.

## 4.5 Incident and Injury Management

### 4.5.1 Incident reporting and investigation – EPC Contractor

Incident reporting by the EPC Contractor is in accordance with DGDC-OHS-039

Investigation of incidents is in accordance with the EPC Contractor's procedures. DGDC will participate in the investigation of significant incidents.

### 4.5.2 Incident reporting and investigation – OE / Owner's Team

Any OHS incident affecting the Owner's Team will be reported in accordance with the EPC Contractor procedures. Independently of this, the Owner's Engineer incident management process will also be enacted. This process is outlined in the DGDC-OHS-039

### 4.5.3 Injury management

The EPC Contractor is required to have site resources for injury management which includes a doctor, nurse and medical facilities. For any injury that occurs to the DGDC Team on site, the first reference will be to the EPC Contractor's medical centre.

For injuries that occur off site referral will be made to the local medical centres and services.

## 4.6 Inspections, Reviews and Reporting

To monitor the health and safety performance of the EPC, the DGDC Team will carry out various reviews and inspections. These will be carried out at a frequency appropriate for the type of review and will include:

| Nature of review | Frequency | Attendees |
|---|---|---|
| Structured site inspections by the Owner's Team | Part of the weekly formal site walk-around | Owner, Owners Engineer Site Project Manager, DGDC Safety Officer, EPC Site Manager, EPC OHS Manager |
| Safety reviews by the Owner's on-site safety management team | Daily (minimum) | Safety Officer, EPC OHS Manager, EPC Site Manager |

| Nature of review | Frequency | Attendees |
|---|---|---|
| Safety reviews by off-shore specialists | One monthly Safety review – or Safety Oversight | DGDC OHS Representative |
| Ad hoc Safety reviews across all site activities | Every member of the Owner's team. | Owner's team members |
| Incident Investigation | As required | As described in the OHS Management plan |

The Owner's Team will also produce ad-hoc Safety Observation Reports (SORs) while on site.

# Part 2 - Employer’s Requirements

Section VII - Employer’s Requirements

# 5. Forms

# Form of Completion Certificate

Date: _____

Loan/Credit Nº: _____

RFB Nº: _____

To: _____

Dear Ladies and/or Gentlemen,

Pursuant to GCC Clause 24 (Completion of the Facilities) of the General Conditions of the Contract entered into between yourselves and the Employer dated _____, relating to the _____, we hereby notify you that the following part(s) of the Facilities was (were) complete on the date specified below, and that, in accordance with the terms of the Contract, the Employer hereby takes over the said part(s) of the Facilities, together with the responsibility for care and custody and the risk of loss thereof on the date mentioned below.

1. Description of the Facilities or part thereof: _____

2. Date of Completion: _____

However, you are required to complete the outstanding items listed in the attachment hereto as soon as practicable.

This letter does not relieve you of your obligation to complete the execution of the Facilities in accordance with the Contract nor of your obligations during the Defect Liability Period.

Very truly yours,

_____

Title

(Project Manager)

# Form of Operational Acceptance Certificate

Date: _____

Loan/Credit N$^{o}$: _____

RFB N$^{o}$: _____

To: _____

Dear Ladies and/or Gentlemen,

Pursuant to GCC Sub-Clause 25.3 (Operational Acceptance) of the General Conditions of the Contract entered into between yourselves and the Employer dated _____, relating to the _____, we hereby notify you that the Functional Guarantees of the following part(s) of the Facilities were satisfactorily attained on the date specified below.

1. Description of the Facilities or part thereof: _____
2. Date of Operational Acceptance: _____

This letter does not relieve you of your obligation to complete the execution of the Facilities in accordance with the Contract nor of your obligations during the Defect Liability Period.

Very truly yours,

_____

Title

(Project Manager)

# Change Order Procedure and Forms

Date: _____

Loan/Credit Nº: _____

RFB Nº: _____

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2. Change Order Log
3. References for Changes

ANNEXES

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Annex 2 Estimate for Change Proposal
Annex 3 Acceptance of Estimate
Annex 4 Change Proposal
Annex 5 Change Order
Annex 6 Pending Agreement Change Order
Annex 7 Application for Change Proposal

# Change Order Procedure

## 1. General

This section provides samples of procedures and forms for implementing changes in the Facilities during the performance of the Contract in accordance with GCC Clause 39 (Change in the Facilities) of the General Conditions.

## 2. Change Order Log

The Contractor shall keep an up-to-date Change Order Log to show the current status of Requests for Change and Changes authorized or pending, as Annex 8. Entries of the Changes in the Change Order Log shall be made to ensure that the log is up-to-date. The Contractor shall attach a copy of the current Change Order Log in the monthly progress report to be submitted to the Employer.

## 3. References for Changes

(1) Request for Change as referred to in GCC Clause 39 shall be serially numbered CR-X-nnn.

(2) Estimate for Change Proposal as referred to in GCC Clause 39 shall be serially numbered CN-X-nnn.

(3) Acceptance of Estimate as referred to in GCC Clause 39 shall be serially numbered CA-X-nnn.

(4) Change Proposal as referred to in GCC Clause 39 shall be serially numbered CP-X-nnn.

(5) Change Order as referred to in GCC Clause 39 shall be serially numbered CO-X-nnn.

Note: (a) Requests for Change issued from the Employer's Home Office and the Site representatives of the Employer shall have the following respective references:

| | |
|---|---|
| Home Office | CR-H-nnn |
| Site | CR-S-nnn |

(b) The above number "nnn" is the same for Request for Change, Estimate for Change Proposal, Acceptance of Estimate, Change Proposal and Change Order.

# Annex 1. Request for Change Proposal

(Employer's Letterhead)

To: _____ Date: _____

Attention: _____

Contract Name: _____

Contract Number: _____

Dear Ladies and/or Gentlemen:

With reference to the captioned Contract, you are requested to prepare and submit a Change Proposal for the Change noted below in accordance with the following instructions within _____ days of the date of this letter_____.

1. Title of Change: _____
2. Change Request No. _____
3. Originator of Change: Employer: _____

   Contractor (by Application for Change Proposal No. _____[1]:
4. Brief Description of Change: _____
5. Facilities and/or Item No. of equipment related to the requested Change: _____
6. Reference drawings and/or technical documents for the request of Change:

   Drawing No./Document No. Description
7. Detailed conditions or special requirements on the requested Change: _____
8. General Terms and Conditions:
   (a) Please submit your estimate to us showing what effect the requested Change will have on the Contract Price.
   (b) Your estimate shall include your claim for the additional time, if any, for completion of the requested Change.

_____

(c) If you have any opinion negative to the adoption of the requested Change in connection with the conformability to the other provisions of the Contract or the safety of the Plant or Facilities, please inform us of your opinion in your proposal of revised provisions.

(d) Any increase or decrease in the work of the Contractor relating to the services of its personnel shall be calculated.

(e) You shall not proceed with the execution of the work for the requested Change until we have accepted and confirmed the amount and nature in writing.

_____

(Employer's Name)

_____

(Signature)

_____

(Name of signatory)

_____

(Title of signatory)

# Annex 2. Estimate for Change Proposal

(Contractor's Letterhead)

To: _____ Date: _____

Attention: _____

Contract Name: _____

Contract Number: _____

Dear Ladies and/or Gentlemen:

With reference to your Request for Change Proposal, we are pleased to notify you of the approximate cost of preparing the below-referenced Change Proposal in accordance with GCC Sub-Clause 39.2.1 of the General Conditions. We acknowledge that your agreement to the cost of preparing the Change Proposal, in accordance with GCC Sub-Clause 39.2.2, is required before estimating the cost for change work.

1. Title of Change: _____
2. Change Request No./Rev.: _____
3. Brief Description of Change: _____
4. Scheduled Impact of Change: _____
5. Cost for Preparation of Change Proposal: _____[2]

| | | | |
|---|---|---|---|
| (a) | Engineering | | (Amount) |
| | (i) Engineer | _____ hrs x _____ rate/hr = | _____ |
| | (ii) Draftsperson | _____ hrs x _____ rate/hr = | _____ |
| | Sub-total | _____ hrs | _____ |
| | Total Engineering Cost | | _____ |
| (b) | Other Cost | | _____ |
| Total Cost (a) + (b) | | | _____ |

[2] Costs shall be in the currencies of the Contract.

(Contractor’s Name)

(Signature)

(Name of signatory)

(Title of signatory)

# Annex 3. Acceptance of Estimate

(Employer's Letterhead)

To: _____ Date: _____

Attention: _____

Contract Name: _____

Contract Number: _____

Dear Ladies and/or Gentlemen:

We hereby accept your Estimate for Change Proposal and agree that you should proceed with the preparation of the Change Proposal.

1. Title of Change: _____

2. Change Request No./Rev.: _____

3. Estimate for Change Proposal No./Rev.: _____

4. Acceptance of Estimate No./Rev.: _____

5. Brief Description of Change: _____

6. Other Terms and Conditions: In the event that we decide not to order the Change accepted, you shall be entitled to compensation for the cost of preparation of Change Proposal described in your Estimate for Change Proposal mentioned in para. 3 above in accordance with GCC Clause 39 of the General Conditions.

_____

(Employer's Name)

(Signature)

(Name and Title of signatory)

# Annex 4. Change Proposal

(Contractor's Letterhead)

To: _____ Date: _____

Attention: _____

Contract Name: _____

Contract Number: _____

Dear Ladies and/or Gentlemen:

In response to your Request for Change Proposal No. _____, we hereby submit our proposal as follows:

1. Title of Change: _____
2. Change Proposal No./Rev.: _____
3. Originator of Change: Employer: [_____

   Contractor: _____
4. Brief Description of Change: _____
5. Reasons for Change: _____
6. Facilities and/or Item No. of Equipment related to the requested Change: _____
7. Reference drawings and/or technical documents for the requested Change:

   Drawing/Document No. Description

8. Estimate of increase/decrease to the Contract Price resulting from Change Proposal:[3]

   (Amount)

   (a) Direct material _____

   (b) Major construction equipment _____

[3] Costs shall be in the currencies of the Contract.

(c) Direct field labor (Total ____ hrs) _____

(d) Subcontracts _____

(e) Indirect material and labor _____

(f) Site supervision _____

(g) Head office technical staff salaries

| | | | |
|---|---|---|---|
| Process engineer | _____ hrs @ | _____ rate/hr | _____ |
| Project engineer | _____ hrs @ | _____ rate/hr | _____ |
| Equipment engineer | _____ hrs @ | _____ rate/hr | _____ |
| Procurement | _____ hrs @ | _____ rate/hr | _____ |
| Draftsperson | _____ hrs @ | _____ rate/hr | _____ |
| Total | _____ hrs | | _____ |

(h) Extraordinary costs (computer, travel, etc.) _____

(i) Fee for general administration, _____ % of Items _____

(j) Taxes and customs duties _____

Total lump sum cost of Change Proposal _____

*(Sum of items (a) to (j))*

Cost to prepare Estimate for Change Proposal _____

*(Amount payable if Change is not accepted)*

9. Additional time for Completion required due to Change Proposal

10. Effect on the Functional Guarantees

11. Effect on the other terms and conditions of the Contract

12. Validity of this Proposal: within *[Number]* days after receipt of this Proposal by the Employer

13. Other terms and conditions of this Change Proposal:

    (a) You are requested to notify us of your acceptance, comments or rejection of this detailed Change Proposal within _____ days from your receipt of this Proposal.

    (b) The amount of any increase and/or decrease shall be taken into account in the adjustment of the Contract Price.

(c) Contractor's cost for preparation of this Change Proposal:[2]

(Contractor's Name)

(Signature)

(Name of signatory)

(Title of signatory)

[2] Specify where necessary.

## Annex 5. Change Order

(Employer's Letterhead)

To: _____ Date: _____

Attention: _____

Contract Name: _____

Contract Number: _____

Dear Ladies and/or Gentlemen:

We approve the Change Order for the work specified in the Change Proposal (No. _____), and agree to adjust the Contract Price, Time for Completion and/or other conditions of the Contract in accordance with GCC Clause 39 of the General Conditions.

1. Title of Change: _____
2. Change Request No./Rev.: _____
3. Change Order No./Rev.: _____
4. Originator of Change: Employer: _____
   Contractor: _____
5. Authorized Price:
   Ref. No.: _____ Date: _____
   Foreign currency portion _____ plus Local currency portion _____
6. Adjustment of Time for Completion
   None Increase _____ days Decrease _____ days
7. Other effects, if any

Authorized by: _____ Date: _____
(Employer)

Accepted by: _____ Date: _____
(Contractor)

## Annex 6. Pending Agreement Change Order

(Employer's Letterhead)

To: _____ Date: _____

Attention: _____

Contract Name: _____

Contract Number: _____

Dear Ladies and/or Gentlemen:

We instruct you to carry out the work in the Change Order detailed below in accordance with GCC Clause 39 of the General Conditions.

1. Title of Change: _____
2. Employer's Request for Change Proposal No./Rev.: _____dated: _____
3. Contractor's Change Proposal No./Rev.: _____ dated: _____
4. Brief Description of Change: _____
5. Facilities and/or Item No. of equipment related to the requested Change: _____
6. Reference Drawings and/or technical documents for the requested Change:

   Drawing/Document No. Description

7. Adjustment of Time for Completion:
8. Other change in the Contract terms:
9. Other terms and conditions:

_____

(Employer's Name)

_____

(Signature)

(Name of signatory)

(Title of signatory)

# Annex 7. Application for Change Proposal

(Contractor's Letterhead)

To: _____ Date: _____

Attention: _____

Contract Name: _____

Contract Number: _____

Dear Ladies and/or Gentlemen:

We hereby propose that the below-mentioned work be treated as a Change in the Facilities.

1. Title of Change: _____

2. Application for Change Proposal No./Rev.: _____ dated: _____

3. Brief Description of Change: _____

4. Reasons for Change:

5. Order of Magnitude Estimation (in the currencies of the Contract):

6. Scheduled Impact of Change:

7. Effect on Functional Guarantees, if any:

8. Appendix:

_____

(Contractor's Name)

(Signature)

(Name of signatory)

(Title of signatory)

# Part 2 - Employer's Requirements

Section VII - Employer's Requirements

# 6. DOMLEC Generation Code

# The Commonwealth of Dominica

# Electric Utility Sector Generation Code

**November 2015**

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## DOCUMENT TITLE AND APPROVAL PAGE

**DOCUMENT NUMBER**:2015/TBD by IRC

1. **DOCUMENT TITLE**: Electric Utility Sector Generation Code. November 2015

2. **PURPOSE OF DOCUMENT**

This document covers the guiding principles, operating procedures and technical standards governing the operation of the electric power grid in the Commonwealth of Dominica and all interconnected generating facilities. The Code seeks to facilitate the economic, safe and reliable operation of the Dominican Power Grid and to avoid any undue discrimination among Generators. The provisions of the Code are enforceable under the Electricity Supply Act #10 of 2006.

3. **RECORD OF DOCUMENT ON ISSUE**

| Document Number | Description | Date |
|---|---|---|
| | Electric Utility Sector Generation Code | |

4. **APPROVAL**

This document is approved by the Independent Regulatory Commission (IRC) and the provisions therein become effective on_____day of_____2015.

On behalf of the IRC:

……
Date:

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## PREFACE

The Generation Code (the "Code") covers the guiding principles, operating procedures and Technical Standards governing operation of the Power Grid of the Commonwealth of Dominica and all interconnected Generating Facilities. The Code seeks to facilitate the economic, safe and reliable operation of the Commonwealth of Dominica Power System and to avoid any undue discrimination among Generators. The provisions of the Code are enforceable under the Electricity Supply Act #10 of 2006. (the "Act"). The Code is divided into the following sections:

**Connection Conditions** specifies the normal method of connection and the minimum technical, design and operational criteria which must be complied with by all Generators and prospective Generators.

**Operational Metering** specifies the Technical Standards and procedures for metering applicable to Metering Systems installed by Generators.

**Generation Scheduling and Dispatch** specifies the procedures for Generating Unit scheduling, dispatch, System security and communications between Generators and the System Operator via an Authorized Person.

**Load Shedding and Power Restoration** specifies the procedures for automatic and manual shedding of load and restoration of power following partial or total black out.

**Generator Maintenance Planning** specifies the criteria and procedures governing the planning and scheduling of maintenance requirements of Generators' Generating Facilities.

**Testing and Monitoring** specifies the list, time table and procedures for all tests to be performed by the Generator and System Operator.

**General** Provisions encompass several provisions pertinent to the functioning of the Code, including procedures for review of the Code and for derogation of existing installations and equipment not in compliance with the standards specified in this Code at the time of execution.

Dominica Electricity Services Limited ("DOMLEC") has responsibilities under this Code in two distinct capacities. These are as follows:

i) DOMLEC is responsible for prudent and efficient management of the electricity system of the Commonwealth of Dominica and, in that capacity, for dealing with all Generators in a consistent and non-discriminatory manner. This Code applies the term "System Operator" whenever referring to DOMLEC in this capacity;

ii) As the owner of power stations, DOMLEC is also subject to the rights and obligations in this Code as it applies to Independent Power Producers and Grid Connected Distributed Generation Facilities. Any reference to "Generators" in this Code should be interpreted to include DOMLEC in this capacity.

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**INTERPRETATION OF CODE**

In this code:

i) Expressions defined under `Terms and Definitions' (Schedule A) shall bear the respective meaning set out therein;

ii) The headings are for convenience only and shall not be used in construing the Code;

iii) The singular includes the plural and vice versa;

iv) Terms not herein defined shall have the meaning ascribed thereto in the Oxford English Dictionary; such meaning as ascribed under the relevant statute of the Act and regulations, as well as such meaning as normally ascribed and accepted within the power industry; and

v) References to clauses, recitals and schedules are, unless the contents otherwise requires, references to clauses of and recitals and schedules to this Code.

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# 1. INTERCONNECTION CONDITIONS

Interconnection Conditions specifies the normal method of connection and the minimum technical, design and operational criteria which must be complied with by any Generator and prospective Generators.

In addition, details specific to each Generator's connection may be set out in a separate Interconnection Agreement or in some cases a Power Purchase Agreement. The Interconnection Conditions set out in the Code shall be read in conjunction with either or both of these Agreements as relevant. In the event that, there is any conflict between the provisions of the Code and any Interconnection Agreement and/or Power Purchase Agreement and the said Interconnection Agreement and/or Power Purchase Agreement was signed before the present Code came into effect, then, the provisions of the Interconnection Agreement and/or Power Purchase Agreement will supersede the Code. Notwithstanding the foregoing, all Interconnection Agreements and/or Power Purchase Agreements shall be read in conjunction with the Code in force at any material time and in accordance with Sub-section 7.1 of this Code.

## 1.1 METHOD OF INTERCONNECTION

The method of interconnection shall be determined on the basis of several technical and economic factors which include:

i Safety
ii Generating Unit MW rating or Generating Facility MW capacity;
iii Supply voltage;
iv Proximity to the Grid;
v Reliability considerations;
vi Auxiliary power supply;
vii Substation configuration; and
viii Costs.

It should be noted that it will not be technically or economically practicable to achieve uniformity of the method of interconnection. In all cases however, Prudent Utility Practice will influence the method adopted.

The method chosen by the Generator shall be reviewed and approved by the System Operator on the grounds of System security, stability and safety.

Distributed renewable intermittent grid connected systems shall be interconnected as per the Interconnection Policy approved by the Independent Regulatory Commission.

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### 1.1.1 INTERCONNECTION POINT

The Generating Unit(s) shall be interconnected to the Grid via a circuit breaker if the facility's output voltage matches that of the system at the Interconnection Point, or via a Substation.

If via a Substation the Interconnection Point shall normally be on the High Voltage side (Grid side) of the Generating Unit(s) transformer.

Unless otherwise negotiated the Interconnection Point will demarcate the boundary of responsibility between the Generator and the System Operator.

The Generator shall be responsible for the installation of all auxiliary and interconnecting equipment on the Generator's side of the Interconnection Point.

The finalized number of connection points shall be determined by the relevant System Analysis Studies at the time of interconnection to the system.

The Generator shall be responsible for all costs related to interconnection to the Grid.

### 1.1.2 SUPPLY VOLTAGE

The voltage level at which the Generating Unit(s) are interconnected to the Grid will be dependent on but not limited to the size and number of units and the other factors that determine the Interconnection Point.

Subject to other technical considerations, Generating Units shall be interconnected to the Transmission or Distribution or Supply System at 69kV, 33kV, 11kV or 415/230V as is appropriate for the agreed Interconnection Point.

Distributed Renewable Generating Facilities with rated capacity up to 250 kW may be connected as per DOMLEC’s Interconnection Policy.

The chosen method of interconnection shall be determined by the System Operator on the grounds of system security, stability and safety.

### 1.1.3 CONFIGURATION OF SUBSTATIONS

All Generation Substations shall have the capability to disconnect or separate, from the Grid, any transmission line and/or Generating Unit which is interconnected to the Substation.

For reasons of ensuring safety and reliability of operation, Generation Substations with more than three transmission lines or Generating Units interconnected to them shall be of a "**breaker and a half'** configuration. The size of the Generating Units shall be considered for applicability of the breaker and a half requirement. The Substation shall be equipped with all requisite

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protection measures necessary to meet the System Operator's System protection standards as set out in Section 1.2.4.

## 1.2 GENERATOR PERFORMANCE STANDARDS AND TECHNICAL CRITERIA

### 1.2.1 TECHNICAL STANDARDS

All components of the connection shall be constructed, installed and tested in accordance with the current edition at the time of construction of the following codes and standards, or their international equivalents and Prudent Utility Practice:

| | |
|---|---|
| **ACI** | American Concrete Institute |
| **ANSI** | American National Standards Institute |
| **ASCE** | American Society for Civil Engineers |
| **ASME** | American Society for Mechanical Engineers Performance Test Codes |
| **ASNT** | American Society for Non-Destructive Testing |
| **ASTM** | American Society for Testing Materials |
| **AWS** | American Welding Society |
| **DBOS** | Dominica Bureau of Standards |
| **IEC** | International Electrotechnical Commission |
| **IEEE** | Institute of Electrical and Electronic Engineers |
| **ISO** | International Organization for Standardization |
| **NBS** | National Bureau of Standards |
| **NEC** | National Electric Code |
| **NEMA** | National Electric Manufacturers Association |
| **NESC** | National Electric Safety Code |
| **NETA** | National Electric Testing Association |
| **NFPA** | National Fire Protection Association |
| **NRCA** | Natural Resources Conservation Authority |
| **OSHA** | Occupational Safety and Health Association |
| **SSPC** | Steel Structures Painting Council |
| **UL** | Underwriters Laboratory |

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### 1.2.2 PERFORMANCE STANDARDS

Each Generating Unit interconnected to the Grid shall be required, as a minimum, to meet the following performance standards:

i) Sustained operation at any Load within the loading limits within the System frequency range 48.5 Hz to 51.5 Hz;

ii) Emergency operation at any Load within the loading limits within the system frequency range 48.5 Hz to 51.5 Hz during exceptional circumstances;

iii) Maintain normal rated output at the Grid voltages specified in Clause 1.3; and

iv) Sustained operation at the rated Power Factor range set out in the Interconnection Agreement; and

v) As per Interconnection Policy

### 1.2.3 STATION CAPABILITIES

i) **Synchronizing Facilities**

Each Generating Unit shall be equipped with synchronizing facilities to ensure Synchronization with the Grid. The Synchronization facilities shall include a synchronism check relay to support Synchronization under the following range of conditions:

a) Grid frequency within the limits 48.5 to 51.5 Hz; and
b) Grid voltages within the limits specified in Section 1.3.

ii) **Auxiliary Supply**

Each Generating Unit shall have the facility to provide its auxiliary supply during normal operation. Each Generator shall provide the facility to connect to the Grid for an incoming station service supply from the System Operator.

iii) **Automatic Frequency Response And Automatic Voltage Regulation**

It is required that Dispatch Generating Units have continuously fast acting response automatic governor and excitation control systems to control the Generating Unit's power output and voltage levels without instability of operation within the operating range of the unit.

iv) **Cycling Capability**

Cycling Units as designated by the System Operator will be required to have the capability of generating for up to 8000 hrs but no less than 2000 hrs per annum. The unit should be so designed to possess the capability of withstanding the stresses associated with the expected repeated startup



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and shutdown in its normal operating mode, accommodating at a minimum 350 starts per year.

v) **Governor Response Capability**

The droop characteristics from no load to full load for Generating Units shall be adjustable in the range of 0-5%.

vi) **Black Start Capability**

Some Generating Units shall be designated to have Black Start Capability primarily considering their type and location on the system. This shall enable Generators to restart their facilities without incoming supply from the Grid, connect to a Dead Bus, and supply load as necessary; once on line Generators are required to be in frequency sensitive mode so as to vary with load changes. In the event of the Generator "black starting" the Grid, the Generator may act, temporarily upon the provision of instructions from the System Operator.

The specification of the Black Start Generating Unit will be a subject of the Interconnection Agreement (normally contained in the PPA as a Schedule) between the System Operator and the Generator.

Where a Generator has a facility with a capacity of 1.5MW or greater, at least one source of Black Start supply shall be located at the site. Black Start facilities shall be routinely tested by the Generator to ensure satisfactory operation. The System Operator shall have the right to require the Generator to demonstrate the performance of the Black Start Capability.

At a minimum, the Generator is required to provide a formal report to the System Operator twice a year, detailing the results of the Black Start generator test. One of these reports must be based on a test done in May of that year and shall be submitted to the System Operator before June 1 (the official start of the hurricane season).

A failed event shall automatically trigger the reporting of that black start test event by the relevant Generator to the System Operator. A further report is also to be immediately submitted by the Generator to the System Operator upon subsequent successful maintenance and operation of said black start generator.

vii) **Fuel Supply Capability** (Thermal Plants Only)

If the interconnected units use gaseous or liquid fuels, the Generator shall ensure firm arrangements to maintain at least twenty (20) days of fuel requirement at normal rated output subject to the provisions of Clause 3.10. The arrangement may include any of the following:

- Wholly owned and maintained storage facility;
- Supplier owned storage with contractual arrangements guaranteeing the required storage;
- A combination of the above.



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**1.2.4 PROTECTION REQUIREMENTS** (Reference is made to IEC Guidelines or Equivalent)

i) Protective systems shall be provided in accordance with the Technical Standards set out in Clause 1.2.1 and Prudent Utility Practice.

ii) All protective relaying equipment shall comply with the appropriate Technical Standards.

iii) Generating Units shall at a minimum have protection against the following incidences:
- a. Loss of excitation;
- b. Under excitation;
- c. Unbalanced load operation;
- d. Stator phase faults and earth faults;
- e. Generating unit differential protection;
- f. Reverse power protection;
- g. Main transformer phase and earth faults, HV and LV;
- h. Station service transformer phase and earth faults, HV and LV;
- i. Transformer tank sudden pressure and transformer differential;
- j. Backup protection in the event that external phase and earth faults are not Cleared by remote protection system;
- k. Backup protection in the event of circuit breaker failure to operate;
- l. Over and under frequency;
- 1) Over speed;
- m) Stator over temperature;
- n) Rotor over temperature; and
- o) Restricted earth fault(s).

iv) Transformers

a) Differential current protection for generator step-up transformers
b) HV/LV phase and ground overcurrent protection (for station service/unit auxiliary transformers)
c) Buchholz and/or Sudden pressure (gas relay)
d) Over excitation protection (for generator step-up transformers)
e) Backup protection in the event of circuit breaker failure to operate for generator step-up transformers
f) Over-temperature protection (winding and oil)

v) Interconnection

a) Differential (line current high-impedance) for Phase and earth faults.
b) Backup interconnection protection in the event that external phase and earth faults are not cleared by remote protection system.
c) Backup protection in the event of circuit breaker failure to operate.

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d) The protection requirements for the HV interconnection with Grid will depend on the connection voltage and the Substation configuration. The detailed arrangements for each Generating Facility are set out in the respective Interconnection Agreement. In all cases it should be ensured that each Generating Unit can be separated from the Grid as rapidly as possible in the event of a sustained electrical fault on either side of the Interconnection Point.

e) The protective relaying systems shall provide the levels of sensitivity, speed and reliability as required by the System Operator. The operation of all protection schemes shall be coordinated with the operation of the System Operator's equipment.

f) The Generator shall submit the following design data for approval by the System Operator:

i Tele-metering single line diagrams;
ii Protection and Metering single line diagrams;
iii Tripping logic diagrams;
iv AC and DC schematic diagrams for the interconnection and Generating Unit protection schemes;
v Setting calculations and setting lists for the interconnection and Generating Unit protection schemes including closing time for major circuit breakers; and
vi Rating and transfer function data as required for computer simulation of the Generating Unit(s). This shall include data on the Generating Unit(s), transformer(s), automatic voltage regulator(s) and prime mover governor.
vii Substation single line diagram.

## 1.3 SYSTEM OPERATOR PERFORMANCE AND TECHNICAL STANDARDS

### i) Grid Frequency

The normal operating frequency of the Grid shall be 50.0 Hz ± 3%.

For the avoidance of doubt, generators shall be designed for sustained operation within the frequency limits as specified in Clause 1.2.2 (i) and for restricted time based operation within the emergency frequency limits as specified in Clause 1.2.2 (ii).

### ii) Grid System Voltages

A. The Nominal Operating Voltages on the Grid shall be:

1. 33 kV or higher on the Transmission System; and
2. 11 kV on the Distribution System
3. 400/230V on the Supply System

B. The Normal Operating voltages shall be within:

1. + 4 % to -8% on the Transmission System;

2. +4% to -8% Distribution System; and



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3. +4% to -8% on the Supply System.

iii) **Short Circuit Levels**

The system shall be designed to withstand a three phase symmetrical short circuit at the Generating Unit Substation for fault levels as specified in the appropriate Technical Standards as set out in Clause 1.2.1.

## 1.4 OTHER RIGHTS VESTED WITH THE SYSTEM OPERATOR

### 1.4.1 INSPECTION OF GENERATING PLANT BY SYSTEM OPERATOR

The System Operator retains the right to inspect any aspect of the Generator's plant in so far as that plant is pertinent to the provision of capacity and/or energy to the Grid, or to the safe and secure operation of the Grid, in order to verify the correct operation of all equipment including controls, circuit breakers, relays (and relay settings), metering and tele-metering. Prior to exercising its right to inspect the Generator's facilities and Metering System, the System Operator must give the Generator two (2) working days' notice and provide adequate reason for the inspection.

The Generator shall keep records to provide verification of tests and maintenance in accordance with agreements between the System Operator and Generator.

### 1.4.2 DISCONNECTION OF GENERATOR BY THE SYSTEM OPERATOR

The System Operator retains the right to disconnect any Generating Facility from the Grid thereby isolating equipment, without prior notice under the following circumstances:

i) In cases of System Emergency or exceptional circumstances;

ii) During system restoration following partial or complete loss of power;

iii) If at any time the Generating Facility is being operated outside acceptable operating parameters in a manner which violates the Connection Conditions set out in the Generation Code or which is likely to cause any of the following:

a) A safety risk to personnel;
b) Risk to stability or security of the Grid or Other Generating Units;
c) Any behavior causing sustained operation outside the normal Grid operating frequency and voltages as stated under Section 1.3; and
d) Any other material breach of the Connection Conditions which prevents the System Operator from meeting its license obligations.

Breach of any Power Purchase Agreement clause which stipulates that this action may be taken.

Notwithstanding the forgoing, in the event of any material breach of Interconnection Conditions which prevents the System Operator from meeting its Licence obligations, the System Operator



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may disconnect after using best commercial efforts to give notice to the Generator.

## 2. OPERATIONAL METERING

Adequate Metering Systems consistent with the technical specifications of this clause shall be installed by the Generator. The Metering System shall comprise a Primary and Backup Metering System and shall be designed, owned, installed and maintained by the System Operator. All associated costs of the design and installation shall be borne by the Generator.

### 2.1 TECHNICAL STANDARDS FOR OPERATIONAL METERING

#### 2.1.1 LOCATION OF PRIMARY AND BACKUP METERS

i) Both Primary and Backup Metering Systems shall be installed to accumulate the outputs and/or inputs at the High Voltage side bushing of the Generating Unit step up transformer.

ii) Each meter shall have its own current transformer (CT) and potential transformers (PT) and necessary independent systems to function effectively.

For Generators less than the quantum stated in the Interconnection Policy, metering requirements of the Standard Offer Contract in addition to Clause 2.2.4 of this code shall apply.

#### 2.1.2 METERING STANDARDS

i) Instrument transformers shall conform to ANSI Standards C12.11 and C57.14 Class 03 and shall have sufficient capacity to handle the attached equipment.

ii) The current transformers secondary winding used for metering purposes shall supply only the metering equipment and associated systems. Notwithstanding the foregoing each current transformer may have other secondary windings that may be used for purposes other than metering.

iii) Potential transformers' secondary windings may be used for metering and other purposes provided that the total loading does not exceed one half the rating of the transformer.

iv) Any metering and accumulating equipment shall have sufficient accuracy so that any error resulting from such equipment shall not exceed ±0.5% of full scale.

#### 2.1.3 SEALING, FIELD TESTING AND INSPECTION OF METERING SYSTEMS

Meters and associated instrument transformer boxes or enclosures shall be sealed by and at the expense of the Generators at the respective meters. The type of seal shall be approved by the System Operator.

For wiring used only for metering purposes, only conduits which comply with IEC or equivalent

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standards shall be used to enclose the wiring connecting the instrument transformers and the related accumulating and metering equipment. Any boxes or enclosures or other devices used to join two or more sections of conduit shall be securely covered, fastened and sealed with seals approved by the System Operator.

If the wiring used for metering must pass through a panel, panel board or switchgear structure, it shall be fastened together and cabled as a unit separate and apart from the rest of the wiring.

At its own expense, the Generator shall provide any terminal blocks that may be used along the length of the metering conductors within a panel, panel board or switchgear with covers or strips that limit access to the respective connections and said covers or strips shall be affixed with a seal approved by the System Operator. Boxes or enclosures shall be sealed with pre-numbered seals

approved by the System Operator.

Seals shall not be broken by anyone except the System Operator's personnel when the meters are to be inspected, tested or adjusted. The System Operator shall notify the Generator in advance of such inspection, testing or adjustment, and the Generator has the right to have a representative present.

Before the commissioning of any Generating Unit, the System Operator shall test the Metering System for correct wiring and accuracy, using equipment whose accuracy is equal to or better than that of the individual meters. Individual meter components found to be inaccurate before commissioning shall be returned to the Generator for replacement. Malfunctioning identified after full acceptance of the Metering System shall be the responsibility of the individual owners.

The System Operator shall test the Metering System within ten (10) days after:

a. The detection of a difference larger than the Allowable Error in the readings of the meters;

b. The repair of all or part of a meter caused by the failure of one or more parts to operate in accordance with the specifications; and/or

c. Each anniversary of the commissioning date of the unit. If any errors in the readings of the meters are discovered by such testing, the Party owning those meters shall repair, recalibrate or replace those meters and shall give the other Party reasonable advance notice so that the Party receiving notice may have a representative present during any such corrective activity.

## 2.2 METER READING PROCEDURES

### 2.2.1 PARAMETERS FOR METER READING

The Generator shall provide and install appropriate equipment and shall make a continuous recording on appropriate magnetic media or equivalent of the Net Energy Output of the Generating Unit(s).

The parameters to be metered shall be subjected to the Interconnection Agreement between the



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Generator and the System Operator, and may consist of but not limited to any or all of the following parameters:

i) Active energy (MWh) OUT;
ii) Active energy (MWh) IN;
iii) Reactive energy (MVArh) First Quadrant;
iv) Reactive energy (MVArh) Fourth Quadrant;
v) Active Power Demand (MW) OUT;
vi) Active Power Demand (MW) IN;
vii) Apparent Power Demand (MVA) OUT;
viii) Apparent Power Demand (MVA) IN;
ix) Reactive Power Demand (MVAr) First Quadrant; and
x) Reactive Power Demand (MVAr) Fourth Quadrant.

### 2.2.2 FREQUENCY OF READING

The Demand Interval shall be thirty (30) minutes and shall be set to start at the beginning of the hour. Demand shall be calculated by averaging the respective parameters over the stated Demand Interval.

The System Operator shall read the appropriate meters and the Demand register shall be reset, within five (5) minutes of midnight of the last day of each Month or two Month period as agreed upon by the Parties. If readings are obtained remotely, copies of the printout produced by the computer which initiates the reading protocol shall be made and provided to the Generator.

The System Operator shall read the appropriate meters to prevent clock drift. The clocks shall be checked and reset as agreed by the Parties. If readings are obtained remotely, copies of the data produced by the computer which initiates the reading protocol can be made and provided to the Generator if requested.

The meters shall be read by the System Operator at an interval as agreed between the System Operator and the Generator.

### 2.2.3 CONTROL PROCEDURES

The System Operator shall inform the Generator at least 24 hours prior to reading the meters and the Generator shall have the right to have a representative to witness such readings.

As a backup of the manual records of the Demand actually experienced throughout the billing period, the meters shall be equipped with a mass memory module which will record the MWh and MVArh produced during each Demand Interval.

### 2.2.4 METERING REQUIREMENTS FOR GENERATORS LESS THAN OR EQUAL TO 250 kW

For small Generating Facilities with rated capacity equal to or below 250 kW the full metering requirements in Sub-section 2.1 may be reduced. These Facilities will be permitted to be metered

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using separate import and export meters. The terms and conditions of this arrangement shall be guided by the Standard Offer Contract (SOC).

The metering equipment shall be a bi-directional device or a smart meter having the capability of mass memory, remote reading and power quality monitoring. Specification of the meter shall be provided by the System Operator.

## 2.3 RECONCILIATION PROCEDURES

If the Primary Metering System is known to be inaccurate or otherwise functioning improperly, then the Backup Metering System shall be used during the period that the Primary Metering System is not in service and the provisions described in Section 2.2 shall apply to the reading for the Backup Metering System.

If the Primary Metering System is found to be inaccurate by more than the Allowable Error or to otherwise have functioned improperly during the previous Month, then the correct amount of Net Energy Output and Dependable Capacity for the actual period, during which inaccurate measurements if any were made, shall be determined as follows:

i) First, the reading of the Backup Metering System shall be utilized to calculate the correct amount of Net Energy Output and Dependable Capacity, unless a test of such Backup Metering System, as required by either Party, reveals that the Backup Metering System is inaccurate by more than the Allowable Error or is otherwise functioning improperly; and

ii) If the Backup Metering System is not within the acceptable limits of accuracy or is otherwise functioning improperly, then the Generator and the System Operator shall jointly prepare a reasonable estimate of the correct reading on the basis of all available information and such guidelines as may have been previously agreed to between the Generator and the System Operator. This estimate shall take into account but not be limited to Dispatch Instructions as recorded in the System Operator dispatch log and meter readings, remote or manual.

## 2.4 RESOLUTION OF DISPUTES OVER RECORDED METERING DATA

If the System Operator and the Generator fail to agree upon an estimate for the correct reading within 30 days of the Dispute being raised, then the matter may be referred by either party for determination by the IRC pursuant Clause 7.6 of this document.

If the System Operator and the Generator fail to agree upon an estimate for the correct reading within a reasonable time (as specified in the relevant PPA) of the Dispute being raised, then the matter may be referred for arbitration by either Party in accordance with the relevant PPA.

# 3. GENERATOR SCHEDULING AND DISPATCH

The System Operator is required to operate and maintain a merit order system for Generating Units as per Section 3.2.

In order to operate the Grid in a safe, secure and economic manner, the System Operator will require accurate and timely information on Generating Units' availability, efficiency and technical



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operating capability.

This section outlines the procedures used to determine how individual Generating Units or Complex are operated in parallel to achieve these objectives based on the information received by the System Operator.

## 3.1 CRITERIA FOR SCHEDULING AND DISPATCH

The System Operator, shall seek at all times to minimize the total cost of production and supply of electricity subject to constraints of system security and reliability, safety, fuel availability, emission limits and other environmental considerations and contractual obligations.

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## 3.2 MERIT ORDER SCHEDULING

The System Operator shall establish a Merit Order based on least cost principles and efficiency. The fuel surcharge exerts a significant influence on the tariff. Consequently the preceding informed the methodology for determining the merit order under the following guidelines:

a) Maximise hydro production commensurate with the existing lake level and water flows

b) Diesel units must not run below the minimum of 50% of installed capacity

c) Spinning Reserve to be kept on Diesel units only.

d) When diesel units are to run at low loads, maximise loading at SL units and reduce loading at FC medium speed units.

e) Match minimum diesel production with most appropriate buildup of medium speed units, excluding inefficient units

f) When a unit has to be run continuously below 50%, a medium speed unit must be the ONLY choice

g) Spinning Reserve must be equal to the output of the largest unit currently online.

h) Units are dispatched by order of best actual fuel efficiency and effective forced outage rate (EFOR). Fuel efficiency takes precedence.

   i) Fuel efficiency Formula (kWh/IG): $\frac{\text{Electrical Energy delivered in kWh}}{\text{Fuel Consumed in Imperial Gallons (IG)}}$

ii) Effective Forced Outage Rate Formula (%): Forced Outage Hours for Operating Period x 100
Operating Period Hours

### 3.2.1 REVIEW OF MERIT ORDER

### a) FOSSIL FUEL GENERATORS

The Merit Order is reviewed on the following bases:

i. Daily Fuel Efficiency and availability checks done by Operations
ii. Semiannual comprehensive Fuel Efficiency Tests mandated by the IRC

The Generator may request a fuel efficiency test of its own unit if it can provide information to substantiate that it has made improvements in the performance of its Unit(s). No more than two such requests will be accommodated within any calendar year.

Fuel Efficiency Tests for all Generating Units, shall be coordinated by the System Operator. Such tests are to be held on dates mutually agreed upon with the Generator. The System Operator shall reserve the right to witness all such tests.

The IRC shall be duly notified beforehand when such tests are contemplated and carried out and reserves the right to witness all such tests. The IRC will be provided with the results of the tests within one month of the conduct of the tests.

### b. RENEWABLE GENERATORS

For Generators supplying electrical power from renewable source(s) these units will be dispatched as per the Merit Order and the Power Purchase Agreement.

### 3.2.2. NOTIFICATION OF MERIT ORDER

i) The System Operator shall notify the Generator as to the relative position of its Generating Unit(s) in the Merit Order in terms of ranking number each day.

ii) The System Operator shall notify the IRC of the revised Merit Order each day.

## 3.3. SYSTEM SECURITY STANDARDS

### 3.3.1. SPINNING RESERVE

The System Operator shall carry a minimum Spinning Reserve margin as set out in Schedule D subject to the approval of the IRC. Before such approval can be granted, the System Operator shall submit the revised Spinning Reserve policy to the IRC for review, analysis and determination. The determination of the Spinning Reserve margin shall be based on economics and System security considerations.

### 3.3.2. OPERATING RESERVE



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The System Operator shall co-ordinate Scheduled Outages such that the N-2 Reserve margin and the Operating Reserve margin are maintained at or above the level set out in Schedule D. This shall allow the Grid to be able to accommodate at least two (2) of the largest Generating Units being out of service and still maintain adequate available Capacity to meet System Demand. In the case of System Emergency and unplanned outages, the Scheduled Outages of Generating Units shall be rescheduled if possible to maintain this reserve margin.

## 3.4 UNIT COMMITMENT SCHEDULING AND SYSTEM OPERATION

It is the System Operator's obligation to prepare a Unit Commitment Schedule which reasonably reflects the likely System conditions. This schedule shall be prepared for the following week and revised on a daily basis. The scheduling of Generating Units shall be in accordance with the most recent available Merit Order, subject to relevant technical constraints specified in Clause 3.2.

Each Generator must submit to the System Operator by approved communication means a declaration of plant availability and Capacity, and any other information as agreed between the Generator and the System Operator from time to time. This data is to be declared to facilitate the timely preparation of a Unit Commitment Schedule over the short term period specified.

A Weekly Unit Commitment Schedule shall not be regarded by any Generator to be Dispatch Instructions but shall be provided as a service to Generators for planning purposes.

The daily revision of the Unit Commitment Schedule will at all times take over the short term predictions.

### 3.4.1. PREPARATION OF UNIT COMMITMENT SCHEDULE

In the preparation of Unit Commitment Schedule, the System Operator must take into consideration, among other things, pertinent to commitment schedule, the following factors:

i Forecasted Demand and geographical Demand distribution;
ii Each Generator's declaration of each of their Generating Unit(s) MW capability and availability;
iii Generator's contracted operating characteristics;
iv Contracted and declared Heat Rate Curves;
v Fuel prices and constraints;
vi System reserve requirements;
vii System Stability implications and frequency and voltage control; and
viii Grid constraints.

Monday - Friday: The daily schedule of expected availability and Generation Dispatch shall be prepared by each Generator and made available to the System Operator by 3 p.m. each day for the 24 hour period starting 12 a.m. (midnight) the following day. This shall be reviewed by 7 am on the following morning.

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Weekends: The daily schedule of expected availability and generation levels for the weekend shall be done and made available to the System Operator by 3 p.m. on the Friday preceding the weekend. This schedule shall cover the period from Saturday 12 am to Tuesday 12 a.m. and shall be reviewed by 7 am on the following Monday morning.

To facilitate preparation of these schedules, the Generator shall make a declaration of plant availability and Capacity and any other information, as agreed between the Generator and the System Operator from time to time for the following day starting at 12 midnight and no later than 1:00 pm.

The specific procedure for receiving data and making notification of commitment of Generating Units for dispatch shall be based on the following:

i) An agreed and approved means of communication between the Generator and System Operator with adequate backup in case of the failure of this approved means; and

ii) In order to ensure rapid transfer of information an interim declaration shall normally be verbally submitted in the first instance and shall be confirmed by the approved means without delay.

Where a Generator becomes aware of any changes in these declared values or other data

subsequent to the declaration, then the Generator shall without delay notify the System Operator

**3.5. DISPATCH INSTRUCTIONS**

This section sets out the procedures for issuing Dispatch Instructions to the Generators operating Dispatchable Generating Units, and the responsibilities of the System Operator in the minute to minute control time frame.

**Real Power (kW)**

Real Power (kW) dispatch shall be based on actual fuel efficiency. Dispatch Instructions are normally given on a half hourly basis or anytime that is warranted by the operational requirements of the System.

**Reactive Power (kVAr)**

Reactive Power (kVAr) is dispatched at the discretion of System Operator to maintain the System voltage within the tolerable limits. Under normal operating conditions Generating Units may operate at 0.85 pf but could be required to operate at as low as 0.8 pf.

In instances when the System Operator makes the request for the Generator to absorb VArs, the Generator should not be penalized on their electricity bill during that period, to the extent that the



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absorption of reactive power has affected the ratcheting mechanism. All Generators are required to provide the generator capability curve for the unit upon request by the System Operator. The System Operator shall at all times use the most economical choice available to manage the system voltage.

**Ancillary Service**

The System Operator subject to the approval of the IRC may contract with suitably qualified Generators for ancillary services (Voltage Support, Frequency Control, Reserve Support, etc.) to the extent that it does not violate the Power Purchase Agreements.

### 3.5.1. INSTRUCTION TO SYNCHRONIZE / DESYNCHRONIZE

The times at which a Generator shall be synchronized and desynchronized shall be directed by the System Operator.

### 3.5.2 FREQUENCY AND VOLTAGE CONTROL

Adherence to the frequency and voltage standards shall be the responsibility of the System Operator who shall issue to each Generator the required Dispatch Instructions for both Real Power (kW) and Reactive Power (kVAr) output in accordance with the declared operating limits of each Generating Unit as agreed upon between the System Operator and the Generators to ensure adherence to these operating standards.

Automatic Generation Control (AGC) can be used to perform frequency control by sending signals to the generating unit to adjust output. To the extent that the application of AGC is deemed economically feasible to the consumer and technically possible based on the specific generator capability and/or its expected operating regime, each new Generator shall ensure that the Generating Units are AGC enabled and can, without human intervention, accept and respond to a signal to adjust load. Additionally, the SCADA/EMS system shall have the capability to facilitate the use of AGC. The range of control afforded by the implementation of AGC shall be the subject of the Generator's PPA.

**System Operator Responsibility**

The System Operator shall be responsible for issuing any instruction necessary to:

i) Maintain the voltage on the 11 kV and 33 kV or 69kV Systems in accordance with the stated operational limits with the normal operational limits of + 4% /- 8%;

ii) Maintain, or enable others to maintain, the voltage of supply to consumers within the statutory limits of +4- 8% of the Nominal Operating Voltages;

iii) Supply the Reactive Power requirements of the System as economically as possible, and to organize the disposition of Reactive Power reserves for proper control of the System voltage in accordance with the requirement of i) and ii) above;

iv) Maintain frequency within the limits of 48.5 Hz to 51.5 Hz.



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v) Designate Generating Units to operate in Dispatch or Spinning Reserve mode

**Generator Responsibility**

The Generator shall be responsible for:

i) Ensuring that Generating Units operate in frequency control mode unless operation in this mode has been agreed as being impracticable between the Generator and the System Operator;

ii) Ensuring that Generating Unit automatic voltage regulators are in service continuously. The System Operator shall be informed whenever a Generating Unit is operating without its automatic voltage regulator or Reactive Power Limiter; and

iii) Notifying immediately the System Operator of any unusual voltage, frequency or power condition or any dynamic disturbances occurring upon any Generating Unit.

In the event of a sudden change in System voltage a Generator must not take action to override automatic Reactive Power generation response, unless instructed otherwise by the System Operator or unless immediate action is necessary to comply with stability limits or declared constraints of plant apparatus.

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## 3.5.3 CHANGES TO GENERATION CONDITIONS

The Generator shall notify the System Operator as soon as possible of any factors which will or are likely to, affect the power output capacity, flexibility, response or cost of production of any of its Generating Units.

Generating Units and apparatus shall not be taken out of service or rendered unavailable without reference to the System Operator except in cases of Emergency. In such cases the System Operator should be informed as soon as possible of the action taken.

A Generator experiencing an unplanned outage of any of its Generating Units shall inform the System Operator as soon as possible of all relevant details concerning this outage. As soon as the cause of the outage has been properly assessed and a recovery plan established, the Generator shall inform the System Operator of the expected time and the condition under which the Generating Unit shall return to service.

The actual time that the outage occurred and the Generating Unit was returned to service and any other information deemed to be important in relation to the outage shall be logged by the System Operator and the Generator

## 3.6. SWITCHING INSTRUCTIONS

High Voltage switching shall only be carried out with the permission of the System Operator except for agreed routine switching or in case of System Emergencies. Persons required to carry out high voltage switching must be specifically authorized by the System Operator to carry out such switching.

The following procedures should be adhered to when carrying out complex switching operations:

i) When switchgear, normally operated to the instruction of the System Operator has been operated without instruction from him, the Generator concerned shall notify the System Operator immediately. Switchgear normally operated to the instruction of the System Operator shall not be operated without his permission;

ii) the System Operator shall ensure that any instruction for switching issued by him is repeated phrase by phrase as received and at the termination of the message is read back to him in full by the recipient; and

iii) Any instruction issued by the System Operator relating to the operation of switchgear shall, be written down and every such instruction shall be repeated phrase by phrase as received. At the termination of the message it shall be read back in full to sender to ensure that the instruction has been accurately received.

Instructions from the System Operator shall be carried out without delay and at the time of completing the operation or sequence of operations shall be reported back to the System Operator

A Generator shall inform the System Operator immediately of any objection to any instruction. The System Operator shall then investigate the matter and if necessary refer it to higher authority endowed with the necessary powers of authority, to make a determination on such matters.

## 3.7 NON-CENTRALLY DISPATCHED PLANT

Non Dispatchable Generating Units shall operate as agreed upon between the System Operator and the Generator. The System Operator shall inform such Generators where there is a need for outage on the Generating Unit or of any incident which would affect the operations or safety of the Generating Unit. During an Emergency or where there is life at risk the System Operator reserves the right to disconnect and so isolate any Generating Unit without prior notification.

The Generator shall communicate with the System Operator on matters of switching and Synchronization during normal operations and in the event of System Emergency.

## 3.8. COMMUNICATION AND REPORTING

The Generator is required to provide information as requested pertaining to the operation of their Generating Unit(s).

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### 3.8.1 DESIGNATED CONTACT PERSONS

The System Operator shall at all times have a suitably qualified person designated for communication with the Generators on matters relating to the operation of the Grid as per above.

Each Generator shall at all times have a suitably qualified person designated for communicating with the System Operator in matters relating to the operation of the Generating Units and the Grid.

### 3.8.2. SYSTEM OPERATOR RECORD OF DISPATCH

A record of events shall be kept at the System Operator's facility, which shall include, but not be limited to:

a. All instructions regarding switching, voltage control and Generating Unit operation;

b. Details of changes in target frequency;

c. Each operation or sequence of operations of circuit breakers, disconnectors and earthing switches under the control of the System Operator and, where appropriate, alarms and protection indications;

d. Transformer tap changes instructed or operated by the System Operator;

e. The synchronization or taking off-line of Generating Units according to local procedures;

f. Details of the application and removal of main short and grounds and other safety precautions, including the issue and cancellation of safety documents and HV live line working certificates, by the System Operator or designate as required by the System Operator's safety rules;

g. The commissioning, taking out of service or re-commissioning of plant and apparatus, including automatic switching systems, protection and changes to relay settings, together with relevant details;

h. The failure, or change of state, of plant or apparatus on the Grid together with relevant details;

i. The failure of plant or apparatus affecting the availability of Generating Unit(s), together with relevant details;

j. The location and identification of switchgear for which a risk of trip is accepted;

k. Generating Units which are not operating in the frequency sensitive mode;

l. Any significant abnormal or dangerous occurrence in operation including incidents involving the use of emergency public service;

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m. Any interruption and restoration of supply together with relevant details;

n. Details of the System Operator system load reductions, restorations and Demand control;

### 3.8.3 GENERATOR OPERATIONS LOG

The Generator shall maintain an accurate and up-to-date Operations Log. The purpose of this Operations Log is to record events, plans, requests and instructions. Entries into the Operations Log should be made on a daily basis and should include, as necessary, the following:

i) Dispatching Instructions and times of receipt of such instructions from the System Operator

ii) Time of implementation of instructions;

iii) Any request from the Generator to the System Operator which includes:

a) Scheduled outages;
b) Forced outages;
c) Load adjustments;
d) Maintenance Outages;
e) Emergencies of any kind affecting the operation of the Generating Facility; and
f) Daily available Capacity.

iv) Names and status of all personnel on each shift;

v) Daily midnight readings of fuel used in stock;

vi) Statements relating to abnormal running conditions of Generating Unit (s) and auxiliaries;

vii) All Real (kW) and Reactive (kVAr) Power at half hour intervals, frequency, 11 kV bus voltage and 33 kV bus voltage at half hour intervals;

viii) Time of trip-out or removal of Generating Units from service and the time of return to service; and

ix) Visits by local regulatory agencies (e.g. IRC, etc.) to the Generator's facility.

### 3.9. FUEL PLAN

All Generators using fuel storage systems shall be required to:

i) Obtain and maintain reliable supply of fuel of quality and quantity sufficient to generate the Dependable Capacity and the Net Energy Output requirements of their Generating Facilities for a period of at least 20 days;

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ii) Provide the System Operator, for its prior written approval, the Fuel Supply Plan;

iii) Only enter into fuel supply arrangements consistent with the Fuel Supply Plan most recently approved by the System Operator.

### 3.9.1 FUEL SUPPLY AGREEMENT

The Fuel Supply Agreement shall:

a. Demonstrate a dependable and sufficient fuel supply;
b. Detail the infrastructure installed for delivery of the fuel from the central storage point to the generating Units;
c. Provide mitigating strategies in the event of natural disaster affecting the supply
d. of fuel delivery to the Commonwealth of Dominica ;
e. Detail Fuel Transportation Agreement; and
f. Detail alternative fuel supply arrangements and infrastructure requirements.

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All Generators shall be required to:

1. Obtain and maintain reliable supply of fuel (on-site storage plus offsite storage arrangements exclusive to the Generator's facility) of quality and quantity sufficient to generate the Dependable Capacity and the Net Energy Output requirements of their Generating Facilities for a period of at least eighteen (18) days and the minimum inventory level should be 7-10 days. Generators must report inventory levels weekly in writing, and advise the System Operator when the levels are below required levels or trending negatively for uninterrupted operations. The System Operator shall seek permission via an application to the IRC to trigger an emergency plan.

2. Provide the System Operator the Fuel Supply Plan; as duly approved by the IRC in consultation with the System Operator.

3. Only enter into fuel supply arrangements consistent with the Fuel Supply Plan.

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## 3.10. GENERATOR SCHEDULING & DISPATCHING TOOLS

1. The System Operator is required to ensure consistency and objectivity in the decision making mechanisms used.

2. These mechanisms may be in the form of standardized procedures and/or computational systems.

3. The System Operator is responsible for updating the System Dispatch and Operations Policy & Procedures as required, due to changes in the system characteristics or international best practices, where it has relevance to the Commonwealth of Dominica's Electric Power Grid.

   Documentation of the procedures followed in making System operations decisions must be promulgated to individual Generators after ratification by the IRC.

4. The tools used to assist in the Generating Units Scheduling and Dispatch optimization process must be based on an internationally accepted optimization algorithm. The tools must be used in accordance with its intended design and the System Operator is responsible for ensuring that it is functional and accurate.

## 3.11. TRANSPARENCY AND FAIRNESS

In order to assure transparency and fairness while being cognizant of the confidentiality provisions in individual contracts, the following outlines how and what type of information will be shared among stakeholders in the generation market. Unless explicitly stated otherwise in the document, the following shall prevail:

i **The Regulator:** The IRC shall be allowed access to any and all available information it requires from both the individual Generators and the System Operator. Periodically as agreed between the System Operator and the IRC, Technical Reports will be compiled by the System Operator and provided to the IRC, and will contain information from the logged system parameters as agreed from time to time.

ii **Individual Generator:** The System Operator is required to provide, in a timely manner, individual Generators with any technical system information that affects the operation of interconnected Generating Units for example, fault information should be shared with all Generators, with due consideration of the specific confidentiality provisions contained in each PPA and Licence.

iii **System Operator:** The System Operator shall have timely access to all information it reasonably requires from the individual Generators.

New generation technologies that have parameters not covered by this Code may be given consideration for inclusion to the Grid. However, the IRC, in full consultation with the System Operator, shall first provide written approval of the technical compatibility of the technology with the Grid, before the new technology can be interconnected.

# 4 LOAD SHEDDING AND POWER RESTORATION

## 4.1 LOAD SHEDDING PROCEDURES

### 4.1.1 UNDER FREQUENCY (AUTOMATIC) LOAD SHEDDING

During incidents in which the frequency decay is such that the Generating Units' governors cannot adequately compensate for the decay, the Under frequency Load Shedding Scheme is designed to shed the appropriate amount of Load to improve the System frequency so as to prevent damage to the Generating Unit(s) and/or collapse of the power System.

The System Operator shall provide the IRC with the details of the Under-frequency Load Shedding Scheme which may be in force from time to time.

**LOW FREQUENCY ALARMS**

Low frequency alarms shall be installed in power station control rooms and shall be set at 49.5 Hz. These alarms will warn Unit Controllers of low frequency problems, but no action should be taken without verification from the System frequency meter at the System Operator.

Low frequency alarms shall be installed at the System Operator's premises and shall similarly be set at 49.5 Hz.

**ACTION AT LOW FREQUENCY ALARMS**

At a low frequency alarm, Plant Operators shall confirm:

i) That the alarm is genuine by reading the analog and digital frequency meters/charts; and

ii) Whether the System is still interconnected and whether the alarm is for the entire System or section(s) thereof.

At the first stage alarm the Generator shall not act to restore the System frequency without prior consultation of the System Operator.

The exception to this rule is allowed when the decay in System frequency results from a loss in Generating Unit output, in which case the relevant Generator shall act to restore its former level of output. The System Operator must be informed as soon as possible thereafter.

**ACTION BELOW 49.5 HZ**

At 49.5 Hz and falling the Generator shall act to increase Generating Unit output within operating limits, in order to restore the System frequency and then report action taken to the System Operator.

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To help relieve the System overload, the System Operator may carry out further manual load shedding in accordance with Clause 4.1.2.

**ACTION BELOW 48.5 HZ AND FALLING**

In order to save the System from total collapse and prolonged outage, the circuit breakers of the affected Generating Units shall be opened.

The auxiliaries, however, should be on `unit supply' as the objective is not to trip the Generating Unit but to remove it from the System with it operating on its own unit auxiliary power.

After a total System failure is confirmed Generating Units should be black started as quickly as possible to be ready to restore supply as instructed by the System Operator in accordance with black start procedures.

Should a System failure occur, restoration of the System will commence as soon as possible in accordance with the procedures set out in Clause 4.2.

**4.1.2 MANUAL LOAD SHEDDING**

Where there is insufficient generation to meet the Load it may be necessary for the System Operator to institute Load Shedding on a programmed basis. When it is known that Generation deficiency will extend over a period of several hours or days, particularly during Peak Hours, such Load Shedding shall be done in blocks consisting of a number of feeders supplying various sections of the System, usually for 1 to 4 hour periods. The Load represented by the blocks shall be arranged to equate the amount of Load shed with the extent of the known generation deficiency and also to equitably distribute the time and period of Load Shedding among the blocks.

A manual Load Shedding procedure may be implemented to rotate the blocks shed after Under-frequency Load Shedding has taken place. Manual Load Shedding may also be implemented to prevent further Under-frequency Load Shedding.

Every effort must be made to ensure that the programmed duration of each outage is maintained as near as possible to the planned schedule or for a shorter duration where possible.

Feeders supplying critical loads should be identified and whenever possible the shedding of these feeders should be avoided.

If the shedding of feeders supplying hospitals and other critical loads becomes necessary the following actions must be taken by the System Operator prior to effecting this measure:

i) Alert the hospital(s) and critical loads supplied from the feeder(s); and
ii) Advise the staff at these institutions to activate stand-by plant if available.

In order to maintain supplies to the maximum number of consumers permitted by available Capacity, the System Control Operator must, whenever possible, avoid shedding a complete block of Load when a portion thereof will provide the necessary relief to the Generating Units. The Load



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Shedding log sheet shall be properly completed.

To achieve Load reduction and upon consultation with higher authority, the System Control Operator may decide to change the target frequency from 50.0 Hz to a minimum of 49.6 Hz. or reduce busbar voltages by up to 4% if necessary at all Generating Facilities.

It should be noted that Substation locations having automatic on-load tap changers will attempt to maintain normal voltage. The result of bus voltage reduction must be carefully noted.

Any adverse effect of changing target frequencies and/or voltages on any Generating Unit must be reported to the System Control Operator immediately who will take the necessary corrective action.

## 4.2 CONTINGENCY PLANS FOR POWER RESTORATION

### 4.2.1. PROCEDURES FOR RESTORATION OF POWER FOLLOWING WIDESPREAD BLACKOUT

The System Operator is responsible for coordinating all activities required to restore the System following partial or total System shutdown.

During the event of a total System shutdown the following procedures shall apply to restore power system-wide:

i) Designate Generating Units with Black Start Capabilities to commence restoration;

ii) Restart these designated Generating Units;

iii) Establish a transmission line pathway to the nearest other Generating Unit which is to be restarted while clearing all Load in this pathway;

iv) Establish a manageable distribution load preferably adjacent to the Generating Unit;

v) Start and synchronize the Generating Unit;

vi) Repeat procedures 4.2.1. (iv) to 4.2.1. (v) above until all Generating Units required to restore power are brought back into service; and

vii) Gradually return Load to the System while ramping up the power output of the Generating Units until System is totally restored.

Procedures 4.2.1 (iv) to 4.2.1 (vii) shall be used to restore the System after partial System shutdown.

### 4.2.2 PERIODIC REVIEW OF RESTORATION PLAN

At the end of each year or less than a year if deemed appropriate, the System Operator shall review its System restoration plans based on any changes in the configuration of the System. The revised



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plan shall be presented to the Generation Code Review Panel for review prior to implementation.

Following implementation, the System Operator shall have the right to audit and test each Generator's ability to carry out the assigned duties.

# 5. GENERATOR MAINTENANCE PLANNING

## 5.1 LONG TERM MAINTENANCE

### 5.1.1 PLANNING HORIZON

The System Operator shall develop an overall generation maintenance plans for three (3) years in advance. The plans which must incorporate statutory maintenance requirements shall be reviewed annually and updated as may be necessary.

To achieve this objective, Generators shall submit to System Operator on or before the first day of September each year a rolling three year plan for the scheduled maintenance requirement for their facility beginning in January of the following year.

The System Operator shall endeavour to schedule both long and short term Maintenance Outages in a non-discriminatory manner as far as System security constraints allow. Both System Operator and Generator shall make best efforts to ensure that interconnection and other related facilities are maintained within the periods stipulated for scheduled maintenance of the Generating Facility.

### 5.1.2 ANNUAL COMMITMENT OF MAINTENANCE PROGRAM

Generators shall submit to the System Operator on or before the first day of September of each year, a schedule called the `Maintenance Schedule' describing the proposed availability of the Generating Facility for each month of the twelve (12) month period beginning with January of the following year. The Maintenance Schedule shall indicate the Generators' preferred dates and durations of all scheduled maintenance. In developing the plans the System Operator shall take into account the manufacturer’s recommendations for maintenance of the plant.

The System Operator shall notify the Generator in writing whether the scheduled maintenance periods requested on the Maintenance Schedule are acceptable. The System Operator shall have the right to request the Generator to conduct scheduled maintenance during periods other than those indicated in the Maintenance Schedule, provided that the period specified by the System Operator shall be as close as reasonably practicable to the periods requested by the Generator, shall be of equal duration as the periods requested by the Generator and shall be within the range of time periods identified by the Generator as the range of time periods within which such scheduled maintenance must be performed in accordance with the manufacturer's recommendations for the Generating Facility.

### 5.1.3 CHANGES TO THE COMMITTED MAINTENANCE SCHEDULES

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Committed Generating Unit Maintenance Schedules shall be strictly adhered to unless unanticipated circumstances may mean interruption of supply to customers or a compromise in System security if the Maintenance Schedule is not adjusted. Under such circumstances both the System Operator and the Generator shall make best efforts to reschedule the outage as follows:

i) System Operator may upon ten (10) days prior notice request Generator to reschedule a scheduled maintenance provided, however, that System Operator shall not request that scheduled maintenance be rescheduled to a time that is outside of the range of time periods identified by the Generator as the range of time periods within which such scheduled maintenance must be performed in accordance with the manufacturers recommendations for the Generating Facility;

ii) The Generator may, upon five (5) days prior written notice, request that it be permitted to conduct additional scheduled maintenance period not identified in the Maintenance Schedule if the maintenance to be conducted cannot be postponed until the next period of scheduled maintenance identified on the Maintenance Schedules without damaging or otherwise threatening the Generating Facilities. The Generator's request shall also identify the range of time periods within which such additional scheduled maintenance must be performed in order to avoid damaging or otherwise threatening the Generating Facilities. The System Operator may upon three (3) days prior written notice, request the Generator to reschedule such additional scheduled maintenance; provided, however, that System Operator shall not request that such additional scheduled maintenance be rescheduled to a time that is outside of the time periods identified by the Generator as the range of time period within which such additional scheduled maintenance must be performed in order to avoid damaging or otherwise threatening the Generating Facilities.

### 5.2. SHORT TERM OUTAGE PROGRAM

For short term outages Generators shall give System Operator at least two (2) hours' notice prior to taking the Generating Facilities out of service.

## 6. TESTING AND MONITORING

### 6.1 PROCEDURES FOR CONDUCTING TESTS

The Generator shall provide to the System Operator a timetable and list of all tests to be performed on the Generating Units, and such tests shall be subject to approval by the System Operator. The System Operator shall be given five (5) days' notice of any testing and shall reserve the right to have a representative present during any such tests.

### 6.2 STANDARD TESTS

This section addresses procedures for testing and monitoring of Generating Units for purposes of determining available Capacity and, if relevant, operating characteristics in accordance with the commercial and technical conditions of Power Purchase Agreements. The manufacturer's representative shall be required for the commissioning of new Generating Facilities.

#### 6.2.1. TESTS PRIOR TO FIRST SYNCHRONIZATION OF A GENERATING UNIT

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Prior to the Synchronization of each new Generating Unit, the Generator shall carry out, or shall cause its contractors to carry out, the following tests at the Generator's expense:

Mandatory Tests that may be carried out at the Factory prior to Equipment delivery at the Site of the New Generator Facility

i Automatic voltage regulator setting up and adjusting, statically and with the Generating Unit running at no load;
ii Governor control checks;
iii Open and short circuit tests on the Generating Unit; open and short circuit tests on the generator as per IEC 60034 or equivalent under the standard bodies of Clause 1.2.1; and
iv Grounding test at the generator switchyard.
v Functional testing and timing of High Voltage switchgear in the Substation;
vi Voltage phasing checks between the Substation to which the Generating Unit is connected and the Grid;
vii Primary and/or secondary injection tests and functional tests to prove the calibration and function of the Generating Unit inter-tripping protection scheme under conditions inclusive of the following:

a) Loss of excitation;
b) Stator earth fault;
c) Negative phase sequence;
d) Reverse power;
e) Generating Unit transformer over current and earth faults;
f) Generating Unit under/over voltage and under/over frequency protection; and;
g) Differential protection relays covering all zones;
h) Engine/Turbine Overspeed

viii) The System Operator shall have the right to request additional testing if, in its sole judgment, any test results are not satisfactory for establishing the purpose for which the test was intended. Such additional testing shall be performed at the Generator's expense;

ix) The Generator shall confirm to the System Operator the program for any test as specified or advise of any adjustments thereto, not less than five (5) days prior to the commencement;

x) Upon completion of each test the Generator shall within forty eight (48) hours provide System Operator with two (2) copies of the results of such tests.

In each instance, the Generator shall provide the System Operator with the results of all such tests, within a reasonable time of the test being completed.

**Tests that shall be completed at the Site of New Generating Facility**

a) Grounding test at the generator switchyard;

b) functional testing and timing of High Voltage switchgear in the Substation;



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c) voltage phasing checks between the Substation to which the Generating Unit is connected and the Grid;

d) primary and/or secondary injection tests and functional tests to prove the calibration and function of all electrical protection schemes installed for the Generating Unit(s) and the Facility.

Upon completion of each test the Generator shall within forty eight (48) hours provide the System Operator with two (2) copies of the results of such tests.

The System Operator shall have the right to request additional testing if, in its judgment verified by an Independent Engineer, any test results are not satisfactory for establishing the purpose for which the test was intended. Such additional testing shall be performed at the Generator's expense.

The Generator shall confirm to the System Operator the programme for any test as specified or advise of any adjustments thereto, not less than five (5) days prior to the commencement.

### 6.2.2. TESTS AFTER FIRST SYNCHRONIZATION

After the Pre-Synchronization tests as defined in Clause 6.2.1 and prior to the commissioning date, and under such subsequent conditions as defined by the PPA, the Generator shall carry out the following tests at the Generator's expense:

**i) Dependable Capacity**

If the Generator intends to supply capacity and energy the Generator shall test the Dependable Capacity of the Generating Unit. The test shall be performed according to ASME, IEEE, and NEMA standards or to equivalent standards approved by the System Operator. If any such standards are inconsistent in any respect, the test shall be performed in accordance with the most stringent standard.

**ii) Reliability Run**

The Generator shall test the reliability of the Generating Unit. The test shall be in accordance with industry standards based on the type of plant and prudent utility practice. The method and duration of this test shall be agreed by the System Operator and the Generator

**iii) Automatic Voltage Regulator (AVR) Droop**

The Generator shall test the AVR to demonstrate control of the Generating Unit voltage over the range of plus or minus five (±5) percent of rated voltage with a droop characteristic of plus or minus one half (±0.5) percent.

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**iv) Governor Operation**

The Generator shall demonstrate that the speed governor for each Generating Unit operates over its range, the droop being adjustable from two (2) percent to five (5) percent.

**v) Reactive Capacity**

The Generator shall test each Generating Unit's capability to operate at rated voltage and frequency at power factors and under reactive conditions as follows:

100% output: 0.80 lag; 0.99 lead

**vi) Short-term Load Capability**

The Generator shall test each Generating Unit's capability to operate at a maximum safe load of one hundred ten (110) percent of the Dependable Capacity for one (1) hour and at a minimum safe load of zero (0) percent of the Dependable Capacity (0 MW) for one (1) hour.

**vi) Response of Unit to Step Load Changes**

The Generator shall test the capability of each Generating Unit to increase load by steps.

**vii) Full Load Rejection**

The Generator shall test the capability of each Generating Unit and auxiliaries to withstand full and part load rejection, all the while remaining in a safe condition and without initiating a trip of the Generating Unit.

**viii) Thermal Performance Tests**

The Generator shall test the Heat Rate of each fuel burning Generating Unit and shall be conducted according to IEC Standards or equivalent.

The System Operator shall have the right to request additional testing if, in its sole judgment, any test results are not satisfactory for establishing the purpose for which the test was intended. Such additional testing shall be performed at the Generator's expense. The results of the immediately prior test shall govern until the additional test is completed. The results of the additional test shall supersede the prior test for all purposes commencing on the day following the additional test.

The Generator shall notify the System Operator of the proposed program for any test specified in this Section, or advise of any adjustments thereto, not less than five (5) days prior to the proposed commencement of the relevant test. Upon receiving such notice, the

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System Operator shall have the right to reschedule the commencement of such test; provided that the rescheduled commencement shall not be more than three (3) days before the proposed commencement nor more than ten (10) days after the proposed commencement. The System Operator shall be entitled to have representatives present for the purpose of observing any such test.

Upon completion of each test specified in this Section, the Generator shall promptly provide the System Operator with two (2) copies of the results of such test; provided that the Generator shall submit all such test results to the System Operator no later than ninety (90) days after the commissioned date of the relevant unit.

## 6.3 CO-GENERATORS AND NON-DISPATCHABLE GENERATORS

Co-Generators and Generators with Non-Dispatchable Generating Units shall be required to perform all tests as listed in Section 6.2

## 6.4 TESTING OF METERING SYSTEM

These tests are specified in Clause 2 of this Code.

## 6.5 PARAMETERS MONITORING

For modeling of the Grid, Generators shall be required to periodically (5-10 years) submit the Generator operating parameters to determine if there is any decay which should be modeled.

Generators shall carry out routine and prototype response tests on excitation systems and governor systems (unit frequency response) for new power stations coming on-line or power stations at which major refurbishment or upgrades of these systems have taken place. Routine review is required of all power stations at least once every five (5) years.

# 7. GENERAL PROVISIONS

## 7.1 MATTERS TO BE AGREED

### 7.1.1. IRC RULINGS AND DIRECTIONS

In the event of any conflict between the provisions of the Generation Code (the "Code) and any direction or ruling issued by the IRC, such direction or ruling shall prevail, provided that the direction or ruling is legally binding on the person to whom it is addressed. No Party to this agreement shall be deemed to be in non-compliance of this Code for failing to comply with the conflicting provisions.

### 7.1.2 OTHER AGREEMENTS

It is recognized that existing Power Purchase Agreements contain clauses which may in a number of situations overlap with parts of the Generation Code. However, in the event of any conflict



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between the provisions of this code or any other commercial bilateral agreements on System operations and security, the provisions of the Code shall have precedence over these agreements unless otherwise specified.

Where it is clearly undesirable to disturb the existing commercial contracts the procedures for exemption from the conflicting provisions shall be followed as outlined in Clauses 7.4 and 7.5 respectively.

Notwithstanding the above provisions, Generators existing prior to the adoption of the Code shall be required to immediately adopt the Code and come into compliance within 14 months. New Power Purchase Agreements shall explicitly be required to comply with the terms and conditions of the Code.

### 7.1.3 TREATMENT OF THIRD PARTY CONTRACTS

All obligations and rights under the Code shall remain with the Generator when engaging third party services. In instances where third party contractors are granted access to a Generator's facility by a Generator, the responsibility for ensuring that the rules and regulations under this Code are adhered to remain with the Generator.

## 7.2 MONITORING AND REVIEW OF THE GENERATION CODE

### 7.2.1 THE ROLE OF THE IRC

The role of the IRC with respect to this code shall be to promulgate, apply and enforce its provisions. The rights and obligations under this Code and the application thereof cannot be changed or otherwise altered without the written approval of the IRC. Such approval shall not be unreasonably withheld.

Upon receipt of a revised version of the Code from the Panel, the IRC shall submit comments to the Panel within 30 days and the final ratification process of the Code should take no more than 3 months.

### 7.2.2 THE GENERATION CODE REVIEW PANEL

The IRC shall establish and maintain a Generation Code Review Panel (the "Panel"), which will be a standing body charged with keeping the Generation Code and its working under review. The Panel shall report to the IRC on its dealings and, as appropriate, recommend amendments to the Generation Code for the IRC’s approval.

The Panel shall start the Code review at June 1 of each year and has up to 3 months to conduct the review before making its submission to the IRC.

**Duties**

As part of its mandate, the Panel shall have following duties:

i) Review of the Code prior to the beginning of each calendar Year to ensure that all



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operational procedures and requirements governed by the Code remain up to date;

ii) Review all proposals for amendments to the Generation Code which the System Operator, the Generators or the IRC from time to time may wish to submit to the Panel for consideration;

iii) Following any unforeseen circumstances referred to it by the System Operator and in accordance with Clause 7.3 consider; whether the actions taken by the System Operator was justified; and what changes, if any, are necessary to the Generation Code;

iv) Present recommendations to the IRC as to amendments to the Generation Code that the Panel considers warranted and the reason for such changes.

**Composition**

The Panel shall consist of the following persons:

i One person representing the System Operator's Control Centre;
ii One person representing System Operator's Transmission System;
iii Two persons representing DOMLEC's Generation Department;
iv One person for each Generator with a total installed capacity above **250kW**; and
v One person for each Generator with a total installed capacity of less than or equal to **250kW**.

The IRC shall appoint the chairperson of the Panel.

Each Generator interconnected to the Grid shall have a licence to supply electricity generating capacity and a PPA or SOC with the System Operator.

The entities eligible for membership on the Generation Code Review Panel shall be responsible for providing the names of the persons (Primary and Alternate) who shall represent its membership to the Panel.

These names shall be provided to the IRC one month prior to the start of each annual review period starting January of each calendar year.

The person named as Alternate is required to remain fully abreast of all relevant discussions and proceedings to ensure a seamless transition from Primary to Alternate if required.

Each entity eligible for membership on the Panel reserves the right to change its named representative to the Panel at any time.

The tenure of the chairperson shall be one year, unless summarily removed by majority vote of the panel.

In addition to the annual review, the Chairperson shall preside over quarterly meetings of the Panel, to review and address issues relevant to the Code that may arise from time to time.

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The IRC shall set up and maintain a Generation Code Secretariat responsible for providing routine administrative support to the Generation Code Review Panel.

Administrative responsibilities of the Secretariat include, inter alia, compiling a list of the Code issues received throughout the year, arranging meetings of the Panel, developing and managing a budget (provided by the IRC); taking minutes of meetings and also liaising with the Chairperson of the Panel; disseminating information generated by the Panel among other things.

The Generation Code Secretariat shall work in tandem with the Chairperson on matters relating to the Code.

**Rules and Procedures for Conduct of Business**

The Panel shall establish and comply at all times with its own rules and procedures governing the conduct of its business which the IRC shall approve.

If the Panel on any matter presented before it is unable to reach unanimous agreement or consensus, that matter shall be referred to the IRC for determination. Any such referral to the IRC shall set out the cause of disagreement and the views held by the respective members.

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### 7.2.3 REVISIONS OF THE CODE

The System Operator, from time to time shall prepare and issue amended versions of the Generation Code containing such amendments as has been discussed by the Panel and approved by the IRC. The System Operator shall inform, in writing, all Generators subject to this Code that an amended version has been issued.

## 7.3 UNFORESEEN CIRCUMSTANCES AND SYSTEM EMERGENCIES

### 7.3.1 UNFORESEEN CIRCUMSTANCES

If circumstances arise which the provisions of the Generation Code had not foreseen the System Operator, shall, to the extent practicable in the circumstances, consult promptly and in good faith with all affected Parties in an effort to reach agreement as to the required course of action. If such agreement cannot be reached in the time available the System Operator shall determine the course of action to be taken.

Whenever the System Operator makes a determination, it shall do so having regard, wherever possible, the view expressed by the Generators and, in any event, to what is reasonable in the circumstances. Each Generator shall comply with the instructions given to it by the System Operator as a consequence of such a determination, provided that the instructions are consistent with the technical parameters set out in the Code and the Interconnection Agreement or, as

appropriate, the Power Purchase Agreement. The System Operator shall promptly refer all unforeseen circumstances and any determinations to the Generation Code Review Panel for consideration.

### 7.3.2 FORCE MAJEURE

All Parties should note that the provisions of the Generation Code may be suspended in whole, or in part, due to Force Majeure.

## 7.4 NON-COMPLIANCE

If a Generator finds that it is, or will be, unable to comply with any provision of the Generation Code it shall, without delay, report such non-compliance to the System Operator and, subject to Clause 7.5 make all reasonable efforts as are required to remedy the cause of non-compliance as soon as reasonably practicable.

The System Operator shall report all material incidents of non-compliance to the IRC.

## 7.5 DEROGATION

### 7.5.1. NORMAL PROCEDURE WHEN NON-COMPLIANCE IS:

i) In respect of apparatus connected to the Grid and is caused solely or mainly as a result of amendments to the Generation Code issued pursuant to Clause 7.2 ; or

ii) In respect of apparatus for which approval to connect is being sought; and the Generator judges that it would be unreasonable to require it to remedy the non-compliance or that it should be granted an extended period to remedy the non-compliance, the Generator shall promptly submit a request, in writing, to System Operator for a derogation from the affected provisions in the Generation Code.

**Request for Derogation**

A request for derogation from any provision in the Generation Code shall contain the following information:

i) The clause against which the present or predicted non-compliance is identified;
ii) The reason for non-compliance with the provision;
iii) Identification of the apparatus in respect of which a derogation is being sought;
iv) Whether the derogation sought is for a delay in achieving compliance or permanent; and
v) If a delay in achieving compliance is being sought, the date by which the non-compliance will be remedied.

**Basis for Granting or Refusing Derogation**

On receipt of a request for derogation pursuant to this clause, the System Operator shall consider whether such derogation can be granted without having a material adverse effect on the security,



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stability or economics of System operation. The System Operator shall submit its recommendation to grant or refuse derogation for approval by the IRC. The submission shall set out the reason for the recommendation and the original request.

Once a decision has been made and approved by the IRC, the System Operator shall promptly inform the requesting party of the decision and, in the event that the request is refused, the reason for such refusal.

### 7.5.2 DEROGATION FOR EXISTING APPARATUS NOT IN COMPLIANCE

Not all apparatus in use as at the date of adoption of this Code will be able to meet the Technical Standards defined by this Code. In some cases, it may not be economical or technically necessary to upgrade such existing apparatus to the required Technical Standards.

In order to allow existing Generators time to assess the condition of its equipment and, where appropriate, prepare a submission for derogation, the IRC has granted derogation for all existing apparatus until 14 months after code has been agree/approved. Requests for derogation of apparatus after this date shall be submitted in accordance with the procedures set out in Clause 7.5.1. Summary description of apparatus and installation will, within reasons, be accepted.

## 7.6 DISPUTE RESOLUTION

### 7.6.1 MUTUAL DISCUSSION

If a dispute or difference of any kind whatsoever (the "Dispute") between parties in connection with, or arising out of, any clause in this Code, either Party may issue to the other Party a written notice (the "Dispute Notice") outlining the matter in dispute. Following issue of a Dispute Notice both Parties shall discuss in good faith and attempt to settle the dispute between them.

### 7.6.2 REFERRAL AND DETERMINATION BY THE IRC

If the Dispute cannot be settled within 30 days after issue of the Dispute Notice, either Party shall have the right to refer the Dispute to the IRC for resolution.

I) The request for referral shall be made in writing to the IRC and a dated copy of the original Dispute Notice between the Parties shall be attached.

ii) Upon receipt of a request for referral, the IRC shall write to both Parties acknowledging that the Dispute has been referred to the IRC for determination.

iii) Following receipt of the IRC’s acknowledgment, each Party shall have five (5) working days to submit their reason (s) as to the cause of the Dispute in writing to the IRC.

iv) No later than ten (10) working days after the IRC has received each Party's reason (s) in writing, the IRC shall write to each Party setting out how the IRC intends to resolve the Dispute and indicate a date by which a determination may be expected.

The determination by the IRC shall be legally binding on both Parties subject to provisions of the



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IRC decision documents and the parties' right of appeal in law.

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# SCHEDULES TO GENERATION CODE

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## Schedule A

## Terms and Definitions

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| **Allowable Error** | This term shall have the meaning assigned to in Clause 2.12.iv |
| **Backup Metering System** | The meters and metering devices owned by the Generator and used to measure the delivery and receipt of Net Energy Output, Dependable Capacity and other parameters pursuant to Section 2 of this Code. |
| **Base Load Unit** | A Generating Unit designated to operate for more than 8000 hours per annum and does not go through cycles of economic shut down. |
| **Black Start Capability** | This term shall have the meaning assigned thereto in Clause 1.2.3. |
| **Black Start Generating Unit** | A Generating Unit with Black Start Capability |
| **Code** | This Generation Code and the Schedules hereto. |
| **Cogeneration Facility** | The facility which simultaneously provides electrical and thermal energy for a customer's process requirements and electrical output to Grid. |
| **Interconnection Condition** | This term shall have the meaning assigned thereto in Clause 1. |
| **Control Centre/Primary Control Centre** | A physical location from where the System Operator will give and receive information and instructions related to the operation of the Electric System. |
| **Cycling Units** | A Generating Unit required to operate less than 8000 hours per annum and designed to withstand cycle of economic shut down and start up. |
| **Day** | The 24 hour period beginning and ending at 00:00 hours Eastern Standard Time. |
| **Demand** | The rate at which electric energy is being used. |
| **Demand Interval** | The period over which the Demand is integrated |
| **Dependable Capacity** | The maximum Capacity modified for ambient limitations which a Generating Unit, or item of electrical equipment can sustain over a specified period of time. |
| **Dispatch Instructions** | The instructions issued by the System Operator to the Generator to schedule and control its generation in order to increase or decrease the electricity delivered to the Grid. |

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| **Dispatchable Generating Unit** | Generating Units whose required level of output at any instant of time is determined and regulated by the System Operator. |
| **Dispute** | The meaning ascribed thereto in Clause 7.6 |
| **Dispute Notice** | The meaning ascribed thereto in Clause 7.6 |
| **Distribution System** | That portion of an electric system which transfers electric energy from the bulk electric system to the customers. |
| **Economic Dispatching Technique** | The approved method used to rank Generating Units by their economic merit and to determine at which level they should be dispatched to minimize total variable operating cost subject to Generating Units operating limits and system constraints. |
| **Emergency Control Centre** | A physical location from where, the System Operator will give and receive information and instructions related to the operation of the Electric System, in the event of the unavailability of the primary control centre. |
| **Force Majeure** | Causes beyond the reasonable control of and without the fault or negligence of the Party claiming Force Majeure. It shall include failure or interruption of the delivery of electric power due to causes beyond that Party's control, including acts of God wars, sabotage, riots, hurricanes and other actions of the elements, civil disturbances and strikes. |
| **Forced Outage** | An interruption of a Generating Unit's capability to generate power that is not the result of (i) a request by the Grid Operator (ii) a Scheduled Outage or a Maintenance Outage; or (iii) an event or occurrence of Force Majeure. |
| **Fuel Supply Plan** | The Generator's plan for providing fuel to ensure its operation in accordance with the terms and provisions of this Code or any contracted Power Purchase Agreement. The Fuel Supply Plan shall include, but not be limited to, the Generator's proposed fuel specification, fuel supply and transportation arrangements, and the Generator's plans to obtain fuel |

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| | on the most economic basis at any given time. |
| Generator | Owner and/or operator of an electricity generating facility, supplying power system to the System Operator via the Grid. Includes DOMLEC. |
| **Generating Facility** | Any facility whether privately or DOMLEC owned containing one or more Generating Units and associate infrastructure producing and delivering electrical energy to the Grid |
| **Generating Unit** | Any electric power generating plant or apparatus, whether privately or DOMLEC owned, delivering electrical energy to the Grid. |
| **Generation Code** | The Code which covers the guiding principles, operating procedures and technical standards governing operations of the power grid and all interconnected generating facilities |
| **Generation Code Review Panel** | A panel responsible for keeping this Code and its working under review in accordance with Clause 7.2.2. |
| **Heat Rate** | The measure of a Generating Unit thermal efficiency, expressed as the number of thermal energy units to produce one kWh of electrical energy. |
| **Heat Rate Curve** | A plot of Heat Rate changes between minimum and maximum output levels of a Generating Unit. |
| **Heat Rate Test** | A test of a Generating unit thermal efficiency carried out in accordance with internationally accepted standards |
| **High Voltage (HV)** | Voltage exceeding 1kV (IEC 60269-1:2006, IEC 62271-200:2003) |
| **Incremental Cost** | The meaning ascribed thereto in clause 3.6. |
| **Interconnection Agreement** | An agreement which outlines the specific requirements for the interconnection of Generating Units to the Grid as arrived at between a Generator and the System Operator. |
| **Interconnection** | The physical point(s) where the Generator and the |

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| **Point** | Grid are connected as specified in clause 1.1.1 |
| **Independent Power Producer (IPP)** | Any private Generator other than DOMLEC selling power to the Grid. |
| **kW** | Kilowatts |
| **kWh** | Kilowatt hours |
| **Load** | Demand or Energy |
| **Low Voltage (LV)** | Voltage less than 1kV (IEC 60269-1:2006, IEC 62271-200:2003) |
| **Load Shedding** | Disconnecting or interrupting the electrical supply to a customer Load by the utility, usually to mitigate the effects of generating Capacity deficiencies or transmission limitations. |
| **Maintenance Outage** | An interruption or reduction of the Generating Unit capability that:<br>i) is not a Scheduled Outage; or<br>ii) has been scheduled and allowed by the grid Operator in accordance with Section 5; and<br>iii) is for the purpose of performing work on specific components, which work could be postponed by at least six (6) Days but not be postponed until the Scheduled Outage. |
| **Merit Order** | The ranking of Generating Units based on their order of dispatch unto based on their order of dispatch unto the Grid as per sections 3.1. and 3.2. |
| **Metering System** | All meters and metering devices (including the Primary and Backup Metering Systems) used to measure the delivery and receipt of Net Energy Output, Dependable Capacity and other parameters pursuant to Section 2 of this Code. |
| **Month** | A calendar month according to the Gregorian calendar beginning at 00:00 hours local time on the last day of the preceding month and ending at 00:00 hours local time on the last day of that month. |
| **kVA** | Kilovolts Amperes |
| **kVAr** | Kilovars |
| **kW** | Kilowatts |
| **kWh** | Kilowatt hours |

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| **Net Energy Output** | Net energy delivered by the Generator for sale to the Grid Operator at the Interconnection Point in accordance with a valid Dispatch Instruction. |
| **Nominal Operating Voltage** | Voltage that is required electrically at any point of the Grid |
| **Non-Dispatchable Generating Units** | Generating Units will be classed as Non-Dispatchable when it is not practical to control or dictate the required level of output of these units to the System Grid on an ongoing basis. |
| **Non Spinning Reserve** | That reserve in kW not connected to the System but capable of serving Demand within a specified time. |
| **Operating Reserve** | Generating capability in kW above firm System Demand available to provide for regulation, load forecasting error, equipment forced and scheduled outage. It consists of Spinning and Non Spinning Reserve. |
| **Operations Log** | A record of significant operating events plans, requests and instructions |
| **Party** | Stakeholder to an agreement, incident or other occasion related to this Code |
| **Peak Hours** | The hours between 9:00 am and 9:00 pm Eastern Standard Time every day of the week. |
| **Power Factor (pf)** | Ratio of Kilowatt output to corresponding kVA |
| **Primary Metering System** | All meters and metering devices used to measure the delivery and receipt of Net Energy Output, Dependable Capacity and other parameters pursuant to Section 2 of this Code. |
| **Project** | The design, financing, construction, ownership, operation and maintenance of Generating Units and all activities incidental thereto. |
| **Prudent Utility Practice** | The practices generally followed by the electric utility industry in respect to the design, construction, operation, and maintenance of electric generating, transmission, and distribution facilities, including, but not limited to, the engineering, operating, and safety practices generally followed by such utility Industries and in compliance with IEC Standards or equivalent. |
| **Rated Capacity** | A measure of the ability to generate electric power continuously usually expressed in Megawatts or kilo Watts. |
| **Reactive Power (kVAr)** | The product of voltage and current, which the Generating Unit shall provide to or absorb from the Grid and which is measured in kVAr. |
| **Scheduled Outage** | A planned interruption of the Generator's generating |

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| | capability that:<br>i) is a maintenance outage<br>ii) has been scheduled and allowed by the System Operator in accordance with Section 5; and<br>iii) is for inspection, testing, preventive maintenance, corrective maintenance or improvement. |
| **Spinning Reserve** | Unloaded generating capacity in MW which is synchronized and ready to serve additional Demand. |
| **Standard Offer Contract** | A long term agreement between a power authority and renewable electricity generating facility. The facility is installed for the primary purpose of self-generation with the excess capacity being off taken by the power authority. |
| **Sub Station** | Grouping of equipment inclusive of transformers, circuit breakers, switches and protective devices used to facilitate among other things the transformation of voltages and switching operations. A combination of generation, transmission, and distribution components within a specially defined area. |
| **System Emergency** | A condition or situation that, materially and adversely, or is likely to materially and adversely; (i) affect the ability of the System Operator to maintain safe, adequate and continuous electrical service to its customers, or (ii) endanger the security of person, plant or equipment. |
| **System Operator** | The entity responsible for prudent and efficient management of the electricity system of the Commonwealth of Dominica and in that capacity, for dealing with all Generators in a consistent and nondiscriminatory manner. |
| **Grid** | The Interconnected Facilities and any other transmission or distribution facilities on the System Operator' side of the Interconnection Point(s) through which the electrical energy output from the Generating Unit(s) will be distributed by the System Operator to users of electricity. |
| **Synchronization** | The controlled interconnection of System facilities to operate in phase at the same frequency and voltage. |
| **Technical Standards** | All standards as outlined in clause 1.2.1 or any other acceptable benchmark or method as defined or in use by the System Operator |
| **Ten Minutes Reserve** | An additional amount of operating reserve sufficient to reduce generation deficiency within ten minutes following the loss of generating capacity; |
| **Transmission System** | That section of the System Grid between the interconnection point and the Distribution and Supply |

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| | Systems. |
| **Unit Commitment Schedule** | This System is operated at 33kV or higher voltages. The sequence of startup and shutdown time of thermal Generating Units which minimizes the total production cost including startup and shutdown costs over a period of at least 24 hours or up to a week, given the load forecast, and taking into account the Maintenance Schedule, generation reserve requirement and System security. |
| **Week** | A period of seven (7) consecutive days beginning at 00:00 hours local time falling between a Saturday and a Sunday. |
| **Year** | Each twelve (12) Month period commencing on 00:00 hours Local Time on December 31 and ending on 00:00 hours Eastern Standard Time the following December 31 during the term of this Code. |

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## SCHEDULE B

## REQUIRED COMMUNICATION EQUIPMENT

The Generator shall provide at its sole cost and expense:

1. Adequate control, communication and data acquisition channels to the System Operator for the purpose of telemetering, protection and telecommunications.

2. An extension of System Controls Center PBX System in the Generating Units control room to facilitate voice communication between the Generator control room and System Operator.

3. Equipment in the Generating Units control room to transmit and receive telecopies and electronic mail to and from System Operator respectively.

4. UHF and/or VHF radio equipment to permit voice communication between the Generating Unit control room and System Operator.

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# Part 2 - Employer's Requirements

Section VII - Employer's Requirements

# 7. Contour Data

Refer to supplied contour data file

# Part 2 - Employer's Requirements

Section VII - Employer's Requirements

# 8. Geotechnical Data Report

# Dominica Geothermal Project

Dominica Geothermal Development Company

## Geotechnical Data Report

RZ042100-CG-RPT-001 | 01

31 May 2019

# Dominica Geothermal Project

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|---|---|
| Project No: | RZ042100 |
| Document Title: | Geotechnical Data Report |
| Document No.: | RZ042100-CG-RPT-001 |
| Revision: | 01 |
| Date: | 31 May 2019 |
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| Project Manager: | Sam Pearce |
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## Document history and status

| Revision | Date | Description | By | Review | Approved |
|---|---|---|---|---|---|
| 0 | 31/01/19 | Final | C. Ritchie | S .Nelis | L. Stanfield |
| 1 | 31/05/19 | Updated J&S report included | C. Ritchie | S. Nelis | L. Stanfield |
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## Important note about your report

The sole purpose of this report is to present the findings of the geotechnical field findings carried out by Jacobs for the Dominica Geothermal Development Company ('the Client') in connection with the Dominica Geothermal Project. This report was produced in accordance with and is limited to the scope of services set out in the contracts between Jacobs and the Client.

All reports and conclusions that deal with sub-surface conditions are based on interpretation and judgement and as a result have uncertainty attached to them. No study can investigate every risk, and even a rigorous assessment and/or sampling programme may not detect all problem areas within a site.

The findings are the result of standard assessment techniques used in accordance with normal practices and standards, and (to the best of our knowledge). Sampling techniques, by definition, cannot determine the conditions between the sample points and so this report cannot be taken to be a full representation of the sub-surface conditions. This report only provides an indication of the likely sub surface conditions at the sample locations.

Conditions encountered when site work commences may be different from those inferred in this report, for the reasons explained in this limitation statement. If site conditions encountered during site works are different from those encountered during the Jacobs site investigation, we reserve the right to revise any of the findings, observations and conclusions expressed in this report.

The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report.

Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report does not address environmental or geo-environmental issues including the presence of any contaminants or hazardous materials at the site. Jacobs makes no statement or representation of any kind concerning the suitability of the site for any purpose or the permissibility of any use.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

This report has been prepared in connection with the provisions of the agreement between Jacobs and its Client (DGDC). Jacobs or DGDC accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

# 1. Introduction

## 1.1 Background and Purpose of the Report

Jacobs New Zealand Limited (Jacobs) have been commissioned by Dominica Geothermal Development Company (DGDC) as Owner's Engineer for the development of a proposed 6mW geothermal power plant and associated infrastructure in Dominica, West Indies. The purpose of this report is to present the factual geotechnical data, to assist with the interpretation of the geotechnical conditions for the Dominica Geothermal Project.

Intrusive geotechnical investigations consisting of machine boreholes (including logging), in-situ testing and laboratory testing were undertaken by Jaca & Sierra Testing Laboratories (J&S) under the supervision of a J&S Geotechnical Engineer. The results of these investigations are presented in Appendix D.

## 1.2 Ground Investigation Scope

The overall scope of the ground investigation consisted of field mapping, test pitting and machine boreholes.

### 1.2.1 Jacobs Scope

The ground investigation was carried out by Jacobs New Zealand Limited and J&S.

The scope of the geotechnical investigation performed by Jacobs consists of the following:

- Field exposure logging by a Jacobs Engineering Geologist;
- Two machine excavated test pits, logged by a Jacobs Engineering Geologist;
- Two hand dug excavations, logged by a Jacobs Engineering Geologist;
- Monitoring of standpipe piezometers installed by J&S following completion of machine boreholes;
- Production of investigation plans;
- Geotechnical Data Report.

### 1.2.2 Jaca & Sierra Scope

Jaca & Sierra were appointed by the DGDC to undertake the intrusive geotechnical investigations and in-situ testing.

J&S (Appendix D) performed the following scope:

- Seven boreholes, with rotary coring on six of the seven boreholes
- 14 Dynamic cone penetrometer tests
- Suite of laboratory testing
- Downhole seismic test
- Soil and rock logging to ATSM standards by a J&S Geotechnical Engineer
- Factual Report

# 2. Site Description

## 2.1 Location

The proposed geothermal site is located between Trafalgar and Laudat near the Roseau Valley, Dominica West Indies.

The geothermal development is split into two discrete locations:

- The proposed geothermal power station located near Laudat;
- A 3km long reinjection line which runs from reinjection well at Trafalgar to the production well at Laudat

The proposed power plant is located on the lower flanks of Mount Micotrin, within an existing farm and orchard.

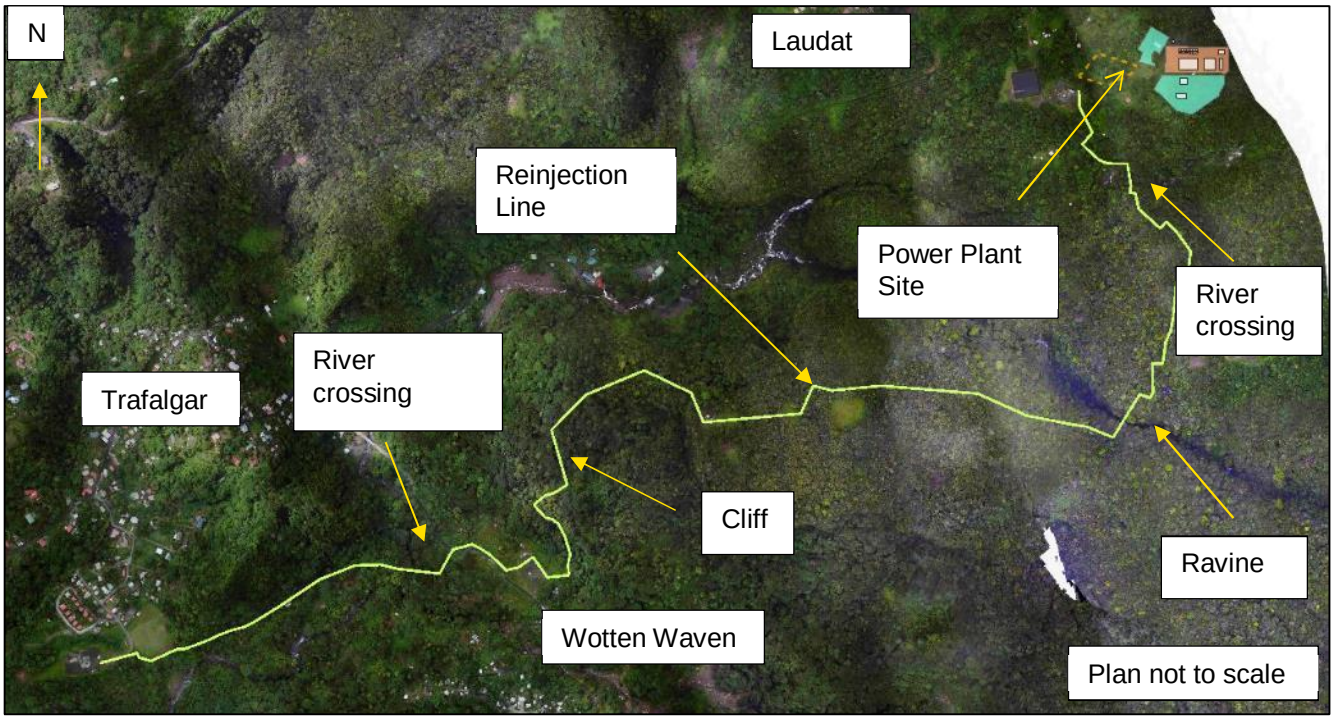



Figure 2-1 Site description

## 2.2 Topography

Topography at the proposed geothermal power plant consists of gentle (10-15 degrees) north-west facing slopes, which progressively steepen to the north-west.

The reinjection line transverses along typically shallow slopes (5-10 degrees), but intersects a number of significant topographical features, listed from north to south:

- River crossing near Titou Gorge;
- Significant ravine crossing up to 80m deep, 150m wide near the Aerial Tramway;
- Cliff drop at Wotten Waven;
- River crossing near Wotten Waven.

# 3. Investigation

## 3.1 Jacobs Fieldwork Methodology

A Jacobs Engineering Geologist undertook a site visit from the 16th September to the 5th October 2018. The fieldwork undertaken by Jacobs is summarised in the section below

### 3.1.1 Field Observations

Field observation locations were chosen to provide factual geotechnical information for critical features of the scheme and to gain a general understanding of the engineering geological and geotechnical constraints of the power station and re-injection line sites. Factual information collected at each location included:

- Engineering geological logging of outcrops to ATSM Standards, including soil, rock and defect descriptions;
- Discontinuity orientations on rock outcrops, measured as dip, dip direction, measured using an digital compass device, verified using a compass to true north applying declination correction.
- Pocket Penetrometer measurements of soils.
- N-Type Schmidt rebound hammer measurements at rock outcrops to gain an indication of relative strength of the rock intact rock. Readings have been normalised for the hammer inclination.

Table 3-1 summaries the measurements taken at each location. The field observation sheets can be found in Appendix B.

Table 3-1 Summary of field observation locations

| Locality number | Description of locality | Measurements taken | | | Coordinates (UTM Grid 20P)[2] | |
|---|---|---|---|---|---|---|
| | | Engineering Geological Logging | N-type Schmidt Hammer | Defect Measurements | Easting (m) | Northing (m) |
| LOC1 | Base of proposed pipeline cliff drop | P | P | P | 673082 | 1692019 |
| LOC2 | Base of proposed pipeline cliff drop | P | P | P | 678450 | 1694892 |
| LOC3 | Soil cut near pipeline route | P | | | 679912 | 1695009 |
| LOC4 | Stream outcrop near pipeline route | P | P | | 679471 | 1695386 |
| LOC5 | Rock outcrop above proposed pipeline route | P | P | P | 677570 | 1694361 |
| LOC6 | Outcrop near proposed pipeline cliff drop | P | P | P | 678519 | 1694927 |

| Locality number | Description of locality | Measurements taken | | | Coordinates (UTM Grid 20P)[2] | |
|---|---|---|---|---|---|---|
| | | Engineering Geological Logging | N-type Schmidt Hammer | Defect Measurements | Easting (m) | Northing (m) |
| LOC7 | Outcrop near cliff drop | P | P | P | 678530 | 1694906 |
| LOC8 | Outcrop near cliff drop | P | P | P | 678538 | 1694913 |
| LOC9 | Outcrop along pipe route, near Well pad R1 | P | P | | 678543 | 1694865 |
| LOC10 | Outcrop along pipe route | P | | P | 679427 | 1695577 |
| LOC11 | Boulders on Power Plant Access Road | P | P | | 679644 | 1695610 |
| LOC12 | Boulders on Power Plant Access Road | P | P | | 679615 | 1695614 |
| LOC13 | Temporary access track within Power Plant Site cut | P | P | | 679770 | 1695678 |
| LOC14 | Temporary access track within Power Plant Site cut | P | | | 679831 | 1695677 |
| LOC15 | Borrow pit within proposed power plant site | | | | 679774 | 1695640 |

### 3.1.2 Intrusive investigation – Test Pits

Jacobs and the DGDC undertook a series of test pits, at locations not easily accessible by the rotary drilling rig . These were excavated either by using Hand Tools (J&S drilling staff) or by using a 35 tonne excavator (Caribbean Contractors Limited). Test pit logs and photographs can be found in Appendix C.

Table 3-2 Summary of intrusive investigations logged by DGDC and Jacobs. *RL-B3-TP03 was not logged by a geotechnical engineer or geologist, excavator refusal depth and photographs are provided.

| Location ID | Excavation Method | Termination Depth (mbgl) | Coordinates (UTM Grid 20P)[2] | |
|---|---|---|---|---|
| | | | Easting (m) | Northing (m) |
| PP-TP01 | Machine | 4.5 | 679848 | 1695694 |
| PP-TP02 | Machine | 4.0 | 679800 | 1695680 |
| RL-B2-TP01 | Hand | 1.2 | 678521 | 1694821 |

| Location ID | Excavation Method | Termination Depth (mbgl) | Coordinates (UTM Grid 20P)[2] | |
|---|---|---|---|---|
| | | | Easting (m) | Northing (m) |
| RL-B2-TP02 | Hand | 1.0 | 678521 | 1694955 |
| RL-B3-TP03* | Machine | 4.0 | 678049 | 1694534 |

## 3.2 Groundwater monitoring

25mm diameter standpipe piezometers were installed in two of the boreholes drilled by J&S. Table 3-3 below displays the screened interval for each piezometer.

Table 3-3 Installed piezometers

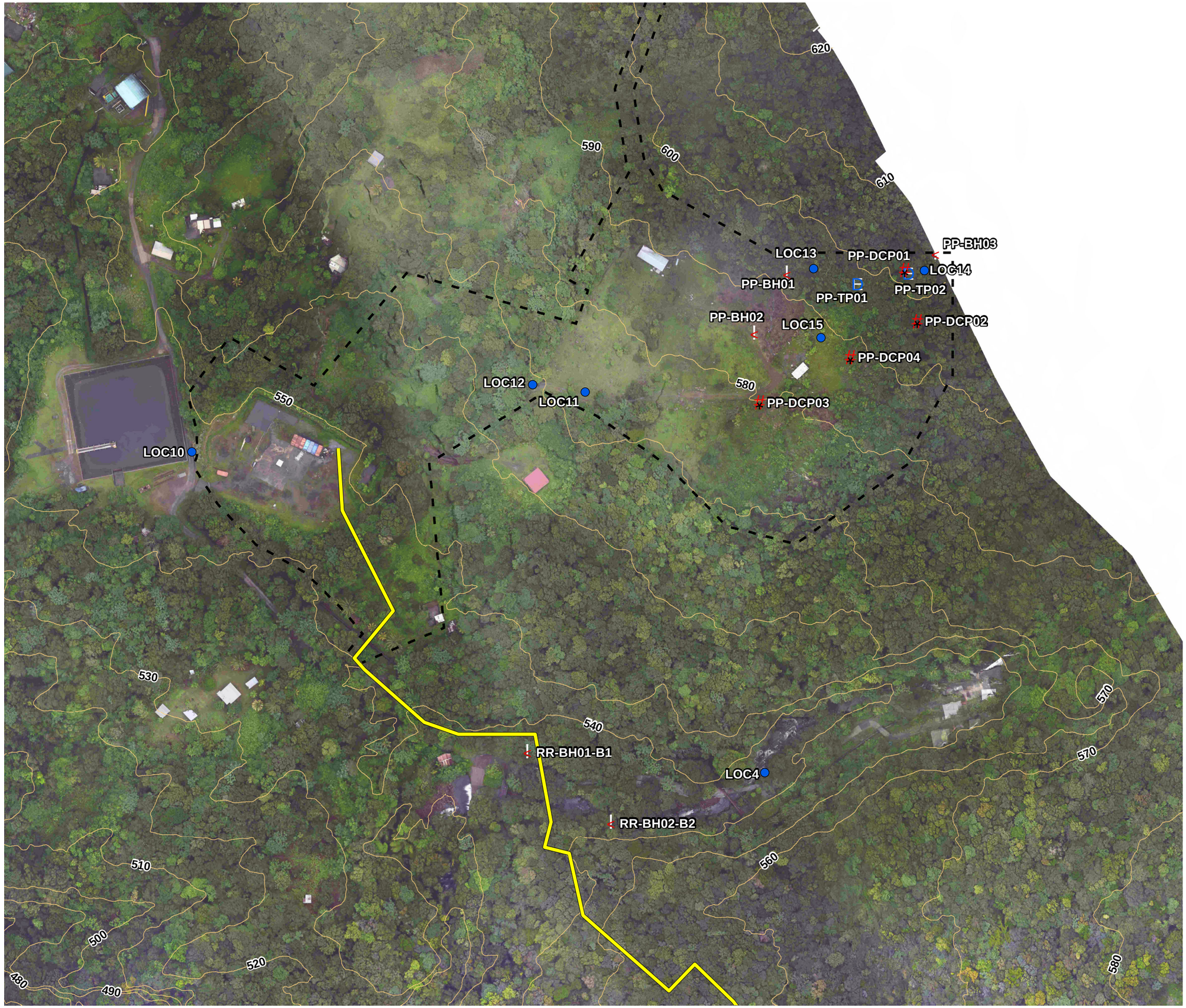
| Piezometer Reference | Screened interval (mbgl) | Response zone geology |
|---|---|---|
| PP-BH01 | 6.00 – 9.00 | Pyroclastic deposits (Ash and Boulders) |
| PP-BH03 | 13.5 - 16.5 | Pyroclastic deposits (unwelded ash) |

Groundwater measurements were taken periodically by Jacobs and the DGDC project engineer following completion of the monitoring installation. The results are found in the Table 3-4 below.

Table 3-4 Piezometer measurements

| Monitoring Date | Depth to groundwater (mbgl)[1] | |
|---|---|---|
| | PP-BH01 | PP-BH03 |
| 10/10/18 | N/A | Dry |
| 12/10/18 | Dry | Dry |
| 22/11/18 | Dry | Dry |
| 29/11/18 | Dry | Dry |
| 27/12/18 | Dry | Dry |
| 18/1/19 | Dry | Dry |

# Appendix A. Investigation Plan




## Legend

535

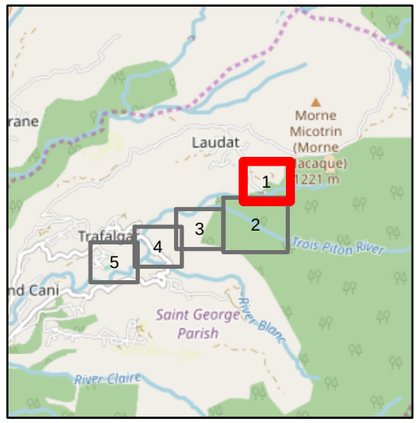
- Site Perimeter
- Reinjection Route

**Investigation Locations (Jacobs)**

- Field Exposure Log
- Test Pit
- Hand Dug Test Pit

**Investigation Locations (Jaca & Sierra)**

- Bore Hole
- DCP




0 25 50 100 Meters

**Dominica Geothermal Reinjection Line Section 1**

CLIENT
Dominica Geothermal Development Company

PROJECT
Dominica Geothermal

SCALE
1:2,000 @ A3

PROJECT CODE
RZ020300

PROJECT MANAGER
LS

DRAWN
OH

PROJECT DIRECTOR

DATE
28/01/2019

FIGURE NO
1

REVISION
DRAFT

JACOBS
Level 8
1 Grey Street
Wellington
04 473 4265

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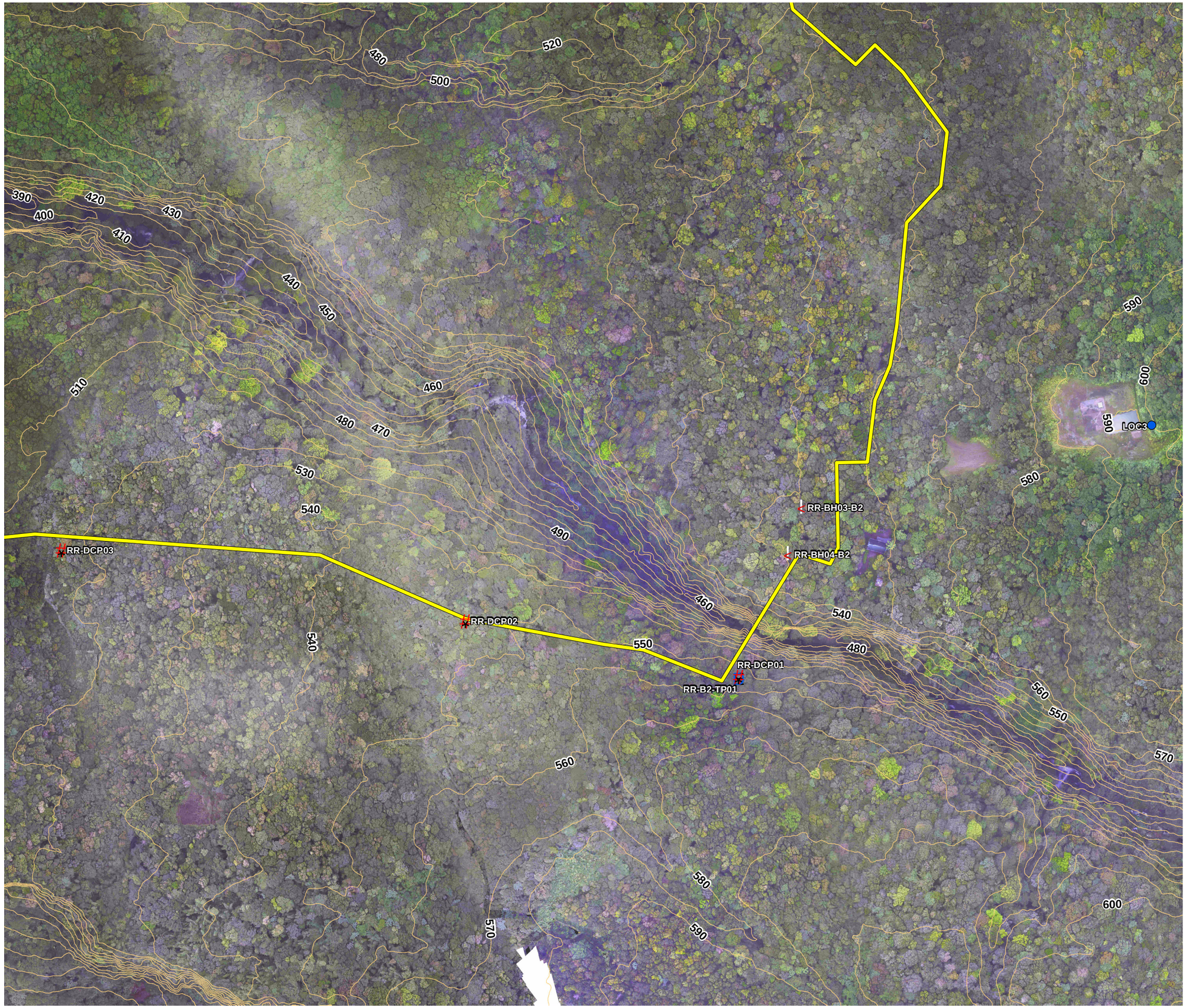



## Legend

536

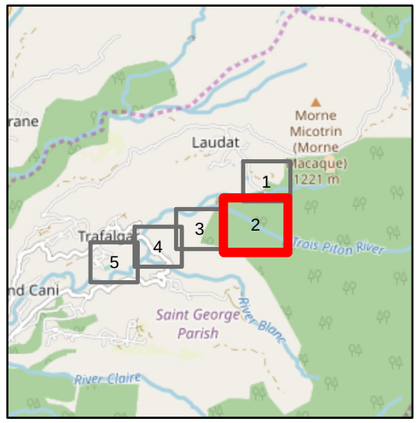
- Site Perimeter
- Reinjection Route

**Investigation Locations (Jacobs)**

- Field Exposure Log
- Test Pit
- Hand Dug Test Pit

**Investigation Locations (Jaca & Sierra)**

- Bore Hole
- DCP




0 25 50 100 Meters

**Dominica Geothermal Reinjection Line Section 2**

CLIENT
Dominica Geothermal Development Company

PROJECT
Dominica Geothermal

SCALE
1:2,720 @ A3

PROJECT CODE
RZ020300

PROJECT MANAGER
LS

DRAWN
OH

PROJECT DIRECTOR

DATE
28/01/2019

FIGURE NO
2

REVISION
DRAFT

JACOBS
Level 8
1 Grey Street
Wellington
04 473 4265

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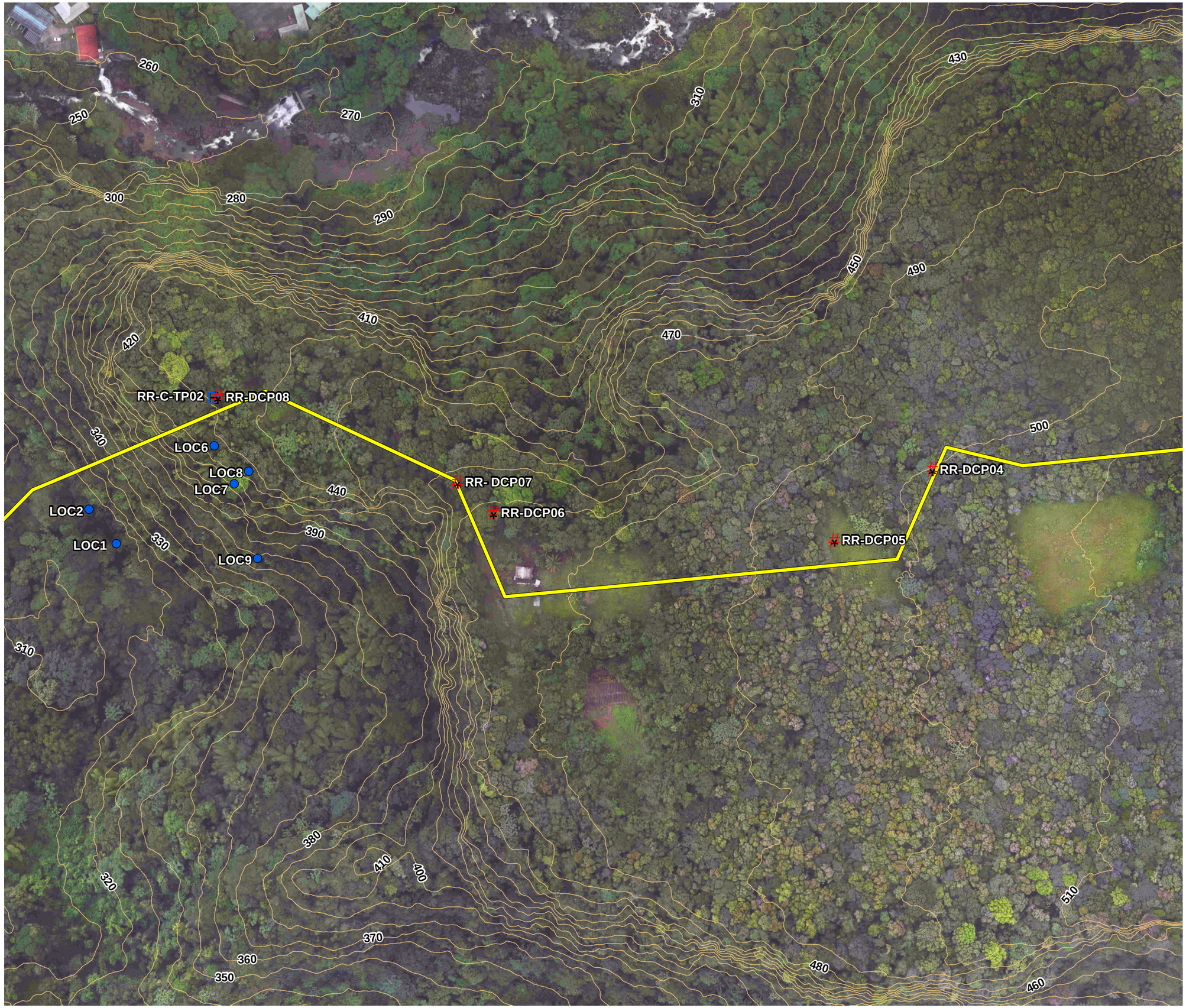


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## Legend

537

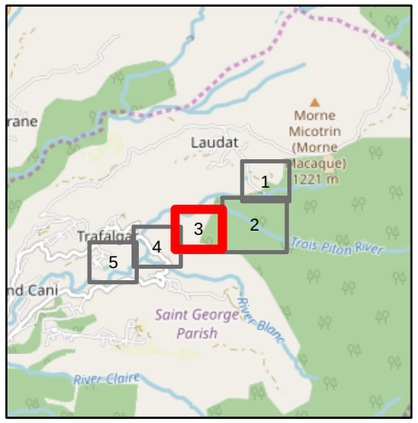
- Site Perimeter
- Reinjection Route

**Investigation Locations (Jacobs)**

- Field Exposure Log
- Test Pit
- Hand Dug Test Pit

**Investigation Locations (Jaca & Sierra)**

- Bore Hole
- DCP




0 25 50 100 Meters

**Dominica Geothermal Reinjection Line Section 3**

CLIENT
Dominica Geothermal Development Company

PROJECT
Dominica Geothermal

SCALE
1:2,000 @ A3

PROJECT CODE
RZ020300

PROJECT MANAGER
LS

DRAWN
OH

PROJECT DIRECTOR

DATE
28/01/2019

FIGURE NO
3

REVISION
DRAFT

JACOBS
Level 8
1 Grey Street
Wellington
04 473 4265




## Legend

538

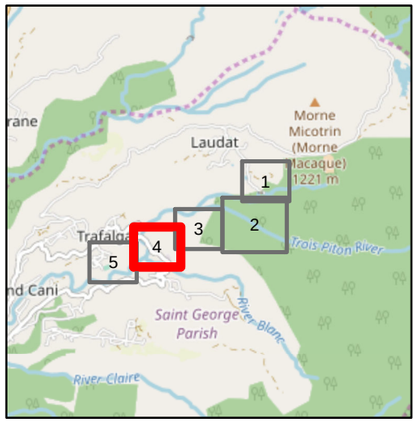
- Site Perimeter
- Reinjection Route

**Investigation Locations (Jacobs)**

- Field Exposure Log
- Test Pit
- Hand Dug Test Pit

**Investigation Locations (Jaca & Sierra)**

- Bore Hole
- DCP




0 25 50 100 Meters

**Dominica Geothermal Reinjection Line Section 4**

CLIENT
Dominica Geothermal Development Company

PROJECT
Dominica Geothermal

SCALE
1:2,000 @ A3

PROJECT CODE
RZ020300

PROJECT MANAGER
LS

DRAWN
OH

PROJECT DIRECTOR

DATE
28/01/2019

FIGURE NO
4

REVISION
DRAFT

JACOBS
Level 8
1 Grey Street
Wellington
04 473 4265

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## Legend

539

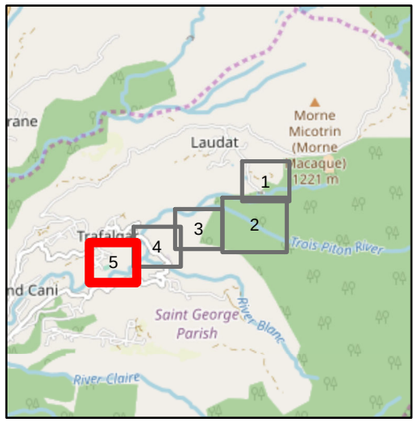
- Site Perimeter
- Reinjection Route

**Investigation Locations (Jacobs)**

- Field Exposure Log
- Test Pit
- Hand Dug Test Pit

**Investigation Locations (Jaca & Sierra)**

- Bore Hole
- DCP




0 25 50 100 Meters

**Dominica Geothermal Reinjection Line Section 5**

CLIENT
Dominica Geothermal Development Company

PROJECT
Dominica Geothermal

SCALE
1:2,000 @ A3

PROJECT CODE
RZ020300

PROJECT MANAGER
LS

DRAWN
OH

PROJECT DIRECTOR

DATE
28/01/2019

FIGURE NO
5

REVISION
DRAFT

JACOBS
Level 8
1 Grey Street
Wellington
04 473 4265

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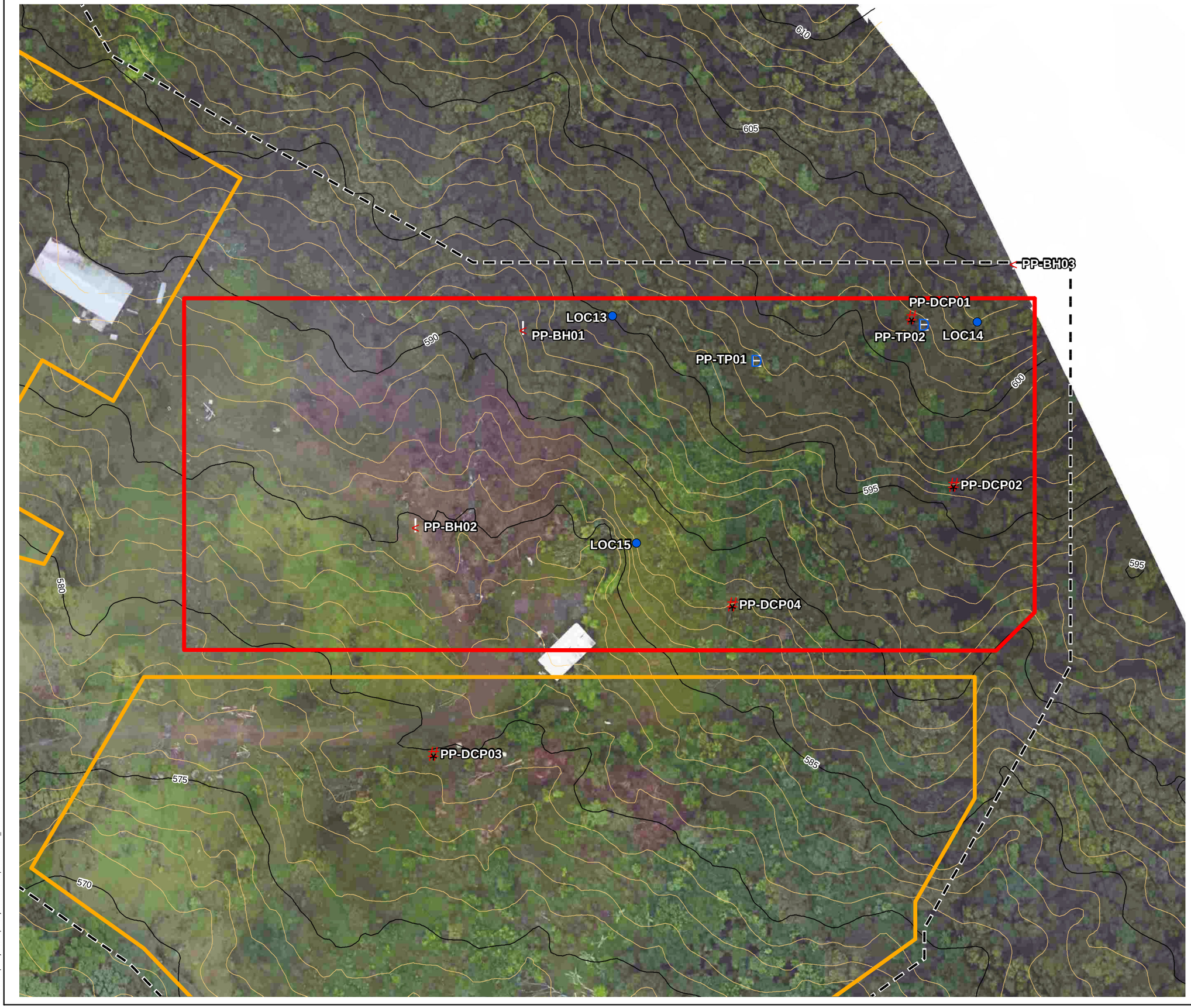



## Legend

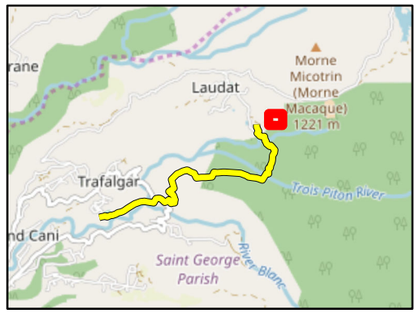
- Site Perimeter
- Laydown
- Power Plant
- Reinjection Route

### Investigation Locations (Jacobs)

- Field Exposure Log
- Test Pit
- Hand Dug Test Pit

### Investigation Locations (Jaca & Sierra)

- Bore Hole
- DCP




0 15 30 Meters

**Dominica Geothermal Power Plant site**

CLIENT
Dominica Geothermal Development Company

PROJECT
Dominica Geothermal

SCALE
1:600 @ A3

PROJECT CODE
RZ020300

PROJECT MANAGER
LS

DRAWN
OH

PROJECT DIRECTOR

DATE
28/01/2019

FIGURE NO

REVISION
DRAFT

JACOBS
Level 8
1 Grey Street
Wellington
04 473 4265

C:\Users\hopkinsj\Desktop\ReinjectionLine Mapbook Bores _PowerPlant.mxd

# Appendix B. Field Exposure Logs

# Rock Outcrop Description

**Locailty** 1

## WELDED IGNIMBRITE





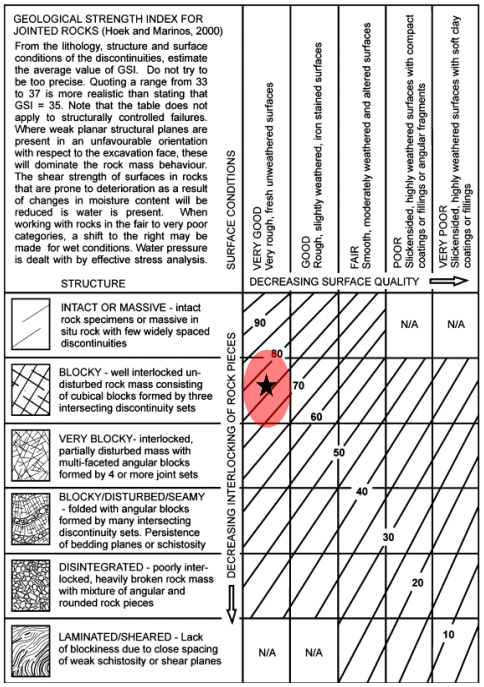


Jointed ignibrimite, joints are typically widely spaced.




Ignimbrite rock texture

### Geological Strength Index (GSI) Assessment




| GSI Summary | |
|---|---|
| Upper | 80 |
| Mean | 75 |
| Lower | 70 |

### Rock Mass Description

VOLCANIC ROCK (IGNIMBIRTE), thickly bedded, dark brown grey, slightly weathered, very soft to soft.
Columnar jointed, with vertical columns (three sets observed), spacing of the columns is very wide (average 1.0m), column persistence is at least 3m (end not observed). Defects are rough, planar and closed, no seepage observed.

### Schmidt hammer readings (horizontal)

12, 13, 12, 16, 16, 21 ,16, 12, 16

### Defect measurements (dip, dip direction)

89.086 85.007 77.219 80.049 81.049 81.229

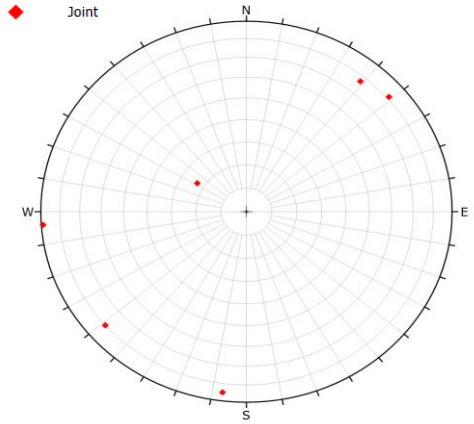
### Co-ordinates (UTM Zone 20P)

| Eastinngs | Northings |
|---|---|
| 673082 | 1692019 |

### Other Notes

Defect measurements adjusted to true north

### Stereonet (equal area, poles)



# Rock Outcrop Description

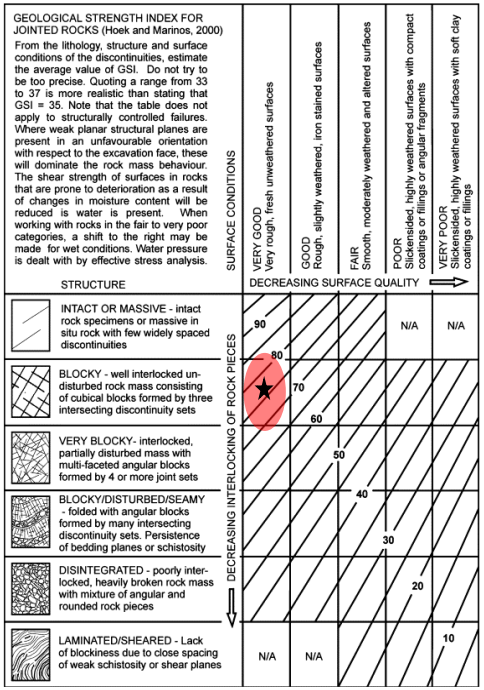
**Locailty** **2**

## WELDED IGNIMBRITE




Spacing of columnar joints reduced from Locality 1

### Geological Strength Index (GSI) Assessment




| GSI Summary | |
|---|---|
| Upper | 80 |
| Mean | 75 |
| Lower | 70 |

### Rock Mass Description

VOLCANIC ROCK (IGNIMBIRTE), thickly bedded, dark brown grey, slightly weathered, very soft to soft.
Columnar jointed, with vertical columns (three sets observed), spacing of the columns is wide (300mm to 1000mm), column persistence is at least 2m (end not observed). Defects are rough, planar and open, no seepage observed.

### Schmidt hammer readings (horizontal)

22, 16, 16, 18, 16, 16, 20, 18, 18, 20

### Defect measurements (dip, dip direction)

68. 321 83. 239 79. 227 83. 152

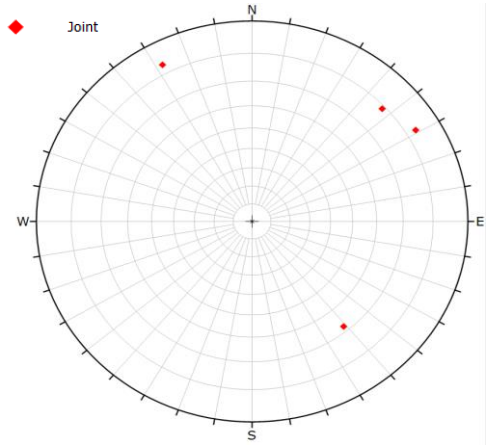
### Co-ordinates (UTM Zone 20P)

| Eastings | Northings |
|---|---|
| 678450 | 1694892 |

### Other Notes

Defect measurements adjusted to true north

### Stereonet (equal area, poles)



# Soil Mass Description

**Locailty** 3

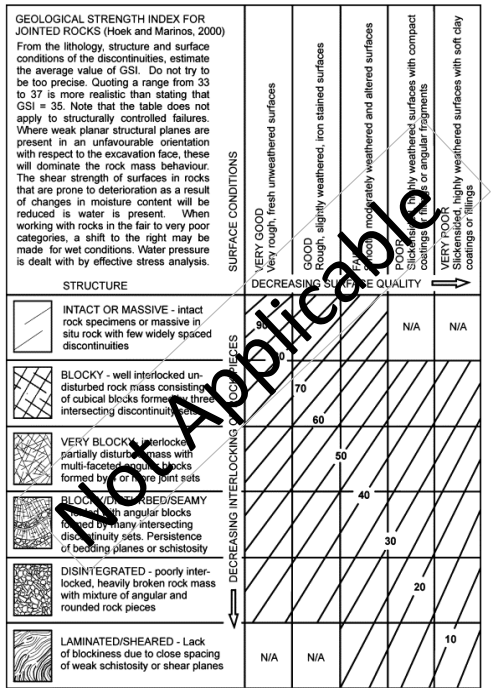
## PYROCLASTIC DEPOSIT






Ash deposit in cut slope. Able to be scraped with pick on geological hammer.

### Geological Strength Index (GSI) Assessment




Not Applicable

| GSI Summary | |
|---|---|
| Upper | |
| Mean | |
| Lower | |

### Soil Mass Description

Poorly graded SAND silt, “dense”, light grey with black flecks, sand is fine to medium grained, moist.

**Schmidt hammer readings (horizontal)**

N/A

**Defect measurements (dip, dip direction)**

N/A

**Co-ordinates (UTM Zone 20P)**

| Eastinngs | Northings |
|---|---|
| 679912 | 1695009 |

**Other Notes**

**Stereonet (equal area, poles)**

N/A

# Rock Outcrop Description

**Locailty** 4

## WELDED IGNIMBRITE





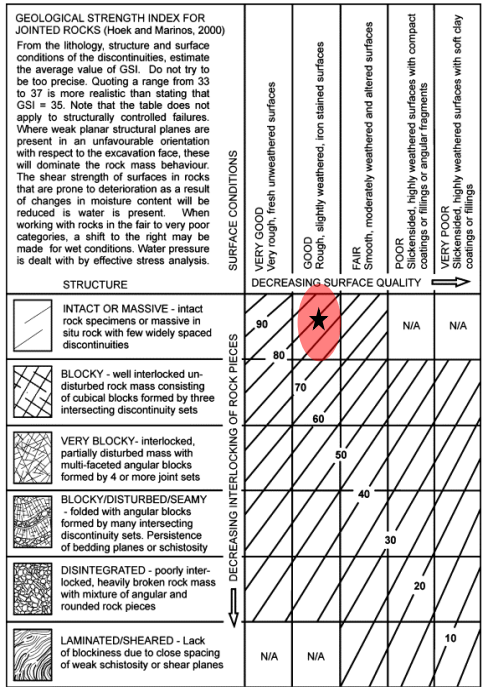


View of Northern River Bank, block and ash deposit contacting with basal Ignimbrite




View of Northern River Bank (towards power plant site). Block and Ash Deposit.

### Geological Strength Index (GSI) Assessment




| GSI Summary | |
|---|---|
| Upper | 85 |
| Mean | 80 |
| Lower | 75 |

### Rock Mass Description

VOLCANIC ROCK (IGNIMBIRTE), bedding not observed, dark brown grey, slightly weathered, soft.

### Schmidt hammer readings (vertical)

20, 16, 18, 16 12 18, 15

### Stereonet (equal area, poles)

### Defect measurements (dip, dip direction)

None taken

### Co-ordinates (UTM Zone 20P)

| Eastinngs | Northings |
|---|---|
| 679471 | 1695386 |

### Other Notes

# Rock Outcrop Description

**Locailty** 5

## WELDED IGNIMBRITE



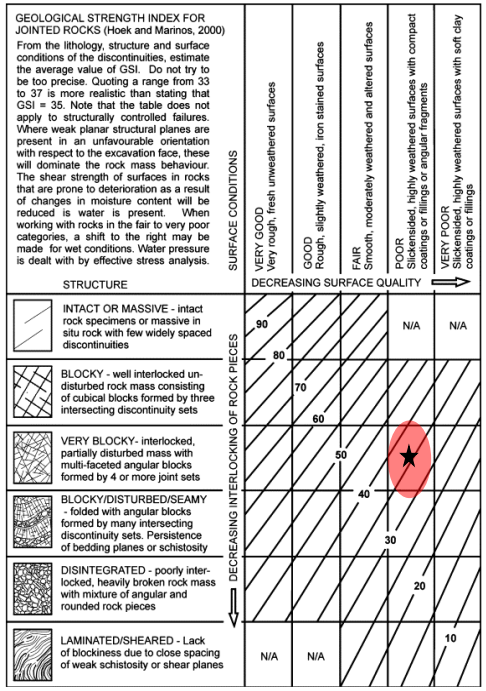



Joint face with block size 300mm by 100mm.



Joint face, perpendicular to joint face in above phot.

### Geological Strength Index (GSI) Assessment




| GSI Summary | |
|---|---|
| Upper | 40 |
| Mean | 35 |
| Lower | 30 |

### Rock Mass Description

VOLCANIC ROCK (IGNIMBIRTE), orange grey, slightly weathered, soft. Joints are closely to moderately widely spaced, rough, planar, some weathered infill (clay). Three joint sets, block sizes are typically 300x100x300mm.

### Schmidt hammer readings (horizontal)

20, 22, 24, 22, 15, 20, 20

### Defect measurements (dip, dip direction)

41,220 86, 86 42, 221 57, 236 59, 135

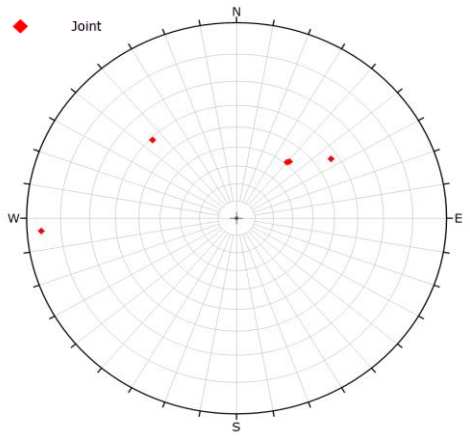
### Co-ordinates (UTM Zone 20P)

| Eastings | Northings |
|---|---|
| 677570 | 1694361 |

### Other Notes

Defect measurements adjusted to true north

### Stereonet (equal area, poles)



# Rock Outcrop Description

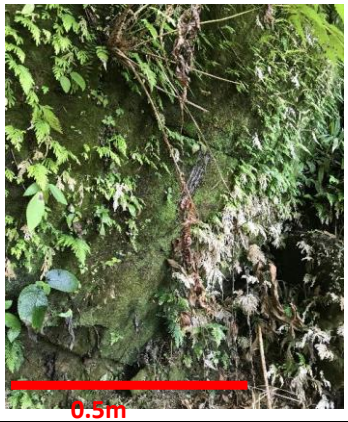
**Locailty** **6**

## WELDED IGNIMBRITE



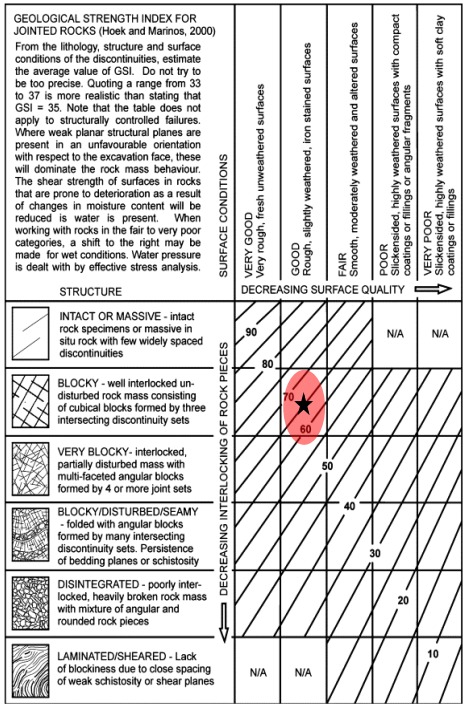



Ignimbrite texture




Defect, sub horizontal set intersecting sub vertical

### Geological Strength Index (GSI) Assessment




| GSI Summary | |
|---|---|
| Upper | 75 |
| Mean | 70 |
| Lower | 65 |

### Rock Mass Description

VOLCANIC ROCK (IGNIMBIRTE), thickly bedded, light grey with orange and black flecks, moderately to slightly weathered, Very soft.
Columnar jointed, with vertical columns (two sets observed), spacing of the columns widely spaced to very widely spaced (300mm to 3000mm), column persistence is approximately 500mm. Defects are smooth, planar to undulating, open and clean, no seepage observed.

**Schmidt hammer readings (hozizontal)**

18, 22, 18, 18, 22, 22 18

**Defect measurements (dip, dip direction)**

78, 138 31, 123

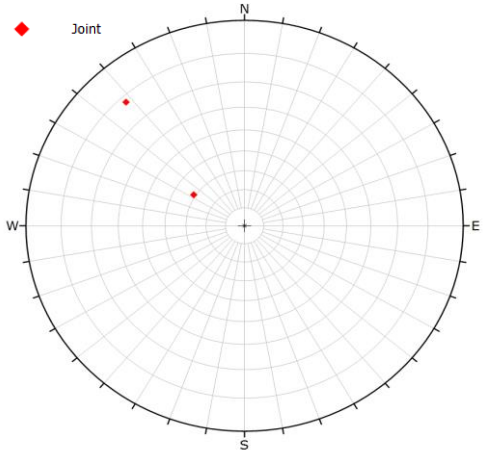
**Co-ordinates (UTM Zone 20P)**

| Eastings | Northings |
|---|---|
| 678519 | 1694927 |

**Other Notes**

Defect measurements adjusted to true north

**Stereonet (equal area, poles)**



# Rock Outcrop Description

**Locailty** **7**

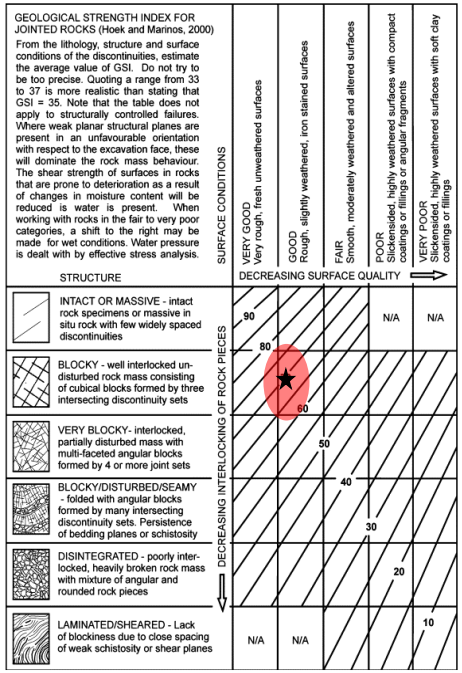
## WELDED IGNIMBRITE






Approximately 15m to the SE from Locality7 , the rock mass becomes massive, unjointed. Red box is Locality 7.

### Geological Strength Index (GSI) Assessment




| GSI Summary | |
|---|---|
| Upper | 80 |
| Mean | 70 |
| Lower | 60 |

### Rock Mass Description

VOLCANIC ROCK (IGNIMBIRTE), thickly bedded, light grey with orange and black flecks, moderately to slightly weathered, very soft to soft

Columnar jointed, with vertical columns (three sets observed) and one horizontal bedding, spacing of the columns widely spaced, column persistence is approximately 1500-2000mm. Defects are rough, undulating, open and clean, no seepage observed.

**Schmidt hammer readings (hozizontal)**

18,20 ,16, 18, 22, 20, 20

**Defect measurements (dip, dip direction)**

86. 214 8. 223 89. 049 84. 188

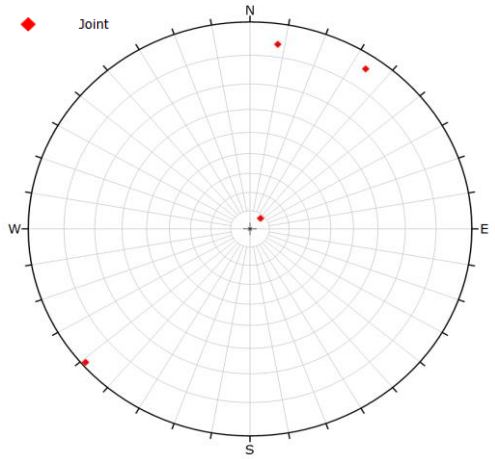
**Co-ordinates (UTM Zone 20P)**

| Eastings | Northings |
|---|---|
| 678530 | 1694906 |

**Other Notes**

Defect measurements adjusted to true north

**Stereonet (equal area, poles)**



# Rock Outcrop Description

**Locailty** **8**

## WELDED IGNIMBRITE



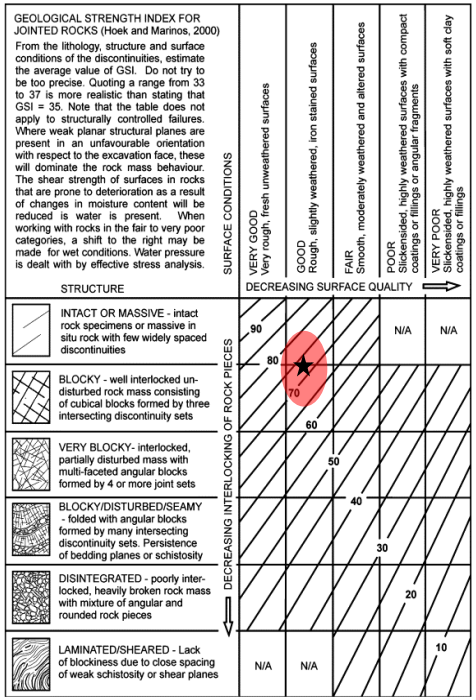
1m



Bedding within ignimbrite, large columnar blocks

1m

### Geological Strength Index (GSI) Assessment




| GSI Summary | |
|---|---|
| Upper | 80 |
| Mean | 75 |
| Lower | 70 |

### Rock Mass Description

VOLCANIC ROCK (IGNIMBIRTE), thickly bedded, light grey with black flecks, slightly weathered, soft.
Two vertical joint sets observed, one horizontal. Vertical joints are planar to undulating, rough, open and clean. Persistence 800mm to 3000mm (wide to very widely spaced).

**Schmidt hammer readings (horizontal)**

21, 25, 40, 28, 28, 25, 26,28

**Defect measurements (dip, dip direction)**

23, 122 78, 184 85, 269 79, 290 88, 057 87, 083 88, 035

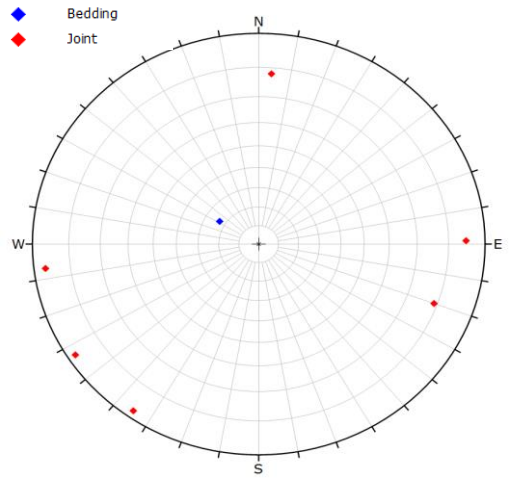
**Co-ordinates (UTM Zone 20P)**

| Eastings | Northings |
|---|---|
| 678538 | 1694913 |

**Other Notes**

Defect measurements adjusted to true north

**Stereonet (equal area, poles)**



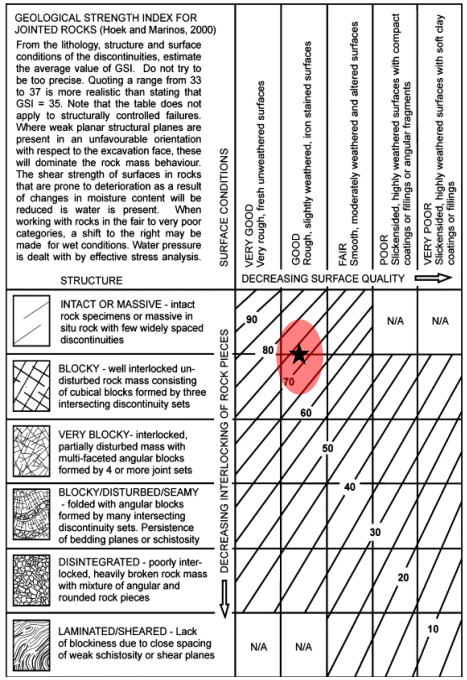
# Rock Outcrop Description

**Locailty** **9**

## WELDED IGNIMBRITE




### Geological Strength Index (GSI) Assessment




| GSI Summary | |
|---|---|
| Upper | 80 |
| Mean | 75 |
| Lower | 70 |

### Rock Mass Description

VOLCANIC ROCK (IGNIMBIRTE), thickly bedded, light grey with black flecks, slightly weathered, soft.
Two vertical joint sets observed, one horizontal. Vertical joints are planar to undulating, rough, open and clean. Persistence 800mm to 3000mm (wide to very widely spaced).

**Schmidt hammer readings (horizontal)**

Not taken

**Defect measurements (dip, dip direction)**

29. 100 23. 085 39. 100

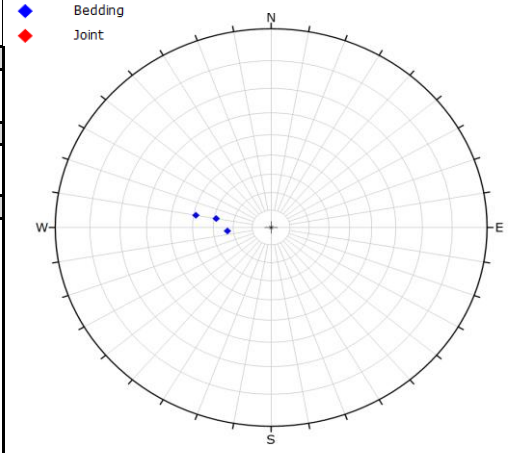
**Co-ordinates (UTM Zone 20P)**

| Eastings | Northings |
|---|---|
| 678543 | 1694865 |

**Other Notes**

Defect measurements adjusted to true north

**Stereonet (equal area, poles)**



# Soil Mass Description

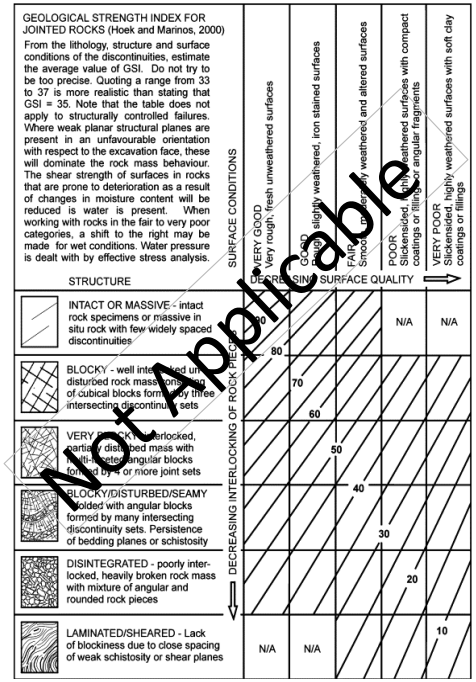
**Locailty** **10**

## PYROCLASTIC DEPOSIT






### Geological Strength Index (GSI) Assessment




| GSI Summary | |
|---|---|
| Upper | |
| Mean | |
| Lower | |

### Soil Mass Description

PYROCLAST DEPOSIT, Well-graded SAND with fine to coarse gravels and cobbles; ‘dense’; light grey brown and red; 50% fine to coarse sand, 40% gravels; 10% cobbles. Gravels and cobbles are moderately weathered andesite and dacite, angular, hard.

**Schmidt hammer readings (horizontal)**

Not taken

**Stereonet (equal area, poles)**

**Defect measurements (dip, dip direction)**

N.A

**Co-ordinates (UTM Zone 20P)**

| Eastings | Northings |
|---|---|
| 679427 | 1695577 |

**Other Notes**

# Soil Outcrop Description

**Locailty** 11

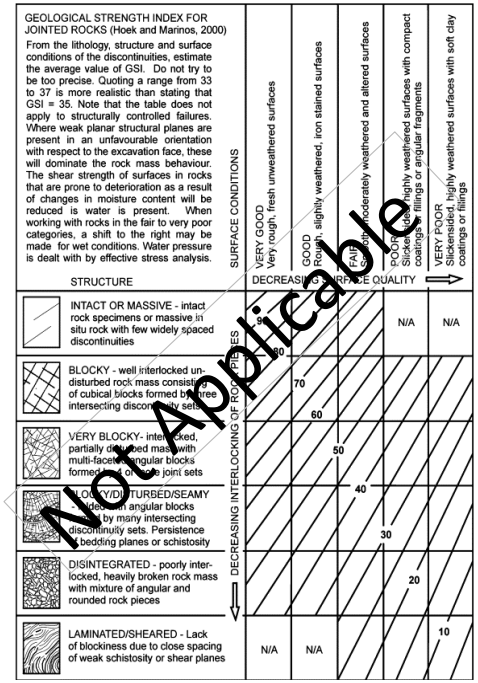
## PYROCLASTIC DEPOSIT






Boulder rock texture

### Geological Strength Index (GSI) Assessment




Not Applicable

| GSI Summary | |
|---|---|
| Upper | |
| Mean | |
| Lower | |

### Rock Mass Description

Large boulder approximately 3m in diameter. VOLCANIC ROCK (Dacite); slightly weathered; light grey with black flecks; moderately hard to hard.

**Schmidt hammer readings (horizontal)**

42, 50, 46, 45, 30, 50, 50, 48, 45

**Stereonet (equal area, poles)**

**Defect measurements (dip, dip direction)**

N/A

**Co-ordinates (UTM Zone 20P)**

| Eastinngs | Northings |
|---|---|
| 679644 | 1695610 |

**Other Notes**

Boulder displaced by excavator when clearing access track

# Rock Outcrop Description

**Locailty** 12

## PYROCLASTIC DEPOSIT

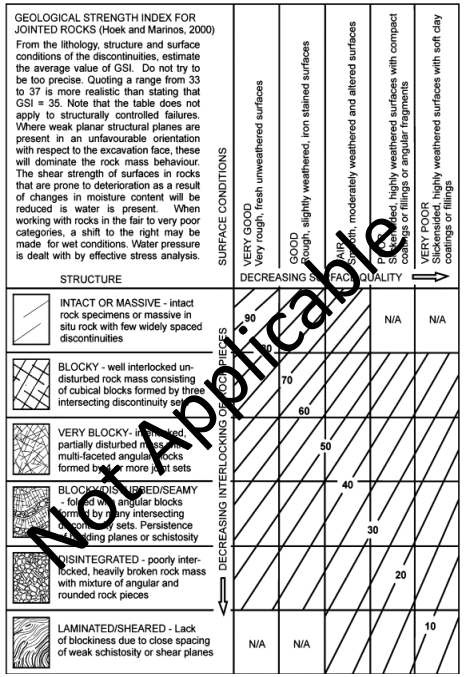





Large boulder, approximately 4 m in diameter



### Geological Strength Index (GSI) Assessment




Not Applicable

| GSI Summary | |
|---|---|
| Upper | |
| Mean | |
| Lower | |

### Rock Mass Description

VOLCANIC ROCK (Dacite); slightly weathered; light grey with black flecks; moderately hard to hard; sizes range from 500mm to 4000mm, angular

**Schmidt hammer readings (horizontal)**

40. 28 40, 50, 33, 45, 30

**Stereonet (equal area, poles)**

**Defect measurements (dip, dip direction)**

N/A

**Co-ordinates (UTM Zone 20P)**

| Eastinngs | Northings |
|---|---|
| 679614 | 1695615 |

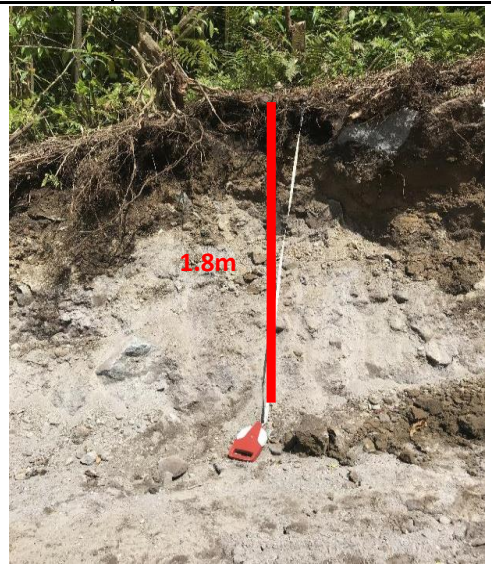
**Other Notes**

Boulder displaced by excavator when clearing access track

# SOIL MASS DESCRIPTION

**Locailty** **13**

## PYROCLASTIC DEPOSIT



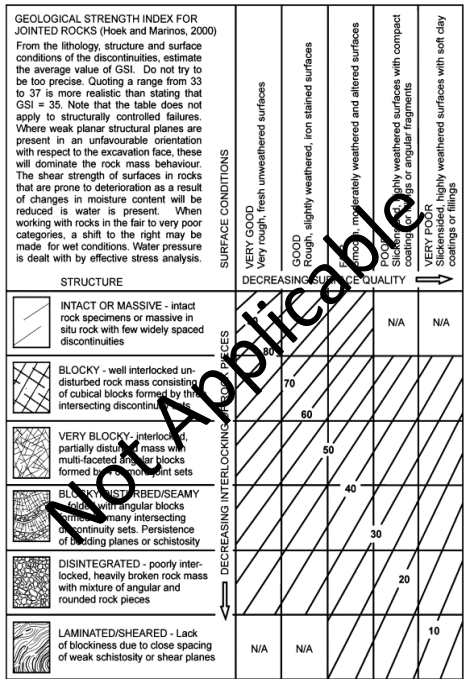



Access road cut



Access road cut, zoomed in

### Geological Strength Index (GSI) Assessment




| GSI Summary | |
|---|---|
| Upper | |
| Mean | |
| Lower | |

Not Applicable

### Soil Mass Description

Top Soil- 0-0.2 SILT with clay; firm; dark brown, clayey silt; wet
0.2-1.8 SAND with GRAVEL and COBBLES; medium dense; light brown and grey; dry; gravel sizes range from 50mm to 300mm, angular, hard.

**Schmidt hammer readings (horizontal)**

45, 48, 50, 48, 46, 50, 50 (on boulders)

**Stereonet (equal area, poles)**

**Defect measurements (dip, dip direction)**

**Co-ordinates (UTM Zone 20P)**

| Eastinngs | Northings |
|---|---|
| 679770 | 1695678 |

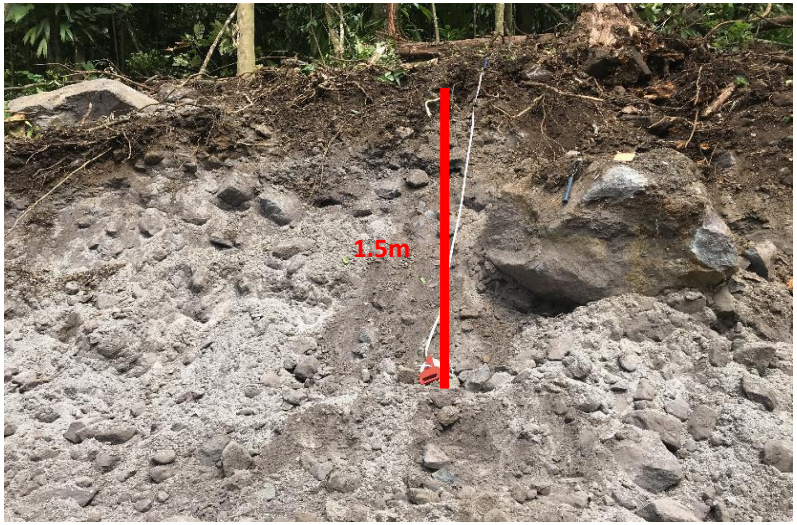
**Other Notes**

Cut slope on access track

# SOIL MASS DESCRIPTION

**Locailty** **14**

## PYROCLASTIC DEPOSIT



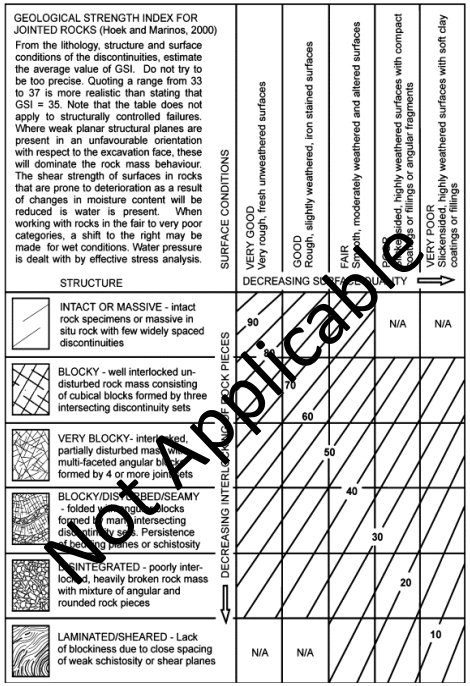



Large boulder in cut slope, approximately 1m in diameter, moderately strong.



Water pit near the cut slope, approximately 3m deep, Regular cobble to boulder sized clasts of dacite.

### Geological Strength Index (GSI) Assessment




Not Applicable

| GSI Summary | |
|---|---|
| Upper | |
| Mean | |
| Lower | |

### Soil Mass Decription

SAND with GRAVEL, COBBLES and BOULDERS; medium dense; light brown and grey; sand is medium to coarse; clasts are 50mm to 1000mm in size, angular, poorly sorted; dacite; hard.

**Schmidt hammer readings (horizontal)**

48, 50, 55, 40, 48, 58 (on boulders)

**Stereonet (equal area, poles)**

**Defect measurements (dip, dip direction)**

N/A

**Co-ordinates (UTM Zone 20P)**

| Eastinngs | Northings |
|---|---|
| 679831 | 1695677 |

**Other Notes**

Cut slope on access track

# SOIL MASS DESCRIPTION

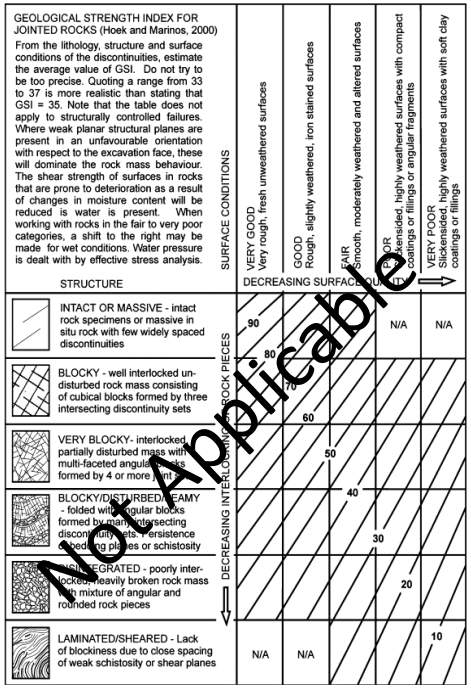
**Locailty** **15**

## PYROCLASTIC DEPOSIT






### Geological Strength Index (GSI) Assessment




Not Applicable

| GSI Summary | |
|---|---|
| Upper | |
| Mean | |
| Lower | |

### Soil Mass Description

SAND with GRAVEL, COBBLES and BOULDERS; medium dense; light brown and grey; clasts are angular; poorly sorted; dacite; hard.

**Schmidt hammer readings (horizontal)**

Not Taken

**Stereonet (equal area, poles)**

**Defect measurements (dip, dip direction)**

N/A

**Co-ordinates (UTM Zone 20P)**

| Eastinngs | Northings |
|---|---|
| 679774 | 1695640 |

**Other Notes**

Borrow pit ("tarish") on power plant site

# Appendix C. Jacobs Test Pit Logs

## Hole Type

AH - Augerhole
AP - Air Percussive drilling
BH - Borehole
CH - Slope surface protection strip
CP - Cable Percussion (Shell and Auger)
CPT - Cone Penetration Test
DCP - Dynamic Cone Penetrometer
DP - Dynamic Probe Sampling
EXP - Logged exposure
GCOP - GCO Probe
ICBR - In Situ CBR
IDEN - In Situ Density
INST - Instrument
IP - Inspection Pit / Trench
IRDX - In Situ redox Test
IRES - In Situ Resistivity
IVAN - In Situ Penetration Vane test
SCP - Static Cone Penetrometer
TP - Trial Pit / Trench
TRAV - Linear logging traverse or scanline
WS - Window Sampler
WLS - Windowless Sampler

## Techniques

CC - Concrete Coring
CFHSA - Continuous flight hollow stem auger
CFSSA - Continuous flight solid stem auger
DHH - Down hole hammer
EXC - Excavator
GEOBOR S - Geobor S
HA - Hand auger
HQ3 - HQ triple tube
HQWL - HQ wire line
HSA - Hollow stem auger
MAZIER - Maizer sampler
NQ3 - NQ triple tube
NQWL - NQ Wire line
OB - Open Barrel
PERC - Air Percussion
PQ3 - PQ triple tube
PQWL - PQ wire line
RC - Reverse circulation
RCDHH - Reverse circulation down hole hammer
SPT - Standard Penetration Test
SSA - Solid stem auger
TBX - Thin wall tube sample
TNX - Shelby tube sample
VAC EX - Vacuum excavation
WASH - Wash drilling
WS - Window Sampler
WLS - Windowless Sampler

## Sampling

### Undisturbed

BLK - Block
C - Core sample
GRAB - Grab sample
M - Mazier sample
PSTN - Piston sample
TNX - Shelby tube sample
TBX - Thin wall tube sample
U - Undisturbed sample

### Disturbed

AMAL - Amalgamated sample
B - Bulk sample
CBR - CBR mould sample
D - Small disturbed sample
LB - Large bulk sample
SPTLS - SPT liner sample

### Other

ES - Environmental soil sample
EW - Environmental water sample
G - Gas sample
W - Water sample

## Test Records

**Standard Penetration Test records**
s or c - open shoe (s) or solid raymond cone (c)
The Standard Penetration Test is defined in BS1377: Part 9 (1990). The incremental blow counts are given in the test column. Each increment is 150mm unless stated otherwise and any penetration under self weight is noted. Where the full 300mm test drive is achieved the total number of blows for the test drive is presented as N = ** in the test column. Where the seating or test drive blows reach 50 (either in total or for a single increment) the total blow count beyond the seating drive is given for the length of drive (N = **/*** mm).

**Shear Vane Tests**
Shear Vane test performed as per BS1377:1990 with a calibrated vane and recorded on the investigation logs as per NZGS Guidelines, December 2005.
Shear Vane tests given as $I_{VP}$ peak and $I_{VR}$ remoulded shear strengths (kN/m$^2$), corrected for vane calibration.
Where a shear vane test is performed at the end of the core barrel, prior to extruding the core, the result is superseeded by $^{c}$. Where a shear vane test is performed in a suitably sized piece of spoil, the result is superseeded by $^{s}$.
UTP denotes shear vane unable to penetrate.

Pocket Penetrometer Test results are given as a mean undrained shear strength (kN/m$^2$) and the result is superseeded by *pp*.

## Relative Strength

EW - Extremely Weak
VW - Very Weak
W - Weak
MS - Moderately Strong
S - Strong
VS - Very Strong
ES - Extremely Strong

## Weathering Grade

RS - Residual Soil
CW - Completely Weathered
HW - Highly Weathered
MW - Moderately Weathered
SW - Slightly Weathered
UW - Unweathered

## Rock Classification

$J_n$ - Joint Set Number
$J_r$ - Joint Roughness Number
$J_a$ - Joint Alteration Number

## Defect Description

### Aperture

JCN - Clean
CT - Coating (>=1 mm)
FILLED - Filled
SN - Stain
VNR - Veneer (<1 mm)

### Planarity

CU - Curved
DIS - Discontinuous
IR - Irregular
PR - Planar
ST - Stepped
UN - Undulose

### Roughness

POL - Polished
RF - Rough
S - Smooth
SL - Slickensided
VR - Very rough

### Infill Material

CA - Calcite
Clay - Clay
Fe - Iron oxide
Fe Clay - Iron oxide clay
KT - Chlorite
MS - Secondary mineral
MU - Unidentified mineral
Qz - Quartz
X - Carbonaceous

### Type

BP - Bedding parting
CL - Cleavage
CO - Contact
CS - Crushed seam
CZ - Crushed zone
DB - Drilling break
DK - Dyke
DL - Drill lift
DZ - Decomposed zone
FC - Fracture
FL - Foliation
FZ - Fracture zone
HB - Handling break
IS - Infilled seam
JT - Joint
SH - Schistosity
SI - Sill
SM - Seam
SS - Shear seam
SZ - Shear zone
VN - Vein
VO - Void

## Installations

### Installation Materials


Drill Cuttings

Bentonite Seal

Grout

Gravel Backfill

Concrete

Sand Filter

### Instrument Details


Standpipe

Slotted Standpipe

Watera

Transducer Wire

VES Wire

## Ground Water Records


Water Strike

Standing Water Level

JACOBS 3.01.2 CJR EDITS LIB V5.GLB GrfcText JACOBS SYMBOL LEGEND SHEET DOMINICA GINT TEST PITS.GPJ <<DrawingFile>> 28/01/2019 17:54 10.0.000 Datgel Lab and In Situ Tool - DGD | Lib: Jacobs 3.01.2 2017-03-09 Prj: Jacobs 3.01.1 2017-02-28

This log was created for Jacobs' client. Jacobs accepts no responsibility for any reliance on this information by third parties.

| | | | |
|---|---|---|---|
| **Project:** | Dominica Geothermal Project | **Project No:** | RZ0421000 |
| **Client:** | Dominica Geothermal Development Company | **Page:** | 1 of 1 |
| **Location:** | Dominica, West Indies | | |

# Graphic Legend


TOPSOIL


SILT


Gravelly bouldery SAND


Cobbly bouldery SAND


IGNIMBRITE

JACOBS 3.01.2 CJR EDITS LIB V5.GLB GrfcText JACOBS MATERIAL GRAPHIC LEGEND SHEET DOMINICA GINT TEST PITS.GPJ <<DrawingFile>> 28/01/2019 17:53 10.0.000 Datgel Lab and In Situ Tool - DGD | Lib: Jacobs 3.01.2 2017-03-09 Prj: Jacobs 3.01.1 2017-02-28

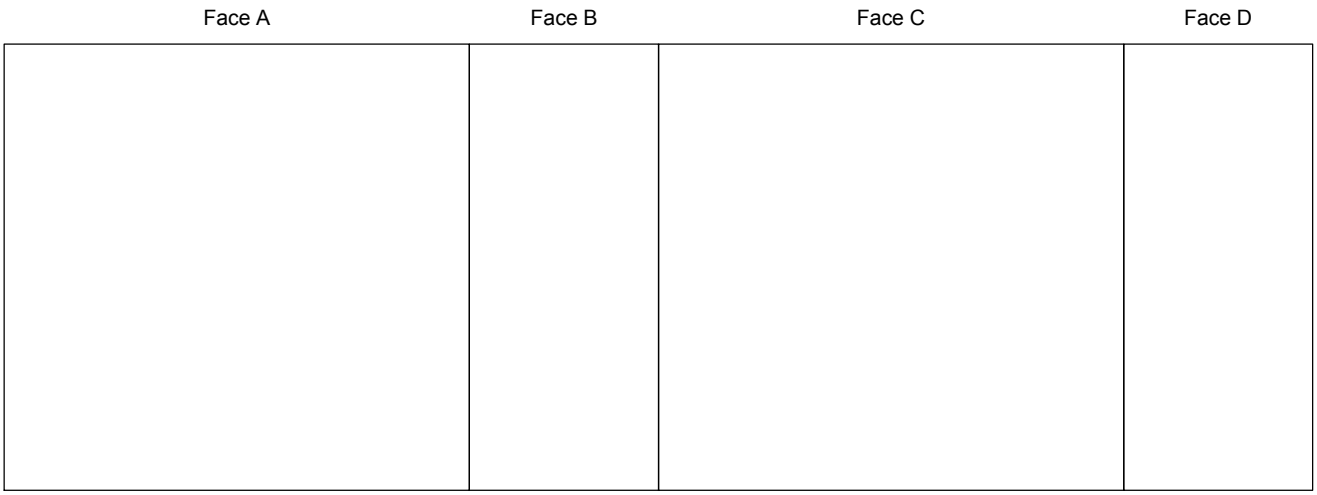
This log was created for Jacobs' client. Jacobs accepts no responsibility for any reliance on this information by third parties.

# Inspection Pit

| | | | |
|---|---|---|---|
| **Project:** | Dominica Geothermal Project | **Hole ID:** | RR-B2-TP01 |
| **Client:** | Dominica Geothermal Development Company | **Project No:** | RZ0421000 |
| **Location:** | Dominica, West Indies | **Page:** | 1 of 1 |

560

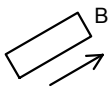
*Face Sketch (including stratum boundaries and face(s) sketched).*




| R.L. (m) | Depth (m) | In-Situ Testing | Sampling | Geology Legend | Groundwater | Description of Strata | Geological Unit |
|---|---|---|---|---|---|---|---|
| | | | | | | 0.10 Topsoil | |
| | | 110*pp* | | | | SILT with fine to medium sand, light brown, grey. Meidum stiff to stiff, wet, low plasticity. *0.30m: some gravels to cobbles of highly weathered volcanic sandstone (ignimbrite)* | Young Pleistocene Volcanics |
| | 1 | 250*pp* | | | | 1.00 | |
| | | | | | | 1.20 VOLCANIC SANDSTONE (Ignimbrite, pumecous), highly weathered, light grey and yellowish brown. Very soft to soft. | |
| | | | | | | Hole Terminated at 1.20 m<br>Refusal | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Contractor:** | Jaca & Sierra | **Easting:** | 679790.0 | **Elevation:** | | **Started:** | 25/09/2018 |
| **Plant:** | Hand Dug | **Northing:** | 1694821.0 | **Datum:** | | **Finished:** | 25/09/2018 |
| **Logged by:** | CR | **Grid:** | UTM Zone 20P | **Stability:** | Stable | **Standard:** | ASTM |
| **Checked by:** | SN | **Accuracy:** | hhGPS5 | **Shoring:** | Not required | **Status:** | Final |

**Length:** 1
**Width:** 1
**Orientation:** ° (As arrow)




**Excavation Remarks:**
Hole location determined by hhGPS5
Groundwater not encountered.

JACOBS 3.01.2 CJR EDITS LIB V5 GLB Log JACOBS NZ INSPECTION PIT LOG DOMINICA GINT TEST PITS.GPJ <<DrawingFile>> 28/01/2019 17:52 10.0.000 Datgel Lab and In Situ Tool - DGD | Lib: Jacobs 3.01.2 2017-03-09 Prj: Jacobs 3.01.1 2017-02-28

This log was created for Jacobs' client. Jacobs accepts no responsibility for any reliance on this information by third parties.



**Depth 0 - 1.2m**

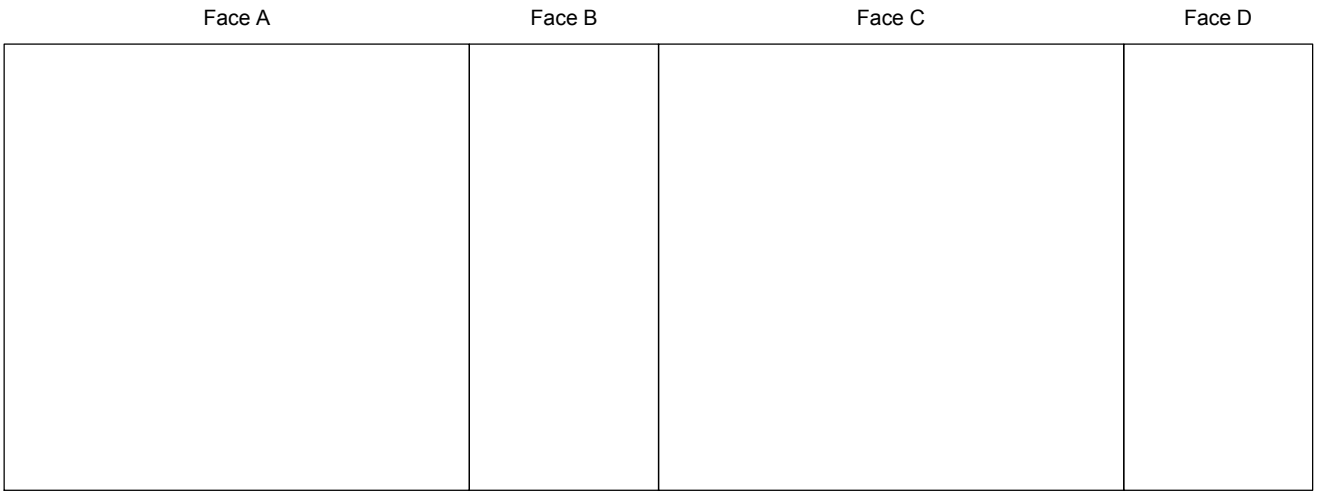
| | | | | | |
|---|---|---|---|---|---|
| *Title* | **RR-B2-TP01** | *Project* | **Dominica Geothermal Project** | *Client* | **DGDC** |
| *Scale* | **N/A** | *Rev* | **0** | | |

JACOBS®

# Inspection Pit

| | | | | |
|---|---|---|---|---|
| **Project:** | Dominica Geothermal Project | **Hole ID:** | RR-B3-TP03 | 562 |
| **Client:** | Dominica Geothermal Development Company | **Project No:** | RZ0421000 | |
| **Location:** | Dominica, West Indies | **Page:** | 1 of 1 | |

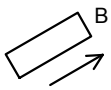
*Face Sketch (including stratum boundaries and face(s) sketched).*




| R.L. (m) | Depth (m) | In-Situ Testing | Sampling | Geology Legend | Groundwater | Description of Strata | Geological Unit |
|---|---|---|---|---|---|---|---|
| | | | | | | Alluivum - test pit not logged | |
| | 1 | | | | | Recent to young plesitocene aged volcanics | |
| | 2 | | | | | | |
| | 3 | | | | | | |
| | 4 | | | | | *4.00m: excavator refusal at 4.0m, too hard to excavate*<br>Hole Terminated at 4.00 m<br>Refusal | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Contractor:** | CCL | **Easting:** | 678103.0 | **Elevation:** | | **Started:** | 17/11/2018 |
| **Plant:** | 20t Excavator | **Northing:** | 1694528.0 | **Datum:** | | **Finished:** | 17/11/2018 |
| **Logged by:** | | **Grid:** | UTM Zone 20P | **Stability:** | Stable | **Standard:** | ASTM |
| **Checked by:** | | **Accuracy:** | hhGPS5 | **Shoring:** | Not required | **Status:** | Final |

**Length:** 4
**Width:** 1
**Orientation:** ° (As arrow)




**Excavation Remarks:**
Hole location determined by hhGPS5
Groundwater at base of excavation.

JACOBS 3.01.2 CJR EDITS LIB V5.GLB Log JACOBS NZ INSPECTION PIT LOG DOMINICA GINT TEST PITS.GPJ <<DrawingFile>> 28/01/2019 17:52 10.0.000 Datgel Lab and In Situ Tool - DGD | Lib: Jacobs 3.01.2 2017-03-09 Prj: Jacobs 3.01.1 2017-02-28

This log was created for Jacobs' client. Jacobs accepts no responsibility for any reliance on this information by third parties.



**Depth 0 - 4.0 m**



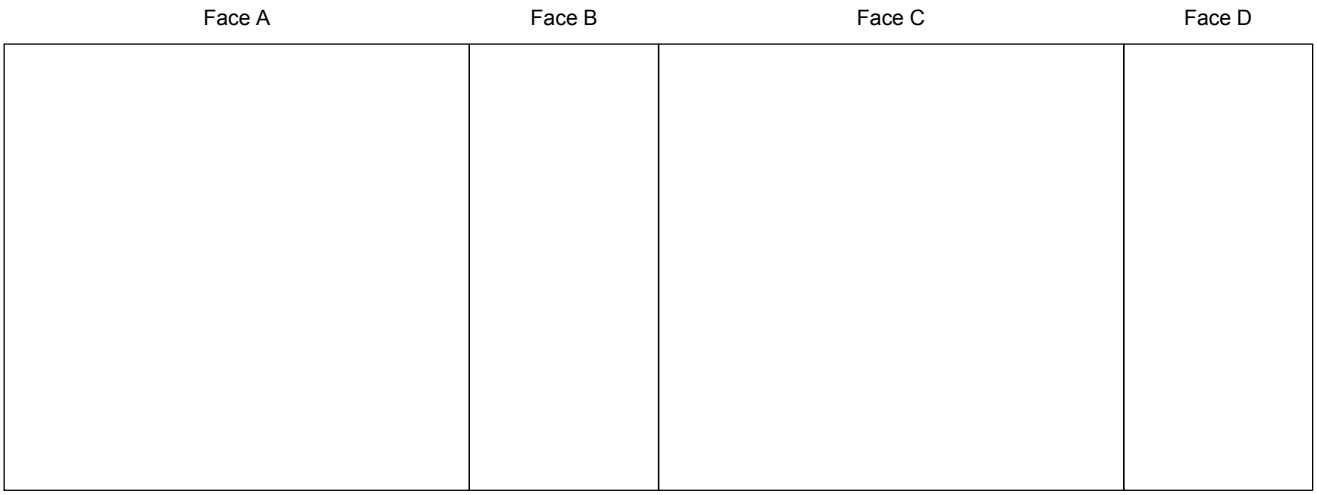
**Depth 0 -4.0 m**

| | | | | | |
|---|---|---|---|---|---|
| *Title* | **RR-B3-TP03** | *Project* | **Dominica Geothermal Project** | *Client* | **DGDC** |
| *Scale* | **N/A** | *Rev* | **0** | | |

# Inspection Pit

| | | | | | |
|---|---|---|---|---|---|
| **Project:** | Dominica Geothermal Project | | **Hole ID:** | RR-C1-TP02 | 564 |
| **Client:** | Dominica Geothermal Development Company | | **Project No:** | RZ0421000 | |
| **Location:** | Dominica, West Indies | | **Page:** | 1 of 1 | |

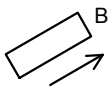
*Face Sketch (including stratum boundaries and face(s) sketched).*




| R.L. (m) | Depth (m) | In-Situ Testing | Sampling | Geology Legend | Groundwater | Description of Strata | Geological Unit |
|---|---|---|---|---|---|---|---|
| | 1 | 120*pp* | | | | 0.20 Topsoil<br>SILT with medium sand, medium stiff, light brown, moist, low plasticity (residual ignimbrite)<br>*0.30m: some angular gravels (100-200mm) of moderately weathered ignimbrite, light grey with red and black flecks*<br>0.50 IGNIMBRITE; fine grained; light brown grey; soft, moderately weathered<br>1.00 Hole Terminated at 1.00 m<br>Refusal | Young Pleistocene Volcanics |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Contractor:** | Jaca & Sierra | **Easting:** | 678521.0 | **Elevation:** | | **Started:** | 25/09/2018 |
| **Plant:** | Hand Dug | **Northing:** | 1694955.0 | **Datum:** | | **Finished:** | 25/09/2018 |
| **Logged by:** | CR | **Grid:** | UTM Zone 20P | **Stability:** | Stable | **Standard:** | ASTM |
| **Checked by:** | SN | **Accuracy:** | hhGPS5 | **Shoring:** | Not required | **Status:** | Final |

**Length:** 1
**Width:** 1
**Orientation:** ° (As arrow)




**Excavation Remarks:**
Hole location determined by hhGPS5
Groundwater not encountered.

JACOBS 3.01.2 CJR EDITS LIB V5 GLB Log JACOBS NZ INSPECTION PIT LOG DOMINICA GINT TEST PITS.GPJ <<DrawingFile>> 28/01/2019 17:53 10.0.000 Datgel Lab and In Situ Tool - DGD | Lib: Jacobs 3.01.2 2017-03-09 Prj: Jacobs 3.01.1 2017-02-28

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**Depth 0 - 1.0 m**

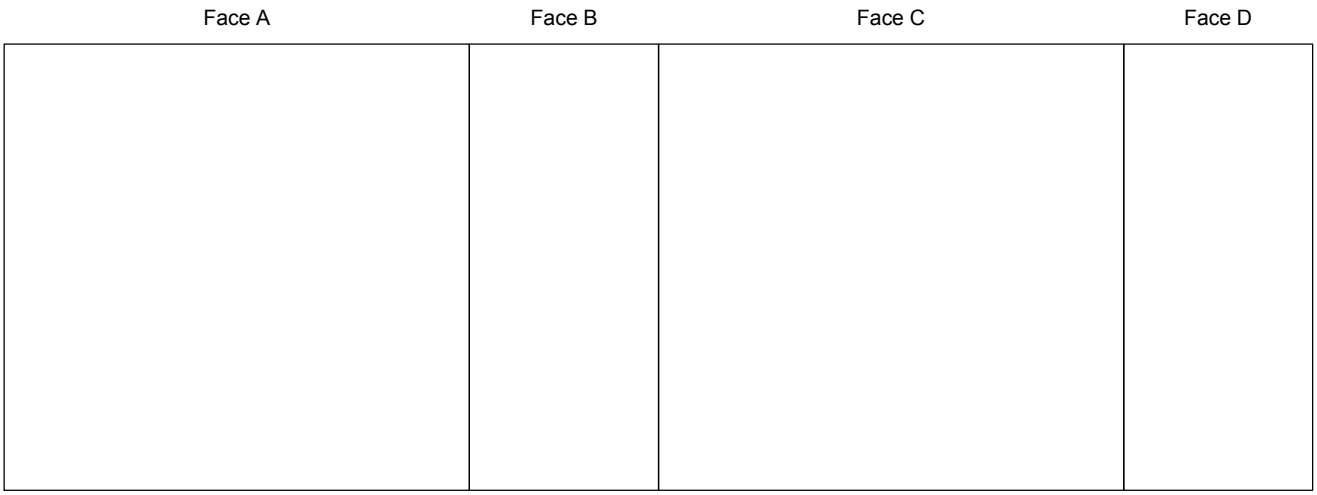
| | | | | | |
|---|---|---|---|---|---|
| *Title* | **RR-C1-TP02** | *Project* | **Dominica Geothermal Project** | *Client* | **DGDC** |
| *Scale* | **N/A** | *Rev* | **0** | | |

# Inspection Pit

| | | | |
|---|---|---|---|
| **Project:** | Dominica Geothermal Project | **Hole ID:** | PP-TP01 |
| **Client:** | Dominica Geothermal Development Company | **Project No:** | RZ0421000 |
| **Location:** | Dominica, West Indies | **Page:** | 1 of 1 |



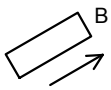
*Face Sketch (including stratum boundaries and face(s) sketched).*




| R.L. (m) | Depth (m) | In-Situ Testing | Sampling | Geology Legend | Groundwater | Description of Strata | Geological Unit |
|---|---|---|---|---|---|---|---|
| | | | | | | 0.20 Topsoil | |
| | 1 | | | | | Poorly graded SAND with BOULDERS and COBBLES (30%); dense, brown and grey; dry; boulders and cobbles are subauglar DACITE, 20mm to 400mm in diameter | |
| | | | | | | *1.00m: difficult to excavate, layer of 400mm diameter boulders* | |
| | 2 | | B | | | *2.00m: gravels to cobbles becoming 80% of soil mass, 20% sand* | Recent to Youung Plesticocene Volcanics |
| | 3 | | | | | *3.20m: 1000mm diameter boulder* | |
| | 4 | | | | | 4.00 | |
| | | | B | | | Hole Terminated at 4.00 m<br>Machine Limit | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Contractor:** | CCL | **Easting:** | 679848.0 | **Elevation:** | | **Started:** | 05/10/2018 |
| **Plant:** | 35t Excavator | **Northing:** | 1695694.0 | **Datum:** | | **Finished:** | 05/10/2018 |
| **Logged by:** | CR | **Grid:** | UTM Zone 20P | **Stability:** | Stable | **Standard:** | ASTM |
| **Checked by:** | SN | **Accuracy:** | hhGPS5 | **Shoring:** | Not required | **Status:** | Final |

**Length:** 4
**Width:** 1
**Orientation:** ° (As arrow)




**Excavation Remarks:**

Hole location determined by hhGPS5
Groundwater not encountered.

JACOBS 3.01.2 CJR EDITS LIB V5.GLB Log JACOBS NZ INSPECTION PIT LOG DOMINICA GINT TEST PITS.GPJ <<DrawingFile>> 28/01/2019 17:51 10.0.000 Datgel Lab and In Situ Tool - DGD | Lib: Jacobs 3.01.2 2017-03-09 Prj: Jacobs 3.01.1 2017-02-28

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**Depth 0 - 4.0 m**



**Spoil Pile**

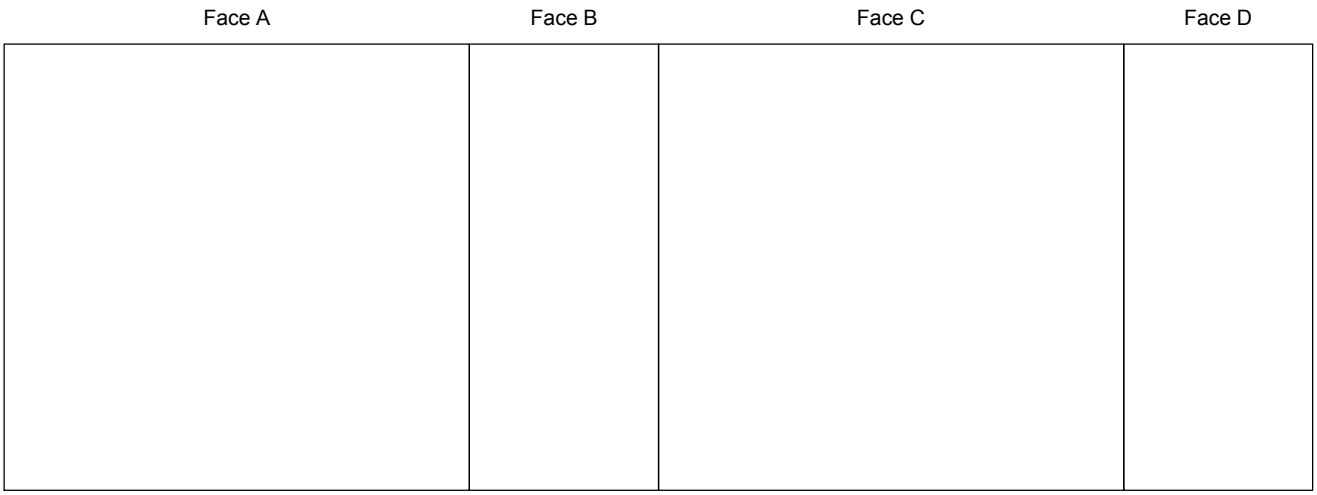
| | | | | | |
|---|---|---|---|---|---|
| *Title* | **PP-TP01** | *Project* | **Dominica Geothermal Project** | *Client* | **DGDC** |
| *Scale* | **N/A** | *Rev* | **0** | | |

JACOBS

# Inspection Pit

| | | | |
|---|---|---|---|
| **Project:** | Dominica Geothermal Project | **Hole ID:** | PP-TP02 |
| **Client:** | Dominica Geothermal Development Company | **Project No:** | RZ0421000 |
| **Location:** | Dominica, West Indies | **Page:** | 1 of 1 |

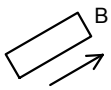
*Face Sketch (including stratum boundaries and face(s) sketched).*




| R.L. (m) | Depth (m) | In-Situ Testing | Sampling | Geology Legend | Groundwater | Description of Strata | Geological Unit |
|---|---|---|---|---|---|---|---|
| | | | | | | 0.20 Topsoil | |
| | 1 | | B | | | Poorly graded SAND (60%) with GRAVELS and BOULDERS (40%); very dense, brown and grey; moist; sand is medium to coarse; boulders and gravels are subauglar DACITE, 20mm to 800mm in diameter | Young Pleistocene Volcanics |
| | 2 | | | | | *2.50m: boulders increase to 1500mm diameter in size, 70% boulders, 30% sand* | |
| | 3 | | B | | | | |
| | 4 | | | | | *4.00m: becomes SAND with cobbles, 70% sand, 30% cobbles, sand is medium to coarse, cobbles are 30-300mm in diameter* | |
| | | | | | | 4.50 Hole Terminated at 4.50 m<br>Machine Limit | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Contractor:** | CCL | **Easting:** | 679800.0 | **Elevation:** | | **Started:** | 05/10/2018 |
| **Plant:** | 35t Excavator | **Northing:** | 1695680.0 | **Datum:** | | **Finished:** | 05/10/2018 |
| **Logged by:** | CR | **Grid:** | UTM Zone 20P | **Stability:** | Stable | **Standard:** | ASTM |
| **Checked by:** | SN | **Accuracy:** | hhGPS5 | **Shoring:** | Not required | **Status:** | Final |

**Length:** 4
**Width:** 1
**Orientation:** ° (As arrow)




**Excavation Remarks:**
Hole location determined by hhGPS5
Groundwater not encountered.

JACOBS 3.01.2 CJR EDITS LIB V5.GLB Log JACOBS NZ INSPECTION PIT LOG DOMINICA GINT TEST PITS.GPJ <<DrawingFiles>> 28/01/2019 17:52 10.0.000 Datgel Lab and In Situ Tool - DGD | Lib: Jacobs 3.01.2 2017-03-09 Prj: Jacobs 3.01.1 2017-02-28

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**Depth 0 - 4.5 m**



**Spoil Pile**

| | | | | | |
|---|---|---|---|---|---|
| *Title* | **PP-TP02** | *Project* | **Dominica Geothermal Project** | *Client* | **DGDC** |
| *Scale* | **N/A** | *Rev* | **0** | | |

# Appendix D. Jaca & Sierra Factual Report

JACA & SIERRA
Testing Laboratories
Geotechnical Engineers

# FACTUAL REPORT

## ON THE GEOTECHNICAL EXPLORATION PERFORMED FOR THE PROPOSED DOMINICA GEOTHERMAL PLANT

***Submitted to:***

*Dominica Geothermal Development Company*
Att: Mark Tomkins

***Prepared by:***

Manuel E. Candelario Cosme, MSCE, PE
Carlos R. Sierra Del Llano, MSCE, PE

***Date:***

February 12, 2019

**Job No. 7909**

*This report contains 109 pages including cover*

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**FACTUAL REPORT**

**ON THE GEOTECHNICAL INVESTIGATION PERFORMED FOR THE PROPOSED GEOTHERMAL PLANT AT DOMINICA**

## 1.0 INTRODUCTION:

*Jaca & Sierra Engineering, PSC* was contracted by *The Dominica Geothermal Development Company (DGDC)* to perform site investigations for the proposed 7MW Geothermal Plant at the Roseau Valley, Dominica. The project consisted of two phases: the power plant site located at Laudat; and the brine reinjection line extending from Laudat to Wotten Waven and Trafalgar.

The scope of field investigations and laboratory tests was performed following instructions from DGDC and Jacobs, who is the project designer and geotechnical engineer of the project. Our services excluded interpretation, evaluation and geotechnical recommendations.

Preliminary boring logs and tests results have been sent in advance of this report to DGDC. This report includes updated and complete versions.




**Figure 1: Power Plant Site Location, Laudat, Dominica**

## 2.0 FIELD WORK:

### 2.1 Exploratory Boreholes:

In-situ testing and soil sampling was achieved by means of the Standard Penetration Test (SPT) and split spoon sampler method according to ASTM D 1586. Rock core drilling was achieved according to ASTM D2113. Subsurface drilling was executed by means of the HW casing advancer system and HQ wireline rock coring per ASTM D 1452 using a trailer mounted CME-55 hydraulic rotary drill.

A total of seven (7) borings were performed throughout the site: three (3) at the Power Plant Site; and four (4) at the Reinjection Route.

Collected soil samples were delivered to our laboratory to perform analyses of moisture content, unconfined compressive strength tests, soil classifications, California Bearing Ratios (CBR), compaction test, and uniaxial rock compressive strength tests.

**Table 1: Boring Coordinates provided by others (UTM Grid 20P)**

| Investigation ID | E | N |
|---|---|---|
| BH01-PP | 679755 | 1695676 |
| BH02-PP | 679737 | 1695643 |
| BH03-PP | 679837 | 1695687 |
| BH01-B1-RR | 679612 | 1695412 |
| BH02-B1-RR | 679658 | 1695373 |
| BH03-B2-RR | 679649 | 1694948 |
| BH04-B2-RR | 679639 | 1694913 |

## 2.2 Dynamic Cone Penetration (DCP) Tests:

The DCP is a hand-held device used to measure the insitu strength of soils. The equipment consists of two 16-mm diameter shafts coupled near midpoint. The lower shaft contains a rod and pointed tip that is driven into the soil by dropping a sliding hammer contained on the upper shaft. The underlying soil strength is estimated by measuring the penetration of the lower shaft into the soil after each hammer drop. This value is recorded in millimeters per blow and is known as the DCP penetration index (DPI). This value is then used to correlate other soil strength parameters such as the California Bearing Ratio (CBR) and soil bearing capacity.

### 2.3 Downhole Seismic Test:

The downhole seismic test was performed at the location of boring BH02 of the Power Plant Site. The test was completed following ASTM D 7400 "Standard Test Methods for Downhole Seismic Testing" in order to determine the compression (P) and shear wave (S) velocities throughout the subsurface strata.

The tests consists in generating a seismic wave train at the ground surface offset horizontally from the top of a cased borehole, where a downhole receiver is lowered to detect the arrival of the seismic wave. In this case, the energy source was generated by striking the side of a wooden beam with a 10 lb sledge hammer to simulate the shear wave. The compression wave was generated by striking vertically a plate on the ground. The downhole receiver is positioned at 1 meter intervals. The seismic source is connected to and triggers a data recording system that records the response of the downhole receiver, measuring the travel time of the wave train between the source and receiver. Measurements of the arrival times of the generated P-wave and S-waves are then made so that the low-strain in-situ P-wave and S-wave velocities can be determined.

Results for the shear wave velocities are appended to this report.

# 3.0 LABORATORY TESTING:

## 3.1 Dynamic Cone Penetration Tests:

A total of fourteen (14) Dynamic Cone Penetration (DCP) tests were performed for the project: four (4) at the power plant site and 10 (ten) along the reinjection line. The following table provides the coordinates of the DCP tests based on the UTM coordinate system grid 20P, as provided to us by DGDC. DCP test locations were stacked out in the field by DGDC.

**Table 2: Test Coordinates (UTM Grid 20P)**

| Investigation ID | E | N |
|---|---|---|
| PP-DCP01 | 679820 | 1695678 |
| PP-DCP02 | 679820 | 1695360 |
| PP-DCP03 | 679740 | 1695605 |
| PP-DCP04 | 679790 | 1695630 |
| DCP01-RL | 679602 | 1694821 |
| DCP02-RL | 679397 | 1694863 |
| DCP03-RL | 679094 | 1694916 |
| DCP04-RL | 678915 | 1694915 |
| DCP05-RL | 678861 | 1694876 |
| DCP06-RL | 678673 | 1694891 |
| DCP07-RL | 678653 | 1694908 |
| DCP08-RL | 678521 | 1694955 |
| DCP 09-RL | 677832 | 1694501 |
| DCP10-RL | 677657 | 1694370 |

## 3.2 Downhole Seismic Tests:

The data from the Downhole Seismic Test (BH02-PP) shows shear wave (S) velocity values that range from 450 m/s at the loose ash sandy stratum to about 1,250 m/s at the upper pyroclastic deposit. The table below presents a summary of the velocities per strata. The graphic results are appended to this report.

**Table 3: Approximate Shear Wave Velocity Values per Stratum**

| Layer Description | Approx. depth below ground surface (m) | Approx. Shear Wave Velocity (m/s) |
|---|---|---|
| Pyroclastic Deposit | 0 - 8 | 750 - 1,250 |
| Ash/Silty Sand | 8 - 21 | 450 - 750 |
| Ash/Silty Sand | 21 - 29 | 450 - 1,000 |

## 3.3 General Laboratory Testing:

A series of laboratory tests were required to be performed on selected soil samples obtained throughout the exploratory program. The following list presents the standards followed for the testing procedures as stated by the American Society for Testing and Materials (ASTM):

- Water content: ASTM D2216 - Standard test method for laboratory determination of water (moisture) content of soil and rock by mass;
- Atterberg limits: ASTM D4318 – Standard test method for liquid limit, plastic limit, and plasticity index of soils;

- Particle density: ASTM D7263 - Standard test method for laboratory determination of density (unit weight) of soil specimens;
- Wet sieve: ASTM D422 Standard test method for particle-size analysis of soils;
- Normal compaction: ASTM D698 - Standard test method for laboratory compaction characteristics of soil using standard effort (12400 ft-lb/ft$^3$ (600 KN-M/M$^3$);
- California Bearing Ratio (heavy, remolded, soaked): ASTM D1883 - Standard test method for California Bearing Ratio (CBR) of laboratory-compacted soils;
- Uniaxial compressive strength: ASTM D7012 - Standard test method for compressive strength and elastic moduli of intact rock core specimens under varying states of stress and temperatures;
- Bulk density of rock samples: ASTM D7263 - Standard test method for laboratory determination of density (unit weight) of soil specimens;
- Moisture content: ASTM D2216 - Standard test method for laboratory determination of water (moisture) content of soil and rock by mass.

### 3.3.1 Soil Classification Testing:

This section will cover the results of Water Content, Atterberg Limits, Particle Density and Sieve Analyses. The following table summarizes the results for the testing performed on the required soil samples.

**Table 4: Laboratory Test Results Summary**

| Boring | Sample no. | Depth (m) | Water Content (%) | Atterberg Limits | | | Sieve Analysis | | | Particle Density (kn/m³) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | LL | PL | PI | Gravel % | Sand % | Fines % | |
| PP-BH01 | S-2 | 0.60 - 1.07 | 115 | - | - | - | - | - | - | - |
| PP-BH01 | S-4 | 1.83 - 2.28 | 13 | - | - | - | 38.1 | 50.0 | 11.9 | - |
| PP-BH01 | HQ-11 | 10.97 - 12.5 | 2 | - | - | - | 24.4 | 52.1 | 23.5 | - |
| PP-BH01 | S-14 | 15.54 - 16.0 | 22 | - | - | - | - | - | - | - |
| PP-BH02 | S-2 | 0.60 - 1.07 | 9 | NP* | NP* | NP* | 61.3 | 31.2 | 7.5 | - |
| PP-BH02 | HQ-4 | 1.83 - 3.35 | - | - | - | - | 97.3 | 2.2 | 0.5 | - |
| PP-BH02 | S-8 | 7.92 - 8.38 | 38 | - | - | - | 3.7 | 56.3 | 40.0 | - |
| PP-BH02 | S-12 | 14.0 - 14.48 | 43 | - | - | - | 1.2 | 53.0 | 45.8 | - |
| PP-BH02 | S-14 | 17.07 - 17.52 | 30 | - | - | - | - | - | - | - |
| PP-BH02 | S-16 | 20.12 - 20.57 | 30 | - | - | - | - | - | - | - |
| PP-BH03 | S-3 | 1.22 - 1.68 | 9 | - | - | - | - | - | - | 21.36** |
| PP-BH03 | S-6 | 4.27 - 4.72 | 10 | - | - | - | - | - | - | - |
| PP-BH03 | HQ-16 | 19.51 - 21.03 | 1 | - | - | - | - | - | - | - |
| PP-TP01 | - | 4.0 | 7 | NP* | NP* | NP* | 46.3 | 42.6 | 11.1 | - |
| PP-TP02 | - | 1.0 | 13 | NP* | NP* | NP* | 55.5 | 34.7 | 8.3 | - |

**N.P. = Non – Plastic*

***Determined by Method-B of ASTM D7263 on remolded sample. The provided value represents approximate maximum density.*

### 3.3.2 Testing on Rock Core Samples:

This section will cover the results of Bulk Density and Uniaxial Compressive Strength tests on rock core samples. The following table summarizes the results for the testing performed on the required soil samples.

**Table 5: Laboratory Test Results Summary (Power Plant Site)**

| Boring | Sample no. | Depth (m) | Unit Weight (kn/m³) | Rock Compressive Strength (kPa) |
|---|---|---|---|---|
| PP-BH01 | HQ-6 | 3.35 – 4.85 | 24.7 | 62,652 |
| PP-BH01 | HQ-11 | 10.97 – 12.49 | * | * |
| PP-BH03 | HQ-9 | 8.84 – 10.36 | 23.9 | 27,358 |
| PP-BH03 | HQ-11 | 11.89 – 13.41 | 24.8 | 78,014 |
| PP-BH03 | HQ-14 | 16.46 - 17.98 | * | * |
| PP-BH03 | HQ-15 | 17.98 – 19.50 | 17.9 | 2,564 |

**No sample available for compression test on rock core.*

**Table 6: Laboratory Test Results Summary (Reinjection Line)**

| Boring | Sample no. | Depth (m) | Unit Weight (kn/m³) | Rock Compressive Strength (kPa) |
|---|---|---|---|---|
| RL-BH01 | HQ-5 | 3.05 – 4.57 | 17.69 | 2,413 |
| RL-BH01 | HQ-7 | 6.10 – 7.62 | 18.63 | 4,481 |
| RL-BH03 | HQ-12 | 12.50 – 14.02 | 19.31 | 1,792 |
| RL-BH03 | HQ-16 | 18.59 – 20.11 | 17.56 | 1,861 |
| RL-BH03 | HQ-17 | 20.12 – 21.64 | 18.66 | 3,309 |
| RL-BH04 | HQ-13 | 14.02 – 15.54 | 19.57 | 6,756 |
| RL-BH04 | HQ-17 | 20.12 – 21.64 | 19.13 | 1,861 |
| RL-BH04 | HQ-20 | 24.69 – 26.21 | 18.60 | 5,653 |

### 3.3.3 Compaction and CBR Testing:

This section will cover the results of Normal Compaction and California Bearing Ratio tests. The following table summarizes the results for the testing performed on the required soil samples.

**Table 7: Laboratory Test Results Summary (Power Plant Site)**

| Boring | Depth (m) | Proctor Test | | CBR @ 25.4 mm penetration | | CBR @ 50.8 mm penetration | |
|---|---|---|---|---|---|---|---|
| | | Optimum Moisture Content (%) | Maximum Dry Density (kn/m³) | 25 Blows per Layer | 56 Blows per Layer | 25 Blows per Layer | 56 Blows per Layer |
| PP-TP01 | 4.0 | 10.8 | 19.56 | 99 | 92 | >100 | >100 |
| PP-TP02 | 1.0 | 11.0 | 18.52 | >100 | >100 | >100 | >100 |

Respectfully submitted,
**JACA & SIERRA ENGINEERING, PSC**



Manuel E. Candelario Cosme, MSCE, PE



Carlos R. Sierra Del Llano, MSCE, PE
*Enclosures*

*Appendix A: Boring Logs*
*Appendix B: Dynamic Cone Penetration Test Results*
*Appendix C: Downhole Seismic Test Results*
*Appendix D: General Laboratory Tests Results*
*Appendix E: California Bearing Ratio (CBR) Test Results*




# Appendix A:

Boring Logs

JACA & SIERRA Testing Laboratories Geotechnical Engineers

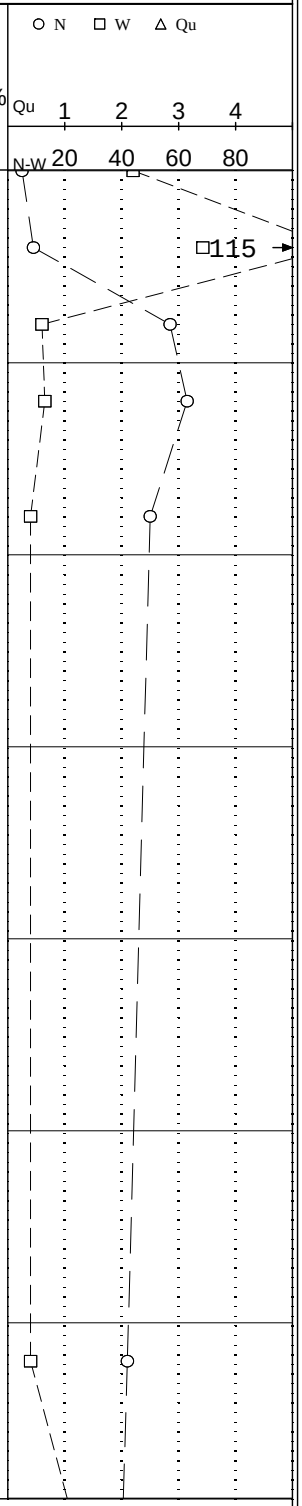
# SUBSURFACE EXPLORATION LOG

584

**BORING No.: PP-BH01**

| | | | |
|---|---|---|---|
| **PROJECT:** Dominica Geothermal Project | | **JOB:** 7909 | **SHEET** 1 **OF** 2 |
| **LOCATION:** Power Plant Site | | **DRILLER/DRILL RIG:** Steven Perez / CME-55 | |
| **COORDINATES:** 679755 E | 1695676 N | **DATE STARTED:** 10-10-18 | **DATE COMPLETED:** 10-10-18 |
| **DESCRIPTION BY:** Manuel Candelario | | **SURFACE ELEVATION (mt):** | |
| **GROUNDWATER (mt):** **Initial:** Dry | **Final:** Dry | **ENGINEER:** Manuel Candelario | |
| **DRILLING METHOD:** HQ Casing Advancer | | **TOTAL DEPTH (mt):** 16 | |

| ELEV (mt) | DEPTH (mt) | DESCRIPTION | LEGEND | SAMPLE NO. | TYPE | BLOWS | SPT N | W | Qu | RC | RQD% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | | | | | | | | | | |
| 0 | 0 | 0<br>SILTY SAND with clay, gravel and organic matter (roots), loose, brown, gray | | S-1 | | 1<br>1<br>4 | 5 | 44 | | | |
| | | | | S-2 | | 4<br>4<br>5 | 9 | 115 | | | |
| 1 | 1 | 4<br>GRAVEL and cobbles, with sand some silt, very dense, brownish gray, dark yellowish brown | | S-3 | | 6<br>23<br>34 | 57 | 12 | | | |
| 2 | 2 | Gravel: 38%<br>Sand: 50%<br>Fines: 12% | | S-4 | | 26<br>30<br>33 | 63 | 13 | | | |
| | | | | S-5 | | 50/1" | 50/1" | 8 | | | |
| 3 | 3 | 11<br>VOLCANIC SANDSTONE, slightly weathered, (Possible Boulders), moderately fractured, light gray, mottled black and white<br>Rock Compressive Strength: 62,652 Kpa (strong)<br>Unit Weight: 24.7 Kn/m3 | | HQ-6 | | | | | | 88 | 73 |
| 4 | 4 | | | | | | | | | | |
| 5 | 5 | | | HQ-7 | | | | | | 85 | 70 |
| 6 | 6 | | | | | | | | | | |
| 7 | 7 | As Above... (Possible Boulders) slightly weathered, moderately fractured, light gray, pale red, light yellowish brown | | HQ-8 | | | | | | 35 | 16 |
| 8 | 8 | | | HQ-9 | | | | | | 20 | 0 |
| 9 | 9 | 31 | | | | | | | | | |
| 10 | 10 | PYROCLASTIC Deposit: cobbles to boulders, (1 inch. to 6 inch. diam.) with gravel, sand some silt, yellowish brown, light gray, pinkish gray (5" recovery on cored sample) | | HQ10 | | 10<br>18<br>24 | 42 | 8 | | 8 | 0 |




"N" - Number of blows required to drive the sampling spoon a distance of 30 cm. with a 52 kg hammer falling 76 cm.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in kilo pascals.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
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Initial G.W. Depth
Final G.W. Depth

JACA & SIERRA
Testing Laboratories
Geotechnical Engineers

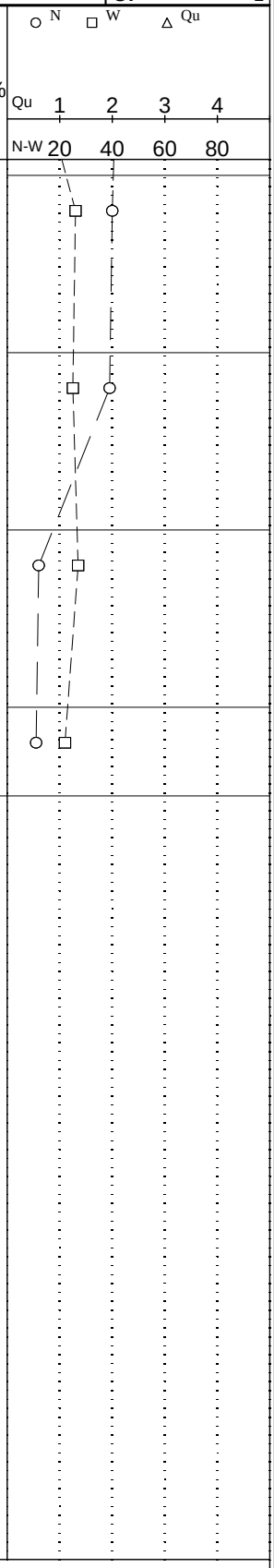
# SUBSURFACE EXPLORATION LOG

**BORING NUMBER: PP-BH01**

## BORING LOG (CONT. SHEET)

| PROJECT | JOB | SHEET | OF |
|---|---|---|---|
| Dominica Geothermal Project | 7909 | 2 | 2 |

| ELEV (mt) | DEPTH (mt) | DESCRIPTION | LEGEND | SAMPLE NO. | TYPE | BLOWS | SPT N | W | Qu | RC | RQD% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | | | | | | | | | | |
| | | 36 | | | | | | | | | |
| 11 | 11 | As above... welded ash flow - sand and silt, pale red, pinkish gray<br>Rock Compressive Strength: N/A | | HQ11 | | 8<br>19<br>21 | 40 | 26 | | 31 | 10 |
| 12 | 12 | | | | | | | | | | |
| | | | | HQ12 | | 6<br>22<br>17 | 39 | 25 | | 36 | 25 |
| 13 | 13 | | | | | | | | | | |
| 14 | 14 | As above... sand, silt (ash;) medium density, pale red, pinkish gray (no recovery on cored sampled) | | HQ13 | | WH<br>6<br>6 | 12 | 27 | | 0 | 0 |
| 15 | 15 | | | | | | | | | | |
| | | | | S-14 | | 4<br>5<br>6 | 11 | 22 | | | |
| 16 | 16 | | | | | | | | | | |
| 17 | 17 | | | | | | | | | | |
| 18 | 18 | | | | | | | | | | |
| 19 | 19 | | | | | | | | | | |
| 20 | 20 | | | | | | | | | | |
| 21 | 21 | | | | | | | | | | |
| 22 | 22 | | | | | | | | | | |

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Initial G.W. Depth
Final G.W. Depth

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## Core Runs Field Photographs – Power Plant – PP-BH01



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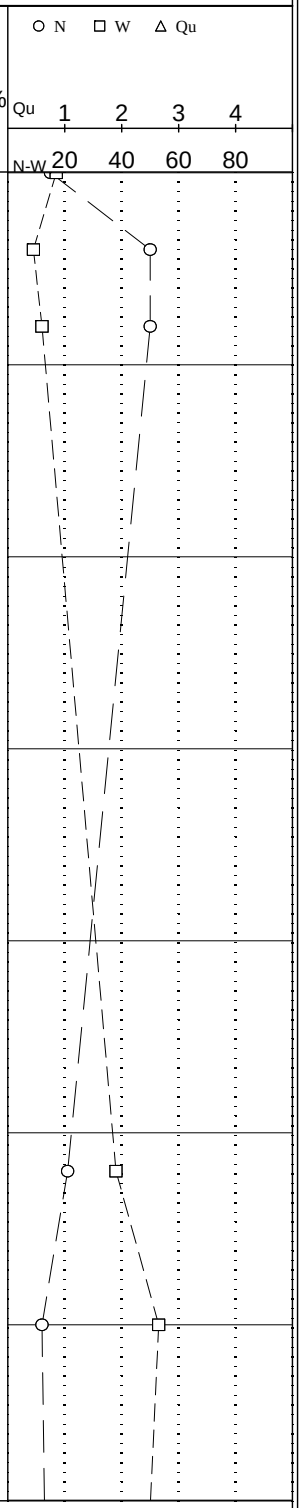
# SUBSURFACE EXPLORATION LOG

588

**BORING No.: PP-BH02**

| | | | |
|---|---|---|---|
| **PROJECT:** Dominica Geothermal Project | | **JOB:** 7909 | **SHEET** 1 **OF** 3 |
| **LOCATION:** Power Plant Site | | **DRILLER/DRILL RIG:** Steven Perez / CME-55 | |
| **COORDINATES:** 679737 E | 1695643 N | **DATE STARTED:** 10-1-18 | **DATE COMPLETED:** 10-1-18 |
| **DESCRIPTION BY:** Manuel Candelario | | **SURFACE ELEVATION (mt):** | |
| **GROUNDWATER (mt):** **Initial:** Dry | **Final:** Dry | **ENGINEER:** Manuel Candelario | |
| **DRILLING METHOD:** HQ Casing Advancer | | **TOTAL DEPTH (mt):** 29.4 | |

| ELEV (mt) | DEPTH (mt) | DESCRIPTION | LEGEND | SAMPLE NO. | TYPE | BLOWS | SPT N | W | Qu | RC | RQD% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | | | | | | | | | | |
| 0 | 0 | 0<br>GRAVEL and cobbles with sand some silt, medium to very dense, yellowish brown, light gray<br>A-1-a (AASHTO)<br>Gravel: 61%<br>Sand: 31%<br>Fines: 8%<br>PI: Non Plastic | | S-1 | | 15<br>7<br>8 | 15 | 17 | | | |
| | | | | S-2 | | 8<br>50/5" | 50/5" | 9 | | | |
| 1 | 1 | | | S-3 | | 30<br>30<br>50/5" | 50/5" | 12 | | | |
| | | 6<br>PYROCLASTIC Deposit: cobbles to boulders, slightly weathered, moderately fractured, light gray, pale red, pinkish gray<br>Rock Compressive Strength: 20,112 Kpa (weak)<br>Unit Weight: 23.25 Kn/m3 | | HQ-4 | | | | | | 50 | 12 |
| 2 | 2 | | | | | | | | | | |
| 3 | 3 | | | HQ-5 | | | | | | | |
| 4 | 4 | | | | | | | | | 20 | 0 |
| 5 | 5 | | | HQ-6 | | | | | | | |
| 6 | 6 | | | | | | | | | 28 | 0 |
| | | (no recovery on cored sampled) | | HQ-7 | | | | | | | |
| 7 | 7 | | | | | | | | | 0 | 0 |
| | | 26<br>SILTY SAND trace gravel, medium density, light gray, light yellowish brown | | S-8 | | 9<br>10<br>11 | 21 | 38 | | | |
| 8 | 8 | | | | | | | | | | |
| 9 | 9 | 31 | | | | 5<br>5<br>7 | 12 | 53 | | | |
| | | Welded ash flow - sand and silt, pinkish gray, yellowish brown | | HQ-9 | | | | | | 22 | 7 |
| 10 | 10 | | | | | | | | | | |

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"Qu" - Unconfined Compressive Strength in kilo pascals.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
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▽ Initial G.W. Depth
▼ Final G.W. Depth

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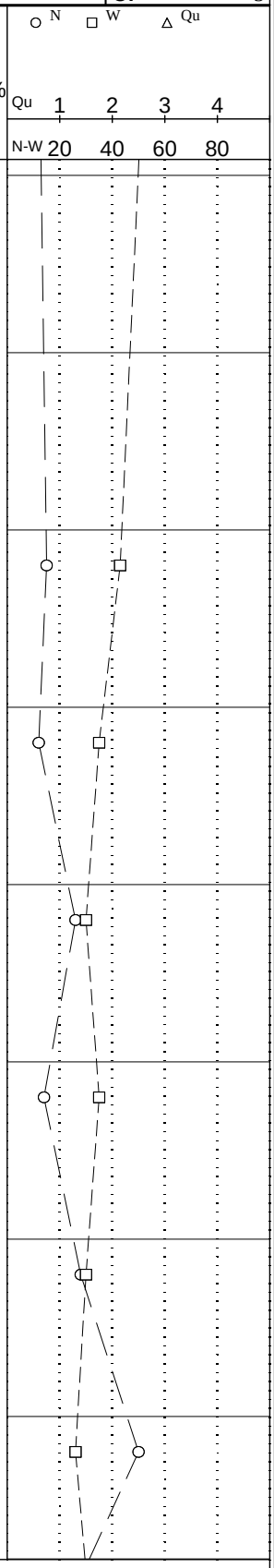
# SUBSURFACE EXPLORATION LOG

**BORING NUMBER: PP-BH02**

## BORING LOG (CONT. SHEET)

| PROJECT | JOB | SHEET | OF |
|---|---|---|---|
| Dominica Geothermal Project | 7909 | 2 | 3 |

| ELEV (mt) | DEPTH (mt) | DESCRIPTION | SAMPLE NO. | TYPE | BLOWS | SPT N | W | Qu | RC | RQD% |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | | | | | | | | | |
| 11 | 11 | | HQ10 | | | | | | 45 | 0 |
| 12 | 12 | 41 | | | | | | | | |
| | | SILTY SAND (ash), medium density, light gray, yellowish brown | S-11 | | | | | | | |
| 13 | 13 | | | | | | | | | |
| 14 | 14 | Gravel: 1%<br>Sand: 53%<br>Fines: 46% | S-12 | | 3<br>6<br>9 | 15 | 43 | | | |
| 15 | 15 | | | | | | | | | |
| | | | S-13 | | 5<br>5<br>7 | 12 | 35 | | | |
| 16 | 16 | | | | | | | | | |
| 17 | 17 | | S-14 | | 9<br>11<br>15 | 26 | 30 | | | |
| 18 | 18 | | | | | | | | | |
| | | | S-15 | | 4<br>4<br>10 | 14 | 35 | | | |
| 19 | 19 | | | | | | | | | |
| 20 | 20 | | S-16 | | 9<br>11<br>17 | 28 | 30 | | | |
| 21 | 21 | | | | | | | | | |
| | | As above... pinkish gray | S-17 | | 27<br>50/5" | 50/5" | 26 | | | |
| 22 | 22 | | | | | | | | | |

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▽ Initial G.W. Depth
▼ Final G.W. Depth

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# SUBSURFACE EXPLORATION LOG

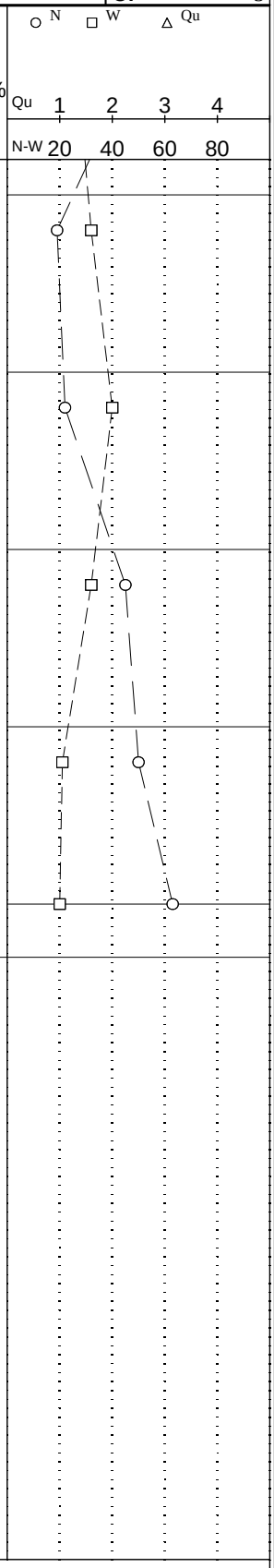
590

**BORING NUMBER: PP-BH02**

## BORING LOG (CONT. SHEET)

| PROJECT | JOB | SHEET | OF |
|---|---|---|---|
| Dominica Geothermal Project | 7909 | 3 | 3 |

| ELEV (mt) | DEPTH (mt) | DESCRIPTION | LEGEND | SAMPLE NO. | TYPE | BLOWS | SPT N | W | Qu | RC | RQD% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | | | | | | | | | | |
| 23 | 23 | As above... light gray | | S-18 | | 4<br>6<br>13 | 19 | 32 | | | |
| 24 | 24 | | | | | | | | | | |
| 25 | 25 | | | S-19 | | 9<br>9<br>13 | 22 | 40 | | | |
| 26 | 26 | As above... light gray, yellowish brown | | S-20 | | 9<br>15<br>30 | 45 | 32 | | | |
| 27 | 27 | | | | | | | | | | |
| 28 | 28 | As above... yellowish brown | | S-21 | | 30<br>50/4" | 50/4" | 21 | | | |
| 29 | 29 | | | S-22 | | 10<br>23<br>40 | 63 | 20 | | | |
| 30 | 30 | | | | | | | | | | |
| 31 | 31 | | | | | | | | | | |
| 32 | 32 | | | | | | | | | | |
| 33 | 33 | | | | | | | | | | |
| 34 | 34 | | | | | | | | | | |

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▽ Initial G.W. Depth
▼ Final G.W. Depth

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## Core Runs Field Photographs – Power Plant – PP-BH02



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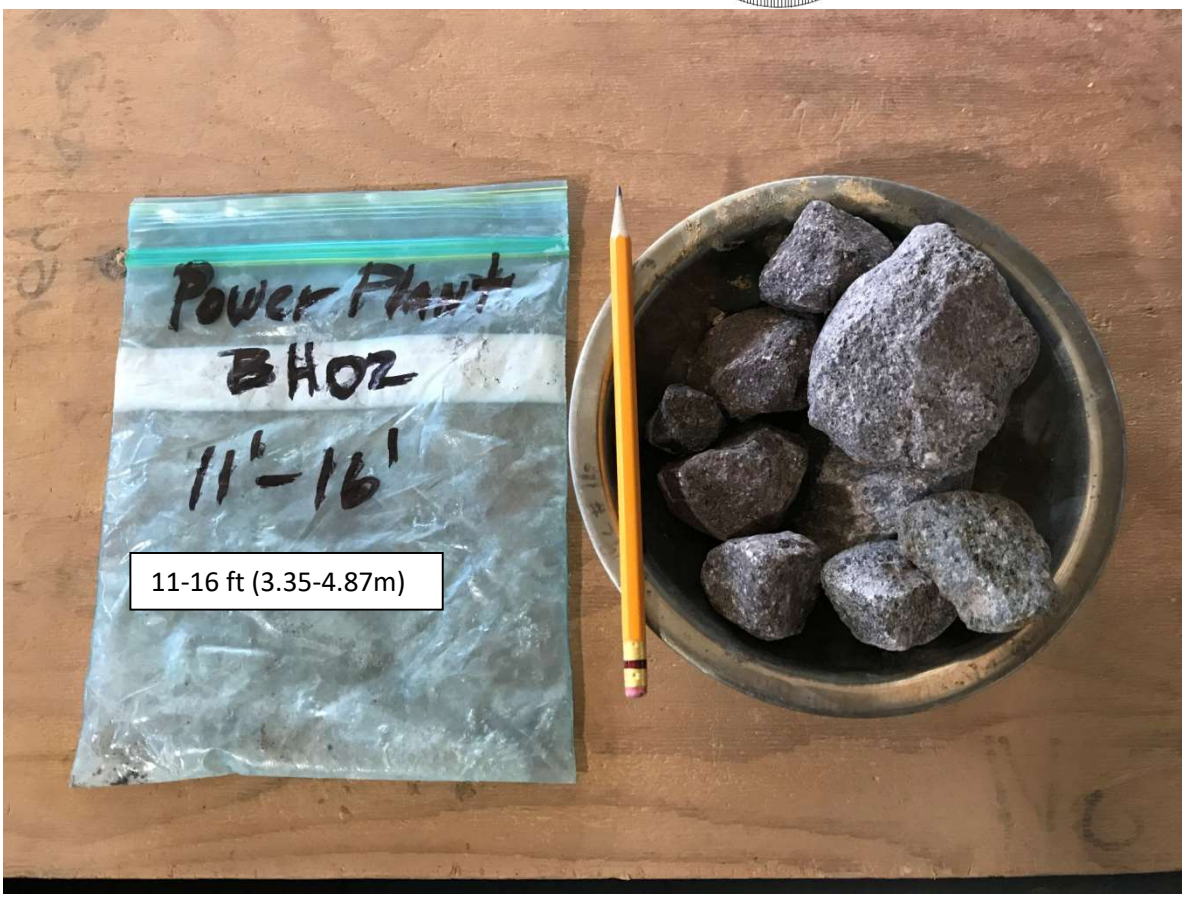

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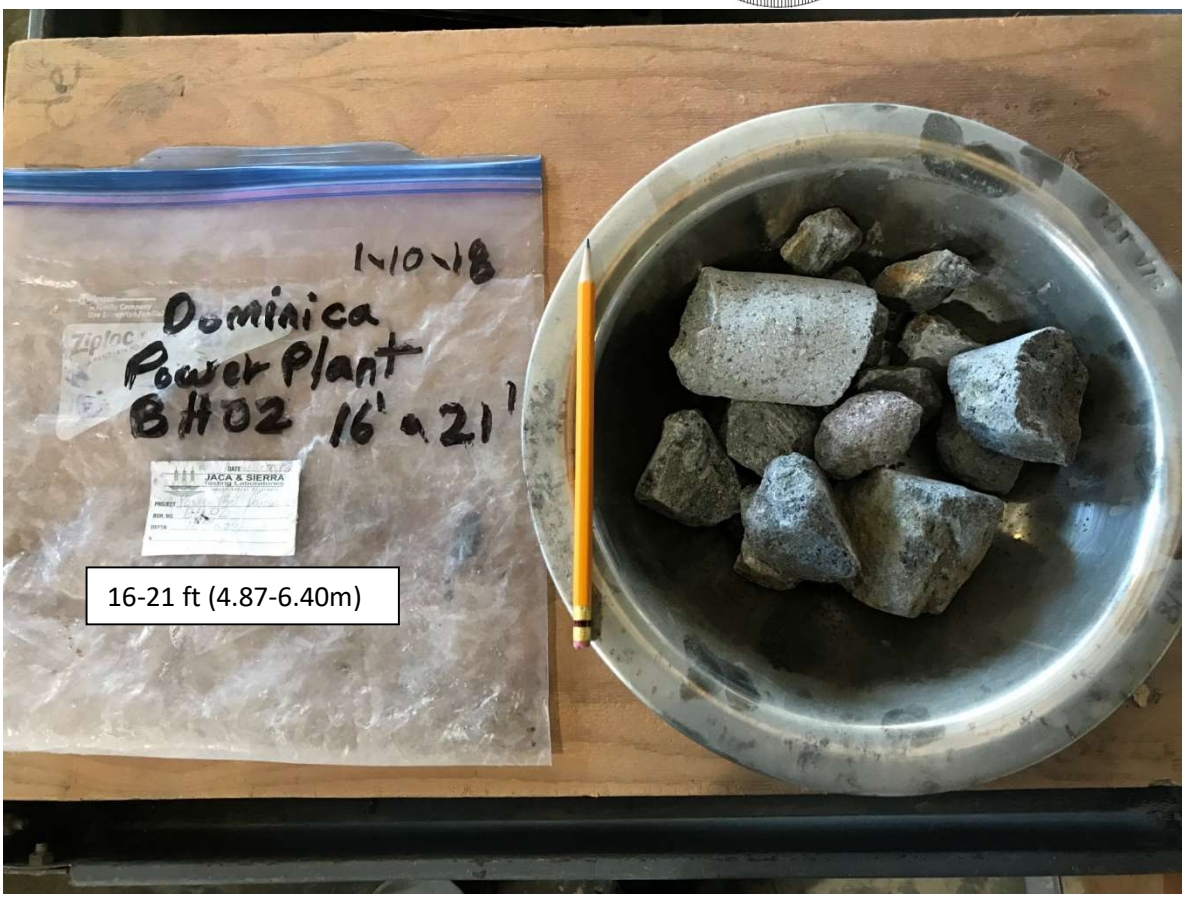

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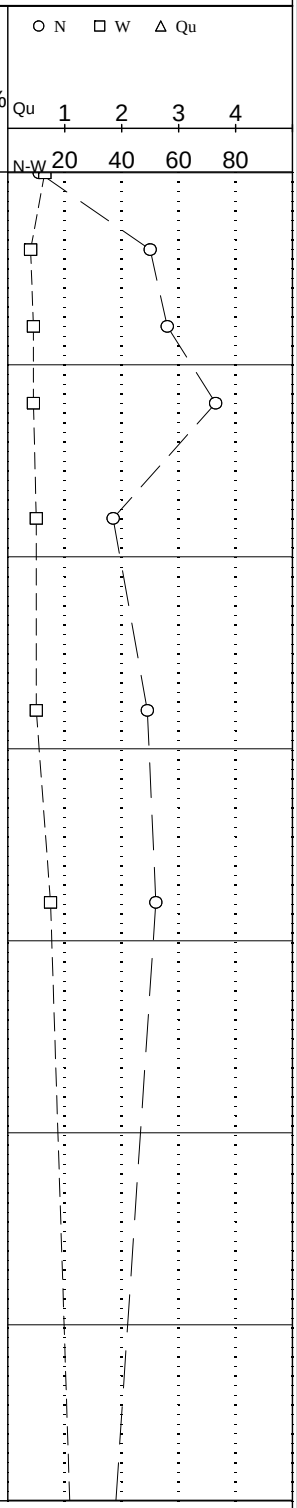
# SUBSURFACE EXPLORATION LOG



**BORING No.: PP-BH03**

| | | | |
|---|---|---|---|
| **PROJECT:** Dominica Geothermal Project | | **JOB:** 7909 | **SHEET** 1 **OF** 3 |
| **LOCATION:** Power Plant Site | | **DRILLER/DRILL RIG:** Steven Perez / CME-55 | |
| **COORDINATES:** 679837 E | 1695687 N | **DATE STARTED:** 10-6-18 | **DATE COMPLETED:** 10-6-18 |
| **DESCRIPTION BY:** Manuel Candelario | | **SURFACE ELEVATION (mt):** | |
| **GROUNDWATER (mt):** **Initial:** Dry | **Final:** Dry | **ENGINEER:** Manuel Candelario | |
| **DRILLING METHOD:** HQ Casing Advancer | | **TOTAL DEPTH (mt):** 24.1 | |

| ELEV (mt) | DEPTH (mt) | DESCRIPTION | LEGEND | SAMPLE NO. | TYPE | BLOWS | SPT N | W | Qu | RC | RQD% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | | | | | | | | | | |
| 0 | 0 | 0<br>GRAVEL to COBBLES with silty sand, medium to very dense, yellowish brown, gray, pinkish gray | | S-1 | | 2<br>4<br>7 | 11 | 13 | | | |
| | | | | S-2 | | 50/6" | 50/6" | 8 | | | |
| 1 | 1 | | | S-3 | | 11<br>23<br>33 | 56 | 9 | | | |
| 2 | 2 | | | S-4 | | 12<br>28<br>45 | 73 | 9 | | | |
| 3 | 3 | | | S-5 | | 15<br>17<br>20 | 37 | 10 | | | |
| 4 | 4 | | | S-6 | | 10<br>27<br>22 | 49 | 10 | | | |
| 5 | 5 | | | | | | | | | | |
| 6 | 6 | | | S-7 | | 17<br>22<br>30 | 52 | 15 | | | |
| 7 | 7 | 24<br>VOLCANIC SANDSTONE, slightly to severely weathered, moderately fractured, light to dark gray, pale red | | HQ-8 | | | | | | 77 | 43 |
| 8 | 8 | | | | | | | | | | |
| 9 | 9 | Rock Compressive Strength: 27,358 Kpa (medium) Unit Weight: 23.9 Kn/m3 | | HQ-9 | | | | | | 60 | 23 |
| 10 | 10 | | | HQ10 | | | | | | | |

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Initial G.W. Depth
Final G.W. Depth

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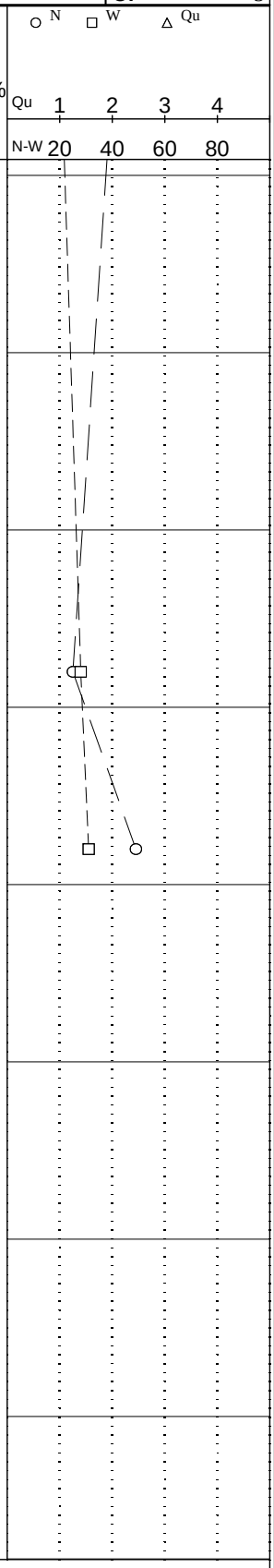
# SUBSURFACE EXPLORATION LOG

**BORING NUMBER: PP-BH03**

## BORING LOG (CONT. SHEET)

| PROJECT | JOB | SHEET | OF |
|---|---|---|---|
| Dominica Geothermal Project | 7909 | 2 | 3 |

| ELEV (mt) | DEPTH (mt) | DESCRIPTION | LEGEND | SAMPLE NO. | TYPE | BLOWS | SPT N | W | Qu | RC | RQD% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | | | | | | | | | | |
| 11 | 11 | | | | | | | | | 20 | 0 |
| 12 | 12 | Rock Compressive Strength: 78,014 Kpa (strong)<br>Unit Weight: 24.8 Kn/m3 | | HQ11 | | | | | | 28 | 0 |
| 13 | 13 | (no recovery on cored sampled) | | HQ12 | | | | | | 0 | 0 |
| 14 | 14 | | | | | | | | | | |
| | | 49 | | | | | | | | | |
| 15 | 15 | SAND some silt trace gravel, medium density, gray, yellowish brown | | S-13 | | 7<br>12<br>13 | 25 | 28 | | | |
| 16 | 16 | | | | | | | | | | |
| | | 54 | | | | | | | | | |
| 17 | 17 | PYROCLASTIC Deposit: welded ash flow, sand and silt, pale red, pinkish gray, light gray<br>Rock Compressive Strength: N/A | | HQ14 | | 17<br>20<br>29 | 49 | 31 | | 70 | 0 |
| 18 | 18 | Rock Compressive Strength: 2,564 Kpa (very weak)<br>Unit Weight: 17.9 Kn/m3 | | HQ15 | | | | | | 100 | 58 |
| 19 | 19 | | | | | | | | | | |
| | | | | HQ16 | | | | | | | |
| 20 | 20 | | | | | | | | | 100 | 0 |
| 21 | 21 | | | HQ17 | | | | | | | |
| 22 | 22 | | | | | | | | | 75 | 0 |

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Initial G.W. Depth
Final G.W. Depth

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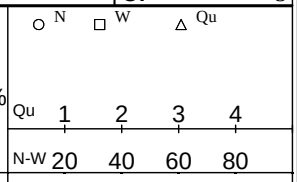
# SUBSURFACE EXPLORATION LOG

**BORING NUMBER: PP-BH03**

## BORING LOG (CONT. SHEET)

| PROJECT | JOB | SHEET | OF |
|---|---|---|---|
| Dominica Geothermal Project | 7909 | 3 | 3 |

| ELEV (mt) | DEPTH (mt) | DESCRIPTION | LEGEND | SAMPLE NO. | TYPE | BLOWS | SPT N | W | Qu | RC | RQD% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | | | | | | | | | | |
| 23 | 23 | | | HQ18 | | | | | | 73 | 0 |
| 24 | 24 | | | | | | | | | | |
| 25 | 25 | | | | | | | | | | |
| 26 | 26 | | | | | | | | | | |
| 27 | 27 | | | | | | | | | | |
| 28 | 28 | | | | | | | | | | |
| 29 | 29 | | | | | | | | | | |
| 30 | 30 | | | | | | | | | | |
| 31 | 31 | | | | | | | | | | |
| 32 | 32 | | | | | | | | | | |
| 33 | 33 | | | | | | | | | | |
| 34 | 34 | | | | | | | | | | |

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▽ Initial G.W. Depth
▼ Final G.W. Depth

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## Core Runs Field Photographs – Power Plant – PP-BH03



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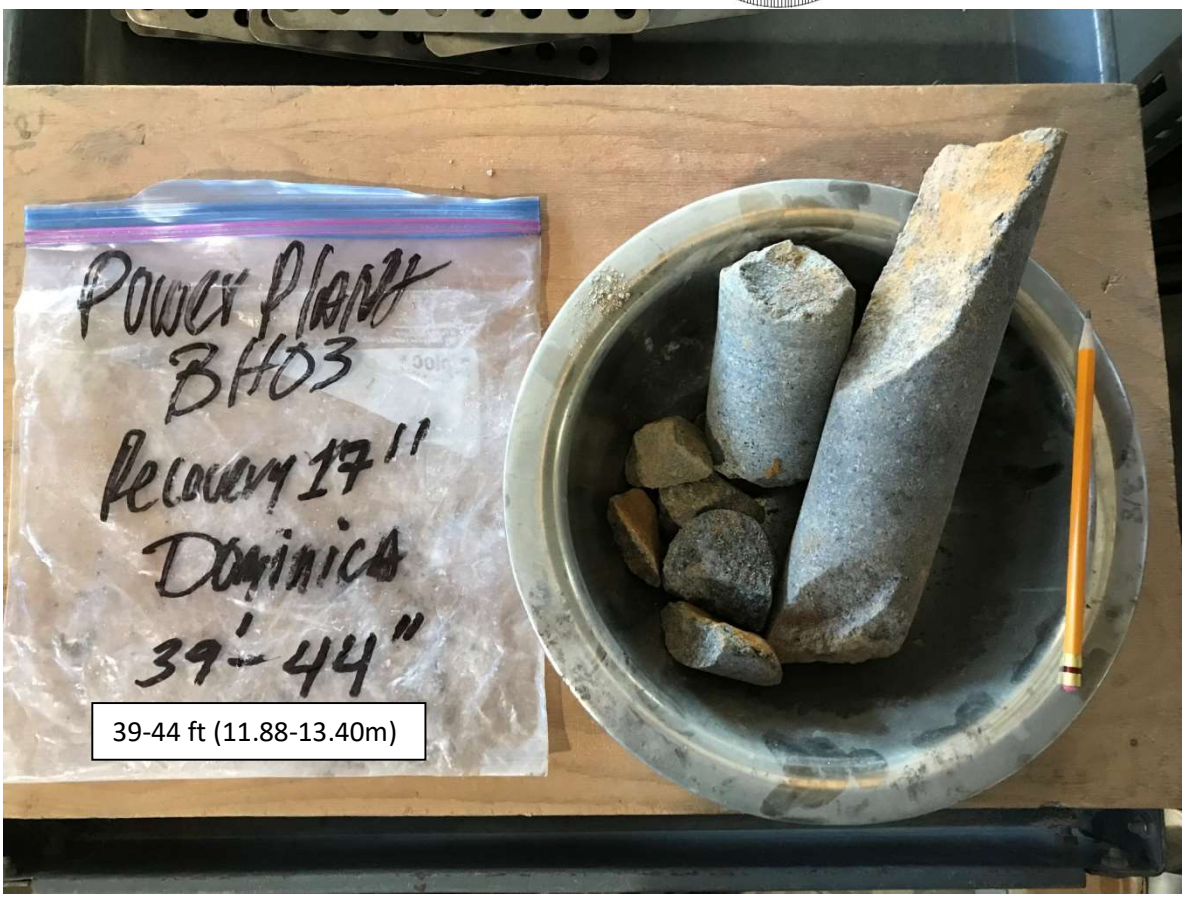


39-44 ft (11.88-13.40m)

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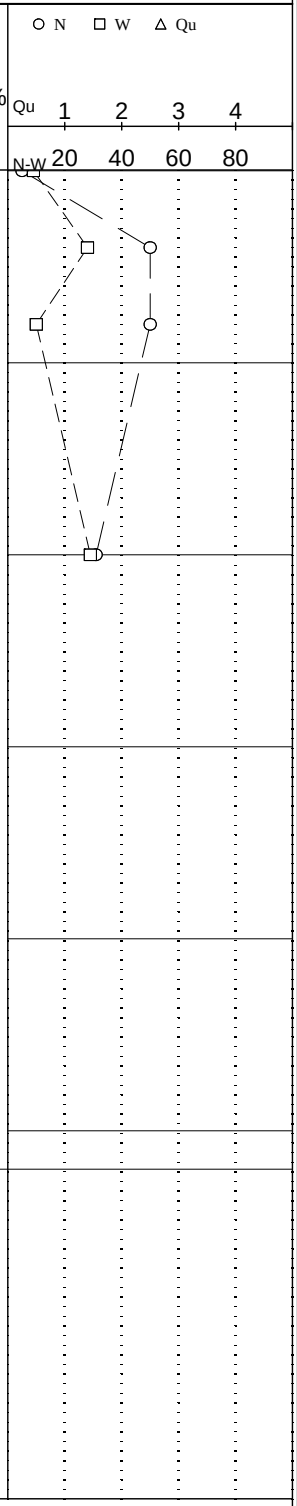
# SUBSURFACE EXPLORATION LOG

**RL-B1** 204

**BORING No.: BH01**

| | | | |
|---|---|---|---|
| **PROJECT:** Dominica Geothermal Project | | **JOB:** 7909-A | **SHEET** 1 **OF** 1 |
| **LOCATION:** Reinjection Line | | **DRILLER/DRILL RIG:** Steven Perez / CME-55 | |
| **COORDINATES:** 679612 E | 1695412 N | **DATE STARTED:** 9-24-18 | **DATE COMPLETED:** 9-24-18 |
| **DESCRIPTION BY:** Manuel Candelario | | **SURFACE ELEVATION (mt):** | |
| **GROUNDWATER (mt):** **Initial:** Dry | **Final:** Dry | **ENGINEER:** Manuel Candelario | |
| **DRILLING METHOD:** HQ Casing Advancer | | **TOTAL DEPTH (mt):** 7.9 | |

| ELEV (mt) | DEPTH (mt) | DESCRIPTION | LEGEND | SAMPLE NO. | TYPE | BLOWS | SPT N | W | Qu | RC | RQD% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | | | | | | | | | | |
| 0 | 0 | 0 GRAVEL with silty sand, loose to very dense, gray, brownish gray | | S-1 | | 3<br>3<br>2 | 5 | 9 | | | |
| | | | | S-2 | | 50/5" | 50/5" | 28 | | | |
| 1 | 1 | | | S-3 | | 50/2" | 50/2" | 10 | | | |
| | | 5 VOLCANIC SANDSTONE, slightly to highly weathered, highly fractured, pale red, pinkish gray, mottled black and white | | HQ-4 | | | | | | 83 | 51 |
| 2 | 2 | | | | | | | | | | |
| 3 | 3 | As above... light gray, light yellowish brown, mottled black and white<br>Rock Compressive Strength: 2,413 Kpa (very weak)<br>Unit Weight: 17.69 Kn/m3 | | HQ-5 | | 2<br>11<br>20 | 31 | 29 | | 100 | 48 |
| 4 | 4 | | | | | | | | | | |
| | | | | HQ-6 | | | | | | 100 | 7 |
| 5 | 5 | | | | | | | | | | |
| 6 | 6 | Rock Compressive Strength: 4,481 Kpa (very weak)<br>Unit Weight: 18.63 Kn/m3 | | HQ-7 | | | | | | | |
| 7 | 7 | | | | | | | | | 100 | 80 |
| | | | | HQ-8 | | | | | | | |
| 8 | 8 | | | | | | | | | | |
| 9 | 9 | | | | | | | | | | |
| 10 | 10 | | | | | | | | | | |




"N" - Number of blows required to drive the sampling spoon a distance of 30 cm. with a 52 kg hammer falling 76 cm.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in kilo pascals.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

Initial G.W. Depth
Final G.W. Depth

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## Core Runs Field Photographs – Reinjection Route, RL-B1-BH01



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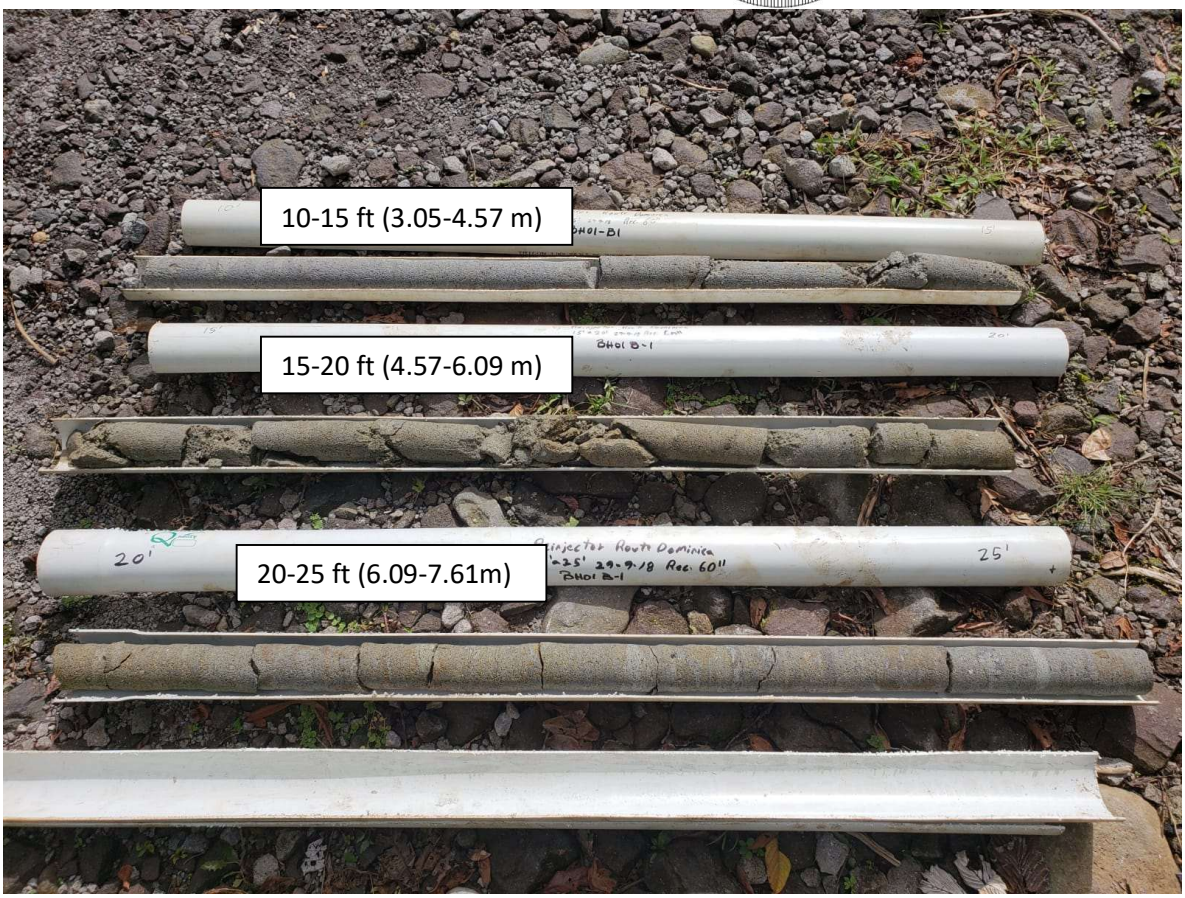


**No Rock Coring in RL-B1-BH02 of Reinjection Route Site**

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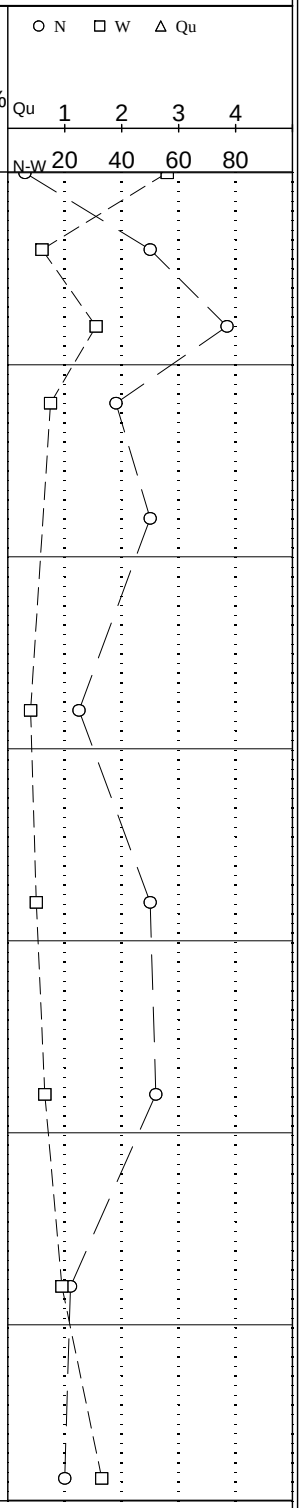
# SUBSURFACE EXPLORATION LOG

RL-B1 007

**BORING No.:** BH02

| | | | |
|---|---|---|---|
| **PROJECT:** Dominica Geothermal Project | | **JOB:** 7909-A | **SHEET** 1 **OF** 2 |
| **LOCATION:** Reinjection Line | | **DRILLER/DRILL RIG:** Steven Perez / CME-55 | |
| **COORDINATES:** 679658 E | 1695373 N | **DATE STARTED:** 10-14-18 | **DATE COMPLETED:** 10-14-18 |
| **DESCRIPTION BY:** Manuel Candelario | | **SURFACE ELEVATION (mt):** | |
| **GROUNDWATER (mt):** **Initial:** Dry | **Final:** Dry | **ENGINEER:** Manuel Candelario | |
| **DRILLING METHOD:** HQ Casing Advancer | | **TOTAL DEPTH (mt):** 10.8 | |

| ELEV (mt) | DEPTH (mt) | DESCRIPTION | LEGEND | SAMPLE NO. | TYPE | BLOWS | SPT N | W | Qu | RC | RQD% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | | | | | | | | | | |
| 0 | 0 | 0<br>GRAVEL, cobbles to boulders (15-30 cm) with clayey sand, medium to dense, yellowish brown, gray, pale red, pinkish gray | | S-1 | | WH<br>2<br>4 | 6 | 56 | | | |
| | | | | S-2 | | 50/2" | 50/2" | 12 | | | |
| 1 | 1 | | | S-3 | | 11<br>36<br>41 | 77 | 31 | | | |
| 2 | 2 | | | S-4 | | 18<br>23<br>15 | 38 | 15 | | | |
| 3 | 3 | | | S-5 | | 26<br>50/3" | 50/3" | | | | |
| 4 | 4 | | | S-6 | | 15<br>13<br>12 | 25 | 8 | | | |
| 5 | 5 | | | | | | | | | | |
| 6 | 6 | | | S-7 | | 50/4" | 50/4" | 10 | | | |
| 7 | 7 | | | | | | | | | | |
| 8 | 8 | | | S-8 | | 48<br>28<br>24 | 52 | 13 | | | |
| 9 | 9 | 30<br>CLAYEY SAND trace gravel, medium density, yellowish brown, gray | | S-9 | | 22<br>12<br>10 | 22 | 19 | | | |
| 10 | 10 | | | S-10 | | 7 | 20 | 33 | | | |




"N" - Number of blows required to drive the sampling spoon a distance of 30 cm. with a 52 kg hammer falling 76 cm.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in kilo pascals.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

Initial G.W. Depth
Final G.W. Depth

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# SUBSURFACE EXPLORATION LOG RL-B1 608

**BORING NUMBER: BH02**

## BORING LOG (CONT. SHEET)

| PROJECT | JOB | SHEET | OF |
|---|---|---|---|
| Dominica Geothermal Project | 7909-A | 2 | 2 |

| ELEV (mt) | DEPTH (mt) | DESCRIPTION | LEGEND | SAMPLE NO. | TYPE | BLOWS | SPT N | W | Qu | RC | RQD% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | | | | | 8<br>12 | | | | | |
| 11 | 11 | | | | | | | | | | |
| 12 | 12 | | | | | | | | | | |
| 13 | 13 | | | | | | | | | | |
| 14 | 14 | | | | | | | | | | |
| 15 | 15 | | | | | | | | | | |
| 16 | 16 | | | | | | | | | | |
| 17 | 17 | | | | | | | | | | |
| 18 | 18 | | | | | | | | | | |
| 19 | 19 | | | | | | | | | | |
| 20 | 20 | | | | | | | | | | |
| 21 | 21 | | | | | | | | | | |
| 22 | 22 | | | | | | | | | | |

○ N □ W △ Qu

Qu 1 2 3 4

N-W 20 40 60 80

"N" - Number of blows required to drive the sampling spoon a distance of 30 cm. with a 52 kg hammer falling 76 cm.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in kilo pascals.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
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▽ Initial G.W. Depth
▼ Final G.W. Depth

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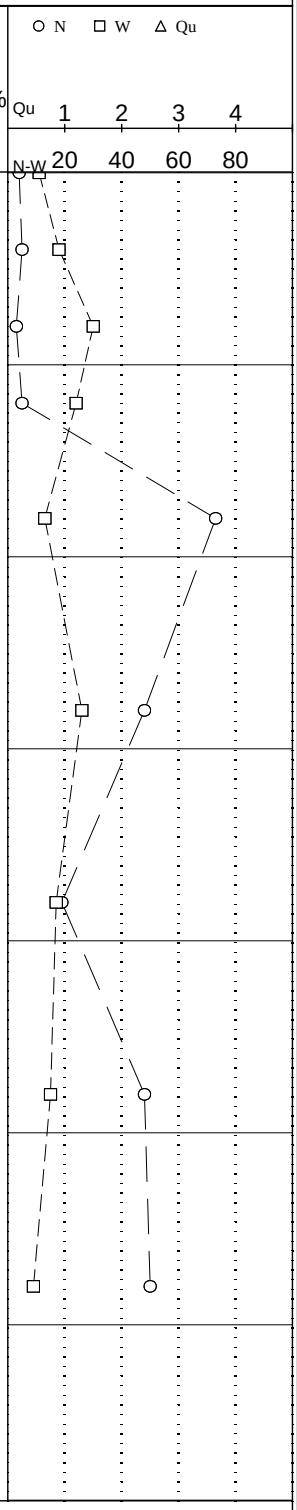
# SUBSURFACE EXPLORATION LOG

**RL-B2** 2009

**BORING No.: BH03**

| | | | |
|---|---|---|---|
| **PROJECT:** Dominica Geothermal Project | | **JOB:** 7909-A | **SHEET** 1 **OF** 2 |
| **LOCATION:** Reinjection Line | | **DRILLER/DRILL RIG:** Steven Perez / CME-55 | |
| **COORDINATES:** 679649 E | 1694948 N | **DATE STARTED:** 11-7-18 | **DATE COMPLETED:** 11-8-18 |
| **DESCRIPTION BY:** Manuel Candelario | | **SURFACE ELEVATION (mt):** | |
| **GROUNDWATER (mt):** **Initial:** Dry | **Final:** Dry | **ENGINEER:** Manuel Candelario | |
| **DRILLING METHOD:** HQ Casing Advancer | | **TOTAL DEPTH (mt):** 21.6 | |

| ELEV (mt) | DEPTH (mt) | DESCRIPTION | LEGEND | SAMPLE NO. | TYPE | BLOWS | SPT N | W | Qu | RC | RQD% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | | | | | | | | | | |
| 0 | 0 | 0<br>CLAYEY SAND trace gravel, very loose, yellowish brown, light gray, reddish yellow | | S-1 | | 5<br>2<br>2 | 4 | 11 | | | |
| | | | | S-2 | | 3<br>2<br>3 | 5 | 18 | | | |
| 1 | 1 | | | S-3 | | 1<br>1<br>2 | 3 | 30 | | | |
| 2 | 2 | | | S-4 | | 22<br>3<br>2 | 5 | 24 | | | |
| | | 10 | | S-5 | | 23<br>38<br>35 | 73 | 13 | | | |
| 3 | 3 | HIGHLY WEATHERED VOLCANIC SANDSTONE sampled as silty sand trace clay, medium to very dense, pinkish gray, yellowish brown | | | | | | | | | |
| 4 | 4 | | | S-6 | | 7<br>18<br>30 | 48 | 26 | | | |
| 5 | 5 | | | | | | | | | | |
| 6 | 6 | | | S-7 | | 7<br>8<br>11 | 19 | 17 | | | |
| 7 | 7 | | | | | | | | | | |
| | | | | S-8 | | 7<br>18<br>30 | 48 | 15 | | | |
| 8 | 8 | | | | | | | | | | |
| 9 | 9 | | | S-9 | | 50/4" | 50/4" | 9 | | | |
| | | 31 | | HQ10 | | | | | | | |
| 10 | 10 | VOLCANIC SANDSTONE, slightly to severely weathered, moderately fractured, yellowish brown, light gray | | | | | | | | 100 | 48 |




"N" - Number of blows required to drive the sampling spoon a distance of 30 cm. with a 52 kg hammer falling 76 cm.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in kilo pascals.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

Initial G.W. Depth
Final G.W. Depth

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# SUBSURFACE EXPLORATION LOG RL-B2



**BORING NUMBER: BH03**

## BORING LOG (CONT. SHEET)

| PROJECT | JOB | SHEET | OF |
|---|---|---|---|
| Dominica Geothermal Project | 7909-A | 2 | 2 |

| ELEV (mt) | DEPTH (mt) | DESCRIPTION | LEGEND | SAMPLE NO. | TYPE | BLOWS | SPT N | W | Qu | RC | RQD% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | | | | | | | | | | |
| 11 | 11 | | | HQ11 | | | | | | | |
| 12 | 12 | | | | | | | | | 100 | 100 |
| | | Rock Compressive Strength: 1,792 Kpa (very weak) | | HQ12 | | | | | | | |
| 13 | 13 | Unit Weight: 19.31 Kn/m3 | | | | | | | | 100 | 22 |
| 14 | 14 | | | HQ13 | | | | | | | |
| | | | | | | | | | | 100 | 100 |
| 15 | 15 | | | | | | | | | | |
| | | | | HQ14 | | | | | | | |
| 16 | 16 | | | | | | | | | 100 | 86 |
| 17 | 17 | | | HQ15 | | | | | | | |
| 18 | 18 | | | | | | | | | 100 | 78 |
| | | Rock Compressive Strength: 1,861 Kpa (very weak) | | HQ16 | | | | | | | |
| 19 | 19 | Unit Weight: 17.56 Kn/m3<br>Rock joint at approx. 19.8m | | | | | | | | 100 | 15 |
| 20 | 20 | | | | | | | | | | |
| | | Rock Compressive Strength: 3,309 Kpa (very weak) | | HQ17 | | | | | | | |
| | | Unit Weight: 18.66 Kn/m3 | | | | | | | | | |
| 21 | 21 | Weathered zones | | | | | | | | 100 | 32 |
| 22 | 22 | | | | | | | | | | |

○ N □ W △ Qu

Qu 1 2 3 4

N-W 20 40 60 80

"N" - Number of blows required to drive the sampling spoon a distance of 30 cm. with a 52 kg hammer falling 76 cm.
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"Qu" - Unconfined Compressive Strength in kilo pascals.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
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▽ Initial G.W. Depth
▼ Final G.W. Depth

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## Core Runs Field Photographs – Reinjection Route, RL-B2-BH03



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41-46 ft (12.50-14.02m)

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56-61 ft (17.06-18.59m)

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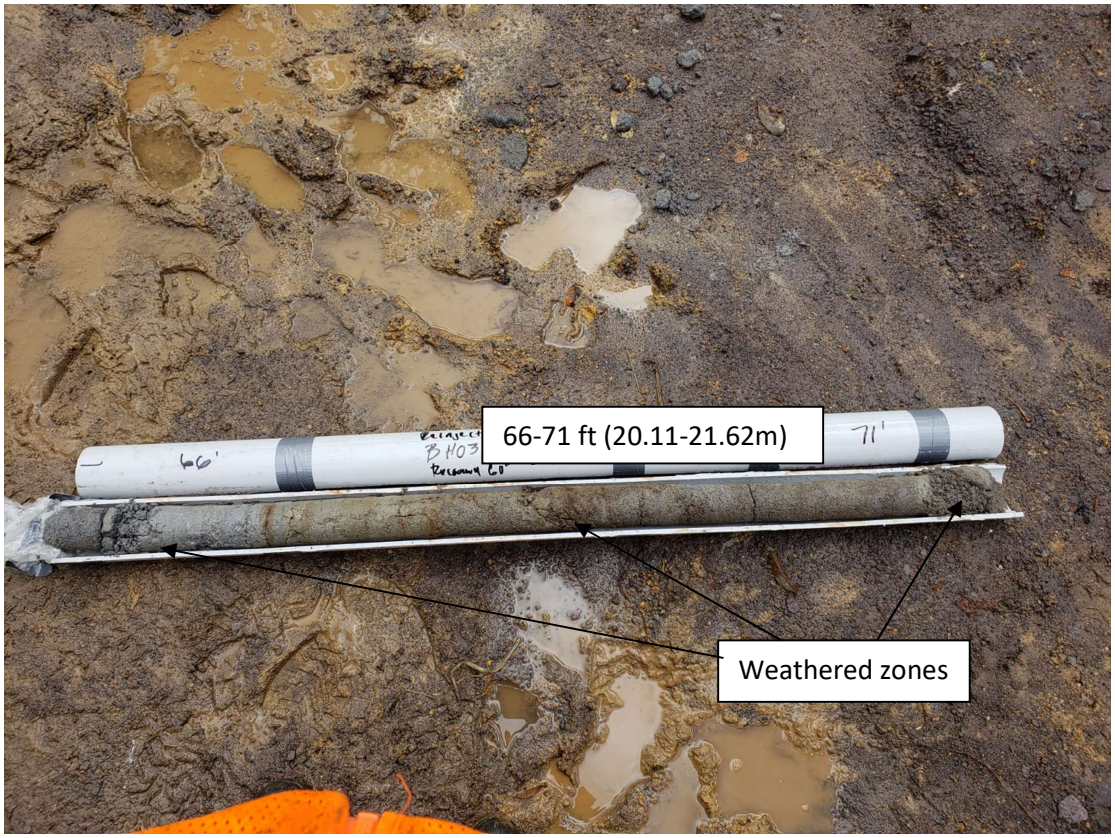

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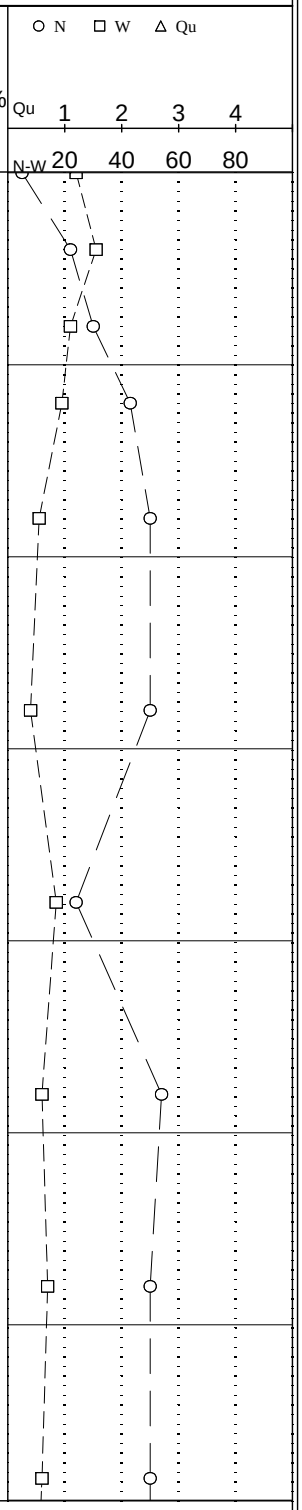
# SUBSURFACE EXPLORATION LOG

**RL-B2** 2017

**BORING No.: BH04**

| | | | |
|---|---|---|---|
| **PROJECT:** Dominica Geothermal Project | | **JOB:** 7909-A | **SHEET** 1 **OF** 3 |
| **LOCATION:** Reinjection Line | | **DRILLER/DRILL RIG:** Steven Perez / CME-55 | |
| **COORDINATES:** 679639 E | 1694913 N | **DATE STARTED:** 11-3-18 | **DATE COMPLETED:** 11-5-18 |
| **DESCRIPTION BY:** Manuel Candelario | | **SURFACE ELEVATION (mt):** | |
| **GROUNDWATER (mt):** **Initial:** Dry | **Final:** Dry | **ENGINEER:** Manuel Candelario | |
| **DRILLING METHOD:** HQ Casing Advancer | | **TOTAL DEPTH (mt):** 27.7 | |

| ELEV (mt) | DEPTH (mt) | DESCRIPTION | LEGEND | SAMPLE NO. | TYPE | BLOWS | SPT N | W | Qu | RC | RQD% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | | | | | | | | | | |
| 0 | 0 | 0 CLAYEY SAND trace gravel, loose to very dense, yellowish brown, gray | | S-1 | | 2 1 4 | 5 | 24 | | | |
| | | | | S-2 | | 10 10 12 | 22 | 31 | | | |
| 1 | 1 | 4 | | | | | | | | | |
| | | HIGHLY WEATHERED VOLVANIC SANDSTONE sampled as silty sand trace clay, medium to very dense, yellowish brown, pinkish gray | | S-3 | | 8 13 17 | 30 | 22 | | | |
| 2 | 2 | | | S-4 | | 15 25 18 | 43 | 19 | | | |
| | | | | S-5 | | 50/5" | 50/5" | 11 | | | |
| 3 | 3 | | | | | | | | | | |
| 4 | 4 | | | S-6 | | 50/6" | 50/6" | 8 | | | |
| 5 | 5 | | | | | | | | | | |
| | | | | S-7 | | 11 13 11 | 24 | 17 | | | |
| 6 | 6 | | | | | | | | | | |
| 7 | 7 | | | S-8 | | 20 25 29 | 54 | 12 | | | |
| 8 | 8 | | | | | | | | | | |
| | | | | S-9 | | 31 50/4" | 50/4" | 14 | | | |
| 9 | 9 | | | | | | | | | | |
| 10 | 10 | | | S-10 | | 50/4" | 50/4" | 12 | | | |




"N" - Number of blows required to drive the sampling spoon a distance of 30 cm. with a 52 kg hammer falling 76 cm.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in kilo pascals.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
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Initial G.W. Depth
Final G.W. Depth

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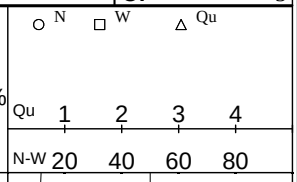
# SUBSURFACE EXPLORATION LOG RL-B2

**BORING NUMBER: BH04**

## BORING LOG (CONT. SHEET)

| PROJECT | JOB | SHEET | OF |
|---|---|---|---|
| Dominica Geothermal Project | 7909-A | 2 | 3 |

| ELEV (mt) | DEPTH (mt) | DESCRIPTION | LEGEND | SAMPLE NO. | TYPE | BLOWS | SPT N | W | Qu | RC | RQD% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | | | | | | | | | | |
| 11 | 11 | | | | | | | | | | |
| 12 | 12 | | | S-11 | | 50/3" | 50/3" | 9 | | | |
| | | 41 | | | | | | | | | |
| | | VOLCANIC SANDSTONE, slightly to severely weathered, moderately fractured, yellowish brown, light gray | | HQ12 | | | | | | 100 | 83 |
| 13 | 13 | | | | | | | | | | |
| 14 | 14 | Rock Compressive Strength: 6,756 Kpa (very weak)<br>Unit Weight: 19.57 Kn/m3 | | HQ13 | | | | | | 100 | 47 |
| 15 | 15 | | | | | | | | | | |
| | | Rock joint at approx. 16.6m | | HQ14 | | | | | | | |
| 16 | 16 | | | | | | | | | 85 | 26 |
| 17 | 17 | Rock joint at approx. 17.2m | | HQ15 | | | | | | | |
| 18 | 18 | | | | | | | | | 91 | 45 |
| | | | | HQ16 | | | | | | | |
| 19 | 19 | | | | | | | | | 100 | 70 |
| 20 | 20 | Rock Compressive Strength: 1,861 Kpa (very weak)<br>Unit Weight: 19.13 Kn/m3<br>Rock joint at approx. 20.2m | | HQ17 | | | | | | | |
| 21 | 21 | | | | | | | | | 100 | 6 |
| | | | | HQ18 | | | | | | | |
| 22 | 22 | | | | | | | | | 100 | 46 |

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"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
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▽ Initial G.W. Depth
▼ Final G.W. Depth

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# SUBSURFACE EXPLORATION LOG RL-B2

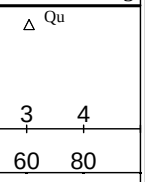


**BORING NUMBER: BH04**

## BORING LOG (CONT. SHEET)

| PROJECT | JOB | SHEET | OF |
|---|---|---|---|
| Dominica Geothermal Project | 7909-A | 3 | 3 |

| ELEV (mt) | DEPTH (mt) | DESCRIPTION | LEGEND | SAMPLE NO. | TYPE | BLOWS | SPT N | W | Qu | RC | RQD% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | | | | | | | | | | |
| 23 | 23 | | | HQ19 | | | | | | | |
| 24 | 24 | | | | | | | | | 100 | 85 |
| 25 | 25 | Rock Compressive Strength: 5,653 Kpa (very weak)<br>Unit Weight: 18.60 Kn/m3<br>Rock joint at approx. 25.9m | | HQ20 | | | | | | | |
| | | | | | | | | | | 100 | 48 |
| 26 | 26 | | | HQ21 | | | | | | | |
| 27 | 27 | | | | | | | | | 100 | 0 |
| 28 | 28 | | | | | | | | | | |
| 29 | 29 | | | | | | | | | | |
| 30 | 30 | | | | | | | | | | |
| 31 | 31 | | | | | | | | | | |
| 32 | 32 | | | | | | | | | | |
| 33 | 33 | | | | | | | | | | |
| 34 | 34 | | | | | | | | | | |

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"Qu" - Unconfined Compressive Strength in kilo pascals.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

▽ Initial G.W. Depth
▼ Final G.W. Depth

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## Core Runs Field Photographs – Reinjection Route, RL-B2-BH04



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46-51 ft (14.02-15.54m)

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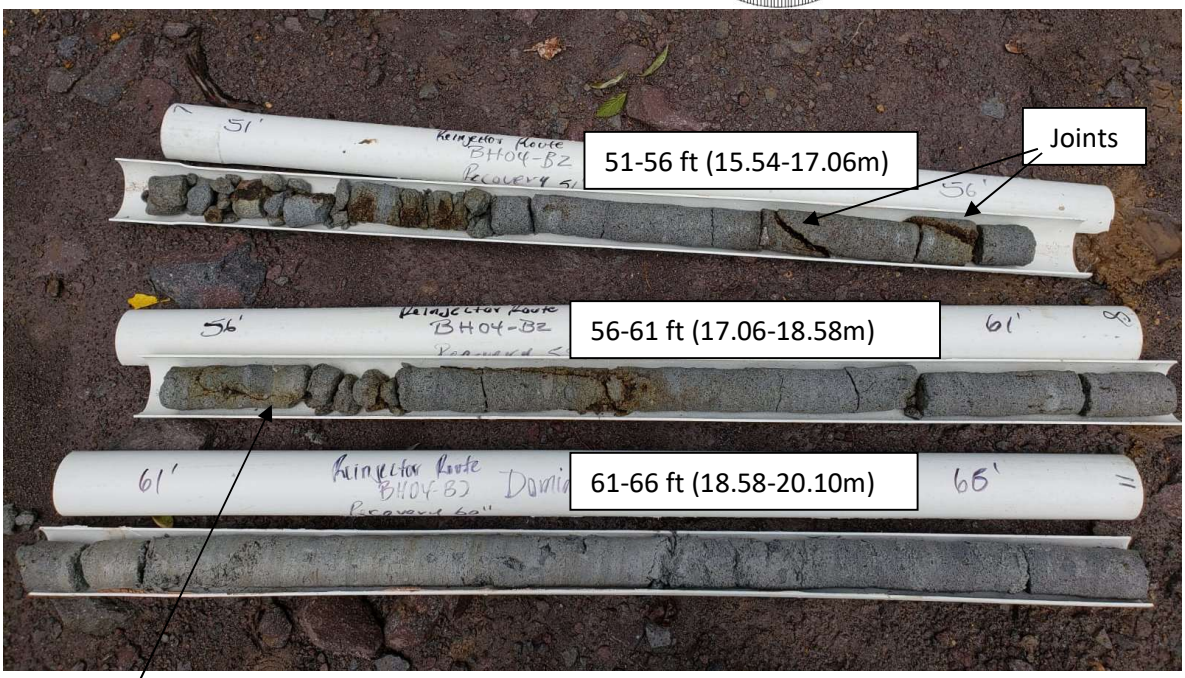

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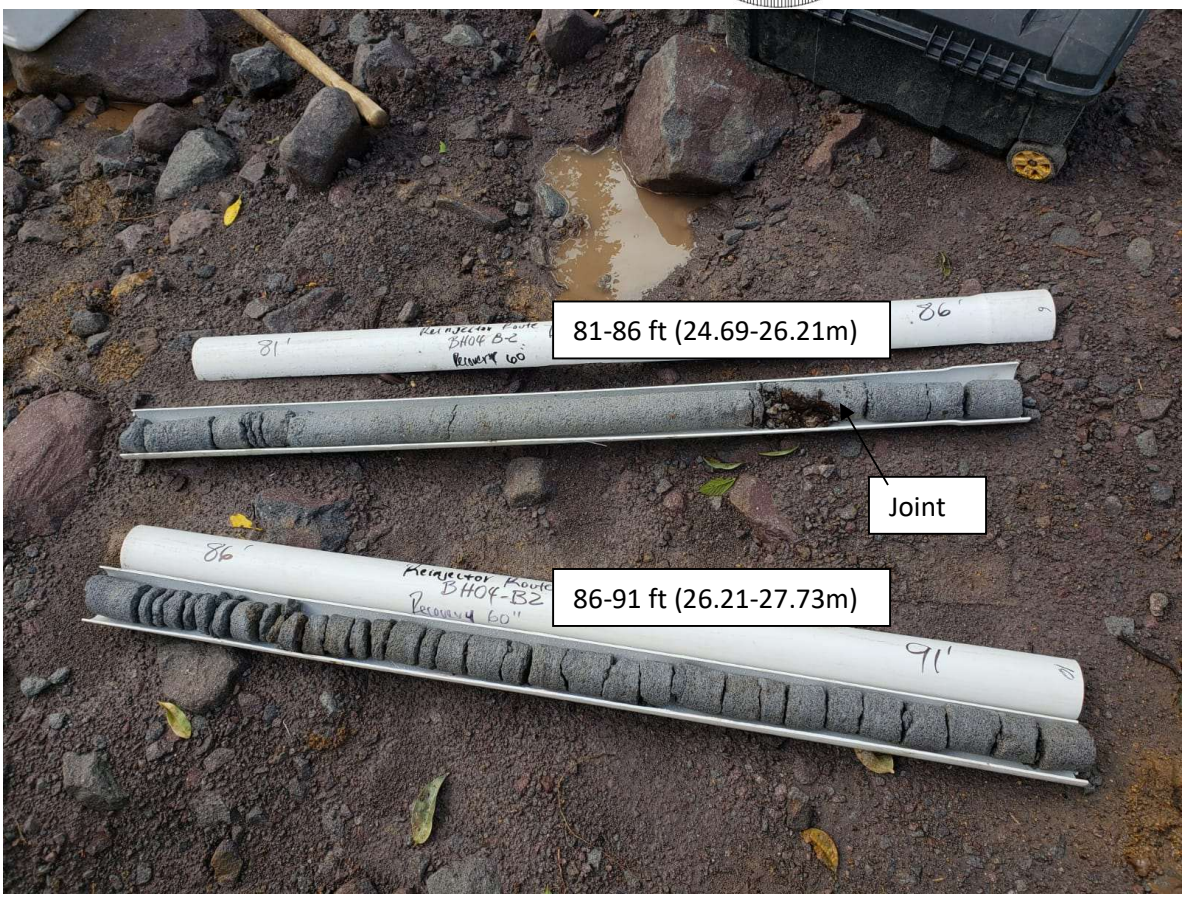

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# **Appendix** B:

## Dynamic Cone Penetration Test Results

# DCP TEST DATA

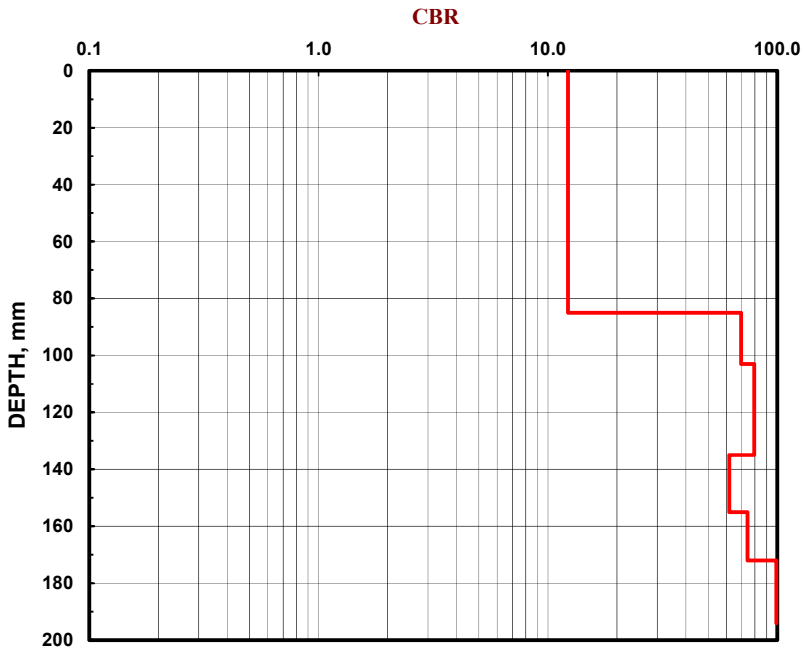
**Project:** *Dominica Geothermal Project* **Date:** 9-Oct-18

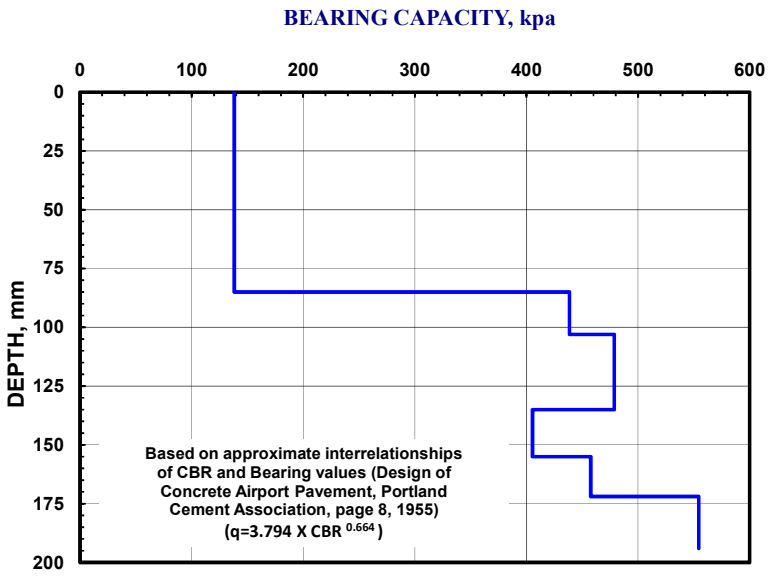
**Location:** PP-DCP-01 **Coordinates** E 679820, N 1695678

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

| No. of Blows | Accumulative Penetration (mm) | Type of Hammer |
|---|---|---|
| 0 | 0 | 1 |
| 5 | 85 | 1 |
| 5 | 103 | 1 |
| 5 | 119 | 1 |
| 5 | 135 | 1 |
| 5 | 155 | 1 |
| 5 | 172 | 1 |
| 5 | 183 | 1 |
| 5 | 189 | 1 |
| 5 | 194 | 1 |



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# PP-DCP-1

| Penetr./ | Penetr./ | Hammer | DCP | CBR | CBR | Depth | Depth | Bearing Capacity | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Blow Set | Blow | Blow | Index | % | % | in. | mm | psf | psi | kpa |
| mm | mm | Factor | | | | | | | | |
| [3] | [4] | [5] | [6] | | | [8] | [9] | [10] | [11] | |
| ----- | ----- | ----- | ----- | --- | --- | 0.0 | 0 | | | |
| 85 | 17 | 1 | 17 | 12.2 | 12 | 0.0 | 0 | 2880 | 20.00 | 138.2 |
| 85 | 17 | 1 | 17 | 12.2 | 12 | 3.3 | 85 | 2880 | 20.00 | 138.2 |
| 18 | 4 | 1 | 4 | 69.6 | 70 | 3.3 | 85 | 9136 | 63.45 | 438.5 |
| 18 | 4 | 1 | 4 | 69.6 | 70 | 4.1 | 103 | 9136 | 63.45 | 438.5 |
| 16 | 3 | 1 | 3 | 79.4 | 79 | 4.1 | 103 | 9973 | 69.25 | 478.7 |
| 16 | 3 | 1 | 3 | 79.4 | 79 | 4.7 | 119 | 9973 | 69.25 | 478.7 |
| 16 | 3 | 1 | 3 | 79.4 | 79 | 4.7 | 119 | 9973 | 69.25 | 478.7 |
| 16 | 3 | 1 | 3 | 79.4 | 79 | 5.3 | 135 | 9973 | 69.25 | 478.7 |
| 20 | 4 | 1 | 4 | 61.8 | 62 | 5.3 | 135 | 8448 | 58.66 | 405.5 |
| 20 | 4 | 1 | 4 | 61.8 | 62 | 6.1 | 155 | 8448 | 58.66 | 405.5 |
| 17 | 3 | 1 | 3 | 74.2 | 74 | 6.1 | 155 | 9533 | 66.20 | 457.6 |
| 17 | 3 | 1 | 3 | 74.2 | 74 | 6.8 | 172 | 9533 | 66.20 | 457.6 |
| 11 | 2 | 1 | 2 | 120.7 | 99 | 6.8 | 172 | 11549 | 80.20 | 554.4 |
| 11 | 2 | 1 | 2 | 120.7 | 99 | 7.2 | 183 | 11549 | 80.20 | 554.4 |
| 6 | 1 | 1 | 1 | 238.1 | 99 | 7.2 | 183 | 11549 | 80.20 | 554.4 |
| 6 | 1 | 1 | 1 | 238.1 | 99 | 7.4 | 189 | 11549 | 80.20 | 554.4 |
| 5 | 1 | 1 | 1 | 292.0 | 99 | 7.4 | 189 | 11549 | 80.20 | 554.4 |
| 5 | 1 | 1 | 1 | 292.0 | 99 | 7.6 | 194 | 11549 | 80.20 | 554.4 |

# DCP TEST DATA

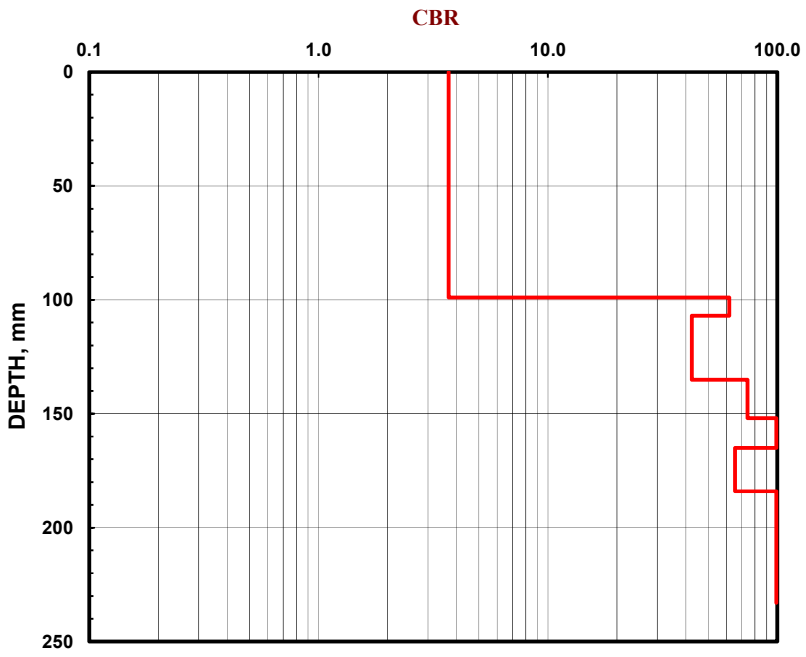
**Project:** *Dominica Geothermal Project* **Date:** 9-Oct-18

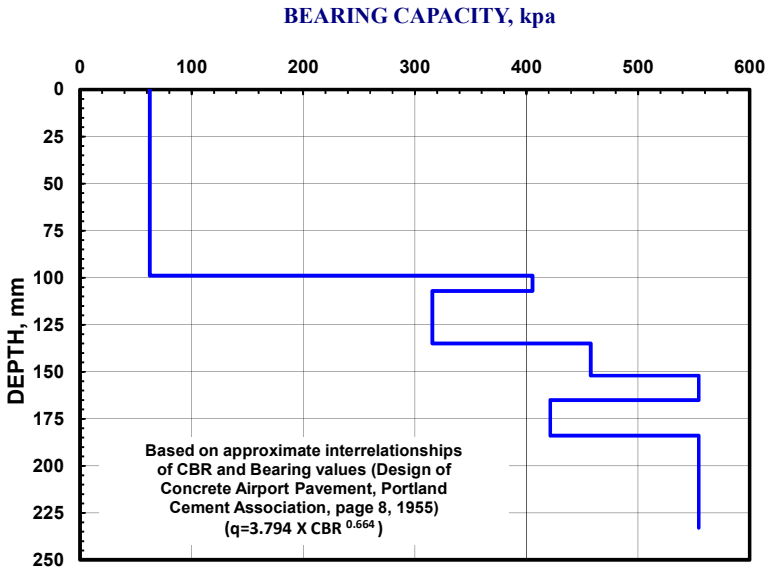
**Location:** PP-DCP-02 **Coordinates** E 679827, N 1695650

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

| No. of Blows | Accumulative Penetration (mm) | Type of Hammer |
|---|---|---|
| 0 | 0 | 1 |
| 2 | 99 | 1 |
| 2 | 107 | 1 |
| 5 | 135 | 1 |
| 5 | 152 | 1 |
| 5 | 165 | 1 |
| 5 | 184 | 1 |
| 5 | 194 | 1 |
| 5 | 204 | 1 |
| 5 | 215 | 1 |
| 5 | 225 | 1 |
| 5 | 231 | 1 |
| 5 | 233 | 1 |



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# PP-DCP-2

| Penetr./ Blow Set | Penetr./ Blow | Hammer Blow | DCP Index | CBR % | CBR % | Depth in. | Depth mm | Bearing Capacity psf | Bearing Capacity psi | Bearing Capacity kpa |
|---|---|---|---|---|---|---|---|---|---|---|
| mm | mm | Factor | | | | | | | | |
| [3] | [4] | [5] | [6] | | | [8] | [9] | [10] | [11] | |
| ----- | ----- | ----- | ----- | --- | --- | 0.0 | 0 | | | |
| 99 | 50 | 1 | 50 | 3.7 | 4 | 0.0 | 0 | 1301 | 9.03 | 62.4 |
| 99 | 50 | 1 | 50 | 3.7 | 4 | 3.9 | 99 | 1301 | 9.03 | 62.4 |
| 8 | 4 | 1 | 4 | 61.8 | 62 | 3.9 | 99 | 8448 | 58.66 | 405.5 |
| 8 | 4 | 1 | 4 | 61.8 | 62 | 4.2 | 107 | 8448 | 58.66 | 405.5 |
| 28 | 6 | 1 | 6 | 42.4 | 42 | 4.2 | 107 | 6578 | 45.68 | 315.7 |
| 28 | 6 | 1 | 6 | 42.4 | 42 | 5.3 | 135 | 6578 | 45.68 | 315.7 |
| 17 | 3 | 1 | 3 | 74.2 | 74 | 5.3 | 135 | 9533 | 66.20 | 457.6 |
| 17 | 3 | 1 | 3 | 74.2 | 74 | 6.0 | 152 | 9533 | 66.20 | 457.6 |
| 13 | 3 | 1 | 3 | 100.1 | 99 | 6.0 | 152 | 11549 | 80.20 | 554.4 |
| 13 | 3 | 1 | 3 | 100.1 | 99 | 6.5 | 165 | 11549 | 80.20 | 554.4 |
| 19 | 4 | 1 | 4 | 65.5 | 65 | 6.5 | 165 | 8776 | 60.94 | 421.3 |
| 19 | 4 | 1 | 4 | 65.5 | 65 | 7.2 | 184 | 8776 | 60.94 | 421.3 |
| 10 | 2 | 1 | 2 | 134.3 | 99 | 7.2 | 184 | 11549 | 80.20 | 554.4 |
| 10 | 2 | 1 | 2 | 134.3 | 99 | 7.6 | 194 | 11549 | 80.20 | 554.4 |
| 10 | 2 | 1 | 2 | 134.3 | 99 | 7.6 | 194 | 11549 | 80.20 | 554.4 |
| 10 | 2 | 1 | 2 | 134.3 | 99 | 8.0 | 204 | 11549 | 80.20 | 554.4 |
| 11 | 2 | 1 | 2 | 120.7 | 99 | 8.0 | 204 | 11549 | 80.20 | 554.4 |
| 11 | 2 | 1 | 2 | 120.7 | 99 | 8.5 | 215 | 11549 | 80.20 | 554.4 |
| 10 | 2 | 1 | 2 | 134.3 | 99 | 8.5 | 215 | 11549 | 80.20 | 554.4 |
| 10 | 2 | 1 | 2 | 134.3 | 99 | 8.9 | 225 | 11549 | 80.20 | 554.4 |
| 6 | 1 | 1 | 1 | 238.1 | 99 | 8.9 | 225 | 11549 | 80.20 | 554.4 |
| 6 | 1 | 1 | 1 | 238.1 | 99 | 9.1 | 231 | 11549 | 80.20 | 554.4 |
| 2 | 0 | 1 | 0 | 814.8 | 99 | 9.1 | 231 | 11549 | 80.20 | 554.4 |
| 2 | 0 | 1 | 0 | 814.8 | 99 | 9.2 | 233 | 11549 | 80.20 | 554.4 |

# DCP TEST DATA

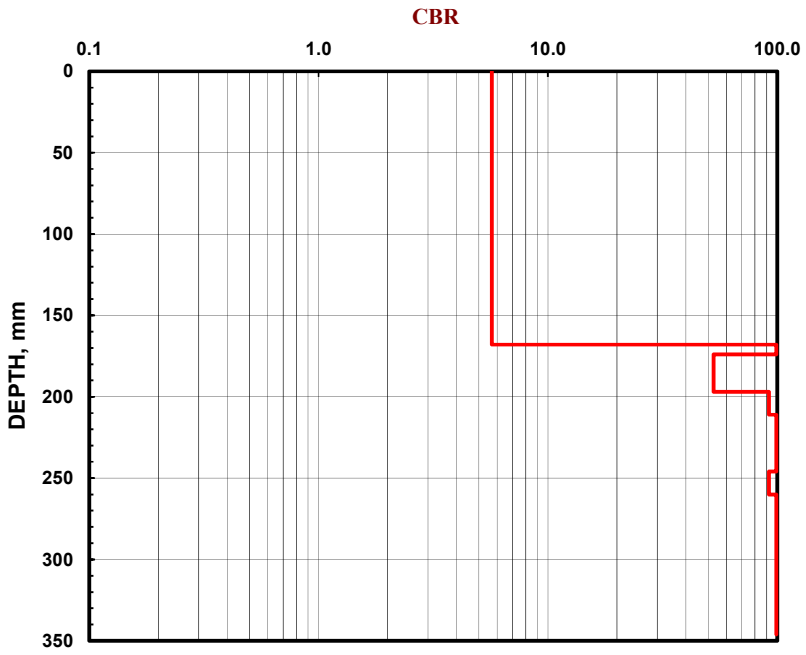
**Project:** *Dominica Geothermal Project* **Date:** 9-Oct-18

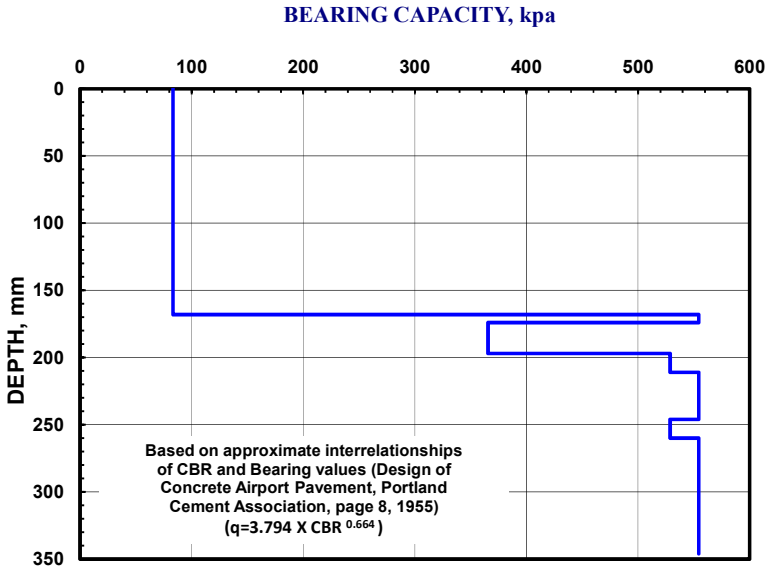
**Location:** PP-DCP-03 **Coordinates** E 679740, N 1695605

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

| No. of Blows | Accumulative Penetration (mm) | Type of Hammer |
|---|---|---|
| 0 | 0 | 1 |
| 5 | 168 | 1 |
| 5 | 174 | 1 |
| 5 | 197 | 1 |
| 5 | 211 | 1 |
| 5 | 224 | 1 |
| 5 | 237 | 1 |
| 5 | 246 | 1 |
| 5 | 260 | 1 |
| 5 | 267 | 1 |
| 5 | 274 | 1 |
| 5 | 279 | 1 |
| 5 | 285 | 1 |
| 5 | 293 | 1 |
| 5 | 300 | 1 |
| 5 | 307 | 1 |
| 5 | 310 | 1 |
| 5 | 315 | 1 |
| 5 | 319 | 1 |
| 5 | 323 | 1 |
| 5 | 327 | 1 |
| 5 | 332 | 1 |
| 5 | 337 | 1 |
| 5 | 340 | 1 |
| 5 | 344 | 1 |
| 5 | 346 | 1 |



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# PP-DCP-3

| Penetr./ Blow Set | Penetr./ Blow | Hammer Blow | DCP Index | CBR % | CBR % | Depth in. | Depth mm | Bearing Capacity psf | psi | kpa |
|---|---|---|---|---|---|---|---|---|---|---|
| mm | mm | Factor | | | | | | | | |
| [3] | [4] | [5] | [6] | | | [8] | [9] | [10] | [11] | |
| ----- | ----- | ----- | ----- | --- | --- | 0.0 | 0 | | | |
| 168 | 34 | 1 | 34 | 5.7 | 6 | 0.0 | 0 | 1735 | 12.05 | 83.3 |
| 168 | 34 | 1 | 34 | 5.7 | 6 | 6.6 | 168 | 1735 | 12.05 | 83.3 |
| 6 | 1 | 1 | 1 | 238.1 | 99 | 6.6 | 168 | 11549 | 80.20 | 554.4 |
| 6 | 1 | 1 | 1 | 238.1 | 99 | 6.9 | 174 | 11549 | 80.20 | 554.4 |
| 23 | 5 | 1 | 5 | 52.9 | 53 | 6.9 | 174 | 7614 | 52.87 | 365.5 |
| 23 | 5 | 1 | 5 | 52.9 | 53 | 7.8 | 197 | 7614 | 52.87 | 365.5 |
| 14 | 3 | 1 | 3 | 92.2 | 92 | 7.8 | 197 | 11014 | 76.48 | 528.7 |
| 14 | 3 | 1 | 3 | 92.2 | 92 | 8.3 | 211 | 11014 | 76.48 | 528.7 |
| 13 | 3 | 1 | 3 | 100.1 | 99 | 8.3 | 211 | 11549 | 80.20 | 554.4 |
| 13 | 3 | 1 | 3 | 100.1 | 99 | 8.8 | 224 | 11549 | 80.20 | 554.4 |
| 13 | 3 | 1 | 3 | 100.1 | 99 | 8.8 | 224 | 11549 | 80.20 | 554.4 |
| 13 | 3 | 1 | 3 | 100.1 | 99 | 9.3 | 237 | 11549 | 80.20 | 554.4 |
| 9 | 2 | 1 | 2 | 151.2 | 99 | 9.3 | 237 | 11549 | 80.20 | 554.4 |
| 9 | 2 | 1 | 2 | 151.2 | 99 | 9.7 | 246 | 11549 | 80.20 | 554.4 |
| 14 | 3 | 1 | 3 | 92.2 | 92 | 9.7 | 246 | 11014 | 76.48 | 528.7 |
| 14 | 3 | 1 | 3 | 92.2 | 92 | 10.2 | 260 | 11014 | 76.48 | 528.7 |
| 7 | 1 | 1 | 1 | 200.3 | 99 | 10.2 | 260 | 11549 | 80.20 | 554.4 |
| 7 | 1 | 1 | 1 | 200.3 | 99 | 10.5 | 267 | 11549 | 80.20 | 554.4 |
| 7 | 1 | 1 | 1 | 200.3 | 99 | 10.5 | 267 | 11549 | 80.20 | 554.4 |
| 7 | 1 | 1 | 1 | 200.3 | 99 | 10.8 | 274 | 11549 | 80.20 | 554.4 |
| 5 | 1 | 1 | 1 | 292.0 | 99 | 10.8 | 274 | 11549 | 80.20 | 554.4 |
| 5 | 1 | 1 | 1 | 292.0 | 99 | 11.0 | 279 | 11549 | 80.20 | 554.4 |
| 6 | 1 | 1 | 1 | 238.1 | 99 | 11.0 | 279 | 11549 | 80.20 | 554.4 |
| 6 | 1 | 1 | 1 | 238.1 | 99 | 11.2 | 285 | 11549 | 80.20 | 554.4 |
| 8 | 2 | 1 | 2 | 172.5 | 99 | 11.2 | 285 | 11549 | 80.20 | 554.4 |
| 8 | 2 | 1 | 2 | 172.5 | 99 | 11.5 | 293 | 11549 | 80.20 | 554.4 |
| 7 | 1 | 1 | 1 | 200.3 | 99 | 11.5 | 293 | 11549 | 80.20 | 554.4 |
| 7 | 1 | 1 | 1 | 200.3 | 99 | 11.8 | 300 | 11549 | 80.20 | 554.4 |
| 7 | 1 | 1 | 1 | 200.3 | 99 | 11.8 | 300 | 11549 | 80.20 | 554.4 |
| 7 | 1 | 1 | 1 | 200.3 | 99 | 12.1 | 307 | 11549 | 80.20 | 554.4 |
| 3 | 1 | 1 | 1 | 517.4 | 99 | 12.1 | 307 | 11549 | 80.20 | 554.4 |
| 3 | 1 | 1 | 1 | 517.4 | 99 | 12.2 | 310 | 11549 | 80.20 | 554.4 |
| 5 | 1 | 1 | 1 | 292.0 | 99 | 12.2 | 310 | 11549 | 80.20 | 554.4 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 1 | 1 | 292.0 | 99 | 12.4 | 315 | 11549 | 80.20 | 554.4 |
| 4 | 1 | 1 | 1 | 374.9 | 99 | 12.4 | 315 | 11549 | 80.20 | 554.4 |
| 4 | 1 | 1 | 1 | 374.9 | 99 | 12.6 | 319 | 11549 | 80.20 | 554.4 |
| 4 | 1 | 1 | 1 | 374.9 | 99 | 12.6 | 319 | 11549 | 80.20 | 554.4 |
| 4 | 1 | 1 | 1 | 374.9 | 99 | 12.7 | 323 | 11549 | 80.20 | 554.4 |
| 4 | 1 | 1 | 1 | 374.9 | 99 | 12.7 | 323 | 11549 | 80.20 | 554.4 |
| 4 | 1 | 1 | 1 | 374.9 | 99 | 12.9 | 327 | 11549 | 80.20 | 554.4 |
| 5 | 1 | 1 | 1 | 292.0 | 99 | 12.9 | 327 | 11549 | 80.20 | 554.4 |
| 5 | 1 | 1 | 1 | 292.0 | 99 | 13.1 | 332 | 11549 | 80.20 | 554.4 |
| 5 | 1 | 1 | 1 | 292.0 | 99 | 13.1 | 332 | 11549 | 80.20 | 554.4 |
| 5 | 1 | 1 | 1 | 292.0 | 99 | 13.3 | 337 | 11549 | 80.20 | 554.4 |
| 3 | 1 | 1 | 1 | 517.4 | 99 | 13.3 | 337 | 11549 | 80.20 | 554.4 |
| 3 | 1 | 1 | 1 | 517.4 | 99 | 13.4 | 340 | 11549 | 80.20 | 554.4 |
| 4 | 1 | 1 | 1 | 374.9 | 99 | 13.4 | 340 | 11549 | 80.20 | 554.4 |
| 4 | 1 | 1 | 1 | 374.9 | 99 | 13.5 | 344 | 11549 | 80.20 | 554.4 |
| 2 | 0 | 1 | 0 | 814.8 | 99 | 13.5 | 344 | 11549 | 80.20 | 554.4 |
| 2 | 0 | 1 | 0 | 814.8 | 99 | 13.6 | 346 | 11549 | 80.20 | 554.4 |

# DCP TEST DATA

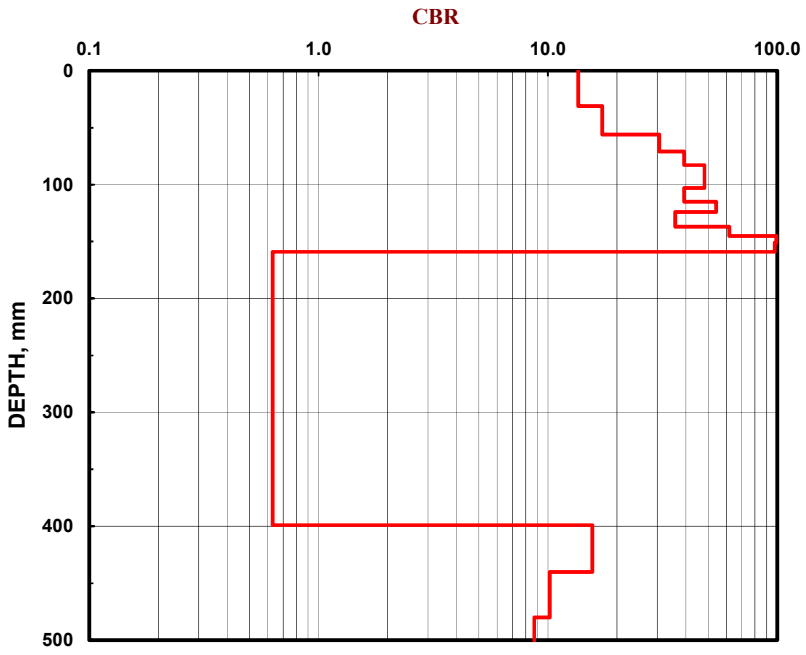
**Project:** *Dominica Geothermal Project* **Date:** 9-Oct-18

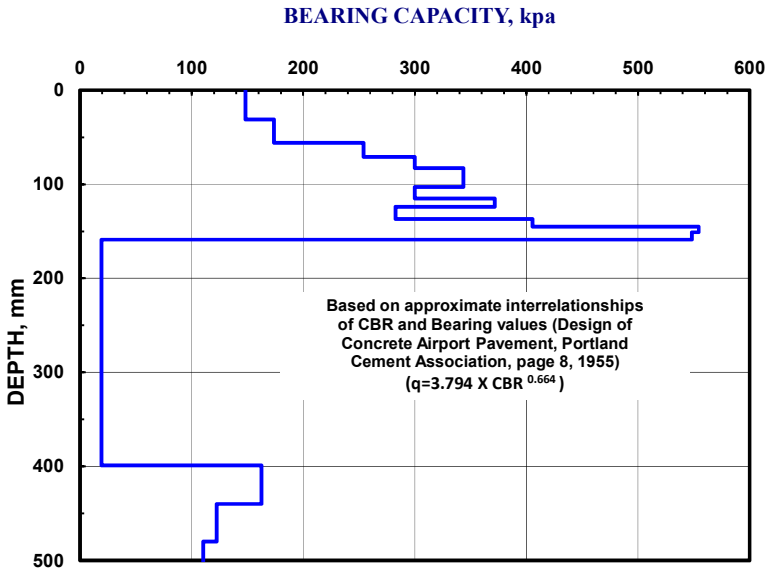
**Location:** PP-DCP-04 **Coordinates** E 679790 , N 1695630

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

| No. of Blows | Accumulative Penetration (mm) | Type of Hammer |
|---|---|---|
| 0 | 0 | 1 |
| 2 | 31 | 1 |
| 2 | 56 | 1 |
| 2 | 71 | 1 |
| 2 | 83 | 1 |
| 2 | 93 | 1 |
| 2 | 103 | 1 |
| 2 | 115 | 1 |
| 2 | 124 | 1 |
| 2 | 137 | 1 |
| 2 | 145 | 1 |
| 3 | 151 | 1 |
| 3 | 159 | 1 |
| 1 | 399 | 1 |
| 3 | 440 | 1 |
| 2 | 480 | 1 |
| 1 | 503 | 1 |



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# PP-DCP-4

| Penetr./ | Penetr./ | Hammer | DCP | CBR | CBR | Depth | Depth | Bearing Capacity | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Blow Set | Blow | Blow | Index | % | % | in. | mm | psf | psi | kpa |
| mm | mm | Factor | | | | | | | | |
| [3] | [4] | [5] | [6] | | | [8] | [9] | [10] | [11] | |
| ----- | ----- | ----- | ----- | --- | --- | 0.0 | 0 | | | |
| 31 | 16 | 1 | 16 | 13.6 | 14 | 0.0 | 0 | 3085 | 21.42 | 148.1 |
| 31 | 16 | 1 | 16 | 13.6 | 14 | 1.2 | 31 | 3085 | 21.42 | 148.1 |
| 25 | 13 | 1 | 13 | 17.3 | 17 | 1.2 | 31 | 3620 | 25.14 | 173.8 |
| 25 | 13 | 1 | 13 | 17.3 | 17 | 2.2 | 56 | 3620 | 25.14 | 173.8 |
| 15 | 8 | 1 | 8 | 30.6 | 31 | 2.2 | 56 | 5293 | 36.76 | 254.1 |
| 15 | 8 | 1 | 8 | 30.6 | 31 | 2.8 | 71 | 5293 | 36.76 | 254.1 |
| 12 | 6 | 1 | 6 | 39.3 | 39 | 2.8 | 71 | 6249 | 43.39 | 299.9 |
| 12 | 6 | 1 | 6 | 39.3 | 39 | 3.3 | 83 | 6249 | 43.39 | 299.9 |
| 10 | 5 | 1 | 5 | 48.1 | 48 | 3.3 | 83 | 7156 | 49.69 | 343.5 |
| 10 | 5 | 1 | 5 | 48.1 | 48 | 3.7 | 93 | 7156 | 49.69 | 343.5 |
| 10 | 5 | 1 | 5 | 48.1 | 48 | 3.7 | 93 | 7156 | 49.69 | 343.5 |
| 10 | 5 | 1 | 5 | 48.1 | 48 | 4.1 | 103 | 7156 | 49.69 | 343.5 |
| 12 | 6 | 1 | 6 | 39.3 | 39 | 4.1 | 103 | 6249 | 43.39 | 299.9 |
| 12 | 6 | 1 | 6 | 39.3 | 39 | 4.5 | 115 | 6249 | 43.39 | 299.9 |
| 9 | 4 | 1 | 4 | 54.2 | 54 | 4.5 | 115 | 7739 | 53.74 | 371.5 |
| 9 | 4 | 1 | 4 | 54.2 | 54 | 4.9 | 124 | 7739 | 53.74 | 371.5 |
| 13 | 7 | 1 | 7 | 35.9 | 36 | 4.9 | 124 | 5887 | 40.89 | 282.6 |
| 13 | 7 | 1 | 7 | 35.9 | 36 | 5.4 | 137 | 5887 | 40.89 | 282.6 |
| 8 | 4 | 1 | 4 | 61.8 | 62 | 5.4 | 137 | 8448 | 58.66 | 405.5 |
| 8 | 4 | 1 | 4 | 61.8 | 62 | 5.7 | 145 | 8448 | 58.66 | 405.5 |
| 6 | 2 | 1 | 2 | 134.3 | 99 | 5.7 | 145 | 11549 | 80.20 | 554.4 |
| 6 | 2 | 1 | 2 | 134.3 | 99 | 5.9 | 151 | 11549 | 80.20 | 554.4 |
| 8 | 3 | 1 | 3 | 97.3 | 97 | 5.9 | 151 | 11421 | 79.31 | 548.2 |
| 8 | 3 | 1 | 3 | 97.3 | 97 | 6.3 | 159 | 11421 | 79.31 | 548.2 |
| 240 | 240 | 1 | 240 | 0.6 | 1 | 6.3 | 159 | 402 | 2.79 | 19.3 |
| 240 | 240 | 1 | 240 | 0.6 | 1 | 15.7 | 399 | 402 | 2.79 | 19.3 |
| 41 | 14 | 1 | 14 | 15.6 | 16 | 15.7 | 399 | 3388 | 23.53 | 162.6 |
| 41 | 14 | 1 | 14 | 15.6 | 16 | 17.3 | 440 | 3388 | 23.53 | 162.6 |
| 40 | 20 | 1 | 20 | 10.2 | 10 | 17.3 | 440 | 2552 | 17.72 | 122.5 |
| 40 | 20 | 1 | 20 | 10.2 | 10 | 18.9 | 480 | 2552 | 17.72 | 122.5 |
| 23 | 23 | 1 | 23 | 8.7 | 9 | 18.9 | 480 | 2300 | 15.97 | 110.4 |
| 23 | 23 | 1 | 23 | 8.7 | 9 | 19.8 | 503 | 2300 | 15.97 | 110.4 |

# DCP TEST DATA

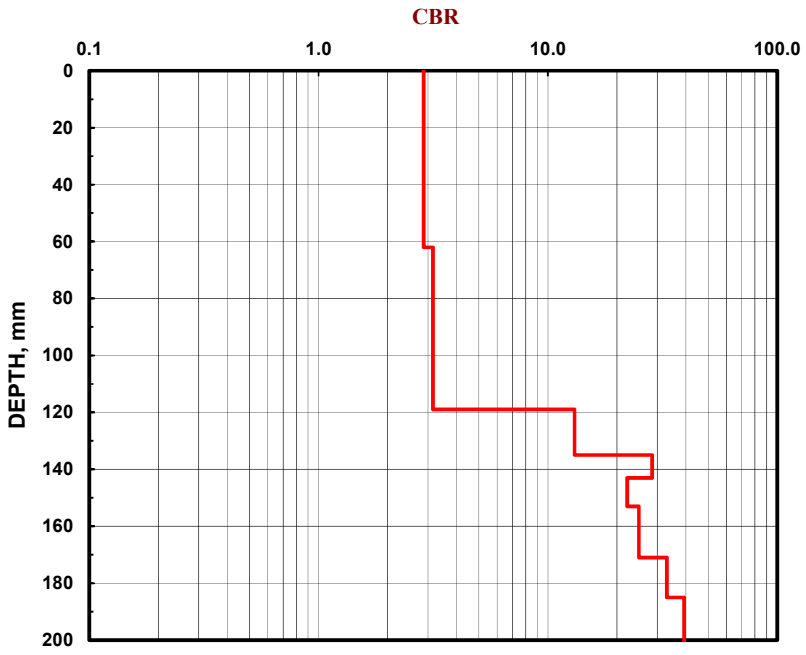
**Project:** *Dominica Geothermal Project* **Date:** 10-Oct-18

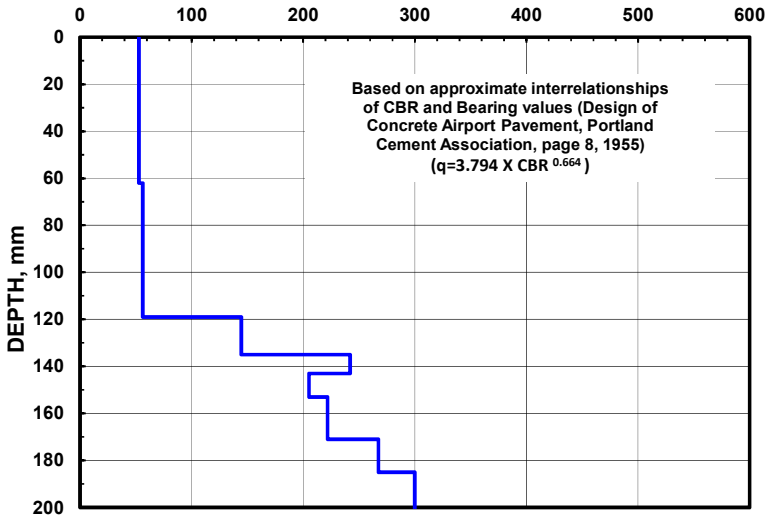
**Location:** RL-DCP-01 **Coordinates** E 679602, N 1694821

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

| No. of Blows | Accumulative Penetration (mm) | Type of Hammer |
|---|---|---|
| 0 | 0 | 1 |
| 1 | 62 | 1 |
| 1 | 119 | 1 |
| 1 | 135 | 1 |
| 1 | 143 | 1 |
| 1 | 153 | 1 |
| 1 | 162 | 1 |
| 1 | 171 | 1 |
| 1 | 178 | 1 |
| 1 | 185 | 1 |
| 1 | 191 | 1 |
| 1 | 197 | 1 |
| 1 | 203 | 1 |



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# RL-DCP-1

| Penetr./ | Penetr./ | Hammer | DCP | CBR | CBR | Depth | Depth | Bearing Capacity | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Blow Set | Blow | Blow | Index | % | % | in. | mm | psf | psi | kpa |
| mm | mm | Factor | | | | | | | | |
| [3] | [4] | [5] | [6] | | | [8] | [9] | [10] | [11] | |
| ----- | ----- | ----- | ----- | --- | --- | 0.0 | 0 | | | |
| 62 | 62 | 1 | 62 | 2.9 | 3 | 0.0 | 0 | 1100 | 7.64 | 52.8 |
| 62 | 62 | 1 | 62 | 2.9 | 3 | 2.4 | 62 | 1100 | 7.64 | 52.8 |
| 57 | 57 | 1 | 57 | 3.2 | 3 | 2.4 | 62 | 1171 | 8.13 | 56.2 |
| 57 | 57 | 1 | 57 | 3.2 | 3 | 4.7 | 119 | 1171 | 8.13 | 56.2 |
| 16 | 16 | 1 | 16 | 13.1 | 13 | 4.7 | 119 | 3013 | 20.92 | 144.6 |
| 16 | 16 | 1 | 16 | 13.1 | 13 | 5.3 | 135 | 3013 | 20.92 | 144.6 |
| 8 | 8 | 1 | 8 | 28.4 | 28 | 5.3 | 135 | 5045 | 35.03 | 242.2 |
| 8 | 8 | 1 | 8 | 28.4 | 28 | 5.6 | 143 | 5045 | 35.03 | 242.2 |
| 10 | 10 | 1 | 10 | 22.2 | 22 | 5.6 | 143 | 4274 | 29.68 | 205.1 |
| 10 | 10 | 1 | 10 | 22.2 | 22 | 6.0 | 153 | 4274 | 29.68 | 205.1 |
| 9 | 9 | 1 | 9 | 24.9 | 25 | 6.0 | 153 | 4622 | 32.10 | 221.9 |
| 9 | 9 | 1 | 9 | 24.9 | 25 | 6.4 | 162 | 4622 | 32.10 | 221.9 |
| 9 | 9 | 1 | 9 | 24.9 | 25 | 6.4 | 162 | 4622 | 32.10 | 221.9 |
| 9 | 9 | 1 | 9 | 24.9 | 25 | 6.7 | 171 | 4622 | 32.10 | 221.9 |
| 7 | 7 | 1 | 7 | 33.0 | 33 | 6.7 | 171 | 5572 | 38.69 | 267.4 |
| 7 | 7 | 1 | 7 | 33.0 | 33 | 7.0 | 178 | 5572 | 38.69 | 267.4 |
| 7 | 7 | 1 | 7 | 33.0 | 33 | 7.0 | 178 | 5572 | 38.69 | 267.4 |
| 7 | 7 | 1 | 7 | 33.0 | 33 | 7.3 | 185 | 5572 | 38.69 | 267.4 |
| 6 | 6 | 1 | 6 | 39.3 | 39 | 7.3 | 185 | 6249 | 43.39 | 299.9 |
| 6 | 6 | 1 | 6 | 39.3 | 39 | 7.5 | 191 | 6249 | 43.39 | 299.9 |
| 6 | 6 | 1 | 6 | 39.3 | 39 | 7.5 | 191 | 6249 | 43.39 | 299.9 |
| 6 | 6 | 1 | 6 | 39.3 | 39 | 7.8 | 197 | 6249 | 43.39 | 299.9 |
| 6 | 6 | 1 | 6 | 39.3 | 39 | 7.8 | 197 | 6249 | 43.39 | 299.9 |
| 6 | 6 | 1 | 6 | 39.3 | 39 | 8.0 | 203 | 6249 | 43.39 | 299.9 |

# DCP TEST DATA

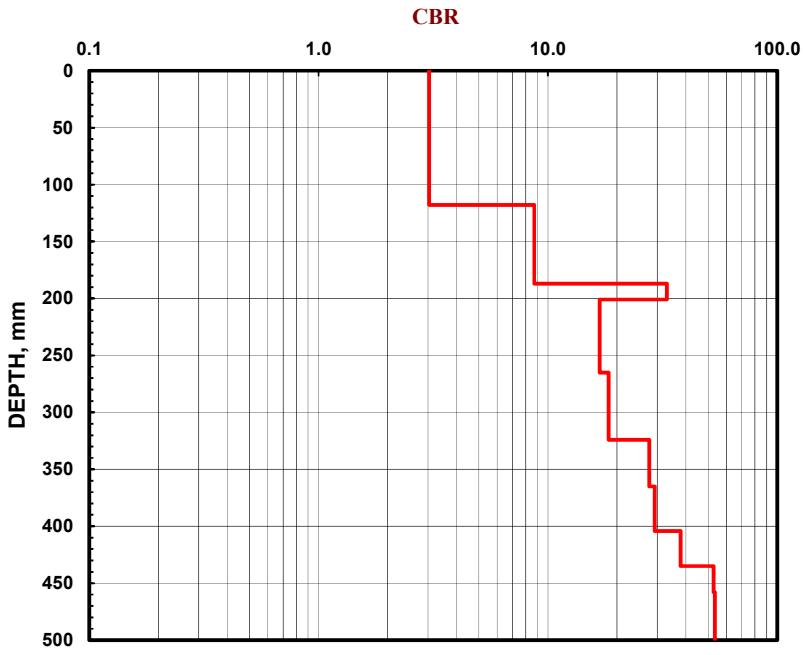
**Project:** *Dominica Geothermal Project* **Date:** 10-Oct-18

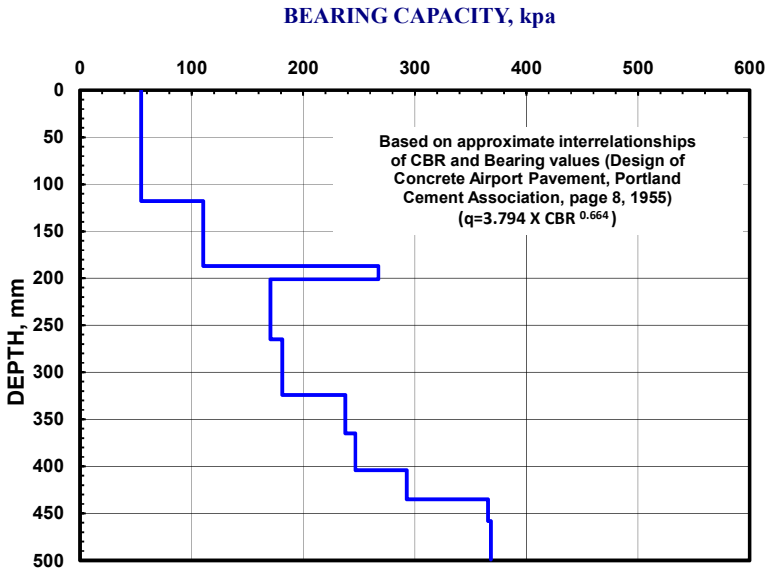
**Location:** RL-DCP-02 **Coordinates** E 679397, N 1694863

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

| No. of Blows | Accumulative Penetration (mm) | Type of Hammer |
|---|---|---|
| 0 | 0 | 1 |
| 2 | 118 | 1 |
| 3 | 187 | 1 |
| 2 | 201 | 1 |
| 5 | 265 | 1 |
| 5 | 324 | 1 |
| 5 | 365 | 1 |
| 5 | 404 | 1 |
| 5 | 435 | 1 |
| 5 | 458 | 1 |
| 9 | 499 | 1 |



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# RL-DCP-2

| Penetr./ Blow Set | Penetr./ Blow | Hammer Blow | DCP Index | CBR % | CBR % | Depth in. | Depth mm | Bearing Capacity psf | Bearing Capacity psi | Bearing Capacity kpa |
|---|---|---|---|---|---|---|---|---|---|---|
| mm | mm | Factor | | | | | | | | |
| [3] | [4] | [5] | [6] | | | [8] | [9] | [10] | [11] | |
| ----- | ----- | ----- | ----- | --- | --- | 0.0 | 0 | | | |
| 118 | 59 | 1 | 59 | 3.0 | 3 | 0.0 | 0 | 1142 | 7.93 | 54.8 |
| 118 | 59 | 1 | 59 | 3.0 | 3 | 4.6 | 118 | 1142 | 7.93 | 54.8 |
| 69 | 23 | 1 | 23 | 8.7 | 9 | 4.6 | 118 | 2300 | 15.97 | 110.4 |
| 69 | 23 | 1 | 23 | 8.7 | 9 | 7.4 | 187 | 2300 | 15.97 | 110.4 |
| 14 | 7 | 1 | 7 | 33.0 | 33 | 7.4 | 187 | 5572 | 38.69 | 267.4 |
| 14 | 7 | 1 | 7 | 33.0 | 33 | 7.9 | 201 | 5572 | 38.69 | 267.4 |
| 64 | 13 | 1 | 13 | 16.8 | 17 | 7.9 | 201 | 3557 | 24.70 | 170.7 |
| 64 | 13 | 1 | 13 | 16.8 | 17 | 10.4 | 265 | 3557 | 24.70 | 170.7 |
| 59 | 12 | 1 | 12 | 18.4 | 18 | 10.4 | 265 | 3779 | 26.24 | 181.4 |
| 59 | 12 | 1 | 12 | 18.4 | 18 | 12.8 | 324 | 3779 | 26.24 | 181.4 |
| 41 | 8 | 1 | 8 | 27.7 | 28 | 12.8 | 324 | 4953 | 34.40 | 237.8 |
| 41 | 8 | 1 | 8 | 27.7 | 28 | 14.4 | 365 | 4953 | 34.40 | 237.8 |
| 39 | 8 | 1 | 8 | 29.3 | 29 | 14.4 | 365 | 5141 | 35.70 | 246.8 |
| 39 | 8 | 1 | 8 | 29.3 | 29 | 15.9 | 404 | 5141 | 35.70 | 246.8 |
| 31 | 6 | 1 | 6 | 37.8 | 38 | 15.9 | 404 | 6098 | 42.35 | 292.7 |
| 31 | 6 | 1 | 6 | 37.8 | 38 | 17.1 | 435 | 6098 | 42.35 | 292.7 |
| 23 | 5 | 1 | 5 | 52.9 | 53 | 17.1 | 435 | 7614 | 52.87 | 365.5 |
| 23 | 5 | 1 | 5 | 52.9 | 53 | 18.0 | 458 | 7614 | 52.87 | 365.5 |
| 41 | 5 | 1 | 5 | 53.4 | 53 | 18.0 | 458 | 7669 | 53.26 | 368.1 |
| 41 | 5 | 1 | 5 | 53.4 | 53 | 19.6 | 499 | 7669 | 53.26 | 368.1 |

# DCP TEST DATA

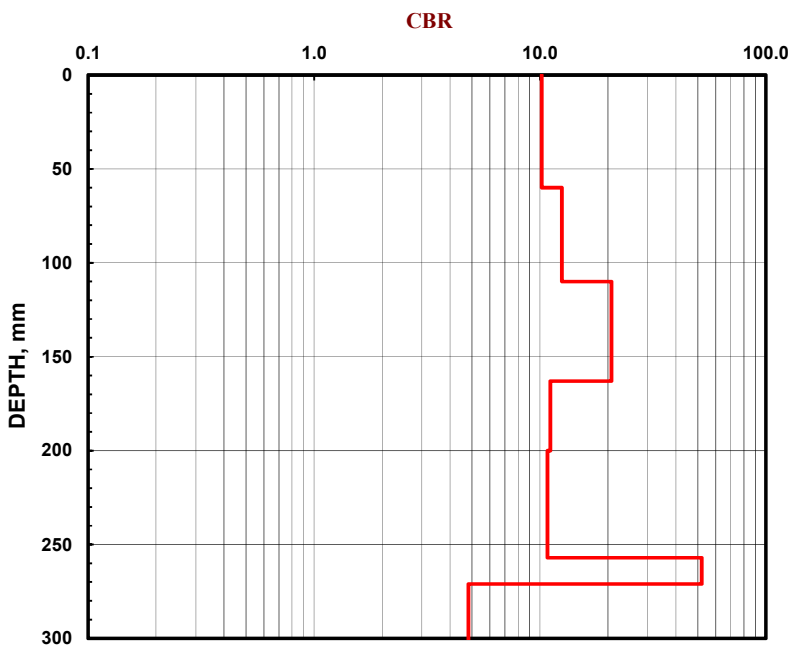
**Project:** *Dominica Geothermal Project* **Date:** 10-Oct-18

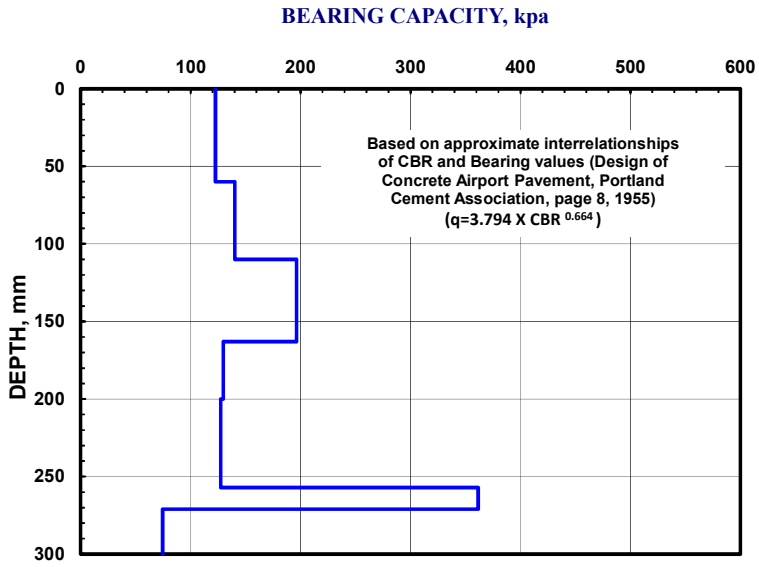
**Location:** RL-DCP-03 **Coordinates** E 679094, N 1694916

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

| No. of Blows | Accumulative Penetration (mm) | Type of Hammer |
|---|---|---|
| 0 | 0 | 1 |
| 3 | 60 | 1 |
| 3 | 110 | 1 |
| 5 | 163 | 1 |
| 2 | 200 | 1 |
| 2 | 238 | 1 |
| 1 | 257 | 1 |
| 3 | 271 | 1 |
| 1 | 310 | 1 |
| 5 | 310 | 1 |



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# RL-DCP-3

| Penetr./ | Penetr./ | Hammer | DCP | CBR | CBR | Depth | Depth | Bearing Capacity | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Blow Set | Blow | Blow | Index | % | % | in. | mm | psf | psi | kpa |
| mm | mm | Factor | | | | | | | | |
| [3] | [4] | [5] | [6] | | | [8] | [9] | [10] | [11] | |
| ----- | ----- | ----- | ----- | --- | --- | 0.0 | 0 | | | |
| 60 | 20 | 1 | 20 | 10.2 | 10 | 0.0 | 0 | 2552 | 17.72 | 122.5 |
| 60 | 20 | 1 | 20 | 10.2 | 10 | 2.4 | 60 | 2552 | 17.72 | 122.5 |
| 50 | 17 | 1 | 17 | 12.5 | 13 | 2.4 | 60 | 2923 | 20.30 | 140.3 |
| 50 | 17 | 1 | 17 | 12.5 | 13 | 4.3 | 110 | 2923 | 20.30 | 140.3 |
| 53 | 11 | 1 | 11 | 20.8 | 21 | 4.3 | 110 | 4092 | 28.42 | 196.4 |
| 53 | 11 | 1 | 11 | 20.8 | 21 | 6.4 | 163 | 4092 | 28.42 | 196.4 |
| 37 | 19 | 1 | 19 | 11.1 | 11 | 6.4 | 163 | 2705 | 18.78 | 129.8 |
| 37 | 19 | 1 | 19 | 11.1 | 11 | 7.9 | 200 | 2705 | 18.78 | 129.8 |
| 38 | 19 | 1 | 19 | 10.8 | 11 | 7.9 | 200 | 2651 | 18.41 | 127.3 |
| 38 | 19 | 1 | 19 | 10.8 | 11 | 9.4 | 238 | 2651 | 18.41 | 127.3 |
| 19 | 19 | 1 | 19 | 10.8 | 11 | 9.4 | 238 | 2651 | 18.41 | 127.3 |
| 19 | 19 | 1 | 19 | 10.8 | 11 | 10.1 | 257 | 2651 | 18.41 | 127.3 |
| 14 | 5 | 1 | 5 | 52.0 | 52 | 10.1 | 257 | 7533 | 52.31 | 361.6 |
| 14 | 5 | 1 | 5 | 52.0 | 52 | 10.7 | 271 | 7533 | 52.31 | 361.6 |
| 39 | 39 | 1 | 39 | 4.8 | 5 | 10.7 | 271 | 1553 | 10.79 | 74.6 |
| 39 | 39 | 1 | 39 | 4.8 | 5 | 12.2 | 310 | 1553 | 10.79 | 74.6 |
| 39 | 8 | 1 | 8 | 29.3 | 29 | 12.2 | 310 | 5141 | 35.70 | 246.8 |
| 39 | 8 | 1 | 8 | 29.3 | 29 | 12.2 | 310 | 5141 | 35.70 | 246.8 |

# DCP TEST DATA

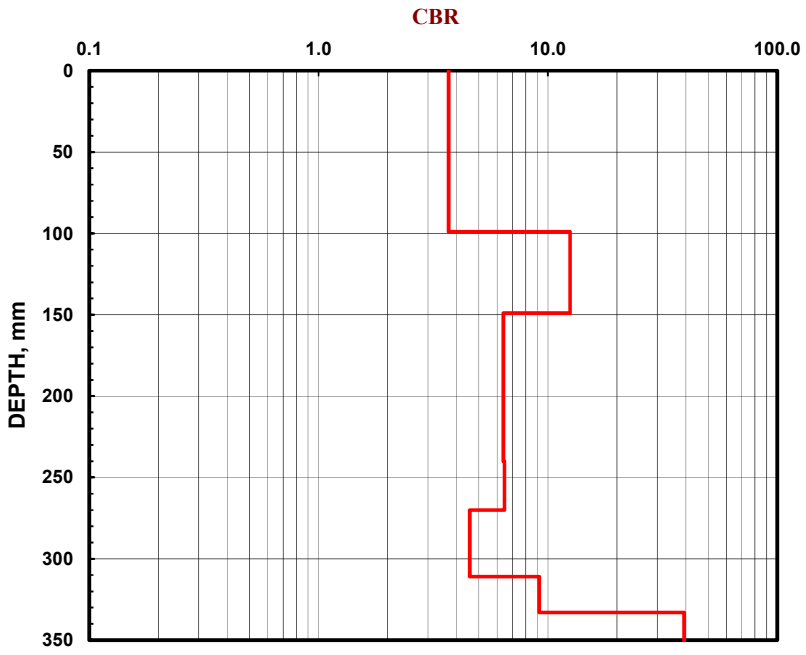
**Project:** *Dominica Geothermal Project* **Date:** 10-Oct-18

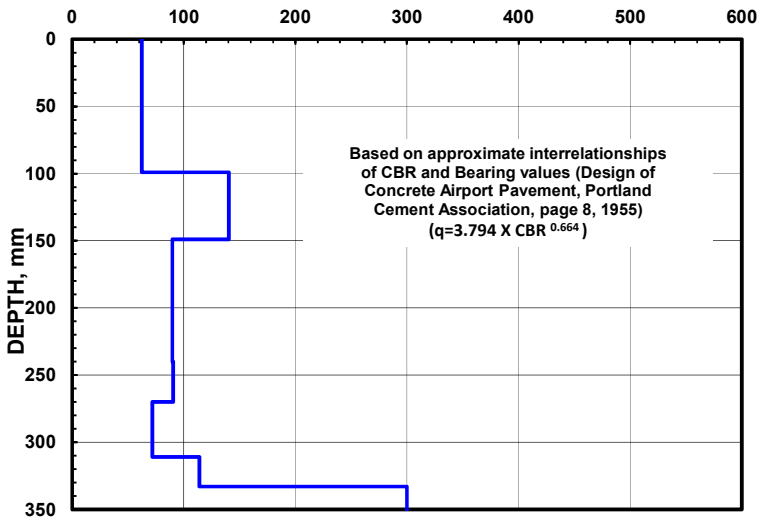
**Location:** RL-DCP-04 **Coordinates** E 678915, N 1694915

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

| No. of Blows | Accumulative Penetration (mm) | Type of Hammer |
|---|---|---|
| 0 | 0 | 1 |
| 2 | 99 | 1 |
| 3 | 149 | 1 |
| 3 | 240 | 1 |
| 1 | 270 | 1 |
| 1 | 311 | 1 |
| 1 | 333 | 1 |
| 3 | 351 | 1 |



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# RL-DCP-4

| Penetr./ Blow Set | Penetr./ Blow | Hammer Blow | DCP Index | CBR % | CBR % | Depth in. | Depth mm | Bearing Capacity psf | psi | kpa |
|---|---|---|---|---|---|---|---|---|---|---|
| mm | mm | Factor | | | | | | | | |
| [3] | [4] | [5] | [6] | | | [8] | [9] | [10] | [11] | |
| ----- | ----- | ----- | ----- | --- | --- | 0.0 | 0 | | | |
| 99 | 50 | 1 | 50 | 3.7 | 4 | 0.0 | 0 | 1301 | 9.03 | 62.4 |
| 99 | 50 | 1 | 50 | 3.7 | 4 | 3.9 | 99 | 1301 | 9.03 | 62.4 |
| 50 | 17 | 1 | 17 | 12.5 | 13 | 3.9 | 99 | 2923 | 20.30 | 140.3 |
| 50 | 17 | 1 | 17 | 12.5 | 13 | 5.9 | 149 | 2923 | 20.30 | 140.3 |
| 91 | 30 | 1 | 30 | 6.4 | 6 | 5.9 | 149 | 1872 | 13.00 | 89.9 |
| 91 | 30 | 1 | 30 | 6.4 | 6 | 9.4 | 240 | 1872 | 13.00 | 89.9 |
| 30 | 30 | 1 | 30 | 6.5 | 6 | 9.4 | 240 | 1888 | 13.11 | 90.6 |
| 30 | 30 | 1 | 30 | 6.5 | 6 | 10.6 | 270 | 1888 | 13.11 | 90.6 |
| 41 | 41 | 1 | 41 | 4.6 | 5 | 10.6 | 270 | 1497 | 10.39 | 71.8 |
| 41 | 41 | 1 | 41 | 4.6 | 5 | 12.2 | 311 | 1497 | 10.39 | 71.8 |
| 22 | 22 | 1 | 22 | 9.2 | 9 | 12.2 | 311 | 2378 | 16.51 | 114.1 |
| 22 | 22 | 1 | 22 | 9.2 | 9 | 13.1 | 333 | 2378 | 16.51 | 114.1 |
| 18 | 6 | 1 | 6 | 39.3 | 39 | 13.1 | 333 | 6249 | 43.39 | 299.9 |
| 18 | 6 | 1 | 6 | 39.3 | 39 | 13.8 | 351 | 6249 | 43.39 | 299.9 |

# DCP TEST DATA

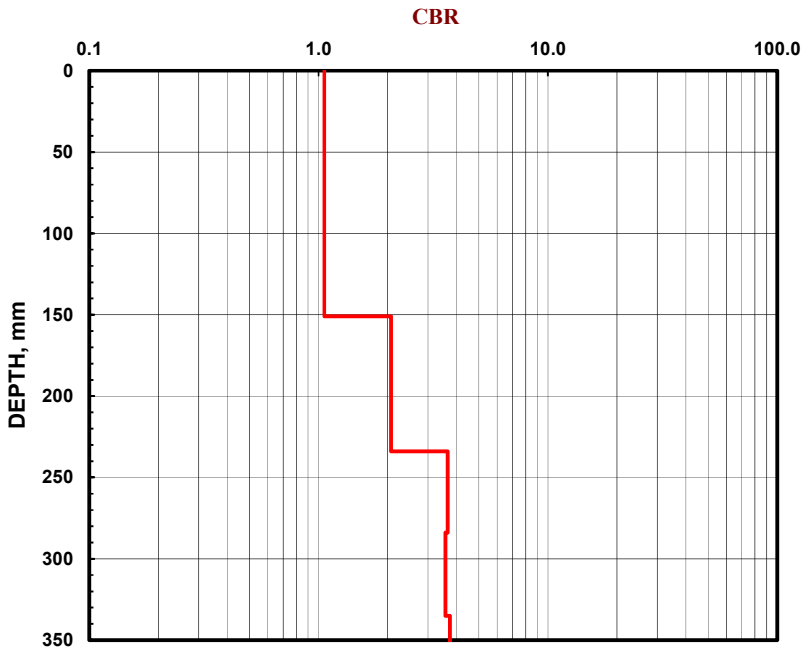
**Project:** *Dominica Geothermal Project* **Date:** 10-Oct-18

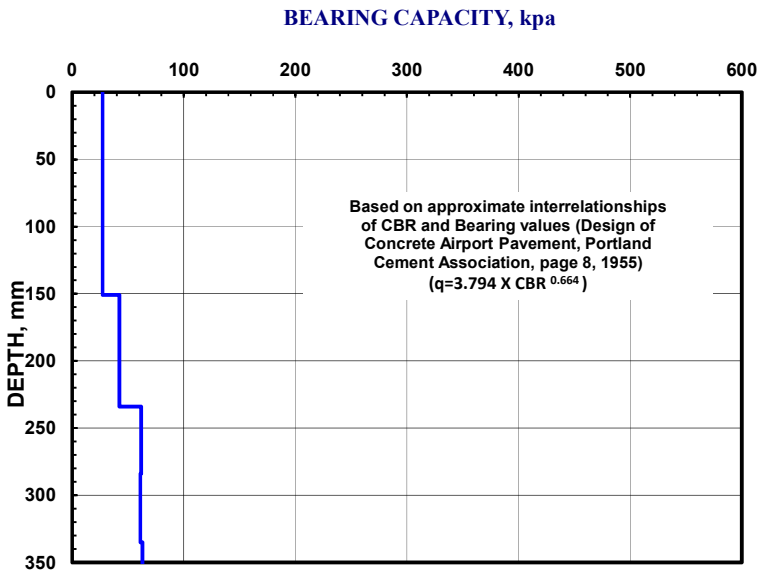
**Location:** RL-DCP-05 **Coordinates** E 678861, N 1694876

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

| No. of Blows | Accumulative Penetration (mm) | Type of Hammer |
|---|---|---|
| 0 | 0 | 1 |
| 1 | 151 | 1 |
| 1 | 234 | 1 |
| 1 | 284 | 1 |
| 1 | 335 | 1 |
| 1 | 384 | 1 |
| 1 | 429 | 1 |
| 1 | 451 | 1 |



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# RL-DCP-5

| Penetr./ | Penetr./ | Hammer | DCP | CBR | CBR | Depth | Depth | Bearing Capacity | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Blow Set | Blow | Blow | Index | % | % | in. | mm | psf | psi | kpa |
| mm | mm | Factor | | | | | | | | |
| [3] | [4] | [5] | [6] | | | [8] | [9] | [10] | [11] | |
| ----- | ----- | ----- | ----- | --- | --- | 0.0 | 0 | | | |
| 151 | 151 | 1 | 151 | 1.1 | 1 | 0.0 | 0 | 568 | 3.94 | 27.2 |
| 151 | 151 | 1 | 151 | 1.1 | 1 | 5.9 | 151 | 568 | 3.94 | 27.2 |
| 83 | 83 | 1 | 83 | 2.1 | 2 | 5.9 | 151 | 886 | 6.15 | 42.5 |
| 83 | 83 | 1 | 83 | 2.1 | 2 | 9.2 | 234 | 886 | 6.15 | 42.5 |
| 50 | 50 | 1 | 50 | 3.7 | 4 | 9.2 | 234 | 1291 | 8.97 | 62.0 |
| 50 | 50 | 1 | 50 | 3.7 | 4 | 11.2 | 284 | 1291 | 8.97 | 62.0 |
| 51 | 51 | 1 | 51 | 3.6 | 4 | 11.2 | 284 | 1272 | 8.84 | 61.1 |
| 51 | 51 | 1 | 51 | 3.6 | 4 | 13.2 | 335 | 1272 | 8.84 | 61.1 |
| 49 | 49 | 1 | 49 | 3.7 | 4 | 13.2 | 335 | 1311 | 9.10 | 62.9 |
| 49 | 49 | 1 | 49 | 3.7 | 4 | 15.1 | 384 | 1311 | 9.10 | 62.9 |
| 45 | 45 | 1 | 45 | 4.1 | 4 | 15.1 | 384 | 1396 | 9.70 | 67.0 |
| 45 | 45 | 1 | 45 | 4.1 | 4 | 16.9 | 429 | 1396 | 9.70 | 67.0 |
| 22 | 22 | 1 | 22 | 9.2 | 9 | 16.9 | 429 | 2378 | 16.51 | 114.1 |
| 22 | 22 | 1 | 22 | 9.2 | 9 | 17.8 | 451 | 2378 | 16.51 | 114.1 |

# DCP TEST DATA

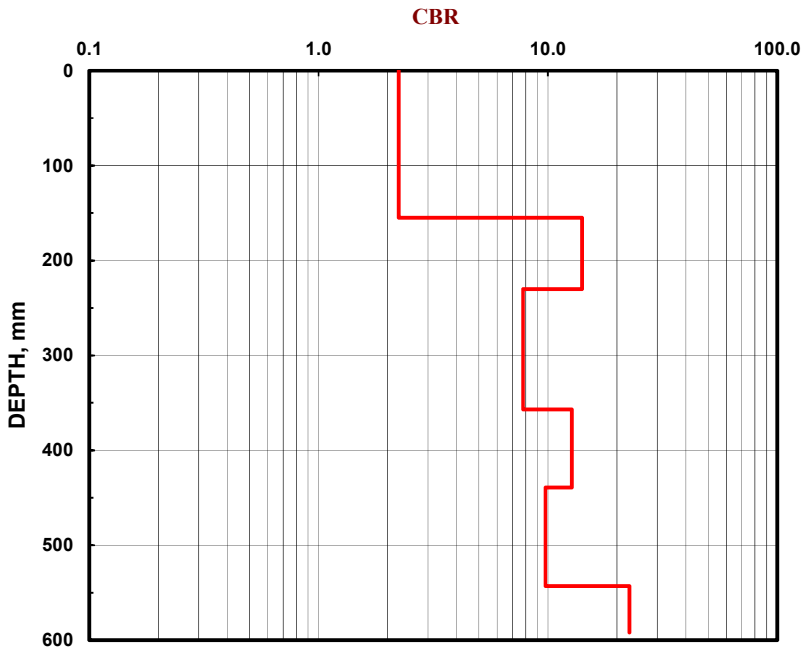
**Project:** *Dominica Geothermal Project* **Date:** 10-Oct-18

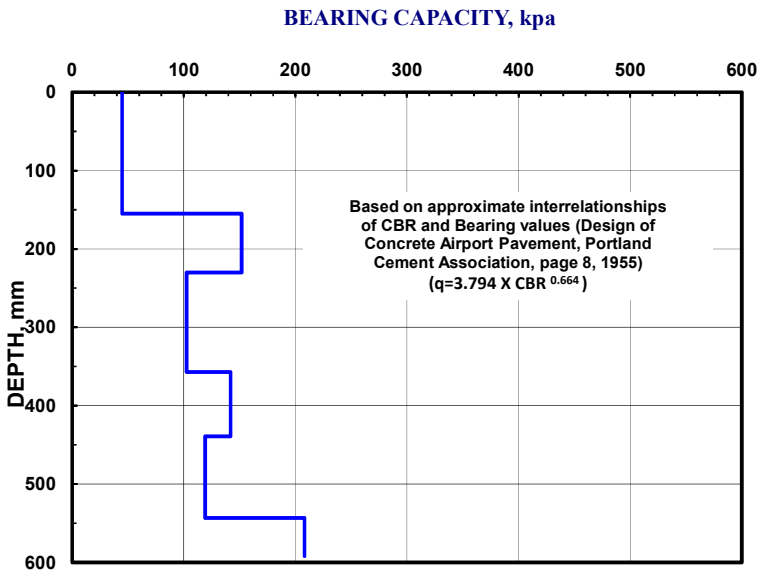
**Location:** RL-DCP-06 **Coordinates** E 678673, N 1694891

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

| No. of Blows | Accumulative Penetration (mm) | Type of Hammer |
|---|---|---|
| 0 | 0 | 1 |
| 2 | 155 | 1 |
| 5 | 230 | 1 |
| 5 | 357 | 1 |
| 5 | 439 | 1 |
| 5 | 543 | 1 |
| 5 | 592 | 1 |



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# RL-DCP-6

| Penetr./ Blow Set | Penetr./ Blow | Hammer Blow | DCP Index | CBR % | CBR % | Depth in. | Depth mm | Bearing Capacity psf | Bearing Capacity psi | Bearing Capacity kpa |
|---|---|---|---|---|---|---|---|---|---|---|
| mm | mm | Factor | | | | | | | | |
| [3] | [4] | [5] | [6] | | | [8] | [9] | [10] | [11] | |
| ----- | ----- | ----- | ----- | --- | --- | 0.0 | 0 | | | |
| 155 | 78 | 1 | 78 | 2.2 | 2 | 0.0 | 0 | 932 | 6.47 | 44.7 |
| 155 | 78 | 1 | 78 | 2.2 | 2 | 6.1 | 155 | 932 | 6.47 | 44.7 |
| 75 | 15 | 1 | 15 | 14.1 | 14 | 6.1 | 155 | 3161 | 21.95 | 151.7 |
| 75 | 15 | 1 | 15 | 14.1 | 14 | 9.1 | 230 | 3161 | 21.95 | 151.7 |
| 127 | 25 | 1 | 25 | 7.8 | 8 | 9.1 | 230 | 2137 | 14.84 | 102.6 |
| 127 | 25 | 1 | 25 | 7.8 | 8 | 14.1 | 357 | 2137 | 14.84 | 102.6 |
| 82 | 16 | 1 | 16 | 12.7 | 13 | 14.1 | 357 | 2958 | 20.54 | 142.0 |
| 82 | 16 | 1 | 16 | 12.7 | 13 | 17.3 | 439 | 2958 | 20.54 | 142.0 |
| 104 | 21 | 1 | 21 | 9.8 | 10 | 17.3 | 439 | 2479 | 17.21 | 119.0 |
| 104 | 21 | 1 | 21 | 9.8 | 10 | 21.4 | 543 | 2479 | 17.21 | 119.0 |
| 49 | 10 | 1 | 10 | 22.7 | 23 | 21.4 | 543 | 4338 | 30.13 | 208.2 |
| 49 | 10 | 1 | 10 | 22.7 | 23 | 23.3 | 592 | 4338 | 30.13 | 208.2 |

# DCP TEST DATA

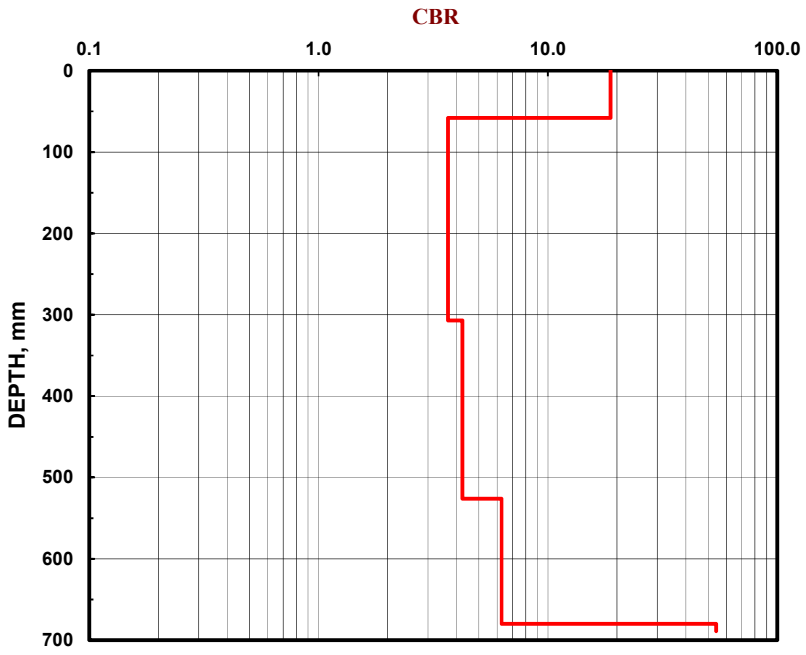
**Project:** *Dominica Geothermal Project* **Date:** 10-Oct-18

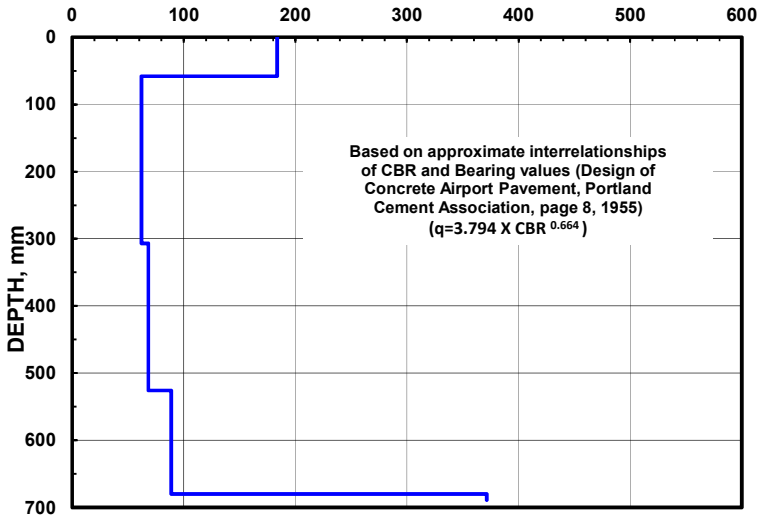
**Location:** RL-DCP-07 **Coordinates** E 678653, N 1694908

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

| No. of Blows | Accumulative Penetration (mm) | Type of Hammer |
|---|---|---|
| 0 | 0 | 1 |
| 5 | 58 | 1 |
| 5 | 307 | 1 |
| 5 | 526 | 1 |
| 5 | 680 | 1 |
| 2 | 689 | 1 |



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# RL-DCP-7

| Penetr./ Blow Set | Penetr./ Blow | Hammer Blow | DCP Index | CBR % | CBR % | Depth in. | Depth mm | Bearing Capacity psf | Bearing Capacity psi | Bearing Capacity kpa |
|---|---|---|---|---|---|---|---|---|---|---|
| mm | mm | Factor | | | | | | | | |
| [3] | [4] | [5] | [6] | | | [8] | [9] | [10] | [11] | |
| ----- | ----- | ----- | ----- | --- | --- | 0.0 | 0 | | | |
| 58 | 12 | 1 | 12 | 18.8 | 19 | 0.0 | 0 | 3827 | 26.58 | 183.7 |
| 58 | 12 | 1 | 12 | 18.8 | 19 | 2.3 | 58 | 3827 | 26.58 | 183.7 |
| 249 | 50 | 1 | 50 | 3.7 | 4 | 2.3 | 58 | 1295 | 8.99 | 62.2 |
| 249 | 50 | 1 | 50 | 3.7 | 4 | 12.1 | 307 | 1295 | 8.99 | 62.2 |
| 219 | 44 | 1 | 44 | 4.2 | 4 | 12.1 | 307 | 1425 | 9.89 | 68.4 |
| 219 | 44 | 1 | 44 | 4.2 | 4 | 20.7 | 526 | 1425 | 9.89 | 68.4 |
| 154 | 31 | 1 | 31 | 6.3 | 6 | 20.7 | 526 | 1851 | 12.86 | 88.9 |
| 154 | 31 | 1 | 31 | 6.3 | 6 | 26.8 | 680 | 1851 | 12.86 | 88.9 |
| 9 | 5 | 1 | 5 | 54.2 | 54 | 26.8 | 680 | 7739 | 53.74 | 371.5 |
| 9 | 5 | 1 | 5 | 54.2 | 54 | 27.1 | 689 | 7739 | 53.74 | 371.5 |

# DCP TEST DATA

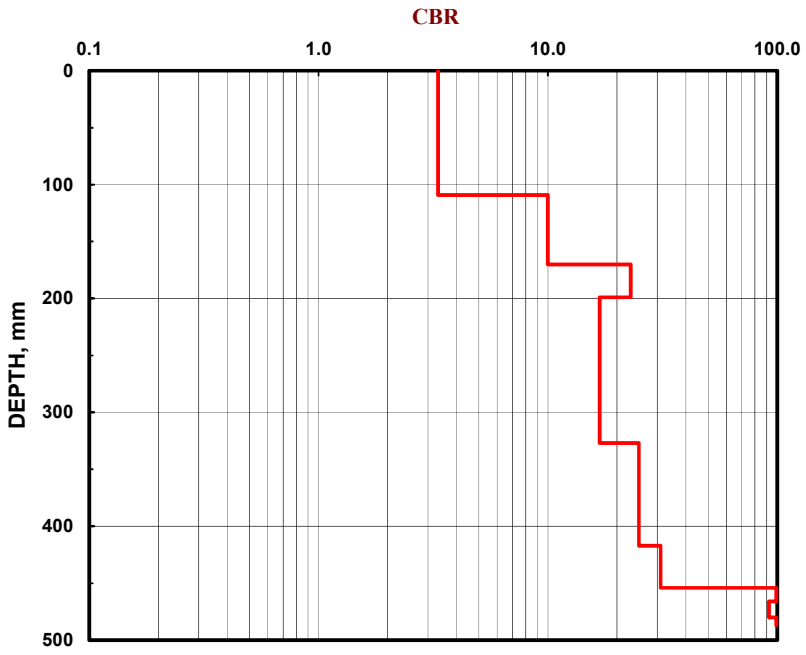
**Project:** *Dominica Geothermal Project* **Date:** 10-Oct-18

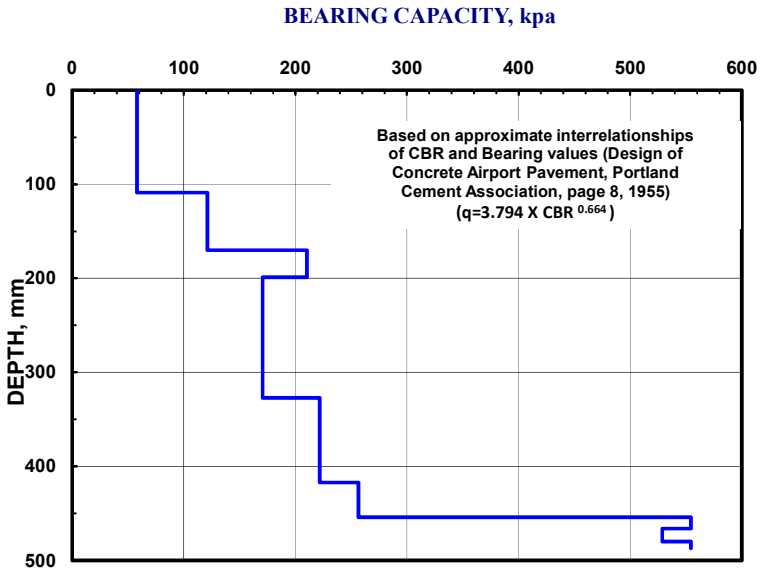
**Location:** RL-DCP-08 **Coordinates** E 678521 , N 1694955

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

| No. of Blows | Accumulative Penetration (mm) | Type of Hammer |
|---|---|---|
| 0 | 0 | 1 |
| 2 | 109 | 1 |
| 3 | 170 | 1 |
| 3 | 199 | 1 |
| 5 | 263 | 1 |
| 5 | 327 | 1 |
| 5 | 372 | 1 |
| 5 | 417 | 1 |
| 5 | 454 | 1 |
| 5 | 466 | 1 |
| 5 | 480 | 1 |
| 4 | 487 | 1 |



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# RL-DCP-8

| Penetr./ Blow Set | Penetr./ Blow | Hammer Blow | DCP Index | CBR % | CBR % | Depth in. | Depth mm | Bearing Capacity psf | psi | kpa |
|---|---|---|---|---|---|---|---|---|---|---|
| mm | mm | Factor | | | | | | | | |
| [3] | [4] | [5] | [6] | | | [8] | [9] | [10] | [11] | |
| ----- | ----- | ----- | ----- | --- | --- | 0.0 | 0 | | | |
| 109 | 55 | 1 | 55 | 3.3 | 3 | 0.0 | 0 | 1211 | 8.41 | 58.1 |
| 109 | 55 | 1 | 55 | 3.3 | 3 | 4.3 | 109 | 1211 | 8.41 | 58.1 |
| 61 | 20 | 1 | 20 | 10.0 | 10 | 4.3 | 109 | 2521 | 17.51 | 121.0 |
| 61 | 20 | 1 | 20 | 10.0 | 10 | 6.7 | 170 | 2521 | 17.51 | 121.0 |
| 29 | 10 | 1 | 10 | 23.0 | 23 | 6.7 | 170 | 4383 | 30.44 | 210.4 |
| 29 | 10 | 1 | 10 | 23.0 | 23 | 7.8 | 199 | 4383 | 30.44 | 210.4 |
| 64 | 13 | 1 | 13 | 16.8 | 17 | 7.8 | 199 | 3557 | 24.70 | 170.7 |
| 64 | 13 | 1 | 13 | 16.8 | 17 | 10.4 | 263 | 3557 | 24.70 | 170.7 |
| 64 | 13 | 1 | 13 | 16.8 | 17 | 10.4 | 263 | 3557 | 24.70 | 170.7 |
| 64 | 13 | 1 | 13 | 16.8 | 17 | 12.9 | 327 | 3557 | 24.70 | 170.7 |
| 45 | 9 | 1 | 9 | 24.9 | 25 | 12.9 | 327 | 4622 | 32.10 | 221.9 |
| 45 | 9 | 1 | 9 | 24.9 | 25 | 14.6 | 372 | 4622 | 32.10 | 221.9 |
| 45 | 9 | 1 | 9 | 24.9 | 25 | 14.6 | 372 | 4622 | 32.10 | 221.9 |
| 45 | 9 | 1 | 9 | 24.9 | 25 | 16.4 | 417 | 4622 | 32.10 | 221.9 |
| 37 | 7 | 1 | 7 | 31.0 | 31 | 16.4 | 417 | 5346 | 37.13 | 256.6 |
| 37 | 7 | 1 | 7 | 31.0 | 31 | 17.9 | 454 | 5346 | 37.13 | 256.6 |
| 12 | 2 | 1 | 2 | 109.5 | 99 | 17.9 | 454 | 11549 | 80.20 | 554.4 |
| 12 | 2 | 1 | 2 | 109.5 | 99 | 18.3 | 466 | 11549 | 80.20 | 554.4 |
| 14 | 3 | 1 | 3 | 92.2 | 92 | 18.3 | 466 | 11014 | 76.48 | 528.7 |
| 14 | 3 | 1 | 3 | 92.2 | 92 | 18.9 | 480 | 11014 | 76.48 | 528.7 |
| 7 | 2 | 1 | 2 | 156.0 | 99 | 18.9 | 480 | 11549 | 80.20 | 554.4 |
| 7 | 2 | 1 | 2 | 156.0 | 99 | 19.2 | 487 | 11549 | 80.20 | 554.4 |

# DCP TEST DATA

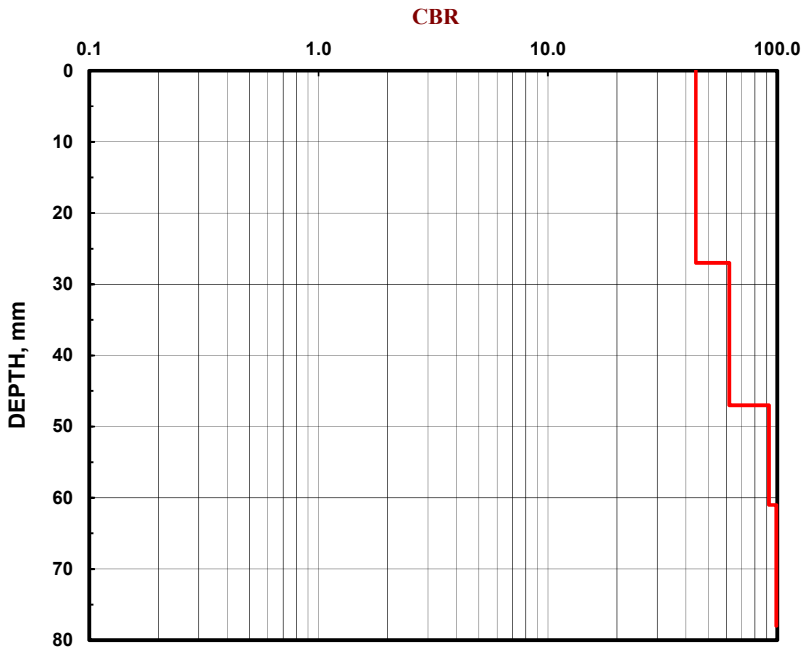
**Project:** *Dominica Geothermal Project* **Date:** 10-Oct-18

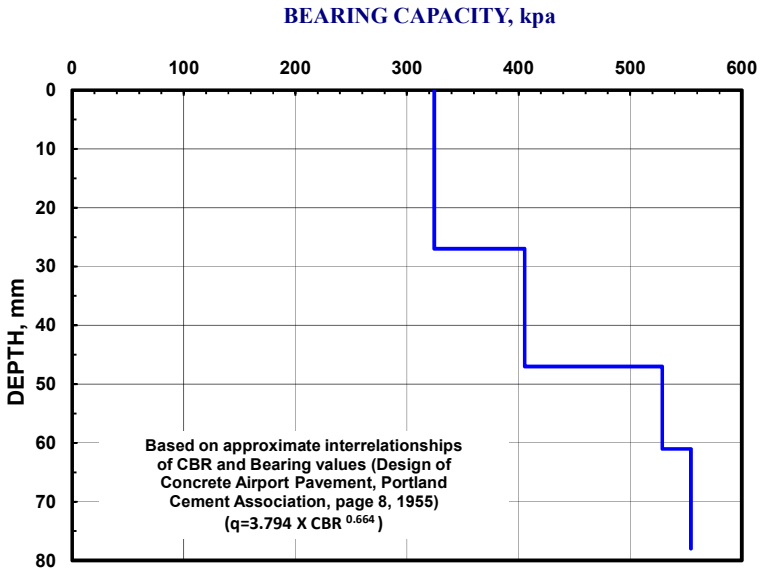
**Location:** RL-DCP-09 **Coordinates** E 677832, N 1694501

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

| No. of Blows | Accumulative Penetration (mm) | Type of Hammer |
|---|---|---|
| 0 | 0 | 1 |
| 5 | 27 | 1 |
| 5 | 47 | 1 |
| 5 | 61 | 1 |
| 5 | 71 | 1 |
| 5 | 77 | 1 |
| 5 | 78 | 1 |



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# RL-DCP-9

| Penetr./ | Penetr./ | Hammer | DCP | CBR | CBR | Depth | Depth | Bearing Capacity | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Blow Set | Blow | Blow | Index | % | % | in. | mm | psf | psi | kpa |
| mm | mm | Factor | | | | | | | | |
| [3] | [4] | [5] | [6] | | | [8] | [9] | [10] | [11] | |
| ----- | ----- | ----- | ----- | --- | --- | 0.0 | 0 | | | |
| 27 | 5 | 1 | 5 | 44.2 | 44 | 0.0 | 0 | 6758 | 46.93 | 324.4 |
| 27 | 5 | 1 | 5 | 44.2 | 44 | 1.1 | 27 | 6758 | 46.93 | 324.4 |
| 20 | 4 | 1 | 4 | 61.8 | 62 | 1.1 | 27 | 8448 | 58.66 | 405.5 |
| 20 | 4 | 1 | 4 | 61.8 | 62 | 1.9 | 47 | 8448 | 58.66 | 405.5 |
| 14 | 3 | 1 | 3 | 92.2 | 92 | 1.9 | 47 | 11014 | 76.48 | 528.7 |
| 14 | 3 | 1 | 3 | 92.2 | 92 | 2.4 | 61 | 11014 | 76.48 | 528.7 |
| 10 | 2 | 1 | 2 | 134.3 | 99 | 2.4 | 61 | 11549 | 80.20 | 554.4 |
| 10 | 2 | 1 | 2 | 134.3 | 99 | 2.8 | 71 | 11549 | 80.20 | 554.4 |
| 6 | 1 | 1 | 1 | 238.1 | 99 | 2.8 | 71 | 11549 | 80.20 | 554.4 |
| 6 | 1 | 1 | 1 | 238.1 | 99 | 3.0 | 77 | 11549 | 80.20 | 554.4 |
| 1 | 0 | 1 | 0 | 1771.0 | 99 | 3.0 | 77 | 11549 | 80.20 | 554.4 |
| 1 | 0 | 1 | 0 | 1771.0 | 99 | 3.1 | 78 | 11549 | 80.20 | 554.4 |

# DCP TEST DATA

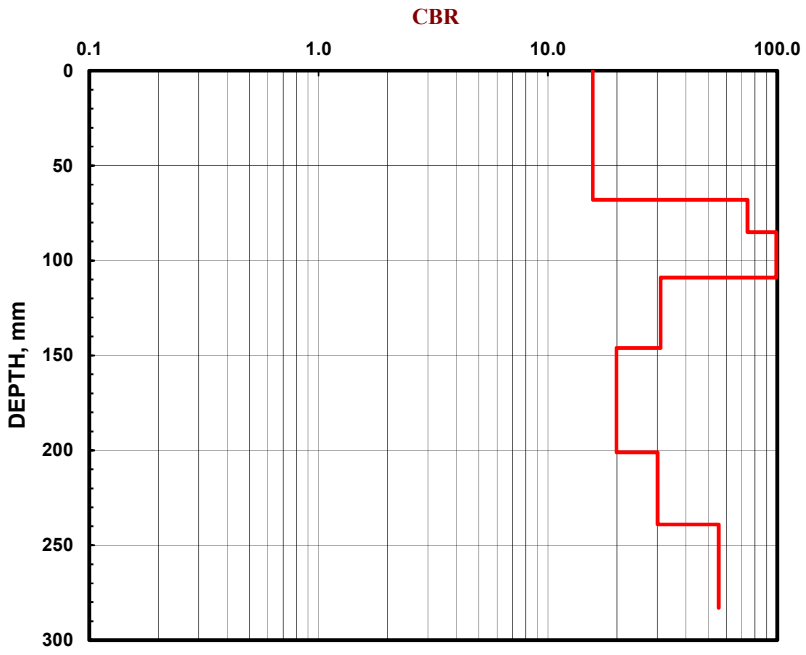
**Project:** *Dominica Geothermal Project* **Date:** 10-Oct-18

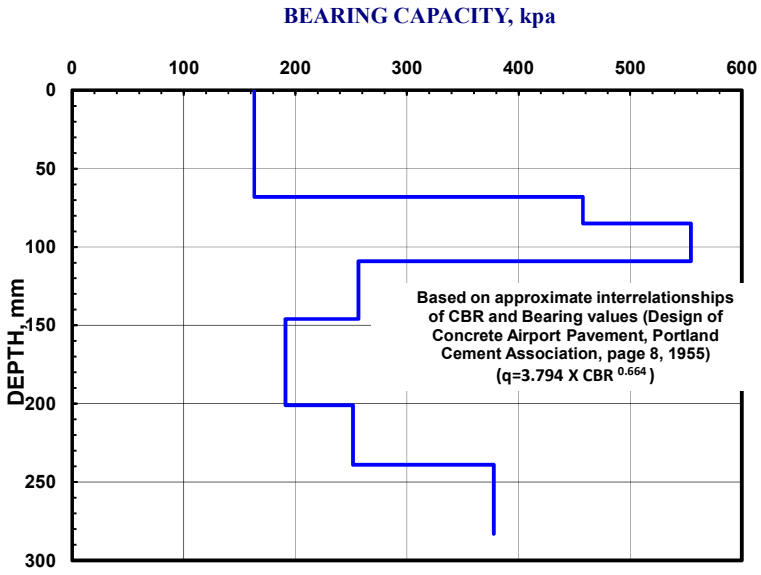
**Location:** RL-DCP-10 **Coordinates** E 677657, N 1694370

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

| No. of Blows | Accumulative Penetration (mm) | Type of Hammer |
|---|---|---|
| 0 | 0 | 1 |
| 5 | 68 | 1 |
| 5 | 85 | 1 |
| 5 | 97 | 1 |
| 5 | 109 | 1 |
| 5 | 146 | 1 |
| 5 | 201 | 1 |
| 5 | 239 | 1 |
| 5 | 261 | 1 |
| 5 | 283 | 1 |



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# RL-DCP-10

| Penetr./ | Penetr./ | Hammer | DCP | CBR | CBR | Depth | Depth | Bearing Capacity | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Blow Set | Blow | Blow | Index | % | % | in. | mm | psf | psi | kpa |
| mm | mm | Factor | | | | | | | | |
| [3] | [4] | [5] | [6] | | | [8] | [9] | [10] | [11] | |
| ----- | ----- | ----- | ----- | --- | --- | 0.0 | 0 | | | |
| 68 | 14 | 1 | 14 | 15.7 | 16 | 0.0 | 0 | 3400 | 23.61 | 163.2 |
| 68 | 14 | 1 | 14 | 15.7 | 16 | 2.7 | 68 | 3400 | 23.61 | 163.2 |
| 17 | 3 | 1 | 3 | 74.2 | 74 | 2.7 | 68 | 9533 | 66.20 | 457.6 |
| 17 | 3 | 1 | 3 | 74.2 | 74 | 3.3 | 85 | 9533 | 66.20 | 457.6 |
| 12 | 2 | 1 | 2 | 109.5 | 99 | 3.3 | 85 | 11549 | 80.20 | 554.4 |
| 12 | 2 | 1 | 2 | 109.5 | 99 | 3.8 | 97 | 11549 | 80.20 | 554.4 |
| 12 | 2 | 1 | 2 | 109.5 | 99 | 3.8 | 97 | 11549 | 80.20 | 554.4 |
| 12 | 2 | 1 | 2 | 109.5 | 99 | 4.3 | 109 | 11549 | 80.20 | 554.4 |
| 37 | 7 | 1 | 7 | 31.0 | 31 | 4.3 | 109 | 5346 | 37.13 | 256.6 |
| 37 | 7 | 1 | 7 | 31.0 | 31 | 5.7 | 146 | 5346 | 37.13 | 256.6 |
| 55 | 11 | 1 | 11 | 19.9 | 20 | 5.7 | 146 | 3981 | 27.65 | 191.1 |
| 55 | 11 | 1 | 11 | 19.9 | 20 | 7.9 | 201 | 3981 | 27.65 | 191.1 |
| 38 | 8 | 1 | 8 | 30.1 | 30 | 7.9 | 201 | 5241 | 36.40 | 251.6 |
| 38 | 8 | 1 | 8 | 30.1 | 30 | 9.4 | 239 | 5241 | 36.40 | 251.6 |
| 22 | 4 | 1 | 4 | 55.6 | 56 | 9.4 | 239 | 7870 | 54.65 | 377.7 |
| 22 | 4 | 1 | 4 | 55.6 | 56 | 10.3 | 261 | 7870 | 54.65 | 377.7 |
| 22 | 4 | 1 | 4 | 55.6 | 56 | 10.3 | 261 | 7870 | 54.65 | 377.7 |
| 22 | 4 | 1 | 4 | 55.6 | 56 | 11.1 | 283 | 7870 | 54.65 | 377.7 |

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# Appendix C:

## Downhole Seismic Test Results

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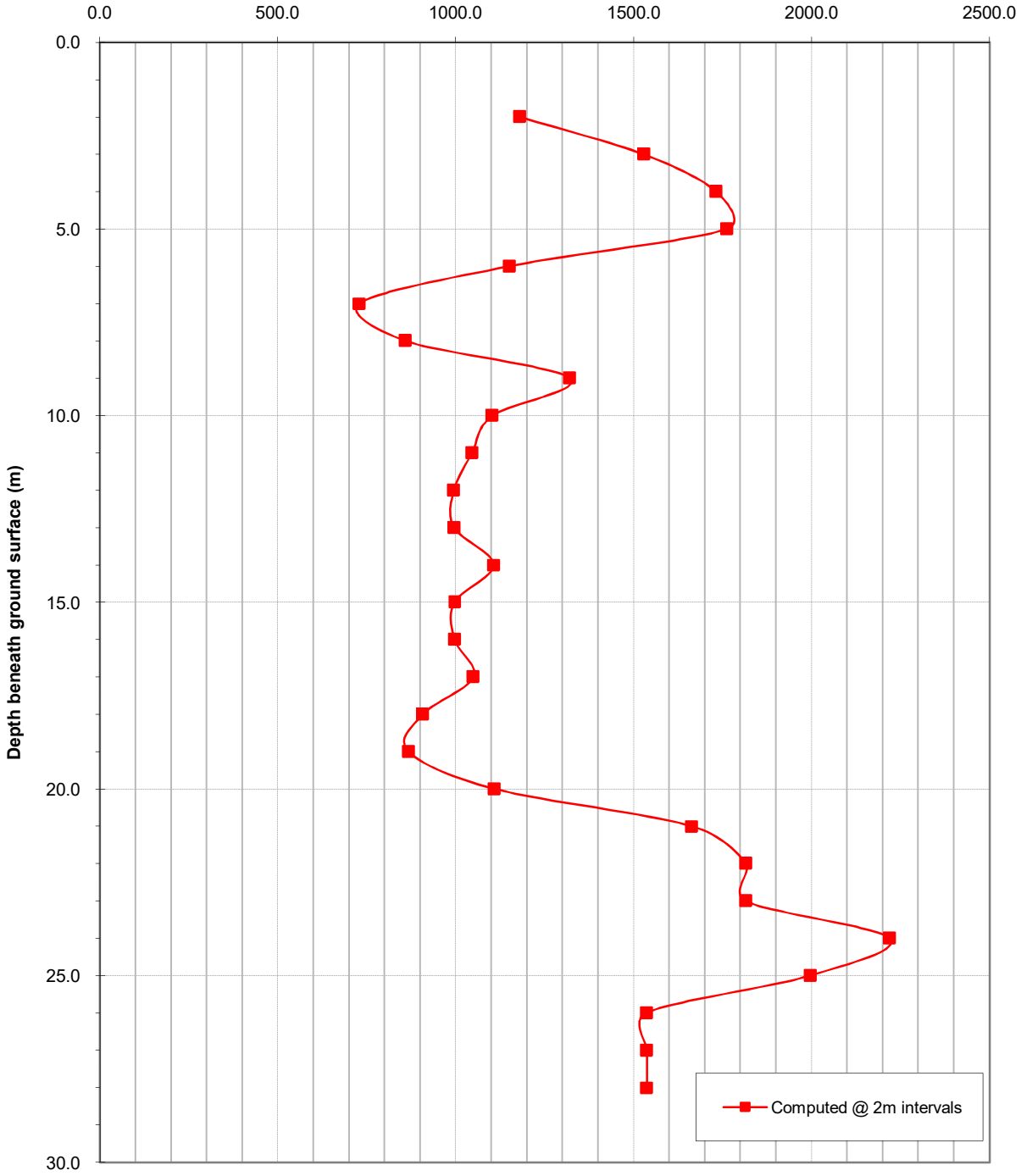
# Downhole Seismic Test - PP-BH02 - Power Plant Site, Dominica Geothermal Project

**Pseudo Interval Compressional Wave Velocity, Vp (m/s)**



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# Downhole Seismic Test - PP-BH02 - Power Plant Site, Dominica Geothermal Project

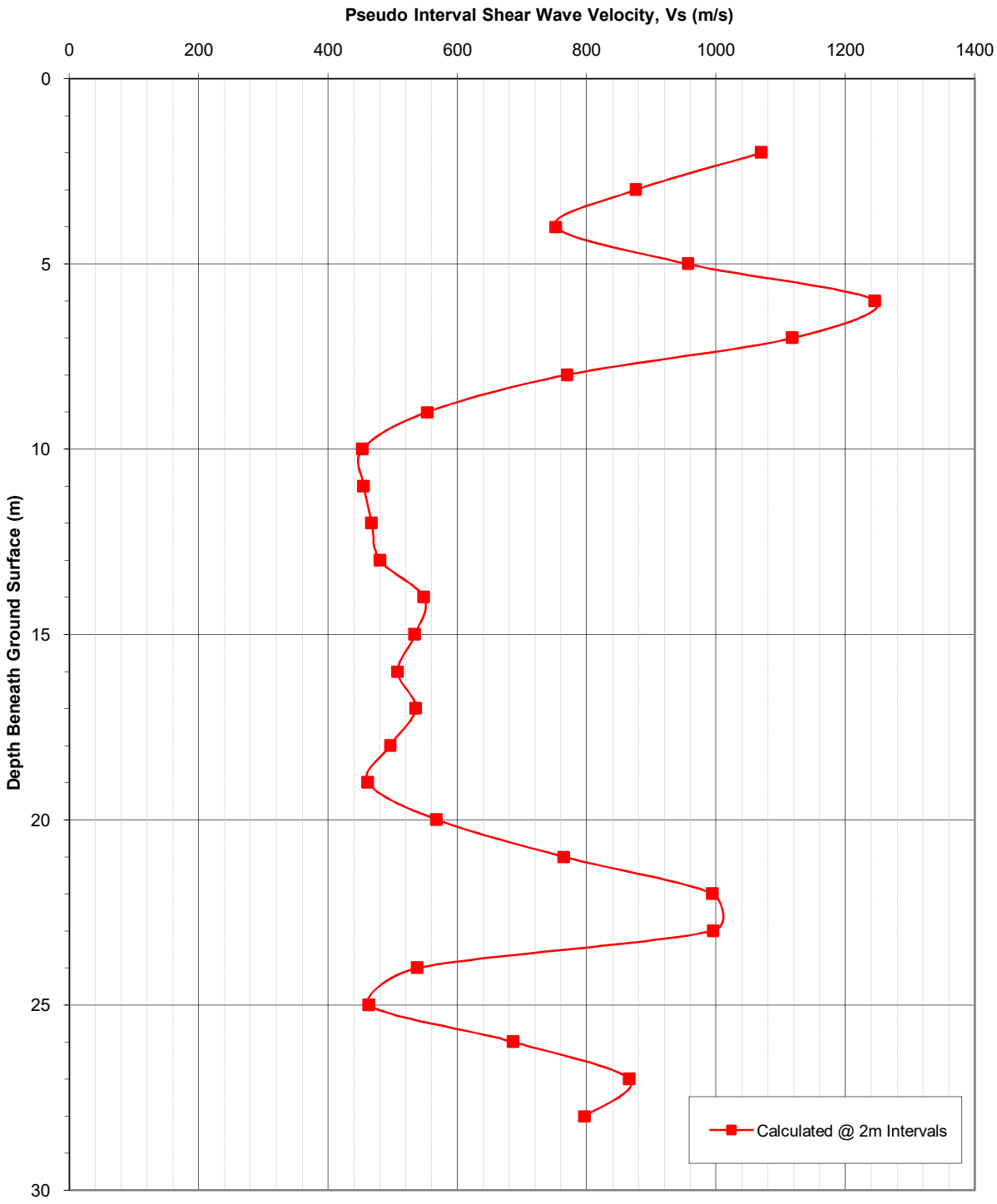

**Table 2: SUMMARY FOR DOWNHOLE SEISMIC TEST- BORING PP-BH02**

**Project: Dominica Geothermal Project, Power Plant Site**

| Depth (m) | Direct S wave (m/s) | Direct P wave (m/s) |
|---|---|---|
| 1 | 235 | 319 |
| 2 | 272 | 406 |
| 3 | 321 | 507 |
| 4 | 356 | 598 |
| 5 | 392 | 687 |
| 6 | 433 | 756 |
| 7 | 475 | 773 |
| 8 | 504 | 750 |
| 9 | 516 | 790 |
| 10 | 513 | 819 |
| 11 | 504 | 832 |
| 12 | 503 | 850 |
| 13 | 498 | 854 |
| 14 | 499 | 868 |
| 15 | 504 | 880 |
| 16 | 503 | 882 |
| 17 | 504 | 892 |
| 18 | 507 | 898 |
| 19 | 504 | 894 |
| 20 | 502 | 895 |
| 21 | 509 | 911 |
| 22 | 518 | 934 |
| 23 | 531 | 952 |
| 24 | 539 | 973 |
| 25 | 532 | 997 |
| 26 | 533 | 1013 |
| 27 | 541 | 1024 |
| 28 | 548 | 1038 |
| 29 | 553 | 1048 |

| 3m Pseudo Interval Depth (m) | 3m Pseudo Interval Compression Wave (m/s) | 3m Pseudo Interval Depth (m) | 3m Pseudo Interval Shear Wave (m/s) |
|---|---|---|---|
| 2 | 1181 | 2 | 1071 |
| 3 | 1529 | 3 | 876 |
| 4 | 1732 | 4 | 753 |
| 5 | 1763 | 5 | 956 |
| 6 | 1151 | 6 | 1246 |
| 7 | 729 | 7 | 1119 |
| 8 | 859 | 8 | 769 |
| 9 | 1321 | 9 | 554 |
| 10 | 1103 | 10 | 454 |
| 11 | 1046 | 11 | 456 |
| 12 | 995 | 12 | 468 |
| 13 | 995 | 13 | 481 |
| 14 | 1107 | 14 | 548 |
| 15 | 997 | 15 | 534 |
| 16 | 997 | 16 | 508 |
| 17 | 1050 | 17 | 536 |
| 18 | 907 | 18 | 496 |
| 19 | 868 | 19 | 462 |
| 20 | 1109 | 20 | 568 |
| 21 | 1664 | 21 | 765 |
| 22 | 1815 | 22 | 995 |
| 23 | 1816 | 23 | 995 |
| 24 | 2219 | 24 | 538 |
| 25 | 1998 | 25 | 463 |
| 26 | 1537 | 26 | 687 |
| 27 | 1537 | 27 | 867 |
| 28 | 1537 | 28 | 797 |

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**TABLE 1.** SHEAR WAVE VELOCITY MEASUREMENT ASTM D7400
DOWNHOLE SEISMIC TEST - BORING PP-BH02

| | | |
|---|---|---|
| Operator: | M. Candelario | |
| Test Date / Weather: | October 9th, 2018 | |
| Source: | 12 lb Sledge Hammer | |
| Downhole Receiver: | BHG 2 Triaxial Geophone | |
| Recording Equipment | ES 3000-Seismograph | |
| Borehole Information: | Grouted Cased Borehole | |
| Method of Installation: | 4 inch ID Casing Advancer System | |
| Casing Diameter: | 2 inch Sch.40 PVC | |
| Clamp Method: | Mechanical Spring | |
| Ground Surface Elevation @ Source, Eg: | - | m |
| Shear Wave Source Horizontal Offset, Xs: | 7.4147 | ft |
| Compression (P) Wave Source Offset, Xp | 4.0682 | ft |
| Pipe Stickup: | 0 | ft |
| Receiver Offset from Reference Point: | 0 | ft |
| Ground Surface Elevation @ Borehole, Eg: | | m |

| Recorded Geophone Depth (ft) | Corrected Geophone Depth (ft) | Corrected Geophone Depth (m) | Receiver Depth, $D_G$(ft) | Receiver Elevation (m) | Source Slant Distance, $L_R$ (ft) | Reference Shear Wave Arrival Time (millisec) | Interval Arrival Time Difference $\Delta$Ts (millisec) | **Interval Shear Wave Velocity, Vs (ft/sec)** | **Interval Shear Wave Velocity, Vs (m/sec)** |
|---|---|---|---|---|---|---|---|---|---|
| 5 | 5 | 1.5 | 5 | -1.52 | 8.94 | 10.5 | | | |
| | | | | | | | 0.6 | **5,843** | **1,781** |
| 10 | 10 | 3.0 | 10 | -3.05 | 12.45 | 11.1 | | | |
| | | | | | | | 0.6 | **7,139** | **2,176** |
| 15 | 15 | 4.6 | 15 | -4.57 | 16.73 | 11.7 | | | |
| | | | | | | | 1.2 | **3,831** | **1,168** |
| 20 | 20 | 6.1 | 20 | -6.10 | 21.33 | 12.9 | | | |
| | | | | | | | 1.1 | **4,315** | **1,315** |
| 25 | 25 | 7.6 | 25 | -7.62 | 26.08 | 14 | | | |
| | | | | | | | 0.8 | **6,033** | **1,839** |
| 30 | 30 | 9.1 | 30 | -9.15 | 30.90 | 14.8 | | | |
| | | | | | | | 0.7 | **6,963** | **2,122** |
| 35 | 35 | 10.7 | 35 | -10.67 | 35.78 | 15.5 | | | |
| | | | | | | | 1 | **4,905** | **1,495** |
| 40 | 40 | 12.2 | 40 | -12.20 | 40.68 | 16.5 | | | |
| | | | | | | | 1.5 | **3,284** | **1,001** |
| 45 | 45 | 13.7 | 45 | -13.72 | 45.61 | 18 | | | |
| | | | | | | | 2 | **2,470** | **753** |
| 50 | 50 | 15.2 | 50 | -15.24 | 50.55 | 20 | | | |
| | | | | | | | 2.3 | **2,153** | **656** |
| 55 | 55 | 16.8 | 55 | -16.77 | 55.50 | 22.3 | | | |
| | | | | | | | 2 | **2,479** | **756** |
| 60 | 60 | 18.3 | 60 | -18.29 | 60.46 | 24.3 | | | |
| | | | | | | | 2.2 | **2,257** | **688** |
| 65 | 65 | 19.8 | 65 | -19.82 | 65.42 | 26.5 | | | |
| | | | | | | | 1.9 | **2,616** | **797** |
| 70 | 70 | 21.3 | 70 | -21.34 | 70.39 | 28.4 | | | |
| | | | | | | | 1.7 | **2,926** | **892** |
| 75 | 75 | 22.9 | 75 | -22.87 | 75.37 | 30.1 | | | |
| | | | | | | | 2 | **2,489** | **759** |
| 80 | 80 | 24.4 | 80 | -24.39 | 80.34 | 32.1 | | | |
| | | | | | | | 1.9 | **2,621** | **799** |
| 85 | 85 | 25.9 | 85 | -25.91 | 85.32 | 34 | | | |
| | | | | | | | 1.8 | **2,768** | **844** |
| 90 | 90 | 27.4 | 90 | -27.44 | 90.30 | 35.8 | | | |
| | | | | | | | 2.2 | **2,265** | **691** |
| 95 | 95 | 29.0 | 95 | -28.96 | 95.29 | 38 | | | |

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# Appendix D:

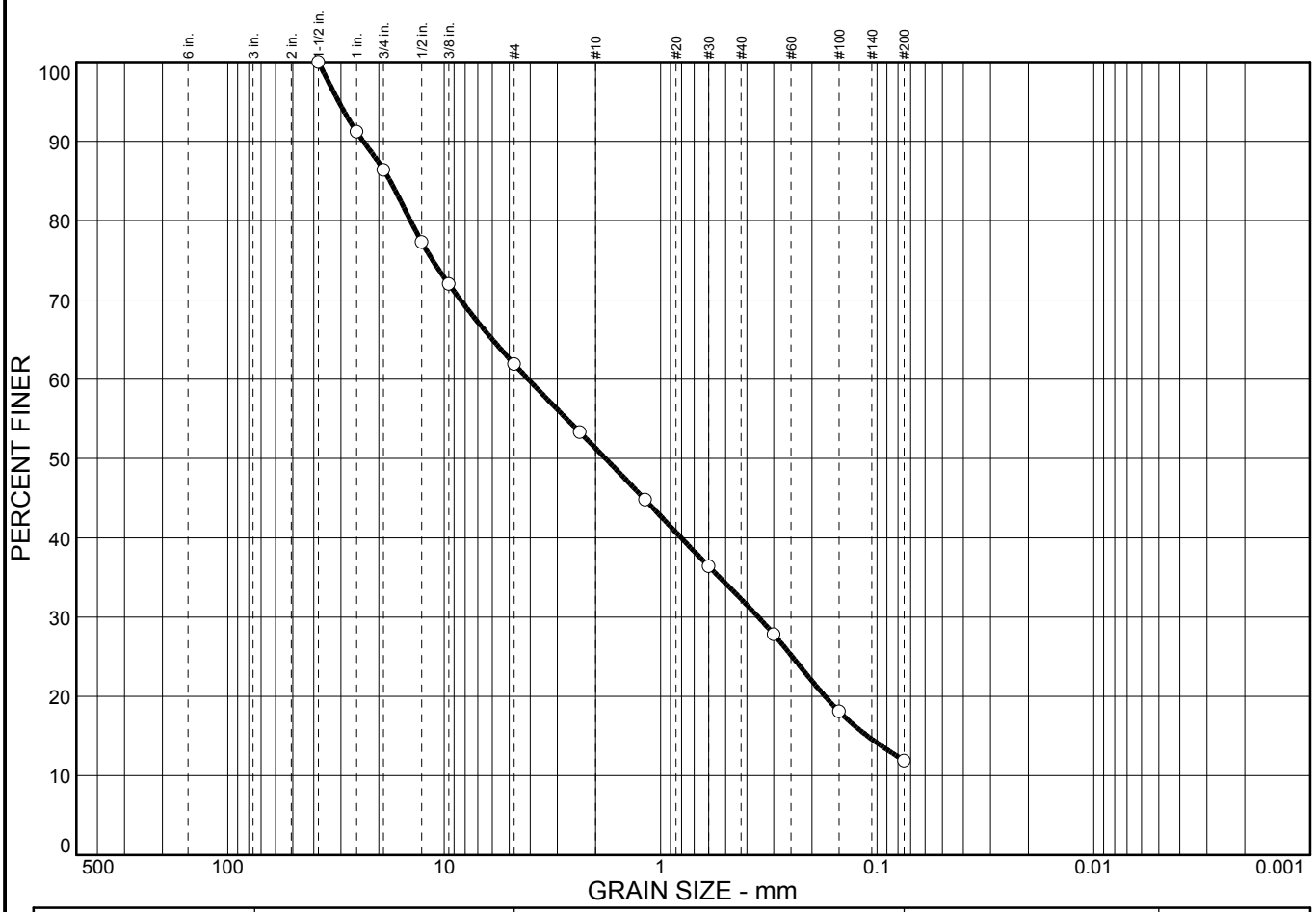
## General Laboratory Tests Results

*Soil Classifications*

*Atterberg Limits*

*Proctor Compaction Test*

# Particle Size Distribution Report




| % +75 MM | % GRAVEL | % SAND | % SILT | % CLAY |
|---|---|---|---|---|
| 0.0 | 38.1 | 50.0 | 11.9 | |

| SIEVE SIZE | PERCENT FINER | SPEC.* PERCENT | PASS? (X=NO) |
|---|---|---|---|
| 1.5 in. | 100.0 | | |
| 1 in. | 91.2 | | |
| .75 in. | 86.4 | | |
| .5 in. | 77.3 | | |
| .375 in. | 72.0 | | |
| #4 | 61.9 | | |
| #8 | 53.3 | | |
| #16 | 44.8 | | |
| #30 | 36.4 | | |
| #50 | 27.8 | | |
| #100 | 18.1 | | |
| #200 | 11.9 | | |

* (no specification provided)

**Material Description**

Gray, poorly graded sand with silt and gravel.

**Atterberg Limits**

PL= - LL= - PI= -

**Coefficients**

$D_{85}$= 17.8 $D_{60}$= 4.09 $D_{50}$= 1.80
$D_{30}$= 0.354 $D_{15}$= 0.111 $D_{10}$=
$C_u$= $C_c$=

**Classification**

USCS= AASHTO=

**Remarks**

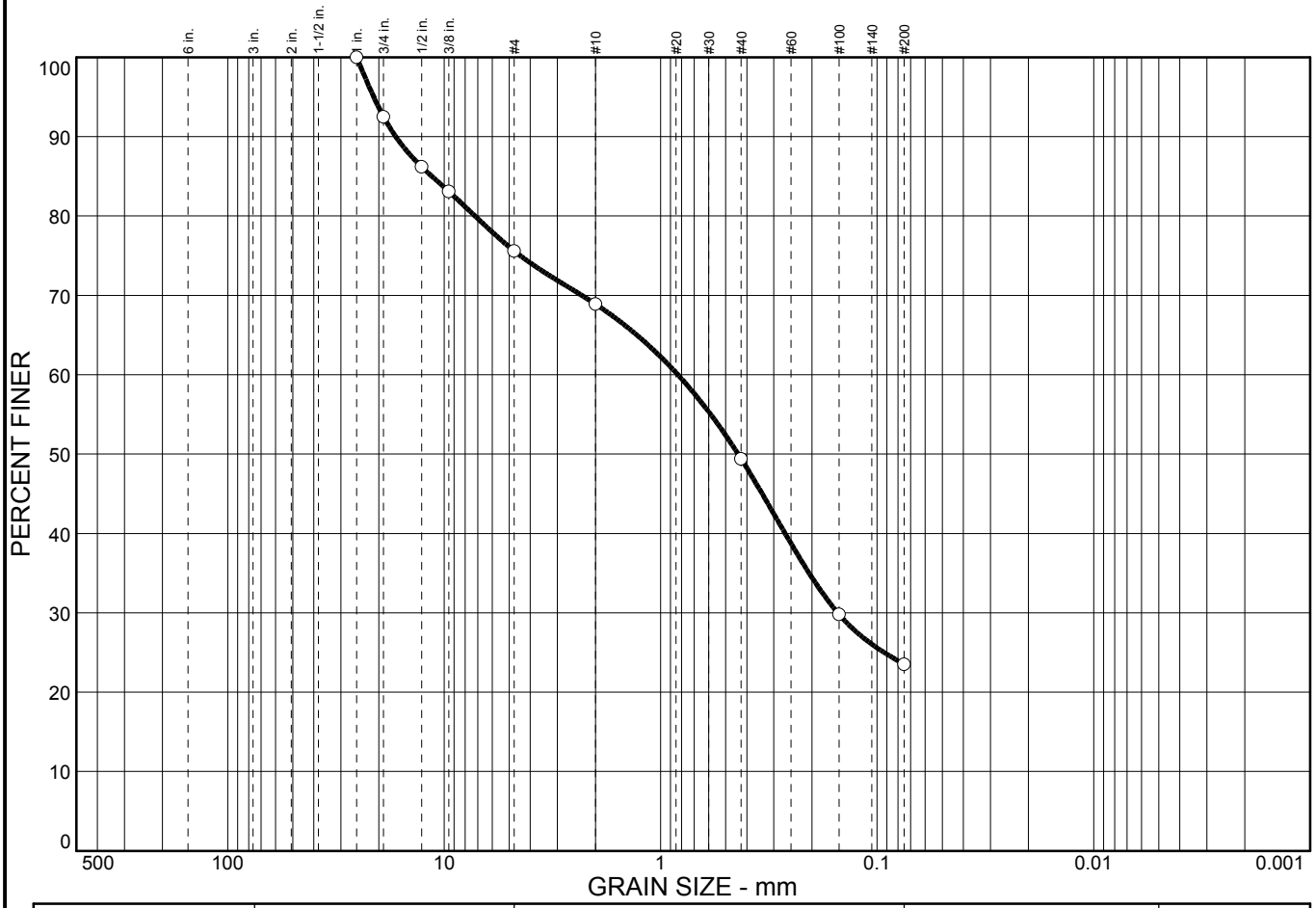
Tested by: L. Medina
Checked by: Manuel Candelario Cosme, MSCE, PE
F.M.=3.99

**Sample No.:** PP-BH-01 **Source of Sample:** Project Site **Date:** 11/14/18
**Location:** Dominica **Elev./Depth:** 6-7.5'

**JACA & SIERRA TESTING LABORATORIES**
**San Juan, Puerto Rico**

**Client:** DGDC
**Project:** Power Plant-Dominica
**Project No:** 7909 **Figure**

# Particle Size Distribution Report




| % +75 MM | % GRAVEL | % SAND | % SILT | % CLAY |
|---|---|---|---|---|
| 0.0 | 24.4 | 52.1 | 23.5 | |

| SIEVE SIZE | PERCENT FINER | SPEC.* PERCENT | PASS? (X=NO) |
|---|---|---|---|
| 1 in. | 100.0 | | |
| .75 in. | 92.5 | | |
| .5 in. | 86.2 | | |
| .375 in. | 83.1 | | |
| #4 | 75.6 | | |
| #10 | 68.9 | | |
| #40 | 49.4 | | |
| #100 | 29.8 | | |
| #200 | 23.5 | | |

* (no specification provided)

**Material Description**

Silty sand with gravel.

**Atterberg Limits**

PL= NP LL= NP PI= NP

**Coefficients**

$D_{85}$= 11.4 $D_{60}$= 0.833 $D_{50}$= 0.439
$D_{30}$= 0.152 $D_{15}$= $D_{10}$=
$C_u$= $C_c$=

**Classification**

USCS= SM AASHTO= A-1-b

**Remarks**

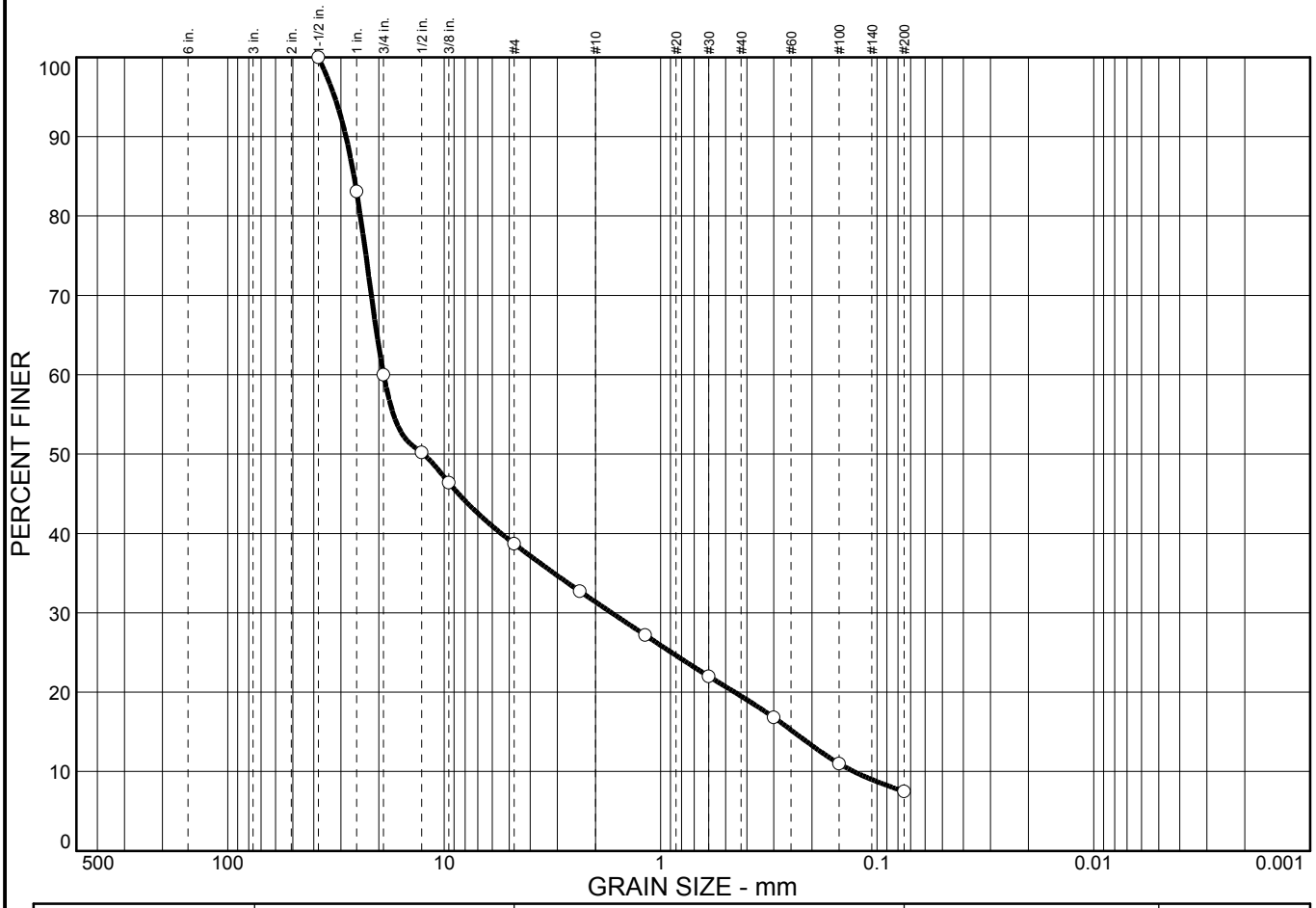
Tested by: A. Roman
Checked by: Manuel Candelario Cosme, MSCE, PE

**Sample No.:** PP-BH-01 **Source of Sample:** Project Site **Date:** 11/30/18
**Location:** Dominica **Elev./Depth:** 36'

**JACA & SIERRA TESTING LABORATORIES**
**San Juan, Puerto Rico**

**Client:** DGDC
**Project:** Power Plant-Dominica
**Project No:** 7909 **Figure**

# Particle Size Distribution Report




| % +75 MM | % GRAVEL | % SAND | % SILT | % CLAY |
|---|---|---|---|---|
| 0.0 | 61.3 | 31.2 | 7.5 | |

| SIEVE SIZE | PERCENT FINER | SPEC.* PERCENT | PASS? (X=NO) |
|---|---|---|---|
| 1.5 in. | 100.0 | | |
| 1 in. | 83.1 | | |
| .75 in. | 60.0 | | |
| .5 in. | 50.2 | | |
| .375 in. | 46.4 | | |
| #4 | 38.7 | | |
| #8 | 32.7 | | |
| #16 | 27.2 | | |
| #30 | 22.0 | | |
| #50 | 16.8 | | |
| #100 | 11.0 | | |
| #200 | 7.5 | | |

* (no specification provided)

**Material Description**

Dark gray, well-graded gravel with silt and sand.

**Atterberg Limits**

PL= NP LL= NP PI= NP

**Coefficients**

$D_{85}$= 26.1 $D_{60}$= 19.0 $D_{50}$= 12.4
$D_{30}$= 1.68 $D_{15}$= 0.244 $D_{10}$= 0.128
$C_u$= 148.63 $C_c$= 1.16

**Classification**

USCS= GW-GM AASHTO= A-1-a

**Remarks**

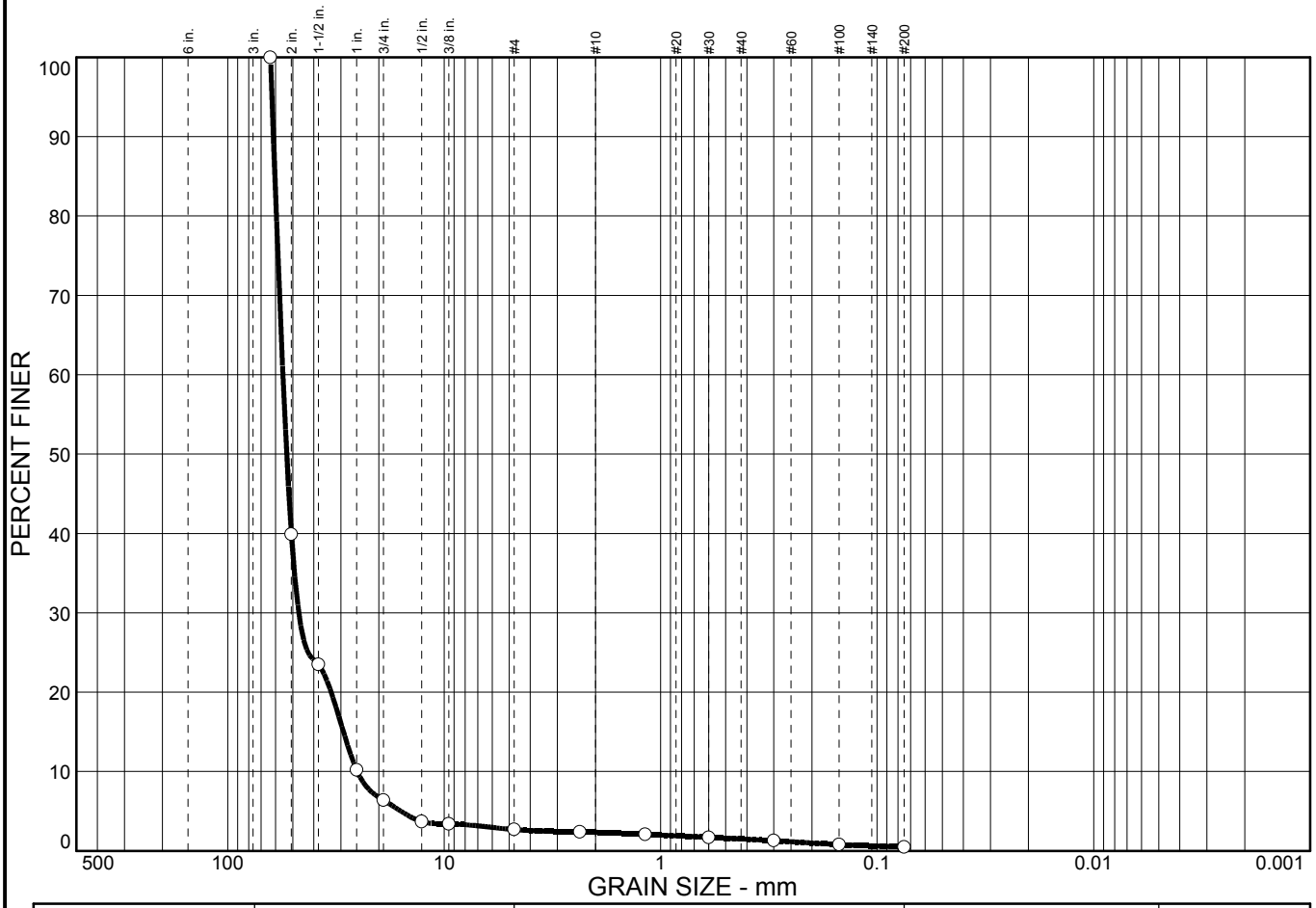
Tested by: J. Ortiz
Checked by: Manuel Candelario Cosme, MSCE, PE

**Sample No.:** PP-BH-02 **Source of Sample:** Project Site **Date:** 11/13/18
**Location:** Dominica **Elev./Depth:** 2-3.5'

**JACA & SIERRA TESTING LABORATORIES**
**San Juan, Puerto Rico**

**Client:** DGDC
**Project:** Power Plant-Dominica
**Project No:** 7909 **Figure**

# Particle Size Distribution Report




| % +75 MM | % GRAVEL | % SAND | % SILT | % CLAY |
|---|---|---|---|---|
| 0.0 | 97.3 | 2.2 | 0.5 | |

| SIEVE SIZE | PERCENT FINER | SPEC.* PERCENT | PASS? (X=NO) |
|---|---|---|---|
| 2.5 in. | 100.0 | | |
| 2 in. | 39.9 | | |
| 1.5 in. | 23.5 | | |
| 1 in. | 10.2 | | |
| .75 in. | 6.4 | | |
| .5 in. | 3.7 | | |
| .375 in. | 3.4 | | |
| #4 | 2.7 | | |
| #8 | 2.4 | | |
| #16 | 2.1 | | |
| #30 | 1.7 | | |
| #50 | 1.3 | | |
| #100 | 0.8 | | |
| #200 | 0.5 | | |

* (no specification provided)

**Material Description**

Poorly graded gravel.

**Atterberg Limits**

PL= - LL= - PI= -

**Coefficients**

$D_{85}$= 60.6 $D_{60}$= 55.6 $D_{50}$= 53.4
$D_{30}$= 47.0 $D_{15}$= 29.2 $D_{10}$= 25.2
$C_u$= 2.21 $C_c$= 1.57

**Classification**

USCS= AASHTO=

**Remarks**

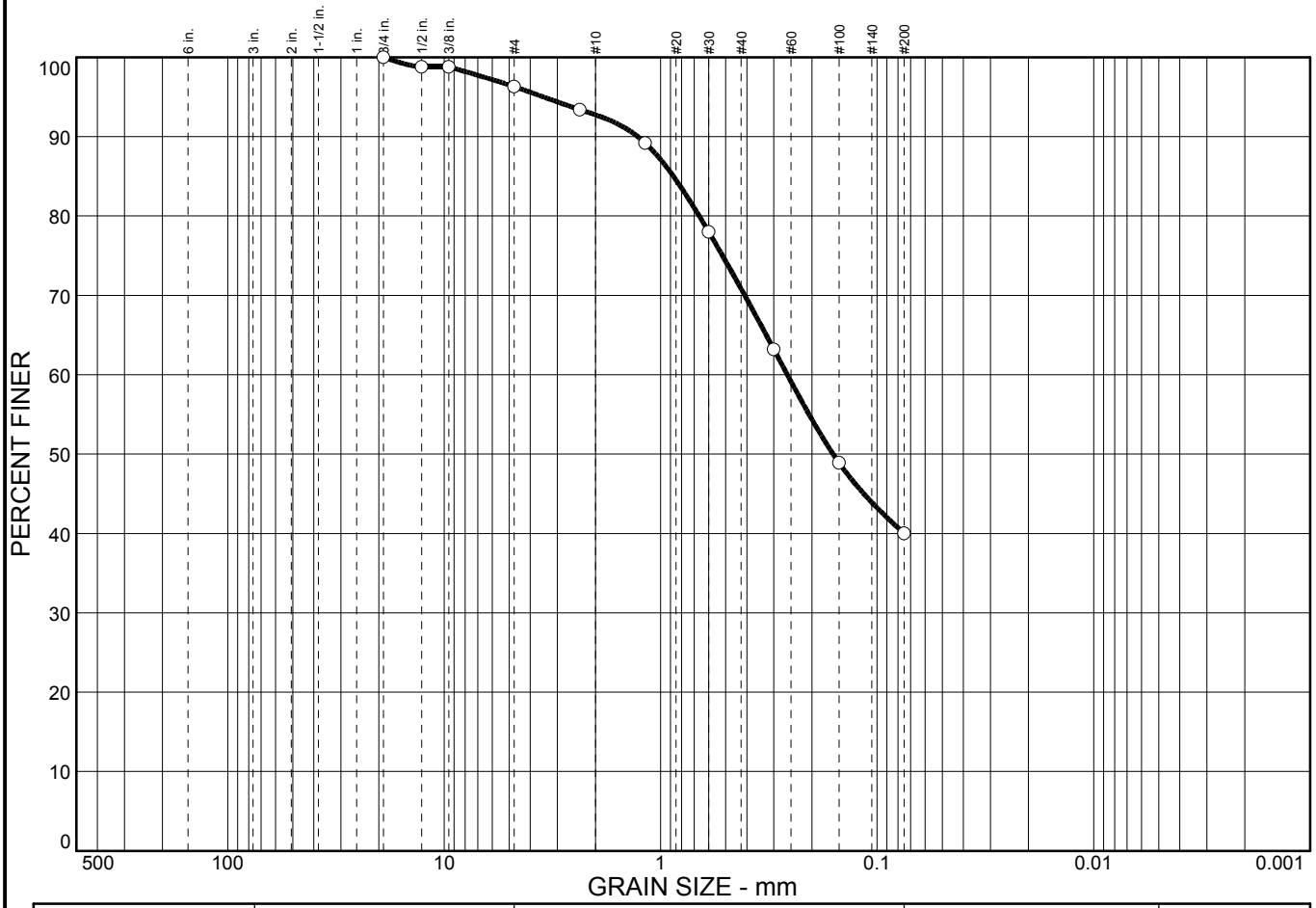
Tested by: A. Diaz
Checked by: Manuel Candelario Cosme, MSCE, PE
F.M.=8.56

**Sample No.:** PP-BH-02 **Source of Sample:** Project Site **Date:** 1/11/19
**Location:** Dominica **Elev./Depth:** 6-11'

**JACA & SIERRA TESTING LABORATORIES**
**San Juan, Puerto Rico**

**Client:** DGDC
**Project:** Power Plant-Dominica
**Project No:** 7909 **Figure**

# Particle Size Distribution Report




| % +75 MM | % GRAVEL | % SAND | % SILT | % CLAY |
|---|---|---|---|---|
| 0.0 | 3.7 | 56.3 | 40.0 | |

| SIEVE SIZE | PERCENT FINER | SPEC.* PERCENT | PASS? (X=NO) |
|---|---|---|---|
| .75 in. | 100.0 | | |
| .5 in. | 98.8 | | |
| .375 in. | 98.8 | | |
| #4 | 96.3 | | |
| #8 | 93.4 | | |
| #16 | 89.2 | | |
| #30 | 78.0 | | |
| #50 | 63.2 | | |
| #100 | 48.9 | | |
| #200 | 40.0 | | |

* (no specification provided)

**Material Description**

Silty sand.

**Atterberg Limits**

PL= - LL= - PI= -

**Coefficients**

$D_{85}$= 0.874 $D_{60}$= 0.260 $D_{50}$= 0.160
$D_{30}$= $D_{15}$= $D_{10}$=
$C_u$= $C_c$=

**Classification**

USCS= AASHTO=

**Remarks**

Tested by: F. De Los Santos
Checked by: Manuel Candelario Cosme, MSCE, PE
F.M.=1.32

**Sample No.:** PP-BH-02 **Source of Sample:** Project Site **Date:** 1/10/19
**Location:** Dominica **Elev./Depth:** 26-27.5'

**JACA & SIERRA TESTING LABORATORIES**
**San Juan, Puerto Rico**

**Client:** DGDC
**Project:** Power Plant-Dominica
**Project No:** 7909 **Figure**

# Particle Size Distribution Report




| % +75 MM | % GRAVEL | % SAND | % SILT | % CLAY |
|---|---|---|---|---|
| 0.0 | 1.2 | 53.0 | 45.8 | |

| SIEVE SIZE | PERCENT FINER | SPEC.* PERCENT | PASS? (X=NO) |
|---|---|---|---|
| .5 in. | 100.0 | | |
| .375 in. | 99.7 | | |
| #4 | 98.8 | | |
| #8 | 97.3 | | |
| #16 | 93.4 | | |
| #30 | 82.3 | | |
| #50 | 69.4 | | |
| #100 | 54.4 | | |
| #200 | 45.8 | | |

* (no specification provided)

**Material Description**

Light gray, silty sand.

**Atterberg Limits**

PL= - LL= - PI= -

**Coefficients**

$D_{85}$= 0.695 $D_{60}$= 0.198 $D_{50}$= 0.112
$D_{30}$= $D_{15}$= $D_{10}$=
$C_u$= $C_c$=

**Classification**

USCS= AASHTO=

**Remarks**

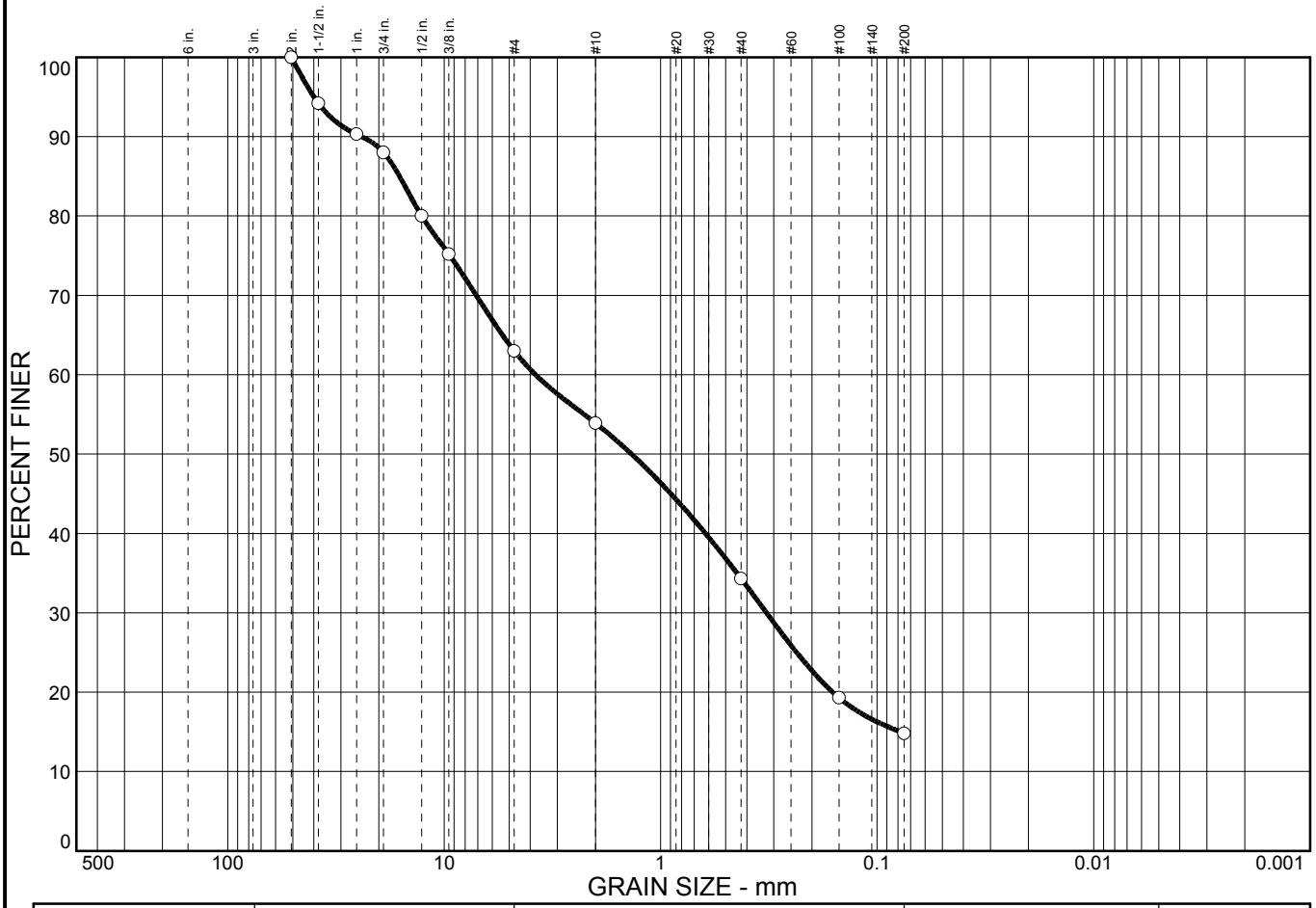
Tested by: L. Medina
Checked by: Manuel Candelario Cosme, MSCE, PE
F.M.=1.05

**Sample No.:** PP-BH-02 **Source of Sample:** Project Site **Date:** 11/14/18
**Location:** Dominica **Elev./Depth:** 46-47.5'

**JACA & SIERRA TESTING LABORATORIES**
**San Juan, Puerto Rico**

**Client:** DGDC
**Project:** Power Plant-Dominica
**Project No:** 7909 **Figure**

# Particle Size Distribution Report




| % +75 MM | % GRAVEL | % SAND | % SILT | % CLAY |
|---|---|---|---|---|
| 0.0 | 37.0 | 48.2 | 14.8 | |

| SIEVE SIZE | PERCENT FINER | SPEC.* PERCENT | PASS? (X=NO) |
|---|---|---|---|
| 2 in. | 100.0 | | |
| 1.5 in. | 94.2 | | |
| 1 in. | 90.3 | | |
| .75 in. | 88.0 | | |
| .5 in. | 80.0 | | |
| .375 in. | 75.2 | | |
| #4 | 63.0 | | |
| #10 | 53.9 | | |
| #40 | 34.3 | | |
| #100 | 19.3 | | |
| #200 | 14.8 | | |

* (no specification provided)

**Material Description**

Silty sand with gravel.

**Atterberg Limits**

PL= NP LL= NP PI= NP

**Coefficients**

$D_{85}$= 16.1 $D_{60}$= 3.78 $D_{50}$= 1.36
$D_{30}$= 0.325 $D_{15}$= 0.0782 $D_{10}$=
$C_u$= $C_c$=

**Classification**

USCS= SM AASHTO= A-1-b

**Remarks**

Tested by: F. De Los Santos
Checked by: Manuel Candelario Cosme, MSCE, PE

**Sample No.:** PP-BH-03 **Source of Sample:** Project Site **Date:** 12/7/18
**Location:** Dominica **Elev./Depth:** 4-5.6'

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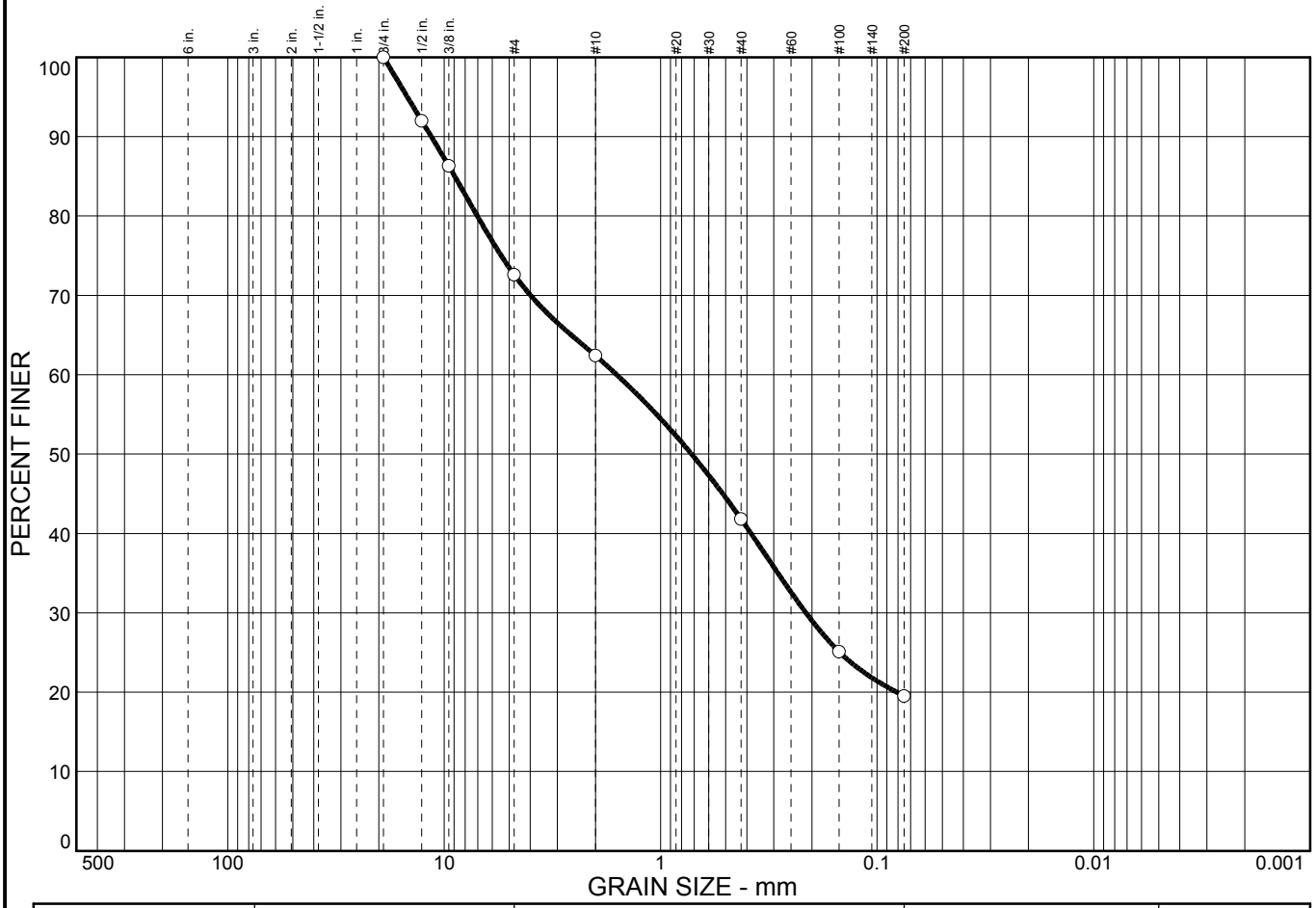
**Client:** DGDC
**Project:** Power Plant-Dominica
**Project No:** 7909 **Figure**

# Particle Size Distribution Report




| % +75 MM | % GRAVEL | % SAND | % SILT | % CLAY |
|---|---|---|---|---|
| 0.0 | 27.4 | 53.1 | 19.5 | |

| SIEVE SIZE | PERCENT FINER | SPEC.* PERCENT | PASS? (X=NO) |
|---|---|---|---|
| .75 in. | 100.0 | | |
| .5 in. | 92.0 | | |
| .375 in. | 86.3 | | |
| #4 | 72.6 | | |
| #10 | 62.4 | | |
| #40 | 41.8 | | |
| #100 | 25.1 | | |
| #200 | 19.5 | | |

* (no specification provided)

**Material Description**

Gray, silty sand with gravel.

**Atterberg Limits**

PL= NP LL= NP PI= NP

**Coefficients**

$D_{85}$= 8.94 $D_{60}$= 1.60 $D_{50}$= 0.720
$D_{30}$= 0.213 $D_{15}$= $D_{10}$=
$C_u$= $C_c$=

**Classification**

USCS= SM AASHTO= A-1-b

**Remarks**

Tested by: L. Merdina
Checked by: Manuel Candelario Cosme, MSCE, PE

**Sample No.:** PP-BH-03 **Source of Sample:** Project Site **Date:** 11/27/18
**Location:** Dominica **Elev./Depth:** 54-59'

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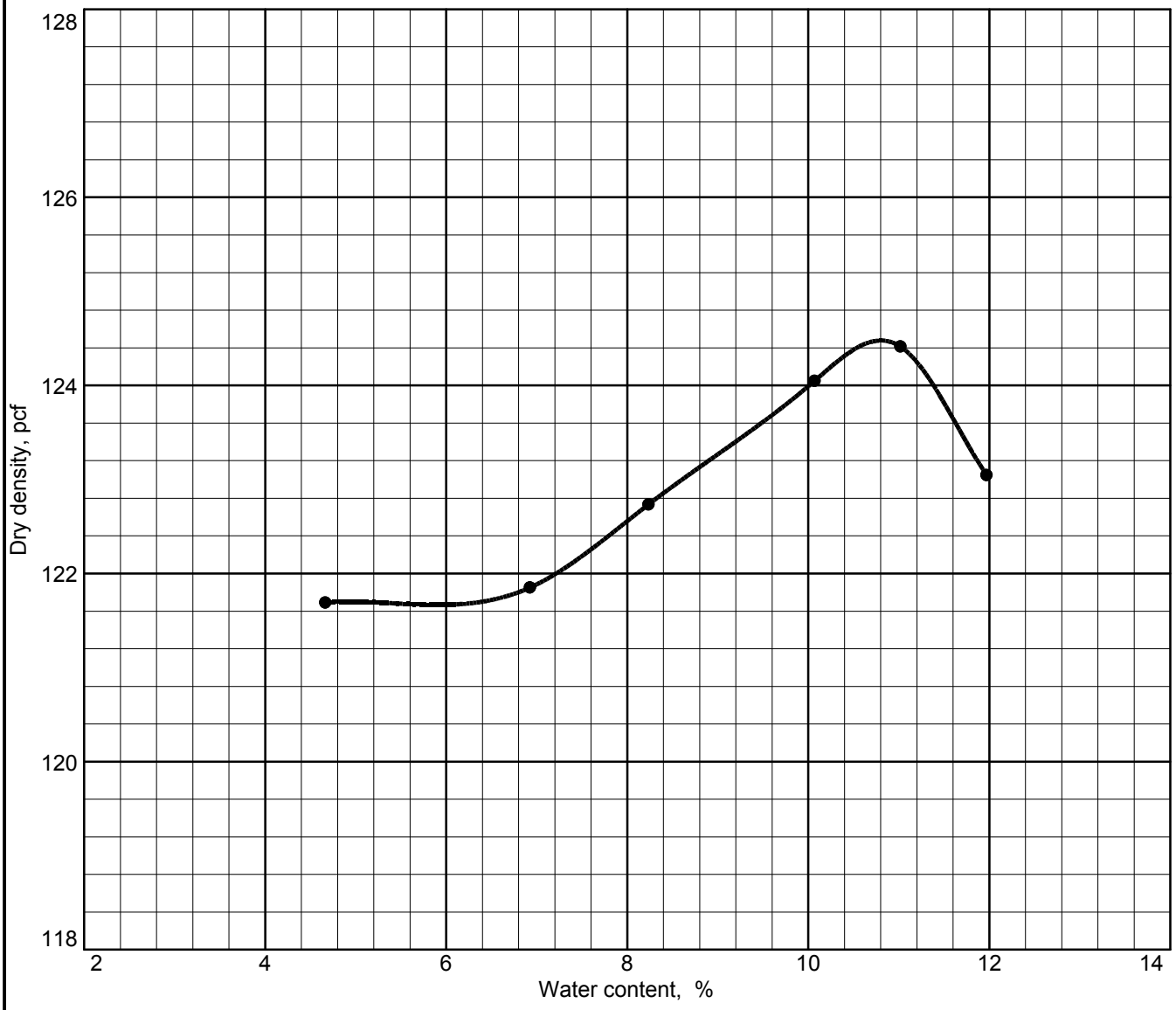
**San Juan, Puerto Rico**

**Client:** DGDC
**Project:** Power Plant-Dominica
**Project No:** 7909 **Figure**

# COMPACTION TEST REPORT




Test specification: ASTM D 1557-91 Procedure C Modified

| Elev/ Depth | Classification | | Nat. Moist. | Sp.G. | LL | PI | % > 3/4 in. | % < No.200 |
|---|---|---|---|---|---|---|---|---|
| | USCS | AASHTO | | | | | | |
| 4 meter | GP-GM | A-1-a | | | NP | NP | | 11.1 |

**TEST RESULTS**

Maximum dry density = 124.5 pcf

Optimum moisture = 10.8 %

**MATERIAL DESCRIPTION**

Light gray, poorly graded gravel with silt and sand.
PP-TP-01 4 meter

**Project No.** 7909 **Client:** DGDC

**Project:** Power Plant-Dominica

**Date:** 12/28/18

● **Location:** Dominica Source Sample: Project Site PP-TP01

**JACA & SIERRA TESTING LABORATORIES**

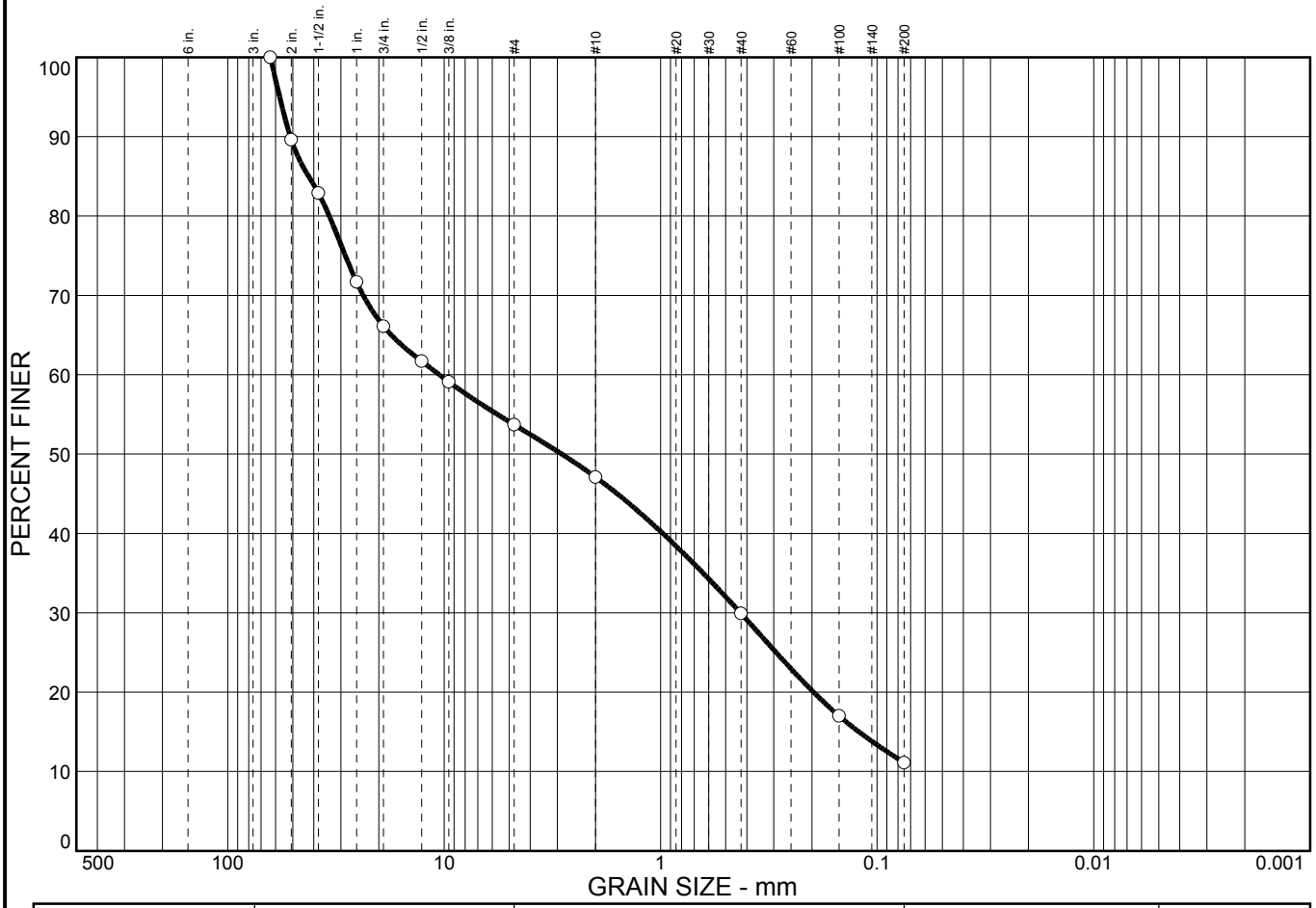
**San Juan, Puerto Rico**

**Remarks:**

Tested by: F. De Los Santos/M. Rodriguez
Checked by: Manuel Candelario Cosme, MSCE, PE
Job No.: 7909

**Figure**

# Particle Size Distribution Report




| % +75 MM | % GRAVEL | % SAND | % SILT | % CLAY |
|---|---|---|---|---|
| 0.0 | 46.3 | 42.6 | 11.1 | |

| SIEVE SIZE | PERCENT FINER | SPEC.* PERCENT | PASS? (X=NO) |
|---|---|---|---|
| 2.5 in. | 100.0 | | |
| 2 in. | 89.6 | | |
| 1.5 in. | 82.9 | | |
| 1 in. | 71.7 | | |
| .75 in. | 66.1 | | |
| .5 in. | 61.7 | | |
| .375 in. | 59.1 | | |
| #4 | 53.7 | | |
| #10 | 47.1 | | |
| #40 | 29.9 | | |
| #100 | 17.0 | | |
| #200 | 11.1 | | |

* (no specification provided)

**Material Description**

Light gray, poorly graded gravel with silt and sand.
PP-TP-01 4 meter

**Atterberg Limits**

PL= NP LL= NP PI= NP

**Coefficients**

$D_{85}$= 42.3 $D_{60}$= 10.5 $D_{50}$= 2.86
$D_{30}$= 0.428 $D_{15}$= 0.122 $D_{10}$=
$C_u$= $C_c$=

**Classification**

USCS= GP-GM AASHTO= A-1-a

**Remarks**

Tested by: A. Perez
Checked by: Manuel Candelario Cosme, MSCE, PE

**Sample No.:** PP-TP-01 **Source of Sample:** Project Site **Date:** 1/8/19
**Location:** Dominica Source Sample: Project Site PP-TP01 **Elev./Depth:** 4 meter

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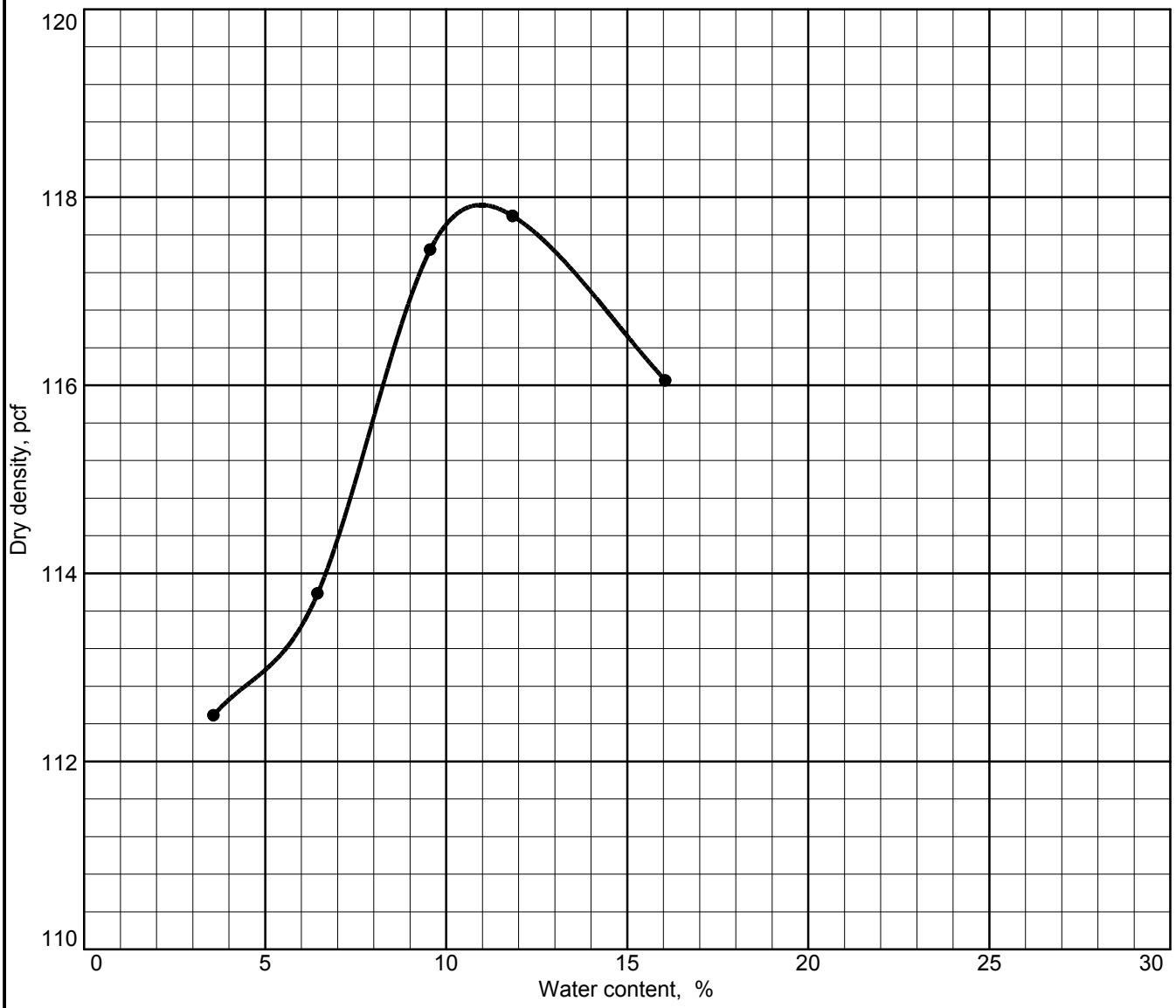
**San Juan, Puerto Rico**

**Client:** DGDC
**Project:** Power Plant-Dominica
**Project No:** 7909 **Figure**

# COMPACTION TEST REPORT




Test specification: ASTM D 1557-91 Procedure C Modified

| Elev/ Depth | Classification | | Nat. Moist. | Sp.G. | LL | PI | % > 3/4 in. | % < No.200 |
|---|---|---|---|---|---|---|---|---|
| | USCS | AASHTO | | | | | | |
| 1 meter | GP-GM | A-1-a | | | NP | NP | | 8.3 |

**TEST RESULTS**

Maximum dry density = 117.9 pcf

Optimum moisture = 11.0 %

**MATERIAL DESCRIPTION**

Light gray, poorly graded gravel with silt and sand.
PP-TP-02 1 Meter

**Project No.** 7909 **Client:** DGDC

**Project:** Power Plant-Dominica

**Date:**

● **Location:** Dominica Source Sample: Project Site PP-TP02

**JACA & SIERRA TESTING LABORATORIES**

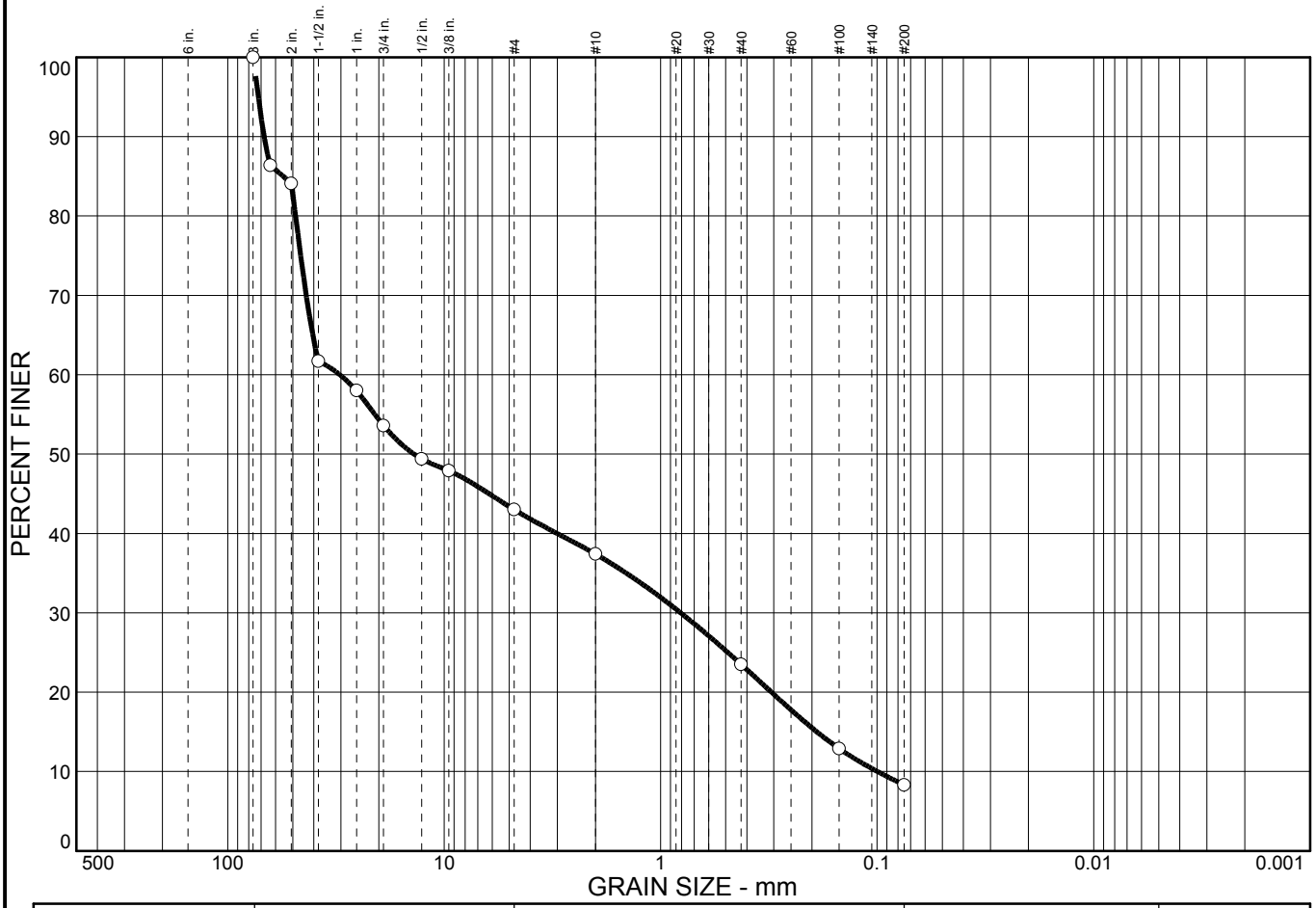
**San Juan, Puerto Rico**

**Remarks:**

Tested by: M. Pereira
Checked by: Manuel Candelario Cosme, MSCE, PE
Job No.: 7909

**Figure**

# Particle Size Distribution Report




| % +75 MM | % GRAVEL | % SAND | % SILT | % CLAY |
|---|---|---|---|---|
| 1.5 | 55.5 | 34.7 | 8.3 | |

| SIEVE SIZE | PERCENT FINER | SPEC.* PERCENT | PASS? (X=NO) |
|---|---|---|---|
| 3 in. | 100.0 | | |
| 2.5 in. | 86.4 | | |
| 2 in. | 84.1 | | |
| 1.5 in. | 61.7 | | |
| 1 in. | 58.0 | | |
| .75 in. | 53.6 | | |
| .5 in. | 49.4 | | |
| .375 in. | 47.9 | | |
| #4 | 43.0 | | |
| #10 | 37.4 | | |
| #40 | 23.5 | | |
| #100 | 12.9 | | |
| #200 | 8.3 | | |

* (no specification provided)

**Material Description**

Light gray, poorly graded gravel with silt and sand.
PP-TP-02 1 Meter

**Atterberg Limits**

PL= NP LL= NP PI= NP

**Coefficients**

$D_{85}$= 55.4 $D_{60}$= 30.4 $D_{50}$= 13.8
$D_{30}$= 0.809 $D_{15}$= 0.190 $D_{10}$= 0.0996
$C_u$= 305.25 $C_c$= 0.22

**Classification**

USCS= GP-GM AASHTO= A-1-a

**Remarks**

Tested by: L. Medina
Checked by: Manuel Candelario Cosme, MSCE, PE

**Sample No.:** PP-TP-02 **Source of Sample:** Project Site **Date:** 11/13/18
**Location:** Dominica Source Sample: Project Site PP-TP02 **Elev./Depth:** 1 meter

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**San Juan, Puerto Rico**

**Client:** DGDC
**Project:** Power Plant-Dominica
**Project No:** 7909 **Figure**

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# Appendix E:

## California Bearing Ratio Test Results

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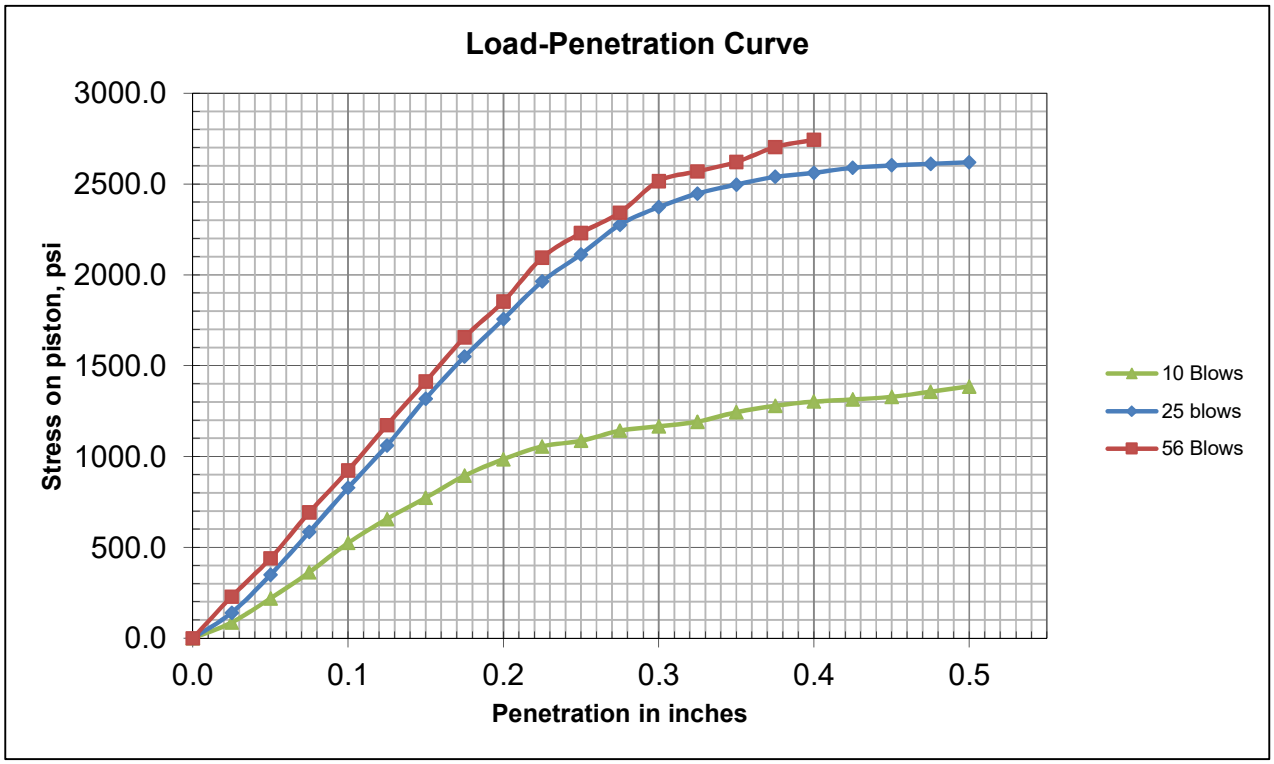
## CALIFORNIA BEARING RATIO TEST REPORT (ASTM D1883)

| | | |
|---|---|---|
| Date | : | January 8, 2019 |
| Client | : | DGDC |
| Project | : | Power Plant Site, Dominica |
| Sample Description | : | Light gray, graded gravel with silt and sand. |
| Sample ID | : | PP-TP-01 @ 4.0 mts |
| USCS Class. | : | GW |
| AASHTO Class. | : | A-1-a |
| Liquid Limit | : | - |
| Plastic Limit | : | - |
| Plasticity Index | : | NP |




| Blows | 10 Blows* | 25 Blows* | 56 Blows |
|---|---|---|---|
| CBR at 0.1-in. penetration | 59 | 99 | 92 |
| CBR at 0.2-in. penetartion | 68 | 100+ | 100+ |
| Swell | - | - | - |

*Corrected CBR Values

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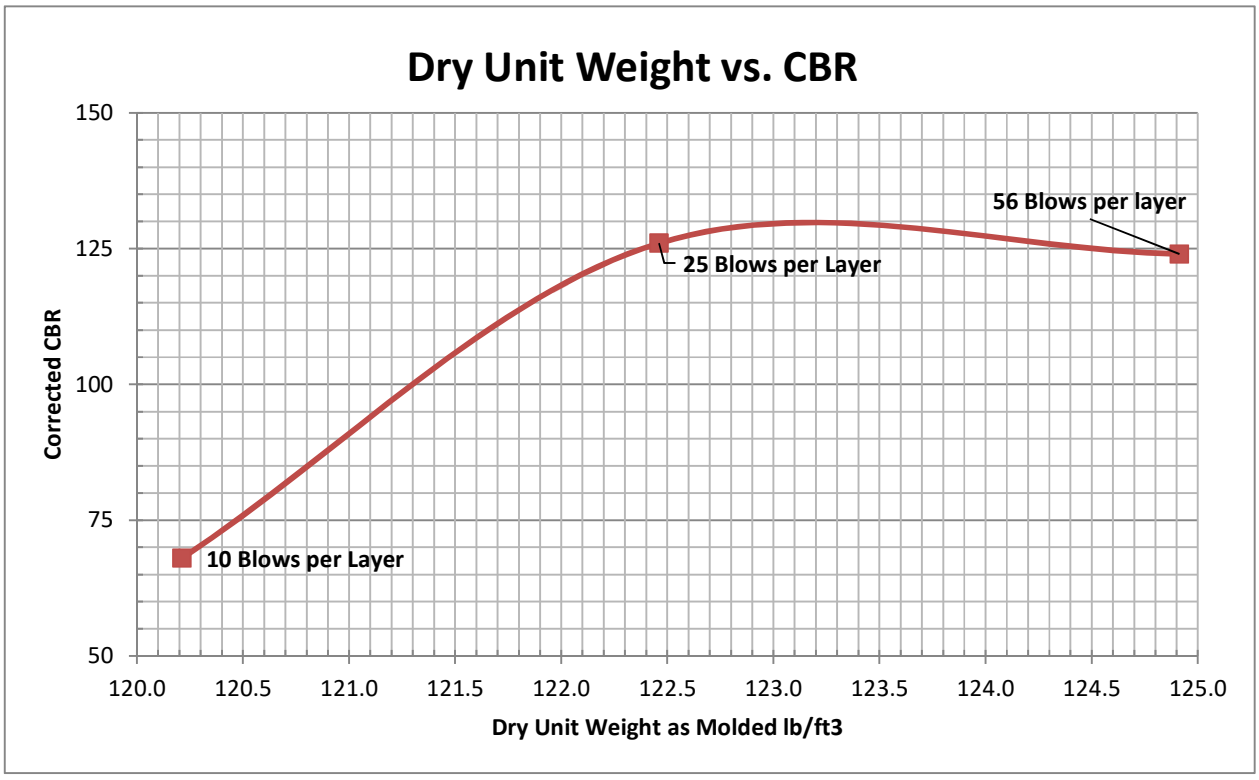
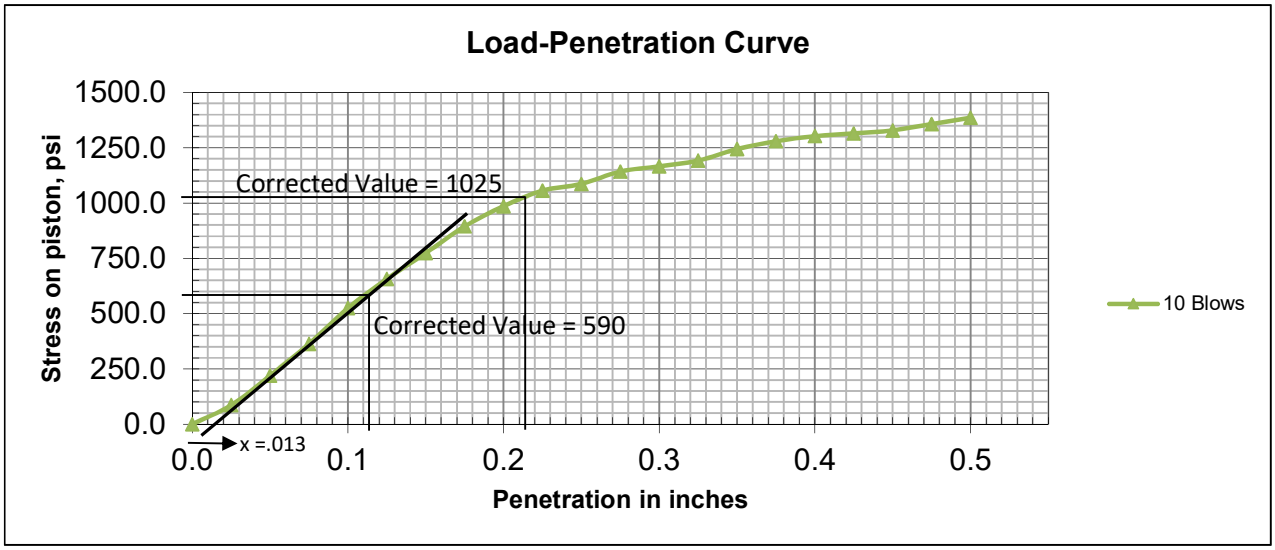
## CALIFORNIA BEARING RATIO TEST REPORT (ASTM D4429)

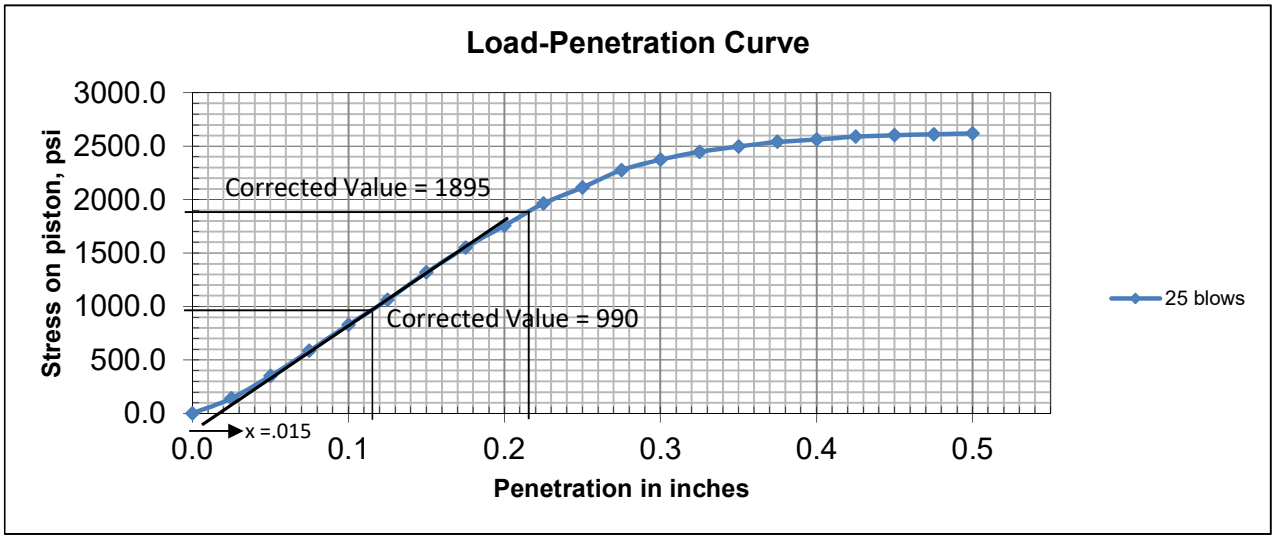
| | | |
|---|---|---|
| Date | : | January 8, 2019 |
| Client | : | DGDC |
| Project | : | Power Plant Site, Dominica |
| Sample Description | : | Light gray, graded gravel with silt and sand |

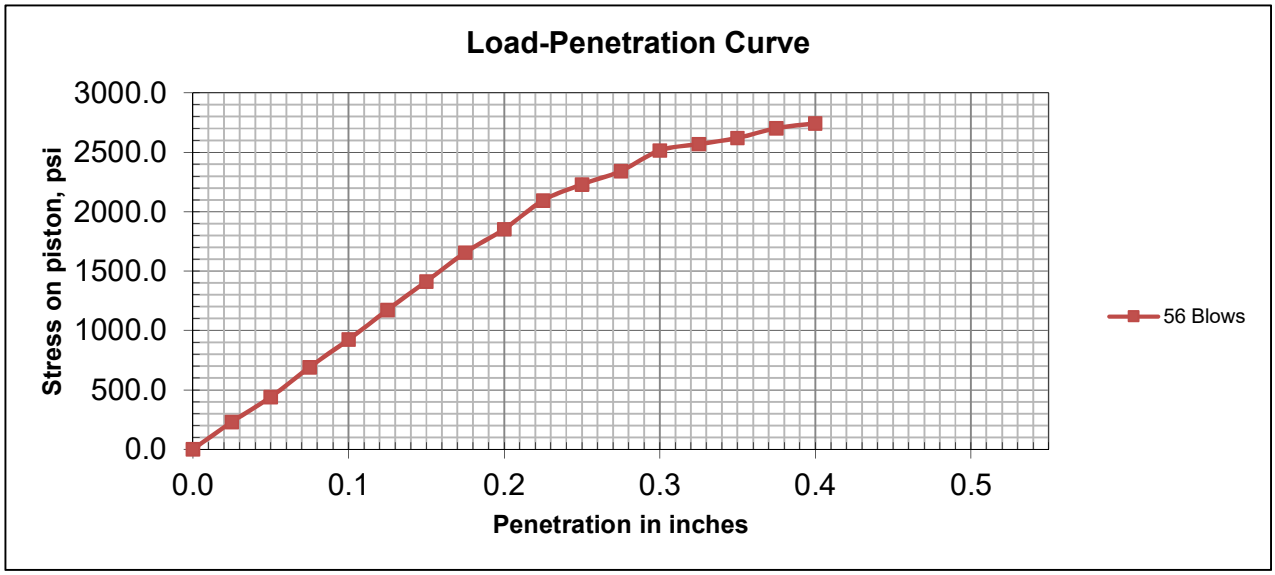
| Blows | Condition of Sample | Dry Density (Tested) lb/ft³ | Moisture Content (%) | Moisture Content (%) | Swell | CBR |
|---|---|---|---|---|---|---|
| | | | Before Compaction (%) | After Compaction (%) | | |
| 10 | Soaked | 120.2 | 8.3 | 11.0 | - | 68 |
| 25 | Soaked | 122.5 | 7.7 | 10.7 | - | 126 |
| 56 | Soaked | 124.9 | 8.2 | 10.2 | - | 124 |



## Correction of Load-Penetration Curves



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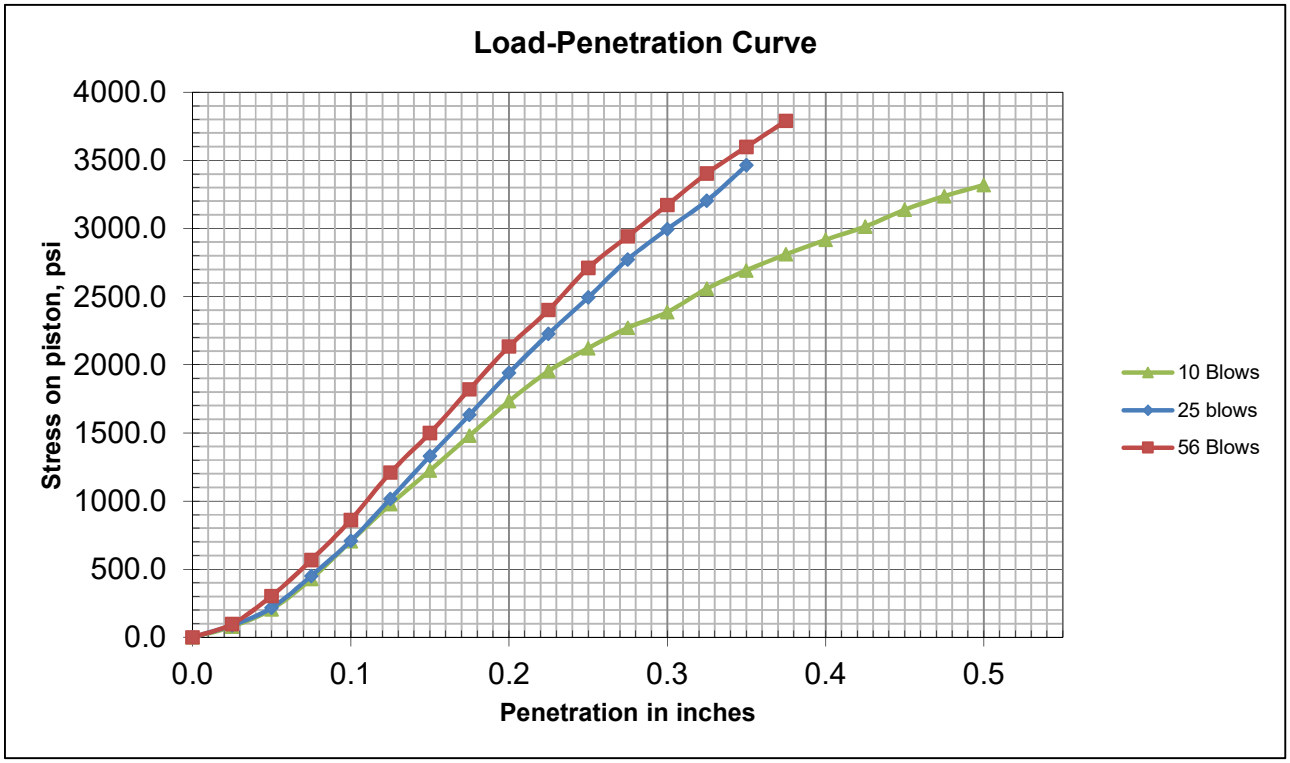
## CALIFORNIA BEARING RATIO TEST REPORT (ASTM D4429)

| | | |
|---|---|---|
| Date | : | November 19, 2018 |
| Client | : | DGDC |
| Project | : | Power Plant Site, Dominica |
| Sample Description | : | Light gray, graded gravel with silt and sand. |
| Sample ID | : | PP-TP-02 |
| USCS Class. | : | GW |
| AASHTO Class. | : | A-1-a |
| Liquid Limit | : | - |
| Plastic Limit | : | - |
| Plasticity Index | : | NP |




| Blows | 10 Blows | 25 Blows | 56 Blows |
|---|---|---|---|
| CBR at 0.1-in. penetration | 99 | 100+ | 100+ |
| CBR at 0.2-in. penetartion | 100+ | 100+ | 100+ |
| Swell | - | - | - |

Jaca Sierra Eng., PSC
TEL. 787-761-2570
FAX. 787-748-6970
www.jacasierra.com

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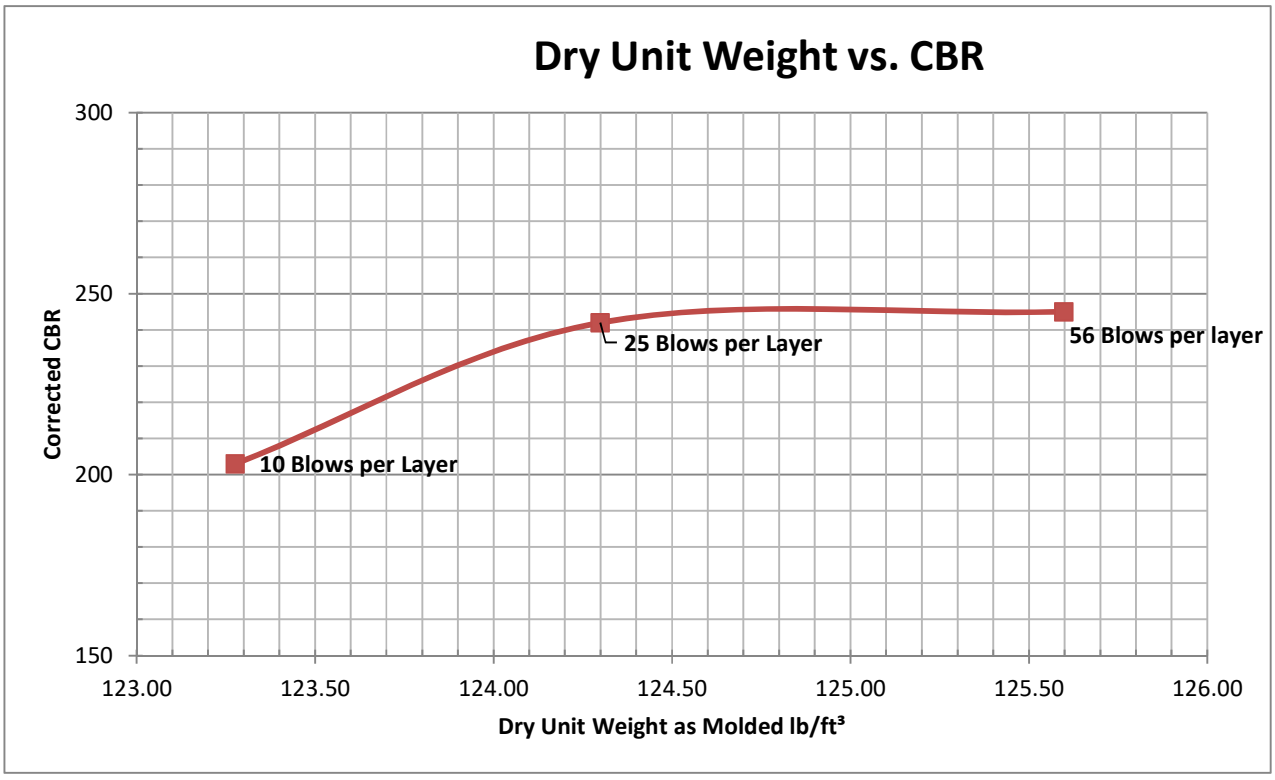
## CALIFORNIA BEARING RATIO TEST REPORT (ASTM D4429)

| | | |
|---|---|---|
| Date | : | November 19, 2018 |
| Client | : | DGDC |
| Project | : | Power Plant Site, Dominica |
| Sample Description | : | Light gray, graded gravel with silt and sand. |

| Blows | Condition of Sample | Dry Density (Tested) lb/ft³ | Moisture Content (%) | Moisture Content (%) | Swell | CBR |
|---|---|---|---|---|---|---|
| | | | Before | After | | |
| 10 | Soaked | 123.28 | 8.6 | 11.3 | - | 203 |
| 25 | Soaked | 124.30 | 9.4 | 10.50 | - | 242 |
| 56 | Soaked | 125.60 | 9.3 | 10 | - | 245 |

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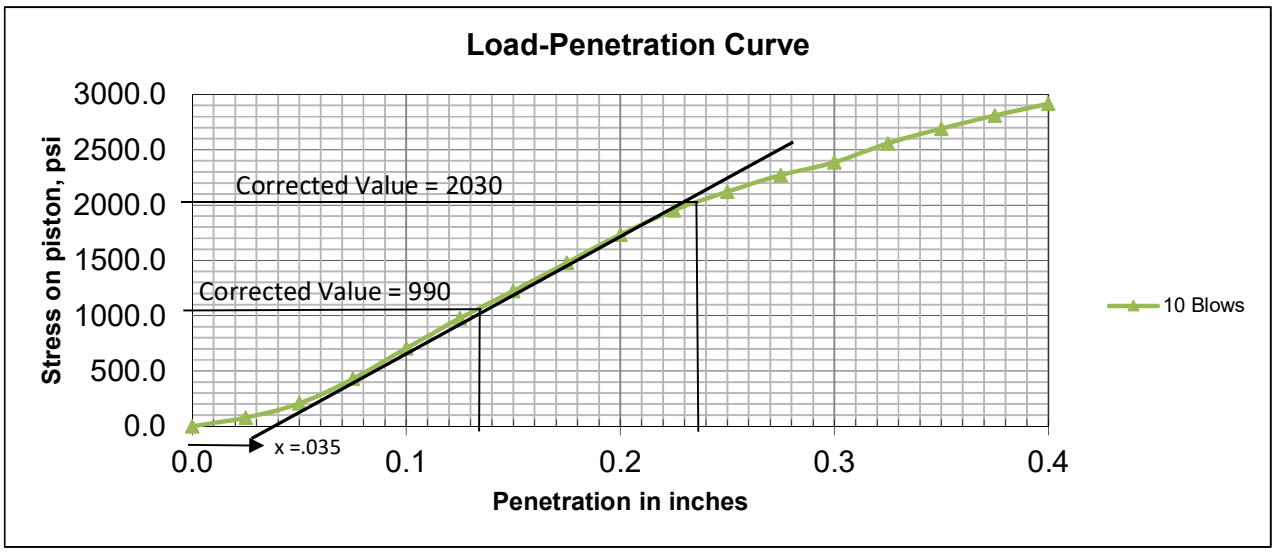
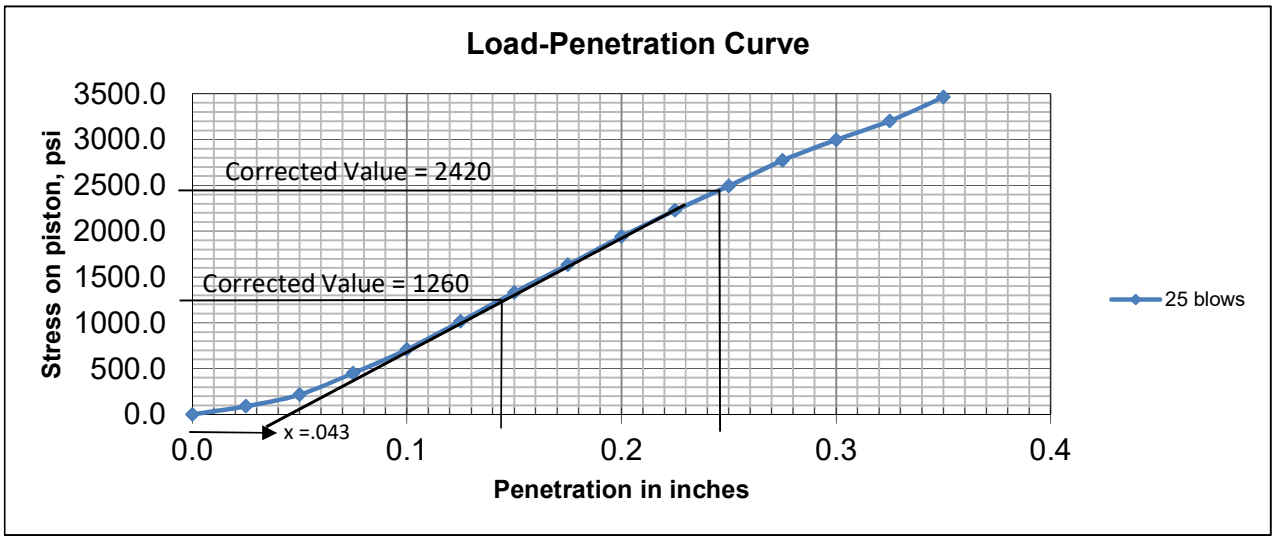
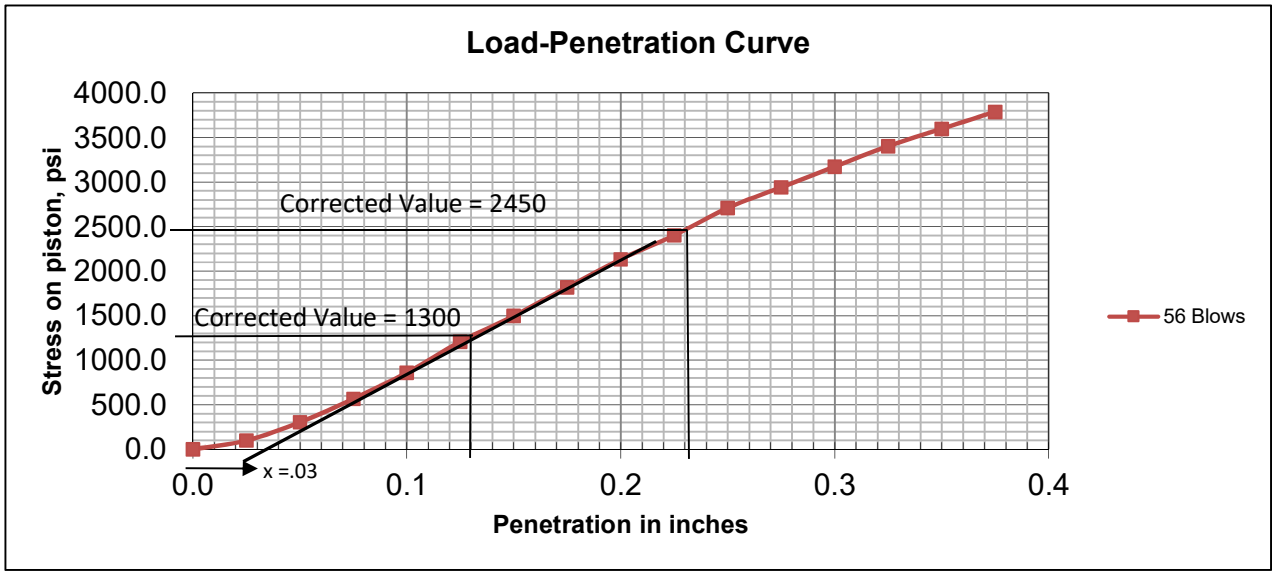
## Corrected CBR Calculation

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# Part 2 - Employer's Requirements

Section VII - Employer's Requirements

# 9. Environmental and Social Impact Assessment (ESIA))

Dominica Geothermal Development Company Limited
*Powering a New Generation...*

JACOBS

# Dominica Geothermal Development - Environmental Impact Assessment

NZ Ministry of Foreign Affairs & Trade

## Non-Technical Summary

RZ020300-NP-RPT-0009 | V2

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# Dominica Geothermal Development – ESIA: Non-Technical Summary

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# 1. Introduction

## 1.1 Overview

This Non-Technical Summary (NTS) provides an overview, in plain language, of the main findings of the Environmental and Social Impact Assessment (ESIA) prepared for the construction and operation of the Dominica Geothermal Project (hereafter referred to as 'the Project'). The Project is the construction and operation of geothermal wells, reinjection systems and a geothermal power plant with a capacity of 7 Mega Watts (MW) and connection to the Dominica electrical grid and associated infrastructure. When complete, the Project will make an important contribution to the socio-economic development of the region and the Commonwealth of Dominica. It will provide a stable source of electricity for the island and reduce the overall reliance on diesel generation.

It is important to note that this NTS does not, and is not intended to, convey all of the information relating to the Project and its potential impacts on the physical and social environment. The text provided herein is a summary of the detailed assessments discussed in the ESIA. Therefore, for more detailed information pertaining to any part of this NTS, please refer to the ESIA and supporting specialist Technical Reports, which are available at the offices of the Dominica Geothermal Development Company Ltd (DGDC) (refer Section 4.6).

## 1.2 What is the Project?

The key components of the proposed 7 MW power plant development include:

- Geothermal Power Plant (nominally 7 MW);
- Production well (called WW-P1) which provides steam and brine to drive the power plant;
- Reinjection wells (called WW-R1 and WW-01) for the return of brine to the below ground geothermal reservoir;
- Steamfield infrastructure including two phase piping, steam separators, atmospheric flash tank, steam gathering system, brine collection and disposal system, condensate collection and disposal system, pressure relief system and storage sump;
- Supporting infrastructure including well pads, turbine building, primary and ancillary equipment, cooling system, road network, water supply and wastewater treatment; and
- 11 kV underground interconnection to the DOMLEC electricity grid at the power plant site.

An overview of the Project and the location of its elements is provided below in Figure 1.1.

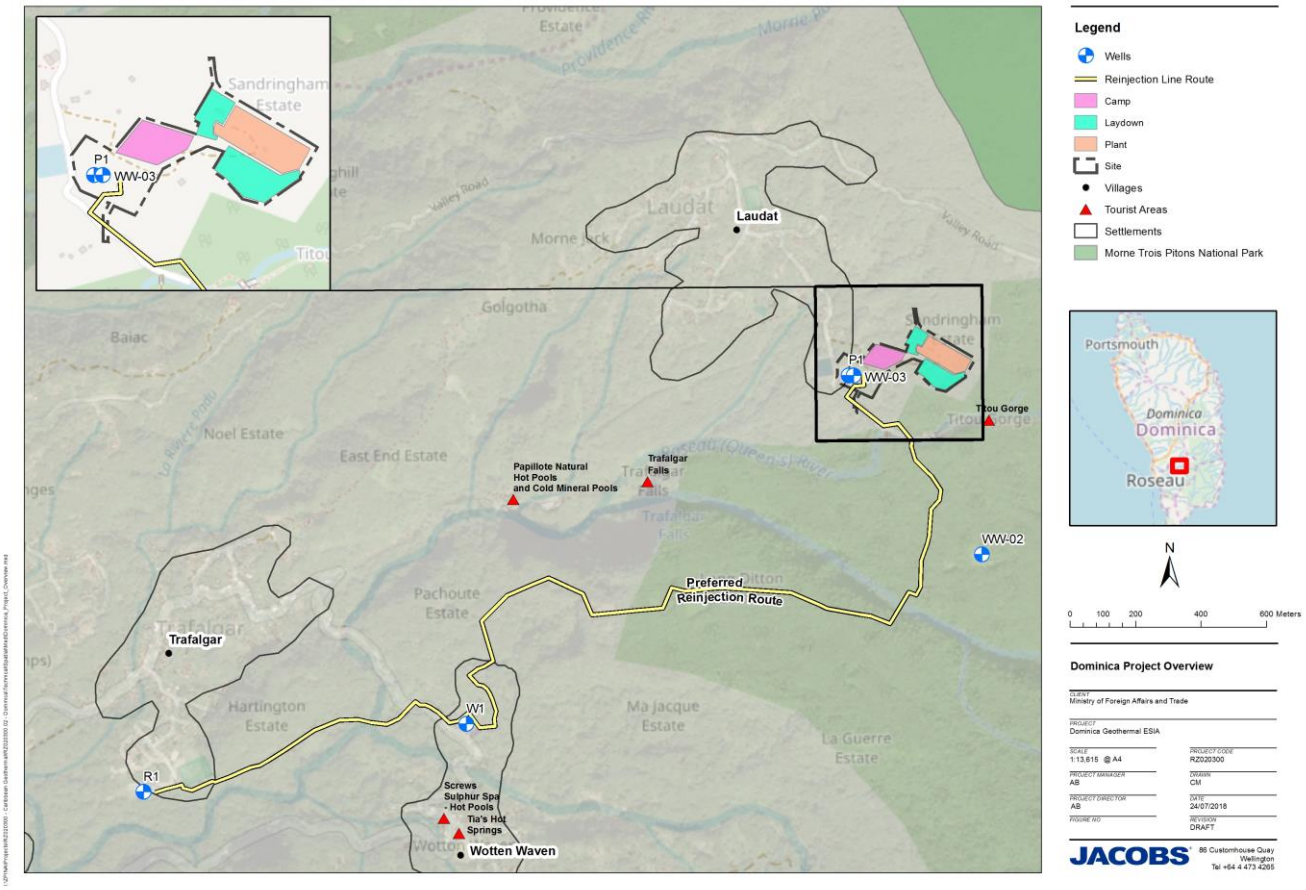


**Figure 1.1 : Project Overview**

## 1.3 Why is the Project Needed?

Dominica's power system relies heavily on diesel fuel imports to generate electricity. As with many other island nations, Dominica's primary source of electricity production is from diesel generation, which exposes the country's economy to price uncertainty relating to the cost of diesel imports. The power system is operated by DOMLEC, a privately owned organisation that has the exclusive licence to transmit, distribute and supply electricity on the island, and a non-exclusive licence to generate electricity.

Changing the power generation mix and reducing the cost and volatility of electricity prices have become development priorities for Dominica. Being a relatively young volcanic island, Dominica has significant geothermal resource potential. Therefore, the Government of the Commonwealth of Dominica (GoCD) has pursued an exploration programme to evaluate the viability of geothermal resource in the Roseau Valley.

GoCD is actively moving towards a renewable sources of energy such as geothermal energy and away from a reliance on fossil fuel energy generation such as diesel and this change will assist in reduction in greenhouse gas emissions.

## 1.4 Where is the Project Located?

The Project is located in the Roseau Valley of Dominica, in close vicinity to a number of communities. The Power Plant is partially located within the settlement boundary of Laudat and the reinjection pipeline passes through the settlement areas of Wotten Waven and Trafalgar. The location of the power plant and reinjection line route within the Roseau Valley is shown in Figure 1.2 and Figure 1.3.

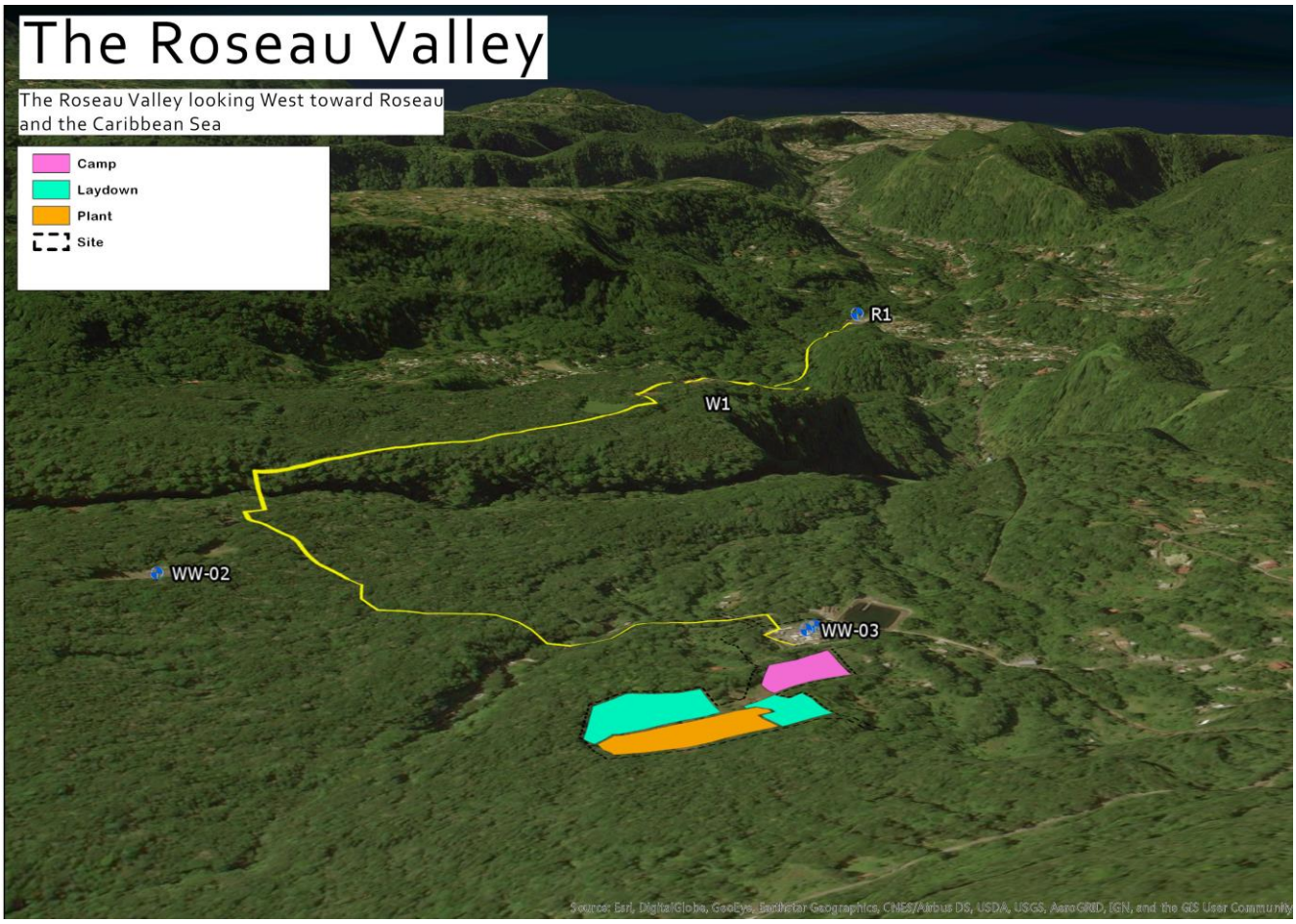


**Figure 1.2 : The Roseau Valley looking west towards Roseau and the Caribbean Sea. The power plant and reinjection pipeline routes are also shown. Source: Google Earth, 2017**

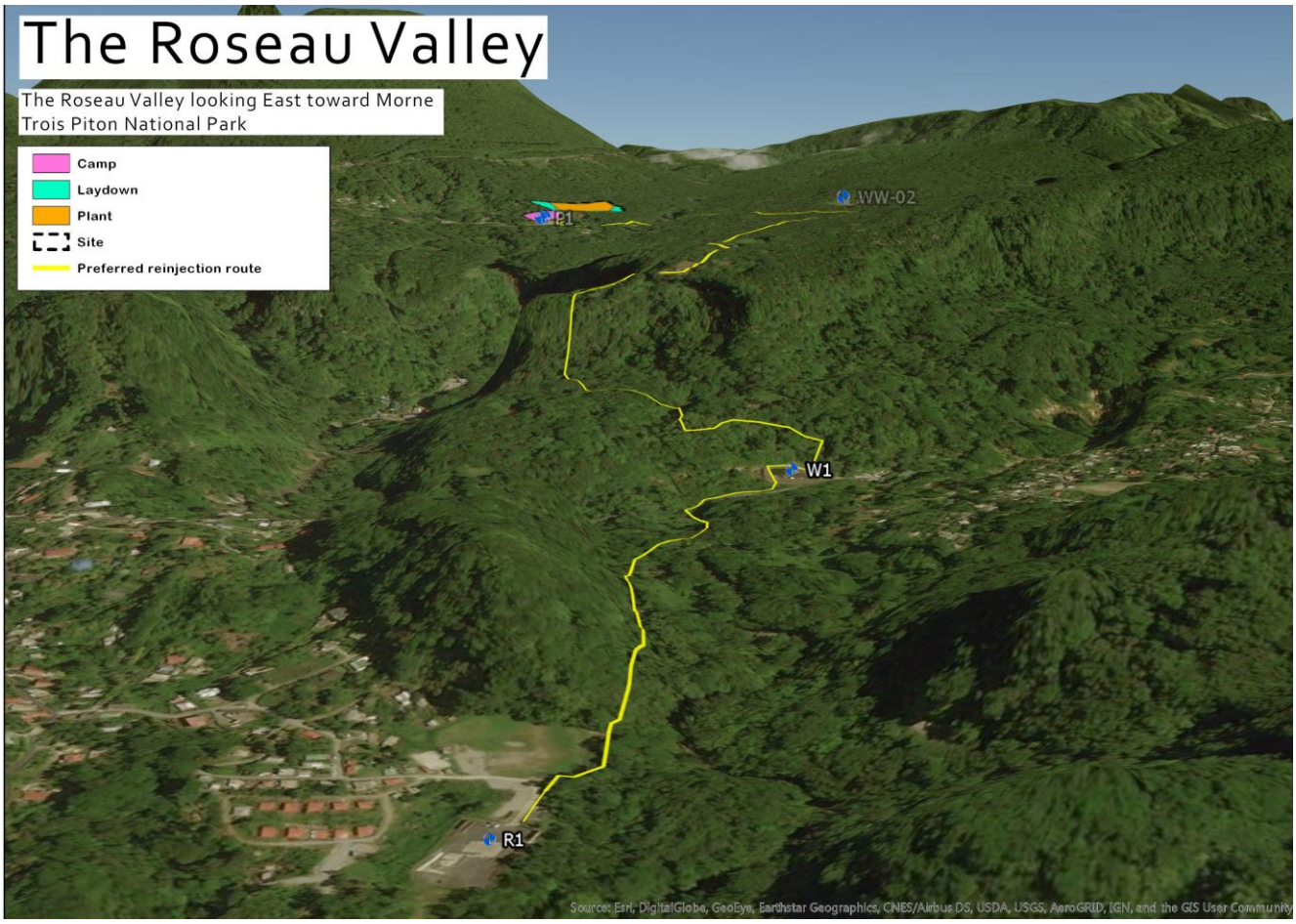


**Figure 1.3 : The Roseau Valley looking west towards Morne Trois Piton National Park. The power plant and reinjection pipeline routes are also shown. Source: Google Earth, 2017**

## 1.5 What will the Project look like?

Geothermal projects typically connect a production well through a steamfield facility to a power plant, which is connected to an electricity grid. Geothermal fluids consist of steam, hot water (brine) and a small quantity of non-condensable gases (mostly carbon dioxide and trace gases including hydrogen sulphide). In this project, steam will be separated from the brine and used to drive a turbine. Used geothermal fluids produced by the geothermal projects (separated brine and steam condensate) are returned to the geothermal reservoir via reinjection wells, which may be located some distance away (i.e. over 1 km) from the production wells to avoid short-circuiting or premature cooling of the production wells.

An aerial image of how the power plant will look is shown below in Figure 1.4. Typical geothermal power plants wellpads, pumps and pipes are shown in Figure 1.5 - Figure 1.7.

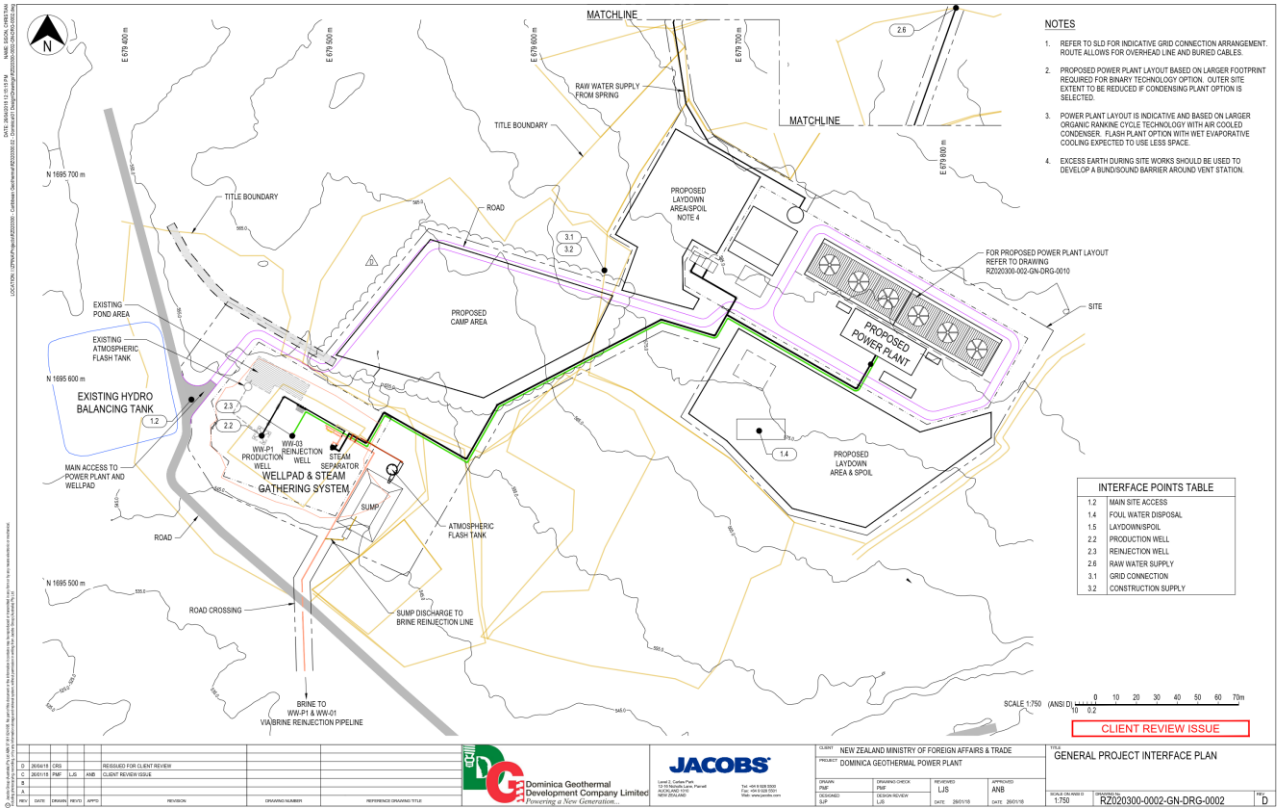


**Figure 1.4 : General Power Plant and Steamfield Layout**



**Figure 1.5 : Typical Wellpads (left and right)**



**Figure 1.6 : Typical Production Well (left) and Reinjection Pipeline (right)**



**Figure 1.7 : Typical Bringe Pump (left) and Cooling Tower only 1-2 cells likely required for Dominica Project (right)**

## 1.6 When will Construction start?

The construction of the project is anticipated to last 18 months to two years, following the indicative schedule below. Construction is anticipated to start in late 2018 or early 2019.

**Table 1.1 : Indicative Construction Schedule**

| Phase | Year 1 | | | | Year 2 | | | |
|---|---|---|---|---|---|---|---|---|
| Off-site preparatory work | ■ | | | | | | | |
| Site preparation | | ■ | ■ | | | | | |
| Foundations for equipment and pipelines | | | ■ | ■ | | | | |
| Powerhouse & permanent buildings | | | | ■ | ■ | | | |
| Major equipment installation | | | | | ■ | ■ | | |
| Interconnecting piping, wiring and instrumentation | | | | | | ■ | ■ | |
| Switchyard and transmission line | | | | | | | | ■ |

The operational life of the geothermal development is anticipated to be 25 years.

## 1.7 What land requirements will there be?

The GoCD has ownership of the existing well pads, however, additional land will be required for the power plant site and for the reinjection pipeline. The land required for the power plant, and hence civil works required to prepare the site, will depend on the power plant technology selected. DGDC and the GoCD will be entering into a land acquisition process with the landowners whose land will be required for the power plant and reinjection pipeline.

The proposed plant layout as presented in Figure 1.4 has a land requirement estimate of 20,000 $m^2$ (2 hectares), for the larger binary plant option – including laydown / spoil areas. Approximately 10% of the power plant site will be concreted and the rest covered with gravel. The remaining areas of the site will be landscaped and replanted.

## 1.8 What will happen during the construction phase?

The majority of the construction activities will be concentrated on the main power plant, switchyard and separator station sites, but other work is required at the individual well-sites and in the piping corridors linking the wells to the power plant. The main activities during construction will include:

- Site preparation involving bulk earthworks, roading, and establishment of temporary construction facilities, security fencing, drainage controls and access control.
- Construction of foundations for major structures, equipment and pipelines.
- Construction of the powerhouse and permanent ancillary and amenity buildings.
- Erection of major and ancillary equipment such as steam-turbine generators, cooling towers, pumps.
- Interconnecting piping, electrical wiring and instrument installation.
- Switchyard and transmission line construction and connection to the grid.
- Construction of the reinjection pipeline, including the use of small drilling rigs for creating foundations, mobile cranes, trucks to transport materials and equipment, generators for pipe welding as well as excavators and trucks for foundation excavations. The felling of trees and other shrubs will be necessary in constructing a reinjection pipe corridor.
- Civil works at three existing well pads (including slope stabilisation, drainage works, fencing, security lighting etc.).

## 1.9 What will happen during the operation phase?

Prior to the plant being brought into operation a range of performance and reliability tests are undertaken. Having completed and passed performance and reliability tests the plant is handed over for commercial operation. This stage is known as ‘commissioning’ and will involve pre-operational testing of the steamfield, power plant and reinjection line.

The operation of the steamfield and power plant covers three phases:

1) **Start-up** - Involves the start-up of production wells and the introduction of steam into the piping systems. Process drain valves are generally left open to remove condensate from the pipes and vessels, draining to storage sumps. Brine from separator vessels and silencers are discharged to the storage sumps at the power plant and separator station locations. Steam is vented to atmosphere through the steam vent valves located at high point vents as well as at the rock mufflers located at the power plant.
2) **Operation** - during normal operation minimal steam venting occurs, the production steam is sent to the power plant and brine is sent to the power plant or directly to reinjection wells. When all power plant systems are in operation, the power plant generates electricity which is exported to the grid.

3) **Shut-down** - May be planned or due to unscheduled maintenance / outage or in some instances may involve a major transmission line outage. During shut-down the unit(s) stops generating electricity for export. The power plant vent valves will emit steam until the production wells are trimmed back to match the required remaining station demand. For a complete station shut-down the steamfield will likely be closed down and the steamfield piping systems will be drained to local storage sumps as well as to the separator stations' and power plant brine sumps. The production well will be either shut in or placed on bleed.

# 2. Description of the Environment

## 2.1 What are the general environmental conditions at the site?

The Commonwealth of Dominica is a small island developing state in the Caribbean Sea with a population of approximately 72,000 people and a land area of approximately 750 km$^2$. The island is the largest and most northerly of the Windward Islands in the Lesser Antilles, lying between Guadeloupe and Martinique. An estimated 60% of the land is classified as the Morne Trois Piton National Park (MTPNP) World Heritage site by UNESCO, due to its rich biodiversity. The capital Roseau is located to the south-west of the island and has a population of around 15,000 people.

The climate of Dominica is tropical all year round, with high temperatures, high humidity and heavy rainfall. The magnitude of variation in ambient temperature is low, generally ranging from 26°C during the day in January to 32°C in June.

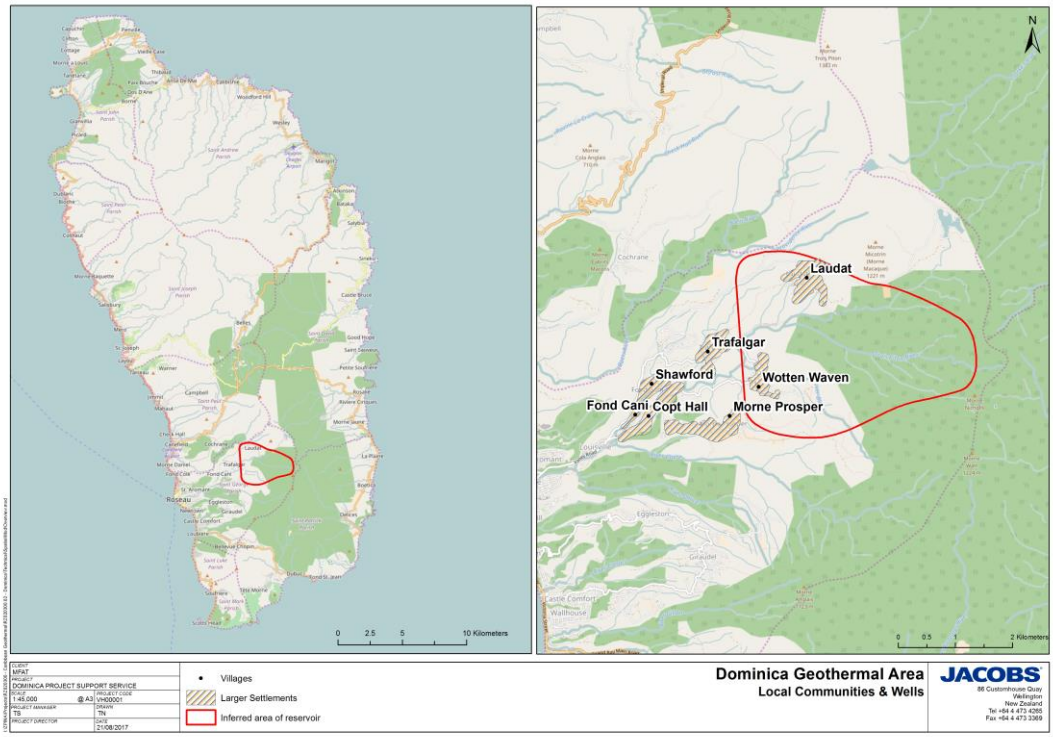


**Figure 2.1 : Location of Roseau Valley (Site of proposed Geothermal Power Plant)**

## 2.2 What is the condition of the physical environmental at the site?

### 2.2.1 Air Quality

The existing air quality in the vicinity of the Project is expected to be generally good, given the relatively low population, absence of heavy industry, and the relatively small size of the island. Sources of air pollution are primarily limited to diesel-fired power generators, traffic, and solid fuel combustion for cooking, etc. As Dominica is a volcanic island there are natural sources of emissions, including steam, carbon dioxide, and hydrogen sulphide, via natural geothermal features such as vents and fumaroles. In some areas the smell of hydrogen sulphide is noticeable.

### 2.2.2 Water

Site investigations and observations of the stream channels indicate that the tropical environment and steep gradients leads to promotion of high velocity flood events with significant erosive force that may put infrastructure at risk during large events. Titou Gorge, the Roseau River and the Blanc River are all watercourses that may be potentially affected by the Project.

### 2.2.3 Geology and Soils

Dominica is a summit of a submerged mountain chain at the eastern edge of the Caribbean Tectonic Plate and consists of almost entirely of volcanic rocks. Soils found are consistent with those found in wet climates and receive a large volume of rain.

### 2.2.4 Natural Hazards

#### Hurricanes

Dominica is located in the hurricane belt and since 1979, tropical systems of note (storms and hurricanes) which have impacted Dominica include David (1979), Gert (1981), Gilbert (1988), Hugo (1989), Iris (1995), Marilyn (1995), Hortense (1996), Lenny (1999), Dean (2007) and Maria (2017).

#### Landslides

Landslides are a potential hazard throughout Dominica and especially in the high rainfall steeper areas. West and South of Morne Micotrin are within the high landslide risk including the entire village of Laudat.

#### Volcanic Eruptions

Dominica is characterised by the presence of volcanoes and historical eruptions and there are nine active volcanoes within Dominica. Frequent volcanic earthquakes and geothermal activity indicate that the island is still underlain by an active magma reservoir system and that future eruptions are highly likely, possibly within the next 100 years. There are a number of volcanic hazards within or adjacent to the Project area including Titou Gorge, the Boiling Lake and the Valley of Desolation.

#### Induced Seismicity and Subsidence

The proposed power plant site is located partially within ‘moderate’ and ‘very low’ earthquake risk areas. The majority of the reinjection pipeline is located within a very low risk area with only the lower section within a moderate risk area. The nearest area classified as having a high risk of earthquakes is located to the south west, 1.5 km from the end of the reinjection pipeline.

### 2.2.5 Geothermal Features

The Roseau Valley contains several geothermal features that are popular tourist attractions. These are listed below:

- Papillote Natural Hot Pools and Cold Mineral Pools (Trafalgar Falls);
- Screws Sulphur Spa Hot Pool (Wotten Waven);
- Tia’s Hot Springs (Wotten Waven);
- Ti Kwen Glo Cho Hot Springs (Wotten Waven);
- Boiling Lake; and
- Valley of Desolation.

### 2.2.6 Landscape and Visual

Dominica is a volcanic island 46 km in length with a central mountain ridge running from Cape Melville in the north to the cliffs in the south. Morne Diablotin, the highest mountain on the island, rises to 1,447 m. There are numerous mountain streams and rivers, with waterfalls and luxuriantly wooded mountains, which has resulted in Dominica gaining the nickname the 'Nature Isle'.

The Roseau Valley is heavily vegetated with various scattered villages present as you travel up the valley from Roseau (Trafalgar, Laudat, Fond Cani and Wotten Waven). The Roseau Valley is characterised by key landscape types such as tropical rainforest, mountain forest, abandoned agricultural land urban villages and connecting roads.

The power plant is situated on disused agricultural land adjacent to patchy secondary growth rainforest. The reinjection line is located in areas of secondary growth rainforest and small-scale agricultural land.



**Figure 2.2 : Typical Landscape types of the Roseau Valley. Left: Dense tropical rainforest, Right: Disused agricultural land with montane rainforest in the background (taken at the proposed power plant site). Source: Jacobs, December 2016**



**Figure 2.3 : Photographs from the Power Plant Site (left and right)**



**Figure 2.4 : Photographs from the Reinjection Line Site (left and right)**

### 2.2.7 Noise

The nearest and most representative affected properties in the surrounding villages are potential receptors for noise generated by the Project: Laudat, Trafalgar, Copt Hall, Shawford, Fond Cani, Morne Prosper and Wotten Waven. Additionally, the following natural locations have been considered as potentially being affected by levels of noise: Boiling Lake, Valley of Desolation and Freshwater Lake (2.5 km north-east of Laudat).

## 2.3 What is the condition of the biological environmental at the site?

### 2.3.1 Freshwater Environment

Overall the water quality appears to be good across sampled rivers (Blanc River and Roseau River) both upstream and downstream of the proposed power plant operations. Ecological state varies and this appears to be especially linked to the flow and season, with poorer ecological conditions observed in the wetter season. However, in drier weather at both Roseau River sites and the Blanc Upstream site the ecology appears to be in a generally good state.

### 2.3.2 Land Animals, Birds and Bats

97% of Dominica's 205 resident and visiting bird species are categorised as Least Concern by IUCN, whilst 2% are Near Threatened, and 3% (equating to 6 species) are Globally Threatened, which comprises the categories: Vulnerable (3); Endangered (2); and Critically Endangered (1). None of these species were recorded during field surveys. Along the Trafalgar transect, 325 individual birds of 26 species were identified during the survey, all of Least Concern.

The same five species endemic to the Lesser Antilles, five are endemic to the Caribbean, and two native to a small number of Lesser Antillean islands were present at all three survey locations. These Dominican endemics/near endemics are the blue-headed hummingbird (*Cyanophaia bicolor*) and plumbeous warbler (*Dendroica plumbea*).

At all locations, field signs of agouti (*Dasyprocta antillensis*) were noted, and common opossum (*Didelphys marsupialis*) and rats (*Rattus rattus*) are reported. Along the Trafalgar transect and at the Wooten Waven and Laudat infrastructure locations, one amphibian was recorded, the Near Threatened tink frog *Eleutherodactylus martinicensis*.

No species which are Threatened or Rare have been recorded in the study area. One such species which is verifiably understood to be present, is the Red-necked parrot, which is determined to be Vulnerable. Habitat supporting this species is considered very important. The species occurs primarily in rainforest canopies, but is known to visit coastal areas to search for food. It is increasingly observed on agricultural land, feeding on citrus, passion fruit and mango plantations.

### 2.3.3 Plants and Habitat

The major vegetation type in all areas surveyed is secondary rain forest at varying stages of succession. Some agricultural habitats were also present, both those currently under cultivation and those apparently abandoned. No rare or threatened plant species were identified in any of the transects or plot-based surveys.

### 2.3.4 Morne Trois Pitons National Park

The Morne Trois Pitons National Park (MTNP) is a site of global importance and one of the world's Key Biodiversity Areas. The MTPNP covers nearly 7,000 ha area of the volcanic island, comprising rugged mountain landscape and deep canyons. It supports at least five species considered Threatened by IUCN: two amphibians, two parrots and one passerine bird. There are five live volcanic centres within the park, the highest of which reaches 1342m. The landscape is scenically striking and features natural hot springs, bubbling mud ponds, lakes and magnificent waterfalls. Within the park are the sources of the southern part of the island's major watercourses.

## 2.4 What is the condition of the economy and communities at the site?

### 2.4.1 The Roseau Valley

The Roseau Valley mainly consists of secondary forest and plantation. The eastern part of the valley tends to be agricultural land (including Wotten Waven and Laudat). The urban areas in the Roseau Valley are particularly concentrated at the entrance to the valley and in the eastern part of the valley.

Eight urban communities exist in the Roseau Valley, organised into independent urban areas: Laudat, Morne Prosper (at the Southern boundary of the study area), Wotten Waven, Trafalgar-Shawford, Fond Canie, Copt hall, Louisville and Silver Lake. Each urban area is organised around a main road with houses distributed along the streets directly leading off.

Tourist accommodation is scattered throughout the valley, notably in Wotten Waven. The urban areas are not scattered sporadically throughout the Roseau Valley and the houses are not aligned but rather distributed between forests, river and roads with varying orientations. There are local shops at crossroads and some informal dwellings (sheet metal and wooden cabins) that may not be properly permitted are regularly observed.

There are 88 total buildings within the 200 m buffer of the plant and reinjection line route (Figure 2.5 and Figure 2.6). It should be noted that these buildings were identified from aerial imagery and therefore may not all be occupied.

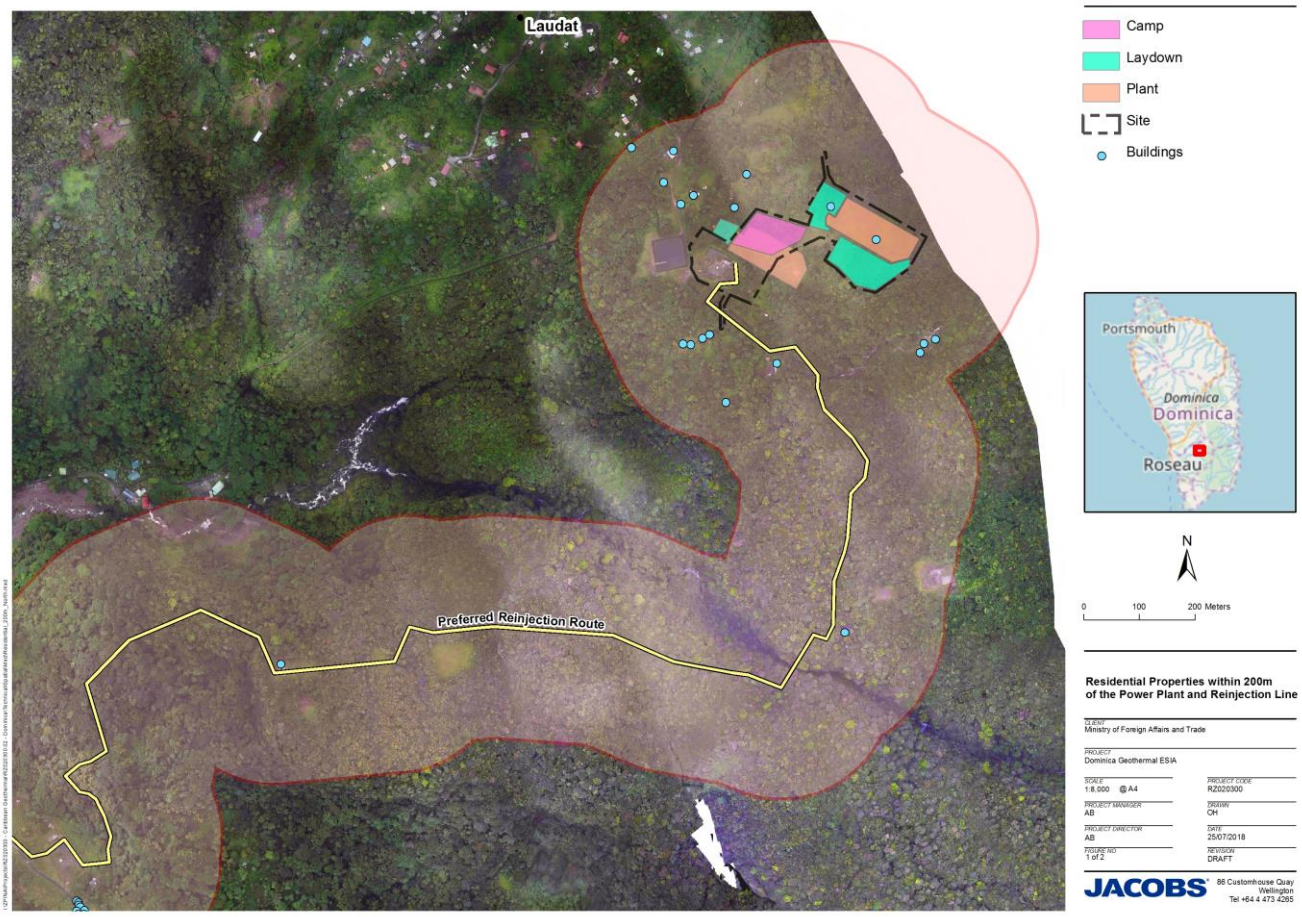


**Figure 2.5 : Buildings within 200 m of the power plant and reinjection pipeline (northern end)**




**Figure 2.6 : Buildings within 200 m of reinjection pipeline (southern end)**

Within the Roseau Valley, three main communities were considered relevant for this study because they were in closest proximity to the proposed Project footprint and represent the main communities that to would be likely to be impacted by any employment, resettlement, community health and safety issues. The communities of Trafalgar, Wotten Waven and Laudat have been identified as the primary area of influence for the social impact assessment. All of these fall within the Roseau Valley and data from the Roseau Valley itself is utilised where appropriate and when more detailed data for each community is not available. Figure 2.7 shows the location of Trafalgar, Wotten Waven and Laudat**.**

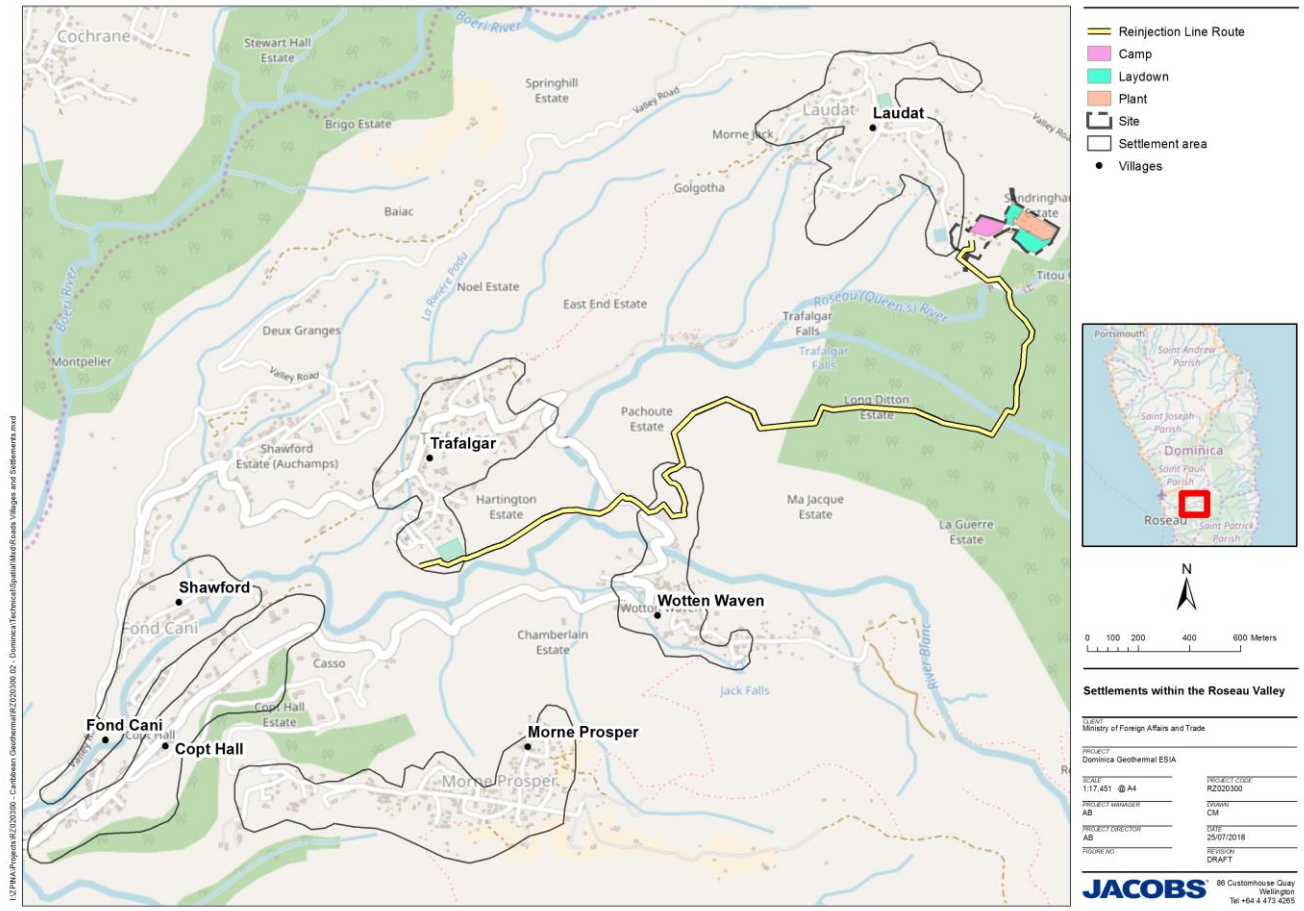


**Figure 2.7 : Settlements within the Roseau Valley**

### 2.4.2 Population

According to the Population and Housing Census of 2011, Dominica's population was 71,293. Between 1991 and 2001, the population of the main townships of Dominica declined, including within the capital Roseau. The population of Dominica shows little increase in general, due to the exodus of people to other countries such as the more prosperous West Indies islands, the United States, the United Kingdom and Canada.

Approximately 1,800 people live in the Roseau Valley, of which nearly 1000 live in Trafalgar and Shawford, and the remaining in the hamlets of Wotten Waven/Casseau, Copthall, and Laudat. According to the 2011 census, the Roseau Valley gained 500 inhabitants between 2001 and 2011, i.e. a substantial increase of 32%. According to the Central Statistical Office, average household size in the Roseau Valley is 2.7

### 2.4.3 People of the Roseau Valley

**Language**

The great majority of the population is of African descent. English is the official language and is understood by everyone, but due to historical French influence, a French-based Creole language is widely spoken. The island is also the home of the last remaining indigenous population of the West Indies – the Caribs – who number 3,000, however they do not reside in the Project area.

**Religion**

Religion is important aspect of life for many Dominicans. The majority consider themselves as Catholic (61.4 %), 7-8 % of the population practice other types of Christianity, 7% are not religious; 6% of the population are 7th day Adventists, 5% Pentecostal, 4% Baptist, 3% Methodist, and approximately 1-3% identify as Rastafarian, Church of God, or other religions. There are several churches in the Roseau Valley representing various religions. They are well-attended and play an important role in the island's social life.

**Gender**

The breakdown of the population by gender in the Roseau Valley is similar to national averages (48% of females and 52% of males, compared to 49% and 51% respectively for Dominica as a whole). There are, nevertheless, a few differences in certain communities such as a slightly higher proportion of females in Copthall (52%) and fewer at Wotten Waven (44%).

**Education**

National school enrolment rates are quite high in Dominica at 97.5% for 5-9 year olds and 98.3% for 10-14 year olds (The Caribbean Development Bank, 2010). According to the Ministry of Education, in 2014, 75 pupils from the Roseau Valley were attending primary school. Approximately 224 students from the Roseau Valley were in Secondary School in 2014. Every village in the Roseau Valley has its own primary school, but pupils must travel to Roseau once they reach secondary school age. This can represent a significant cost for parents, especially for transport.

**Health**

According to 2017 data from the Ministry of Health, 5.5-6% of births in the country were born to residents of the Roseau Valley in 2015-2016. In 2016, 162 people were seen at the Roseau Valley health clinic for issues ranging from hypertension, diabetes, asthma and colds to heart disease and anaemia. Approximately 75% of these patients were women. The death rate in Dominica is relatively low, 8.1-9.5 per 1000 live births between 2010 to 2015. Life expectancy is 77 years (81 for women and 74 for men). The infant mortality rate was 20.8 per 1000 live births in 2015. There were relatively few deaths in the Roseau Valley in 2015, 19 in total. Chronic illnesses recorded in the valley in 2015 included cancer, pneumonia, pregnancy related illness, hypertension, heart disease, motor neuron disease, birth defect, and diseases of the urinary system. Incidences of each were between 1-2 peopleAt least 30 cases of Zika virus were confirmed in Dominica in 2016. According to the CIA Factbook, in 2014 5.5% of GDP was spent on health.

There are three health centres in the valley one in each of the potentially affected communities (Trafalgar, Wotten Waven and Laudat). The Roseau Valley is also close to the capital of Roseau and its health facilities including the Princess Margaret Hospital, which is the country's top health care establishment. The hospital has 224 beds (including 56 in a psychiatric unit) and was recently expanded.

### 2.4.4 Cultural Heritage

The complex and ancient history of human occupation of the island has led to numerous influences on current and past architecture in the Roseau Valley. One example from Wotten Waven includes a water mill dating from the 18th century. However, it is generally considered that the Roseau Valley has few examples of extant historical heritage. Despite the rich and complex history of the island, with its multitude of anthropogenic influences long before the arrival of Europeans in the 15th century, few physical traces are still present. To date, there are no significant archaeological sites in the Roseau Valley.

### 2.4.5 Economy and Tourism

Gross Domestic Product (GDP) estimated in 2016 was 812 million dollars according to the CIA World Factbook. The economy in Dominica used to be primarily driven by agriculture, but has recently shifted towards tourism as

the Government increasingly promotes Dominica as a tourist destination. The income of the residents of Trafalgar, Wotten Waven and Laudat is primarily derived from agriculture, which is comprised of family-based farming for both local consumption and commercial purposes, and tourism. Most of the Roseau Valley residents have several jobs, including employment in the town of Roseau.

The Roseau Valley also includes the Boiling Lake, Waitukubuli National Trail, Middleham Falls, Freshwater Lake and Boeri Lake, the "Dragon's Mouth" (an accessible cave with hot water) and Twin Falls and Middleham Falls in Trafalgar, Titou Gorge, the freshwater lakes, and the various hot springs in Wotten Waven and Papillote, the tropical gardens in the rainforest, and outdoor adventure activities among other attractions.

The villagers are trying to develop regional tourism involving exploration of the wildlife and geothermal resources. Several guest houses and self-catering holiday homes have opened in recent years. Tourist attractions are small in size and employ only a small number of persons. The average unemployment rate in Dominica is about 23%.

The Roseau Valley is a popular tourism site due to its proximity to the Morne Trois Pitons National Park. According to the Ministry of Tourism, tourism is now the main source of income for around 60% of the population according to local elected officials. In addition, many cruise ships that stop for the day in the Port of Roseau allow visitors to visit the Aerial Tram in the Roseau Valley. According to the Tourism Board, in 2008 approximately 590,000 people visited Dominica and the Roseau Valley on one-day organised tours.

### 2.4.6 Transportation

The area observed is characterised by a variety of terrain types ranging from flat areas to steep and mountainous areas with rock formations of which the topography makes driving conditions dangerous. The main road in the Roseau Valley area is Valley Road, which provides a link for traffic between Roseau City and Roseau Valley.

**Cruise Ships**

Cruise ships are a regular occurrence in Roseau during the cruise seasons (November to March) and occasionally there can as much as two or three in the port in a single day. They can range in size from a small ship carrying 100-200 passengers to a 'Royal' class cruise ship holding over 4,000 passengers. The passengers from the cruise ships add to the road network as they tend to travel by either buses or private taxis.

**Public Transport Network**

While no reliable information has been found regarding the public transport network in Roseau, it was found in the traffic surveys that there is a relatively high volume of buses on the network. While not all of these buses are likely to be public – some are most likely from the cruise ship passengers being shuttled to tourist sites. Anecdotally, the public transport services in Roseau runs regularly and are popular with the locals.

**The Waitukubuli National Trail**

The Waitukubuli National Trail is the only large scale marked trail in the East Caribbean and is an important attraction for Dominica's image as the 'Nature Isle'. The Waitukubuli National Trail was officially declared as an eco-tourism site on May 10, 2013, in accordance with the Commonwealth of Dominica Statutory Rules and Orders No. 7 of 2013 National Parks and Protected Areas Regulations. Many tourists visit Dominica to experience a rugged and untouched side of the Caribbean the trail provides a relatively accessible marked route through the entire length of the island.

# 3. Consultation

## 3.1 What consultation has occurred?

During the current Project development phase, a town hall meeting was held in Trafalgar in December 2016 with approximately 40 in attendance to discuss the current project and ESIA. Another town hall meeting was held in Laudat in July 2017 with 43 in attendance. A third town hall meeting was held in Wotten Waven in August 2017. A final townhall meeting will be held to present the findings of the ESIA in June or July 2018.

In order to facilitate further understanding of community needs and conditions, focus group meetings were held in 2016, 2017 and 2018 in Wotten Waven, Trafalgar and Laudat, described in further detail below. Because the total population of the Project AOI is relatively small (approximately 1,600), and given that the general public and many of the focus groups and landowners that would be affected by the Project are the same parties, the four formal public meetings and 15 informal forums held on the Project were considered representative of the community.

A total of 15 focus group meetings were held as part of the ESIA baseline data collection. A meeting with six representative community leaders from all of the potentially affected communities was held in Trafalgar in November 2016 to discuss the Project and the most effective means of stakeholder engagement. Focus groups meetings were also held in June, July and August of 2017 including meetings with representatives of local hotels and resorts, handicraft vendors, hot springs businesses, and unemployed parties in the area. Groups consisted of 5-15 people and targeted questions were asked and recorded.

Five focus group meetings were held in the communities in March 2018 following Hurricane Maria. These included meetings with the community women in Laudat, Wotton Waven and Trafalgar, and vendor meetings in Wotton Waven and Trafalgar, to identify the impacts on the community of Hurricane Maria which hit Dominica in September 2017 and to understand how conditions in the Project area have changed since the ESIA baseline data was collected pre-Hurricane Maria.



**Figure 3.1: Community Meeting in Wotten Waven (December 2016)**

## 3.2 What has the feedback of consultation been so far?

Public perceptions of the Project were varied throughout the stakeholder engagement process. Everyone that was spoken to was familiar with the Project and many had been involved in Project related meetings for many years. The 2015 data showed the community had a number of concerns about the Project, but in 2017 most community members expressed support for the Project (approximately 80%). Concerns expressed in 2017 included:

- Health concerns about the steam and air quality emissions associated with the plant;
- Concerns about odours and impacts on the economy from the Project, particularly the tourism industry;
- Noise concerns; and
- Concerns about proper compensation for land to be acquired.

Post-Hurricane Maria, concerns now include:

- Natural disasters;
- Improvement of infrastructure;
- Livelihood and tourism impacts;
- Emergency response planning; and
- Cultural impacts from influx of workers during construction.

At public meetings, many questions also arose about public shares in the Project Company (DGDC) and the likelihood of adverse effects on the geothermal resource impacting on tourist businesses. Local residents also expressed concerns about plant emergencies and interface with storms and natural disasters. The ESIA process was explained and the methodology to be undertaken for analysis of relevant topics and plans and expectations for the company were also addressed. A Project Grievance Mechanism has been prepared, implemented, and disclosed to the local communites and several complaints have been recorded and addressed to date.

## 3.3 What commitments will DGDC make to address concerns?

Building on stakeholder engagement that has already been completed during the drilling phase, a process of identifying relevant stakeholders that may be directly or indirectly affected by the project was completed. A Stakeholder Engagement Plan (SEP) was prepared for the Project to guide engagement activities for the Project. The objectives of this SEP are to:

- Identify the local legal framework of consultation activities and disclosure requirements, particularly in respect of those public consultation activities that are directly required under the local permitting process;
- Identify potential stakeholders in the area of influence, as well as relevant interested parties such as government agencies and other key stakeholders. Vulnerable groups (elderly, disabled, unemployed) will are also identified as stakeholders
- Record all consultation activities, including those prior to the commencement of the ESIA process;
- Describe how concerns or grievances will be handled via a Grievance Mechanism;
- Provide an action plan for further consultation including at least two meetings bi-annually in each affected community during preparation, construction and operational phases of the Project, including details on appropriate formats for effective and culturally meaningful interaction with the community and relevant stakeholders; and
- Provide a disclosure plan, including the identification of any locations where relevant project documentation will be available locally and elsewhere as well as languages to be used.

The SEP will be revised and updated periodically including upon completion of the ESIA to assist with ongoing engagement throughout the Project.

## 3.4 ESIA Non-Technical Summary Disclosure

The ESIA Non-Technical Summary was disclosed to the communities of the Roseau Valley via three public meetings: one in Laudat, one in Trafalgar, and one in Wotten Waven in the first week of July. Meetings were attended by Jacobs, DGDC, and approximately 20 members of each community. The community had another opportunity to express concerns and ask questions about the Project and ESIA findings. Concerns generally included community health and safety issues, natural hazards, employment and construction impacts. A summary of the issues raised by each community is provided below.

### 3.4.1 Laudat

In Laudat, a community meeting was held on Tuesday 4th July 2018. Concerns expressed by the community included technical questions about the pipeline and public health considerations associated with operations of the plant. Community members also voiced concerns about the risks associated with volcanic activity near the project, equipment failure, and other natural disasters. Community members also expressed the desire to see policy changes associated with the Project and the need for some community benefit projects that would be realised in the community. They also asked about land acquisition and noted that Laudat has been the location for several other projects where few benefits were realised in the local community. The DGDC Team explained the costs and the benefits of the project and the ESIA findings in terms of H2S. DGDC also explained the technology being utilised in the plant and the low risks associated with this type of equipment. The DGDC Team further explained the risks and the planning and design measures that were selected for this project given the topography, risk of landslides and recent flooding from Hurricane Maria and the EPC Contractor requirements that will be put in place to reduce nuisance and community health and safety impacts such as the emergency response and other planning procedures. The current status of land acquisition was also explained and the need to complete compensation before construction can begin, as per OP 4.12. Ongoing monitoring and preventative measures such as the traffic management plan and erosion control measures were also explained. Comments on policy and community benefits were noted, but it was explained that this is ultimately under the control of government and policymakers, rather than the project.

### 3.4.2 Trafalgar

In Trafalgar, a community meeting was held on Wednesday 5th July 2018. Fewer comments were made at this meeting than in Laudat or Wotten Waven, likely because the community is further from the power plant site. The community asked a few technical questions about the distance of the pipeline and natural hazards that could affect the project. They also asked about the proximity to the nearby communities from the power plant and emergency response. The DGDC Team explained the risks and the planning and design measures that were selected given the topography, risk of landslides and recent flooding from Hurricane Maria. DGDC also explained the emergency response and planning procedures that will be put in place for the Project. Examples of other projects where a geothermal plant was located in close proximity to the community were given.

### 3.4.3 Wotten Waven

In Wotten Waven, a community meeting was held on Thursday 6th July 2018. A lot of concern was expressed at the meeting particularly about public health issues, employment, and direct benefits to the community. Specifically, people asked about job requirements, accidents at the plant and/or the pipeline, detrimental effects on thermal spas, the expected lifespan of a well, consumer benefits on electricity bills, health impacts of construction and noise, and property acquisition. A community member also suggested the need for a weekly briefing in the community during the construction phase. The DGDC Team explained the design of the plant and reinjection route given the topography, risk of landslides and recent flooding from Hurricane Maria and to reduce noise and visual affects at properties near the power plant. DGDC also explained the technology being utilised in the plant and the low risks associated with this type of equipment. The lack of changes anticipated for the

thermal surface features were also explained given the depth of the wells and associated activity and the plan to conduct ongoing monitoring of these features was also shared. The DGDC Team further explained in detail the noise associated with the steam blowing phase and the limited timeframe for this testing. The current status of land acquisition was also explained and the need to complete compensation before construction as per OP 4.12.

Following the disclosure of the NTS, the full ESIA will be made available to the community in August 2018 via the internet, a hard copy will be available at DGDC's offices, and additional public meetings will be held and publicised by DGDC.

## 3.5 Is there an opportunity to comment on the Project?

Yes, the following member of the DGDC can be contacted below:

| | |
|---|---|
| **Name** | Allan Toussaint |
| **Address** | DGDC<br>P.O. Box 1454, 18 Kennedy Avenue<br>Roseau<br>Commonwealth of Dominica |
| **Email** | allan.toussaint@geodominica.com |
| **Telephone Number** | 767-448-6178/275-7392 |

# 4. Managing Environmental and Social Impacts

## 4.1 How will the environment be affected during construction?

### 4.1.1 Power Plant

The following impacts have been identified during the construction of the power plant:

- Compaction of the site and exposed topsoil due to deforestation and land clearing/levelling during construction could increase runoff and sediment load, thus requiring some form of treatment or retention of water prior to discharge. However, following the implementation of mitigation measures designed to reduce the impacts of runoff and sediment load (i.e. interceptor ditches/sumps/silt fences etc.), this impact will reduce in significance to acceptable levels**.**
- When vegetation is cleared for the power plant the site soils will be highly susceptible to erosion. The resulting sediment runoff could impact upon the Roseau River water quality through increasing turbidity, reducing clarity and causing deposition of fine sediments. Indirect impacts could also affect the ecology of the river by a range of processes including directly smothering species, changes in habitat and direct impacts of sediment upon fish species. Without erosion or sediment controls in place then there is a potential for potential impacts downstream of the proposed works, through detectable changes to water quality and ecological health. With a well-developed Erosion and Sediment Control Procedure in place (incorporating elements such as staging, clean water diversions, sediment retention etc.), as well as other proposed mitigation measures, it is considered that the impacts resulting from of erosion of soils would be reduce in significance to acceptable levels.
- There is potential for hazardous substances or waste to be accidentally discharged to the environment if inappropriately collected and stored on site. However, following the development of mitigation such as the Hazardous Substances and Waste Management Plan, this impact will be reduced to acceptable levels.
- There will be minor temporary impacts for local residents in relation to noise and dust during construction of the power plant, however, it is anticipated that with appropriate mitigation and monitoring by the Construction Contractor, this will be reduced to acceptable levels.

### 4.1.2 Reinjection Pipeline

The following impacts have been identified during the construction of the reinjection line:

- The earthworks and stream crossings phases of the pipeline construction are considered to be the higher risk activities to the existing water quality and ecology. The stream crossings will involve the placing of pipe bridges above the watercourses. Uncontrolled eroded soil material will cause direct and indirect sediment impacts, as discussed for the power plant location. Direct physical disturbance and additional sediment generation would also occur at stream crossing points. Unmitigated, this is considered to give rise to a potentially significant impacts. With a well-developed Erosion and Sediment Control Plan in place (incorporating elements such as staging, clean water diversions, sediment retention etc.), as well as other proposed mitigation measures, it is considered that the impacts resulting from erosion of soils would be reduced to acceptable levels.
- Temporary removal of terrestrial habitats to accommodate the construction corridor for the reinjection line. During construction, the corridor will be 10 m wide (of which 3-4 m will be permanent loss with an associated loss of 1.4 ha Modified Habitat and 1.7 ha Natural Habitat). Parts of the habitats to be lost could support threatened species but are not considered to be core habitat. The extent of the habitat loss is relatively small, and the vegetation along the reinjection line is expected to regenerate rapidly.
- The Waitukubuli National Trail will be intersected by the proposed reinjection line route adjacent to WW-01. During construction, there will be temporary potential impacts on pedestrians wishing to utilise the trail, leading to potential impacts. Following the implementation of mitigation (such as the development of a

Traffic Management Plan), impacts on non-motorised users of the Waitukubuli National Trail will reduce to acceptable levels.

- During construction, pedestrians and cyclists will be disadvantaged by the general increased level of traffic along the roads being used. This may lead to temporary diversions and minor delays, resulting to potential impacts. Following the implementation of mitigation (such as the development of a Traffic Management Plan), impacts on non-motorised users of the road network will reduce to acceptable levels.

## 4.2 How will the environment be affected during operation?

### 4.2.1 Power Plant

The following impacts have been identified during the operation of the power plant:

- There is potential that the Project may increase subsidence in the Project area as a result geothermal fluid extraction and therefore, prior to mitigation there may be potential. Overall, natural hazards including volcanic activity, landslides and hurricanes present potential impacts to the Project. However, following the application of mitigation incorporated through steamfield design and additional mitigation applied during construction and operation (i.e. Subsidence Management Procedure), the impacts are expected to be reduced to acceptable levels**.**
- Once the power plant is operational, ~2 ha will have a permanent change from soil with forest/scrub cover to a mixture of concrete and gravel pads. The power plants site is anticipated to be 10% concrete and 90% gravel. This will permanently increase localised runoff results in potential impacts, given this will lead to a permanent change in runoff characteristics. However, with additional design mitigation in place, such as stormwater management and drainage, the impact will reduce to acceptable levels.

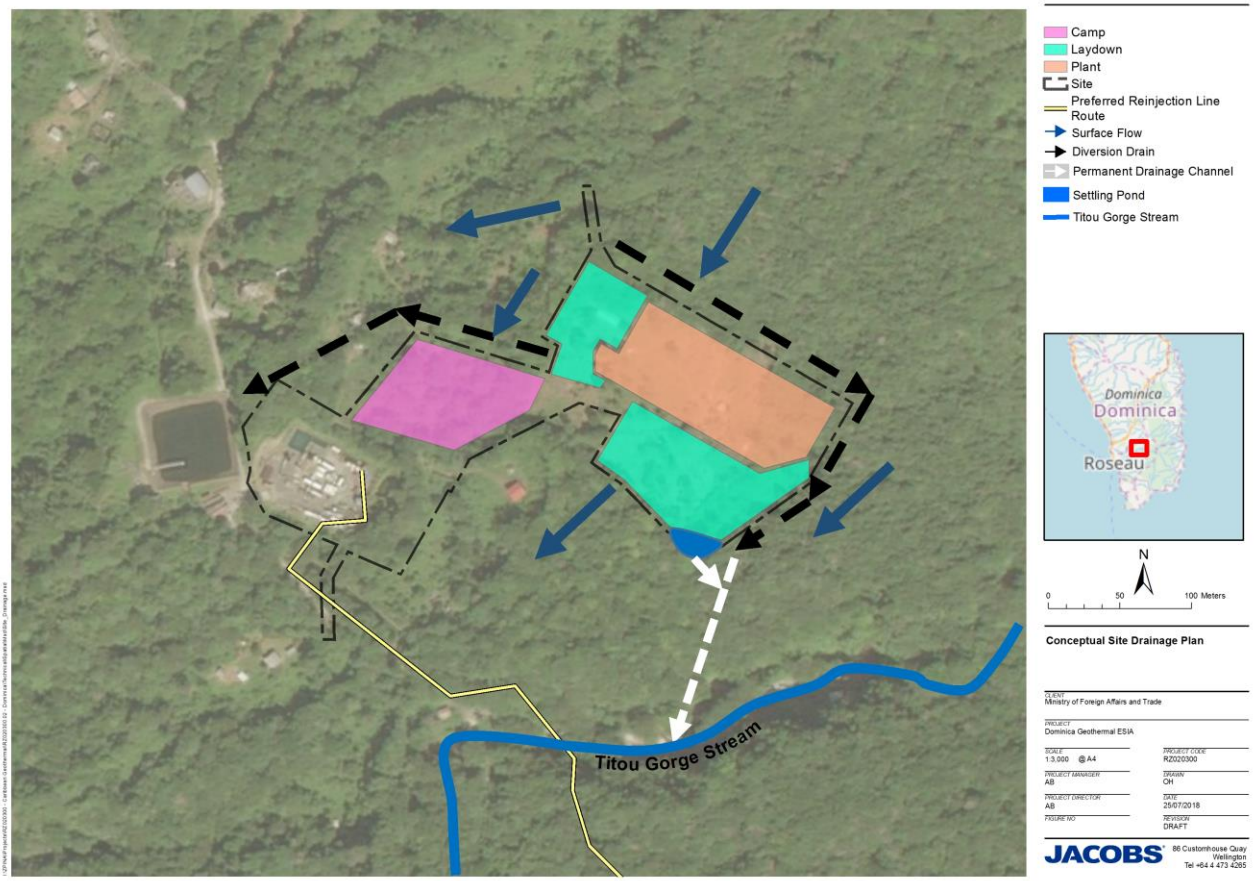


**Figure 4.1 : Conceptual diversion drain and stormwater capture pond**

- During operation there may be a number of properties surrounding the power plant that experience adverse views of the power plant from their properties or when accessing their properties using the existing access road. There are high adverse impacts expected. However, it is anticipated that these adverse views will reduce over time through vegetation growing up around the perimeter of the power plant. Following mitigation measures such as planting regimes and site fencing, the impacts for both the power plant are expected to be reduced to acceptable levels.
- Plant operations are likely to comply with the noise criteria at all surrounding receivers (Figure 4.2). During commissioning works there will be noise impacts at Laudat (south), Trafalgar (east), Trafalgar (south) and Wotten Waven. However, it is understood that commissioning testing will only occur for a relatively short period and following the application of the mitigation measures (operations conducted during daytime periods only; temporary localised screening be installed during steam gathering system operation and commissioning testing), impacts from commissioning activities impacts are considered to reduce to acceptable levels.

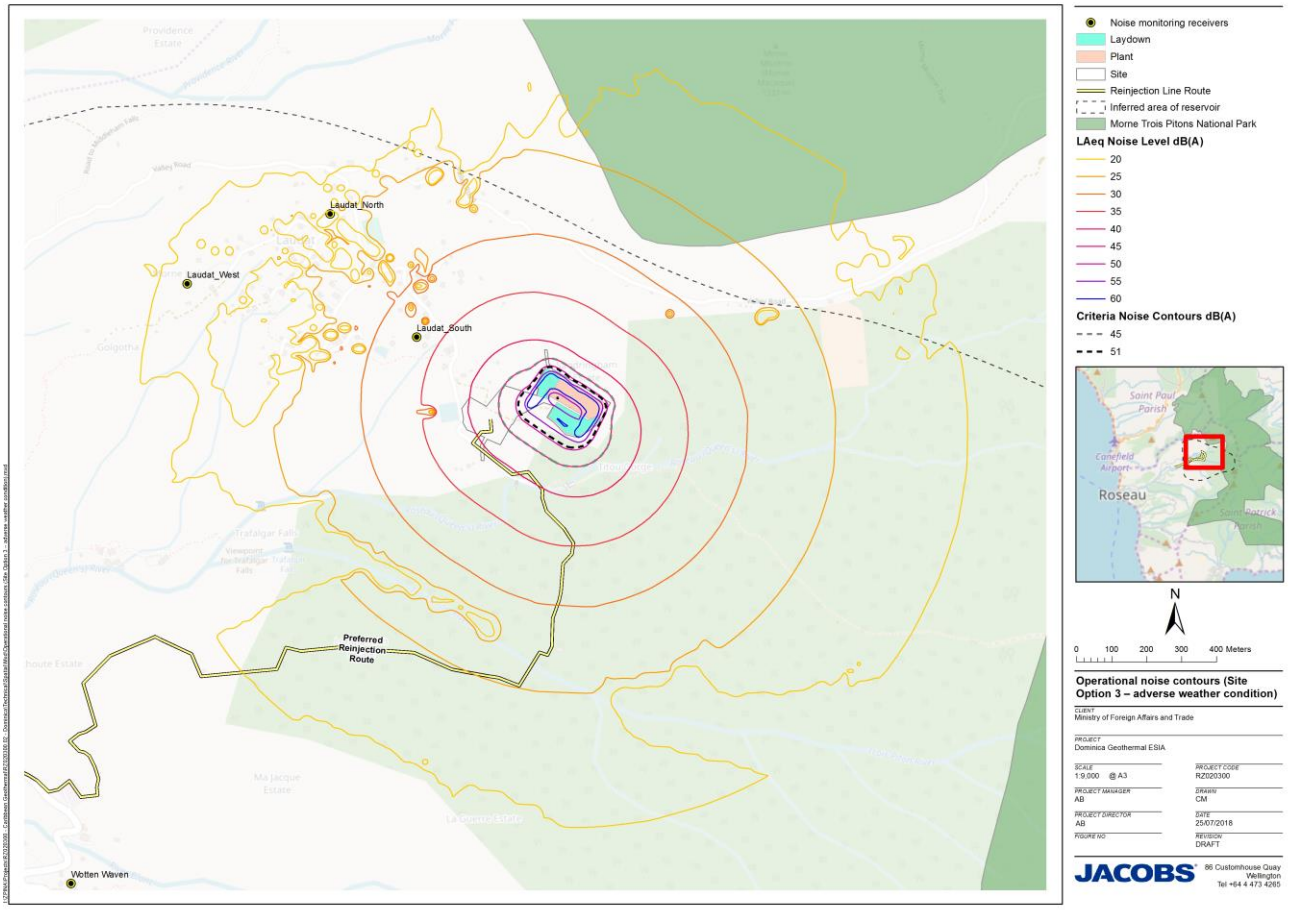


**Figure 4.2 : Predicted noise contours (Adverse weather condition)**

- There is anticipated to be an increase release in $H_2S$ (producing a 'rotten egg smell') as a result of the Project's activities. It is possible that the operation of the power plant could result in a discernible increase in odour from $H_2S$ discharges at residences nearest to the Project area. However, given the active geothermal nature of the area and the existing baseline levels of $H_2S$ in this area, it is unlikely that these would reach nuisance levels. Despite this, ambient monitoring has been recommended to monitor for $H_2S$ during operations, at sensitive locations (e.g. nearby residential areas), using low-level ambient $H_2S$ monitors such as Odalog, which can be deployed at multiple locations for up to two months at a time.

### 4.2.2 Reinjection Pipeline

The following impacts have been identified during the operation of the reinjection pipeline:

- The reinjection pipeline will be at some risk from flooding. The torrential downpours, annual rainfall >8,000 mm/year (in the upper mountains) and steep nature of the catchments result in a flashy system with high peak flows and velocities. Subsequently, any pipe crossings (pipe bridges) over waterways will be at risk from potential flood impacts in terms of high water levels and debris carried with these flows (modelling in the ESIA showed this - Figure 4.3). This could cause significant damage or loss of certain areas of the pipeline and is a critical component to the ongoing success of the power plant and energy supply in Dominica. This is a potential impact to the Project's operability and is considered significant, given this would critically affect infrastructure and lead to plant shut downs. With recommended detailed design mitigation measures in place to reduce the risk of flooding and debris strike, impacts for the reinjection pipeline are to reduce to acceptable levels.

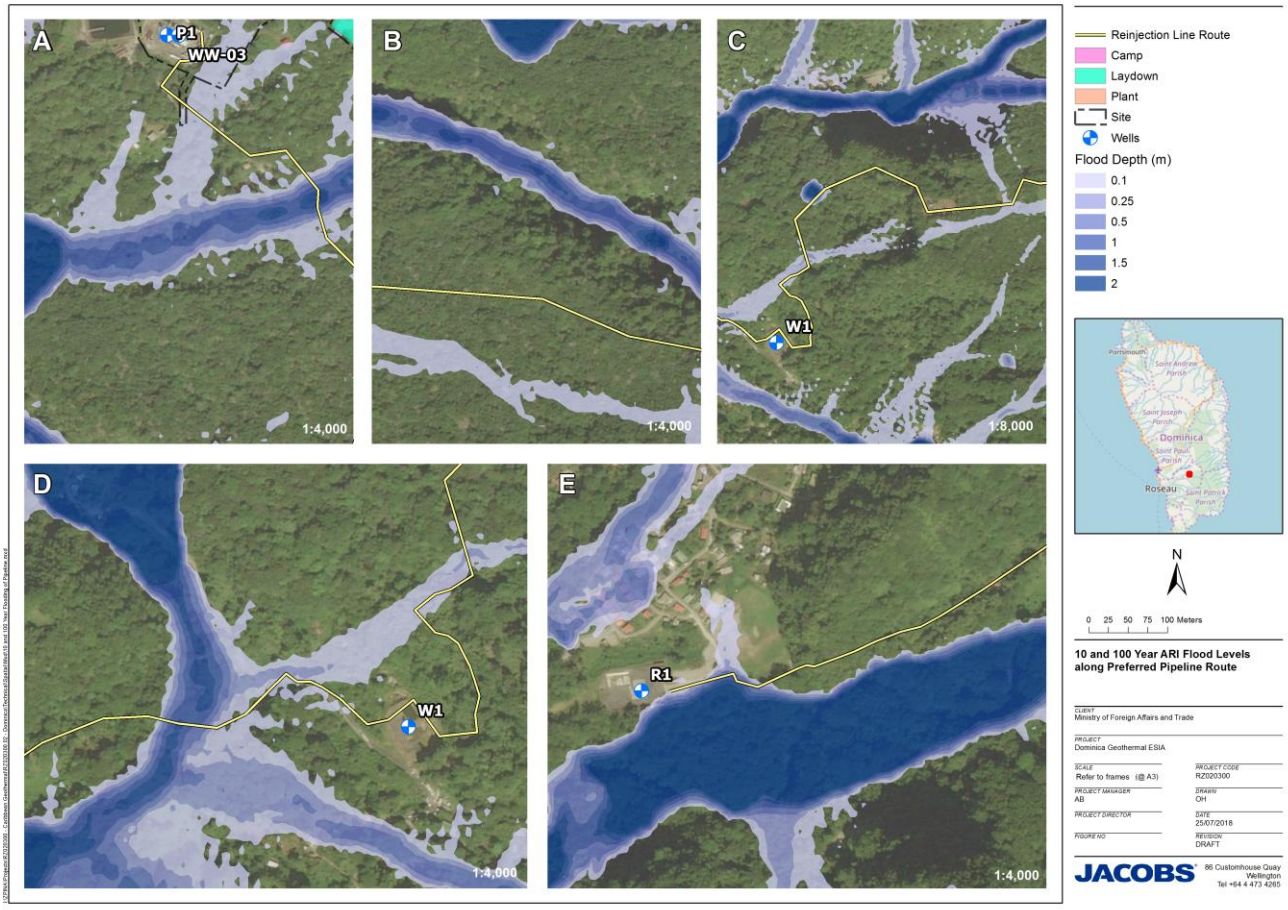


**Figure 4.3 : 100 yr ARI 12 hour flood water levels and the at risk areas of preferred pipeline route.**

## 4.3 What about the potential for natural hazards?

Of particular note when considering natural hazards is the devastating effects that Hurricane Maria brought to Dominica and the increased likelihood of landslides following the event. Based on the location and nature of the proposed Project and natural hazards identified within the vicinity of the Project area, overall potential impacts are considered to be significant. The impacts from natural hazards as result of the proposed Project following the application of mitigation incorporated through steamfield design and additional mitigation applied during construction and operation (i.e. an ESCP including a Landslide Management Procedure), the impacts are expected to be reduced and are therefore not significant.

## 4.4 How will the people be affected?

### 4.4.1 Construction

The social impacts associated with the Project during construction are summarised as:

**Employment**

It is likely that 30 to 40 workers will be the power plant site at the peak of construction and a team of 10 to 15 working on the pipeline. These workers are likely to be sourced from outside of Dominica. The majority of employment during construction is likely to be short-term and significant employment opportunities for local communities would be limited. The unskilled and semi-skilled workforce is anticipated to generally come from the local area, but accommodation in the form of a worker's camp will be developed on the site to house mainly expat and out of town workers for the duration of construction to minimise traffic trips to the site from Roseau. There is the potential for women to be disproportionately affected as many of the construction jobs will be geared towards men. The Project will have a beneficial impact on employment during construction in the Roseau Valley. Additional jobs created indirectly (through retail, hospitality, transportations etc.) would also bring minor beneficial impacts for employment in the local area. Furthermore, the GoCD has committed to funding some community development initiatives along with development of the power plant, which will provide further benefits to the community.

**Land Acquisition**

For construction of the power plant and re-injection route pipeline, approximately 13 properties would need to be acquired including some structures, in consisting of 2-3 residences. Some farming is presently occurring on at least three of the proposed sites.

Of the potential 13 properties to be acquired, physical displacement of structures in approximately three affected properties are predicted to occur as a result of the Project, which will be permanent. Impacts of this nature can result in poverty and / or dislocation of communities and the severance of extended support networks. Post-Hurricane Maria, impacts to any vulnerable parties may be even more severe. If not mitigated appropriately and early, resettlement impacts can cause great controversy and result in significant public objections, time delays and considerable cost overruns for the Project.

For proposed land acquisitions and resettlement associated with the Project, an Abbreviated Resettlement Action Plan (ARAP) has been developed in consultation with affected parties. The ARAP will provide resettlement sites where appropriate and / or cash compensation and livelihood restoration measures including consideration of those considered to be severely affected and or vulnerable.

In the long-term, impacts are expected to decrease further as affected people realise some of the benefits of compensation and livelihood restoration initiatives, and as the other mitigation and monitoring measures are implemented along with community development initiatives.

### 4.4.2 Economic Displacement and Livelihood Impacts

Along with experiencing physical displacement, some of the parties affected by resettlement for the proposed power plant site and the reinjection pipeline route will experience economic displacement effects as many of the affected properties include agricultural crops, livestock, and trees.

Ecotourism resources could also be affected including thermal spas, medicinal plants, handicrafts, and water related resources. The Project could potentially have a negative impact on water resources in the area, which would in turn affect ecosystem services. Post-Hurricane Maria, impacts to any vulnerable parties may be even more severe.

The additional livelihood impacts that could result from impacts to agriculture and livestock as well as ecosystem services would be considered minor prior to mitigation.

### 4.4.3 Impacts to Tourism

Project impacts to tourism could result from roadway access restrictions during construction restricting access for visitors in the Valley; potentially adverse effects to the World Heritage site or geothermal features in the Roseau Valley; and potentially beneficial impacts to local tourism businesses due to increased activity during construction and operations.

Women, in particular, tend to work as vendors in the tourism industry and may be disproportionately impacted by any effects on the tourist industry that would result from the Project. As such, it will be particularly important that any proposed mitigation measures specifically consider additional opportunities for women.

As a result of all of the above both adverse and beneficial impacts to tourism combined, a minor impact on tourism businesses in the community would still be anticipated.

### 4.4.4 Community Health, Safety and Security Impacts

Dust and noise related nuisance impacts from construction are anticipated to be short-term. $H_2S$ concentrations during operations are predicted to be well below World Health Organisation (WHO) thresholds of observed adverse effect levels. Overall health impacts of the Project are therefore considered to be negligible and the life expectancy of 77 years in Dominica is not anticipated to change as a result of the proposed Project.

Community safety impacts from increased roads and traffic and associated safety risks would be considered to have a potential impact of moderate. However, impacts would likely be short-term and localised and risks would be highest during the peak construction period. Children and other vulnerable people and livestock may be more susceptible to traffic risks as elderly, children, and those with existing health problems would likely be most susceptible to the community health risks. With the mitigation measures the impacts are expected to be reduced to an acceptable level.

## 4.5 What will the key mitigation and monitoring for the project to protect the people and the environment of the Roseau Valley?

The Construction Contractor and DGDC will ensure that mitigation and monitoring practices are undertaken during construction and operation of the Project. This will help reduce any adverse impacts on the environment or the communities of the Roseau Valley. Various plans and procedures will be developed for mitigation and monitoring practices. These will include those related to the following topics:

- Pest and weed management;
- Biodiversity restoration;
- Waste management;
- Hazardous substance management;
- Soil and erosion management;
- Air quality/dust management;
- Environmental and social monitoring;
- Stakeholder engagement;
- Grievance mechanism (community and workers);
- Emergency preparedness and response;
- Noise and vibration management;

- Recycling plan;
- Landscape management;
- Subsidence risk management;
- Landslide stabilisation risk management;
- Occupational safety and health management; and
- Traffic management.

## 4.6 Conclusion

This ESIA summarises a large amount of technical work undertaken to assess the impacts of the proposed Project. The ESMP sets out mitigation and monitoring actions that address the key environmental and social impacts identified in the analysis. Control measures will be implemented through a Project Environmental and Social Management System to ensure that the environmental and social impacts of the Project are acceptable and in compliance with the Dominican legislation and international guidelines.

Dominica Geothermal Development Company Limited
*Powering a New Generation...*

JACOBS

# Dominica Geothermal Development - Environmental and Social Impact Assessment

NZ Ministry of Foreign Affairs & Trade

## ESIA Volume 1: Introduction

RZ020300-002-NP-RPT-0004 | 21

July 2018



# Dominica Geothermal Development – Environmental and Social Impact Assessment

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| | | | | | |
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# Glossary

| Term | Description |
|---|---|
| Baseload power plant | Electricity-generating units that are operated to meet the minimum load on the electricity supply system. |
| Binary-cycle plant | A geothermal electricity generating plant employing a closed-loop heat exchange system in which the heat of the geothermal fluid (the "primary fluid") is transferred to a lower-boiling-point fluid (the "secondary" or "working" fluid), which is thereby vaporised and used to drive a turbine/generator set. |
| Brine | A geothermal solution containing appreciable amounts of sodium chloride and/or other salts. |
| Commercial Operation Date (COD) | The date after which all testing and commissioning has been completed and the developer can start producing electricity for sale. |
| Condensate | Liquid water formed by condensation of steam. |
| Condenser | Equipment that condenses turbine exhaust steam into condensate. |
| Cooling tower | A structure in which heat is removed from hot condensate through heat exchange with air. |
| Drilling | Boring into the Earth to access geothermal resources, usually with oil and gas drilling equipment that has been modified to meet geothermal requirements. |
| Dry steam | Superheated steam without a water phase. |
| Efficiency | The ratio of the useful energy output of a machine or other energy-converting plant to the energy input. Technology with a higher efficiency will require less energy to do the same amount of work. |
| Emission | The release or discharge of a substance into the environment; generally, refers to the release of gases or particulates into the air. |
| Enthalpy | A measurement of energy in a thermodynamic system. It is the thermodynamic quantity equivalent to the total heat content of a system. It is equal to the internal energy of the system plus the product of pressure and volume. |
| Fault | A fracture or fracture zone in the Earth's crust along which slippage of adjacent rocks has occurred. |
| Flash plant | Pressure vessels designed to effectively separate flash steam from the liquid phase. |
| Flash steam / Flashing | Steam produced when the pressure on a geothermal liquid is reduced. Also called flashing. |
| Geothermal energy | The Earth's interior heat made available by extraction of geothermal fluids. |
| Geothermal power plant | A facility which uses geothermal steam or heat to drive turbine-generators to produce electricity. Three different types make use of the various temperature ranges of geothermal resources: dry steam, flash and binary. |
| Geothermal reserves | Energy from a geothermal resource that is commercially recoverable now |
| Geothermal reservoir | A large volume of underground hot water and steam in porous and fractured hot rock. The hot water in geothermal reservoirs occupies only 2 to 5% of the volume of rock, but if the reservoir is large enough and hot enough, it can be a powerful source of energy. Geothermal reservoirs are sometimes overlain by a layer of impermeable rock. While geothermal reservoirs usually have surface manifestations such as hot springs or fumaroles, some do not. |
| Geothermal resources | A resource of geothermal nature which requires further work to be classified as a geothermal reserve. |

| Term | Description |
|---|---|
| Geothermal well | Geothermal production and injection wells are constructed of pipes layered inside one another and cemented into the earth and to each other. This protects any shallow drinking water aquifers from mixing with deeper geothermal water. |
| Injection | The process of returning spent geothermal fluids to the subsurface; also referred to as reinjection. |
| Injection well | A well through which geothermal water is returned to an underground reservoir after use. |
| Kilowatt (kW) | One thousand watts of electricity (power). |
| Kilowatt hour (kWh) | One thousand watthours (energy). |
| Megawatt (MW) | A unit of power, equal to a thousand kilowatts (kW) or one million watts(W). The watt is a unit of power (energy/time), the rate energy is consumed or converted to electricity. Assessment of the energy in geothermal systems is commonly in terms of equivalent electrical power or MW, which takes into account the efficiency of conversion. |
| Megawatts under wellhead | A technical measure of the supply of geothermal fluids available at the well head valve, presented in megawatts of electrical energy as proven through testing. |
| Morne Trois Pitons National Park (MTPNP) World Heritage Site | A World Heritage Site is a natural or man-made site or structure recognised as being of outstanding international importance by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) and therefore designated as a site deserving of protection under international treaties. |
| Operations and maintenance (O&M) cost | Operating expenses are associated with operating a facility (e.g. engineering costs). Maintenance expenses are that portion of expenses consisting of labour, materials, and other direct and indirect expenses incurred for preserving the operating efficiency or physical condition of utility plants that are used for power production, transmission, and distribution of energy. |
| Permeability | The capacity of a substance (such as rock) to transmit a fluid. The degree of permeability depends on the number, size, and shape of the pores and/or fractures in the rock and their interconnections. It is measured by the time it takes a fluid of standard viscosity to move a given distance. |
| Production well | A well through which geothermal water, brine and steam is extracted from an underground reservoir to use in the generation of electricity. |
| Proven geothermal reserves | Defined as the electricity that can be generated and sold with reasonable certainty over the project life. Commonly used units are Mega Watt-hour. |
| Separator | A pressure vessel used to separate water and steam, normally by centrifugal action. |
| Slim hole | A geothermal exploration well which is drilled at a smaller diameter than a standard production well. |
| Steam | The vapour form of water that develops when water boils. |
| Subsidence | A sinking of an area of the Earth's crust due to fluid withdrawal and pressure decline. |
| Surface Exploration | Scientific activities to investigate the geothermal reservoir using non-invasive techniques. Typically surface exploration will include geology, geochemistry, geophysics and aerial surveys. |
| Transmission line | Structures and conductors that carry bulk supplies of electrical energy from power-generating units. |
| Turbine | A machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction, or a mixture of the two. |
| Well logging | Assessing the geologic, engineering, and physical properties and characteristics of geothermal reservoirs with instruments placed in the wellbore. |
| Wellhead pressure | A measure of the pressure of geothermal fluids being produced by the geothermal reservoir as measured at the valve opening from the wellhead. |

# List of Abbreviations

| Acronym | Meaning |
|---|---|
| ADEME | Agence de l'Environnement et de la Maîtrise de l'Energie |
| aMSL | Above Mean Sea Level |
| CITES | Convention on the International Trade in Endangered Species of Wild Fauna and Flora |
| DFID | United Kingdom Department for International Development |
| DGDC | Dominica Geothermal Development Company Limited |
| DOMLEC | Dominica Electricity Services Limited |
| DOWASCO | Dominica Water and Sewerage Company Limited |
| EDV | Emergency Dump Valves |
| EHS | Environmental Health and Safety |
| EIA | Environmental Impact Assessment |
| EP | Equator Principles III (2013) |
| EPC | Engineer, Procure and Construct |
| ESIA | Environmental and Social Impact Assessment |
| ESMP | Environmental and Social Management Plan |
| ESMS | Environmental and Social Management System |
| FCS | Fond Cole Power Station |
| FDI | Foreign Direct Investment |
| GoCD | Government of the Commonwealth of Dominica |
| GRG | Geothermal Resource Group |
| IFC | International Finance Corporation |
| IRC | Independent Regulatory Commission |
| ÍSOR | Íslenskar Orkurannsóknir |
| kV | Kilovolt |
| kW | Kilowatt |
| LHS | Laudat Hydro Station |
| MW | Mega Watt |
| NCG | Non-Condensable Gas |
| NDT | Non-Destructive Testing |
| NTS | Non-Technical Summary |
| OECS | Organisation of Eastern Caribbean States |
| ORC | Organic Rankine Cycle |
| PCV | Pressure Control Valves |
| PHS | Padu Hydro Station |
| PS | Performance Standard |
| RPS | Regional Partnership Strategy |
| SEP | Stakeholder Engagement Plan |
| SSI | Silica Saturation Index |

| Acronym | Meaning |
|---|---|
| THS | Trafalgar Hydro Station |
| ToR | Terms of Reference |
| WBG | World Bank Group |
| WHP | Well Head Pressure |

# Important note about your report

The sole purpose of this report and the associated services performed by Jacobs New Zealand Limited ("Jacobs") is to describe the Environmental and Social Impact Assessment (ESIA) for the Dominica Geothermal Power Project development in accordance with the scope of services set out in the contract between Jacobs and the New Zealand Ministry of Foreign Affairs and Trade (the Client). That scope of services, as described in this report, was developed with the Client, the Government of the Commonwealth of Dominica (GoCD) and the Developer (Dominica Geothermal Development Company (DGDC) established and owned by the GoCD).

Jacobs has been contracted by the Client to undertake the conceptual design and overall project definition through their engineering team. In preparing this ESIA report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided. Except as otherwise stated in the ESIA report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced as noted in the ESIA volumes and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of, Jacobs' Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party. However, Jacobs may be able to extend reliance on this report to a third party provided that the third party enters into a third party reliance agreement with Jacobs on Jacobs' terms.

# 1. Introduction

## 1.1 Purpose

This Environmental and Social Impact Assessment (ESIA) has been prepared, in accordance with local legislation and international lending institution safeguards, to assess the environmental and social impacts and risks of the Dominica Geothermal Power Project Development (referred to hereafter as the 'Project') located in the Roseau Valley, Dominica. The Project comprises the construction, completion, testing, commissioning, ownership and operation of geothermal wells, steam gathering and reinjection system, power plant with capacity of 7 MW and connection to electrical grid and associated infrastructure.

## 1.2 Project Background

### 1.2.1 Project Progress to Date

The Commonwealth of Dominica is a small island developing state in the Caribbean Sea with a population of approximately 71,293 people (pre-Hurricane Maria 2011 census) and a land area of approximately 750 km$^2$. About 60% of the land is classified as a World Heritage site by UNESCO, due to its rich biodiversity. It is located near the centre of a string of islands known as the Lesser Antilles, between the neighbouring French territories of Martinique and Guadeloupe. The capital Roseau is located to the south-west of the island and has a population of around 15,000 people (Figure 1.1).

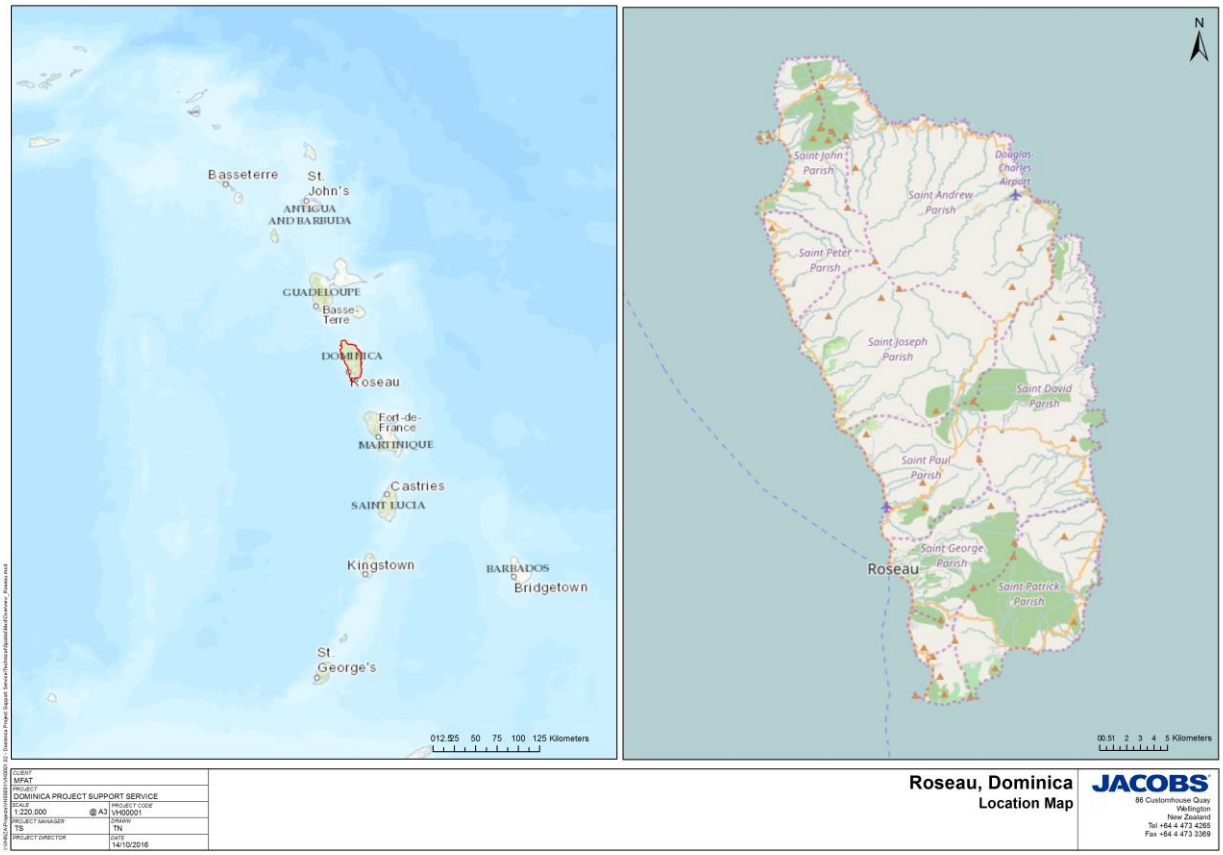


**Figure 1.1 : Dominica's location in the Caribbean**

As with many other island nations, Dominica's primary source of electricity production is from diesel generation, which exposes the country's economy to uncertainty in regard to the cost and supply of diesel imports. Changing the power generation mix and reducing the cost and volatility of electricity prices have become development priorities for Dominica. Being a relatively young volcanic island, Dominica has significant geothermal resource potential. Therefore, since 2006 the Government of the Commonwealth of Dominica (GoCD) has pursued an exploration programme to evaluate the viability of geothermal resource in the Roseau Valley (Figure 1.2).

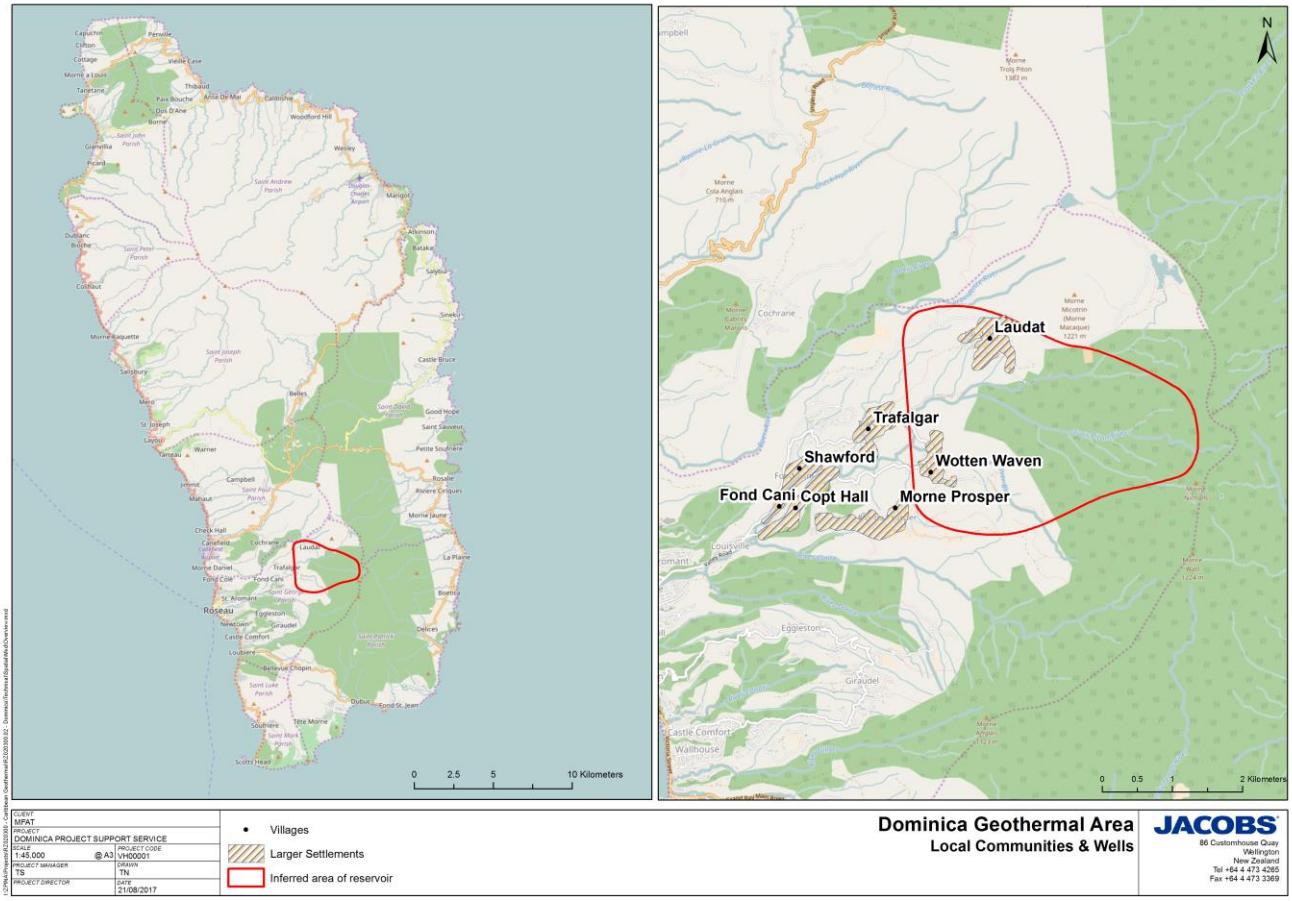


**Figure 1.2 : Location of Roseau Valley and Inferred Area of Geothermal Reservoir (Site of proposed Geothermal Power Plant)**

The exploration programme has been conducted in a phased manner over the course of approximately 10 years and is summarised in Table 1.1.

**Table 1.1 : The phases of the Dominica geothermal exploration programme**

| No. | Phase | Activities | Status |
|---|---|---|---|
| 1 | Preparation | Project establishment, geoscientific investigations | Complete |
| 2 | Exploration | Exploration drilling of three slim hole wells and resource assessment | Complete |
| 3 | Production & Testing | Production drilling and testing of one full size well and drilling of one reinjection well | Complete |
| 4 | Planning / Construction | Present phase comprising power plant and reinjection pipeline construction and start-up | Ongoing |

The geothermal project started as part of the European Cooperation Programme INTERREG III-B Caribbean space, in partnership with the Regional Councils of Guadeloupe and Martinique, the 'Agence de l'Environnement et de la Maîtrise de l'Energie' (ADEME), the 'Bureau de Recherches Géologiques et Minières' (BRGM) and the French company 'CFG Services'. The geothermal study area of interest was identified in June 2008 by BRGM after evaluation of resources and exploratory drilling programme. Focused on the Roseau Valley geothermal field, and located about 8 km east north-east of the Capital of Roseau, it includes part of the high temperature reservoir (210-230°C) (Figure 1.2).

To prove the existence of a viable geothermal resource, an exploratory phase was launched between 2011 and 2012 and involved the drilling of three test (slim) wells in the villages of Wotten Waven (well site WW-01) and Laudat (well sites WW-02 and WW-03). The final drilling depths were between 1200 m and 1613 m and confirmed the presence of a geothermal resource with a 50% probability of having sufficient capacity for approximately 65 MW of power generation.

The next phase of the project commenced in 2013, included drilling and testing of two full size production wells, with a view to developing a 10-15 MW small geothermal power plant. It comprised the installation of a production platform, drilling and testing a production well in Laudat (WW-P1) and a re-injection well in Trafalgar (WW-R1). The drilling of these two full-size wells, with a depth comprised between 1501 m and 1915 m, was completed in 2014.

The GoCD is now proceeding with the planning and construction phase of the Project, establishing the Dominica Geothermal Development Company Ltd (DGDC), which is tasked with developing and operating a 7 MW geothermal power plant. DGDC will sell electricity to DOMLEC under the regulatory framework established through the Electricity Supply Act 2006. DGDC will operate as a private company under the laws of the Commonwealth of Dominica.

Financing for the Project has been arranged by the World Bank and include: $17.2 million IDA credit (principal source of funding); $10 million from CTF including a $1 million grant and $9 million contingent finance; and grants from DFID ($10 million) and SIDS DOCK ($2 million), both channelled through the World Bank. New Zealand has provided a parallel 'in-kind' grant covering project preparation costs and sponsoring the position of DGDC Project Manager.

### 1.2.2 Previous Environmental and Social Work Completed

The Project benefits from having a wealth of environmental studies data collected for environmental assessments for exploration and drilling phases. To date the following environmental and social studies have been completed:

- Caraïbes Environnement Développement & Coll (2009) Regulatory Impact Assessment on the Initial Environment - Environmental Feasibility Study;
- Caraïbes Environnement Développement & Coll (2011) Stage 1: Exploration Drilling Process – Environmental Impact Assessment; and
- Caraïbes Environnement Développement & Coll (2013) Stage 2: Preliminary Environmental Impact Assessment of Geothermal Production and Re-Injection Drilling Wells in Dominica – Environmental Impact Assessment.

To support the preparation of an ESIA for the Project, baseline surveys of the social, physical and biological environment within the Roseau Valley were completed between October 2013 and April 2015. These were summarised in the following reports (collectively referred to as the 'Baseline Study'):

- Caraïbes Environnement Développement & Coll (2015a) Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production. Final report, May 2015. Section 3 Biodiversity / Terrestrial Flora and Fauna; and
- Caraïbes Environnement Développement & Coll (2015b) Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production. Final summary report.

As part of the work undertaken by Jacobs in the ESIA Terms of Reference (TOR), a review of these previous studies was carried out (provided for reference in Appendix C). Further details of these studies are provided in Volume 2 – Environmental Impact Assessment.

### 1.2.3 Hurricane Maria

The ESIA was originally finalised and submitted to the World Bank for comment in early September 2017. However, on 18 September 2017 Hurricane Maria (a Category 5 Hurricane) made landfall in Dominica. The hurricane devastated the island and fundamentally changed the environmental and social baseline (Figure 1.3). The assessment of impacts of the Project in the draft ESIA (submitted September 2017), were originally based on the environmental and social baseline in the Roseau Valley prior to Hurricane Maria. As such, a revision of the ESIA in the 'Post-Maria' scenario was required and was undertaken in March 2018.

**Environmental Indicators**

Some of the environmental indicators will be in a more degraded state than the 'Pre-Maria' situation. This may result in the impacts of the geothermal plant changing from that initially assessed (i.e. some impacts will be reduced and others increased). It was determined to be unrealistic to attempt collect detailed new environmental baseline data and re-evaluate the impacts. The situation in Dominica remains dynamic and trying to evaluate the impact of the Project against the rapidly occurring natural changes is unlikely to provide a sufficiently robust basis to evaluate which mitigation to implement or its effectiveness. In many cases, the logical outcome of this approach would be that the Project will improve the natural environment and as such no mitigations are required.

As part of the ESIA, additional desk and site based activities were undertaken post-Hurriane Maria. These are referred to in ESIA Volume 2: EIA.

**Social Indicators**

As a result of Hurricane Maria, the social situation has changed substantially with homes being lost, livelihoods being destroyed and many persons lacking access to basic services. The number of vulnerable people will have increased and basic priorities will have changed. It is also possible that the people of the Roseau Valley would want to see the Project now as part of the overall redevelopment of the Roseau Valley. Interested parties in the Project will need to think carefully about the messaging, involvement of the community, sharing benefits and ways to mitigate potential grievances.

As part of the ESIA, additional community consultation activities were undertaken post-Hurriane Maria, including Focused Discussion Groups (FDGs), census surveys for landowners and three public meetings to disclose the ESIA to affected communities in July 2018. These are referred to in ESIA Volume 3: SIA, and in the Stakeholder Engagement Plan (SEP), located in ESIA Volume 5: Technical Appendices, and Abbreviated Resettlement Action Plan (ARAP).



**Figure 1.3 : The devastation caused by Hurricane Maria – Roseau Valley (taken in November 2017)**

### 1.2.4 Updates to Project Design

Since the ESIA was originally completed in early September 2017, certain sections of the preferred reinjection pipeline route experienced extensive landslides as a result of Hurricane Maria and as a result the route was resurveyed in June 2018 and some adjustments to the route alignment made which is included in the ESIA However, the final alignment of the reinjection pipeline can only be determined following preliminary engineering design and geotechnical surveys prior to construction commencing. Further work is required to establish the feasibility of river crossings, alignment based on local topographical features, consideration of environmental impacts and alignment based on land boundaries. This will be completed in close co-ordination between environmental and social scientists and the process engineering, mechanical, geotechnical and civil engineering design disciplines, along with the Government, Land and Survey Division.

## 1.3 The Developer

### 1.3.1 Dominica Geothermal Development Company Limited

The Project will be developed by the DGDC, which was legally established by the GoCD in the last quarter of 2016 and became operational in June 2017. The Government's role is as equity provider and lender to the company. The GoCD has all shareholder rights with Directors appointed and replaceable by the shareholder. Initially, four Directors have been appointed, including an Executive Chairman.

### 1.3.2 Roles and Responsibilities

DGDC has five permanent staff members, a Board and a designated Project Manager. The company will operate under the guidance of technical, legal, strategic and commercial advisors. These roles are summarised below in Figure 1.4 (correct as of August 2017).

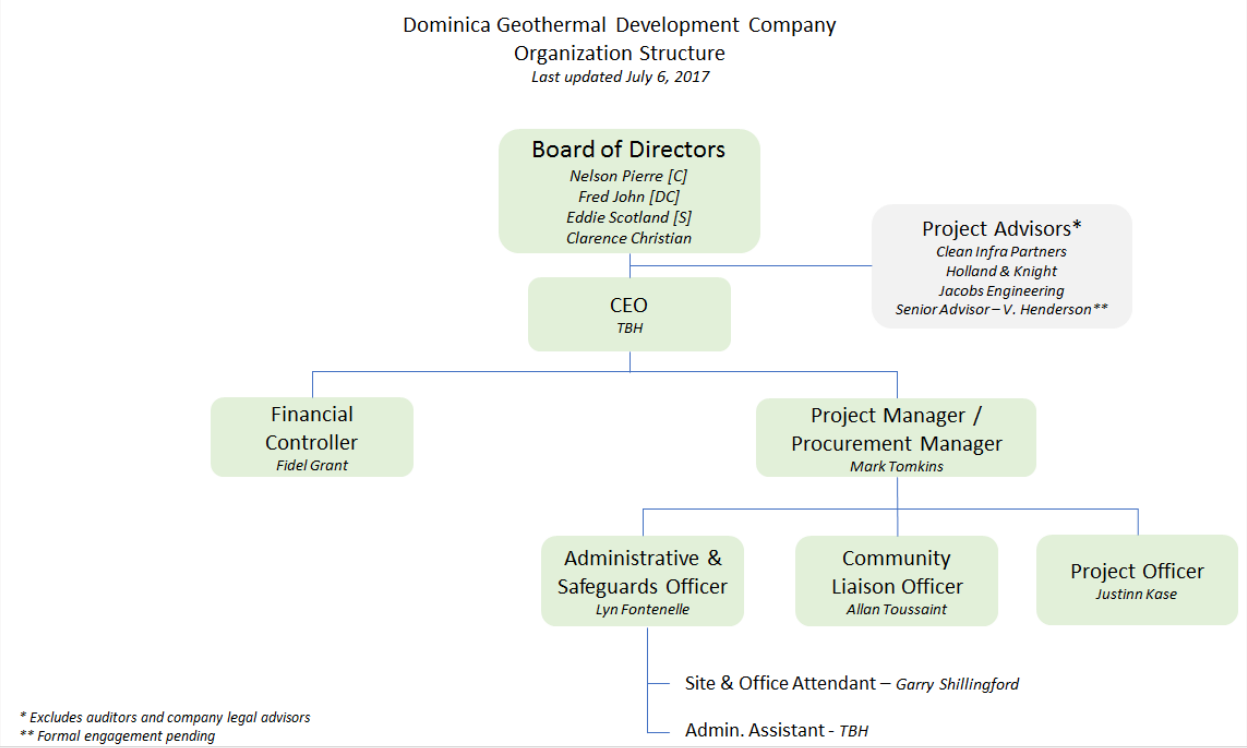


**Figure 1.4 : Geothermal Project Governance**

The Government of New Zealand is funding a Project Manager position for a period of two (plus one) years. The Project Manager will be based in Dominica and perform the following functions:

- Oversee the technical scope and engineering design of project, ensuring that the feasibility of the scope and structure of the project meets good industry practice and international standards;
- Oversee the overall construction of the power plant and its subsequent commissioning;
- Ensure the project meets the necessary environmental and social requirements and oversee the preparation of an ESIA;
- Responsible for overseeing the successful procurement of all goods, services, and skills necessary for the construction and operation of the geothermal power plant;
- Support finalisation of the financing arrangements, including responding to and meeting lender technical due diligence requirements in an efficient and timely manner;
- Work with advisors to finalise all off-take arrangements with DOMLEC; and
- Secure the services of and overseeing the work of various consultants.

DGDC will appoint a technical advisor acting as an Owner's Engineer who will be responsible for a wide range of services pre and post Financial Close. To date geothermal project development technical advisory services have been provided by Jacobs New Zealand Ltd (Jacobs), who were appointed by the Government of New Zealand following a competitive bidding process to deliver their Caribbean Geothermal Technical Assistance

Programme. At the time of writing Jacobs are currently in the final steps of formalising a role as Owner's Engineer to DGDC.

Clean Infra Partners has been appointed by DGDC as a business advisor to conduct Power Purchase Agreements (PPA) negotiations with DOMLEC, undertake financial analysis, and support development of the Financing Plan and business plan.

Holland & Knight has been retained as legal counsel to DGDC with services to include preparation and review of the Geothermal Concession Agreement, Power Purchase Agreement, EPC Contract, Operations & Maintenance contracts and financing agreements.

## 1.4 Structure of ESIA

The ESIA is structured into a Non-Technical Summary (NTS) and five Volumes, as set out in Table 1.2 below.

**Table 1.2 : Structure of the ESIA**

| | | |
|---|---|---|
| **Non-Technical Summary** | | |
| **Volume 1: Introduction** | Introduction | A brief description of the Project, the location and the environmental setting |
| | Legal and Regulatory Framework | • Environmental law<br>• Permits/Licences<br>• Other relevant regulations and law |
| | Project Overview | • Project background<br>• Project land requirements<br>• Project schedule<br>• Description of construction activities |
| | Project Justification and Assessment of Alternatives | • Project justification and site selection<br>• Assessments of alternatives including the 'do-nothing' scenario |
| **Volume 2 : Environmental Impact Assessment** | Introduction | Overview |
| | Impact Assessment Methodology | • Baseline Environmental Conditions Previous Studies<br>• Spatial and Temporary Scope<br>• Impact Assessment Methodology<br>• Impact Identification<br>• Cumulative Impacts |
| | Environmental Impact Assessment | Environmental baseline for the following topics:<br>• Climate<br>• Air Quality<br>• Noise<br>• Natural Hazards<br>• Geothermal Resource<br>• Water Quality and Freshwater Ecology<br>• Landscape and Visual<br>• Terrestrial Ecology<br>• MTPNP World Heritage Site<br>• Soils, Geology and Groundwater<br>• Greenhouse Gas Emissions<br>• Hazardous Substances and Waste<br>• Traffic and Access |

| | | |
|---|---|---|
| | | Each of the topics will contain the following:<br>• Assessment of Impacts<br>• Mitigation and Monitoring measures<br>• Assessment of Residual Impacts |
| | | Occupational Health and Safety & Working Conditions |
| | | Cumulative Impacts |
| | | Summary of Environmental Impacts |
| **Volume 3 : Social Impact Assessment** | Introduction | Overview |
| | Legal and Regulatory Framework | • National and International Requirements |
| | Impact Assessment Methodology | • Data sources<br>• Spatial and Temporary Scope<br>• Impact Assessment Methodology |
| | Social Impact Assessment | Social baseline for the following topics:<br>• Demographic Overview<br>• Ethnicity and Culture<br>• Religion<br>• Gender<br>• Indigenous People<br>• Ecosystem Services<br>• Economic Profile<br>• Educational Profile<br>• Land Use and Tenure<br>• Poverty, Deprivation and Vulnerable Groups |
| | | Stakeholder Engagement |
| | | Impact Assessment for the following:<br>• Employment<br>• Land Acquisition, Physical Displacement, and Resettlement Impacts<br>• Cultural Heritage<br>• Community Health, Safety and Security Impacts<br>• Cumulative Impacts |
| | | Mitigation, Enhancement Measures and Residual Impacts |
| | | Assessment of Residual Impacts |
| **Volume 4 : ESMP, ESMS and Compliance Assessment** | Environmental and Social Management Plan (ESMP) | • Construction Mitigation and Monitoring<br>• Operation Mitigation and Monitoring |
| | Framework Environmental and Social Management System (ESMS) | • Structure of Framework ESMS<br>• Alignment with World Bank Performance Standards<br>• Policies<br>• Roles and Responsibilities<br>• Legal and Other Requirements<br>• Identification of Risks and Impacts |

| | | |
|---|---|---|
| | | • Management Programmes<br>• Monitoring and Review<br>• Stakeholder Engagement<br>• Training<br>• Administration |
| | Compliance Assessment | • Compliance with World Bank Performance Standards |
| **Volume 5: Technical Appendices** | Various Technical Appendices | • WB Performance Standards<br>• Technical Report – Detailed Process Description<br>• ESIA Terms of Reference<br>• Biodiversity Survey Terms of Reference<br>• Technical Report – Air Quality Impact Assessment<br>• Technical Report – Noise Impact Assessment<br>• Technical Report – Morne Trois Pitons National Park Impact Assessment<br>• Technical Report – Terrestrial Ecology Impact Assessment<br>• Occupational Health and Safety & Working Conditions<br>• Stakeholder Engagement – Meeting Minutes<br>• World Bank Performance Standard 5<br>• Stakeholder Engagement Plan including Community Grievance Mechanism<br>• *Caraïbes Environnement Développement & Coll 2015 – Final Summary Report |
| **Abbreviated Resettlement Action Plan (ARAP)** | Abbreviated Resettlement Action Plan (ARAP) | • Socio-Economic Background of Affected Community and PAP Census<br>• Identification of Project Impacts<br>• Eligibility and Entitlements<br>• Valuation and Compensation<br>• Vulnerability Assistance<br>• Stakeholder Engagement<br>• Resettlement Sites<br>• Roles and Responsibilities<br>• Grievance Management<br>• Monitoring and Evaluation<br>• Budget and Schedule |

# 2. Policy, Legal and Administrative Framework

## 2.1 Introduction

This ESIA has been prepared to meet the requirements of the World Bank Performance Standards for Private Sector Activities, OP 4.03 (2013), World Bank General (WBG) Environmental, Health and Safety (EHS) Guidelines (2013) and other associated guidelines, as well as the laws of Dominica.

Project financiers who have adopted the World Bank Guidelines commit to ensuring that projects are developed in a manner that is socially responsible and reflect sound environmental management practices.

DGDC is also required to obtain approvals in accordance with local, regional and national regulations. This chapter also provides an overview of the local regulatory framework for these Dominican approvals. DGDC is obtaining the requisite approvals under local regulations in parallel to the preparation of this ESIA. Both the requisite Dominican approvals and ESIA are based on the same underlying technical data.

## 2.2 Dominica National Legislation

### 2.2.1 Environmental Impact Assessment

With sole responsibility for physical development of land in Dominica, the GoCD manages physical development through the Physical Planning Act (2002). The Physical Planning Act (2002), makes provision for the orderly and progressive development of land in both urban and rural areas, and to preserve and improve the amenities thereof, for the grant of permission to develop land and for other powers of control over the use of land; for the regulation of the construction of buildings and regulated matters; to confer additional powers in respect of the land acquisitions and development of land for planning purposes; and for other matters connected therewith. In accordance with this Act, development permission is required before the construction of the Project may commence.

Applications for development permission must be submitted to the Physical Planning Department within the Ministry of Agriculture and Environmental Protection along with an Environmental Impact Assessment (Clause 20(1)(b)). As defined in the Act an Environmental Impact Assessment (EIA) requires an Environmental appraisal that identifies positive and negative impacts on the site, the immediate communities as well as on the wider regional context. The environmental assessment should also include the direct impact of each project component on the physical, socio-economic and socio-cultural features of the site, the immediate communities as well as the wider regional context.

Before carrying out an EIA a ToR should be submitted to the Ministry for review in order to confirm the scope of the EIA.

In accordance with Clause 22(1) the Chief Physical Planner may require the applicant to publish details of the application at such times and provide details of the application to such persons or authorities as specified in the notice. Further, as specified in Clause 22(3), where an EIA is required, the Authority will publish a notice in at least one daily newspaper and affix a notice on the land to which the application relates, that an application to develop land has been received and will be determined on a date specified in the notice; and invite comments and representations either in writing or orally on the application.

The Chief Physical Planner may also *'consult in writing any public officer or other person who appears to him to be able to provide information relevant to an application for development permission to enable the Chief Physical Planner to advise the Minister or the Authority, as appropriate, with regard to the application'* (Clause 24 (1)).

The Chief Physical Planner has been consulted in relation to the development of this ESIA including reviewing and commenting on the ESIA ToR. The ESIA will be approved by the Physical Planning Department of the

GoCD in consultation with relevant Departments (i.e. the Environmental Coordinating Unit, Lands and Surveys Department, Environmental Health and Safety Department). Monitoring of the implementation of Environmental and Social Management Systems will be conducted by the Environmental Health and Safety Department.

The latest version of the ESIA ToR (RZ020300-0000-NP-RPT-0001_V6) contains a summary of the gap analysis and baseline information at time of issue. It was submitted to the GoCD in April 2017 and minor comments were received. A ToR for a Biodiversity Survey (RZ020300-0001-NP-RPT-0002 Dominica Biodiversity ToR_V2) was developed for the completion of additional baseline biodiversity assessments. Both documents have been reviewed by the World Bank and are provided for reference in ESIA Volume 5: Technical Appendices.

### 2.2.2 Geothermal Resources Development Act 2016

In 2016, the government of Dominica in the Caribbean passed a new piece of geothermal legislation. The Geothermal Resources Development Act 2016 defines a regulatory framework surrounding *"the development, exploration and use of geothermal resources."* The Geothermal Resources Development Act 2016 does not replace or repeal the Physical Planning Act 2002, and development permission must usually be obtained in accordance with the procedure of Part IV of that Act.

The key content elements are:

1) Geothermal resources advisory committee;
2) Geothermal resources;
3) Management of geothermal resource development;
4) Geothermal resource allocation;
5) Procedure for obtaining a geothermal resource development agreement;
6) Fees, bonds and royalities;
7) Record keeping and publicity; and
8) Compliance and enforcement.

The Geothermal Resources Development Act of 2016 provides the legal basis for the development, exploration and use of geothermal resources. It replaces the Geothermal Energy Act of 1976. The Act's objectives are to: 1) enable the sustainable use of geothermal energy according to Dominica's population needs; 2) safeguard the life-supporting capacity of air, water, soil and ecosystems; and 3) avoid remedying or mitigating to any material with adverse effects on the environment. Additionally, the bill declares that all geothermal resources will always be vested in the state and subject to the control of the state which is consistent with part one, section two of the Mines and Minerals Act of 1996.

The Act establishes the Geothermal Resources Advisory Committee (made up of the permanent secretary of the Ministry responsible for energy, the Executive Director of the IRC, the Chief Physical Planner of the Physical Planning Division, a senior state attorney and other public officers, and private professionals as appointed by the Minister) and details its duties and attributions. It determines the rules relating to geothermal activities including the creation, acquisition, transfer, exercise and termination of rights. Activities must only be developed in special geothermal zones set out by the Minister in accordance with the Committee.

### 2.2.3 Other Relevant National Legislation

Relevant Dominica national regulations are summarised in Table 2.1.

**Table 2.1 : Key Dominica National Regulations**

| Regulation (includes any Subsequent Amendments) | Summary |
|---|---|
| **Development** | |
| Physical Planning Act (2002) | The Physical Planning Act (2002), makes provision for the orderly and progressive development of land in both urban and rural areas and to preserve and improve the amenities thereof; for the grant of permission to develop land and for other powers of control over the use of land; for the regulation of the construction of buildings and regulated matters; to confer additional powers in respect of the land acquisitions and development of land for planning purposes and for other matters connected therewith. |
| Electricity Supply Act (2006), Act 10 | Regulates the generation, transmission, distribution and supply of electricity services and for purposes connected therewith; establishes an independent regulatory commission; and repeals the electricity supply act 1996 (No. 21 of 1996). |
| **Water and Wastewater** | |
| Water and Sewerage Act (No. 17, 1989) | An Act to make provision for a national policy for water, for the granting of an exclusive licence to the Dominica Water and Sewerage Company Limited for the development and control of water supply and sewerage facilities in Dominica and for connected or incidental purposes. |
| **Fauna and Flora** | |
| Fisheries Act (1987), Chapter 61:60 | An Act to provide for the promotion and regulation of fishing in the fishery waters of Dominica and for matters incidental thereto and connected therewith. |
| Forestry and Wildlife Act No. 12, (1976) | An Act to make provision for the protection, conservation and management of wild animals, amphibians, crustaceans, freshwater fishes, and reptiles, and for purposes connected therewith. States that the Forestry and Wildlife Division of the Ministry of Agriculture and Fisheries' shall promote forest and wildlife conservation and management in Dominica under the general supervision of the Permanent Secretary of Agriculture and Fisheries' and under the authority of the Minister. |
| Forest Act (1959), Chapter 60:01 | An Act to make provision for the conservation and control of forests, defines the power of the President, the Director of Forestry and Wildlife and forest officers, which are assigned by this Act. |
| National Parks and Protected Areas Act (1975) | Designated the Morne Trois Piton National Park (MTPNP) as a National Park and provides for the establishment of National Park's Section under the Forestry and Wildlife Division, consisting on a National Parks Service, a National Parks Advisory Council and a Director of National Parks, working together with several part-time and full time park officers and a Park Superintendent. A zoning plan is in place for the Park, which determines activity areas with regard to existing land use patterns and interests and existing and allowable uses. Some of these provisions, namely the ones referring to the establishment of a National Parks Service have not been implemented due to budgetary reasons. |
| **Noise** | |
| Noise Abatement Act, Chapter 40:99 | An Act to make provisions concerning the control of noise with a view to its abatement. |
| **Solid waste** | |
| Solid Waste Management Act, (2002) | An Act to establish a national solid waste management corporation and to provide for the management of solid waste in conformity with best environmental practices. |
| **Social** | |
| Culture Act (No. 22, 1981) | An Act to make provision for the further development of culture in the Commonwealth of Dominica and for the purposes connected therewith. |

| Regulation (includes any Subsequent Amendments) | Summary |
|---|---|
| Village Councils Ordinance (Cap. 190) | Responsibility within their jurisdictions for sanitation, waste removal, nuisance abatement, beach control. |

## 2.3 Biodiversity Treaties and Legislation

In addition to being a State Party to the World Heritage Convention, Dominica is also a signatory to the following international biodiversity conventions:

- UN Convention on Biological Diversity;
- UN Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES);
- UN Framework Convention on Climate Change; and
- UN Convention to Combat Desertification Cartagena Protocol on Biosafety International Convention on Civil Liability for Oil Pollution Damage Basel Convention on the Control of Trans Boundary Movements of Hazardous Wastes and their Disposal.

## 2.4 International Guidelines

### 2.4.1 World Bank Performance Standards for Private Sector Activities

As the World Bank has indicated its intention to provide funding to the development, the project is required to demonstrate compliance with the World Bank Performance Standards for Private Sector Activities, OP 4.03, (WBG, 2013) and the WBG Environmental, Health, and Safety Guidelines (hereafter referred to as the 'EHS Guidelines').

**Categorising the Project**

In accordance with the WBG's OP 4.03, the WBG undertakes environmental screening of each proposed project to determine the appropriate extent and type of Environmental Assessment (EA) needed. The WBG classifies the proposed project into one of three key categories, depending on the type, location, sensitivity, and scale of the project, as well as the nature and magnitude of its potential environmental impacts.

- **Category A:** A Category A project is likely to have significant adverse environmental impacts that are sensitive, diverse, or unprecedented. These impacts may affect an area broader than the sites or facilities subject to physical works. The EA for a Category A project examines the project's potential negative and positive environmental impacts, compares them with those of feasible alternatives (including the "without project" scenario), and recommends any measures needed to prevent, minimise, mitigate, or compensate for adverse impacts and improve environmental performance. For a Category A project, the borrower is responsible for preparing a report, normally an Environmental Impact Assessment (or a suitably comprehensive regional or sectoral EA).
- **Category B:** A Category B project has potential adverse environmental impacts on human populations or environmentally important areas - including wetlands, forests, grasslands, and other natural habitats - which are less adverse than those of Category A projects. These impacts are site-specific; few if any of them are irreversible; and in most cases mitigatory measures can be designed more readily than for Category A projects. The scope of EA for a Category B project may vary from project to project, but it is narrower than that of Category A assessment. Like Category A, a Category B environmental assessment examines the project's potential negative and positive environmental impacts and recommends any measures needed to prevent, minimize, mitigate, or compensate for adverse impacts and improve environmental performance. The findings and results of EA for Category B projects are described in the project documentation (Project Appraisal Document and Project Information Document).

- **Category C:** A Category C project is likely to have minimal or no adverse environmental impacts. Beyond screening, no further EA action is required.

All Category A and Category B Projects require an assessment process to address the relevant environmental and social risks and impacts of the proposed project in accordance with the applicable standards (i.e. WBG Performance Standards and/or the WBG Environmental and Social Framework and the WBG EHS Guidelines). The assessment documentation should propose measures to minimise, mitigate, and offset adverse impacts in a manner relevant and appropriate to the nature and scale of the proposed project. For Category A, and as appropriate, Category B Projects, the assessment documentation includes an Environmental and Social Impact Assessment (ESIA), Environmental and Social Management Plan (ESMP) with an Environmental and Social Management System (ESMS) usually prepared and implemented prior to construction commencing.

The assessment process should, in the first instance, address compliance with relevant host country (Dominica) laws, regulations and permits that pertain to environmental and social issues and with the WBG Performance Standards and EHS Guidelines.

The ESIA ToR (ESIA Volume 5: Technical Appendices) determined that based on a description of the Project, a review of previous studies and a preliminary risk assessment, the Project was given a preliminary classification of **Category A** (Jacobs, 2017). This was for the following reasons:

- Based on the initial preliminary risk assessment, most of the potential social and environmental impacts were determined to be of low risk (i.e. to be managed by routine procedures) and would therefore not require any additional design mitigation.
- The injection line route Option C (see Section 4 – Analysis of Alternatives) passed close to the residential area of Laudat and therefore there may be adverse impacts due to:
    - Potential physical relocation or infringement of land use for residents of Laudat.
    - Potential disturbance of habitat (i.e. through vegetation removal) that has been classified as ‘high’ sensitivity by Caraïbes Environnement Développement & Coll (2015a/b). High sensitivity areas were classified as those that contained the following:
        - A high number of protected species inside (International Union for Conservation of Nature (IUCN), French and Dominican legislation);
        - An area with very few anthropic influences; or
        - A high number of endemic species (Dominica and Caribbean).
- Three of the potential power plant sites (see Section 4 – Analysis of Alternatives) fell within habitat that has been classified as ‘high’ sensitivity by Caraïbes Environnement Développement & Coll (2015a/b).
- The power plant is located approximately 500 - 600 m) from the Morne Trois Pitons National Park World Heritage Site.

It should be noted that the habitat classification carried out by Caraïbes Environnement Développement & Coll in 2015 was done at a high level when the potential reinjection pipeline route and power plant site were not known. Assigning the project as Category A was a precautionary approach at the time based on the current level of uncertainty with the locations of the reinjection pipeline and the power plant site. This categorisation has been considered further during the ESIA process based on latest information and reclassification is proposed as part of the ESIA conclusion. For further details, reference should be made to the ESIA TOR (Volume 5 – Technical Appendices).

### 2.4.2 World Bank Group Performance Standards for Private Sector Activities, May 2013

As the Project is considered a private sector led economic development project, the following WBG Performance Standards would apply to the Project (note that these standards are equivalent to the International Finance Corporation (IFC) Performance Standards (IFC, 2012):

- Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts;
- Performance Standard 2: Labour and Working Conditions;
- Performance Standard 3: Resource Efficiency and Pollution Prevention;
- Performance Standard 4: Community Health, Safety, and Security
- Performance Standard 5: Land Acquisition and Involuntary Resettlement;
- Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources;
- Performance Standard 7: Indigenous Peoples; and
- Performance Standard 8: Cultural Heritage.

### 2.4.3 General and Industry Specific EHS Guidelines

In addition to the performance standards, the WBG has developed EHS Guidelines covering both general and industry specific issues. The EHS Guidelines contain the performance levels and measures that are normally acceptable to WBG and are generally considered to be achievable in new facilities at reasonable costs by existing technology. The environmental assessment process may recommend alternative (higher or lower) levels or measures, which, if acceptable to the financiers, become project or site-specific requirements.

In general, when host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures are appropriate in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

The General EHS Guidelines became available for use in April 2007 and will be used in the preparation of the ESIA Report and supporting technical analysis. The industry specific guidelines are as follows:

- Geothermal Power Generation; and
- Electric Power Transmission and Distribution.

### 2.4.4 Environmental, Health and Safety General Guidelines (April, 2007)

The EHS General Guidelines cover the following key areas:

**Environmental**

The general environmental guidelines are:

- Air Emissions and Ambient Air Quality;
- Energy Conservation;
- Wastewater and Ambient Water Quality;
- Water Conservation;
- Hazardous Materials Management;
- Waste Management; and
- Noise.

**Occupational Health and Safety Guidelines**

The general occupational health and safety guidelines are:

- General Facility and Design and Operation;
- Communication and Training;
- Physical Hazards;
- Chemical Hazards;
- Biological Hazards;
- Radiological Hazards;
- Personal Protective Equipment;
- Special Hazard Environments; and
- Monitoring.

**Community Health and Safety Guidelines**

The general community health and safety guidelines are:

- Water Quality and Availability;
- Structural Safety of Project Infrastructure;
- Life and Fire Safety;
- Traffic Safety;
- Transport of Hazardous Materials;
- Disease Prevention; and
- Emergency Preparedness and Response.

**Construction and Demolition Guidelines**

The general construction and demolition guidelines are:

- Environment;
- Occupational Health and Safety; and
- Community Health and Safety.

### 2.4.5 Environmental, Health and Safety Guidelines for Geothermal Power Plants (April, 2007)

These guidelines provide a summary of EHS issues associated with geothermal power generation and recommendations for their management. These include:

**Environmental**

Environmental issues that may occur during geothermal power generation projects, include the following:

- Effluents;
- Air emissions;
- Solid waste;
- Well blowouts and pipeline failures; and
- Water consumption and extraction.

**Occupational Health and Safety**

Occupational health and safety issues during the construction and decommissioning of geothermal power generation projects are common to those of other industrial facilities and their prevention and control are discussed in the General EHS Guidelines. Specific health and safety issues in geothermal power projects include the potential for exposure to:

- Geothermal gases;
- Confined spaces;
- Heat; and
- Noise.

**Community Health and Safety**

Community health and safety issues during the construction and decommissioning of geothermal power generation plants are common to those of large industrial facilities, and are discussed in the General EHS Guidelines. Community health and safety issues during the operation of geothermal power generation plants include:

- Exposure to hydrogen sulphide gas;
- Infrastructure safety; and
- Impacts on water resources.

Performance indicators and monitoring for each of the issues listed above follows the advice provided in the General EHS Guidelines.

### 2.4.6 Environmental, Health, and Safety Guidelines for Electric Power Transmission and Distribution

The EHS Guidelines for Electric Power Transmission and Distribution sets out relevant information that needs to be considered in the environmental and social impact assessment of transmission lines between a generation facility and a substation located within an electricity grid. Key issues covered include:

- Construction and maintenance of Right of Way and impacts on terrestrial habitats;
- Electric and magnetic fields;
- Hazardous materials; and
- Occupational health and safety.

## 2.5 International Labour Organisation (ILO) and United Nations Conventions

It is anticipated that a large portion of personnel working on the site through the construction phase will be employed through DGDC, the EPC Contractors and Subcontractors providing specific services to the Project. It will be a contractual requirement for all providers to the Project that they comply fully with the laws and regulations of the GoCD concerning employment of labour and working conditions. The Project policy for its own employees will also follow the laws and regulations of the GoCD and an employment policy framework will be developed which will comply with (at a minimum):

- ILO Convention 87 on Freedom of Association and Protection of the Right to Organise;
- ILO Convention 98 on the Right to Organise and Collective Bargaining;
- ILO Convention 29 on Forced Labour;
- ILO Convention 105 on the Abolition of Forced Labour;

- ILO Convention 138 on Minimum Age (of Employment);
- ILO Convention 182 on the Worst Forms of Child Labour;
- ILO Convention 100 on Equal Remuneration;
- ILO Convention 111 on Discrimination (Employment and Occupation);
- UN Convention on the Rights of the Child, Article 32.1; and
- UN Convention on the Protection of the Rights of all Migrant Workers and Members of their Families.

# 3. Project Description

## 3.1 Introduction

The purpose of this Section is to provide an overview of the construction, commissioning, operation and decommissioning of the Project. The full technical details used to inform the assessments of impacts are provided in ESIA Volume 5: Technical Appendices, Technical Report – Detailed Process Description. The engineering design for the Project is ongoing, with detailed design to be completed following a formal tender process for an Engineer, Procure and Construct (EPC) Contractor(s). Therefore, some of the descriptions provided in the Process Description are typical of a geothermal development in this setting and cover two power plant generation options. The consideration of design options has been taken forward into the impact assessment (ESIA: Volume 2 – Environmental Impact Assessment and ESIA: Volume 3 – Social Impact Assessment).

The process description covers the following major elements

- Overview;
- Site Location;
- Geothermal Resource – wells, reservoir capacity and production well testing;
- Land Requirements;
- Schedule;
- Construction – power plant and steamfield, reinjection pipeline, civils work at well pads, port to site access, local access and temporary facilities;
- Commissioning – steamfield, power plant and reinjection pipeline;
- Operation – general operating arrangements, well pad, steamfield, power plant (including technology options), use of water, road network, electrical equipment and interconnection, hazardous substances; and
- Decommissioning.

## 3.2 Overview

Geothermal projects connect production wells through a steamfield facility to a power plant, which is connected to an electricity grid. Geothermal fluids consist of steam, hot water (brine) and a small quantity of non-condensable gases (mostly carbon dioxide and trace gases). In this project, steam will be separated from the brine and used to drive a turbine. Used geothermal fluids produced by the geothermal projects (separated brine and steam condensate) are returned to the geothermal reservoir via reinjection wells, which may be located some distance away (i.e. over 1 km) from the production wells to avoid short-circuiting or premature cooling of the production wells.

For this Project, the key components of the proposed 7 MW power plant are summarised below and shown in Figure 3.1.

The key components of the proposed 7 MW power plant include:

- Power plant comprising 2 x 3.5 MW units (either single flash steam condensing cycle or organic Rankine cycle units (binary turbine), which will be adjacent to wells WW-P1 and WW-03. The binary power plants may use wet cooling or dry cooling;
- Production well WW-P1 – The existing geothermal production well at Laudat is indicated to have potential to generate 6 to 9 MW and will be the sole production well for the project;
- Cross-country brine reinjection piping – The 250 to 300 mm diameter reinjection pipeline will be carrying used geothermal fluid from Laudat to Trafalgar with approximate piping length of 3.5 km;

- Reinjection wells WW-R1 (located in Trafalgar) and WW-01 (located in Wotten Waven) – The used geothermal fluid (brine and possibly some steam condensate) produced from production well WW-P1 would be disposed of into reinjection wells WW-R1 and WW-01 transported to the wells via the reinjection pipeline;
- Steamfield infrastructure including two phase piping, steam piping, steam separator, atmospheric flash tank, brine collection and disposal system, condensate collection and disposal system, pressure relief system, storage sump and rock muffler;
- Supporting infrastructure including existing well pads, turbine building, primary and ancillary equipment, cooling system, and water supply; and
- 11 kV underground interconnection to the DOMLEC electricity grid at the power plant site.

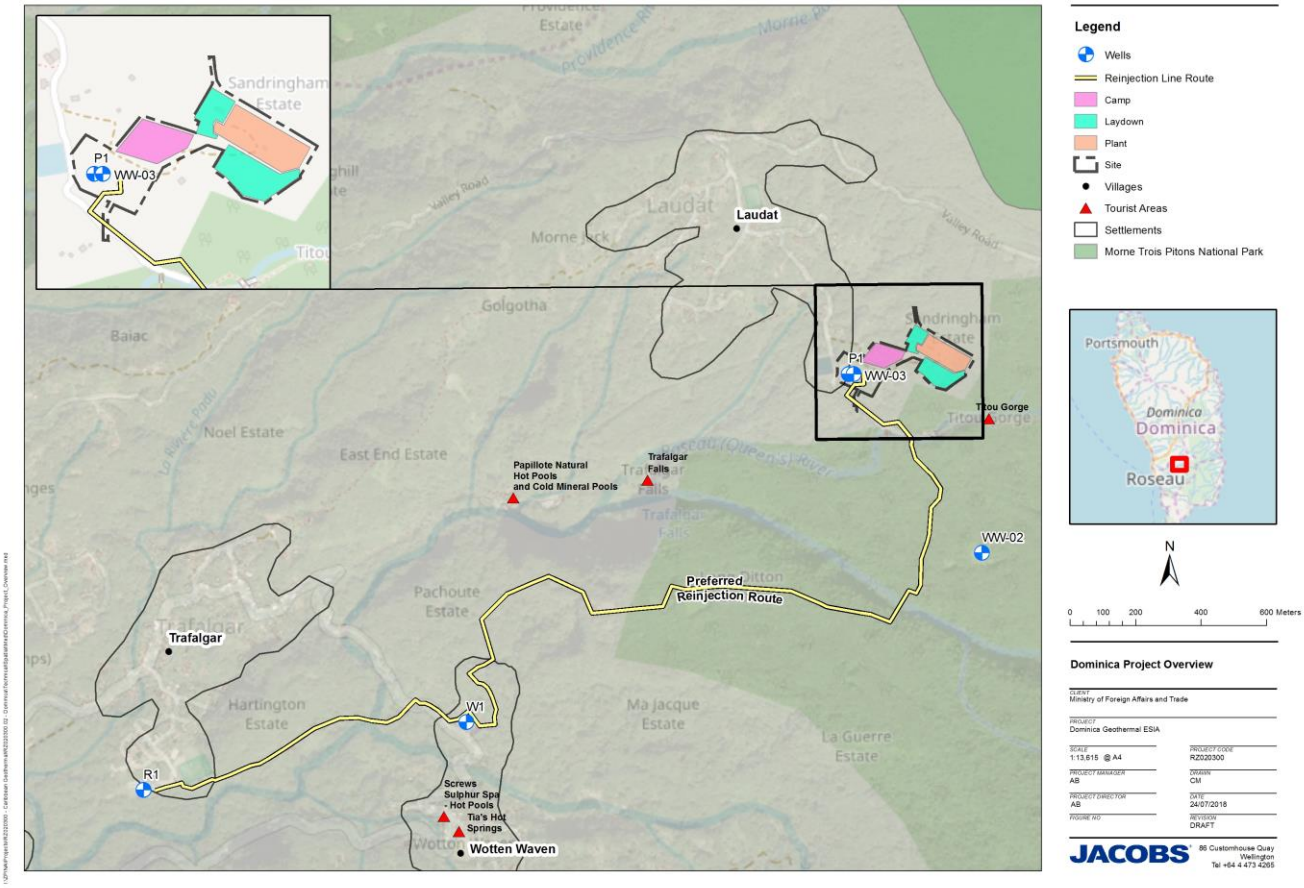


**Figure 3.1 : Project Overview**

## 3.3 Site Location

The Project is located in the Roseau Valley of Dominica, as outlined in Section 1.2. The Project is situated within or in close vicinity to a number of villages: the production well pad and power plant site are partially within the village boundary of Laudat and the reinjection pipeline passes through the villages of Wotten Waven and Trafalgar. Listed below are the approximate distances of the well pads WW-R1, WW-01 and the power plant to the nearest properties:

- WW-P1 & power plant – located 150 m south of residential properties;
- WW-R1 – located 50 m south of residential properties; and

- WW-01 – located 200 m north of residential properties.

The power plant is situated at an estimated elevation of 550 m above mean sea level (aMSL), the ~3.5 km reinjection pipeline route runs down the Roseau Valley starting at the power plant, passing through WW-01 at 235 m aMSL and ending at WW-R1 at 187 m aMSL. Figure 3.2 and Figure 3.3 provide some topographical context to the Roseau Valley and the location of the Project components.

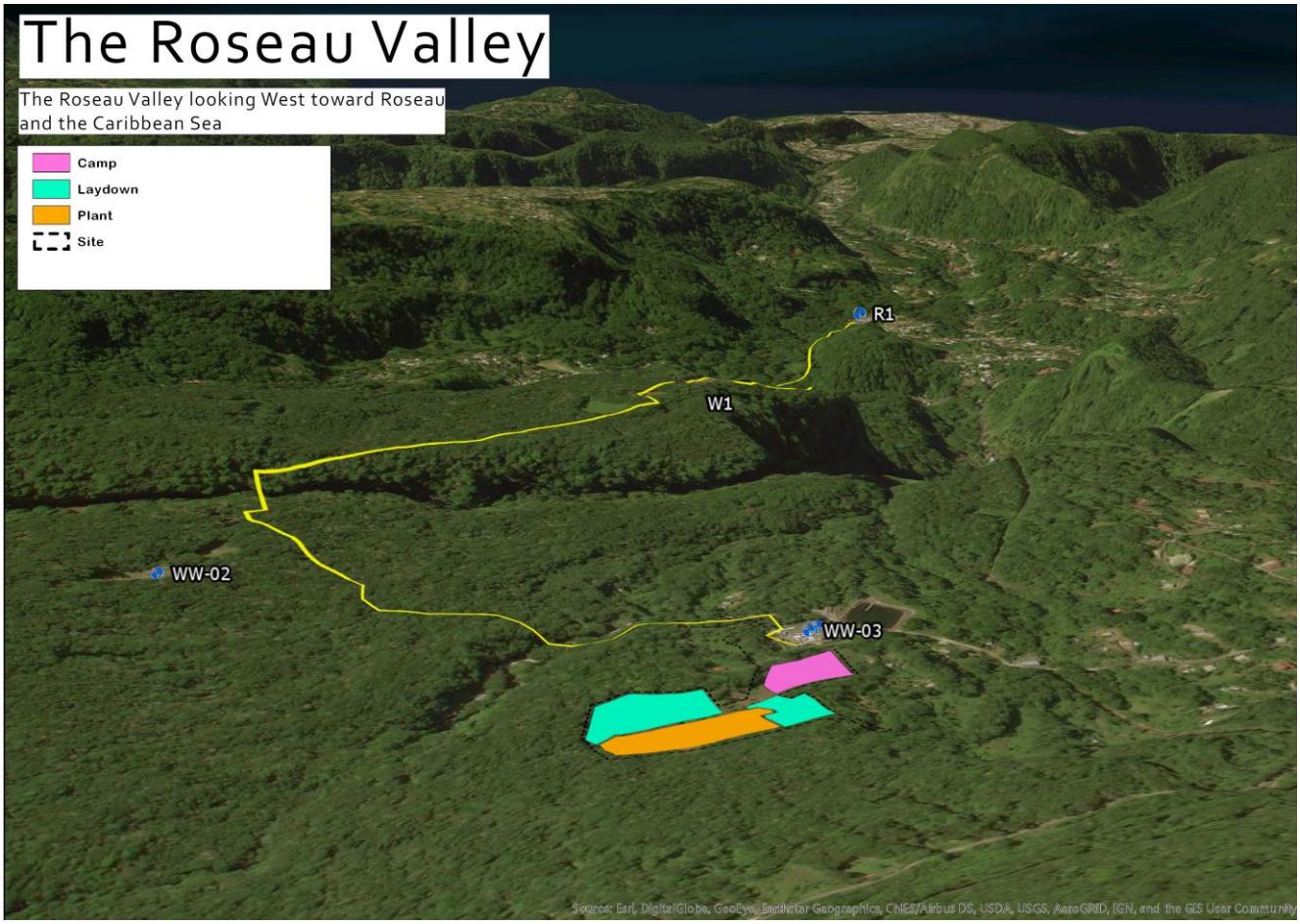


**Figure 3.2 : The Roseau Valley looking west towards Roseau and the Caribbean Sea. The power plant and reinjection pipeline routes are also shown. Source: Google Earth, 2017**

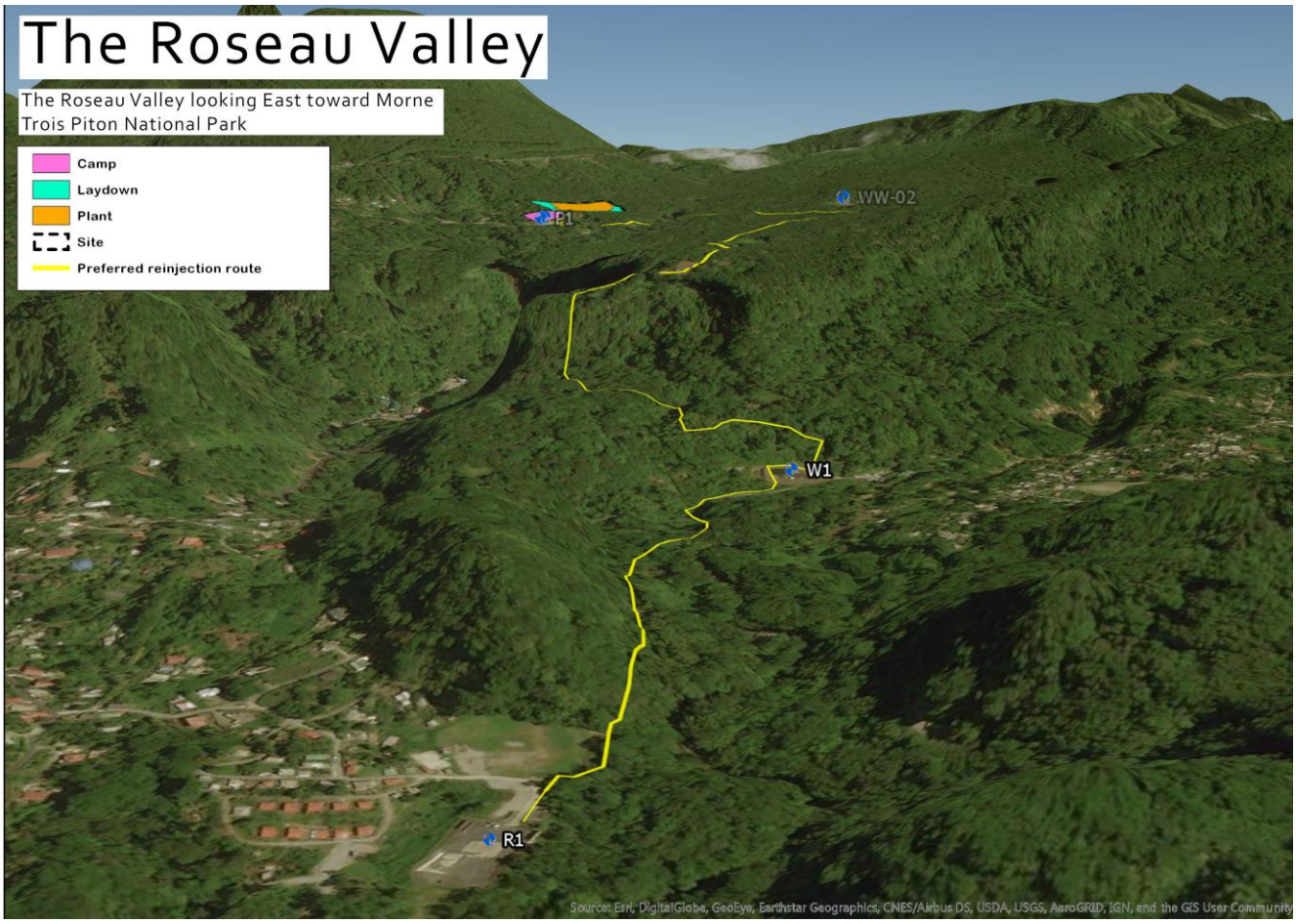


**Figure 3.3 : The Roseau Valley looking west towards Morne Trois Piton National Park. The power plant and reinjection pipeline routes are also shown. Source: Google Earth, 2017**

## 3.4 Geothermal Resource

### 3.4.1 Wells

As outlined in Section 1.2, five wells have been drilled to date as part of the exploratory phase: three slimhole exploration / production wells (WW-01, WW-02 and WW-03), one standard diameter production well (WW-P1) and one standard diameter injection well (WW-R1). The details of these are provided in Table 3.1 below.

**Table 3.1 : Well physical parameters**

| Parameter | WW-01 | WW-02 | WW-03 | WW-P1 | WW-R1 |
|---|---|---|---|---|---|
| **Wellhead, Easting (m)** | 678,302 | 679,822 | n/a | 679,461 | 677,321 |
| **Wellhead, Northing (m)** | 1,694,864 | 1,695,029 | n/a | 1,695,567 | 1,694,334 |
| **Wellhead elevation (aMSL)** | 235 | 580 | 543 | 552 | 187 |
| **Total depth (mRKB)** | 1,200 | 1,469 | 1,613 | 1,505 | 1,914 |
| **Azimuth (°)** | - | - | - | 190 | - |
| **Throw (m)** | - | - | - | 465 | - |
| **Casing size (in)** | 7 | 7 | 7 | 9-5/8 | 9-5/8 |

| | | | | | |
|---|---|---|---|---|---|
| **Casing shoe depth (m)** | 303 | 427.5 | 590.6 | 726 | 607 |
| **Liner size (in)** | 4-1/2 | 4-1/2 | 4-1/2 | 7 | Open hole |
| **Liner depth (m)** | 269-1,200 | 281-1,337 | 569-1,612 | 700-1,505 | 1,914 |

Production well pad WW-P1 and re-injection well pads WW-R1 and WW-01 will be utilised as part of the development. The ESIA assesses workover operations, however, no additional drilling is anticipated to be required as part of the Project. If additional drilling is deemed necessary in the future, this will be subject to a supplementary ESIA.

### 3.4.2 Reservoir Capacity

Following drilling of exploratory wells WW-01, WW-02 and WW-03, the Wotten Waven geothermal system was described in the ELC Preliminary Resource Assessment (ELC, 2012) and the Feasibility Study – Small Geothermal Report (ELC, 2013), together with gap analysis and commentary by World Bank experts (World Bank, 2013).

The reservoir temperatures and pressures measured in the existing in-field wells (excluding WW-R1) are nearly uniform and the deep permeability in these wells is generally good so the indicated (measured) reservoir area corresponds to an area of 3 $km^2$ and is considered to be sufficiently proven to be used as a basis for a small development using existing wells.

ELC estimated that there is a 90% probability that the indicated resource is at least 25 MW, and a 50% probability of supporting 41 MW. These estimates provide sufficient confidence for a small scale development using existing wells to be sustainable for 30 years, although there is a low risk that recharge by low temperature or acidic fluids could prematurely reduce the output of the wells.

### 3.4.3 Production Well Testing

Production well testing was undertaken on well WW-P1 by Geothermal Resource Group (GRG) in June 2014. Using step flow data undertaken from well testing, Íslenskar Orkurannsóknir, Iceland Geosurvey (ÍSOR) calculated the discharge at a Well Head Pressure (WHP) of between 13.0 and 17.0 bara. At atmospheric separation pressure and a WHP of 13.0 bara the estimated steam flow is 22 kg/s. At 7 bara separation pressure the steam flow is calculated (using industry standard to be ~14-18 kg/s. Depending on the type of power plant technology to be installed, ÍSOR found that a separation pressure of 7 bara would generate between 7 and 9 MW (assuming a usage of ~2 kg/s of steam for each MW) (ÍSOR, 2014).

### 3.4.4 Geothermal Fluid Chemistry

Based on the chemical tests ÍSOR concluded that:

- Due to limited changes in the conductivity of the liquid phase throughout the test, the similar chemical composition of the samples collected during the test and the good agreement between geothermometers and logged reservoir temperature indicates that the discharge is representative for the reservoir fluid;
- The deep liquid (reservoir liquid) is relatively dilute with Cl and Na concentrations close to 2,600 mg/L and 1,500 mg/L respectively;
- Boiling due to depressurisation within the well is expected to cause calcite scaling at or slightly above the boiling level; and
- The overall gas content of the steam at 150°C (4.8 bara) based on calculations from samples was 1.6 wt% (at 4.8 bara) or approximately 8 L gas/kg condensate.

## 3.5 Land Requirements

### 3.5.1 Power Plant

The GoCD has ownership of the existing well pads, however, additional land will be required for the power plant site and for the reinjection pipeline right of way. The land required for the power plant, and hence civil works required to prepare the site, will depend on the power plant technology selected and design by the EPC contractor. Figure 3.4 provides nominal land area requirements for the 2 x 3.5 MW power plant, with binary plant requiring an area of approximately 115 m x 60 m (~60 m x 175 m including laydown area) and steam condensing plant requiring approximately 50 m x 60 m (60 m x 90 m including laydown area). This gives estimated minimum land requirements (including laydown) of:

- Steam Condensing Plant: 5,400m$^2$
- Binary Plant: 10,500m$^2$

However, taking into consideration local site factors and specific plant requirements (terrain characteristics, operations facilities, maintenance facilities etc.), the proposed plant layout as presented in Figure 3.4 has a land requirement estimate of 20,000 m$^2$, for the largest case binary plant option – including laydown / spoil areas. Approximately 10% of the power plant site will be concreted and the rest covered with gravel. The remaining areas of the site will be landscaped and replanted.

The proposed power plant site layout based on the largest case binary plant option, is shown in Figure 3.4.

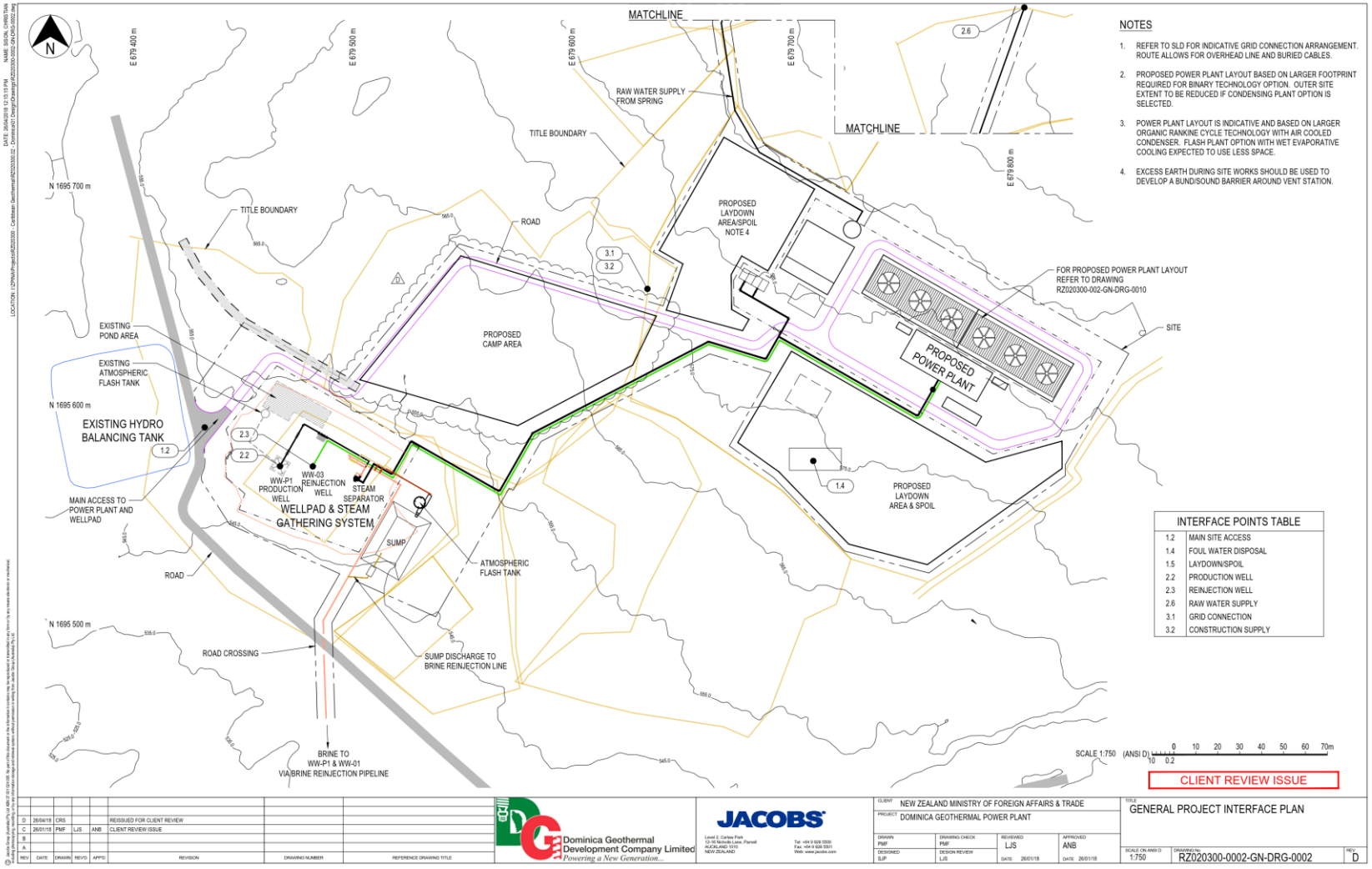


**Figure 3.4 : Proposed Power Plant Site and Production Steamfield Layout**

### 3.5.2 Steamfield and Reinjection Pipeline

The land requirements for the steamfield piping system are dominated by the reinjection pipeline, which will run 3.25 km from WW-P1 to WW-01 and WW-R1. The diameter of the pipeline will be approximately 250 to 300 mm (10 to 12 inches). A corridor of 10 m wide will be required to enable access during construction therefore total land requirements for the reinjection pipeline are approximately 32,500 $m^2$. However, for operation a 4 m wide corridor is required. Expansion loops are required every ~100 m to account for expansion of the steel on contact with the hot brine. A number of trees will need to be felled to allow for space and construction access. A replanting programme along the reinjection route will be undertaken as part of rehabilitating the land, associated with the reduced corridor width required for operation.

The reinjection line route alignment will be finalised in close co-ordination with process engineering, mechanical, geotechnical and civil engineering design disciplines, along with the GoCD, Land and Survey Division and environmental and social scientists (Figure 3.5).

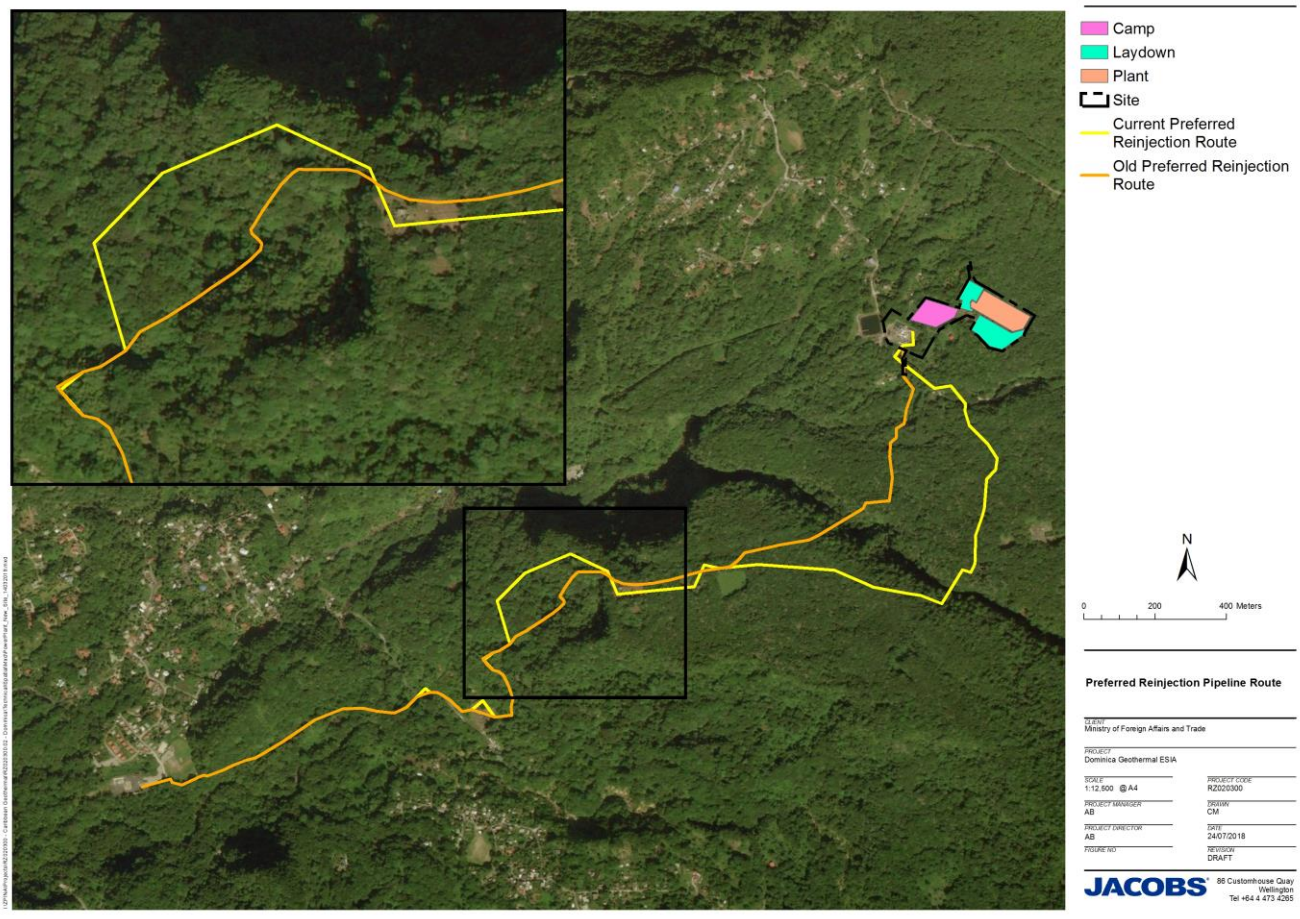


**Figure 3.5 : Preferred injection pipeline route from WW-P1 to WW-01 and WW-R1**

Land requirements for other elements of the steamfield include: wellpads, the sumps, separator and atmospheric flash tanks:

- Steamfield Equipment: 1,700 $m^2$
- Sump at Power Plant: 600 $m^2$
- Wellpad WW-R1 & associated equipment: 2,000 $m^2$

- Wellpad WW-01 & associated equipment: 2,000 $m^2$

This ESIA assumes a 10-metre-wide reinjection pipeline corridor is required. The final alignment of the reinjection pipeline can only be determined following preliminary engineering design and subsequently during detailed design prior to construction.

### 3.5.3 Switchroom & Transmission Line

The Project includes an indoor switchroom that will be located at the power plant site. This will connect to the underground transmission line that will connect to Laudat Hydropower Station to the north. The estimated land requirements are:

- Switchroom: 250 $m^2$
- 300 m Underground Transmission line: 300 $m^2$

## 3.6 Schedule

The construction of the project is anticipated to last 18 months to two years, as outlined in the indicative schedule in Table 3.2 below. The operational life of the geothermal development is anticipated to be 25 years.

**Table 3.2 : Indicative Construction Schedule**

| Phase | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
|---|---|---|---|---|---|---|---|---|
| Off-site preparatory work | ■ | | | | | | | |
| Site preparation | | ■ | ■ | | | | | |
| Foundations for equipment and pipelines | | | ■ | ■ | | | | |
| Powerhouse & permanent buildings | | | | ■ | ■ | | | |
| Major equipment installation | | | | | ■ | ■ | | |
| Interconnecting piping, wiring and instrumentation | | | | | | ■ | ■ | |
| Switchyard and transmission line | | | | | | | | ■ |

## 3.7 Construction

### 3.7.1 Power Plant and Steamfield

The majority of the construction activities will be concentrated on the main power plant, switchyard and separator station sites, but other work is required at the individual well-sites and in the piping corridors linking the wells to the power plant. Construction lay-down areas will be required for storage of equipment required for construction. The equipment for the construction works will include small drilling rigs, excavators, trucks, rollers, compactors, cranes, portable welders and generators and other items that are normal for such construction activities.

Site preparation involves bulk earthworks, upgrades to roads, and establishment of temporary construction facilities, security fencing, drainage controls, access control and a worker's camp that will house an estimated 50 workers (Figure 3.4). Construction facilities include lay-down space for storage of equipment and materials awaiting installation, amenities (washrooms, lunchrooms, car-parking) for construction workforce, and construction management offices.

Sediment and erosion control measures will be constructed in accordance with the Sediment and Rrosion Control Plan and any local regulatory requirements. Specific disposal areas for washing out empty concrete trucks would be set up, with a hose and bunded area for discharge of washwater. The EPC Contractor will

regularly remove accumulated concrete washings and these will be disposed of to landfill, while the water will percolate through the base of the bunded area to the ground.

Site construction work will involve the following:

- Construction of foundations for major structures, equipment and pipelines;
- Construction of the powerhouse and permanent ancillary and amenity buildings;
- Erection of major and ancillary equipment such as steam-turbine generators, cooling towers, pumps;
- Interconnecting piping, electrical wiring and instrument installation; and
- Switchyard and underground transmission line construction and connection to the grid.

The power plant will be constructed on a concrete pad designed to withstand the weight and movement of large pieces of mechanical equipment. It is anticipated that 10% of the power plant site will be concreted with the rest covered by gravel. At this stage no concrete batching plant is anticipated, concrete will be sourced from local plants. The turbine hall may be fully or partly covered and will be constructed to accommodate 2 x 3.5 MW turbines. Some elements of the balance of plant equipment, including circulating water cooling systems and gas extraction systems may be outside but under appropriate cover.

The steamfield comprises the wellpad and separator station. WW-P1 will contain the majority of fluid production and separation equipment. Concrete foundations for the separator station will be constructed, followed by the set up and welding of steel pipes to transport steam and fluids such as brine, condensate, two-phase fluid to and from the power plant. Separator station plant and equipment will also be installed. At the separator station the excavation of a lined holding pond (lining material yet to be determined) for geothermal fluid discharges will be required (refer to Figure 3.4 for overview of the steamfield).

### 3.7.2 Reinjection Pipeline

Connection to wells WW-01 and WW-R1 would be undertaken during construction and installation of the brine injection pipeline. The injection pipeline will be insulated using aluminium or other appropriate material in order to reduce heat loss. The injection pipeline must operate at high temperature and pressure and needs to be carefully designed with suitable supports and guides which safely allow for thermal expansion of the pipe between its hot and cold states. This will require vertical or horizontal u-bends every ~100 m.

The EPC Contractor will form walking tracks within the reinjection pipeline corridor (up to 10 m wide) and install infrastructure services between the track and pipeline route. Concrete foundations for the pipeline will be constructed, followed by the set up and welding of steel pipes to transport the separated brine. The volume of water required for these foundations is minimal and will be sourced from local watercourses. It will be necessary to construct a pipe bridge over Breakfast River Gorge which is anticipated to be 70-100 m in length. Further pipe bridges will be constructed over the intermittent watercourses within the site as appropriate, and dependent on final steamfield configuration. Local ponds (lined) to drain accumulated geothermal fluid during the shutdown of the reinjection pipeline will be excavated at low points in the pipeline. It is anticipated that the pipeline will also contain ubends and culverts, examples of which are shown in Figure 3.6 (however, note that these show pipelines of larger width than proposed for the reinjection pipeline in the Project).



**Figure 3.6 : Examples of a reinjection line culvert underneath a road (left) and a u-bend in a reinjection line (right)**

The plant required for the reinjection pipeline construction works will include small drilling rigs for creating foundations, mobile cranes, trucks to transport materials and equipment, generators for pipe welding as well as excavators and trucks for foundation excavations. This will require manual cartage or potentially use of a helicopter to transport materials into some of the more remote areas. The felling of trees and other shrubs will be necessary in constructing a reinjection pipe corridor for the 250 – 300 mm diameter pipe.

### 3.7.3 Existing Well Pads

Three existing well pads will be used for the development: WW-03 (containing wells WW-P1 and WW-03), WW-01 and WW-R1. Much of the steamfield equipment will be located by WW-P1 including the separator and rock muffler.

The sites will each require remedial works to bring them up to standard and into their original condition. The scope of work will be determined by the DGDC, with the initial indication being as follows:

- Site WW-P1: Site improvement, slope stabilisation, drainage works, fencing, security lighting;
- Site WW-01: Site fencing, slope stabilisation, drain pond; and
- Site WW-R1: Site fencing, security lighting, disposal of material/ general cleanup.

### 3.7.4 Port to Site Access

During construction, all equipment will be required to be transported by sea to the island. Dominica's main port is at Woodbridge Bay, about 2 km north of Roseau. The berth at Woodbridge Bay is used by both cargo and cruise vessels. The port has two shore cranes with capacities of 27 tonnes and 46 tonnes respectively, see Figure 3.7. The port is capable of handling breakbulk, containers, bagged cargo and pallets (Vertraco Shipping website, 2017).



**Figure 3.7 : Woodbridge Bay Port**

Access roads to the well sites have already been established as part of the drilling phase and no further widening is anticipated. Some repair work to the access roads damaged by Hurricane Maria may be required. However, road side foliage may create challenges for machinery and transporters. The access road to WW-P1 is used by locals as it enables access to the forest from the village of Laudat, as well as being the access road for two tourist sites (Titou Gorge and walking track to the Boiling Lake) (Figure 3.8). Access to the power plant site will require the improvement of existing tracks.



**Figure 3.8 : Panoramic view from east of WW-P1 (Caraïbes Environnement Développement & Coll , 2013)**

The reinjection sites WW-01 and WW-R1 (see Figure 3.9 below) are located adjacent to the villages of Wotten Waven and Trafalgar respectively. Both sites are located near to existing road networks.



**Figure 3.9 : Site WW-01 (left). View over Trafalgar (WW-R1) reinjection site (right) (Caraïbes Environnement Développement & Coll, 2013)**

### 3.7.5 Temporary Facilities

The following temporary facilities will be present and utilised during the construction phase:

- Construction laydown area: At present two flat construction laydown areas are being considered adjacent to the power plant site. Other smaller laydown areas may be required along the reinjection pipeline during construction in order to store construction materials.
- Worker's camp:
  - Canteen and showers with hot water facilities;
  - Sleeping quarters (to support an estimated 50 workers);
  - Recreational/games room;
  - Potable water supplies from either a tanker-supplied storage tank, or a dedicated treatment plant; and
  - Septic tanks (on-site) and/or portable latrines (off-site disposal).
- Utility services (telecommunications and electricity).
- Water and wastewater systems.

### 3.7.6 Water and Wastewater Systems

Raw water will be required during construction and ongoing operation and maintenance of the plant. Water abstraction for the Project will require an authorisation application to the "Minister for Housing Lands Settlement and Water Resource Management" (Caraïbes Environnement Développement, 2013).

Raw water for construction and permanent works shall be drawn from a naturally occurring spring located at a higher elevation above the site (location shown in Table 3.3).

DGDC shall be responsible for obtaining the permit to use the water for construction and permanent works. The EPC Contractor shall be responsible for the design, execution and completion of the raw water intake structure and piping required to transfer to the Site.

**Table 3.3: Proposed raw water supply information**

| Item | Natural Spring | Unit |
|---|---|---|
| **Raw Water Source Location** | | |
| Latitude | 15°19'58.20" | N |
| Easting | 61°19'34.22" | W |
| Elevation | 623 | mASL |
| **Water take limits** | | |
| Daily | 10,000 | Litres |
| Monthly | 200,000 | Litres |
| Maximum instant | 5 | Litres/s |

Domestic wastewater from amenities at the power plant site including the worker's camp will need be collected and treated in a package plant to meet discharge requirements. The EPC Contractor will need to maintain the package plant and associated effluent disposal system to meet international guidelines discharge criteria (i.e. WBG EHS Guidelines) and to prevent odour or other nuisance to the community during the period of construction. The EPC Contractor will typically be responsible for decommissioning and removing the unit at the end of the construction period.

## 3.8 Commissioning

As the power plant construction phase nears completion, commissioning commences as described in the sections below. Once the entire plant has been brought into operation a range of performance and reliability tests are undertaken. Having completed and passed performance and reliability tests the plant is handed over for commercial operation.

### 3.8.1 Steamfield

**Two Phase Pipeline from WW-P1 to Separator**

The production well WW-P1 will be brought on-line and used to flush the two phase lines up to the separator.

The brine at the separator station will be discharged to a local flash tank and collected in the wellpad sump for the duration of the blow. Either temporary spool pieces will be installed in place of the separator Emergency Dump Valves (EDV's) or a temporary manual valve in place of an EDV for the initial brine flush, but thereafter the EDVs would be reinstated and would be used to control separator level.

During commissioning, brine disposal is initially to the wellpad sump, therefore, the duration of steam blowing or other tests will be limited by the available sump capacity. If necessary, testing may need to be suspended to allow the sump to be emptied via discharge to an injection well.

**Steam Blow**

Solid particles present within the piping will be removed before connecting the pipework to the steam turbine. Removal of these solid particles from the pipe interior is through steam blowing where hot steam is passed through the piping at high velocity for a sustained period. Repeated exposure to the combination of thermal expansion / contraction and high fluid velocity is able to dislodge and remove the solid contaminants from the bore of the pipework. The source of steam for pipeline cleaning is from the geothermal field, meaning that steam blowing occurs in the early stages of commissioning. A temporary rock muffler will be used to discharge the steam blowing vent to reduce noise emission. As the steam line is quite short it may also be possible to manually clean the line prior to commissioning.

Pressure control valves (PCVs) provide steam pressure control. The PCVs will be removed and replaced by temporary spool pieces to allow steam blowing of the steam piping through to just upstream of the rock muffler. A temporary spool piece will also be installed on the end of the line to vent the steam above and away from ground level. Steam blow of the PCV lines can be done in conjunction with the main steam line.

### 3.8.2 Power Plant

Commissioning of the power plant will involve the following:

- Turbine oil systems – The turbine oil systems will be circulated and flushed through temporary filters in the lines. The only waste generated will be the temporary filters used during the process;
- Cooling water pipes – Cooling water pipes will be flushed and the water will be circulated. Water used during the cleaning will be obtained from the site raw water supply and is usually discharged to the stormwater system. This water is then typically discharged to grade, pending environmental approval. No chemicals will be added during this process. Strainers will collect the minimal (handfuls) amount of debris expected to be generated and the debris will be taken to landfill;
- Wet cooling towers (if selected during tender process) – The cooling towers will have their first basin fill during commissioning. This will come from the site raw water supply. It is expected the fill would be completed over a 24 hour period;
- Biocide and caustic systems – These systems will receive first fill during commissioning. They will be located in separate areas that will be bunded so any potential spillage would be captured by this secondary containment system;
- Electrical systems – The power plant and switchyard electrical systems will be energised under defined and controlled conditions according to contractor and grid operator guidelines; and
- Auxiliary steam blow – Required to clean the power plant piping associated with systems such as steam ejectors. This will be done as per the procedure for the main steamfield blowing and may be carried out simultaneously. The remaining steam piping in the power plant from the governor valves to the turbine is then manually cleaned after the steam blows.

### 3.8.3 Reinjection Pipeline

The reinjection pipeline will be flushed after construction and as part of a hydro-test. Location of a suitable discharge point will depend on the site piping layout and geometry, but is expected to be into one of the sumps at the reinjection wellpad.

## 3.9 Operation

### 3.9.1 General Operating Arrangements

The operation of the steamfield and power plant covers three phases:

1) Start-up;
2) Operation; and
3) Shut-down.

**Start-up**

The start-up operation involves the start-up of production wells and the introduction of steam into the piping systems. Process drain valves are generally left open to remove condensate from the pipes and vessels, draining to storage sumps. Brine from separator vessels and silencers are discharged to the storage sumps at the power plant and separator station locations. Steam is vented to atmosphere through the steam vent valves located at high point vents as well as at the rock mufflers located at the power plant.

**Operation**

During normal operation minimal steam venting occurs, the production steam is sent to the power plant and brine is sent to the power plant or directly to reinjection wells. When all power plant systems are in operation, the power plant generates electricity which is exported to the grid.

**Shut-down**

Shut-down may be planned or due to unscheduled maintenance / outage or in some instances may involve a major transmission line outage. During shut-down the unit(s) stops generating electricity for export. The power plant vent valves will emit steam until the production wells are trimmed back to match the required remaining station demand. For a complete station shut-down the steamfield will likely be closed down and the steamfield piping systems will be drained to local storage sumps as well as to the separator stations' and power plant brine sumps. The production well will be either shut in or placed on bleed.

**Emergency Shut Down**

If conditions arise that requires the power plant to immediately shut down, the plant systems will trip the power plant and steam will be directed away to the vent station. If during the emergency shutdown, the pressure continues to rise in the steamfield due to major equipment failure, the bursting discs may activate to release steam vertically to atmosphere. Under this situation the steam venting from the bursting disc will create a significant noise until the wells are shut in and geothermal fluids stop flowing. This event is considered an emergency and unlikely event.

**Maintenance**

The power plant and its components must be operated, monitored, managed and maintained in accordance with sound industry practice and Original Equipment Manufacturer (OEM) guidelines. The plant will be designed to be operated unmanned with automated emergency shutdown and remote dispatch. Remote monitoring will be provided to raise alarms for plant malfunctioning, fires, unauthorised visitors and so on.

This will be further supported by regular monitoring of critical pieces of equipment is required through daily walk overs to ensure safe operation. An annual outage of several days is required to inspect wellheads, remove silica scaling from the steam gathering system and overhaul pumps, valves, motors and other fittings. Some specialised equipment (e.g. cranes) would be brought onto site for this work.

Major overhauls of the turbines are periodically required (typically every 2-5 years) and are best undertaken by specialist firms. The exception to this is just before the initial defects liability period is to expire when the plant will be inspected carefully by the EPC contractor and DGDC. The four yearly interval unit works takes about two to four weeks to perform (for a typical flash plant) and an increased work force would be required. Additional labour resources would be engaged from local contractors and specialist providers.

Major steamfield maintenance and inspections will be undertaken during power plant unit shutdowns. The steamfield will be taken out of service during which time the separators, scrubbers and flash tanks will be inspected, cleaned and Non-Destructive Testing (NDT) would be carried out. Brine pumps and motors, valves and actuators will be inspected, overhauled and tested.

Other major maintenance work is associated with the steam production and reinjection / injection wells, which require periodic workovers to remove any scale deposition.

### 3.9.2 Well Maintenance

During the life of the station, it will be necessary to undertake cleanouts and workovers to maintain the output from production wells or injection capacity. There may be a requirement to drill additional production or reinjection wells, however this is unknown and not considered as part of this ESIA.

**Cleanouts**

In the course of the productive life of the wells, operational problems such as deposition of scale, silica, or calcite may develop in the wells affecting their operation. When this occurs, cleanouts using a drilling rig are sometimes required to restore the well's productivity or injectivity. Work-over operations are of a relatively short duration (3 days to 15 days) and much of the ancillary equipment required to drill a new well is not required. A basic rig, substructure, BOP, pump and tank are generally sufficient. Water is used as the drilling fluid to avoid damaging permeable formations with drilling mud.

**Workover**

A drilling workover generally entails some form of well repair which may require removing scale in the wellbore, removing the production liner, repairing the casing, deepening or side tracking the original bore, or plugging and abandoning all or part of the well.

A drilling workover operation falls somewhere between a new well and a cleanout. Most of the ancillary equipment, i.e. cementing and mud handling equipment, and drilling consumables are often required.

Rather than scheduling periodic workovers or cleanouts, downhole antiscalant equipment may be fitted to wells. This will require regular site visits, both by operations staff and inhibitor delivering trucks. They will also require a small hut on the wellpad to store the antiscalant.

**Master Valve Change**

Master valve changes can generally be undertaken without a drilling rig. The well is quenched by injecting cold water down the well in a controlled manner to prevent thermal stressing of the casing. Once the well is off-pressure the valve can be changed using a small crane. An alternative method used to change the master valve is installing a retrievable packer in the casing to isolate the well bore and so enabling the valve to be removed. The latter method requires a small drilling rig or other specialist packer installation equipment.

### 3.9.3 Steamfield

The steamfield will be designed, procured and constructed for the full capacity of the 7 MW power plant. The two-phase fluid will be sent to a separator where it is divided into steam and brine phases. Steam will be directed to the power plant, and brine to the injection pipeline. The steamfield will be identical for either option of power plant technology selected. A simplified typical steamfield arrangement is shown in Figure 3.10. The individual systems and typical infrastructure are described in the following sections.

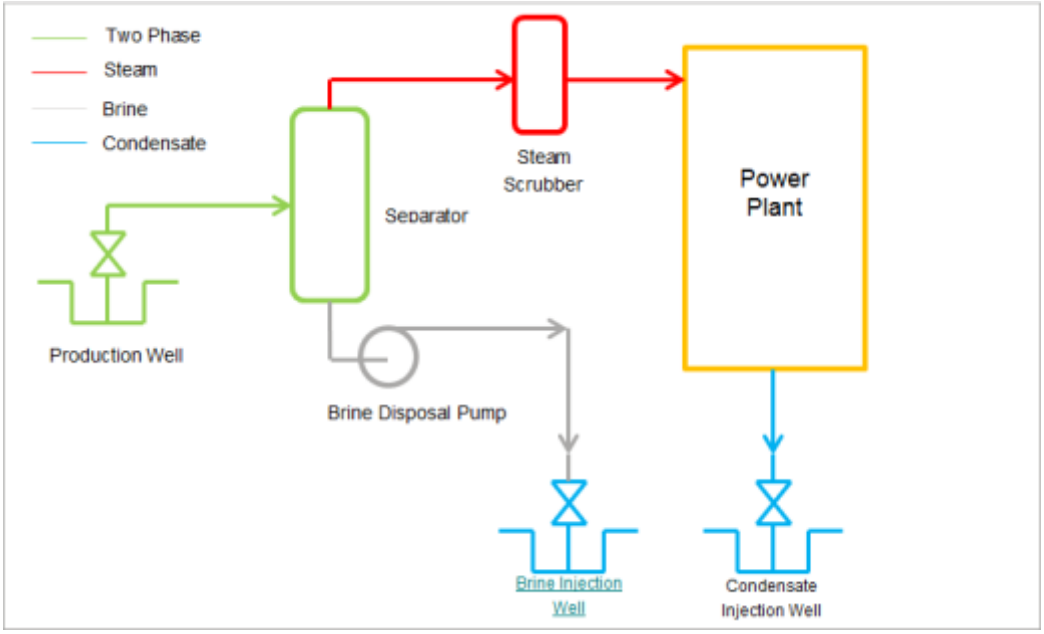


**Figure 3.10 : Typical Steamfield Arrangement (utilising energy in steam phase only)**

### Two phase collection and separation

Two phase collection and separation system including the following:

- production well WW-P1;
- two-phase piping;
- steam separator; and
- atmospheric flash tank (AFT).

The separator to be used on this Project will be located on the WW-P1 well pad and is anticipated to be 7.5-10 m high and approximately 1.5 m in diameter, as shown in Figure 3.7 below. The atmospheric flash tank will be between 1 m and 3 m in diameter and is typically used as a vessel to receive fluid e.g. brine during well testing, start-up or in the event of operational issues. The brine will flash inside the vessel and the steam component will discharge to atmosphere. Brine collected in the AFT is pumped to the reinjection wells for disposal (see Figure 3.11).



**Figure 3.11 : Typical geothermal separator and Atmospheric Flash Tank (AFT / Silencer)**

### Steam gathering system

Steam exiting the separator is collected in a steam header and transported to the power plant. Condensate collection drain pots (CCDPs) located at low points on the piping will be used to collect condensate generated in the piping system. These will be discharged to a storage sump for disposal. High point vents (HPVs) will be used to collect non-condensable gases (NCGs). The piping is typically wrapped in calcium silicate and / or fibre-glass insulation material and an aluminium cladding.

Upstream of the power plant, a steam scrubber is utilised as a final condensate removal stage to ensure that the moisture content of steam is as low as possible prior to admission to the turbine. The geothermal condensate removed from the steam will typically be sent to storage sumps and pumped away for injection at WW-03.

The steam venting and pressure control system is used for the following:

- “Trim” system pressure by venting steam to maintain the desired interface pressure on entry to the turbine;
- Vent steam in the event of system upsets (i.e. turbine trips); and
- steam is vented to a rock muffler to control the release of pressurised steam and attenuate noise associated with this.

During normal operation there will be a small flowrate of steam through the vent system to maintain steam pressure on entry to the turbine. A typical vent system, vent valves and rock muffler from a large steamfield is shown in Figure 3.12.



**Figure 3.12 : Vent system**

### Storage sumps

Storage sumps are used to collect brine or condensate that is discharged due to operational issues. Storage sumps will be located at each of the well pads. It is anticipated that emptying of the sump at WW-P1 will be to reinjection wells WW-01 and WW-R1 via the reinjection pipeline. A typical sump is shown in Figure 3.13 and is approximately 20 m x 40 m x 3 m deep.



**Figure 3.13 : Storage sump**

### Condensate collection and disposal system

Condensate is typically produced in two locations:

- within steam pipes due to temperature differences within the pipe and surrounding atmosphere; and
- discharge of excess condensate from the cooling tower basin.

Condensate is produced within steam pipelines and collected via a Condensate Collection Drain Pot (CCDP), found at local low points on the route, and then disposed to the storage sump. A typical CCDP is shown in

Figure 3.14. If a steam condensing turbine option is selected condensate will be collected from the cooling tower basin. While some of this condensate is re-used inside the cooling tower to make up for losses due to evaporation and drift, the balance will be disposed of via a dedicated pipeline to WW-03. The volume of condensate produced is low compared with brine produced and therefore will not impact on performance of WW-P1.



**Figure 3.14 : Condensate collection drain pot (CCDP)**

**Brine Collection and Reinjection System**

The brine from the separator passes through a brine collection drum into a network of pipes that will feed the brine to wells WW-01 and WW-R1 via gravity. There is a degree of uncertainty around the injection capacities of the two wells and the volume of brine produced. In the unlikely event that the injection capacity does not meet the requirement two possible solutions can be implemented. Firstly, a pump station could be installed at WW-R1 prior to operation in order to increase the brine pressure into WW-R1 and increase the combined injection capacity of WW-R1. The quantity of pumps required is a decision made later in the project design. Secondly well WW-R1 may be stimulated by pumping cold water from the Roseau River at a rate of 20 litres per second over a one month period.

The pipeline will also have drains at any low points for draining down the line on shutdown in order to prevent silica polymerising in the lines due to stagnant conditions. These drain points will be connected to the sumps at the injection well pads for subsequent disposal into the injection wells.

### 3.9.4 Power Plant

This section discusses the options for electricity generation to allow various impacts for each of the two suitable technologies to be established and assessed in the ESIA. The feasibility analysis identified two suitable power plant technology options:

1) Single flash steam condensing cycle; and
2) Organic Rankine Cycle.

It is proposed that suppliers will be invited to offer power plants based on a clear set of technical specifications for the project. That while not prescriptive of the technology to be used, the technical constraints will result in one of the two options above being utilised on the Project.

### Single Flash Steam Condensing Cycle

Geothermal steam from the separator is used directly in a steam turbine connected to a generator. After the steam passes through the steam turbine it is condensed for reinjection. Figure 3.15 presents the single flash plant process.

Steam enters the turbine from the steamfield and the flow rate is modulated by a control valve called a governor valve. Excess steam is vented through an upstream steam vent system consisting of a pressure control valve and rock muffler (which is part of the "steamfield"). Immediately upstream of the governor valve is a main stop valve that shuts if the turbine trips. The geothermal steam is passed through the turbine providing motive force to rotate the turbine and generator. The steam then exhausts into a condenser at a pressure of about 0.1 bara (i.e. under high vacuum). Figure 3.16 provides an indication of the size of plant envisaged for the Dominica project.

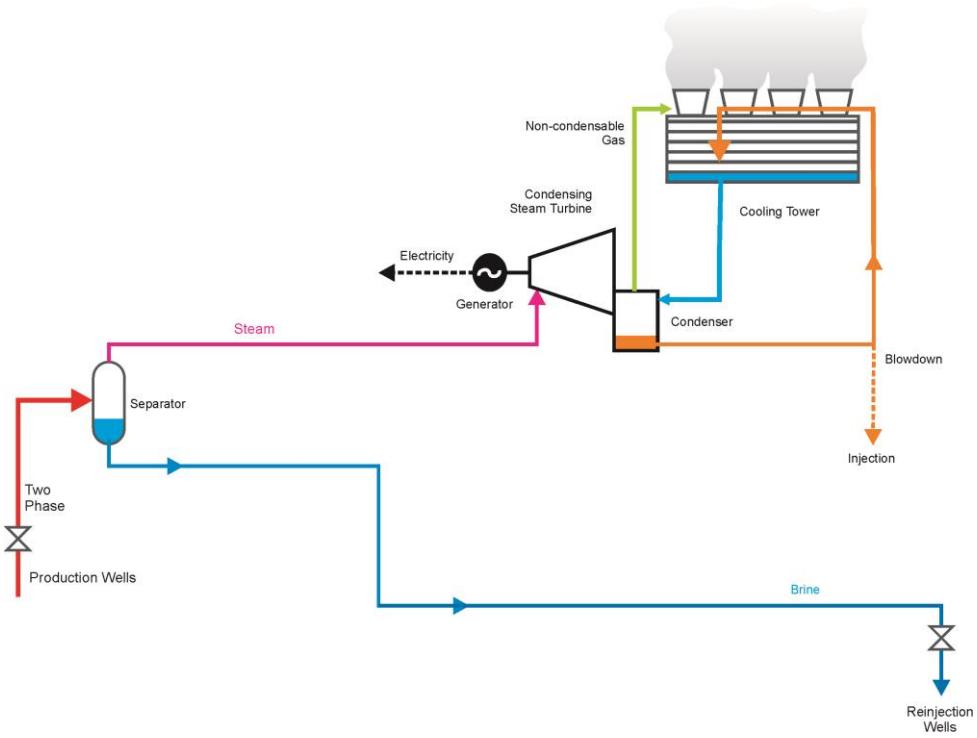


**Figure 3.15 : Typical geothermal single flash steam condensing cycle**



**Figure 3.16 : Condensing Steam Turbine (Source: GDA - http://www.gdareno.com)**

*Condenser*

The purpose of the condenser is to condense the steam, creating a vacuum and thereby generate more power due to the higher pressure differential and higher heat drop across the turbine. They rely on cool water (which comes from previously condensed steam that has passed through the turbine) being directly sprayed into the steam to condense it.

*Gas Extraction Equipment*

In order to maintain the vacuum in the condenser, the non-condensable gases (NCGs) must be continuously removed from the condenser. This is accomplished by use of a gas extraction system, steam-driven ejector or steam ejector / ring pump (hybrid). The type of system is determined during the bidding for the plant, and can be influenced by the value attached to steam used in the ejectors.

Whatever the approach, the NCGs extracted from the condenser are piped to the cooling tower where they are discharged to the atmosphere in the warm plume of moist air and dispersed to the environment.

*Oil System*

A lubricating oil system is required for the turbine generator units. The system includes pumps, coolers, oil tank, filters and purifiers. As mitigation for leakage or spills, oil containment bunds / trays are normally specified around or under all lube oil equipment to contain at least 110% of the total oil system capacity.

*Fire Detection and Protection*

The plant will include a fire detection and protection system to prevent damage to the cooling towers and oil containing equipment including the turbine-generators and oil filled transformers. This would likely comprise a fire ring main and include monitors (spray cannons) covering the cooling tower.

A fire-fighting water tank will be required and sized in accordance with NFPA 850 (Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations). Monitoring systems associated with the fire protection system will be spaced around the site as required by the relevant fire service standards.

### Organic Rankine Cycle

This technology requires geothermal fluids to pass heat to an organic working fluid which boils and the organic vapour then drives a turbine connected to a generator. These are often also called 'Binary Cycle' plants because they use two fluids (the original steam and the organic secondary fluid). Figure 3.17 shows a typical binary plant which uses steam as is proposed for Dominica.

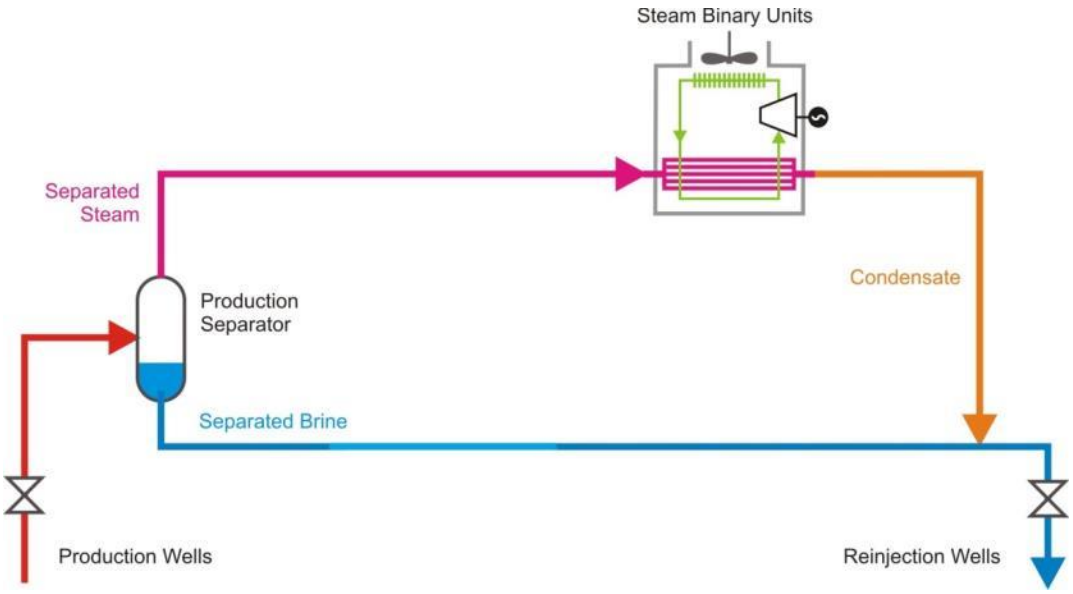


**Figure 3.17 : Typical geothermal Organic Rankine cycle**

Most working fluids employed for power generation with binary processes are flammable. Isopentane or N-pentane is a typical working fluid and is recommended for this Project. Being flammable it brings requirements for safe design, construction, operation and maintenance. The working fluid must be topped-up on an ongoing basis which means that the fluid must be imported and stored safely over the life of the project.

The heat exchangers in a binary plant transfer the energy of the geothermal fluids to the working fluid, see Figure 3.18. They are usually shell and tube type. In a typical plant a pre-heater and a vaporiser will be utilised. Typically, the brine will pass through the pre-heater and heat the working fluid to its boiling point. The steam condensing in the vaporiser will then vaporise the working fluid after which it is delivered to the turbine or expander. The number of heat exchangers will be at the discretion of the EPC Contractor.



**Figure 3.18 : Binary plant heat exchangers (large plant example)**

*Working Fluid Pumps*

The working fluid is circulated in a closed system at elevated pressures in order to extract the maximum amount of power for a given resource condition. Pumps are used to circulate the working fluid around the cycle. The pumps will be supplied by the EPC Contractor.

*Fire Protection*

Due to the flammable nature of the likely working fluid a comprehensive fire protection system will be required. A binary plant using hydrocarbon working fluid such as n-pentane will require a full firefighting system comprising water storage tank (up to two hours supply), fire water pump and jockey pump, fire-water mains, and hydrant/monitors. There will also need to be a fire detection system, plus hydrocarbon gas detectors that would identify any potential leakage.

At the power plant, the fire protection system comprises a fire ring main and spray system that covers the physical plant, and an inert gas ($CO_2$, “inergen” containing a mixture of nitrogen, argon and $CO_2$, or similar) discharge system for the control room and building annex.

A fire-fighting water tank will be required and sized in accordance with NFPA 850 (Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations). Monitoring systems associated with the fire protection system will be spaced around the site as required by the relevant fire standards and regulations.

### 3.9.5 Power Plant Cooling Options

A cooling system is required to reject heat which cannot be converted to electric power. In the case of the condensing steam turbine plant this is always an evaporative water cooling system because cooled water for subsequent heat rejection by evaporation is freely available from the steam which is previously condensed in the process.

In the case of the binary plant the cooling system is almost always air cooling. This is because the binary fluid leaves the binary turbine as a vapour which must then be condensed without direct contact with another fluid

because it is reused again in the process. The condensation can be achieved either by air (dry) cooling or water (evaporative) cooling. The cooling process will be confirmed by the EPC Contractor during bidding.

The main differences between the evaporative (wet) cooling option and the air (dry) cooling options are: the land area required for the cooling towers; overall efficiency; visual emissions or plumes, the reinjection load and the total installed cost (Figure 3.19).

- Wet cooling towers are typically used with condensing steam Rankine cycle plants. Water cooling towers have a visible plume of water vapour when the relative humidity of the atmosphere is high and are particularly visible on cool mornings – this is because the air flow leaving the tower is 100% humid. Towers can be configured so that there is some sensible heating of the air flow leaving the tower which reduces the humidity below 100% and alleviates the visible plume as it leaves the tower. As a large part of the steam condensate is evaporated, the total amount of liquid to be reinjected is less than for air cooling.
- Air coolers have a larger land footprint than water coolers. Air coolers do not have a visible plume of water vapour or emit condensate, but may exhibit a heat haze.



**Figure 3.19 : Air cooling for 9MW binary plant (left). Evaporative cooling tower – only 1-2 cells likely required for Dominica project (right)**

### 3.9.6 Use of Water

**Potable Water Supply**

A potable water supply will be required for the geothermal development for drinking water, showers, toilets and kitchen facilities. The quantities of water required will be small as only a small work force (2 or 3 staff) would be required. Options for water sources include taking water from local streams or rivers, rain water or deliveries of bottled water. Water take from local streams will require filtration and biological treatment. The most likely solution is:

- drinking water delivered; and
- rainwater collection for showers (if permitted) and cleaning.

**Sewage Treatment**

Due to the number of workers living on the site at the worker's camp, a package plant will be required for sewage treatment. The package plant will be located on ground designated for the worker's camp. All fluids discharged from the package plant will comply with international standards (i.e. the WBG EHS Guidelines).

**Supply for Fire Water**

Fire water supply is likely to require tank water consisting of a minimum 500 $m^3$ to be on standby. A tank size in the realm of 12 x 5 m is envisaged and this is likely to provide 1.5 hours of firefighting capacity. Water requirements for fire protection will be aligned with the power plant technology choice and specified in bidding documentation.

**Stormwater Management**

Stormwater management will be required throughout construction and operation of the project infrastructure, taking account of well pads, steamfield equipment and power plant location. Stormwater run-off from buildings and yards will be collected and discharged to local watercourse. Contaminated stormwater (e.g. oily water, hazardous substances) will go to a three stage interceptor before discharge to watercourse. It is not considered feasible to use the reinjection line for any contaminated stormwater.

### 3.9.7 Road Network

The road and track network for the Project existed prior to the geothermal drilling campaigns, although works were required to allow passage of the drilling rig. Road access to the well pads and power plant site has previously been established by the Government. Minor remedial works may be required for the existing road and track network, especially around the preferred reinjection pipeline route, but no new roads or tracks are needed.

### 3.9.8 Electrical Equipment

For each technology option, the layout and design of the electrical equipment will be similar but subject to constraints imposed by the technology chosen. The energy contained within geothermal steam is converted to electrical energy using a steam turbine that is mechanically coupled to a generator. Figure 3.20 shows a typical generator. The electrical power from the generator will be transmitted from the power plant using insulated cables, at 11 kV, allowing connection to the existing DOMLEC 11 kV network at the Trafalgar and Laudat Hydro stations without adding a step-up transformer.

In order to safely operate and transmit electrical power from one location to another an indoor switchroom will be built. This facility will house equipment required to de-energise and protect incoming / outgoing lines / cables etc. Typical switchroom equipment includes circuit breakers, surge arrestors, current transformers and voltage transformers. During operation little work is required to maintain the electrical systems



**Figure 3.20 : Typical 5.8 MW generator (Ngawha Power Station, New Zealand)**

### 3.9.9 Grid Connection

The new geothermal power plant will evacuate power at 11 kV through new three underground cables that will connect to the existing 11 kV switchgear at Laudat Hydro Station. These three new underground cables will run through land to be acquired for the power plant and through land owned by DOMLEC. They will be run under or directly alongside the proposed access road into the Project site. The length of this route is approximately 440 m. The proposed connection arrangement is provided in Figure 4-13.

For installation, trenches will be dug in which the cables will be laid and the trench backfilled. There is the potential to create sediment containing run-off when the trenches are open. This run-off will be handled as part of the mitigation measures proposed for civil construction works in general. Once installed, there will be no visual impact, nor impact on the use of the roads or amenities as they are underground. Therefore, no mitigation specific measures are required.

In addition to the 11 kV underground cable connection to the Laudat Hydro Station, DOMLEC are to also carry out ancillary works on the network. This includes the rebuild of the existing transmission line from Trafalgar Hydro Station to Fond Cole Power Station, which was destroyed by Hurricane Maria. As it represents an opportunity to build back better, DOMLEC have opted to upgrade the line to be capable of operating at 33 kV as part of this rebuild. That entails fitting slightly longer insulators which suspend the transmission wires from the poles. Also, they will extend the line from Trafalgar Hydro Station to Laudat Hydro Station to provide a 2nd circuit using the existing poles. These measures are to improve DOMLEC's network capacity, capability and flexibility and will be carried out even if the geothermal power plant is not developed and as such are not considered to be an associated facility as defined under Performance Standard 1. The construction method to be used for the rebuild will be determined by DOMLEC.




**Figure 3.21 : Proposed connection with DOMLEC Grid**

### 3.9.10 Hazardous Substances

Once upfront design measures for hazardous substances include: secure safe storage (tanks) in a bunded area with signage in place. Bunding is usually specified to contain at least 110% of the volume of the largest tank and piping inside the bunded area. Hazardous substances which require management include:

- All geothermal fluid should be captured and sent to injection wells for re-injection. This is standard practice at most geothermal developments. Geothermal condensate contains few hazardous materials, although they can be rich in boron which will tend to accumulate in the cooling tower sludge. The pH of this fluid is between 6.0 and 8.5.
- Working fluids for ORC cycle power plants. It is anticipated that n-pentane will be used as the working fluid and therefore this is considered as part of the ESIA assessment.
- Acid (normally sulphuric acid) for pH modification of geothermal fluids to avoid silica scaling. This is not expected to be an issue for the envisaged steam separation pressures and so acid use and storage is unlikely.
- Antiscalant for prevention of calcite formation in the production well is likely to be required. This will be a poly-acrylate or poly maleic acid.
- Sodium Hydroxide / Caustic for dosing to ensure the pH of the cooling water circuit is kept within appropriate limits. A system using pre-mixed sodium hydroxide is typical, although this may not be available in Dominica and it may be necessary to pre-mix the solution on site using bagged caustic soda.
- Biocide dosing for wet cooling towers to prevent build-up of biologic growth such as algae. Sodium Hypochlorite (NaOCl) is typically used.
- Cooling tower water dispersant(s) are chemicals that inhibit or prevent scale formation in the tower. As with caustic soda and biocide a bunded storage area is typical for all chemical storage tanks or containers.

Sumps would be provided to allow removal of hazardous chemicals with permanently located submersible pump(s) discharging into the cooling tower basin.

- Lubricating oil can cause adverse environmental impacts if leakage occurs. Plant areas will be bunded and have oily water separators to ensure any leaked or spilled fluids do not contaminate the site.

## 3.10 Decommissioning

Geothermal developments by their nature and design are intended to be renewable and sustainable operations for developing electricity. Decommissioning whole geothermal developments is a rare operation as generally, if the resource conditions are still favourable, equipment can be refurbished or replaced. Power plants can undergo mid or end of life refurbishment at the end of their design life to upgrade and repair equipment to enable operation and generation to continue.

Decommissioning or replacement of equipment throughout the life of a geothermal development is a common occurrence as most equipment, such as pumps, valves etc will have design lives of about 15 years.

For the Dominica geothermal development, it is assumed that design practices will allow for the full decommissioning of the power plant and steamfield, should that be required at the end of the plants design life or before if unforeseen conditions make the development uneconomic.

Due to the uncertainty of when the processes will occur, the potential impacts of decommissioning activities will not be considered in the ESIA.

# 4. Project Justification and Assessment of Alternatives

## 4.1 Project Justification

### 4.1.1 Policy Background

Dominica has struggled to keep pace with other economies in the Eastern Caribbean region. For a number of years, all Organisation of Eastern Caribbean States (OECS) countries have been experiencing a cycle of low growth, high debt, limited fiscal space, exacerbated by a number of exogenous shocks such as the loss of preferential access to European markets; contraction of foreign direct investment due to the 2008 global economic crisis; and natural hazards that frequent the Caribbean. In this context, economic growth in Dominica has been poor. Dominica's development prospects critically hinge upon improving productivity that will enhance its competiveness in traditional economic sectors and assist in developing new ones.

The proposed project is consistent with the Regional Partnership Strategy for the OECS for the period FY15-19, which focuses on three main areas of engagement:

- Competitiveness;
- Public sector modernisation; and
- Resilience.

The RPS has identified the development of geothermal in the OECS, and specifically in Dominica, as a priority area for support.

The project also aligns with the GoCD's Growth and Social Protection Strategy (GSPS) for 2014-2018, which seeks to increase the use of geothermal to improve growth. The GSPS highlights three main objectives for the energy sector, which include:

- Containing energy costs;
- Encouraging energy conservation; and
- Diversifying energy sources and reducing reliance on fossil fuels.

Developing renewable energy, especially geothermal, is considered a solution to achieve several of these objectives and ultimately help achieve Dominica's quest for greater competiveness, higher growth and long-term sustainability.

The proposed project is also consistent with and supports regional and global development objectives including:

- It fulfils part of the Nationally Developed Contributions made by Dominica to address global climate change under the Paris Agreement;
- The affordable and clean energy and the climate action goals of the Sustainable Development Goals; and
- The efforts to double the share of renewables in the energy mix by 2030 under the 'Sustainable Energy for All' (SE4ALL) initiative – both efforts established under the auspices of the United Nations.

### 4.1.2 Power System

Dominica's power system relies heavily on diesel fuel imports to generate electricity. As with many other island nations, Dominica's primary source of electricity production is from diesel generation, which exposes the country's economy to price uncertainty in regard to the cost of diesel imports. The power system is operated by DOMLEC, a privately owned organisation that has the exclusive licence to transmit, distribute and supply electricity on the island, and a non-exclusive licence to generate electricity. The electricity industry is regulated by the Independent Regulatory Commission.

Changing the power generation mix and reducing the cost and volatility of electricity prices have become development priorities for Dominica. Being a relatively young volcanic island, Dominica has significant geothermal resource potential. Therefore, the GoCD has pursued an exploration programme to evaluate the viability of geothermal resource in the Roseau Valley. Geothermal power projects typically connect production wells through a steamfield facility to a power plant which, in turn, is connected to an electricity grid. Geothermal energy extracted from below the ground may take the form of steam, hot water (brine) or a combination of both, and often a quantity of non-condensable gases (mostly carbon dioxide and trace gases). Used geothermal fluids produced by the project are returned to the geothermal reservoir via reinjection wells, which may be located some distance away (i.e. over 1 km) from the production wells.

GoCD is actively moving towards renewable sources of energy such as geothermal energy and away from reliance on fossil fuel energy generation such as diesel. This will assist GoCD meet its development priorities and in reducing greenhouse gas emissions.

## 4.2 Assessment of Alternatives

The preferred power plant site and reinjection pipeline route were selected through a multi-criteria assessment process. The assessment covered a range of issues including:

- Technical aspects – site characteristics, topographical data, geological conditions, geothermal operating conditions and access requirements.
- Socio-economic aspects – existing land tenure, land acquisition requirements, effects on local employment, health of the local population, impact on tourism operators and safety during construction.
- Environmental aspects – air quality and noise impacts, visual intrusion, the Outstanding Universal Values of the UNESCO World Heritage site, meteorological conditions and traffic volumes.

### 4.2.1 Do Nothing Option

The do nothing option for the Project would result in the continued ‘status-quo’ for energy generation and reliance on diesel power within Dominica. The proposed Project represents a step change for the GoCD in moving towards renewable sources of energy generation, increase competitiveness and provide improved energy security. Therefore, the do nothing option is not considered viable as it does not meet the Government’s policy objectives.

## 4.3 Power Plant Siting Options

In July 2016, land around WW-P1 was examined by a field team for suitability to site the geothermal power plant. It was proposed that the new separation plant be located on the western end of the existing wellpad. The remaining space on the wellpad should be conserved for future production drilling. Three areas were identified that may be suitable sites for the development, with relatively modest slope and located in close proximity to existing wellpad, these are described below:

1) **Option 1** - immediately north of WW-P1 is large enough to accommodate a steam condensing plant, with provision to include the Option 1A site for ancillary requirements such as offices and maintenance facilities. Some of this site (1A) is in the ownership of the government as a 3.8 acre parcel of land was acquired for WW-P1;
2) **Option 2** - is to the south-east of WW-P1 and on approximately the same elevation. Ready access could be formed from WW-P1. The site would be suitable for a condensing plant, but also has a potential use as an extended wellpad for future drilling programs. The local preference expressed by the Site Attendant, following community consultation, was that this area be reserved for potential future drilling; and
3) **Option 3** - is a larger site suitable for a binary plant. It is located some 100 m north-east of WW-P1 and has a 12° slope to the north which could be readily levelled to form a platform. It is currently used for small scale agriculture.

The preliminary locations of power plant options are shown in Figure 4.1 below.

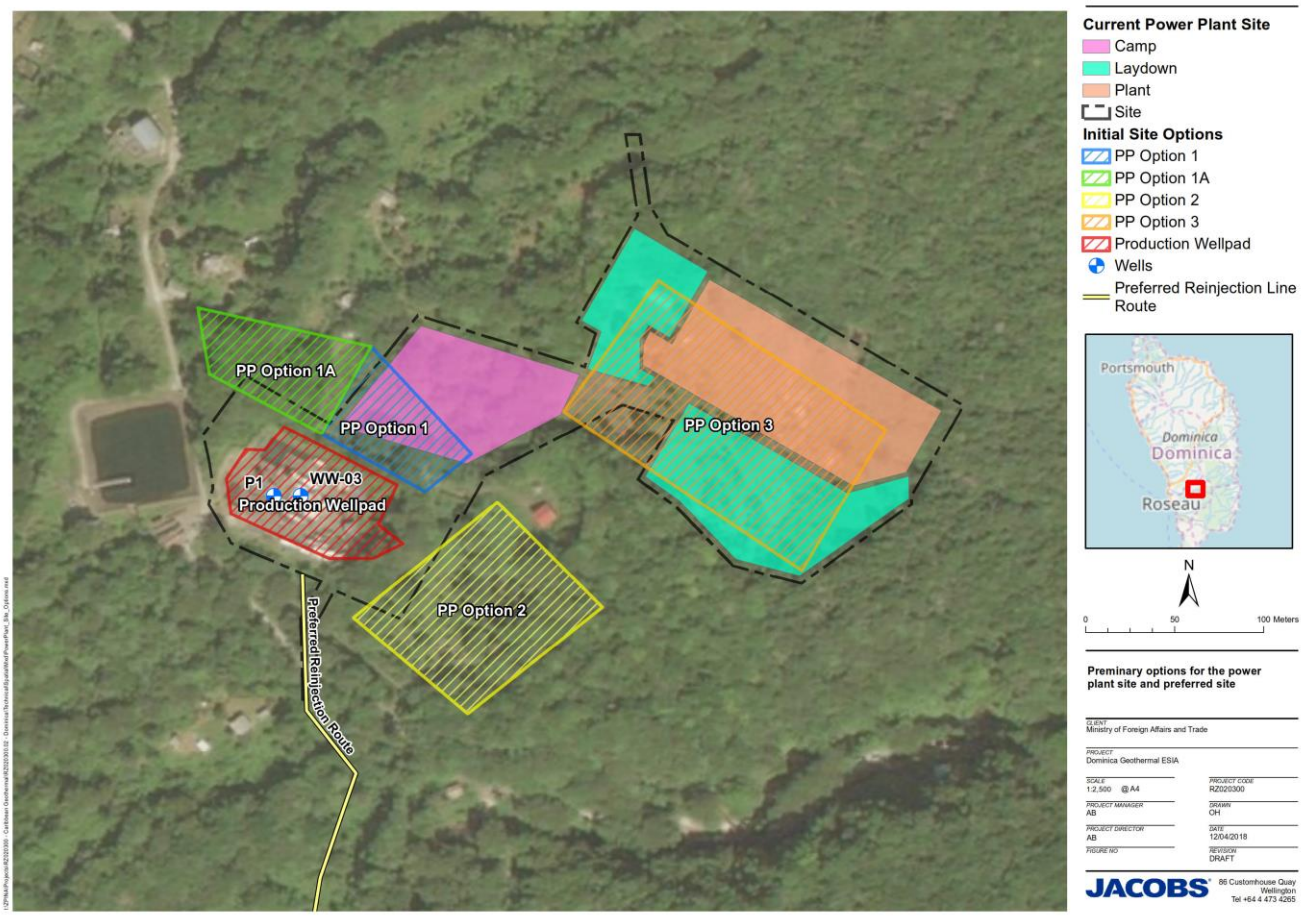


**Figure 4.1 : Power plant site options (source: Google Earth, 2017)**

After the initial identification of these power plant options, a process commenced to identify potentially affected landowners. No cadastral maps exist for this area and so existing titles were obtained from the Department of Land and Surveys. A surveyor was employed to survey the land and demarcate the areas on a map. Subsequently topographic, environmental and social data was collected to help with the evaluation of the site.

The preferred power plant site (Option 3) was selected was based on an evaluation of technical and non-technical considerations. Technical considerations include the topography of the land, civil works requirements, access constraints, proximity to the production well, alignment with prevailing wind direction and future development considerations. A civil engineer undertook a site visit to evaluate the volume of earthworks required to prepare different options such to minimise disruption and removal of soil. Preliminary process engineering was undertaken to assess impacts of the selected site on the steam gathering system and brine injection line routing.

Social factors include the proximity to the local population, use of topography to shield the site, and the lower/lowest number of affected land owners to reduce acquisition requirements. Biodiversity factors included that the site was highly modified habitat currently 100% used for agricultural purposes and as such there was no impact on natural habitat. This resulted in selection of Option 3 for the power plant site.

Table 4.1 provides a brief comparison of the different power plant site options.

**Table 4.1 : Comparison of the Power Plant Options**

| Item | Option 1/1A | Option 2 | Option 3 | Comment |
|---|---|---|---|---|
| Area required | 0.70 ha | 0.82 ha | 1.43 | N/A |
| Proximity to residential properties | • Number of properties within 100 m of residential receivers: 5<br>• Closer proximity of Option 1/1A to residential receptors than Options 2 and 3. Potential for noise, air quality and visual impacts higher for Option 1/1A than Option 2 and 3.<br>• Modified Habitat | • Number of properties within 100 m of residential receivers: 3<br>• Closer proximity of Option 2 to residential receptors than Option 3 but further proximity than Option 1/1A. Potential for noise, air quality and visual impacts lower for Option 2 over Option 1/1A and higher for Option 3.<br>• Predominately modified habitat with small amount of low grade natural habitat. | • Number of properties within 100 m of residential receivers: 2<br>• Option 3 further from residential receptors than Options 1/1A and Option 2. Potential for noise, air quality and visual impacts lower for Option 3 than Option 1/1A and 2.<br>• Modified Habitat | Option 3 considered preferable. |
| Ease of acquisition | Land owned by multiple owners >2) | Land owned by multiple owners (>2) | Land owned by two owners. | Option 3 considered preferable. |

## 4.4 Steamfield and Reinjection Pipeline Siting Options

Options for steam/brine separation, steam pressure control, steam scrubbing, and start-up, normal and emergency shutdown operations were considered and the land required to achieve these operations, has been determined through a preliminary steamfield design exercise. These are essentially the same for both power plant technology options.

In July 2016, site visits by mechanical and geotechnical disciplines identified eight possible pipeline routes. The routes were evaluated on the basis of the constructability, topography, geohazard exposure (i.e. landslides, rock falls, etc.), estimated capital costs, operational considerations and social and environmental constraints.

From the original eight routes identified, an initial evaluation considering constructability, topography and proximity to local villages reduced these to three options (Figure 4.2)

1) Option A, D and F;
2) Option C, D and F; and
3) Option H and F.

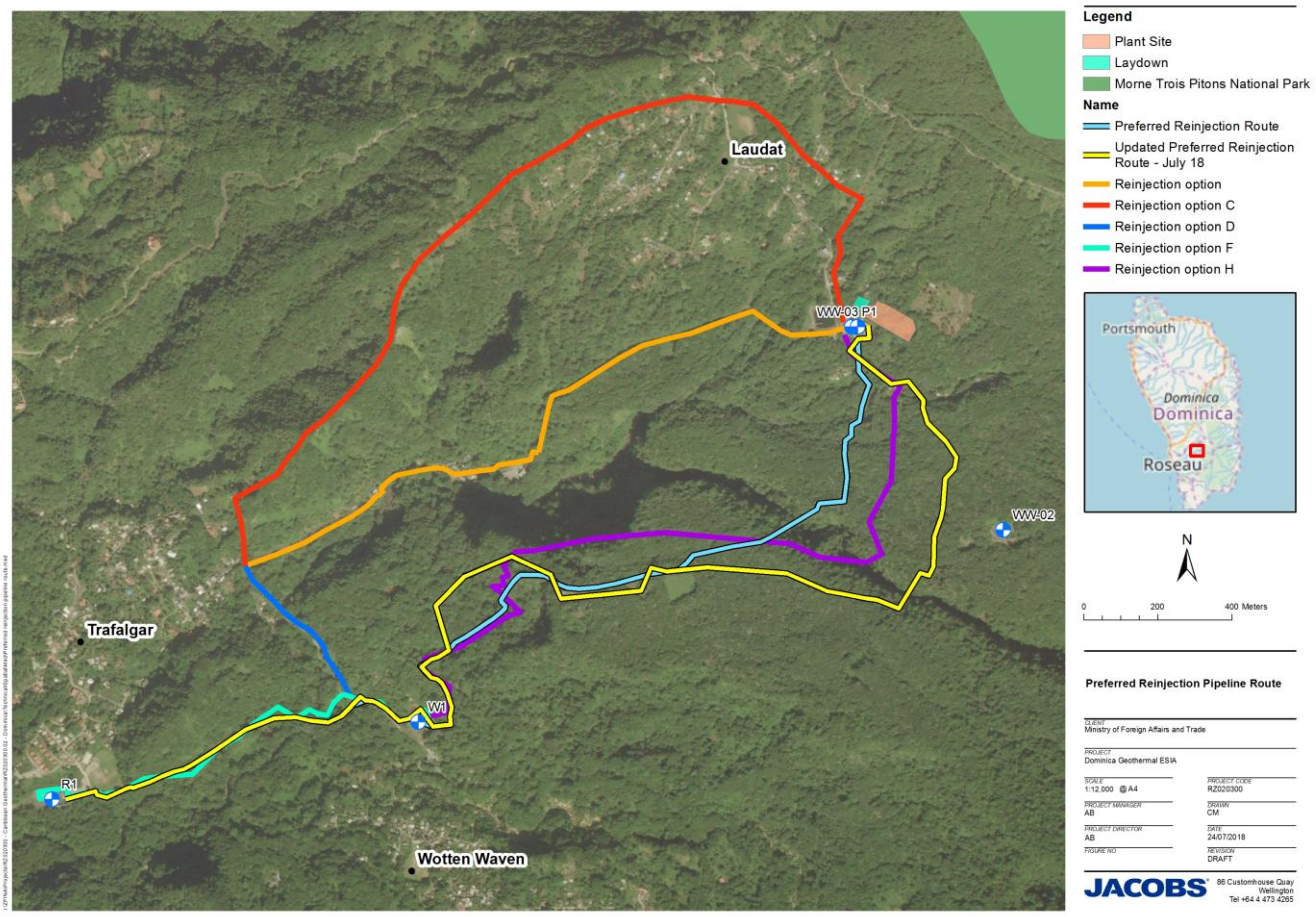


**Figure 4.2 : Main re-injection line options investigated in July 2016. Note that this Figure shows a previous location of the power plant.**

**Option A** - Follows DOMLEC's hydropower pipelines across easily navigated topography and would need to utilise DOMLECs existing bridge which currently carries the penstock. Construction would be simpler in this section and there is adequate space for expansion loops. The pipeline would then need to descend the 60 – 80 m vertical cliff, alongside the existing hydro pipeline (Figure 4.3). Once the cliff has been descended, the route runs alongside the river and the road to Trafalgar Falls. Route runs primarily through modified habitat and moderate grade regenerated natural habitat.

**Option C** – This is the longest route and would require pumping of brine (~80 kW – 100 kW load) from WW-P1 at 554 m ASL to 615 m ASL. The route would follow the existing penstock route, before traversing to the north and west of Laudat to avoid the village itself and associated road/access way crossings. The pipeline would descend down a steep and narrow ridge line on which the Waitukubuli National Trail presently runs. This route is the closest to the Morne Trois Piton National Park boundary and could result in indirect impacts during construction of the reinjection line on the park's biodiversity.

**Option D** – From the point where the Waitukubuki Trail meets the road, the pipeline would cross the river, suspended above the new Bailey Bridge, before following the road to Wotten Waven and pad WW-01. Route runs primarily through moderate grade regenerated natural habitat with some modified habitat.

**Option F** – This section of pipeline would go from WW-01 to WW-R1. The pipeline would cross under the road and follow the river before crossing the gorge with a pipe bridge near the river junction. The last 200 m before the football field would follow a narrow track with minimal space for expansion loops. The track has steep slopes

and would require rockfall protection. Space for construction in this part of the trail is limited. Route runs through a mix of mainly modified habitat with some pockets of regenerated natural habitat.

**Option H** - This route would traverse cross country from WW-P1 to near the old aerial tram station. From there the pipe would cross the Breakfast River Gorge using a suspension bridge of 70 – 100 m. The pipeline would then cross relatively flat terrain before descending down a short section of narrow pathway, which broadens and eventually comes out by WW-01. Route runs for 300m along DOMLEC water pipeline, around 500m along the old tramway, and through a mix of regenerated natural habitat and modified habitat being mainly used for horticulture.

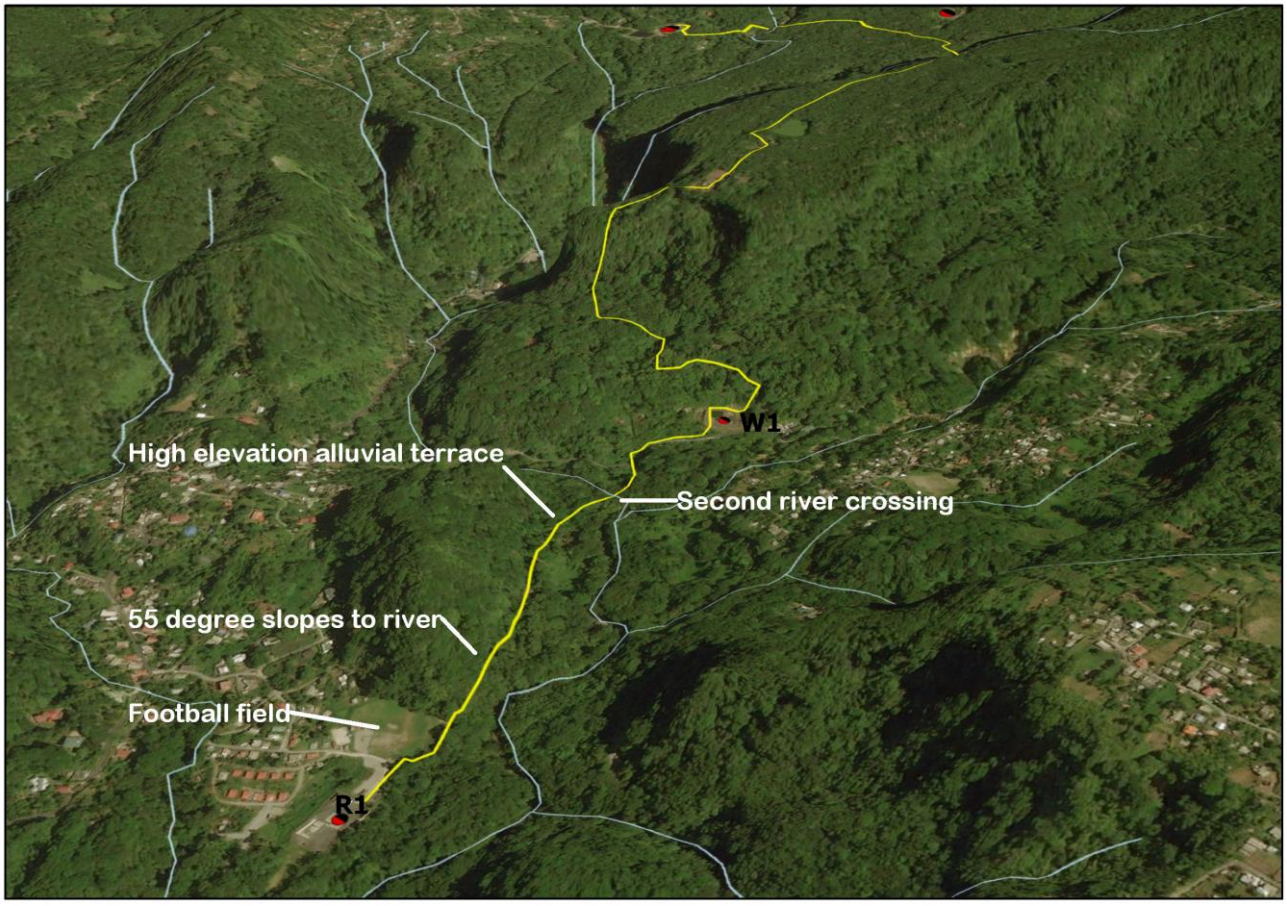


**Figure 4.3 : Recommended reinjection pipeline route from WW-01 to WW-R1.**

The three shortlisted options were discussed at a public meeting in December 2016 to obtain feedback from the community. This resulted in the removal of Option C (red) as it was deemed to interfere too much with the village. The remaining two options are both technically challenging, requiring steep descents, construction of pipe bridges and river crossings.

In May 2017 a LIDAR survey was flown and the results provided the impetus to select the 'Preferred Option' which has some slight modification as a result of the June 2018 survey (shown in yellow in Figure 4.2), principally based on the detailed topographical data obtained. The Preferred Option also provides benefits over the second placed option (Option A/D) in terms of: disturbance to the local community; potential for interference with existing infrastructure (DOMLEC's hydro power pipelines); possible impacts on tourism at Trafalgar falls; reducing the amount of regenerate natural habitat being removed and long term resilience, by avoiding flooding events which may damage infrastructure. The Preferred Option also avoids areas most severely impacted by flooding and soil erosion from Hurricane Maria, however there are still geotechnical assessments required to be undertaken for the route prior to construction.

### 4.4.1 Finalising the Reinjection Pipeline Route

The final alignment of the reinjection pipeline can only be determined following preliminary engineering design and subsequently during construction. Further work is required to establish the feasibility of river crossings, alignment based on local topographical features, consideration of environmental impacts and alignment based on land boundaries. This will be completed in close co-ordination between environmental and social scientists and the process engineering, mechanical, geotechnical and civil engineering design disciplines, along with the Government, Land and Survey Division.

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# Dominica Geothermal Development - Environmental and Social Impact Assessment

NZ Ministry of Foreign Affairs & Trade

## ESIA Volume 2: Environmental Impact Assessment

RZ020300-002-NP-RPT-0005 | V2

July 2018



## Project Name

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# Glossary

| Acronym | Term | Definition |
|---|---|---|
| AoI | Area of Influence | The project AoI is defined through consideration of the project footprint including all ancillary project components and also considering project impacts on various environmental and social components. A number of project areas of influence may result but is best to amalgamate them into an overall project area of influence. In addition to the area of geographical or spatial influence, temporal influence should also be determined. A geographical information system is a useful tool for this purpose. |
| - | Cumulative Impact | Cumulative impacts are changes to the environment that are caused by an action in combination with other past, present and future human actions. The assessment of these effects is called a cumulative impact assessment (CIA). |
| EPC Contractor | Engineering, Procurement and Construction Contractor | The EPC Contractor is responsible for all the activities during construction of the Project from a design, procurement, and construction perspective. |
| ESIA | Environmental and Social Impact Assessment | Identifies and assesses the risks and the impacts associated with the project and provides a series of mitigation measures that when implemented will ensure the project complies with the standards and guidelines it has be evaluated against. |
| ESMP | Environmental and Social Management Plan | Summarises the client's commitments to address and mitigate risks and impacts identified as part of the Assessment, through avoidance, minimisation, and compensation/offset. This may range from a brief description of routine mitigation measures to a series of more comprehensive management plans (e.g. water management plan, waste management plan, resettlement action plan, indigenous peoples plan, emergency preparedness and response plan, decommissioning plan). |
| ESMS | Environmental and Social Management System | The ESMS is the overarching environmental, social, health and safety management system which may be applicable at a corporate or Project level. The system is designed to identify, assess and manage risks and impacts in respect to the Project on an ongoing basis. |
| - | Legal and regulatory framework | The national legal and institutional framework applicable to the project should be defined. This should also include any additional lender requirements and any international agreements or conventions that may also apply. |
| MTPNP World Heritage Site | Morne Trois Pitons National Park World Heritage Site | A World Heritage Site is a natural or man-made site or structure recognised as being of outstanding international importance by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) and therefore designated as a site deserving of protection under international treaties. |
| O&M Contractor | Operation and Maintenance Contractor | The O&M Contractor will provide operation and maintenance services to the Project during operation phase. |
| - | Project Description | A project description describes all project phases from pre-construction, construction, operation and decommissioning and is as detailed as possible in order to identify the environmental aspects resulting from project activities. A summary of the project description is provided in ESIA Volume 1: Introduction |
| ToR | Terms of Reference | The ToR provides a guide as to how an environmental and social assessment should be conducted and the level of detail that is required. As part of the work undertaken by Jacobs in the ESIA Terms of Reference (ToR), a review of these previous studies was carried out. The latest version of the ESIA ToR contains a summary of the gap analysis and baseline information at time of issue. It was submitted to the GoCD in April 2017 and minor comments were received. |

# List of Abbreviations

| Acronym | Meaning |
|---|---|
| ALOHA | Areal Locations of Hazardous Atmospheres |
| ASL | Above Sea Level |
| ARI | Average Recurrence Interval |
| AST | Aboveground Storage Tank |
| BATEA | Best Available Technology Economically Achievable |
| BDI | Biological Diatom Index |
| BLEVE | Boiling Liquid Expanding Vapour Explosion |
| BMP | Best Management Plan |
| CNMP | Construction Noise Management Plan |
| DEM | Digital Elevation Model |
| DGDC | Dominica Geothermal Development Company |
| DOMLEC | Dominica Electricity Services Limited |
| DOWASCO | Dominica Water and Sewerage Company Limited |
| EHS | Environmental Health and Safety |
| EP | Equator Principles III (2013) |
| EPC | Engineer, Procure and Construct |
| ESCP | Erosion and Sediment Control Management Plan |
| ESIA | Environmental and Social Impact Assessment |
| ESMP | Environmental and Social Management Plan |
| ESMS | Environmental and Social Management System |
| GHG | Greenhouse gas |
| GIIP | Good International Industrial Practice |
| GLC | Ground Level Concentrations |
| GoCD | Government of the Commonwealth of Dominica |
| GWP | Global Warming Potential |
| $H_2S$ | Hydrogen Sulphide |
| IFC | International Finance Corporation |
| IFD | Intensity Frequency Duration |
| IUCN | International Union for Conservation of Nature |
| kV | Kilovolt |
| kW | Kilowatt |
| LCM | Lost Circulation Material |
| LOAEL | Lowest Observed Adverse Effect Level |
| MfE | New Zealand Ministry for the Environment |
| mm | millimetres |
| MW | Mega Watt |

| Acronym | Meaning |
|---|---|
| $NO_x$ | Oxides of Nitrogen |
| $NO_2$ | Nitrogen Dioxide |
| NOAA | National Oceanic and Atmospheric Administration |
| ORC | Organic Rankine Cycle |
| OUV | Outstanding Universal Value |
| $O_3$ | Ozone |
| $PM_{2.5}$ | Particulate Matter less than 2.5 microns in size |
| $PM_{10}$ | Particulate Matter less than 10 microns in size |
| PPE | Personal Protective Equipment |
| PRV | Pressure Relief Valve |
| PS | Performance Standard |
| SDS | Safety Data Sheets |
| SEP | Stakeholder Engagement Plan |
| $SO_2$ | Sulphur Dioxide |
| SOP | Standard Operating Procedures |
| ToR | Terms of Reference |
| TSS | Total Suspended Solids |
| U.S. EPA | United States Environmental Protection Agency |
| WBG | World Bank Group |
| WHO | World Health Organisation |
| ZTI | Zone of Theoretical Influence |

# Important note about your report

The sole purpose of this report and the associated services performed by Jacobs New Zealand Limited ("Jacobs") is to describe the Environmental and Social Impact Assessment (ESIA) for the Dominica Geothermal Power Project development in accordance with the scope of services set out in the contract between Jacobs and the New Zealand Ministry of Foreign Affairs and Trade (the Client). That scope of services, as described in this report, was developed with the Client, the Government of the Commonwealth of Dominica (GoCD) and the Developer (Dominica Geothermal Development Company (DGDC) established and owned by the GoCD).

Jacobs has been contracted by the Client to undertake the conceptual design and overall project definition through their engineering team. In preparing this ESIA report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided. Except as otherwise stated in the ESIA report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced as noted in the ESIA volumes and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of, Jacobs' Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party. However, Jacobs may be able to extend reliance on this report to a third party provided that the third party enters into a third party reliance agreement with Jacobs on Jacobs' terms.

# 1. Introduction

## 1.1 Overview

The Environmental and Social Impact Assessment (ESIA) Volume 2: Environmental Impact Assessment (EIA) provides an assessment of potential impacts of the Project on environmental receptors, provides mitigation and monitoring recommendations and provides an assessment of residual impacts. This introduction provides an overview of the EIA process.

## 1.2 Process of ESIA

The ESIA process and how related environmental and social assessments are applied is summarised in Figure 1.1 below. For social impacts, reference should be made to the ESIA Volume 3: Social Impact Assessment.

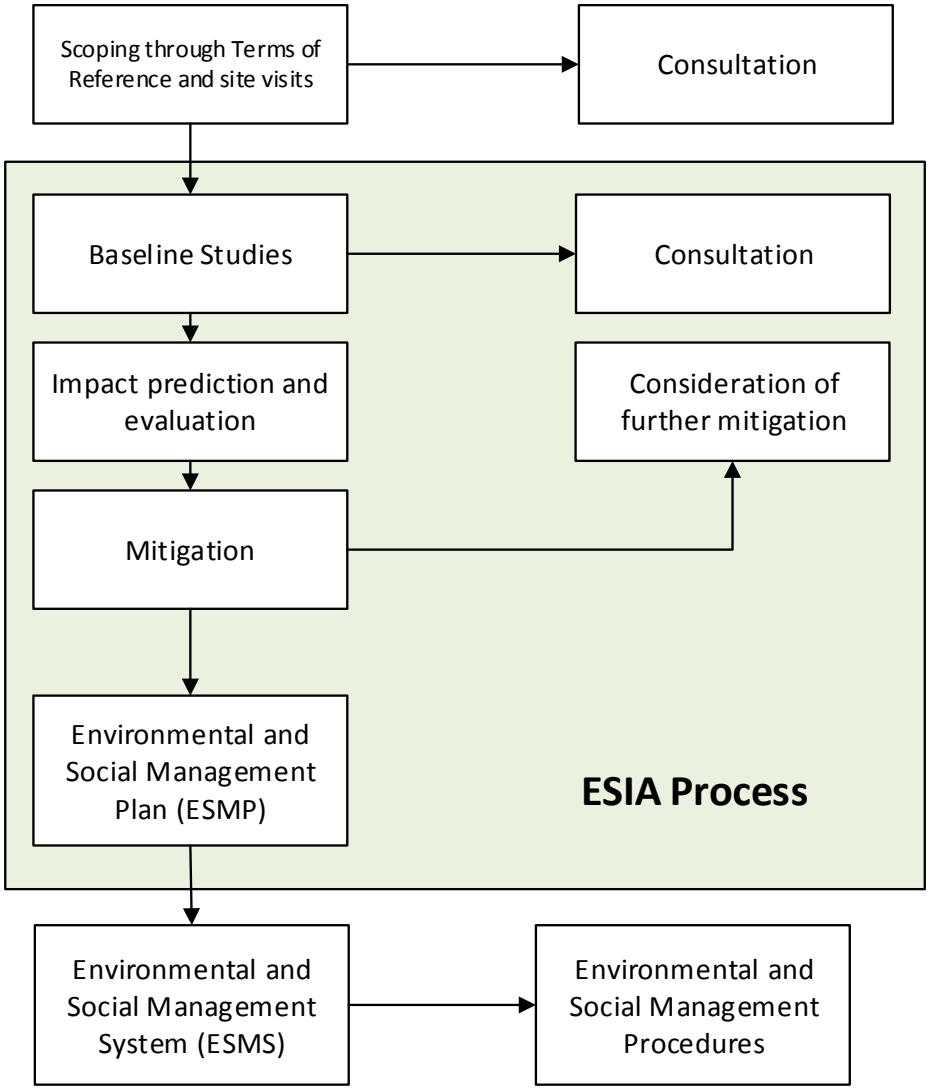


**Figure 1.1 : General overview of the ESIA process**

The following activities were completed in support of the ESIA (refer to Volume 1: Introduction, Volume 3: Social Impact Assessment, Volume 4: ESMP, Framework ESMS and Compliance Assessment and Volume 5: Appendices):

- Environmental scoping was completed at an early stage (within the ESIA Terms of Reference (ToR)) to identify development activities that would require attention in the ESIA. The ESIA ToR is located in the ESIA Volume 5: Appendices.
- Consultation was conducted with government agencies, community leaders and representatives, Roseau Valley communities, businesses and other interest groups.
- Site visits were undertaken by Jacobs Environmental and Social Specialists in November 2016, December 2016 and July 2017. The purpose of these visits was to engage in community consultation exercises and carry out further environmental baseline surveys.
- Following Hurricane Maria in September 2017 (see ESIA Volume 1: EIA), further site visits were carried out by Jacobs Engineering and Environmental Specialists in early 2018. The purpose of these visits was to meet with the World Bank Environmental and Social Safeguards Team to agree how the ESIA should be taken forward, and to evaluate and record the damage in the post-Hurricane Maria situation.
- Additional community consultation activities were undertaken post-Hurricane Maria, including Focused Discussion Groups (FDGs), census surveys for landowners and three public meetings to disclose the ESIA to affected communities in July 2018. These are referred to in ESIA Volume 3: SIA, and in the Stakeholder Engagement Plan (SEP) located in ESIA Volume 5: Technical Appendices and an Abbreviated Resettlement Action Plan (ARAP).

## 1.3 Structure of Volume 2

This ESIA Volume 2: EIA is structured in the following way:

- Section 2 – Methodology
- Section 3 – Environmental Baseline
- Section 4 – Air Quality (Impact Assessment)
- Section 5 – Greenhouse Gas Emissions (Impact Assessment)
- Section 6 – Geology, Soils and Groundwater (Impact Assessment)
- Section 7 – Hydrology (Impact Assessment)
- Section 8 – Water Quality and Freshwater Ecology (Impact Assessment)
- Section 9 – Landscape and Visual (Impact Assessment)
- Section 10 – Natural Geothermal Features (Impact Assessment)
- Section 11 – Natural Hazards (Impact Assessment)
- Section 12 – Noise (Impact Assessment)
- Section 13 – Terrestrial Ecology (Impact Assessment)
- Section 14 – Morne Trois Pitons National Park (MTPNP) World Heritage Site (Impact Assessment)
- Section 15 – Hazardous Substances and Waste (Impact Assessment)
- Section 16 – Traffic and Access (Impact Assessment)
- Section 17 – Occupational Health and Safety
- Section 18 – Cumulative Impacts and Associated Infrastructure
- Section 19 – Summary of Environmental Impact Assessment

- Section 20 – References

# 2. Methodology

## 2.1 Introduction

The impact assessment methodology applies to the assessment of potential environmental impacts arising from the Project. The impact assessment methodology has been developed in accordance with good industry practice and the potential impacts have been identified in the context of the Project's Area of Influence (AoI), in accordance with World Bank Performance Standard 1 (Assessment and Management of Environmental and Social Risks and Impacts).

## 2.2 Spatial and Temporal Scope

The AoI constitutes the spatial extent of the ESIA. The AoI encompasses all areas directly and indirectly affected by Project components, which are primarily contained within the Roseau Valley. For each environmental topic, the spatial and temporal scope will vary and this will be discussed in detail in the methodologies for each.

The study period is a time limit that will be used in predicting and undertaking an impact evaluation as part of the impact assessment. The period is used as a basis to determine if there are any changes to the environmental baseline resulting from the Project activities.

## 2.3 Baseline Environmental Conditions

Baseline data collection refers to the collection of background data in support of the environmental assessment. Ideally baseline data should be collected prior to development of a project, but often this is not possible. Baseline data collection can also occur throughout the life of a project as part of ongoing monitoring of environmental and social conditions.

World Bank (1999) guidance on identification of baseline data states that it *'…describes relevant physical, biological, and socioeconomic conditions, including any changes anticipated before the project commences. Also takes into account current and proposed development activities within the project area but not directly connected to the project. Data should be relevant to decisions about project location, design, operation, or mitigatory measures. The section indicates the accuracy, reliability, and sources of the data.'*

Baseline information used for this ESIA has utilised primary data collected through on-site surveys by Jacobs Environmental and Social Specialists in December 2016 and August 2017 and from previous studies undertaken during earlier stages of the Project's development, as described further below. Where applicable secondary data sources collected from desk-based studies and literature reviews have also been used.

### 2.3.1 Previous Studies

The Project benefits from having a wealth of environmental studies data collected for environmental assessments for exploration and drilling phases. To date the following environmental and social studies have been completed:

- Caraïbes Environnement Développement & Coll (2009) Regulatory Impact Assessment on the Initial Environment - Environmental Feasibility Study;
- Caraïbes Environnement Développement & Coll (2011) Stage 1: Exploration Drilling Process – Environmental Impact Assessment; and
- Caraïbes Environnement Développement & Coll (2013) Stage 2: Preliminary Environmental Impact Assessment of Geothermal Production and Re-Injection Drilling Wells in Dominica – Environmental Impact Assessment.

- To support the preparation of an ESIA for the exploration phase of the geothermal development, baseline surveys of the social, physical and biological environment within the Roseau Valley were completed between October 2013 and April 2015. These were summarised in the following reports (collectively referred to as the 'Baseline Study'):
    - Caraïbes Environnement Développement & Coll (2015a). Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production. Final report, May 2015. Section 3 Biodiversity / Terrestrial Flora and Fauna; and
    - Caraïbes Environnement Développement & Coll (2015b). Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production. Final summary report.

As part of the ESIA ToR, (Jacobs, 2017) a review of these previous studies was carried out. The findings of this review were presented along with any further baseline data collection proposed in the ToR. In addition, a review of the situational analysis prepared by the World Bank was carried out. The latest version of the ESIA ToR (ESIA Volume 5: Appendices) contains a summary of the gap analysis and baseline information at time of issue. It was submitted to the GoCD in April 2017 and minor comments were received. Furthermore, a ToR for a Biodiversity Survey (ESIA Volume 5: Appendices) was developed for the completion of additional baseline biodiversity assessments. Both documents were reviewed by the World Bank prior to submission to the GoCD.

The ESIA ToR (Jacobs, 2017) established that for the majority of environmental and social disciplines, the data collected from previous studies was deemed suitable for use as baseline data in the ESIA. However, the ESIA ToR made the following recommendations for further survey where previous studies were lacking in sufficient baseline information (to be undertaken by Jacobs Environmental and Social Specialists or Subconsultants):

- General site surveys of the Project site;
- Ground-based surveys as part of the terrestrial ecological impact assessment;
- Community consultation and gathering of socio-economic data; and
- Traffic count surveys.

## 2.4 Aspects Identification

The key environmental aspects considered in detail in this ESIA have been determined from the ESIA TOR (Jacobs, 2017). As a result of the scoping assessment the following topics have been technically assessed for the Volume 2: EIA:

- Air Quality;
- Greenhouse Gas Emissions;
- Geology, Soils and Groundwater;
- Hydrology;
- Water Quality and Freshwater Ecology;
- Landscape and Visual;
- Natural Geothermal Features;
- Natural Hazards;
- Noise;
- Terrestrial Ecology;
- Morne Trois Pitons National Park World Heritage Site;
- Hazardous Substances and Waste; and

- Traffic and Access.

## 2.5 Impact Assessment

The impact assessment predicts and assesses the Project's likely positive and negative impacts, in quantitative terms to the extent possible. For each of the environmental aspects listed above, the assessment determined the sensitivity of the receiving environment and identifies impacts and assesses the magnitude and overall significance of environmental impacts. An ESIA will always contain a degree of subjectivity, as it is based on the value judgment of various specialists and ESIA practitioners. The evaluation of significance is thus contingent upon values, professional judgement, and dependent upon the environmental context. Ultimately, impact significance involves a process of determining the acceptability of a predicted impact.

It should be noted that the impacts described in the impact assessment are for those that exist in the 'post-Maria' environment (i.e. impacts on the current baseline).

### 2.5.1 Defining Impact

There are a number of ways that impacts may be described and quantified. An impact is essentially any change to a resource or receptor brought about by the presence of the proposed project component, project discharge or by the execution of a proposed project related activity. The assessment of the significance of impacts and determination of residual impacts takes account of any inherent mitigation measures incorporated into the Project by the nature of its design.

In broad terms, impact significance can be characterised as the product of the degree of change predicted (the magnitude of impact) and the value of the receptor/resource that is subjected to that change (sensitivity of receptor). For each impact the likely magnitude of the impact and the sensitivity of the receptor are defined. Generic criteria for the definition of magnitude and sensitivity are summarised below.

### 2.5.2 Direct vs Indirect Impacts

A direct impact, or first order impact, is any change to the environment, whether adverse or beneficial, wholly or partially, resulting directly from an environmental aspect related to the project. An indirect impact may affect an environmental, social or economic component through a second order impact resulting from a direct impact. For example, removal of vegetation may lead to increased soil erosion (direct impact) which causes an indirect impact on aquatic ecosystems through sedimentation (indirect impact).

### 2.5.3 Magnitude Criteria

The assessment of impact magnitude is undertaken by categorising identified impacts of the Project as beneficial or adverse. Then impacts are categorised as 'major', 'moderate', 'minor' or 'negligible' based on consideration of parameters such as:

- Duration of the impact – ranging from 'well into operation' to 'temporary with no detectable impact'.
- Spatial extent of the impact – for instance, within the site boundary, within district, regionally, nationally, and internationally.
- Reversibility – ranging from 'permanent thus requiring significant intervention to return to baseline' to 'no change'.
- Likelihood – ranging from 'occurring regularly under typical conditions' to 'unlikely to occur'.
- Compliance with legal standards and established professional criteria – ranging from 'substantially exceeds national standards or international guidance' to 'meets the standards' (i.e. impacts are not predicted to exceed the relevant standards) presents generic criteria for determining impact magnitude (for adverse

impacts). Each detailed assessment will define impact magnitude in relation to its environmental or social aspect.

- Any other impact characteristics of relevance.

Table 2.1 below presents generic criteria for determining impact magnitude (for adverse impacts). Each detailed assessment will define impact magnitude in relation to its environmental or social aspect.

**Table 2.1 : General criteria for determining impact magnitude**

| Category | Description |
|---|---|
| Major | Fundamental change to the specific conditions assessed resulting in long term or permanent change, typically widespread in nature and requiring significant intervention to return to baseline; would violate national standards or Good International Industry Practice (GIIP) without mitigation. |
| Moderate | Detectable change to the specific conditions assessed resulting in non-fundamental temporary or permanent change. |
| Minor | Detectable but small change to the specific conditions assessed. |
| Negligible | No perceptible change to the specific conditions assessed. |

### 2.5.4 Sensitivity Criteria

Sensitivity is specific to each aspect and the environmental resource or population affected, with criteria developed from baseline information. Using the baseline information, the sensitivity of the receptor is determined factoring in proximity, number exposed, vulnerability and the presence of receptors on site or the surrounding area. Generic criteria for determining sensitivity of receptors are outlined in Table 2.2 below. Each detailed assessment will define sensitivity in relation to its environmental or social aspect.

**Table 2.2 : General criteria for determining impact sensitivity**

| Category | Description |
|---|---|
| High | Receptor (human, physical or biological) with little or no capacity to absorb proposed changes |
| Medium | Receptor with little capacity to absorb proposed changes |
| Low | Receptor with some capacity to absorb proposed changes |
| Negligible | Receptor with good capacity to absorb proposed changes |

### 2.5.5 Impact Evaluation

The determination of impact significance involves making a judgment about the importance of project impacts. This is typically done at two levels:

- The significance of project impacts factoring in the mitigation inherently within the design of the project; and
- The significance of project impacts following the implementation of additional mitigation measures.

The impacts are evaluated taking into account the interaction between the magnitude and sensitivity criteria as presented in the impact evaluation matrix in Table 2.3 below.

**Table 2.3 : Impact matrix**

| | | Magnitude | | | |
|---|---|---|---|---|---|
| | | **Major** | **Moderate** | **Minor** | **Negligible** |
| **Sensitivity** | **High** | Major | Major | Moderate | Negligible |
| | **Medium** | Major | Moderate | Minor | Negligible |
| | **Low** | Moderate | Minor | Negligible | Negligible |
| | **Negligible** | Minor | Negligible | Negligible | Negligible |

The objective of the ESIA is to identify the likely significant impacts on the environment and people of the project. In this impact assessment, impacts determined to be 'moderate' or 'major' are deemed significant. Consequently, impacts determined to be 'minor' or 'negligible' are not significant.

## 2.6 Mitigation

Mitigation measures are actions taken to avoid or minimise negative environmental or social impacts. Mitigation measure includes those embedded within the design (as already considered as part of the impact evaluation) and any additional mitigation required thereafter. Additional mitigation will be implemented to reduce significant impacts to an acceptable level, this is referred to as the residual impact. The mitigation hierarchy should be followed: avoid, minimise, restore or remedy, offset, compensate. Mitigation measures should be clearly identified and linked to environmental and social management plans.

It should be noted that unless otherwise stated, all construction mitigation measures recommended in this ESIA will be the responsibility of the Engineering, Procurement and Construction (EPC) Contractor and all operation mitigation measures recommended in this ESIA will be the responsibility of the Operation and Maintenance (O&M) Contractor.

## 2.7 Monitoring

Monitoring is not linked to the impact evaluation but is an important component of the ESIA. Monitoring and follow-up actions should be completed to:

- Continue the collection of environmental and social data throughout construction, operation and later decommissioning;
- Evaluate the success of mitigation measures, or compliance with project standards or requirements;
- Assess whether there are impacts occurring that were not previously predicted; and
- In some cases, it may be appropriate to involve local communities in monitoring efforts through participatory monitoring. In all cases, the collection of monitoring data and the dissemination of monitoring results should be transparent and made available to interested project stakeholders.

## 2.8 Residual Impacts

Those impacts that remain once mitigation has been put in place will be described as residual impacts, using Table 2.3 set out above.

## 2.9 Cumulative Impacts

The assessment of cumulative impacts will consider the combination of multiple impacts that may result when:

- The Project is considered alongside other existing facilities within similar discharges;

- The Project is alongside other existing or proposed projects in the same geographic area or similar development timetable; and
- Impacts identified in different environmental and social aspects of the ESIA combine to affect a specific receptor.

The assessment of cumulative impacts will identify where particular resources or receptors would experience significant adverse or beneficial impacts as a result of a combination of projects (inter-project cumulative impacts). In order to determine the full combined impact of the development, potential impacts during construction and operational phases have been assessed where relevant.

# 3. Environmental Baseline

## 3.1 Introduction

This section provides a summary of baseline information known to date for the existing physical and biological environment, using available information and the methodology outlined in Section 2 above. This data is used to quantify the sensitivity of the receiving environment to the proposed Project. The environmental baseline presented in this section represents the 'Pre-Maria' situation (i.e. the state of the environmental baseline prior to Hurricane Maria on the 18 September 2017). At the end of the section is a summary setting out the key environmental baseline changes following Hurricane Maria.

## 3.2 General Environmental Setting

The Commonwealth of Dominica is a small island developing state in the Caribbean Sea with a population of approximately 71,293 people (pre-Hurricane Maria 2011 census) and a land area of approximately 750 km$^2$. The island is the largest and most northerly of the Windward Islands in the Lesser Antilles, lying between Guadeloupe and Martinique. The island measures 40 km by 22 km, extending from 15º10'N-15º40'N and 61º15'W-61º30'W (Caribbean Community Climate Change Centre, 2011a). An estimated 60% of the land is classified as the Morne Trois Pitons National Park (MTPNP) World Heritage site by UNESCO, due to its rich biodiversity. The capital Roseau is located to the south-west of the island and has a population of around 15,000 people (Figure 3.1).

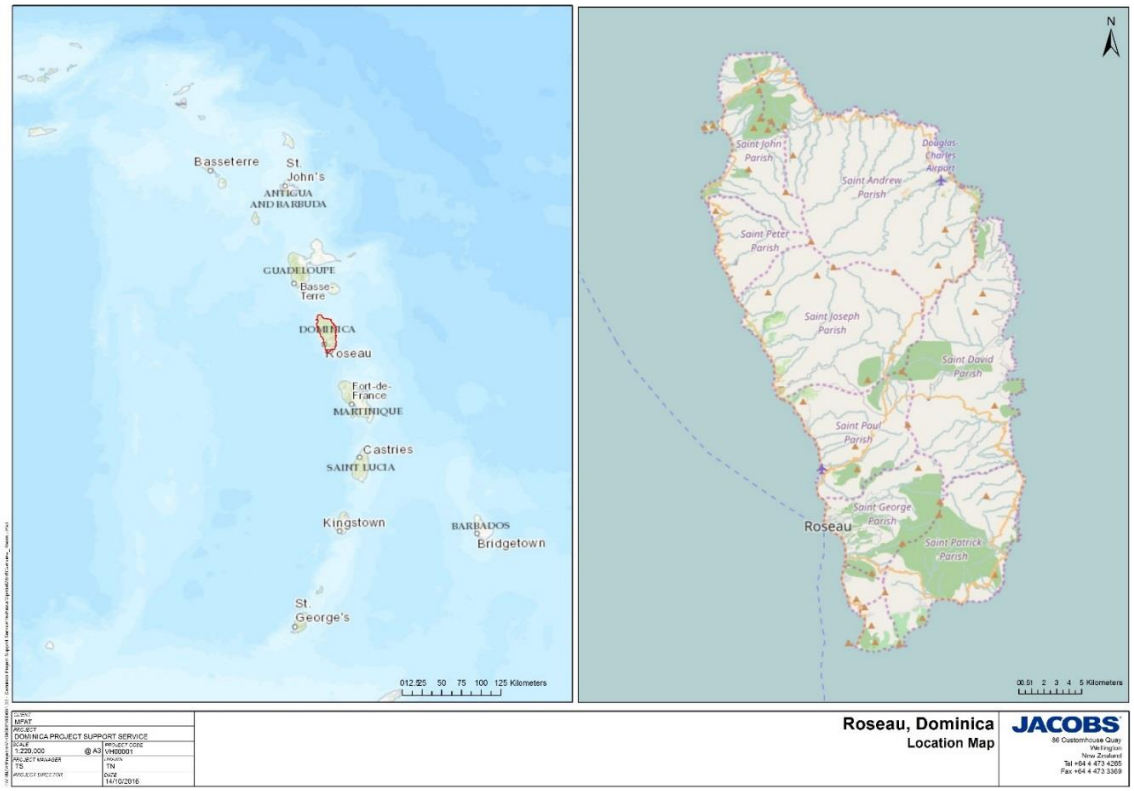


**Figure 3.1 : Dominica's location in the Caribbean**

The Roseau Valley lies inland from the coast, bordering the capital city of Roseau. An overview of the Project area is provided in Figure 3.2 and Figure 3.3.

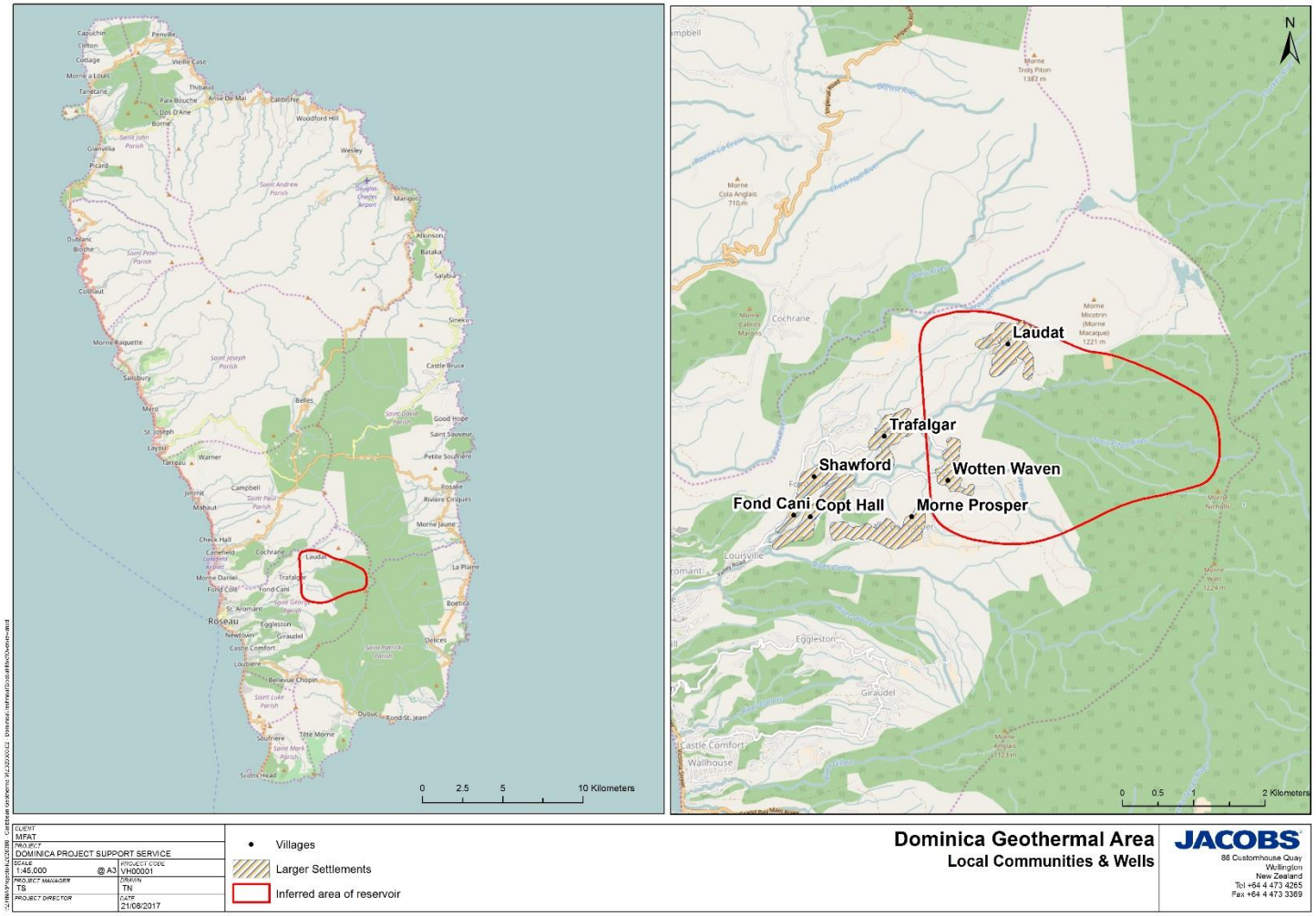


**Figure 3.2 : Location of Roseau Valley (Site of proposed Geothermal Power Plant)**

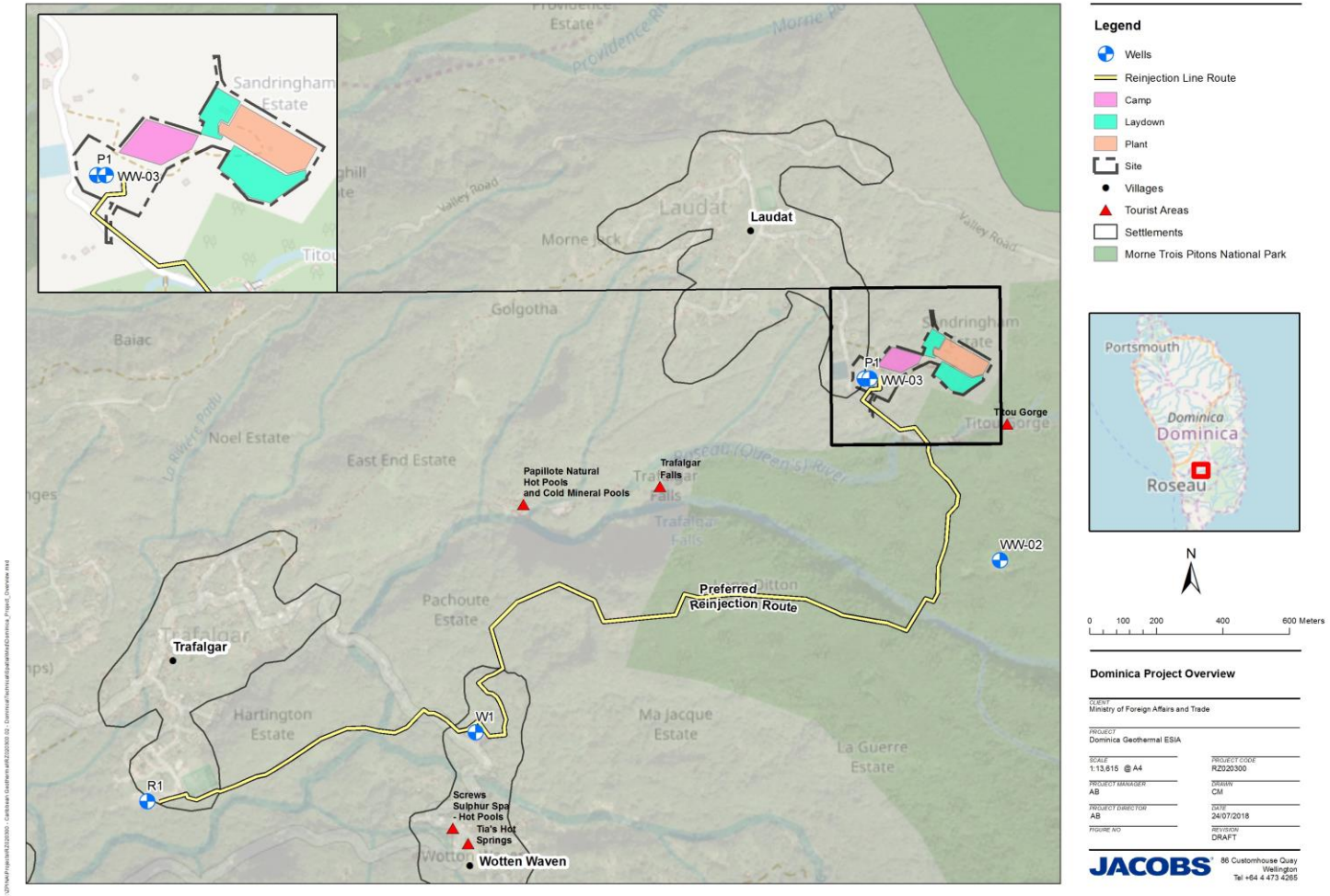


**Figure 3.3 : Location of Power Plant and Reinjection Pipeline (the Project) in the Roseau Valley**

## 3.3 Climate

The climate of Dominica is tropical all year round, with high temperatures, high humidity and heavy rainfall. The magnitude of variation in ambient temperature is low, generally ranging from 26°C during the day in January to 32°C in June (Caraïbes Environnement Développement & Coll, 2015a/b). The relative humidity in Roseau oscillates between 70 and 90%. The driest season occurs between February and May, but humidity seldom falls below 85% (Caribbean Community Climate Change Centre, 2011a). On the highest peaks, temperatures can drop to 13°C. The significant topographic gradient results in much cooler temperatures on the countries interior mountains. As shown in Figure 3.4 below, the annual windrose (2015) for the Project location indicates wind blowing generally from an easterly direction with average wind speeds of 5.38 m/s[1]. The east trade winds blow during most of year, but there is a south-east pattern from July to September when tropical storms can hit the island.

Although its intensity may vary depending on the location on the island, rain is present throughout the year and most of the rainfall is brought by the trade winds. The heaviest rainfall is concentrated between June and October. The average annual rainfall can reach 9,000 mm over the most exposed mountains. Rainfall on the west coast (leeward side) is much more moderate, of the order of 1,800 mm per year. The amount of rainfall explains the intense humidity that bathes the island. Orographic effects on storms occur in the mountainous areas, with annual rainfall >8,000 mm experienced in the high montane forests, while on the lowland forests, rainfall varies from 2,000 to 5,000 mm/year (Caraïbes Environnement Développement & Coll , 2015a/b).

[1] The CALMET diagnostic meteorological model was used to develop three-dimensional wind fields, temperature, and atmospheric stability or use with the CALPUFF dispersion model. Surface and upper air wind and temperature profiles and estimates of the surface humidity and pressure were commissioned from Lakes Environmental Software, who used the Weather Research Forecast (WRF) model, to develop the dataset and generate the windrose (Figure 3.4).

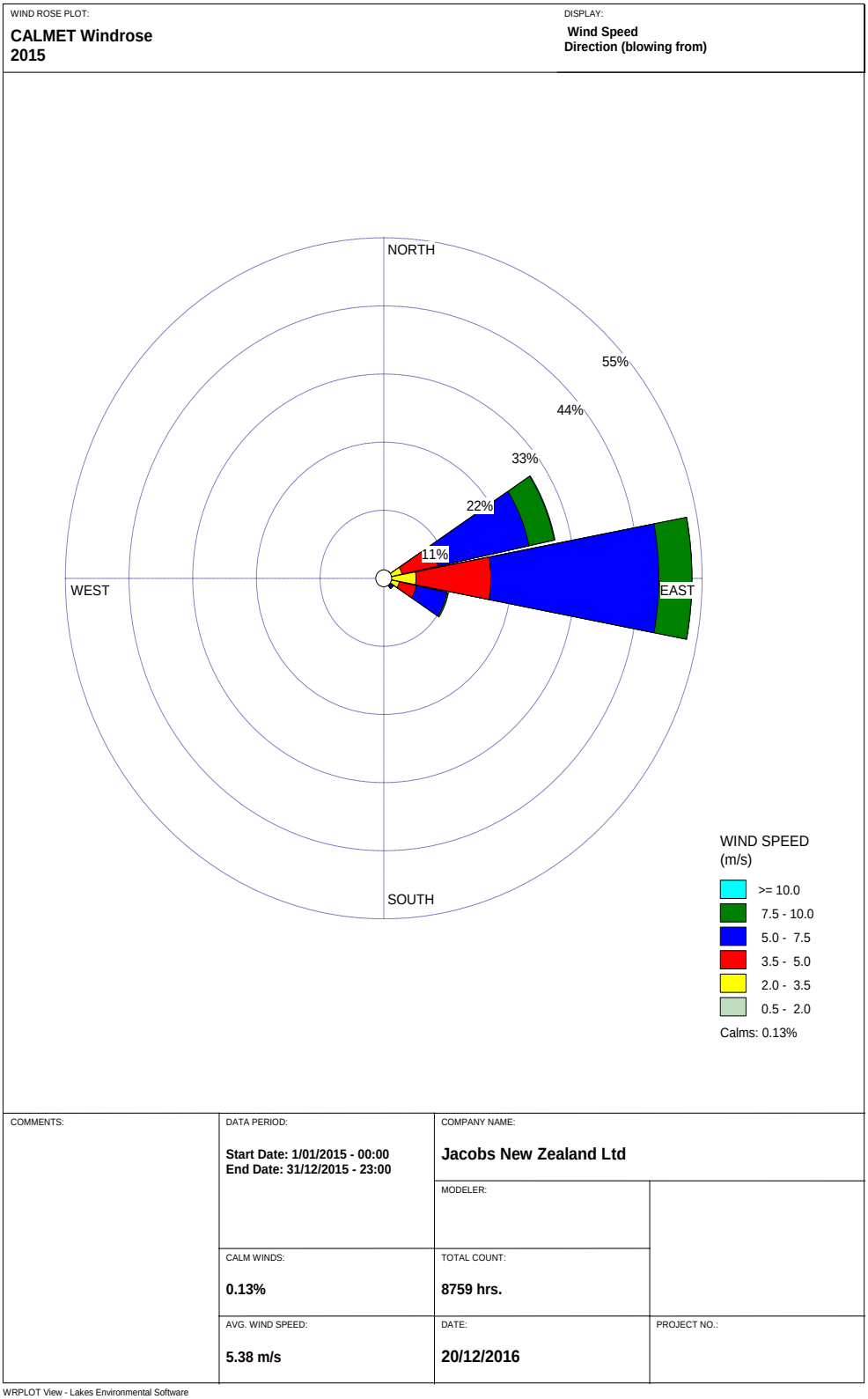


**Figure 3.4 : Calmet Windrose for Project Location (also refer to ESIA Volume 5: Appendices, Technical Report – Air Quality Impact Assessment)**

## 3.4 Air Quality

### 3.4.1 Introduction

The existing air quality in the vicinity of the Project is expected to be generally good, given the relatively low population density, absence of heavy industry, and the relatively small size of the island. Anthropogenic emissions are primarily limited to diesel-fired power generators, traffic, and solid fuel combustion for cooking, etc.

As Dominica is a volcanic island there are natural sources of atmospheric emissions, including steam, carbon dioxide, and hydrogen sulphide, via natural geothermal features such as vents and fumaroles. In some areas of the Roseau Valley, the smell of hydrogen sulphide is noticeable[2]. Further details can be found in ESIA Volume 5: Appendices (Technical Report – Air Quality Impact Assessment).

### 3.4.2 Previous Studies

Baseline monitoring has been undertaken previously to determine the existing levels of contaminants in air, including $H_2S$ but also $NO_2$, $SO_2$, ozone, and particulate matter as $PM_{10}$ and $PM_{2.5}$ (Caraïbes Environnement Développement & Coll, 2015a/b). The monitoring was undertaken at 30 locations for two 15-day periods (one during the wet season and one period during the dry season). The monitoring sites represent a variety of environments across the island of Dominica, including the capital (Roseau), villages in the vicinity of the Project (Laudat, Trafalgar, Fond Cani, Wotten Waven), and the Project area itself (near Laudat). Figure 3.5 shows the location of Trafalgar, Wotten Waven and Laudat**.**

[2] Recorded in field notes from Jacobs site visit (December, 2016).

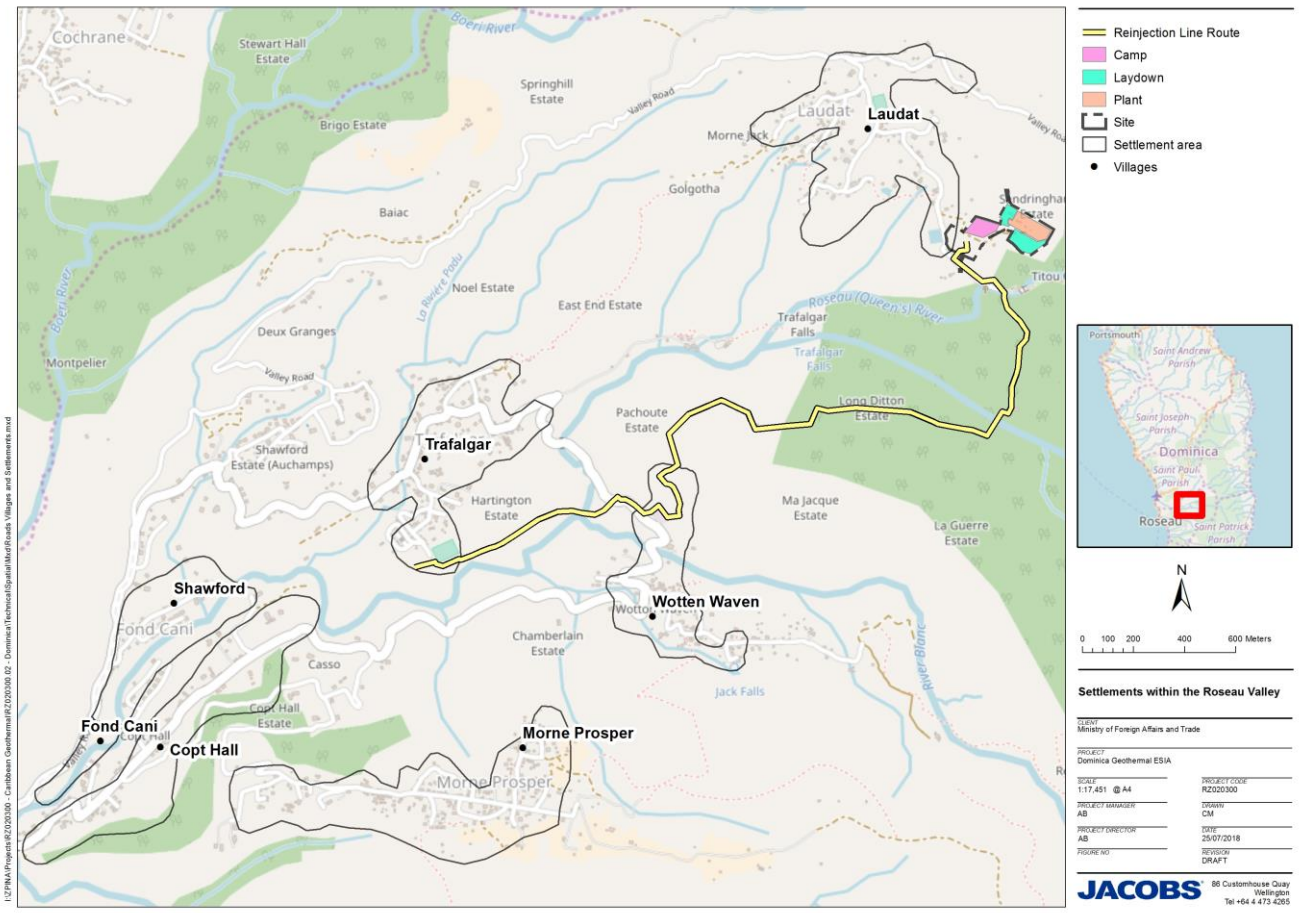


**Figure 3.5 : Settlements within the Roseau Valley**

Monitoring of gaseous contaminants (i.e. $H_2S$, $NO_2$, $SO_2$, and ozone) was done using passive samplers, which provide an integrated concentration for the course of the monitoring period. $PM_{10}$ and $PM_{2.5}$ were continuously measured during the monitoring period using continuous (active) particulate monitors. A summary of the results are provided in Table 3.1.

**Table 3.1 : Baseline Ambient Monitoring Results (average of wet and dry season monitoring results)**

| Site ID | Site Location | Average Contaminant Concentrations, µg/m$^3$ | | | |
|---|---|---|---|---|---|
| | | $NO_2$ | $SO_2$ | $H_2S$ | Ozone |
| LD1 | Fresh lake | 0.2 | 0.2 | 0.7 | 71.5 |
| LD2 | Laudat | 2.3 | 1.5 | 1.0 | 51.9 |
| LD3 | Laudat | 5.7 | 6.3 | 1.4 | - |
| LD4 | Laudat | 2.6 | 7.0 | 6.1 | 48.1 |
| LD5 | Laudat | 0.6 | 0.8 | 6.8 | 36.8 |
| LD6 | Laudat | 0.5 | 8.1 | 1.6 | 54.1 |
| TR7 | Trafalgar | 1.5 | 5.3 | 2.7 | 25.6 |
| TR8 | Trafalgar | 1.8 | 5.6 | 2.5 | 29.9 |
| TR9 | Trafalgar | 3.1 | 15.2 | 5.8 | - |

| Site ID | Site Location | Average Contaminant Concentrations, µg/m³ | | | |
|---|---|---|---|---|---|
| | | $NO_2$ | $SO_2$ | $H_2S$ | Ozone |
| TR10 | Trafalgar | 0.9 | 16.7 | 9.7 | 22.7 |
| TR11 | Trafalgar | 5.0 | 6.3 | 2.3 | - |
| TR12 | Trafalgar | 4.4 | 13.3 | 3.9 | - |
| WW19 | Wotten Waven | 0.9 | 18.5 | 11.5 | 35.4 |
| WW20 | Wotten Waven | 0.9 | 28.1 | 18.6 | 42.3 |
| WW21 | Wotten Waven | 6.1 | 39.6 | 11.4 | 34.8 |
| WW22 | Wotten Waven | 0.9 | 34.0 | 19.1 | 43.0 |
| WW23 | Wotten Waven | 0.4 | 58.4 | 18.4 | - |
| WW24 | Wotten Waven | 0.8 | 3.7 | 5.1 | 22.1 |
| WW25 | Wotten Waven | 3.1 | 21.8 | 11.9 | - |
| WW26 | Wotten Waven | 2.4 | 11.5 | 6.2 | - |
| MP27 | Morne Prosper | 5.8 | 41.4 | 9.4 | 46.5 |
| MP28 | Morne Prosper | 0.7 | 23.5 | 4.7 | - |
| MP29 | Morne Prosper | 2.6 | 17.1 | 5.6 | - |
| FC13 | Fond Cani | 2.7 | 7.7 | 3.5 | - |
| FC14 | Fond Cani | 1.5 | 16.7 | 5.9 | 17.9 |
| FC15 | Fond Cani | 6.7 | 7.8 | 9.3 | 30.4 |
| FC16 | Fond Cani | 10.7 | 9.0 | 5.8 | - |
| FC17 | Fond Cani | 5.5 | 29.1 | 6.9 | - |
| FC18 | Fond Cani | 4.4 | 9.6 | 7.4 | - |
| CT30 | Roseau | 13.9 | 11.8 | 6.2 | - |
| ***Maximum*** | | ***13.9*** | ***58.4*** | ***19.1*** | ***71.5*** |

### 3.4.3 Key Conclusions

Key conclusions resulting from the baseline monitoring include:

- Minor differences were observed between the wet and dry season measurements.
- $NO_2$ levels were low and not significantly affected by anthropogenic emissions.
- Ozone concentrations were similarly low and did not appear to be significantly affected by anthropogenic emissions.
- $SO_2$ concentrations were variable, with some locations, particularly in the Wotten Waven and Morne Prosper sites having the highest measurements. Given the absence of $SO_2$ discharges in the area however, it is likely that these readings are a result of the analysis method for the $SO_2$ passive samples where $H_2S$ was also present resulting in false positives levels.
- $H_2S$ concentrations were above the odour threshold limit of 0.3 µg/m³ at all sites, and at many sites in the Project area exceeded the nuisance threshold value of 7 µg/m³. The highest concentration of $H_2S$ measured was 19.1 µg/m³ as a 15-day average. Using a conversion factor to estimate concentrations from longer averaging periods to 1-hour averages, this equates to around 62 µg/m³ as a 1-hour average for comparison with the odour threshold of 7 µg/m³. However, the measured concentrations are not considered unusual for an active geothermal area.

- Particulate matter (as $PM_{10}$ and $PM_{2.5}$) monitoring results indicated some influence from anthropogenic emissions (i.e. burning vegetation on agricultural plots of land).

## 3.5 Hydrology

### 3.5.1 Previous Studies

A hydrological flooding assessment was undertaken in previous studies for the exploration phase of the geothermal development (Caraïbes Environnement Développement & Coll, 2015a/b). A hydraulic routing model was built in GESRES$^{ISL}$ for a 33.2 km$^2$ catchment, representing the Roseau River. The relatively steep catchment had a gradient of 4% and a time of concentration of 2.8 hours. GESRES$^{ISL}$ uses a rainfall-runoff module similar to the SCS (Soil Conservation Service) unit hydrograph and a Muskingham routing equation.

The study included a simulation of a 12 hour storm based on hourly intensity frequency duration (IFD) rainfall data, which simulates a typical storm profile (and changing rainfall depth over time) for the area. The 10 year Average Recurrence Interval (ARI) storm had a rainfall depth of 221.1 mm, while the 100 year ARI was 326.9 mm. Storm flows were routed through 13 subcatchments and a Telemac-2D model using Saint-Venat equations to characterise changes in flow and velocity (temporally) with the incorporation of structures such as pipes, culverts, bridges and weirs.

The study does not provide peak flow estimates for each of the sub-catchments; however, it provides indicative specific discharge rates which can be used to approximate flows based on a known area. These were:

- 10 year storm – 12 m$^3$/s/km$^2$
- 100 year storm – 18.5 m$^3$/s/km$^2$

Site investigations and observations of the stream channels indicate that the tropical environment and steep gradients leads to promotion of high velocity flood events with significant erosive force that may put infrastructure at risk during large events.

### 3.5.2 Catchments and Runoff

Understanding catchment areas is important to determine the potential yields for water supply, flooding risk to infrastructure (including roads, power plant and pipe bridges) and the aquatic habitat likely to be prevalent.

The subcatchment areas draining near the power plant and various pipe bridges/culverts were determined from the Caraïbes Environnement Développement & Coll (2015a/b) Report.

The primary catchment near the power plant is Titou Gorge, which has an area of 5.4 km$^2$ and a concentration time of ~0.37 hours (see Figure 3.6 and Table 3.2). Times of concentration were determined using the Bressand-Golossof formula and is documented in Caraïbes Environnement Développement & Coll (2015a/b).

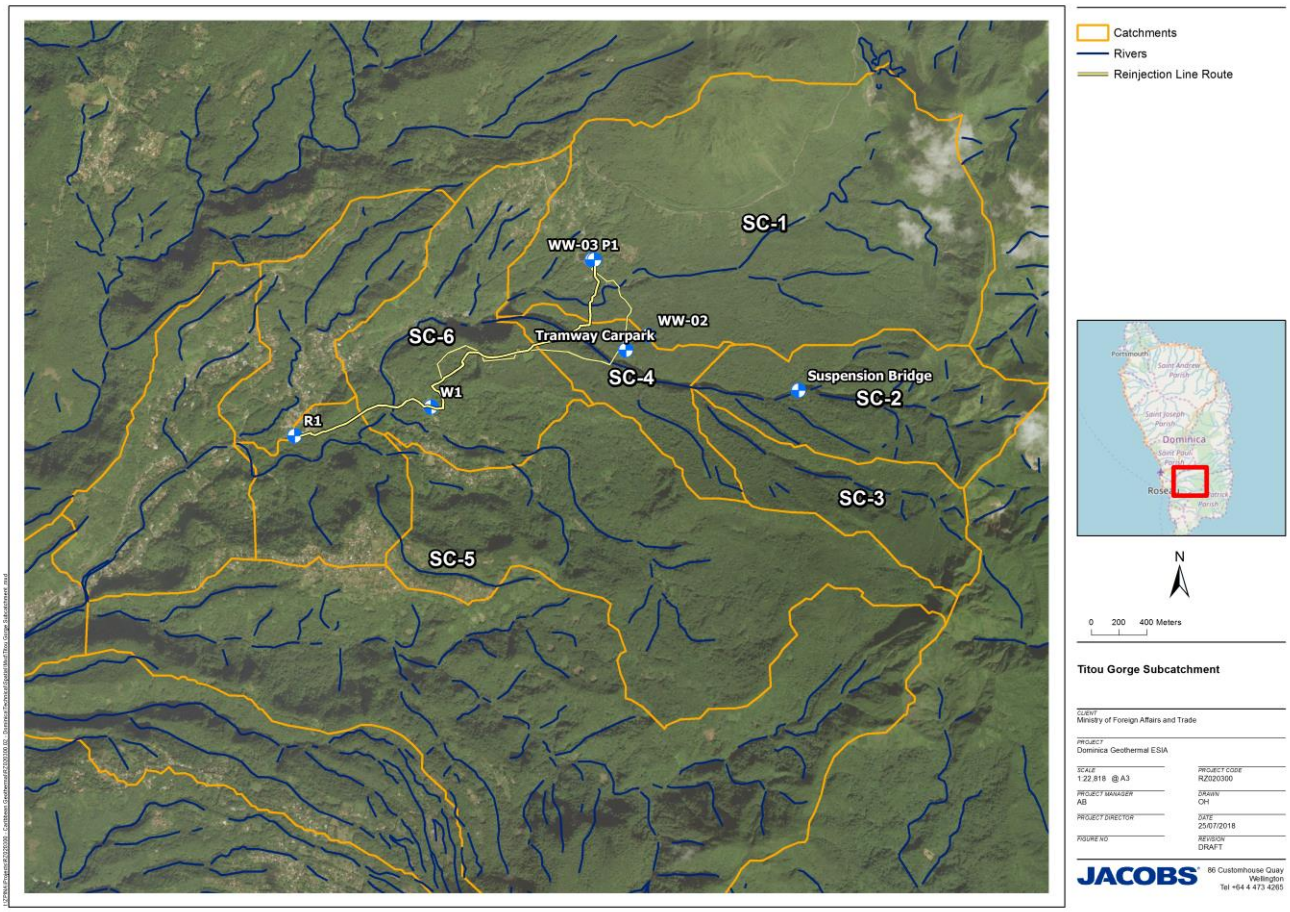


**Figure 3.6 : Titou Gorge Subcatchment (Caraïbes Environnement Développement & Coll 2015b)**

**Table 3.2 : Subcatchment Areas and Time of Concentrations (Caraïbes Environnement Développement & Coll 2015a/b)**

| Subcatchment | Area (km$^2$)** | Time of Concentration (hours)** |
|---|---|---|
| SC-1 | 5.45 | 0.37 |
| SC-2 | 1.73 | 0.24 |
| SC-3 | 1.13 | 0.21 |
| SC-4 | 0.91 | 0.14 |
| SC-5 | 4.15 | 0.38 |
| SC-6 | 2.22 | 0.32 |

** Areas and time of concentrations are for individual catchments. The total catchment draining to an outflow point should include all upstream catchments. For example, SC-6 would have a total catchment area of 15.59 km$^2$. Times of concentrations (Tc) are not cumulative as they differ depending on total catchment stream length and slope characteristics. The Tc's are presented for reference, indicating short duration runoff expected with small and steep catchments.

The preferred reinjection pipeline route will cross five significant stream reaches. The three largest are:

- SC-1 with a total area of ~5.0 km$^2$. The estimated flow based on specific discharges in section 1.2 is 60 and 92.5 m$^3$/s (10 and 100 year ARI).

- SC-4 with a total area of ~3.5 km$^2$. The estimated flow based on specific discharges in section 1.2 is 42 and 64.8 m$^3$/s (10 and 100 year ARI).
- SC-6 with a total area of ~10.8 km$^2$ (this excludes SC-5 as the pipeline crosses upstream of the junction). The estimated flow based on specific discharges in section 3.5.1 is 129.6 and 199.8 m$^3$/s (10 and 100 year ARI).

The areas above have been refined based on the catchment map and where the reinjection pipeline route crosses streams. The largest flows will be expected at SC-6 and SC-1. SC-6 has further design risks as the proposed pipeline route crosses near the apparent junction of another major tributary to the Trafalgar River, which could cause localised flooding. This tributary (SC-5) appears to have a secondary overland flow channel during large events as indicated in Figure 3.7, which results in a potential large inundation area near the pipeline crossing.

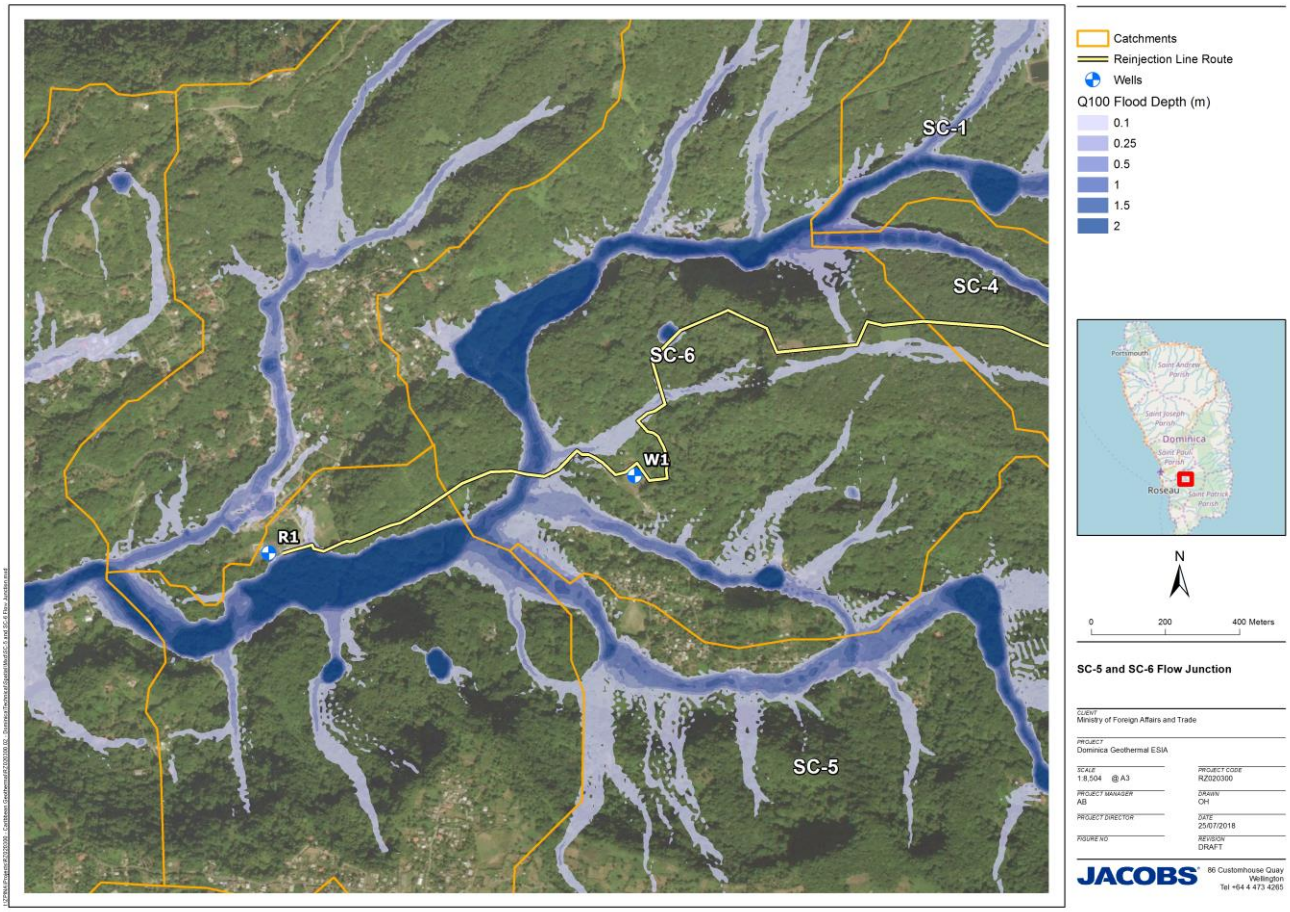


**Figure 3.7 : SC-5 and SC-6 Flow Junction**

Flows cumulate downstream in the Roseau River, which is one of the 10 largest rivers in Dominica (Caraïbes Environnement Développement & Coll, 2015a/b). River Claire joins before the City of Roseau, while River Blanc drains in upstream of River Claire.

### 3.5.3 Observed Streamflow

Little information is available on annual streamflow rates near the proposed power plant site, besides limited spot gaugings undertaken by DOWASCO Laboratory in April 2011 at Titou Gorge (see Figure 3.8 and Table

3.3). However, it could be assumed that streamflow in the mountainous areas are flashy and of high velocity, driven by the regular short and intense rainfall events and the steep terrain.

High annual rainfall will provide regular groundwater recharge and sustained base flow in the lower reaches. However, knowledge of the groundwater-surface water interactions in the mountains is limited and the proportion of rainfall which recharges aquifers that discharge into streams is unknown. Table 3.3 shows that discharges observed in Trafalgar River at lower elevations are greater than those in smaller tributaries upstream (noting there is no rainfall data to verify the stream conditions during gauging, i.e. if this was during a storm event).

**Table 3.3 : Streamflow Gaugings by DOWASCO Laboratory (April 2011)**

| Site Name | Date of Gauging | Discharge (L/s) | Season | Approximate elevation (masl) |
|---|---|---|---|---|
| Titou Gorge | 29 April 2011 | 50.3 | Dry | 570 |
| River Douce | 22 February 2010 | 41.3 | Dry | 104 |
| River Claire | 23 February 2010 | 304.2 | Dry | 452 |
| River Trafalgar | 6 May 2011 | 1,288 | Dry | 237 |
| River Blanc-Tributary 1 | 6 April 2010 | 29.7 | Dry | 548 |
| River Blanc-Tributary 1 | 17 March 2006 | 56.4 | Dry | |

Little information is available on the base flow or mean annual flow within the Roseau River (downstream of the stations gauged in Table 3.3), however a report from the 4 September 2002 indicated the, Roseau River (1.5 km NW of Roseau City) had a flow of 3.3 $m^3/s$ (United States Army Corps, 2004).

Additionally, an indirect assessment of peak flows from Hurricane Erika in 2015 estimated flows in the Roseau River at 923 $m^3/s$, based on visual observations of damage and peak flow correlation with USGS Slope-Area Method and Mannings Roughness Equation (Ogden, 2016). In some parts of Dominica, Erika delivered up to 850 mm of rainfall in 12 hours. Should this estimated flow in Roseau River be reliable, these two studies highlight the extreme variability of flows that may be expected.

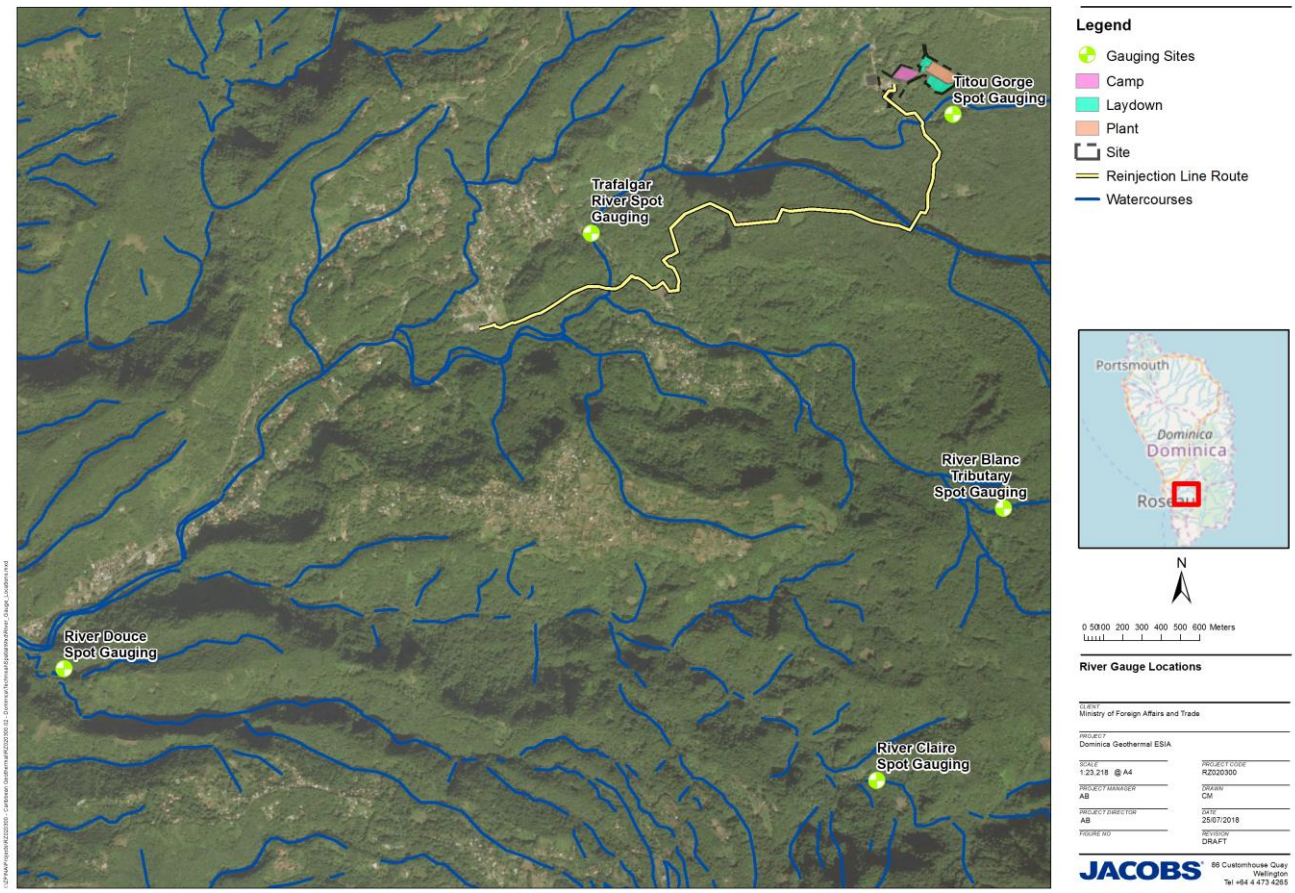


**Figure 3.8 : Spot stream gauging locations**

## 3.6 Water Quality and Freshwater Ecology

The baseline studies in 2015 recorded the current condition of the aquatic habitats, water quality and biological values of two waterways: the Roseau River and the Blanc River (Caraïbes Environnement Développement & Coll, 2015a/b).

The baseline data as described further in this section is considered comprehensive in the documentation of current water quality and the condition of the biota present, including all relevant biological groups (diatoms, macroinvertebrates, microcrustaceans and fish). Although the reinjection pipeline does not cross the Blanc River, it is located in close vicinity (50 m at the closest point) and therefore there is potential for the Project to influence the existing conditions of the river. The sampling points taken on the Blanc River are therefore able to act as a control site to understand potential impacts to both the Roseau and Blanc Rivers from the Project.

It is noted that systems for classifying the health of aquatic communities in the study area were limited. However, appropriate attempts were made by Caraïbes Environnement Développement & Coll (2015a/b) to develop relevant biological indices. These indices have been used as the basis for assessment of potential impacts associated with the proposed development (Section 3.6.2). The protection status of species and identification of whether they are endemic (local) was determined by reference to literature.

### 3.6.1 Methodology and Sample Locations

The sample locations chosen were based on accessibility and ability to account for variations in surrounding environments and wetter and dryer seasons over the year (Caraïbes Environnement Développement & Coll, 2015a/b). The four sample locations selected are as follows and shown in Figure 3.9:

- Roseau River Upstream – This site is upstream and unaffected by the Project and is located in a sparsely populated area. It is downstream of a waterfall that is impassable for most aquatic species and also downstream of an existing water intake for a hydropower station. This hydropower water take therefore modifies the flow and environmental quality of the river downstream.
- Roseau River Downstream – this site is located downstream of all Project features including the power plant site, pipeline and reinjection well.
- Blanc River Upstream – This site is upstream and unaffected by the Project and is located in a sparsely populated area.
- Blanc River Downstream – This site is upstream of the proposed pipeline crossing point.

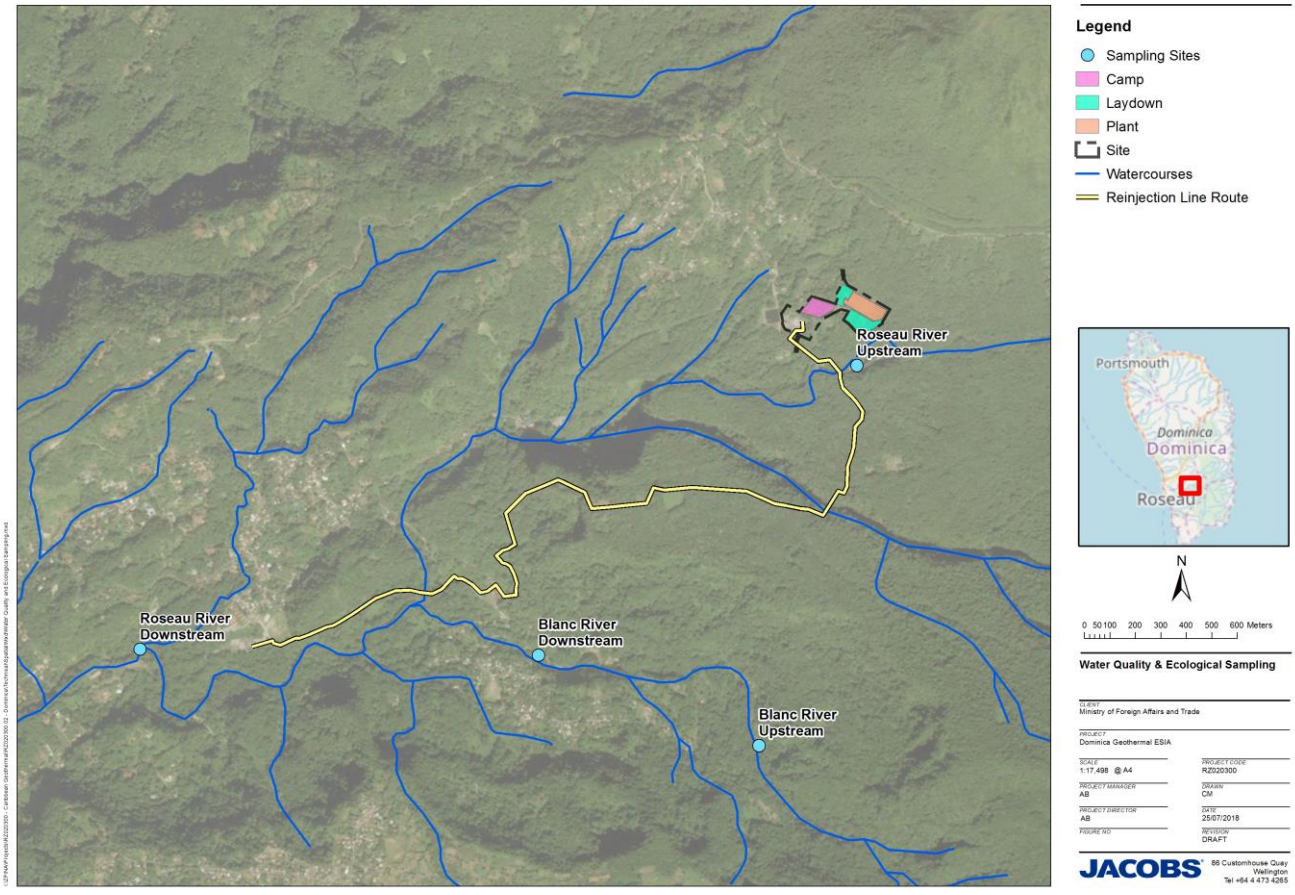


**Figure 3.9 : Water quality and freshwater ecology sample points on the Roseau and Blanc Rivers.**

Sample sites were originally established and monitored in 2013 further data gathered in 2014. Samples have been gathered during the high water period (August to December or winter) and in the low water period (March). At each sample location river morphology, the physical and chemical properties of the water, periphytic diatoms, benthic macroinvertebrates, and fisheries data were gathered by Caraïbes Environnement Développement & Coll team. The methodology for each is discussed below, full details of the approach to each study is reported

in Caraïbes Environnement Développement & Coll (2015a/b) (found in ESIA: Volume 5 – Technical Appendices).

**River Morphology**

Descriptive data on the river bed, bank, riparian zone and floodplain were gathered to describe the physical form of the river and its floodplain and its habitat features. A standard list of descriptors was used by the field teams, which included the following values:

- River bed descriptors - Including channel shape and flow, channel substrate types and sizes, river width and depth, vegetation types and human modification.
- Bank and riparian zone descriptors - Including bank type, material and size, riparian zone size and vegetation types, human modification of riparian zone and vegetation.
- Floodplain descriptors – Including land use, area of floodplain, old river bed, drainage features and other waterbodies, such as ponds.

**Physical and chemical properties**

In-situ and laboratory based monitoring of water quality was undertaken with sampling, in accordance with French standards implementing the European Water Framework Directive (WFD 2000/60/EC). In-situ data was gathered for temperature, pH, conductivity and dissolved and saturated oxygen. Physical samples were analysed by COFRAC-certified laboratories for the following parameters:

- Dissolved (organic and mineral);
- Specific forms (total and organic) of nitrogen and phosphorous;
- Mineral and organic matter in suspension;
- 5-day Biochemical Oxygen Demand (BOD5);
- Chemical Oxygen Demand (COD);
- Metals; and
- Hydrocarbons.

Caraïbes Environnement Développement & Coll (2015a/b) compared data to the 2003 French Water Quality Standards (SEQ-EAU, 2003) quality assessment systems, and the SEQ-EAU version-2 assessment tables to characterise elements of the water quality into five possible categories (very good, good, fair, poor and very poor quality). These categories were applied due to a lack of systems for characterising water quality in islands in the Caribbean. To further assess data in this report the French water quality assessment system has also been compared to USEPA Water Quality Criteria (USEPA Website, 2017) acute and chronic water quality criteria and to the ANZECC (2000) water quality guidelines. Of note the French standards were generally applied to physical and nutrient parameters and not metals. The USEPA and ANZECC guidelines provide information to assess metal concentrations. The monitoring data and water quality limits are outlined in Table 3.4.

**Table 3.4 : Water quality monitoring data and guideline values**

| | Roseau River Upstream | | Roseau River Downstream | | Blanc River Downstream | | | | French Water Quality Standards* | | | | | USEPA** | | ANZECC*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Dec-13 | Mar-14 | Dec-13 | Mar-14 | Dec-13 | Mar-14 | Unit | Limit of detection | Very good quality | Good quality | Fair quality | Poor quality | Very poor quality | Freshwater CMC acute | Freshwater CCC Chronic | |
| Ammonium (NH4) | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | mg/L | 0.025 | 0.5 | 1.5 | 4 | 8 | | | | 0.006 |
| Nitrites (NO2) | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | mg/L | 0.025 | 2 | | | | | | | |
| Nitrates (NO3) | <0.3 | <0.3 | 0.55 | <0.3 | <0.3 | <0.3 | mg/L | 0.3 | 0.03 | 0.3 | 0.5 | 1 | | | | 0.7 |
| Orthophosphates (PO4) | 0.06 | <0.02 | 0.04 | <0.02 | 0.04 | <0.02 | mg/L | 0.02 | 0.1 | 0.5 | 1 | 2 | | | | |
| Total Phosphorous (P) | ~ | 0.04 | ~ | 0.04 | ~ | 0.04 | mg/L | 0.01 | 0.05 | 0.2 | 0.5 | 1 | | | | 0.01 |
| BOD5 | 28 | <3 | 15 | <3 | 10 | <3 | mg/L | 3 | 3 | 6 | 10 | 25 | | | | |
| Kjeldhal Nitrogen (N) | 0.7 | 0.6 | <0.5 | <0.5 | <0.5 | <0.5 | mg/L | 0.5 | 1 | 2 | 6 | 12 | | | | |
| Total Nitrogen | ~ | 0.58 | ~ | 0.47 | ~ | 0.38 | mg/L | | | | | | | | | 0.15 |
| COD | <30 | <30 | <30 | <30 | <30 | <30 | mg/L | 30 | 20 | 30 | 40 | 80 | | | | |
| Suspended solids | <2 | <2 | 8 | 2 | 13 | 4 | mg/L | 2 | | | | | | | | |
| **Mineral micro pollutants** | | | | | | | | | | | | | | | | |
| Arsenic (As) | 1.7 | 2.1 | 5.3 | 8.1 | 0.5 | 0.4 | µg/L | 0.2 | | | | | | 0.34 | 0.15 | 0.013 |
| Cadmium (Cd) | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | <0.025 | µg/L | 0.025 | | | | | | 0.0018 | 0.00072 | 0.0002 |
| Total Chromium (Cr) | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | µg/L | 0.2 | | | | | | 0.016 | 0.011 | 0.001 |
| Copper (Cu) | 0.4 | 0.6 | 0.9 | 0.5 | 0.7 | 0.3 | µg/L | 0.2 | | | | | | | | 0.0014 |
| Manganese (Mn) | 93 | 45 | 34 | 17 | 125 | 100 | µg/L | 5 | | | | | | | | |
| Mercury (Hg) | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | µg/L | 0.015 | | | | | | 0.0014 | 0.00077 | |
| Nickel (Ni) | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | µg/L | 0.2 | | | | | | 0.47 | 0.052 | |

| | Roseau River Upstream | | Roseau River Downstream | | Blanc River Downstream | | | | French Water Quality Standards* | | | | | USEPA** | | ANZECC*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lead (Pb) | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | µg/L | 0.2 | | | | | | 0.065 | 0.0025 | 0.0034 |
| Zinc (Zn) | <2 | <2 | <2 | <2 | <2 | <2 | µg/L | 2 | | | | | | 0.12 | 0.09 | 0.008 |
| **Organic micro pollutants** | | | | | | | | | | | | | | | | |
| Decane (C10) | <4 | <4 | <4 | <4 | <4 | <4 | µg/L | 4 | | | | | | | | |
| Hexane (C6) | <4 | <4 | <4 | <4 | <4 | <4 | µg/L | 4 | | | | | | | | |
| Isooctane | <4 | <4 | <4 | <4 | <4 | <4 | µg/L | 4 | | | | | | | | |
| Toluene | <4 | <4 | <4 | <4 | <4 | <4 | µg/L | 4 | | | | | | | | |
| Trimethylbenzene | <4 | <4 | <4 | <4 | <4 | <4 | µg/L | 4 | | | | | | | | |
| Benzene | <0.2 | - | <0.3 | - | <0.4 | - | µg/L | 0.2 | | | | | | | | 0.95 |
| Decane (C10) | <1 | - | <1 | - | <1 | - | µg/L | 1 | | | | | | | | |
| Equivalent petrol | <50 | <50 | <50 | <50 | <50 | <50 | µg/L | 50 | | | | | | | | |
| Equivalent diesel | <50 | <50 | <50 | <50 | <50 | <50 | µg/L | 50 | | | | | | | | |
| Equivalent mineral oil | <50 | <50 | <50 | <50 | <50 | <50 | µg/L | 50 | | | | | | | | |
| Ethylbenzene | <0.2 | - | <0.3 | - | <0.4 | - | µg/L | 0.2 | | | | | | | | |
| Hexane C6) | <1 | - | <1 | - | <1 | - | µg/L | 1 | | | | | | | | |
| Index C5-C11 | <20 | <20 | <20 | <20 | <20 | <20 | µg/L | 20 | | | | | | | | |
| Isooctane | <0.2 | - | <0.2 | - | <0.2 | - | µg/L | 0.2 | | | | | | | | |
| Toluene | <0.2 | - | <0.2 | - | <0.2 | - | µg/L | 0.2 | | | | | | | | |
| Trimethylbenzene 1,2,4 | <0.2 | - | <0.2 | - | <0.2 | - | µg/L | 0.2 | | | | | | | | |
| (ortho, meta, para) xylenes | <0.2 | - | <0.2 | - | <0.2 | - | µg/L | 0.2 | | | | | | | | |
| Total equivalent hydrocarbons | <50 | <50 | <50 | <50 | <50 | <50 | µg/L | 50 | | | | | | | | |

| | Roseau River Upstream | | Roseau River Downstream | | Blanc River Downstream | | | | French Water Quality Standards* | | | | | USEPA** | | ANZECC*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| equivalent | | | | | | | | | | | | | | | | |
| Hydrocarbon index (C10-C40) | <50 | <50 | <50 | <50 | <50 | <50 | µg/L | 50 | | | | | | | | |
| **Field data** | | | | | | | | | | | | | | | | |
| Temperature | 25.6 | 25.5 | 25.5 | 25.2 | 26.6 | 25.8 | deg C | field | | | | | | | | |
| pH | 6.98 | 7.29 | 6.96 | 7.64 | 6.29 | 7.04 | pH units | field | | | | | | | | |
| Conductivity | 388 | 486 | 204 | 386 | 216 | 249 | uS/cm | field | | | | | | | | |
| Dissolved Oxygen | 7.25 | 7.62 | 8.76 | 8.04 | 7.46 | 7.93 | mg/L | field | 8 | 6 | 4 | 3 | | | | |
| Dissolved Oxygen | 92.7 | 99.4 | 109.1 | 99.1 | 104.5 | 99.3 | %sat | field | 90 | 70 | 50 | 30 | | | | |

Notes:

*French Water Quality Standards - Evaluation system of water quality for water courses - Evaluation tables SEQ-EAU (Version 2) (http://rhin-meuse.eaufrance.fr/IMG/pdf/grilles-seq-eau-v2.pdf).

**USEPA United States Environment Protection Agency Water Quality Criteria Acute and chronic criteria (https://www.epa.gov/wqc).

***ANZECC Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000) Australian and New Zealand Environment and Conservation Council. Trigger values used were for tropical Australia as they are considered to be of a more similar climatic environment due to the higher water temperatures.

**Diatoms**

Diatom sampling and analysis was undertaken using an established protocol previously used elsewhere in the France (French Government, Circular WFD 2004/08). This standardises the cleaning of samples, slide mounting and counting processes. Caraïbes Environnement Développement & Coll (2015a/b) calculated two diatom indices the Specific Pollution Sensitivity Index (IPS) and Biological Diatom Index (BDI) based on their knowledge of similar environments. IPS and BDI vary from 1 ("very polluted" waters) to 20 ("very good quality" waters).

**Macroinvertebrates**

Benthic macroinvertebrate samples were gathered using established protocols for work in the French West Indies. The samples were preserved for species identification in the laboratory. There were no specific benthic macroinvertebrate indices available to allow for characterisation of water quality in Dominica, hence conventional indicators of total abundance of species, taxonomic richness, population structure, Shannon and Simpson Diversity Index and Pielou's Evenness Index were reported. The data were also used to calculate the Biological Index for Macroinvertebrates in the French West Indies (IBMA). This compares a community to its baseline but requires a benchmark value dataset for reference. These do not exist for Dominica hence comparison to a range of other types has been made to give an indication of quality.

**Fish and macrocrustaceans**

The composition and abundance of fish species was identified using electro-fishing methods (qualitative single pass fishing) in a defined area (50 m²). Macrocrustaceans (whose populations are well-represented in West Indies rivers) were recorded at the same time as the fish because the electro-fishing capturing technique for them was effective. No biotic index based on fish and macrocrustacean populations currently exists to analyse data obtained in the French West Indies. Conventional structural indices were therefore used (specific richness, abundance, relative abundance of faunistic groups and densities).

### 3.6.2 Study Results

Fieldwork took place from 29 to 31 August 2013 and from 3 to 5 December 2013 for high-water sampling exercises and from 25 to 28 March 2014 for the low-water sampling exercises. During the December 2013 fieldwork, weather and hydrological conditions were typical of those expected during the winter season. Skies were cloudy, water levels quite high (average depth) and flooding episodes were recorded in the 15 days prior to the sampling exercise. During March 2014 fieldwork, water levels were still relatively high (lowest flow not reached) but appeared stable (no sign of recent flood events).

The results obtained from the two periods of fieldwork (December 2013 and March 2014) sometimes differed widely, especially macroinvertebrate and benthic diatom communities. Broadly speaking, the end of the rainy season (December) is less conducive to assessing river water quality compared to the dry season (March). During this period, the unstable environment (regular flooding causing substrate instability) can naturally hamper the establishment and, therefore, diversity in the structure of in-situ biological communities. This can then affect the assessment of the ecological state of the environment. Therefore, greater confidence can be given to dry season (March) data with respect to describing site conditions.

**Roseau River Upstream**

**Physical description**

In March 2014 the river was 3.9 m wide and 20 cm deep with a bankfull width of 11.2 m. The bed was impacted by a weir at the sampling locations and a dam plus bridge structure upstream that modified flows and substrate. These create pools with low flow that deposit sediment and promote algal growth. The riparian zone contains

mature diverse vegetation that is unaffected by human activity. Full details of the monitoring results are provided in Caraïbes Environnement Développement & Coll (2015a/b).

**Physical and Chemical Water Quality**

Results from the physical and chemical analysis carried out in the laboratory are presented in Table 3.4.

The river is characterised as being in a “good”, or “very good” state with naturally high water mineralisation rates. The dissolved oxygen levels are generally good. Traces of copper (Cu), arsenic (As) and manganese (Mn) were recorded. Arsenic was elevated above USEPA Guidelines (acute and chronic) and ANZECC Guidelines and copper was elevated above ANZECC Guidelines. These elements are naturally present in volcanic formations and as a result elevated concentrations above ANZECC Guidelines are not unexpected. High concentrations of manganese are probably due to natural origins.

**Diatoms**

Based on the results of March 2014 (a more favourable season for ecological assessments), the population is relatively diverse and balanced. According to the IPS and BDI scores in Table 3.5, the Roseau River Upstream site is in a “good ecological state”. The benthic diatom community is largely dominated by relatively pollution-sensitive taxa.

**Macroinvertebrates**

The macroinvertebrate summary data in Table 3.6 demonstrates large differences in abundance and richness between high flow sampling (December) and lower flow sampling (March). The very low abundance of individuals recorded during the winter period suggest, in the absence of physical and chemical disturbances recorded, that the biological communities have been affected by the natural water regime. Based on the results for March the population is relatively diverse and balanced. The site is classed as a “good” ecological state.

One species was found at the site and was identified with certainty as presenting a specific heritage interest. This was *Argia concinna* (Odonate Coenagrionidae) which is endemic to the Lesser Antilles.

**Fish and Macrocrustaceans**

Overall, the fish and macrocrustacean community sampled did not show a high level of diversity. In total, three fish and two macrocrustacean taxa were recorded, with details of species and calculated indices are provided in Caraïbes Environnement Développement & Coll (2015a/b). The most dominant fish species was an introduced Guppy.

Among the species of crustaceans recorded, two were of heritage interest. These are the *Guinotia dentata* crab, which is endemic to the Lesser Antilles, and *Xiphocaris elongate,* which may be endemic to the West Indies (present in the Lesser and Greater Antilles). The other species are widely distributed in the neotropical zone.

There are no endemic fish species in Dominica or the West Indies. Sicydium-type Gobiidae (*S. punctatum and S. plumieri*) are widely distributed in the West Indies and on the South American continent while Guppies (*Poecilia* sp.) are found worldwide.

**Summary**

Water quality was identified as being “good” at this site. The ecological state in the dryer March season was good, despite the obvious modifications to the watercourse in the sampling location (Dam and weir). In the wetter season the ecological state was poorer with the hydrology impacting upon the ecological values.

**Roseau River Downstream**

**Physical Description**

In March 2014 the river was 14.3 m wide and 30 cm deep with a bankfull width of 19.2 m. No human modifications were observed with no modification of flows and erosion/sedimentation processes or obvious visual pollution. The riparian zone contains mature diverse vegetation that is unaffected by human activity. Details of the monitoring results are provided in Caraïbes Environnement Développement & Coll (2015a/b).

**Physical and Chemical Water Quality**

The water quality was good for all general physical and chemical parameters, with the exception of two during December 2013. The BOD5 and slightly high level of suspended material are probably linked to the river's water regime during sampling, such as recent floods and regular rain. Similarly, to the Roseau River Upstream site, traces of copper (Cu), arsenic (As) and manganese (Mn) were detected, but these elements are probably of natural origin (alteration of the volcanic substratum and geothermal activity). Arsenic was elevated above USEPA Guidelines (acute and chronic) and ANZECC Guidelines and copper above ANZECC Guidelines.

**Diatoms**

Based on the results of March 2014 (a more favourable period for ecological assessments), there is little diversity in the population but it is relatively balanced. According to the IPS and BDI scores (Table 3.5), the Roseau River Downstream site is in "less than good" ecological state ("fair"). The benthic diatom community displays a mix of pollution-sensitive diatoms and much more ubiquitous diatoms and those tolerant to organic and mineral contamination.

**Macroinvertebrates**

Similarly, to the Roseau River Upstream site there is variation in the macroinvertebrate populations and indices between December 2014 (high flow) and March 2014 (lower flow) sampling occasions. Based on the results from March 2014 (Table 3.6), the population is diverse and balanced. According to the IBMA scores, the Roseau River Downstream site is in a "good" ecological state at the very least ("good" or "very good ecological state") based on the type of river considered (typology) in this period.

One species was found at the site and was identified with certainty as presenting a specific heritage interest. This was *Argia concinna* (Odonate Coenagrionidae), which is endemic to the Lesser Antilles.

**Fish and Macrocrustaceans**

In total, seven taxa were recorded in December 2013 and five in March 2014, which makes this site the most diverse in the study, although the abundances and densities recorded were very low. The fish, Gobiidae *Sicydium* sp., is the most abundant taxon. The species, *Macrobrachium heterochirus*, was the dominant prawn species during March 2014.

No crustacean species recorded presents any specific heritage interest as they are all widely distributed in the neotropical zone.

**Summary**

This sample location represents an unmodified physical river and riparian zone environment. The water quality is generally good and during the dryer season the macroinvertebrate community is generally assessed as being good. This is impacted by flows during the wetter season. The diatom index represents fair water quality but this may also be affected by using a non-site specific set of indices that does not utilise all species identified. The fish community is relatively diverse but there are low densities of fish and crustaceans.

**Blanc River Upstream**

**Physical Description**

In March 2014 the river was 6 m wide and 20 cm deep with a bankfull width of 8 m. It was reported as being a very dynamic section of river. No human modifications were observed with a natural channel that tends to braid in the upper section with some bedrock outcrops. The riparian zone contains mature diverse vegetation that is unaffected by human activity. Details of the monitoring results are provided in Caraïbes Environnement Développement & Coll (2015a/b). No water quality samples were gathered for this site, ecology samples were only taken in the December 2013 sampling period.

**Diatoms**

Based on the results of December 2013 there is little diversity in the population but it is still balanced (Table 3.8). Based on the IPS and BDI scores, the Blanc River Upstream site is in a “fair” ecological state. The benthic diatom community comprises ubiquitous, or even pollution-resistant taxa, as well as pollution-sensitive taxa. As for other sites it was reported that the indexes used may not be suitable for this site.

**Macroinvertebrates**

Based on the results from December 2013 (a less favourable period for ecological assessments), there is little diversity in the population. According to the IBMA scores, the Blanc River Upstream site is in a “very good” ecological state.

One species was found at the site and was identified as presenting a specific heritage interest. This was *Argia concinna* (Odonate Coenagrionidae), which is endemic to the Lesser Antilles.

**Fish and Macrocrustaceans**

Overall, there is very little diversity in the fish and macrocrustacean community. In total, just one fish taxon and two macrocrustacean taxa were recorded at the Blanc River Upstream site. Densities were also very low. It is possible that flood events in the previous days had an effect with a considerable drop in macro-organisms, and that the electrofishing survey involved less survey area than other sites.

No macrocrustacean species recorded presents any specific heritage interest as they are all widely distributed in the neotropical zone.

**Summary**

Visually the channel and riparian zone at this site appears to be in an unmodified state. The macroinvertebrate populations indicate that it is in a very good ecological state. The diatom data indicated a fair state however these should be treated with caution due to the lack of comparison data for the indices used. Macrocrustacean and fish population densities were low and may have been affected by flow. The lack of water quality data makes direct assessment of water quality state difficult, however, it can be inferred from the very good macroinvertebrate ecology state that the water quality is unlikely to have any significant stressors and could be expected to in general be good.

**Blanc River Downstream**

**Physical description**

In March 2014 the river was 4.5 m wide and 45 cm deep with a bankfull width of 7.2 m. It was reported as being a turbulent section of river. The Blanc Downstream site is clearly affected by human activity with a weir upstream and a low wall on the left bank and a low wall in the middle of the river to divert flow. As a result, there

is pronounced localised erosion on the right bank and silting can be seen periodically. The hydraulic obstructions create a paving effect in areas where the flow is stronger with an artificially rough substrate for the natural conditions. The riparian zone on the wider floodplain is well preserved with woody, mature, continuous, local species). Vegetation on the left bank of the floodplain has probably been affected by construction work as indicated by the presence of young vegetation. Details of the monitoring results are provided in Caraïbes Environnement Développement & Coll (2015a/b).

**Physical and Chemical Water Quality**

Similarly, to the Roseau River Upstream and Roseau River Downstream sites, the Blanc River Downstream site had good water quality results for all the general physical and chemical parameters apart from two parameters during December 2013. There was slightly elevated BOD5 and suspended material, which are likely linked to the recent and regular rain at the time of sampling. As with the Roseau River Upstream site, traces of copper (Cu), arsenic (As) and manganese (Mn) were detected but these elements are probably of natural origin (alteration of the volcanic substratum and geothermal activity). Arsenic was elevated above USEPA (acute and chronic) and ANZECC Guidelines but was in lower concentrations than the Roseau River sites. Copper was elevated above the ANZECC Guidelines. No organic micropollutants were detected.

**Diatoms**

Based on the results from March 2014 (Table 3.5), the population is relatively and balanced. According to the IPS and BDI scores, the Blanc River Downstream station is in a “fair” ecological state. The benthic diatom community on this site comprises a large proportion of ubiquitous taxa and to a lesser extent, much more pollution-resistant diatoms. This site is affected by organic and mineral inputs which have a moderate impact as indicated by the continued presence of some pollution-sensitive species in the population. These inputs can be linked to the natural functions of this catchment basin and its proximity to thermal springs.

**Macroinvertebrates**

Based on the results from March 2014 (Table 3.6), the population is relatively diverse and balanced. According to the IBMA scores, the Blanc River Downstream station was in March in a “poor” or “fair” ecological state or “good” based on the type of river considered. In the December samples the river was characterised as being in very good or good condition. The presence of large numbers of diptera and Chironomidae Orthocladiinae (nearly half of the total population) suggests the existence of factors that limit the ecological quality. This was considered by the samplers to be linked to the presence of mineral silting (sand) on the site. The lack of specific benchmarks for geothermal regions limits our ability to assess the quality for this stretch of the river.

One species was found at the site and was identified as presenting a specific heritage interest. This was *Argia concinna* (Odonate Coenagrionidae), which is endemic to the Lesser Antilles.

**Fish and Macrocrustaceans**

The population of both fish and macrocrustaceans at this site was very low. Only two fish and two macrocrustacean species were recorded with only 1 of each type of macrocrustacean being observed.

No macrocrustacean species recorded presents any specific heritage interest as they are all widely distributed in the neotropical zone.

**Summary**

The river channel has been considerably altered at the Blanc River Downstream site. This probably affects the benthic macroinvertebrate communities, which are very sensitive to this type of disruption. The macroinvertebrate communities represent an ecological state ranging from “poor” to “good” in the March 2014 period according to the type of river considered. The analysis of diatom communities ranks the site as having a

"fair" ecological state regardless of the indicator used or the season considered. Apart from the use of ill-adapted indices, it is possible that sulphur composites of natural origin (geothermal activity around the site) "affect" biological communities. Fish populations are also low. At this site the physical and chemical water quality is good, however, overall the Blanc River Downstream station is of poorer ecological state.

### Summary Tables

Diatom and macroinvertebrate results for all sample sites are shown below in Table 3.4 and Table 3.5.

**Table 3.5 : All Sample Sites - Diatom Results for December 2013 and March 2014**

| Indicators | Roseau River Upstream | | Roseau River Downstream | | Blanc River Upstream | | Blanc River Downstream | |
|---|---|---|---|---|---|---|---|---|
| | December 2013 | March 2014 | December 2013 | March 2014 | December 2013 | March 2014 | December 2013 | March 2014 |
| Taxonomic richness (number of taxa) | 37 | 40 | 23 | 28 | 25 | - | 30 | 36 |
| Shannon & Weaver diversity index | 4.32 | 4.03 | 2.80 | 3.09 | 3.57 | - | 3.49 | 3.80 |
| Evenness | 0.83 | 0.76 | 0.62 | 0.64 | 0.77 | - | 0.71 | 0.74 |
| Specific Pollution Sensitivity Index (IPS) | 15.9 | 15.9 | 12.8 | 10.5 | 11.4 | - | 9.8 | 10.5 |
| Biological Diatom Index (BDI) | 16.2 | 16.7 | 13.9 | 12.0 | 12.4 | - | 9.3 | 9.9 |

| Very poor | Poor | Fair | Good | Very good |
|---|---|---|---|---|

**Table 3.6 : All Sample Sites - Macroinvertebrate Indicator Results for December 2013 and March 2014**

| Indicators | | Roseau River Upstream | | Roseau River Downstream | | Blanc River Upstream | | Blanc River Downstream | |
|---|---|---|---|---|---|---|---|---|---|
| | | December 2013 | March 2014 | December 2013 | March 2014 | December 2013 | March 2014 | December 2013 | March 2014 |
| Abundance (number of individuals) | | 100 | 2325 | 375 | 778 | 108 | - | 73 | 584 |
| Taxonomic richness (number of taxa) | | 23 | 31 | 27 | 34 | 25 | - | 17 | 29 |
| Shannon | | 3.51 | 2.67 | 3.06 | 3.63 | 3.29 | - | 3.13 | 3.00 |
| Simpson | | 0.10 | 0.25 | 0.24 | 0.13 | 0.16 | - | 0.13 | 0.22 |
| Evenness | | 0.78 | 0.54 | 0.64 | 0.71 | 0.71 | - | 0.77 | 0.62 |
| IBMA | G1 | 0.34 | 0.52 | 0.52 | 0.70 | 0.78 | - | 0.75 | 0.42 |
| | G2 | 0.34 | 0.43 | 0.43 | 0.64 | 0.8 | - | 0.66 | 0.38 |
| | G3 | 0.55 | 0.65 | 0.65 | 0.81 | 0.88 | - | 0.79 | 0.61 |
| | M4 | 0.41 | 0.57 | 0.57 | 0.74 | 0.93 | - | 0.74 | 0.54 |
| | M5 | 0.57 | 0.58 | 0.58 | 0.74 | 0.92 | - | 0.76 | 0.56 |

| Very poor | Poor | Fair | Good | Very good |
|---|---|---|---|---|

**Overall Summary**

Overall the water quality appears to be good across the two rivers both upstream and downstream of the proposed power plant operations. Ecological state varies and this appears to be especially linked to the flow and season, with poorer ecological conditions observed in the wetter season. However, in drier weather at both Roseau River sites and the Blanc River Upstream site the ecology appears to be in a generally good state.

## 3.7 Landscape and Visual

### 3.7.1 Landscape of Dominica

Dominica is a volcanic island 46 km in length with a central mountain ridge running from Cape Melville in the north to the cliffs in the south. Morne Diablotin, the highest mountain on the island, rises to 1,447 m. There are numerous mountain streams and rivers, with waterfalls and heavily vegetated mountains, which has resulted in Dominica gaining the nickname the 'Nature Isle' (The Commonwealth Website, 2017).

### 3.7.2 Landscape of the Roseau Valley

The Roseau Valley is heavily vegetated with visitors observing mountainous passes and various scattered villages present as they travel up the valley from Roseau City (Trafalgar, Laudat, Fond Cani and Wotten Waven). The Roseau Valley is home to a number of popular tourist attractions, such as the hot springs at Wotten Waven, Trafalgar Falls, the Boiling Lake, Titou Gorge, Valley of Desolation, and the Freshwater Lake. These are described further in Section 3.7.3 and from a touristic view in ESIA Volume 3: Social Impact Assessment. The general landscape and topography of the Roseau Valley are presented below in Figures 3.10 and 3.11.

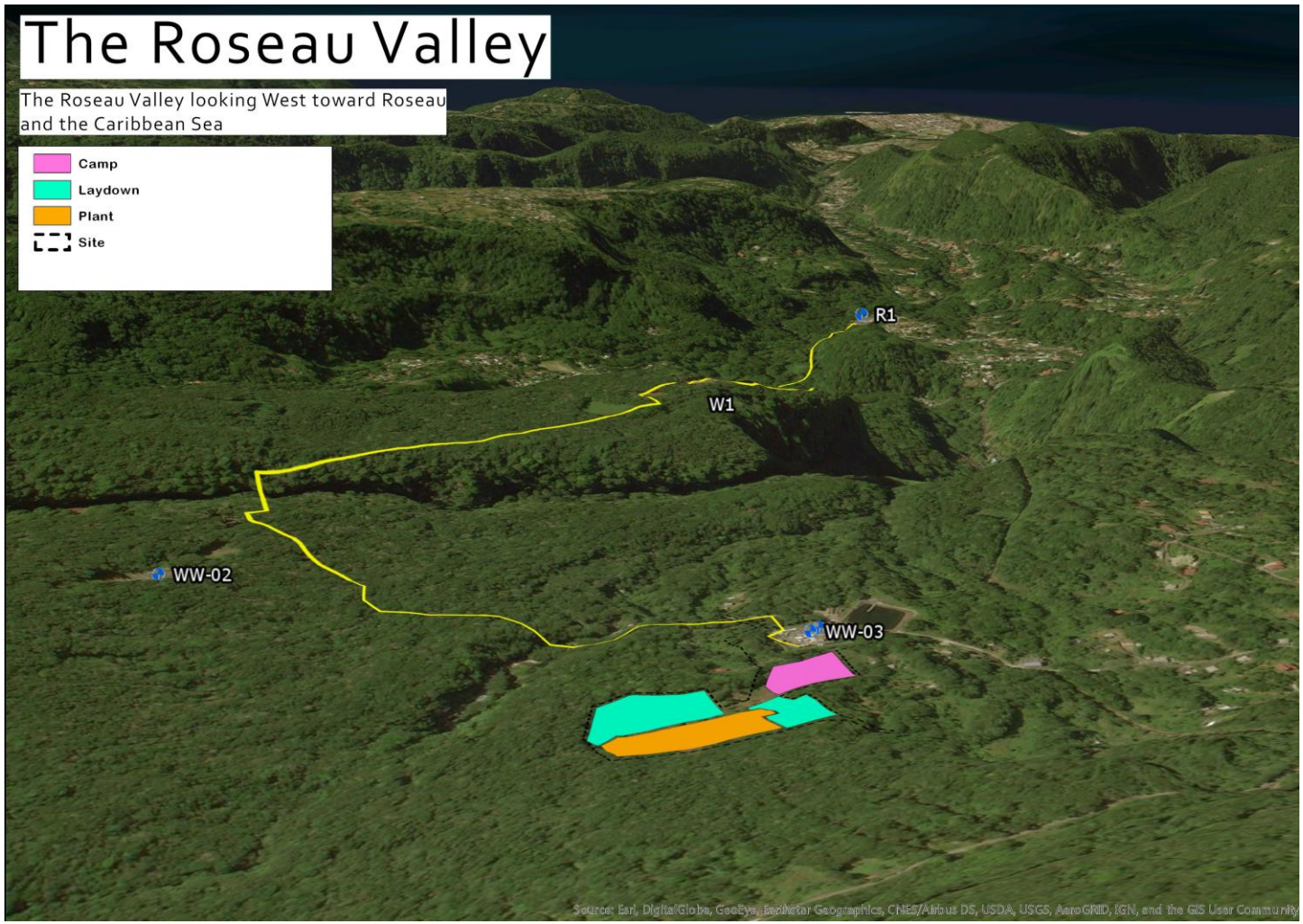


**Figure 3.10 : The Roseau Valley looking west towards Roseau and the Caribbean Sea. The power plant and reinjection pipeline routes are also shown. Source: Google Earth, 2017**

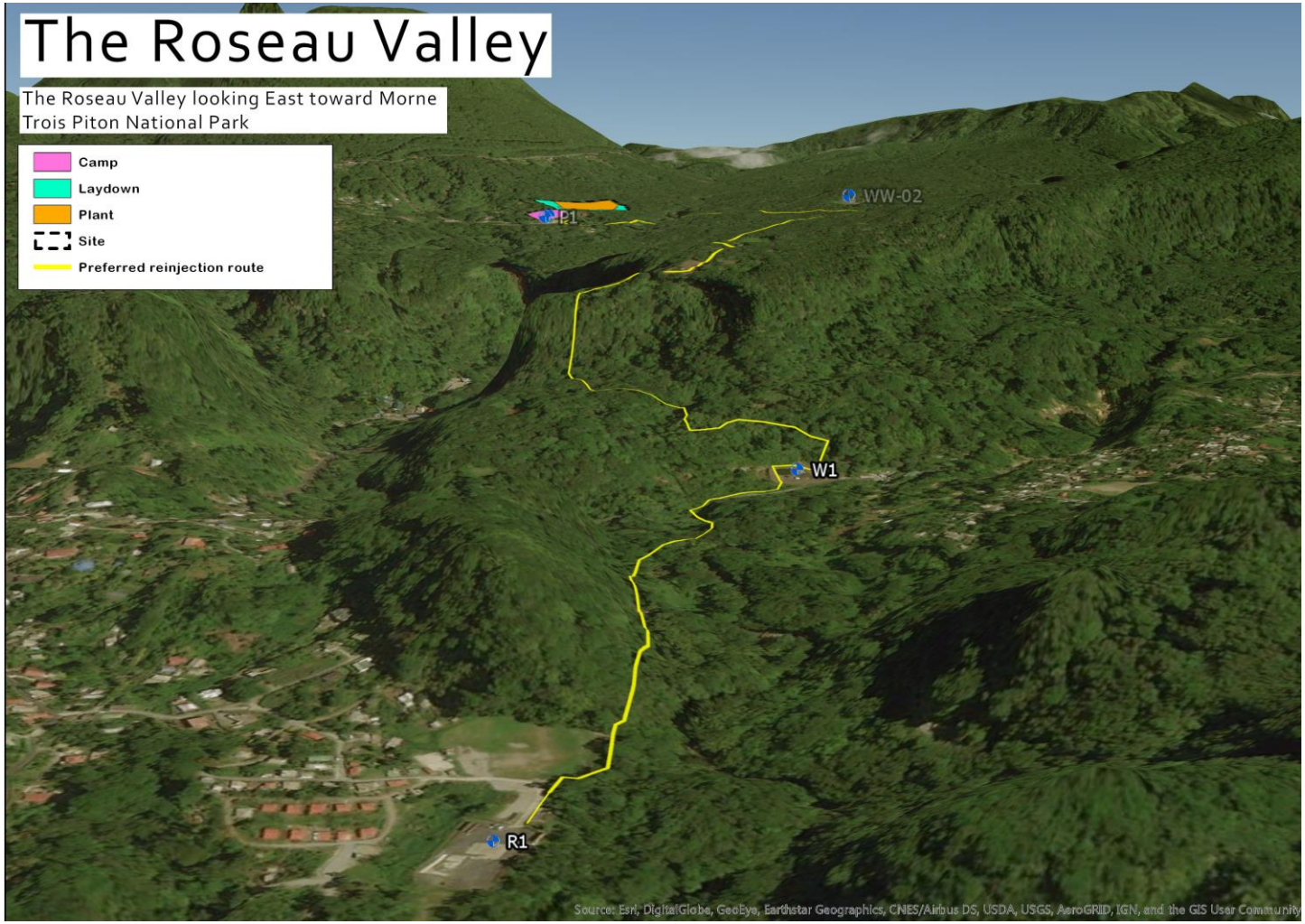


**Figure 3.11 : The Roseau Valley looking west towards Morne Trois Piton National Park. The power plant and reinjection pipeline routes are also shown. Source: Google Earth, 2017**

The skyline of the Roseau Valley is dominated by the peaks of Morne Micotrin (also known as Morne Macaque) (1,221 m) and Morne Watt (1,224 m) (Figures 3.12 to 3.15).



**Figure 3.12 : Morne Watt (1,224 m). Source: Jacobs, December 2016**



**Figure 3.13 : Morne Micotrin (also known as Morne Macaque) (1,221 m). Source: Jacobs, December 2016**



**Figure 3.14 : Morne Micotrin (also known as Morne Macaque) (1,221 m) and the Roseau Valley. Source: Jacobs, December 2016**



**Figure 3.15 : The Roseau Valley from Wotten Waven. Source: Jacobs, December 2016**

### 3.7.3 Landscape Types of Roseau Valley

The Roseau Valley is characterised by the following key landscape types as described in the reports by Caraïbes Environnement Développement & Coll (2015a/b). More information on species compositions of terrestrial habitats is found in Section 3.11 - Terrestrial Ecology.

**Tropical Rainforest**

Dense tropical rainforest is prolific in Dominica, with trees having an average height of 30 m. The canopy is thick throughout the Roseau Valley, with ferns and lianas covered with a variety of epiphytes and creeper species. This forest is present in the northern part of the valley, in Laudat and up above Wotten Waven, and on the foothills of Morne Diablotin.

**Mountain Forest**

Further up the Roseau Valley, Mountain forest emerges above the dense tropical rainforest. Similarities exist with the species found in the tropical rainforest, but trees are smaller and the forest is more open, with a great abundance of epiphytes. An example of this is shown in Figure 3.16.

**Semi-deciduous Forest**

Semi-deciduous forest forms the transition zones with a mixture of deciduous trees and evergreen trees. An abundance of epiphytes and creepers can be observed in the trees.

**Vegetation of Fumarole Sites**

Due to the volcanic nature of soils, plants endure very specific conditions linked to the presence of highly acidic soils and hot water, and are subjected to high temperatures. They are located in the vicinity of sites that produce steam fumaroles with a very clear smell of sulphur.

**Marshlands**

Marshes are observed near the mouth of the Layou River, while the banks of the Freshwater Lake and Roseau River are also colonised by marshland vegetation.

**Savannas**

Savannas comprise a large proportion of deciduous species. Trees are small (6 m) and dominated by Naked Indian species.

**Abandoned Agricultural Land**

Abandoned fields of average size can be found in several relatively scattered places. Remains of former crops (sugar cane, fruit trees, plantain and for livestock pasture) coexist with hardier species and other trees and shrubs covered with epiphytes. An example of abandoned agricultural land is shown in Figure 3.16.

**Urban villages and Connecting roads**

The Roseau Valley contains a number of small urban villages: Laudat, Trafalgar, Wotten Waven, Morne Prosper, Copt Hall, Shawford and Fondi Cani (Figure 3.17). The majority of these villages have views shrouded by thick vegetation and undulating topography.



**Figure 3.16 : Typical Landscape types of the Roseau Valley. Left: Dense tropical rainforest, Right: Disused agricultural land with montane rainforest in the background (taken at the proposed power plant site). Source: Jacobs, December 2016**



**Figure 3.17 : Typical urban areas of the Roseau Valley (Laudat). Source: Jacobs, December 2016**

The power plant is situated on disused agricultural land adjacent to patchy secondary growth rainforest (Figure 3.18). The reinjection line is located in areas of secondary growth rainforest and small-scale agricultural land (Figure 3.19). The general landscape types of the Roseau Valley are summarised below in Figure 3.20.



**Figure 3.18 : Photographs from the Power Plant Site (left and right) (Source: Jacobs, 2018)**



**Figure 3.19 : Photographs from the Reinjection Line Site (left and right) (Source: Jacobs, 2016)**

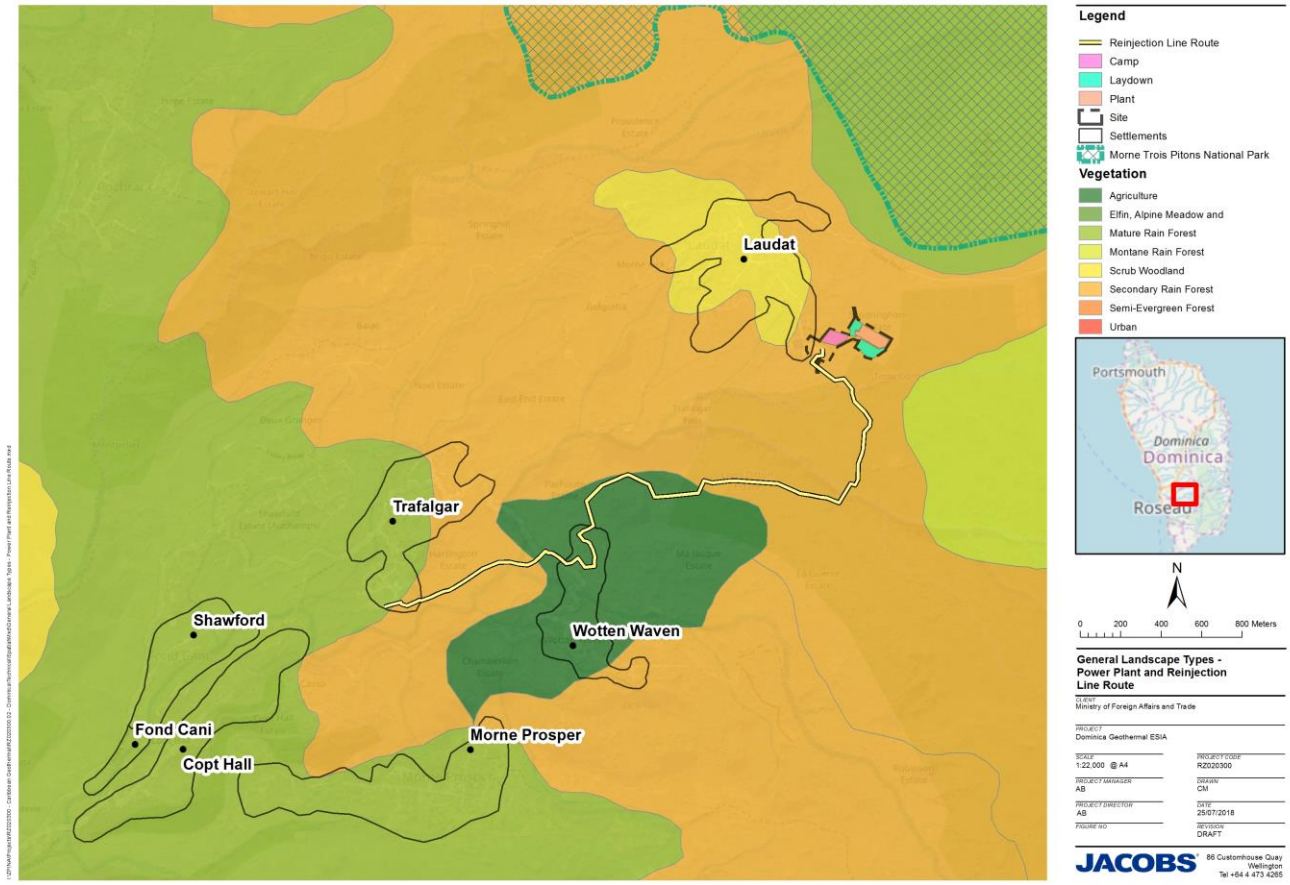


**Figure 3.20 : General Landscape Types – Power Plant and Reinjection Pipeline Route. (Source: GoCD Website, 2017)**

## 3.8 Geothermal Features

The Wotten Waven geothermal system has been extensively investigated between 2008 and 2013, including drilling of three exploratory wells. Specific details can be found in Volume 5 – Technical Appendices (Process Description) but in general the reservoir can be characterised as follows:

- A shallow depth with the top expected to occur at an approximate elevation of 0 m above sea level;
- Medium to high permeability and measured temperatures in the liquid dominated section in the range of 220 – 246 ºC; and
- Lateral extent conservatively estimated at a minimum surface area of approximately 9 $km^2$ and thickness assumed to be around 1,000 m.

The Roseau Valley contains several naturally occurring geothermal features that are popular tourist attractions. These are listed below and shown in Figure 3.21:

- Papillote Natural Hot Pools and Cold Mineral Pools (Trafalgar Falls);
- Screws Sulphur Spa Hot Pool (Wotten Waven);
- Tia's Hot Springs (Wotten Waven);
- Ti Kwen Glo Cho Hot Springs (Wotten Waven);
- Boiling Lake (Morne Trois Pitons National Park); and

- Valley of Desolation (Morne Trois Pitons National Park).

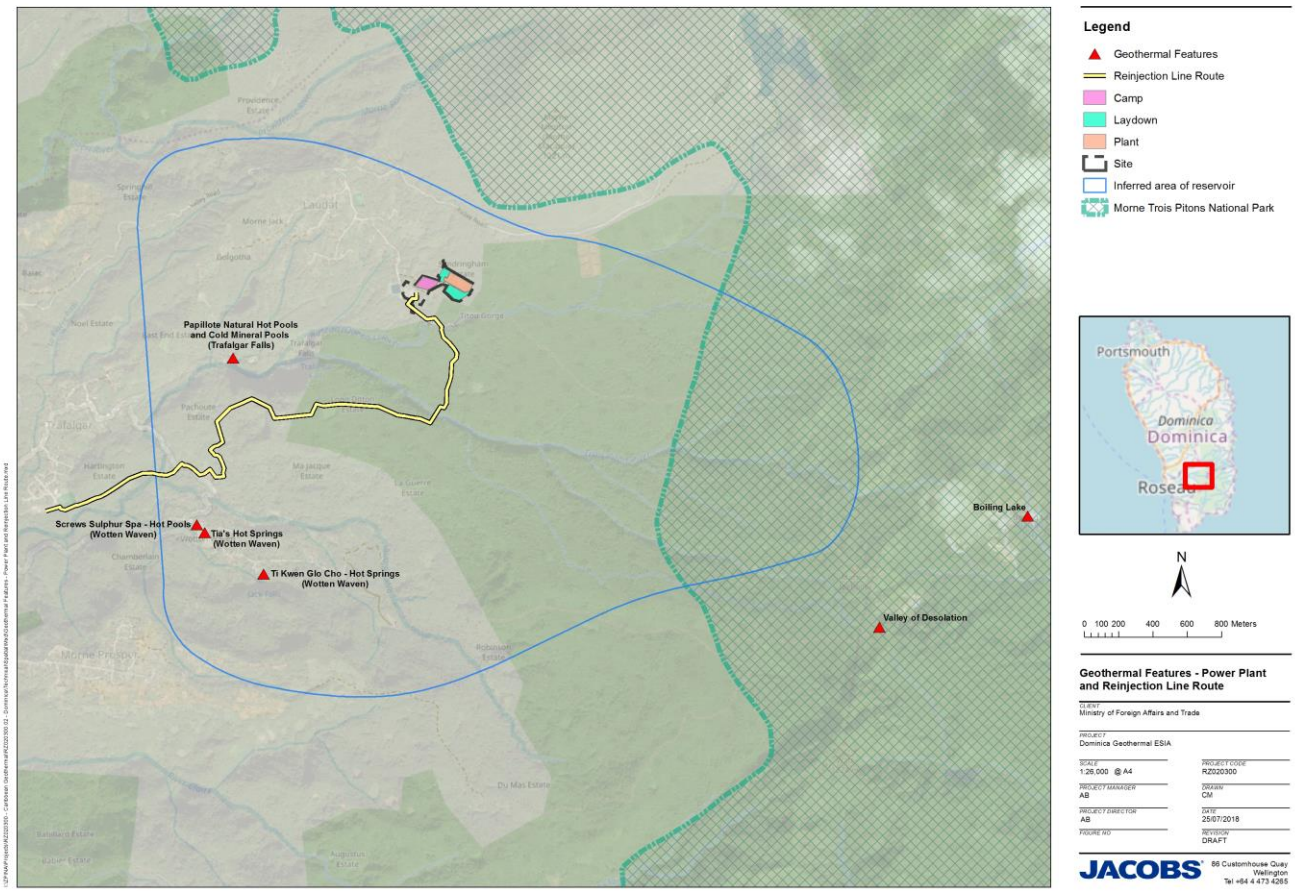


**Figure 3.21 : Geothermal Features - Power Plant and Reinjection Pipeline Route**

Natural fumaroles are also scattered throughout the Roseau Valley and provide an attraction for visitors. Fumaroles are vents or openings in the ground from which steam and geothermal gases (mostly carbon dioxide and hydrogen sulphide) are emitted. Fumaroles are typically located near to other geothermal features such as hot springs.

## 3.9 Natural Hazards

### 3.9.1 Hurricanes

The Caribbean is one of the most hurricane prone regions in the world and major hurricane events can leave Caribbean countries with fractured infrastructure, thousands of people affected, and governments struggling to put together the necessary resources to finance emergency assistance and relief, recovery, and reconstruction (Acevedo, 2016). On average, one major hurricane hits Dominica every 15 years (Caribbean Community Climate Change Centre, 2011a). However, there is growing evidence that the frequency of hurricanes in the Caribbean will increasing in the future, and some climate scientists believe that there is a connection between climate change and tropical cyclone intensity (Acevedo, 2016).

Dominica is located in the hurricane belt and some of the most devastating hurricane experiences (e.g. Marilyn, Lenny, Dean) have occurred since 1995 in the current active phase of the north tropical Atlantic. There is also significant year to year modulation of hurricane frequency and track by El Niño Southern Oscillation (ENSO)

events. Since 1979, tropical systems of note (storms and hurricanes) which have impacted Dominica include David (1979), Gert (1981), Gilbert (1988), Hugo (1989), Iris (1995), Marilyn (1995), Hortense (1996), Lenny (1999), Dean (2007) and Maria (2017).

### 3.9.2 Landslide

Landslides are a potential hazard throughout Dominica and especially in the steeper areas, which receive higher rainfall. Areas located west and south of Morne Micotrin are within an area of high landslide risk. The power plant is located in an area of 'Low' risk of landslide. The reinjection line passes through areas of Low (~50%), Medium (~20%) and High (~30%) landslide risk.

Figure 3.22 shows the risk of landslides to the Roseau Valley (GoCD, 2017).

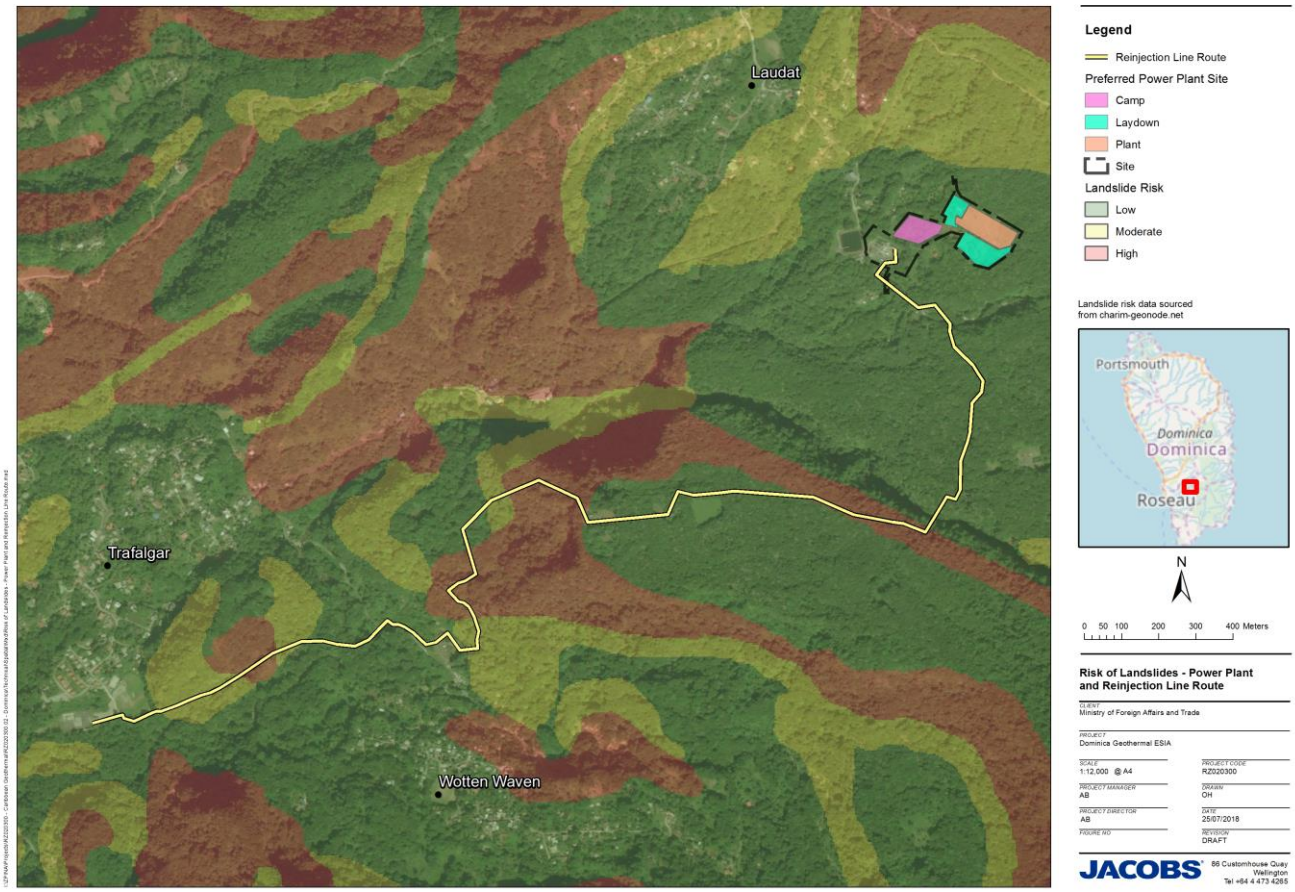


**Figure 3.22 : Risk of Landslides - Power Plant and Reinjection Pipeline Route. (Source: GoCD Website, 2017)**

### 3.9.3 Volcanic Eruptions

Pleistocene volcanoes cover much of Dominica: dated to approximately 400,000 to 500,000 years old, morphologically well preserved and of composite nature. Currently there are nine active volcanoes within Dominica, the closest being the Valley of Desolation located approximately 3 km south-west of the Project site, which experienced the last recorded eruption (phreatic eruption) in 1997. Current volcanic activity is visible in various forms including: sulphur outlets, hot springs, geysers, the Boiling Lake and the Valley of Desolation. Frequent volcanic earthquakes and geothermal activity indicate that the island is still underlain by an active magma reservoir system and that future eruptions are highly likely, possibly within the next 100 years.

Towards the middle of the MTPNP, around Wotten Waven, is an ignimbrite flow cutting the park almost in half (Caribbean Community Climate Change Centre, 2011a). This ignimbrite flow occurred about 30,000 years ago originating from the locus of Morne Trois Pitons producing 60 $km^3$ of material which filled the middle and lower Layou Valley and some tributaries, the Roseau valley and some eastern valleys with partly welded ignimbrite, columned ash and pumice flow (Caribbean Community Climate Change Centre, 2011a). This can be traced southward off the west coast for some 250 km.

Morne Trois Piton itself (three peaks mountain) summit is now occupied by three domes and is an active volcano (Dominica Pubic Seismic Network Website, 2017)). There are ongoing signs of volcanic activity within the MTPNP in the Valley of Desolation and on its fringes at Wotton Waven in the form of a Soufriere activity. Signs of these were reinforced in the 1960 and 1990 when the Grand Soufriere Hills and the south-western fringes of the MTPNP produced sufficiently seismic activities to cause concern that eruptions were imminent (Caribbean Community Climate Change Centre, 2011a).

There is no certainty of imminent volcanic eruptions in the vicinity of the power plant or reinjection lines. However, Titou Gorge, the Boiling Lake and the Valley of Desolation remain classified as being at high risk of volcanic eruption (Caribbean Community Climate Change Centre, 2011a). There are no known lahar slopes adjacent to the power plant or reinjection line sites.

### 3.9.4 Induced Seismicity and Subsidence

The risk of earthquake is classified as moderate to very low in the Roseau Valley (GoCD Website, 2017), as shown in Figure 3.23 below. The proposed power plant site is located partially within a moderate and very low earthquake risk area. The majority of the reinjection pipeline is located within a very low risk seismic area with only the lower section within a moderate risk area. The nearest area classified as having a high risk of earthquakes is located to the south west, 1.5 km from the end of the reinjection pipeline.

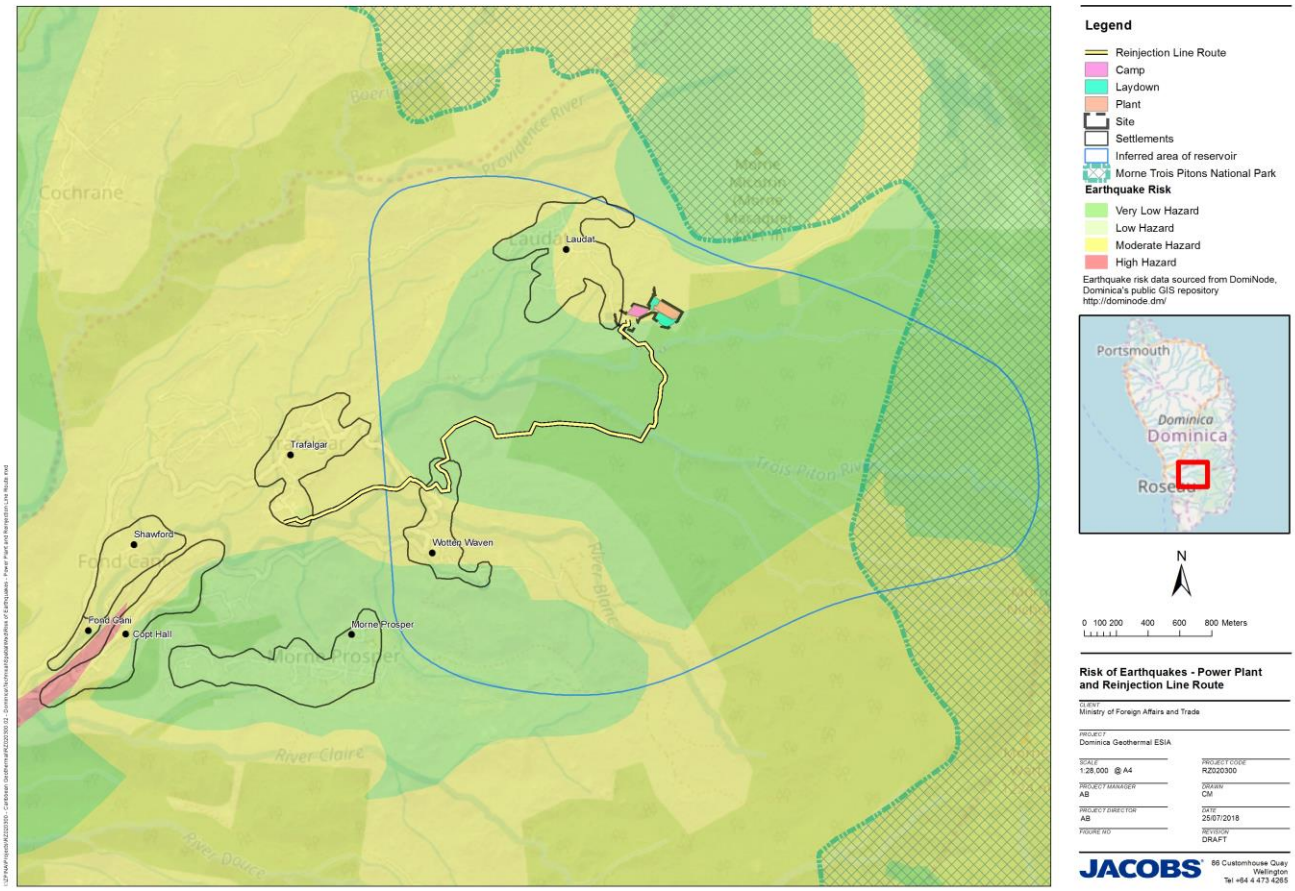


**Figure 3.23 : Risk of Earthquakes - Power Plant and Reinjection Pipeline Route. (Source: GoCD Website, 2017)**

### 3.9.5 Flooding

Floods, particular flash floods, can occur in many streams in the Roseau Valley and are usually a result of rapid run-off after intense storms when the land is saturated: a similar condition to those which favour landslides. Refer to Section 3.5 - Hydrology for further details.

## 3.10 Noise

### 3.10.1 Noise Monitoring Results

When measuring noise levels, the use of statistical descriptors is necessary to understand and describe how variations in the noise environment occur over any given period. A list of common descriptors used in this noise assessment as well as their meaning is given below.

- $L_{Amax}$ maximum noise level measured at a given location over the 15 minute interval.
- $L_{A10}$ – the noise level exceeded for 10% of the 15 minute interval, this is commonly referred to as the average-maximum level.
- $L_{Aeq}$ – the noise level having the same energy as the time varying noise level over the 15 minute interval.
- $L_{A90}$ – the noise level exceeded for 90 percent of the 15 minute interval. This is commonly referred to as the background noise level and represents the quietest 90 seconds in a 15 minute period.

The nearest and most representative affected properties in the surrounding villages have been considered in this assessment. These villages include: Laudat, Trafalgar, Copt Hall, Shawford , Fond Cani, Morne Prosper and Wotten Waven. Additionally, the following natural locations have been considered as potential noise receptors: Boiling Lake, the Valley of Desolation and Freshwater Lake (2.5 km north east of Laudat).

The existing ambient noise environment in areas surrounding the proposed Project site was measured during the peak tourist season of December 2013 and repeated during the off season in April 2014 (Caraïbes Environnement Développement & Coll (2015a/b). Noise monitoring was undertaken at representative locations in five villages surrounding the site (Figure 3.24).




**Figure 3.24 : Noise Monitoring Locations (Caraïbes Environnement Développement & Coll (2015a/b))**

The five residential zones were studied with 54 acoustic measurement points analysed over a 24 hour period. The results of the attend noise measurements have been summarised in Table 3.7 for each of the monitoring locations and detailed results are presented in ESIA Volume 5: Technical Appendices, Technical Report – Noise Impact Assessment.

**Table 3.7 : Attended noise monitoring results**

| Location | Monitored noise level $L_{Aeq}$(period) dB(A) | | | |
|---|---|---|---|---|
| | Peak tourist season December 2013 | | Off tourist season April 2014 | |
| | Daytime (7am to 9pm) | Night time (9pm to 7am) | Daytime (7am to 9pm) | Night time (9pm to 7am) |
| Laudat | | | | |
| Average $L_{Aeq}$ | 44.3 | 47.1 | 44.4 | 46.7 |
| Maximum $L_{Aeq}$ | 53.0 | 53.5 | 51.0 | 52.0 |
| Minimum $L_{Aeq}$ | 35.5 | 40.0 | 38.0 | 42.0 |
| Fond Cani North | | | | |
| Average $L_{Aeq}$ | 44.0 | 48.0 | 39.9 | 44.1 |
| Maximum $L_{Aeq}$ | 49.0 | 49.0 | 43.5 | 49.0 |
| Minimum $L_{Aeq}$ | 38.0 | 46.5 | 36.0 | 37.5 |
| Fond Cani West and South | | | | |
| Average $L_{Aeq}$ | 53.2 | 53.3 | 52.6 | 50.4 |
| Maximum $L_{Aeq}$ | 59.5 | 60.0 | 57.5 | 57.5 |
| Minimum $L_{Aeq}$ | 43.0 | 46.5 | 42.0 | 41.0 |
| Morne Prosper | | | | |
| Average $L_{Aeq}$ | 45.6 | 48.4 | 41.3 | 43.6 |
| Maximum $L_{Aeq}$ | 49.5 | 52.0 | 46.0 | 47.0 |
| Minimum $L_{Aeq}$ | 38.0 | 43.5 | 36.0 | 35.0 |
| Wotten Waven | | | | |
| Average $L_{Aeq}$ | 46.0 | 52.8 | 47.1 | 49.6 |
| Maximum $L_{Aeq}$ | 49.0 | 57.5 | 49.5 | 51.0 |
| Minimum $L_{Aeq}$ | 39.5 | 45.0 | 41.0 | 48.0 |
| Trafalgar | | | | |
| Average $L_{Aeq}$ | 52.0 | 54.4 | 47.1 | 47.3 |
| Maximum $L_{Aeq}$ | 60.0 | 62.5 | 50.5 | 50.5 |
| Minimum $L_{Aeq}$ | 43.5 | 46.5 | 44.0 | 43.5 |

The main sources of noise in the area surrounding the Project are local fauna, residential noise, low traffic on local roads, wind and water courses. Ambient noise levels are generally louder during night time hours due to local fauna such as insects and nocturnal wildlife. In the vicinity of local traffic generating developments, such as schools, hotels and tourist attractions, noise levels were somewhat higher.

## 3.11 Geology, Soils and Groundwater

### 3.11.1 Geology

The island of Dominica is the summit of a submerged mountain chain at the eastern edge of the Caribbean Tectonic Plate. It is the youngest of the islands of the Lesser Antilles volcanic arc, which was formed from the subduction of the North American tectonic plate under the Caribbean tectonic plate. It is almost entirely

comprised of volcanic rocks which have been formed over many millions of years during numerous eruption events. These events have mainly taken the form of phreatic or phreatomagmatic explosive eruptions, usually leaving behind lakes or craters. The oldest formations exposed on Dominica are massive basaltic lava flows and breccias of Miocene age, found between Rosalie and Pagua with numerous Pliocene age dykes cutting through.

Various types of rocks can be found across the island, including:

- Basaltic lavas;
- Andesitic tuff and ash;
- Dacitic and andesitic lavas; and
- Limestones and conglomerates (on the west coast).

Overall, the topography of the island is marked with steep slopes and deep valleys, such as the Roseau valley. The lithology of the project area is described below and shown in Figure 3.25.

- The proposed power plant site sits on Micotrin block and ash flow deposits. These deposits are located at the foot of Morne Micotrin and contain lava blocks, as well as ash deposits.

The reinjection pipelines pass through a number of geological formations. These include:

- Roseau Ignimbrite – these rocks comprise of welded ash (volcanic tuff) and pumice deposits and were formed approximately 40,000 years ago. They are very brittle and contain very fine rock particles projected by a volcanic eruption.
- Massive Lavas – these lavas are the basement rock of the area. They were formed by lava flows that were solidified quickly, which resulted in a black, dense and massive rock.
- Du Mas Estate: debris flow deposits – these deposits are the result of a collapsed crater, with high clay content. Hot springs are found to discharge from these deposits in areas where they are exposed.

Other geological formations within the Roseau Valley which are close to or directly adjacent to the project area include:

- Trois Pitons: reworked pyroclastic deposits – this formation was formed between 7,000 and 17,000 years ago and comprises various rock types accumulated from eruptions on the Trois Pitons Volcano. These rocks include welded ash, tuffs and lava blocks.
- Watt Volcano: massive lavas and pyroclastic deposits – these deposits comprise of various rock types including basalts, volcanic bombs, rhyolites and volcanic ash. These deposits are present in the area of the Boiling Lake and in the Valley of Desolation.
- Dacitic Lava Domes – Morne Micotrin is an example of a dacitic lave dome formed 26,000 to 29,000 years ago.
- Roseau River alluvium – these deposits are fan deposits from the Roseau River, with the width and thickness of deposits becoming larger down the valley.

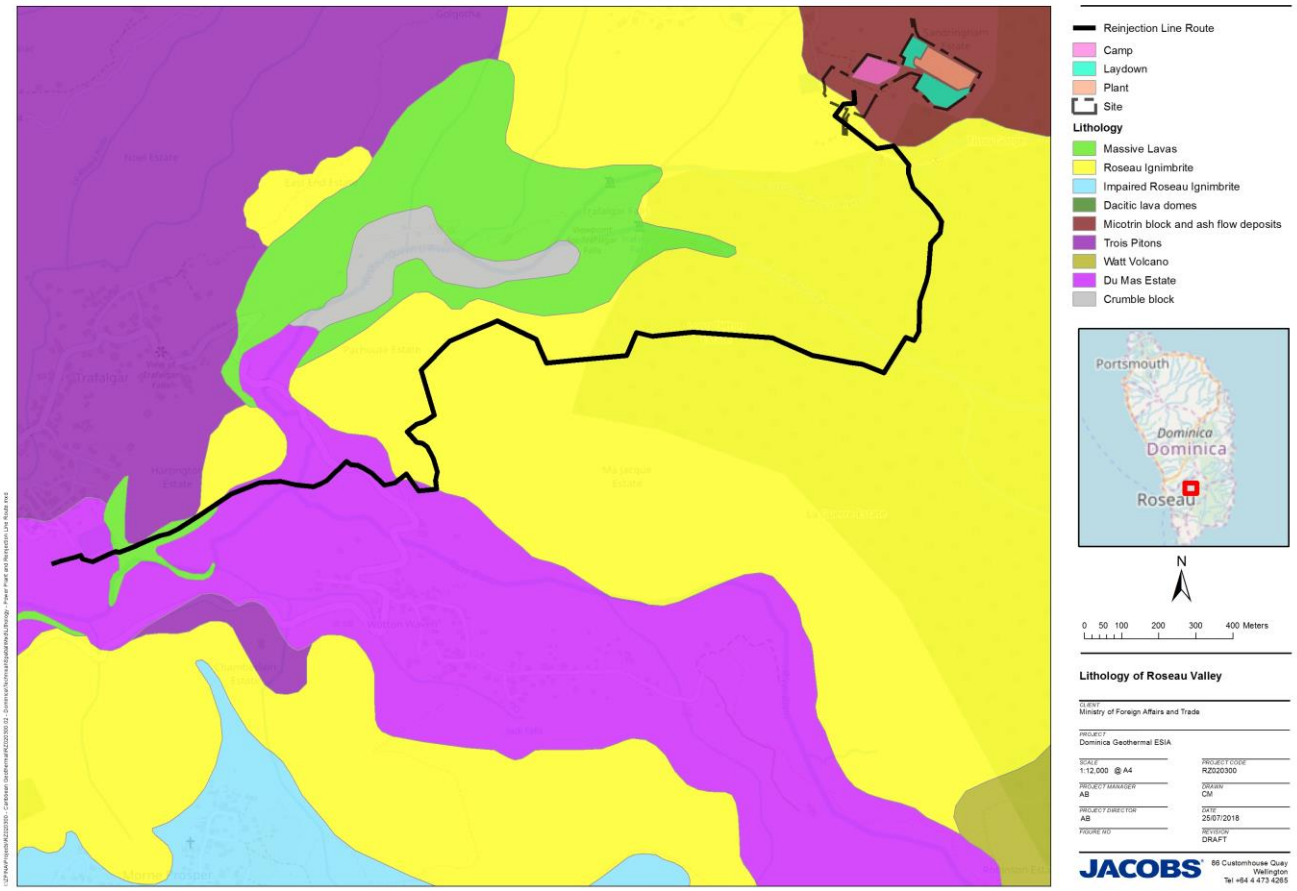


**Figure 3.25 : Geology map of Roseau Valley (Source: Caraibes Environment Development, 2015a/b).**

### 3.11.2 Soils

Around Morne Micotrin, allophanoids podzolic type soils are found; these are related to wet climates and these areas receive a large volume of rain (Caribbean Community Climate Change Centre, 2011a). There are two main areas of differing soil types which are related to geological differences. The larger of the two areas is covered by soils derived from fairly recent material. This is the area of the domes and ash showers from the Morne Trois Pitons/ Morne Macaque episodes. The following soil types are found in this area:

- Allophane podsolic soils;
- Allophane latosolic soils;
- Protosols;
- Soils of the Soufriere affected areas; and
- Poorly drained soils.

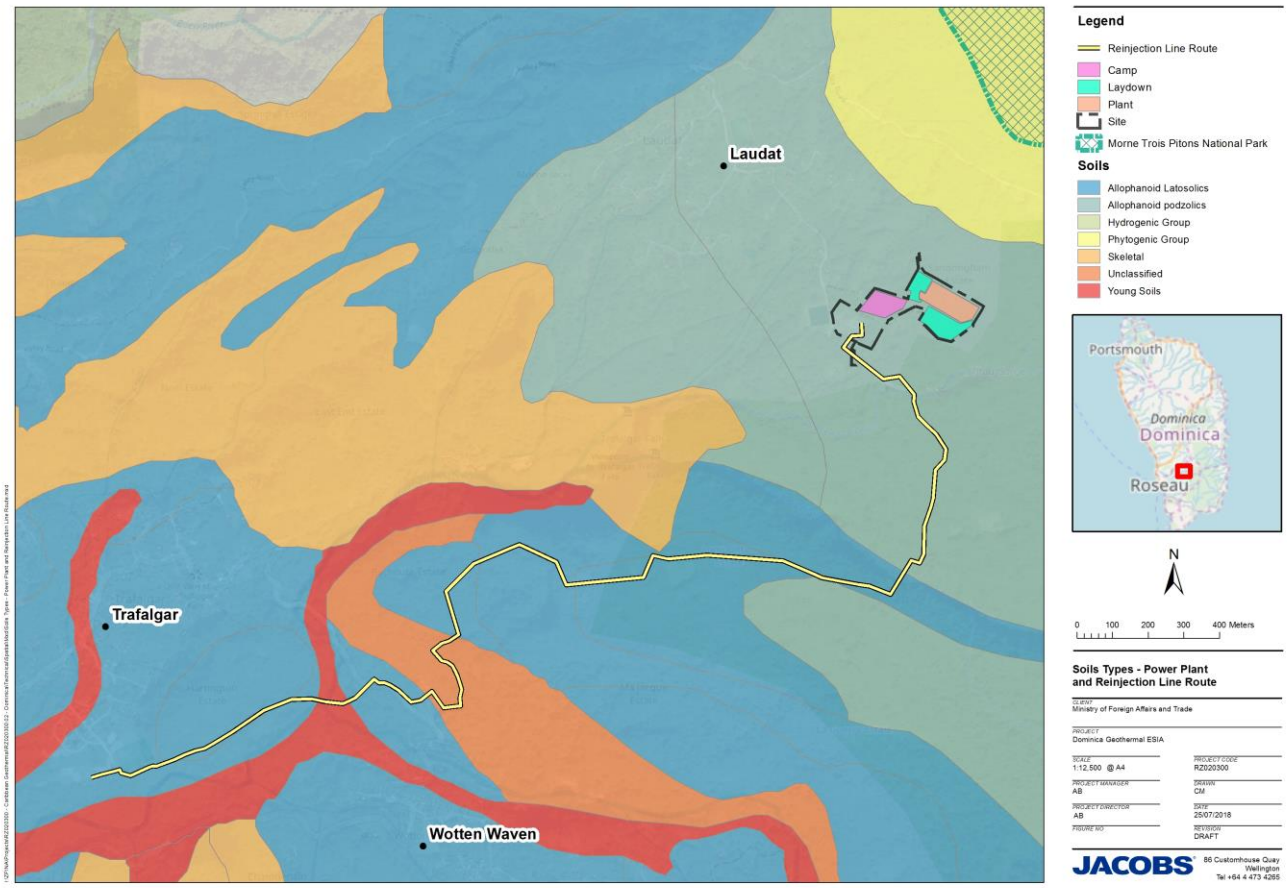


**Figure 3.26 : Soil types of the Roseau Valley. (Source: GoCD Website, 2017).**

### 3.11.3 Groundwater

No specific details on the hydrogeology in the Roseau Valley was found during a literature search of available information.

In general, however, groundwater flow and composition in the area will be influenced by the climate, topography, geomorphology and geology of the island. Regionally, it would be expected that groundwater would flow from the inner parts of the island, where groundwater levels would be the highest, towards the low lying coast, discharging to the sea, while locally groundwater would be expected to flow towards the valleys following the topography of the surface water catchments. Groundwater would be discharged locally through springs or as baseflow to the streams/rivers. The groundwater could be located either within perched aquifers within the pyroclastic deposits (as a result of areas of low permeability materials within the deposits) or through secondary permeability features such as fractured or well jointed lava flows. Reference to hot springs (geothermally influenced) springs has been made within the Du Mas Estate debris flow deposits.

High annual rainfall on Dominica will provide regular groundwater recharge and sustained baseflow in the lower reaches of the rivers. However, knowledge of the groundwater-surface water interactions in the mountains is limited, and the proportion of rainfall which recharges aquifers that discharge into streams is unknown.

There is no information provided to indicate that the groundwater in the vicinity of the proposed development has the potential to be a viable water supply source, particularly as the local villages use surface water sources for their water supply. Surface water was also used as the water supply source to drill all of the exploratory

boreholes drilled to date. Finally, as outlined in ESIA Volume 5: Technical Appendices (Process Description), all water requirements for the future development will be sourced from surface water sources.

## 3.12 Terrestrial Ecology

### 3.12.1 Introduction

The baseline for terrestrial ecology has been summarised in this section. For further details, reference should be made to ESIA Volume 5: Technical Appendices (Terrestrial Ecology Impact Assessment Technical Report; and Morne Trois Pitons National Park World Heritage Site Impact Assessment).

### 3.12.2 Data Collection Prior to 2017

An initial flora and fauna analysis was carried out in 2008 to gain a preliminary understanding of the biodiversity of the Roseau Valley. Three areas were selected in 2011 for detailed flora and fauna assessment, and a fourth was added in 2015. At each of these four areas the dominant habitat and flora and fauna species was described and matched to vegetation type descriptions.

### 3.12.3 Data Collection in 2017

**Survey Methods**

A more targeted approach was required for the ESIA, focussed on habitats in the area of potential impact, i.e. along the preferred re-injection line route and other sites selected for the plant infrastructure.

A preliminary land-use/habitat classification of the study area was prepared in GIS by interpreting satellite imagery and aerial photography. This information was used to stratify the vegetation to ensure that the full range of habitats was systematically sampled. Field ecologists were then able to ground-truth vegetation types using a rapid assessment approach.

Surveys for birds, herpetofauna and mammals was also undertaken. Survey methodologies were replicable and scientifically robust, and used primarily visual and aural methods. Limited nocturnal survey for animal species was also undertaken at accessible locations.

### 3.12.4 Survey Locations

A combination of transects and plot-based surveys was used. The route of the proposed reinjection line was the basis for establishing a transect spanning thre following locations: Trafalgar, Trois Bitons, Wotten Waven and Laudat:

- Trafalgar – 7 quadrats and Wotten Waven – 1 quadrat;
- Trois Bitons – 15 quadrats; and
- Laudat – 6 quadrats.

In addition, in order to enable the evaluation of potential impacts of the proposed infrastructure the biodiversity of the Wotten Waven reinjection site and the proposed power plant construction site in Laudat were surveyed separately. Data collection locations are shown on Figure 3.27.

Particular attention was paid to dominant, rare, endemic, threatened, protected, invasive species, and to those species that are of importance to local communities.

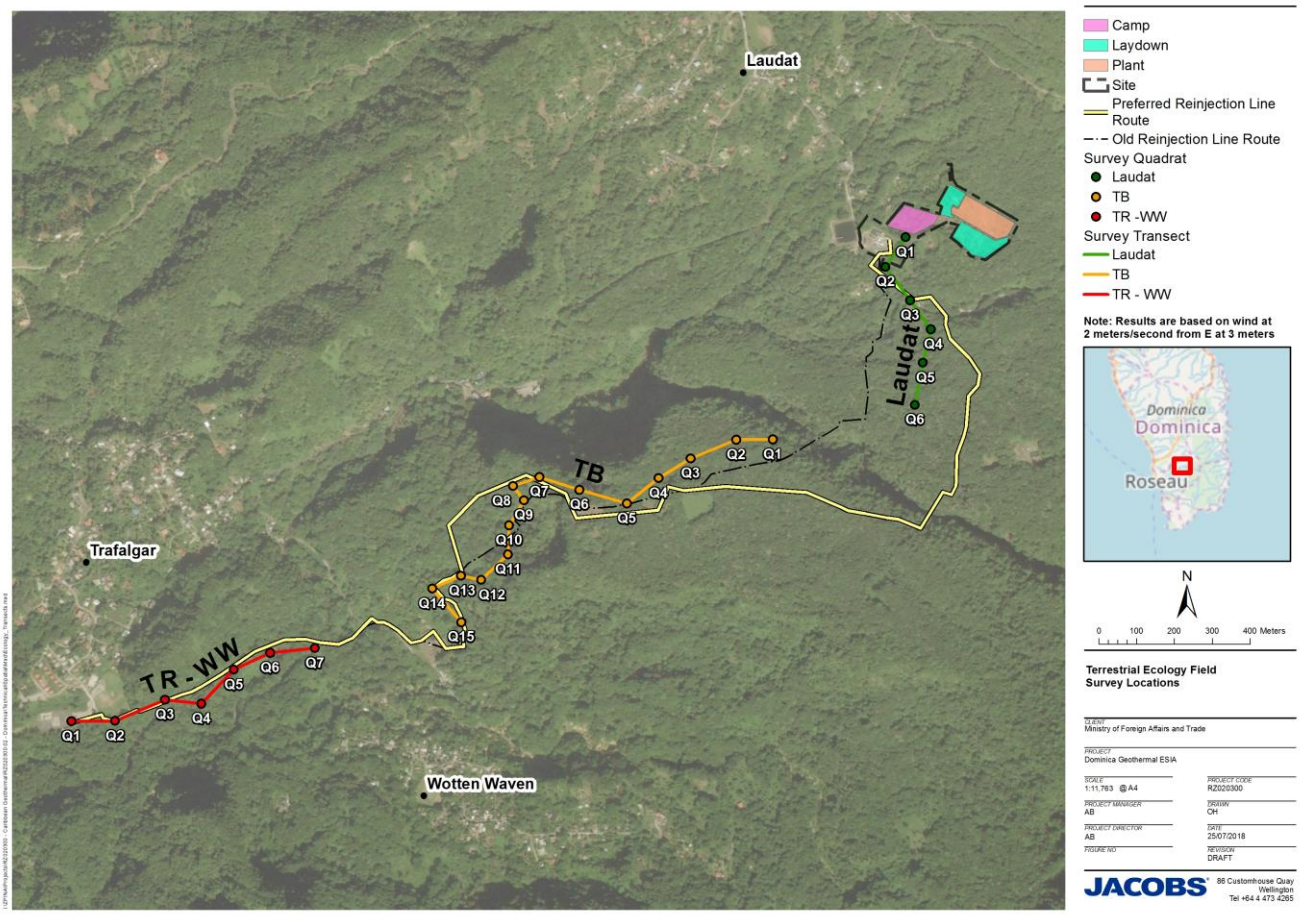


**Figure 3.27 : Field survey locations**

### 3.12.5 Limitations and Assumptions

- Biodiversity data for the Roseau Valley collected in 2008 was not available for review, and thus the more recent data from 2017 has been used in this assessment.
- Some parts of the survey transects were not surveyed due to accessibility and health and safety concerns. Where possible these locations were surveyed from a distance and descriptions provided.
- Where conflicting information within the raw data was provided, professional judgement has been used to make an appropriate and precautionary assessment.

### 3.12.6 Protected Areas

The protected area of principal relevance to the project is Morne Trois Pitons National Park, a World Heritage Site which lies approximately 600 m north-west, and upstream, of the proposed Project infrastructure. Impacts on the ecology of the site have been considered separately and are not discussed further here, other than in the context of the wider diversity of the area.

The MTPNP, along with three other sites on the island, is also designated by BirdLife International as an Important Bird Area (IBA). Two small coastal/island IBAs are located on the south and south-east coasts, and the Morne Diablotin National Park in the north of the island, is the other. The designation also renders all four sites Key Biodiversity Areas (KBA). In addition, an Endemic Bird Area (EBA) extends across the whole of the Lesser Antilles, and supports seven endemic bird genera. Dominica has two endemic bird species of its own, and also supports 18 restricted-range bird species.

Nationally, Dominica recognises 10 protected areas, covering 22% of the terrestrial habitat, and 0.01% of the marine area. No other established or proposed protected areas have been identified.

### 3.12.7 Habitats

The major vegetation type in all areas surveyed is secondary rain forest at varying stages of succession. Some agricultural habitats were also present, both those currently under cultivation and those apparently abandoned.

No rare or threatened plant species were identified in any of the transects or plot-based surveys.

**Trafalgar - Transect**

This transect runs along the southern side of the Trafalgar playing field in a south-easterly direction, through privately-owned land with active and abandoned agriculture. The line ends at the Trafalgar River gorge.

The Trafalgar area is typically secondary rainforest as a result of disturbance, primarily from housing and agricultural development and the impact of Hurricane David. In some areas, vestiges of old stands remain, surrounded by smaller re-growth.

Quadrat 1 (Q1) is adjacent to an access road which leads to the geothermal reinjection line. It supports savannah-like species, with some secondary rainforest vegetation, including some areas which have been cleared. Invasive *Mimosa* spp. were noted to be dominant here. Q2 features a steep slope down to the Roseau River, rendering it inaccessible but it was visually assessed to have a dense secondary forest emerging, with full canopy cover. Q3 is similarly partly inaccessible, being located in an elevated forested area, with evidence of landslides historically. Q4 to Q6 feature flatter terrain and with a greater proportion of active agriculture. Q7 is located towards the edge of a cliff overlooking the river, and has no evidence of active agriculture.

**Trois Bitons - Transect**

This is an estate on an elevated plateau north of the village of Wotten Waven. The site is flanked by a steep escarpment on its southern and western sides, and with the deep gorge of the Trois Pitons River on the north and north-eastern sides. This natural barrier limits access into the area.

The predominant vegetation type is secondary rainforest, with some areas which have been subjected to logging and agriculture. The second half of the route was not safely accessible, and so visual observations were made from the trail that traverses the area. Much of this part of the route was apparently abandoned agricultural land. Q14 and Q15 showed more signs of human activity, in the form of small farming activities, tourism and street vendors, and the main road from Trafalgar to Wotten Waven.

**Laudat - Transect**

The transect was located southeast of the village of Laudat and comprised largely secondary rainforest. The primary forest has been extensively impacted by road construction, establishment of electricity infrastructure, shifting agriculture, tourism development and the impact of extreme weather events, especially Hurricane David in 1979. The DOMLEC pipeline passes near to Q2/Q3.

Some remnants of rainforest were identified, surrounded by natural regeneration, however generally there are few typical rainforest trees present.

**Laudat - Infrastructure Location**

A plot-based survey was undertaken at the proposed location for the power plant site and laydown area. This area includes an abandoned dwelling, and agricultural land with low-growing ground cover and some trees. The primary remaining crop was citrus fruits.

**Wotten Waven – Infrastructure Location**

This site is adjacent to the Wotten Waven to Trafalgar main road, approximately 140 m from the Wotten Waven Sulphur Springs tourist site. The site was originally selected for exploratory drilling and is one of the proposed reinjection wells.

The area is characterized by a high water table, and there is a wetland/marsh area, with patches of fumarolic vegetation and hot water pools. To the southwest and the north lies secondary rainforest and agricultural land, where crops such as banana, coconut, mango and breadfruit are cultivated.

### 3.12.8 Birds

97% of Dominica's 205 resident and visiting bird species are categorised as Least Concern by IUCN, whilst 2% are Near Threatened, and 3% (equating to 6 species) are Globally Threatened, which comprises the categories: Vulnerable (3); Endangered (2); and Critically Endangered (1). None of these species were recorded during field surveys.

Along the Trafalgar transect, 325 individual birds of 26 species were identified during the survey, all of Least Concern. In addition, the barn owl (*Tyto alba nigrescens*) was recorded during a night-time survey. A further three species are thought to frequent the area, one of which is the Vulnerable red-necked parrot (*Amazona arausiaca*), reported to be a frequent visitor earlier in the year, foraging on citrus tree fruits.

At the Wooten Waven proposed infrastructure site, 14 species were recorded and a further 12 were not encountered but have been verified as present by residents and a local guide. At the Laudat proposed infrastructure site, 17 species were recorded and a further 9 are considered to be present.

At all three locations, the same five species endemic to the Lesser Antilles, five endemic to the Caribbean, and two native to a small number of Lesser Antillean islands were present. These Dominican endemics/near endemics are the blue-headed hummingbird (*Cyanophaia bicolor*) and plumbeous warbler (*Dendroica plumbea*). Both have small ranges and declining population, but are within the limits of the category Least Concern. All remaining species are considered common or abundant resident breeders and are also of Least Concern. Across all sites a total of 31 species were identified or verified to be present generally in the area.

### 3.12.9 Mammals

Mammalian diversity was very low at all surveyed locations. Along the Trafalgar transect and at the Wooten Waven and Laudat proposed infrastructure sites, unidentified insectivorous and frugivorous bat species was recorded. At all locations, field signs of agouti (*Dasyprocta antillensis*) were noted, and common opossum (*Didelphys marsupialis*) and rats (*Rattus rattus*) are reported.

### 3.12.10 Herpetofauna

Along the Trafalgar transect and at the Wooten Waven and Laudat infrastructure locations, one amphibian was recorded, the Near Threatened tink frog *Eleutherodactylus martinicensis*. This was in greatest abundance at Trafalgar, with 140 individuals recorded, and only two at Wooten Waven.

The Puerto Rican crested anole (*Anolis cristatellus*) is an introduced species identified at Trafalgar and the Wooten Waven and Laudat infrastructure sites. It is considered invasive due to its competition with the native anole (*Anolis oculatus*). The latter is thought to be present at Laudat, but was not recorded, and despite the impact of the non-native species, the native species is considered of Least Concern. Another endemic, Dominican ground lizard (*Ameiva fuscata*) was recorded at Trafalgar and has not been assessed for its conservation status.

The Dominican boa (*Boa constrictor nebulosi*), black-and-white checkered snake (*Liophis juliae juliae*), house gecko (*Hemidactylus mabouia)*, dwarf gecko (*Sphaerodactylus vincentii*), and golden skink (*Mabouya mabouya*)

were not observed during surveys but are considered present in the Trafalgar area. Previous survey data indicated their presence at Laudat also.

### 3.12.11 Evaluation

No species which are Threatened or Rare have been recorded in the study area. One such species which is verifiably understood to be present, is the Red-necked parrot, which is determined to be Vulnerable.

A Critical Habitat Screening Assessment (CHSA) has been undertaken based on the presence of this species, including an analysis of Modified, Natural and Critical Habitats within the Project area. The CHSA conclusion is that there are no Critical Habitats in the area directly impacted by the Project. For more details on the CHSA please refer to ESIA Volume 5: Technical Appendices – Appendix H Terrestrial Ecology Impact Assessment. In addition to the red-necked parrot, the following endemic or near-endemic species are of unknown or less than Threatened conservation status, but are considered to be of relevance to the assessment:

- Tink frog, Near Threatened;
- Dominican ground lizard, Not Assessed;
- Dominica anole; Least Concern;
- Blue-headed hummingbird, Least Concern; and
- Plumbeous warbler, Least Concern.

## 3.13 MTPNP World Heritage Site

### 3.13.1 Introduction

The MTPNP World Heritage site was first proposed as a forest reserve in 1952. In 1975 it was designated a National Park under the National Parks and Protected Areas Act No.16. It was inscribed as a WHS in 1997 and falls within IUCN Management Category II: National Park.

The MTPNP covers nearly 7,000 hectares of the volcanic island, comprising a rugged mountain landscape and deep canyons. There are five live volcanic centres within the park, the highest of which reaches 1,342 metres. The landscape is scenically striking and features natural hot springs, bubbling mud ponds, lakes and magnificent waterfalls. Within the park are the sources of the major watercourses of the southern part of the island.

Amongst the park's most notable features are the Boiling Lake, a flooded fumarole which is consistently around 95°C, surrounded by impressive cliffs. The sounds, colours, heavy vapours and strong sulphurous smell make this a highly unusual sight. It is the largest feature of its type in the world and is a particular draw for tourists.

Fuelled by abundant seasonal rainfall (c.7 metres annually), lush vegetation covers much of the landscape of the MTPNP – an exception being the comparatively barren 'Valley of Desolation'. The extreme topography and varied mosaic of vegetation and habitats makes for a highly diverse ecological system supporting a wide variety of species.

The area of the inscribed site is 6,857 hectares. A number of changes to the boundaries have taken place since, and formal publication of the current boundary and buffer zone is understood to be expected in the near future.

For further information, reference should be made to ESIA Volume 5: Technical Appendices, Technical Report – MTPNP Impact Assessment.

### 3.13.2 Designation

**Values**

In respect of the "Values" component of OUV, the site was inscribed under natural criteria (viii) and (x).

Criterion (viii): earth processes[3]. The application to this site is summarised as follows:

- The array and intact nature of geomorphologic features;
- The distinctive geology and landforms comprised of three major types of geological formations;
- The spectrum of volcanic activity in the form of streams of various colours, fumaroles, mud ponds and hot springs; and
- The ongoing geomorphological processes of reduction taking place in a largely undisturbed setting, which are of great scenic value and major scientific interest.

Criterion (x): threatened species and their habitats[4]. The application to this site is summarised as follows:

- The site is a very rare example of a largely intact forest areas remaining in the Insular Caribbean;
- Its high levels of endemism (birds, plants and herpetofauna), within a region recognised as a centre of endemism of global importance and with highly threatened biodiversity; and
- The variety of forest types, and associated diverse flora.

**Integrity**

Integrity is a measure of 'wholeness' and requires assessment of the extent to which the site:

1) includes all elements necessary to express its OUV;
2) is of adequate size to ensure the complete representation of features and processes which convey its significance; and
3) suffers from negative effects of developments and/or neglect.

UNESCO (2017a) details the site's compliance with these criteria. It notes that the MTPNP supports a *"microcosm of Dominica's biological diversity and species endemism, and provides intact and protected habitat for a wide diversity of flora and fauna, including a range of endemic species across several taxonomic groups".*

**Protection and Management**

Responsibility for protection and management of the MTPNP falls under the remit of the Division of Forestry, Wildlife and National Parks, which is part of the Ministry of Agriculture and Fisheries. Day-to-day responsibility for the MTPNP lies with the National Parks Unit of the Division.

In March 2017, a joint World Heritage Centre (WHC) and IUCN 'reactive monitoring mission' to the MTPNP took place. The mission reported the site to be in a good state of conservation (UNESCO, 2017a/b). This is in part due to the natural protection afforded by the harsh terrain and the lack of road infrastructure through most of the site. Some agricultural encroachment has been noted in the south of the site. Neither report identified any immediate threat to the park's essential attributes and natural heritage values, provided legal requirements continue to be maintained and enforced. A summary of the mission findings and their implications for the Project is provided in ESIA Volume 5: Technical Appendices, MTPNP Impact Assessment.

[3] *"Outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features"*
[4] *"Contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation."*

### 3.13.3 Existing Site Conditions

Based on the scale of the proposed development, the activities required, and its distance from the MTPNP, a high-level baseline is provided, focussed on threatened and protected features.

**Flora / Habitats**

Five forest types can be distinguished within the MTPNP, including rare elfin or cloud forest at the highest elevations, followed at progressively lower elevations by montane forest, rainforest, seasonal forest, dry scrub woodland and littoral woodland. The microclimatic variations afforded by the terrain support a wealth of plant species, including endemic vascular plant species (recorded as 21 in 1997).

The site is the largest of the national parks in the Windward Islands and Leeward Islands, has the most varied volcanic features, and is the only one with major forest cover.

**Fauna**

The rich and varied fauna includes endemic reptiles and amphibians, and 80% of the island's bird species, including the Vulnerable[5] and endemic red-necked parrot (*Amazona arausiaca*). This species lives in forested areas in just a handful of areas on Dominica. In total 17% of the island's population distribution occurs within the MTPNP. Adjacent areas of critical importance are not protected and one of the major threats to the species is habitat loss, mainly caused by clearance for agriculture (UNESCO, 2017b).

Other species recorded in 1997 were 12 species of bat, 12 species of herpetofauna and 30 decapod crustaceans. The park also provides habitat for the Imperial parrot or Sisserou (*Amazona imperialis*), the island's national bird and of symbolic importance due to its inclusion on the national flag.

**Social Context**

28 villages lie within a mile of the MTPNP boundaries, although there are no settlements or major roads within the park itself. There is a small quarry in the northeast of the park, and very limited areas of other activities, but it is otherwise a largely undisturbed environment. Tourism activities are present but limited in extent due to the poor infrastructure. In 1997, 10,000 -15,000 visitors were thought to hike to the Emerald Pool, and 1,500-2,000 to the Boiling Lake; it is possible that these figures have increased in the intervening years. An 'aerial tram' was developed, which took visitors into the park itself, however operation ceased some years ago due to financial reasons. Water and power rights are granted to DOMLEC through the park and have not resulted in any major issues to date.

### 3.13.4 Evaluation

The impact assessment in Section 14 considers potential impacts of the development on the three elements of OUV of the WHS. The occurrence of a likely significant effect requires both an impact on a sensitive feature, and an effects pathway. As per the site's inscription, the sensitive features of the MTPNP can be categorised as shown in Table 3.8. The presence or absence of an effects pathway from the proposed development on each of the features is therefore also shown.

[5] IUCN Red List http://www.iucnredlist.org/details/22686395/0

**Table 3.8 : Elements of the OUV of MTPNP**

| Component of OUV | Category of feature (where applicable) and examples | Effects pathway possible |
|---|---|---|
| Values | Earth processes:<br>• array of geomorphologic features<br>• the distinctive geology and landforms<br>• the spectrum of volcanic activity including streams, fumaroles, mud ponds and hot springs<br>• the ongoing geomorphological processes | No |
| | Threatened species and their habitats | Yes |
| Integrity | • intact nature of geomorphologic features<br>• largely undisturbed setting<br>• natural attributes considered to be whole and intact<br>• site includes all elements necessary to express its outstanding universal value<br>• site is of adequate size to express its outstanding universal value | Yes |
| Protection and management | • adequate systems of protection and management in place to safeguard the future of the site | No |

As shown in Table 3.8, earth processes and geological/geomorphological features are unlikely to be affected by the proposed scheme as no effects pathways have been identified. The assessments of geology, soils and groundwater, and of geothermal resources within this ESIA Volume 2: EIA concluded no significant impacts on geothermal features inside the park. It should be noted that natural variation is observed in the characteristics of some features of the MTPNP. The Boiling Lake, for example, has been known to vary in water level, and even to disappear periodically; this last occurred in early 2017 and before that, about 12 years ago.

Similarly, to the geomorphology of the MTPNP site, no changes to the protection and management of the site are part of the proposals, and there is considered to be no pathway for impacts on this element of the OUV. Thus no adverse impacts are anticipated on the above, and these features are therefore not discussed further.

### 3.13.5 UNESCO Visit

The objectives and corresponding findings of the 2017 WHC/IUCN mission to the MTPNP are summarised below. The resulting recommendations of the report will sit alongside the mitigation detailed by this assessment.

i. Consider the impacts of existing and potential future geothermal infrastructure in the Roseau Valley.

It was reiterated to the mission team that no development of geothermal infrastructure would ever be allowed within the MTPNP and proposed buffer zone. No actual or potential threats to the site were identified in relation to the four existing but non-operational wells, however two (at Laudat village and Trafalgar) were considered to require specific and enhanced monitoring to safeguard this.

ii. Assess progress towards the development of this ESIA.

Draft Terms of Reference for this ESIA were submitted to the World Heritage Centre for review by IUCN shortly after the mission. These incorporated the need to integrate in the study a specific assessment of potential impacts on the site's OUV.

iii. Identify any other potential threats to the OUV of the site.

Climate change was identified as a primary potential threat in the future, as well as hydropower development and tourism pressure.

iv. Assess current arrangements in respect of integrity, and of protection and management.

Resources were described as “stretched yet effective”, and the legislation was reported to define clearly the site as a no-take area with strictly regulated access. An enhanced management plan in respect of all the protected areas on the island and supported by the United Nations Development Programme (UNDP) is in development. Ongoing studies in relation to a buffer zone and zoning strategy, funded by the World Bank were also reported to be in progress.

## 3.14 Traffic

A site visit was undertaken by Jacobs from the 5 to 15 of December 2016. The following section details observations related to traffic in the area and outcomes of the traffic surveys carried out on the 11, 12 and 13 of December 2016.

### 3.14.1 Road Network

The area observed is characterised by a variety of terrain types ranging from flat areas to steep and mountainous areas with rock formations of which the topography makes driving conditions dangerous. The local road network is shown in Figure 3.27.

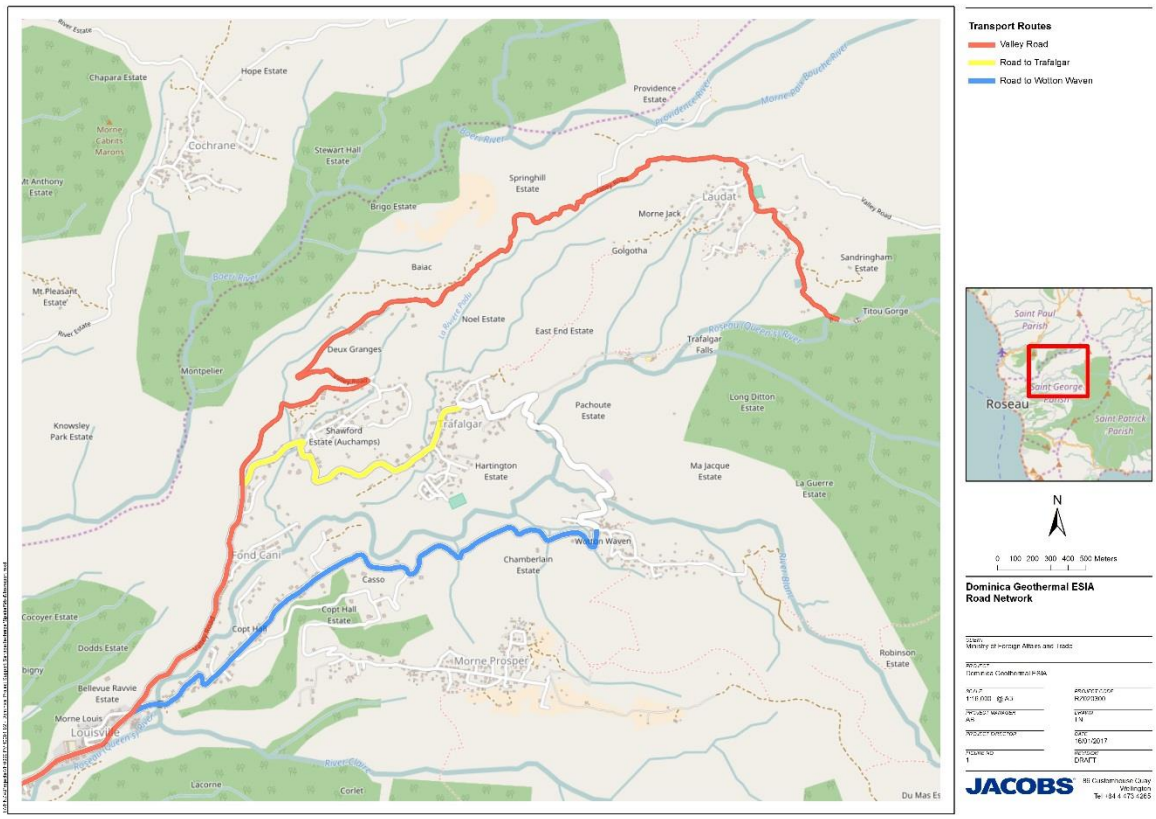


**Figure 3.28 : Existing Road Network**

The main road in the Roseau Valley area is Valley Road, which provides a link for traffic between Roseau City and Roseau Valley. Valley Road is a two-lane road of approximately 5 m width. The narrow sections of Valley Road pass through mountainous terrain, making them likely to be unsuitable for heavy vehicles. Figure 3.28 shows a section of a part of Valley Road, north of the intersection with the local road to Trafalgar.



**Figure 3.29 : Road signage on Valley Road (left) and image showing a section of the road which is collapsed (right) (Source: Jacobs, 2016).**

During the site visit it was observed that some sections of Valley Road have collapsed and are currently cordoned off with drums filled with soil; see Figure 3.28 as an example. The damage on this section of road has reduced the carriageway width to one lane for both northbound and southbound traffic. There is currently signage indicating to motorists that there is 'Broken Pavement Ahead'.

During the site visit it was also observed that road widening has been carried out at certain turning points on Valley Road to accommodate the volumes of two-way traffic and trucks carrying the drill rigs for the exploratory drilling, which has now been completed. Figure 3.29 shows a section of widened road.

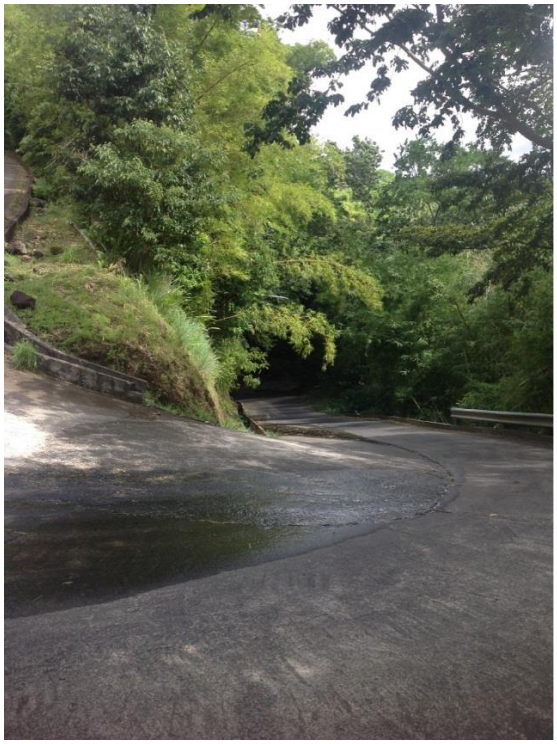

**Figure 3.30 : Section of road that has been widened (Source: Jacobs, 2016).**

As Valley Road traverses out of Roseau City and up the Roseau Valley, it gets narrower and more winding. The terrain near Roseau City is flat and the carriageway width is generally consistent. This section has road

markings, but does not have sealed shoulders. As it approaches north of the intersection with the local road to Wotton Waven, it starts rising with steep and sharp corners with winding geometric curves.

Valley Road intersects with the local road to Wotton Waven, approximately 1.5 km north of Roseau City. The posted speed limit on Valley Road in the vicinity of the intersection is 30 mph. The intersection is a priority controlled intersection where drivers on Valley Road have priority over those on the local road. Figure 3.30 shows the layout of the intersection.



**Figure 3.31 : Valley Road junction with the local road to Wotton Waven (looking north and south) (Source: Jacobs, 2016)**

The existing profile of the intersection is summarised as follows:

- Two way traffic flow with a single lane in each direction;
- No shoulders on either side of the carriageway;
- Open storm water channels on each side of the road leading to Wotton Waven allow for road runoff;
- No footpath and/or cycle facilities are provided along the road corridors;
- No pedestrian crossing facilities provided in the vicinity of the intersection;
- A raised kerb installed on the western side of Valley Road; and
- Sight distance for drivers approaching from the local road is constrained by the sharp angle of intersection and overgrown vegetation on Valley Road.

Valley Road intersects with the local road to Trafalgar approximately 3 km north of Roseau City. The intersection is a “Y” shape with a marked stop line for drivers approaching from the local road. A high concrete wall is installed on the western side of Valley Road which extends right into the bend along the road. The intersection is a stop controlled intersection with the priority road being Valley Road. Figure 3.31 shows the existing layout of the intersection.




**Figure 3.32 : Valley Road junction with local road to Trafalgar (facing north and south) (Source: Jacobs, 2016)**

The existing profile of the intersection is summarised as follows:

- No road markings to define lanes or direction of traffic movement, however, the road allows two-way traffic flow;
- No footpath and/or cycle facilities are provided;
- No pedestrian crossing facilities provided in the vicinity of the intersection;
- Raised kerbs installed on both sides of Valley Road; and
- Sight distance for drivers approaching from Valley Road is constrained by the steep slope and overgrown vegetation on Valley Road.

### 3.14.2 Local Site Access

The Laudat platform (containing WW-P1 and WW-03) is located close to the DOMLEC hydropower balancing reservoir and is an open space cleared of vegetation, closed off with a gate (albeit in need of repair). A paved road runs alongside the boundary fence of the project site and enables access to the forest from the village of Laudat, as well as being the access road for two tourist sites (Titou Gorge and walking track to the Boiling Lake) (Caraïbes Environnement Développement & Coll, 2013). These roads provide the only method of access to the proposed power plant site.



**Figure 3.33 : Panoramic view from east of the Laudat (WW-P1) Platform Site (Caraïbes Environnement Développement & Coll, 2013)**

The reinjection site (WW-01) near Wotten Waven is located directly next to the road and in close proximity to several vendors and tourism attractions (hot pools). To the north is forested area with a few people undertaking small scale farming.

Reinjection site WW-R1 is near the village of Trafalgar and is located in a wetland area characterised by low vegetation. It lies in a small valley that is closed off to the north and south by tree-covered foothills and peaks. As shown in Figure 3.33 below, the reinjection well site is in an inhabited and developed zone with natural and somewhat inaccessible surroundings on all sides.



**Figure 3.34 : Site WW-01 (left). View over Trafalgar (WW-R1) reinjection site (Caraïbes Environnement Développement & Coll, 2013)**

### 3.14.3 Crash Analysis

Jacobs does not have access to any crash data for the study area.

### 3.14.4 Existing Traffic

Traffic surveys were undertaken at the above two intersections during the following times:

- Sunday 11 December 2016, 08:15 – 16:15
- Monday 12 December 2016, 07:30 – 15:30

- Tuesday 13 December 2016, 07:45 – 15:45

Summaries of the peak traffic flows observed by two counters during the survey times are given below, full count data and an example count sheet is provided in ESIA Volume 5: Technical Appendices. Outside of the peak hours defined below, traffic passing through the intersection is lower.

Tables 3.8, 3.9 and 3.10 show the peak traffic counts for the intersection of Valley Road and the local road to Wotton Waven. Within these tables, T = Through, L = Left and R = Right.

**Table 3.9 : Daily traffic - Valley Road intersection with local road to Wotton Waven, Sunday 11 December 2016**

| | Valley Road (N) | | Valley Road (S) | | Local Road | | Total | % Mode Share |
|---|---|---|---|---|---|---|---|---|
| | T | R | T | L | L | R | | |
| Car | 30 | 24 | 49 | 1 | 32 | 3 | 139 | 72% |
| Truck | 0 | 4 | 3 | 0 | 4 | 0 | 11 | 6% |
| Bus | 5 | 5 | 9 | 0 | 7 | 0 | 26 | 13% |
| Cycle | 0 | 4 | 1 | 0 | 2 | 0 | 7 | 4% |
| Pedestrian | 0 | 2 | 1 | 0 | 6 | 1 | 10 | 5% |

*The peak hour during this survey happened between 8:30 and 9:30.

**Table 3.10 : Daily traffic - Valley Road intersection with local road to Wotton Waven, Monday 12 December 2016**

| | Valley Road (N) | | Valley Road (S) | | Local Road | | Total | % Mode Share |
|---|---|---|---|---|---|---|---|---|
| | T | R | T | L | L | R | | |
| Car | 14 | 16 | 104 | 1 | 88 | 0 | 223 | 72% |
| Truck | 3 | 1 | 3 | 0 | 0 | 1 | 8 | 3% |
| Bus | 12 | 15 | 25 | 0 | 22 | 1 | 75 | 24% |
| Cycle | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 1% |
| Pedestrian | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |

*The peak hour during this survey happened between 7:30 and 8:30.

**Table 3.11 : Daily traffic - Valley Road intersection with local road to Wotton Waven, Tuesday 13 December 2016**

| | Valley Road (N) | | Valley Road (S) | | Local Road | | Total | % Mode Share |
|---|---|---|---|---|---|---|---|---|
| | T | R | T | L | L | R | | |
| Car | 18 | 23 | 73 | 0 | 81 | 0 | 195 | 75% |
| Truck | 3 | 1 | 1 | 0 | 1 | 0 | 6 | 2% |
| Bus | 9 | 11 | 19 | 1 | 15 | 1 | 56 | 22% |
| Cycle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| Pedestrian | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 1% |

*The peak hour during this survey happened between 7:45 and 8:45.

The traffic flows observed during the surveys of the intersection of Valley Road and the local road to Wotton Waven are low, with an average worst case scenario of two vehicles every minute. Travel by car is the dominant mode of transport in the area (more than 70%), with bus transport being the second most used mode (13%-24%). Heavy vehicles make up approximately 5% of the traffic and pedestrians and cyclists make up 9% on the Sunday and only 1% on the two week days.

Tables 3.11, 3.12 and 3.13 show the peak traffic counts for the intersection of Valley Road and the local road to Trafalgar. Within these tables, T = Through, L = Left and R = Right.

**Table 3.12 : Daily traffic - Valley Road intersection with local road to Trafalgar, Sunday 11 December 2016**

| | Valley Road (N) | | Valley Road (S) | | Local Road | | Total | % Mode Share |
|---|---|---|---|---|---|---|---|---|
| | T | R | T | L | L | R | | |
| Car | 12 | 21 | 12 | 2 | 29 | 1 | 77 | 75% |
| Truck | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 2% |
| Bus | 2 | 2 | 1 | 0 | 8 | 0 | 13 | 13% |
| Cycle | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1% |
| Pedestrian | 2 | 0 | 1 | 4 | 3 | 0 | 10 | 10% |

*The peak hour during this survey happened between 8:30 and 9:30.

**Table 3.13 : Daily traffic - Valley Road intersection with local road to Trafalgar, Monday 12 December 2016**

| | Valley Road (N) | | Valley Road (S) | | Local Road | | Total | % Mode Share |
|---|---|---|---|---|---|---|---|---|
| | T | R | T | L | L | R | | |
| Car | 9 | 8 | 31 | 0 | 54 | 1 | 103 | 71% |
| Truck | 0 | 2 | 1 | 0 | 1 | 0 | 4 | 3% |
| Bus | 2 | 10 | 5 | 0 | 18 | 0 | 35 | 24% |
| Cycle | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 1% |
| Pedestrian | 0 | 1 | 0 | 0 | 1 | 0 | 2 | 1% |

*The peak hour during this survey happened between 7:30 and 8:30.

**Table 3.14 : Daily traffic - Valley Road intersection with local road to Trafalgar, Tuesday 13 December 2016**

| | Valley Road (N) | | Valley Road (S) | | Local Road | | Total | % Mode Share |
|---|---|---|---|---|---|---|---|---|
| | T | R | T | L | L | R | | |
| Car | 14 | 21 | 14 | 4 | 26 | 2 | 81 | 70% |
| Truck | 1 | 3 | 1 | 0 | 1 | 0 | 6 | 5% |
| Bus | 2 | 5 | 3 | 0 | 6 | 0 | 16 | 14% |
| Cycle | 3 | 0 | 1 | 2 | 2 | 0 | 8 | 7% |
| Pedestrian | 1 | 3 | 0 | 1 | 0 | 0 | 5 | 4% |

*The peak hour during this survey happened between 13:30 and 14:30.

The intersection of Valley Road and the local road to Trafalgar has a similar mode share to the previous intersection. Travel by car is the dominant mode of transport in the area (more than 70%), with bus transport being the second most used mode (13%-24%). Heavy vehicles make up approximately 5% of the traffic and pedestrians and cyclists make up 2%-11%.

The overall car volumes are lower at the intersection to the local road to Trafalgar than they are at the intersection with the local road to Wotton Waven. This suggests that traffic volume on Valley Road gradually reduces as you travel further north towards the Laudat project site.

It is important to note that the weekend survey shows similar traffic volumes to the weekday surveys.

### 3.14.5 Tourism and Cruise Ships

Cruise ships are a regular occurrence in Roseau during the cruise seasons (November to March) and occasionally there can as much as two or three in the port in a single day. They can range in size from a small ship carrying 100-200 passengers to a 'Royal' class cruise ship holding over 4,000 passengers. The passengers from the cruise ships add to the road network as they tend to travel by either buses or private taxis. It is expected that when a large cruise ship comes in to the port, the roads connecting to the local tourist attractions will be impacted by the surge in traffic on these routes.

The traffic surveys were undertaken on a day when there was a cruise ship in port, but it was one of the smaller vessels and as such will have had minimal impact on traffic flows that day. Some bus journeys could be attributed to the cruise ship tourists on the survey days, but the majority of the buses recorded in the surveys are likely to be local services.

### 3.14.6 Public Transport Network

The traffic surveys revealed that there is a relatively high volume of buses on the network. While not all of these buses are likely to be public – some are most likely from the cruise ship passengers being shuttled to tourist sites. Anecdotally, the public transport services in Roseau runs regularly and are popular with the locals (site observation by Jacobs Environmental Specialists, December 2016).

### 3.14.7 Walking Network

There is a short section of footpath on Valley Road near a school located in Louisville which is approximately 200 m south of the intersection of Valley Road and the local road to Wotton Waven.




**Figure 3.35 : Footpath on Valley Road around Louisville (left) and pedestrian crossing outside local school (right) (Source: Jacobs, 2016)**

### 3.14.8 Cycling Network

There are no facilities for cyclists in the study area.

### 3.14.9 The Waitukubuli National Trail

The Waitukubuli National Trail is the only large scale marked trail in the East Caribbean and is an important attraction for Dominica's image as the 'Nature Isle'. The Waitukubuli National Trail was officially declared as an eco-tourism site on May 10, 2013, in accordance with the Commonwealth of Dominica Statutory Rules and Orders No. 7 of 2013 National Parks and Protected Areas Regulations (Waitukubuli National Trail Website, 2017). Many tourists visit Dominica to experience a rugged and untouched side of the Caribbean, the trail provides a relatively accessible marked route through the entire length of the island. During discussions with local taxi drivers in December 2016, Environmental Specialists from Jacobs were told the tourists actively request that taxi drivers take them to the trail. It is steep, muddy and in parts unmaintained but is very scenic nonetheless. A summary of the route is shown in Figure 3.35 below.

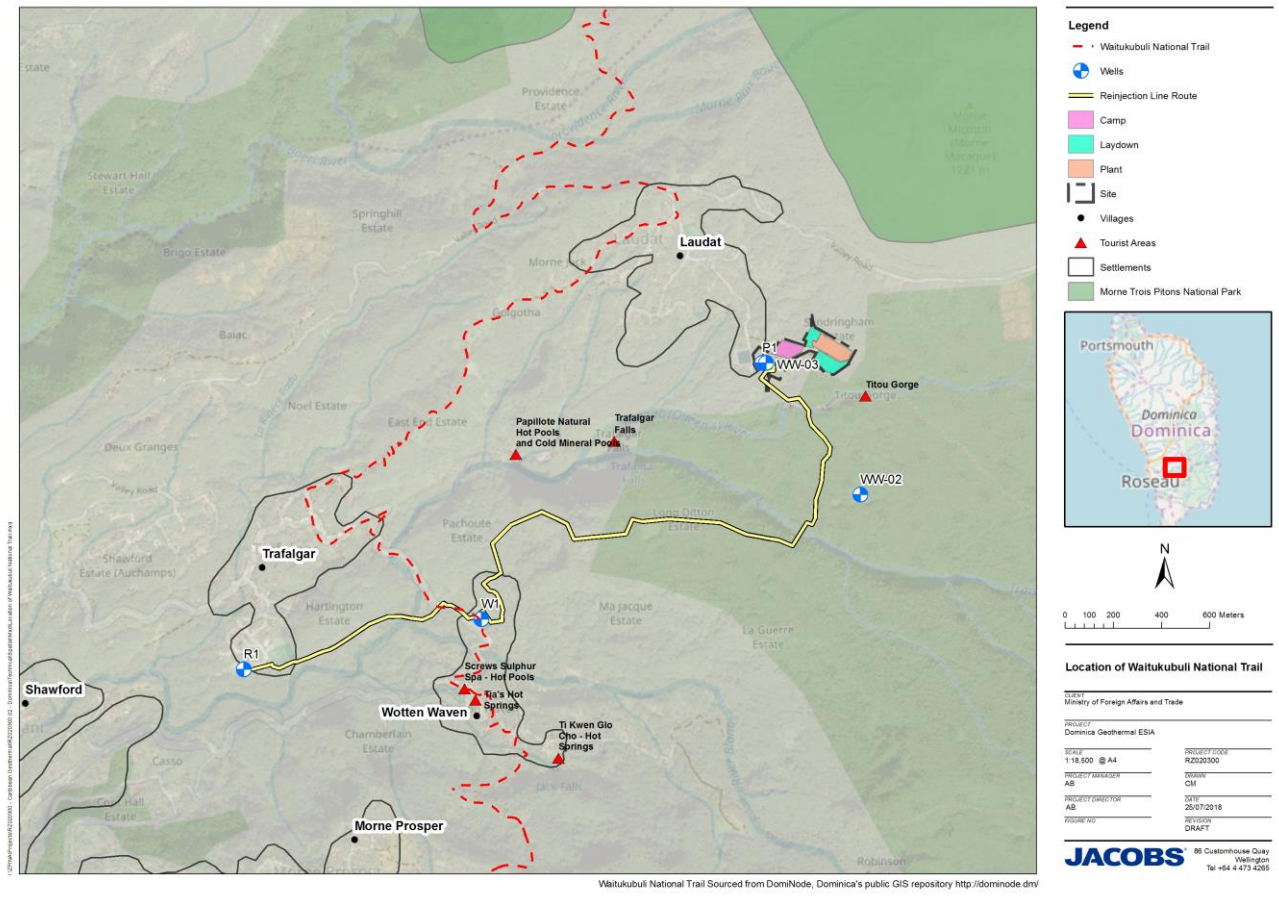


**Figure 3.36 : The location of the Waitukubuli National Trail.**

## 3.15 Changes to the Baseline following Hurricane Maria

### 3.15.1 Introduction

Hurricane Maria devastated Dominica on the 18 September 2017. The storm was one of the most rapidly intensifying storms in recent history, intensifying to a category 5 hurricane roughly 24 hours after being upgraded from a tropical storm. Dominica was exposed to unprecedented winds for more than three hours as the hurricane passed over the centre of the island, accompanied by intense rainfall, which provoked flash floods and landslides (GoCD, 2017).

The environmental damage following Hurricane Maria is estimated to be *'very high, with 80-90 percent of environmental resources significantly affected'* according to the GoCD Post Disaster Needs Assessment (PDNA) Report (2017). Hurricane force wind and intense rainfall produced widespread damage to forests on Dominica and much of the pre-Maria forest was stripped of leaves and damaged, with downed trees were widespread throughout the island. (GoCD, 2017). Ecological services relating to water production, erosion control and land stabilisations will likely be affected for a time after Hurricane Maria (although it is not yet known for how long) and *'may require interventions'* to remedy according to the PDNA Report (GoCD, 2017).

The Post-Disaster Needs Assessment concluded that Hurricane Maria resulted in total damages of EC$2.51 billion (US$930.9 million) and losses of EC$1.03 billion (US$380.2 million), which amounts to 250 percent of 2016 gross domestic product (GDP) (GoCD, 2017).

Following the storm, in November 2017, Dominica Geothermal Development Company Ltd (DGDC) conducted a conditions assessment of their existing assets, the proposed Project sites and their continued viability – this was compiled in the 'Assessment of Assets and Projects Sites Post Hurricane Maria Report' (hereafter referred to as the 'Post Hurricane Maria Report') (DGDC, 2017). This report has been used, alongside the GoCD Post Disaster Needs Assessment Report (2017), further desk based assessment and site based assessment, to inform the overview which describes the key 'post-Maria' baseline changes.



**Figure 3.37 : The devastation caused by Hurricane Maria in the Roseau Valley**

### 3.15.2 Changes to Baseline for Different Environmental Aspects

The section below summarises the key changes to the Post-Maria environmental baseline.

**Air Quality**

There is no change anticipated to the air quality baseline, except potential receptors may no longer be residing adjacent to the power plant or reinjection line. For further details of residences that may have been affected, reference should be made to the ESIA Volume 3: SIA.

**Hydrology**

Following Hurricane Maria there were massive flooding events in the Roseau Valley caused by a heavy rainfall events - evidence of this was observed in from the number of washed out roads and damages to bridges (DGDC, 2017). This Category 5 hurricane is considered the most intense tropical cyclone of 2017. Analysis from NASA using Integrated Multi-Satellite Retrievals for GPM (IMERG) data was used to estimate the total amount of rain Maria dropped from the 17th to the 21st of September. While the eye of the Hurricane passes over Dominica, rainfall intensity increased as the storm tracked north-west towards Puerto Rico and the Virgin Islands. Estimated rainfall at Dominica was between 250-300 mm (NASA 2017).

This volume of rainfall is less than the 100 yr ARI storm (326.9 mm) as documented in Section 3.5.1. Unfortunately, no further data at the time of this report is available to verify the amount of rainfall which occurred near Dominica during Maria.

An assessment of the Project post Hurricane Maria is documented in DGDC Post Hurricane Maria Report (2017). This site assessment reviewed the impact on electrical, structural, roading and site infrastructure. While a number of the access roads have had significant slips and scouring, most are still accessible for small vehicles. A review of the proposed project sites (power plant and re-injection line) determined that minimal surface water issues existed and that the local landowner indicated Hurricane Erika had minimal effects also. It is likely overland flow did occur, however the dense vegetation and steep slopes minimalised flood inundation risk. Further downstream however (near the Trafalgar River), high flows carrying debris has destroyed the DOMLEC pipeline for over 100 m and deposited rocks and vegetation around the river channel. This further indicates the risk for debris strike on the re-injection pipeline, discussed in Section 7.3.3.

**Water Quality and Freshwater Ecology**

There has been significant vegetation loss through the project area with more change in vegetation noted along the reinjection pipeline route rather than the proposed power plant location. A number of landslides have been observed and reported in DGDC Post Hurricane Maria Report (2017) through the access road areas and the reinjection pipeline area. This may result in a change to the location of a stretch of the reinjection pipeline. Photographs of watercourses showed that a large amount of vegetation and other debris (sediments) was mobilised by the hurricane.

As a result of the hurricane event the existing water quality would likely have been very poor and the existing ecology impacted by the effects of the major ‘flush’ of water. This would have mobilised macroinvertebrates and fish and swept them downstream as well as modifying the existing habitat. The pre hurricane assessment identified that the rivers are likely to be dynamic environments ecologically with flushes impacting upon ecological values in the wet season. Hurricane Maria has therefore exacerbated this effect.

There is likely to be an increased risk of landslides and further erosion events that will potentially reduce the water quality over the next few years as greater amounts of suspended sediment could be washed subsequent into the water column of the river during subsequent rainfall events. This may have reduced species and more fine sediments could be deposited within the channels impacting negatively upon habitat for macroinvertebrates and fish. Overall, it is considered likely that the water quality/ecology are currently worse/more impoverished than pre-Maria and that the environments are thus more stressed ecologically as they attempt to recover and therefore more sensitive to other activities that could lead to increased discharges of sediment laden water and or direct disturbance.

In terms of potential for contamination of watercourses due to pollution from chemicals and fuels, the PDNA Report (GoCD, 2017) makes the following conclusions:

*'The impact of pollution from chemicals and fuels has not yet been assessed but likely low. There were no reports of leaking fuel storage facilities and other sources of pollution are associated with wastewater management and end user commodities such as fertilizers, agriculture chemicals and other commodities sold retail to consumers.'*

**Landscape and Visual**

As much of the vegetation has been stripped from the hillsides and many buildings have been destroyed or damaged on the island, the landscape and visual environmental of the Roseau Valley has changed markedly following Hurricane Maria (DGDC, November 2017). However, evidence from more recent photographs (taken by Jacobs Environmental Specialists in March 2018) indicates that the regrowth of vegetation in the Roseau Valley is occurring rapidly. Rainforest ecosystems such as those found on Dominica have been through previous hurricane events and vegetation cover and habitat integrity has returned rapidly (within 2 years as reported by DominicaVibes, 2017).



**Figure 3.38 : 'Before and After' Photographs taken at WW-P1 / WW-03 Wellpad. Left image taken by DGDC in November 2017 and right image by Jacobs Environmental Specialists in March 2018.**

**Geothermal Features**

As geothermal features are fed by the subterranean geothermal reservoir, it is not anticipated that any have been affected by Hurricane Maria. However, the natural springs at Wotten Waven were reportedly closed at the time of the March 2018 surveys by Environmental Specialists, due to being inundated by a nearby stream locally flooding.

**Natural Hazards**

*Landslides*

Hurricane Maria resulted in a tropical downpour that caused landslides right across Dominica and the Roseau Valley. Slope stabilization may be required to protect downstream assets and infrastructure (GoCD, 2017). Evidence of landslides was captured multiple times by DGDC in the Post Hurricane Maria Report (2017). These are summarised below:

- Landslide damage to main road from the Roseau Valley floor to Laudat (DGDC Post Hurricane Maria Report, Figure 4). See traffic section below.
- Significant damage to the original proposed Reinjection Line Route across Breakfast River and Titou Gorge. It appeared that the cliff area is unstable and heavy rainfall is causing the face to erode and collapse (DGDC Post Hurricane Maria Report, Figure 15).
- Reports of general structural damage throughout the valley (i.e. to communication poles).

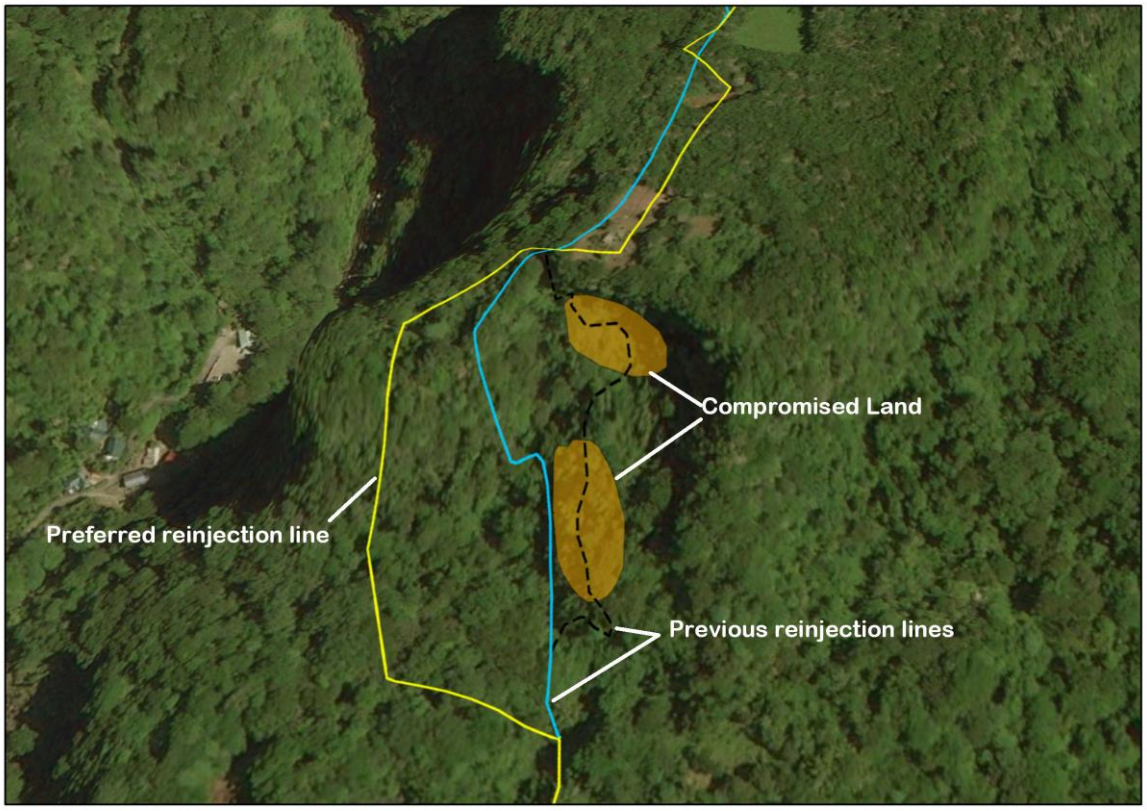


**Figure 3.39 : Area of compromised on reinjection line (red areas) (adapted from the DGDC Post Hurricane Maria Report, 2017)**

Based on the events of Hurricane Maria and due to the loss of vegetation and potential destabilising of soil, there is therefore likely to be an increase in the risk of landslides in the Roseau Valley in certain areas. There is

likely to be an increased risk of landslides and further erosion events with rainfall over the next few years due to the vegetation damage observed.

**Noise**

There is no change anticipated to the noise baseline, except potential receptors may no longer be residing adjacent to the by power plant or reinjection line. For further details of residences that may be potentially affected, references should be made to the ESIA Volume 3: SIA.

**Geology, Soils and Groundwater**

There is likely to be an increase in risk of landslides in the 'post-Maria' Roseau Valley (discussed above under Natural Hazards). It is also like that soils have become more exposed and prone to sedimentation with the loss of vegetation and trees. In terms of potential for contamination of soils due to pollution from chemicals and fuels, the PDNA Report (GoCD, 2017) predicts there to be a low likelihood of significant damage.

**Terrestrial Ecology**

The DGDC Post Hurricane Maria Report (DGDC, 2017) does not provide any specific detail on the condition of the environment or surrounding habitats, however, photographic records have been taken which do provide some level of detail as to the environmental state.

Observations include the following with references to corresponding figures within the DGDC Report (2017):

- Higher exposed areas such as hill-tops have been stripped of tree cover, medium to small trees remain on lower slopes only, but it is clear that some if not all of these have been defoliated to some extent. Ground cover plants and habitats remain intact (see DGDC Post Hurricane Maria Report: Figure 1 and 2);
- Lower more sheltered areas appear to show good vegetation cover that has not been so badly damaged (DGDC Post Hurricane Maria Report, Figure 3);
- Landslides and hill slips have occurred especially along access tracks destabilising vegetation and exposing bare rock and soil to the elements (DGDC Post Hurricane Maria Report, Figure 4, 6, 7);
- Grassed areas on flat surfaces e.g. those around wellheads (see DGDC Post Hurricane Maria Report, Figure 8, 9, 12) appear intact and have not incurred storm damage;
- Some trees located around the proposed power plant site appear to have been defoliated (See DGDC Post Hurricane Maria Report, Figure 13). Text in 3.2.1 notes large quantities of fallen trees and minor edge collapses into river gorges. Large amount of debris in river courses carried downstream;
- Fallen or semi-fallen trees remain a risk along access tracks and may need to be felled to ensure safe passage (see DGDC Post Hurricane Maria Report, Figure 14 and Section 3.2.1);
- Steeper hillside vegetation has been badly damaged which could lead to further erosion and slips (see DGDC Post Hurricane Maria Report, Figure 16). Major landslides evident which could destabilise further in time should another storm event occur;
- River courses have become choked with new debris, rocks, fallen tree materials and other detritus (see DGDC Post Hurricane Maria Report, Figure 18); and
- Defoliated trees around existing infrastructure are likely to die possibly leading to greater exposure until vegetation cover is restored (see DGDC Post Hurricane Maria Report, Figure 19).

Rainforest ecosystems such as those found on Dominica have been through previous hurricane events and vegetation cover and habitat integrity has returned rapidly (within 2 years as reported by DominicaVibes, 2017). Indeed, such events provide many species with new opportunities e.g. similar to when a mature tree is felled in a rainforest, opening up the canopy, and providing dormant seeds the chance to grow. It is clear that the environment has dramatically changed as a result of Hurricane Maria, and that the ecological environment that

will return will be different from what was there before. However, studies completed to date have indicated the presence of a mature habitat representative of the island.

It is therefore proposed that no further ecological studies are undertaken at the time of preparing this ESIA as this would not provide any new information on the underlying habitats present. Instead, the situation post-Maria does provide new opportunities for the Project to work with nature through proposed actions e.g. tree planting to stabilise slopes and stop further erosion and restoring river courses. However, it is proposed that further ecological studies take place along the reinjection pipeline prior to construction (discussed further in Section 13).

**MTPNP World Heritage Site**

MTPNP would have been undoubtedly damaged by Hurricane Maria; indeed, first hand observations mention forest defoliation of between 80 to 90%, ultimately leading to tree deaths (DominicaVibes, 2017) with Dominica's wildlife having been severely hit. Conservation efforts associated with the island's rare bird species (Imperial Parrot and Red-necked parrot) ensured that a number kept in captivity were held safe (American Bird Conservancy, 2018). Populations in the wild have fared less well. Rainforest ecosystems such as those found on Dominica have been through previous hurricane events and vegetation cover and habitat integrity has returned rapidly (within 2 years; DominicaVibes, 2017) reaching semi-maturity or maturity.

It is highly likely that many of the observations described above for the terrestrial ecology section also apply to the baseline situation for the MTPNP World Heritage Site.

**Traffic**

The GoCD Post Disaster Needs Assessment (2017) concluded the following regarding damage to roads and bridges on Dominica:

*'Roads across the island were covered by substantial amounts of tree and flooding debris, and a relatively moderate number of landslides or embankment failures were identified. The major damages were incurred at river crossings, where strong flash flooding carried substantial debris damaging crossings and bridges. In valleys and steep gullies, especially in the south and west, some structures were blocked and overtopped by 1-2 meters (m) of floodwater. Debris deposits of 1-4 m depth filled the riverbeds causing rivers to change course and erode abutments or approaches. The pavements, especially on improved roads with lined surface drainage, were generally undamaged, but more extensive damages were incurred on the less improved secondary and feeder road networks.*

*Six major bridges were seriously damaged and closed – three on the west coast and three in the south – and major erosion or washouts occurred over an estimated 19 km combined length. Vehicles were damaged by flooding and flying tree and building debris, with an estimated one to four percent destroyed and seven to ten percent damaged.'*

There is evidence of significant damage to access roads in the valley following Hurricane Maria. The access road to the power plant site from Laudat has been badly damaged through significant erosion and undermining of the road surface leading to collapse of the road and loss of pavement over a length of about 100m (DGDC Report, 2017). Evidence was provided in the DGDC Post Hurricane Maria Report (2017) and is shown below in Figure 3.40.



**Figure 3.40 : Landslip on the road (right)**

# 4. Air Quality

## 4.1 Introduction

This section describes the potential impacts to ambient air quality from the construction and operation of the Project and sets out mitigation measures to minimise any impacts. The section summarises the findings of the ESIA: Volume 5 – Technical Appendices (Technical Report – Air Quality Impact Assessment).

## 4.2 Methodology

This section describes the nature of emissions and anticipated discharges associated with the Project, the assessment criteria and modelling methodology used to assess potential impacts.

### 4.2.1 Nature of Emissions

**Non-Condensable Gases**

Emission of Non-Condensable Gases (NCGs) is likely to be around 4% of the total combined steam. The NCGs released will include hydrogen sulphide ($H_2S$), carbon dioxide ($CO_2$), and minor pollutants such as mercury (Hg), arsenic (As), ammonia ($NH_3$), fluoride (F-). The IFC EHS Guidelines for Geothermal Power Generation (2007) state: "*Hydrogen sulphide and mercury are the main potential air pollutants* [from geothermal power plants]…*The presence and concentration of potential air pollutants may vary depending on the characteristics of the geothermal resource"*. For this assessment only $H_2S$ and mercury have been considered, as the other pollutants are expected to be present in very minor concentrations and have limited potential to cause adverse impacts.

The IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation (2011) notes that; *"$H_2S$ is toxic, but rarely of sufficient concentration* [from geothermal power plants] *to be harmful after venting to the atmosphere and dispersal"*.

**Dust and Combustion Gas Emissions**

Combustion gas emissions from the exhausts of transport vehicles, construction machinery, and electricity generators using diesel fuel will be associated with construction activities, and to a lesser extent operation and maintenance of the Project. Potential pollutants from diesel combustion include nitrogen oxides ($NO_X$), (which comprises of nitrogen dioxide ($NO_2$) and nitrogen oxide (NO)), sulphur dioxide ($SO_2$), carbon monoxide (CO), and carbon dioxide ($CO_2$), and particulate matter smaller than 10 and 2.5 microns in size ($PM_{10}$ and $PM_{2.5}$ respectively).

There will be some minor discharges of particulate matter associated with wet cooling towers, if this option is selected. Because wet cooling towers provide direct contact between the cooling water and the air passing through the tower, some of the liquid water may be entrained in the air stream and be carried out of the tower as drift droplets.

Construction activities also have the potential to result in fugitive dust discharges that could have nuisance impacts on the surrounding environment.

### 4.2.2 Potential Discharges during Project Phases

**Air Discharges during Construction**

The construction activities with potential to create nuisance dust include:

- Minor reshaping works of the production and reinjection well pad, earthworks for the formation of power plant, and switchyard site and site access roads;
- Excavations for foundations and construction of power plant and steamlines infrastructure; and,
- Clearance and earthworks of the condensate reinjection pipeline route approximately 4 m wide and 3.25 km long.

The two phase pipelines and steam lines will be commissioned via a “steam blow” where hot steam (from the geothermal resource) will be passed through the piping at high velocity for a sustained period. This will remove any solid particles present in the piping interior which may damage the steam turbines. As with production well testing steam and NCGs will be discharged to atmosphere, although for a much shorter time.

During construction activities there will also be a number of sources of combustion gas emissions from the exhausts of drilling rig, transport vehicles, construction machinery, and electricity generators using diesel fuel. Potential pollutants from diesel combustion include nitrogen oxides ($NO_X$), sulphur dioxide ($SO_2$), carbon monoxide (CO), carbon dioxide ($CO_2$), and particulate matter smaller than 10 and 2.5 microns ($PM_{10}$ and $PM_{2.5}$ respectively).

**Air Discharges during Operation**

The Process Description for the ESIA describes two types of technologies for generating electrical energy from this geothermal resource: Rankine steam condensing and ORC (binary). At this stage it is too early to confirm which technology option would be used for the Project. Regardless of the option selected, emissions from the Project will include the release of NCGs from sources such as steam vents and from a point source situated in the cooling tower arrangement. Although these can be considered ‘natural’ in the sense that they are already emitted from numerous existing fumaroles and vents on Dominica, the power plant will emit these in larger quantities than might be experienced naturally. Hydrogen sulphide is the primary NCG of concern with potential to have adverse impacts on the surrounding environment, with nuisance odour impacts occurring at relatively low concentrations.

Additionally, unplanned or intermittent releases of steam and NCGs could result from:

- Pipeline failures due to damage or corrosion;
- Power plant shutdowns in which steam from the steam separator is vented to air via a rock muffler; and
- Overpressure release of steam through flash tanks.

If the Project uses wet cooling towers, in addition to NCGs there will be minor amounts of particulate matter discharged from the cooling towers as water droplets. These droplets may contain trace amounts of dissolved solids that would remain airborne as the droplets evaporate. These discharges are typically mitigated by drift eliminators, and are not expected to have a significant impact on the surrounding environment.

Although very unlikely, there is also the potential for a well blowout to occur during operation, which will result in the unplanned release of geothermal fluids, including NCGs.

Combustion gas emissions during operation will be limited to emergency generators, firewater pumps, and service vehicles required for transporting maintenance equipment and materials.

### 4.2.3 Assessment Criteria

The primary pollutants of concern for the Project include dust generated during construction activities, and emissions of Non Condensable Gases (NCGs) from power plant operation. Of most relevance is likely to be hydrogen sulphide ($H_2S$) as other contaminants are usually present in very minor concentrations. Discharges of other contaminants (e.g. fugitive dust and products of diesel combustion) will be for a limited period during the

construction phase. The assessment criteria used for these potential sources, across all phases, are presented in the following sections.

The assessment of the significance of the impact, taking into account the impact specific assessment criteria, and mitigation measures, has been categorised using the definitions presented in Table 4.1.

**Table 4.1 : Significance of Impacts**

| Significance | Impacts |
|---|---|
| **Positive** | An enhancement of some ecosystems or population parameter |
| **Negligible** | Incidental on-site impact. No ecological consequences. |
| **Minor** | Minor release immediately contained. Reduction in abundance / biomass of flora fauna in affected area. No changes to biodiversity. Minor environmental nuisance. |
| **Moderate** | Off-site release contained with outside assistance. Reduction in biomass in local area without significant loss of pre-impact ecological functioning. Significant sustained environmental nuisance. |
| **Major** | Off-site release with significant impact to biodiversity and ecological functioning with eventual recovery (maybe not to pre impact conditions). |
| **Severe** | Toxic release with off-site detrimental impact. Irreversible changes to abundance of biomass in affected environment. Loss of ecological functioning with little prospect of full recovery. |

### Hydrogen sulphide

There are no national ambient air quality guidelines or standards for Dominica. In the absence of national guidelines and standards the IFC EHS General Guidelines recommend using the WHO Ambient Air Quality Guidelines (WHO AAQG) (2005). The WHO AAQG recommends a guideline value for hydrogen sulphide which is based on the LOAEL of 15,000 µg/m$^3$, the level at which eye irritation is caused. A safety factor of 100 is applied to the LOAEL in order to obtain the WHO AAQG for $H_2S$ of 150 µg/m$^3$ as a 24-hour average.

The New Zealand Government Ministry for the Environment (MfE) Ambient Air Quality Guidelines (NZ AAQG) (2002), provides a guideline value of 7 µg/m$^3$ (1-hour average) for $H_2S$, which is based on odour threshold rather than health effects, and in addition, notes that it may be unsuitable for use in geothermal areas due to decreased sensitivity through continuous exposure.

A summary of the potential health effects of $H_2S$, summarised from the NZ AAQG, is presented in Table 4.2.

**Table 4.2 : Health effects of $H_2S$**

| Concentration (µg/m$^3$) | Effect |
|---|---|
| 0.2-2.0 | Odour threshold - detectable by 50% of people. Considered to have a smell of “rotten eggs” at 3 to 4 times this concentration. |
| 7.0 | Nuisance odour level (not considered applicable to geothermal areas) |
| 15,000* | Eye irritation (LOEAL) |
| 70,000 | Permanent eye damage |
| 225,000 | Paralysis of olfactory perception (odour can no longer be detected) |
| 400,000 | Risk of pulmonary oedema |
| 750,000 | Over-stimulates the central nervous system, causing rapid breathing, cessation of breathing, convulsions, and unconsciousness. |
| 1,400,000 | Lethal |

* The WHO Concise Chemical Assessment Document notes this concentration as the lowest observed adverse effect level (LOAEL) (WHO, 2003)

As shown in Table 4.2, the level at which health effects of $H_2S$ become a concern are well above the level at which it is considered to be a nuisance odour. In general, emissions from most geothermal power plants are at a level which could produce nuisance odour impacts, but are well below levels for adverse health impacts.

The New Zealand Government Ministry for Environment Good Practice Guide for Assessing and Managing Odour in New Zealand (New Zealand Government Ministry for Environment, 2016) (suggests the use of frequency, intensity, duration, offensiveness and length (referred to as FIDOL) for assessing the impact of odours. This method was developed for assessing actual odour events, however can be applied to predicted impacts if reasonable assumptions on the FIDOL parameters can be determined. FIDOL incorporates an assessment of:

- Frequency - how often an individual is exposed to odour;
- Intensity - the strength of the odour;
- Duration - the length of a particular odour event;
- Offensiveness - the 'hedonic tone' of the odour; and
- Location - the type of land use and nature of human activities in the vicinity of an odour source.

**Mercury (Hg)**

The effects of chronic exposure to elemental mercury include central nervous system effects (such as erethism, irritability, insomnia), severe salivation, gingivitis and tremor, kidney effects (including proteinuria) and acrodynia in children. The WHO ambient air guideline for inorganic mercury is 1 µg/m$^3$ as an annual average, and is based on protecting against potential health impacts on the central nervous system. This limit is proposed for the Project.

**Nuisance Dust**

The production of dust from construction works such as the formation of roads and preparation of lay-down and drill zones will be inevitable. For this assessment *Guidance on the Assessment of Dust from Demolition and Construction, Version 1.1* developed by the Institute of Air Quality Management (IAQM) (2014) has been used.

Activities on Site have been divided into four types to reflect their different potential effects. These are:

- Demolition;
- Earthworks;
- Construction; and
- Trackout.

Of these four types of activities, only earthworks and construction are relevant to the Project as no demolition is required.

The IAQM method uses a five step process for assessing dust impacts from construction activities:

- **Step 1** - Screening based on distance to nearest receptor. No further assessment is required if there are no receptors within a certain distance of the works.
- **Step 2** - Assess risk of dust effects from activities by:
    - the scale and nature of the works, which determines the risk of dust arising; and
    - the sensitivity of the area.

- **Step 3** - Determine site specific mitigation for remaining activities with greater than negligible effects.
- **Step 4** - Assess significance of remaining activities after mitigation has been considered.

The Step 1 screening criteria provided by the IAQM guidance suggests screening out assessment of impacts from activities where sensitive 'human receptors' will be more than 350 m from the boundary of the site, 50 m of the route used by construction vehicles, or up to 500 m from the site entrance. Sensitive 'ecological receptors' can be screened out if they are greater than 50 m from the boundary of the site, 50 m of the route used by construction vehicles, or 500 m from the site entrance.

The Step 2 assessment determines the Dust Emission Magnitude for each of four dust generating activities; demolition, earthworks, construction, and track out. The classes are; Large, Medium, or Small, with suggested definitions for each category. The lists of suggested definitions for earthworks and construction activities are presented in ESIA Volume 5: Appendices (Technical Report – Air Quality Impact Assessment).

The class of activity is then considered in relation to the distance of the nearest receptor and a risk category determined through an assessment matrix for each of three categories:

- Sensitivity to dust soiling effects;
- Sensitivity of people to health effects from $PM_{10}$; and,
- Sensitivity of Ecological effects.

A copy of each matrix for earthworks and construction is presented in ESIA Volume 5: Appendices (Technical Report – Air Quality Impact Assessment).

### 4.2.4 Modelling Methodology

Emissions of NCGs from the Project have been modelled using the CALPUFF modelling system, which consists principally of a meteorological model CALMET, and a transport and dispersion model CALPUFF.

The CALMET meteorological model is used to provide meteorological data over the study area which is necessary as an input into the CALPUFF dispersion model. The CALMET model is initialised with terrain and land use data describing the region of interest as well as meteorological data from various sources. In the absence of high quality meteorological data in this area, the WRF meteorological model was used to generate a 50 x 50 kilometre wind field. CALMET used this data to generate a dataset for input into CALPUFF.

CALPUFF is a non-steady-state Gaussian puff dispersion model capable of simulating the effects of time and space-varying meteorological conditions on pollutant transport, transformation, and removal (Scire et al., 2000). This model requires time-variant two and three-dimensional meteorological data output from a model such as CALMET, as well as information regarding the relative location and nature of the sources to be modelled for the application. Outputs from the CALPUFF model includes predicted ground-level concentrations of the species considered, as well as dry and wet depositional fluxes.

Further specific modelling methodology can be found in the ESIA Volume 5: Appendices (Technical Report – Air Quality Impact Assessment).

## 4.3 Impact Assessment

### 4.3.1 Construction

**Health**

Health impacts from $H_2S$ during construction activities will be short term during the well and power plant commissioning, and unlikely to reach levels which would result in an adverse impact on health.

Safety monitoring systems with warning alarms for high emissions of potentially hazardous gases will be incorporated as part of the drilling and power plant set up.

**Odour**

The FIDOL assessment for odour impacts during exploration undertaken above, will equally apply to the construction phase, as there is likely to be $H_2S$ levels above the nuisance odour limit identified in the NZ AAQG, but that the emissions will be for short duration during well testing and will be less noticeable as a result of desensitisation from continuous exposure to elevated background concentrations from natural sources.

**Dust**

Most construction activities can be screened out due to the distance from receptors, which appear from aerial imagery to be greater than 350 m from the Project at all locations, and additional works on tracks and the laydown area would be no greater than the exploration activities already undertaken. It is possible that sections of the reinjection pipeline will be located nearer to receptors, however this will depend on the final design.

A general assessment of the construction activities which may be associated with the reinjection pipeline would class them as “small” following the IAQM assessment definition:

> *‘Total site area <2,500 $m^2$, soil type with large grain size (e.g. sand), <5 heavy earth moving vehicles active at any one time, formation of bunds <4 m in height, total material moved <10,000 tonne, earthworks during wetter months.’*

Similarly, an assessment of the dust emission magnitude of construction activities associated with the Project would class them as “small” following the IAQM assessment definition:

> *‘Total building volume <25,000 $m^3$, construction material with low potential for dust release (e.g. metal cladding or timber).’*

**Table 4.3 : Dust Emission Magnitude**

| Activity | Dust Emission Magnitude |
|---|---|
| Earthworks | Small |
| Construction | Small |

The majority of the construction activities associated with the Project will not be closer than 100 m of the nearest residences, giving the Project a ‘Low’ sensitivity classification in regard to dust soiling impacts.

Similarly, human health impacts are classified as ‘Low’ sensitivity given the absence of residences within 200 m of the Project, and with few residences (estimated at well below 100 residential properties from examining aerial imagery) within 100 m of the Project.

Ecological impacts are classified as ‘Negligible’ sensitivity, as none of the Project area is within 50 m of a sensitive ecological area (e.g. the Morne Trois Pitons National Park).

These sensitivity classifications are summarised in Table 4.4 below.

**Table 4.4 : Outcome of Defining the Sensitivity of the Area to Dust Effects**

| Potential Impact | Earthworks | Construction |
|---|---|---|
| Dust Soiling | Low | Low |
| Human Health | Low | Low |
| Ecological | Negligible | Negligible |

The dust emission magnitude for the earthworks and construction activities in Table 4.3 should be combined with the sensitivity of the area as described in Table 4.4 to determine the risk of impacts with no mitigation applied. The risk matrices are then applied to assign a level of risk for each activity. The resulting dust risk for earthworks and construction activities are shown in Table 4.5 below. As the dust emission magnitude for all activities is classified as 'Small', and the sensitivity of the area is classified as 'Low' for all activities, the resulting risk is therefore classified as 'Negligible' for dust soiling, human health and ecological impacts. For those cases where the risk category is 'Negligible', no mitigation measures beyond those required by legislation will be required, although good practice dust management methods are recommended in any case.

**Table 4.5 : Dust Risk Table to Define Site-Specific Mitigation**

| Source | Dust Soiling | Human Health | Ecology |
|---|---|---|---|
| Earthworks | Negligible | Negligible | Negligible |
| Construction | Negligible | Negligible | Negligible |

When taken in combination with the relatively short duration of the construction, it is considered that there will be no significant impacts (all of **Negligible** significance) from generated dust emissions at these sites.

**Combustion Gases**

Ambient air monitoring undertaken during the baseline monitoring indicate that overall air quality is good with respect to combustion gases, although there is the potential for cumulative impacts of $SO_2$ and particulate matter. However, combustion emissions associated with construction activities will be more than 350 m from the main residential areas and emissions from the main source will occur over a relatively short duration. As such, it is considered that the potential impact on people living and working in the surrounding area combustion gas emissions will be of **Negligible** significance.

### 4.3.2 Operation

**Emissions Estimation**

**Non-Condensable Gases (NCGs)**

Emissions of NCGs from plant operation have been estimated based on assumptions of plant design for both options of geothermal plant (i.e. Rankine steam condensing and ORC). The composition of NCGs in the geothermal fluid is based on tests undertaken during the exploration phase of the project. These assumptions are described below:

- Approximately 2.3 kg/s of steam flow per MWe of power generation (16.1 kg/s total for a 7 MWe power development);
- Steam from the well will consist of around 1.6% NCGs by weight for a total of 0.26 kg/s;
- NCGs consist of 4.3% $H_2S$ by weight for a discharge rate of 11.08 g/s $H_2S$;
- Mercury is present in varying concentrations in geothermal resources, with typical concentrations being around 20 ppb in the steam, but may be up to 500 ppb (Arnorsson, 2004). We have assumed the upper limit for a mass discharge rate of 0.0081 g/s; and
- NCGs will be discharged into the cooling tower plumes in order to enhance dispersion of the gases via thermal buoyancy and mechanical draught provided by the cooling towers.

**Discharge Parameters**

It is understood that two types of power plant are currently being considered for the Project: a standard Rankine steam condensing plant, and an ORC plant. For the purpose of assessing NCG dispersion, the nature of the discharges will be similar, with the main differences being the configuration of the cooling fans/towers. Table 4.6

provides the emission parameters for the two options for the Project, the Rankine steam condensing option and the ORC option. The discharge parameters have been based on preliminary site design drawings and referenced to similar projects. Both options have been assessed as buoyant line sources, under the assumption that the discharges will be vented through the cooling towers in order to enhance buoyancy and therefore dispersion. The most important parameter is the contaminant discharge rate for $H_2S$ of 11.08 g/s, whereas the other parameters would be expected to have less of an influence on the model predictions.

**Table 4.6 : Estimated Discharge Parameters and Emission Rates for Operation of Power Plant**

| Parameter | Rankine Steam Condensing Option | ORC Option |
|---|---|---|
| Line source length (m) | 40 | 100 |
| Line source height(m) | 18 | 7 |
| Building Height | 18 | 7 |
| Building Width (m) | 20 | 20 |
| Temperature (C) | 35 | 35 |
| Buoyancy Parameter ($m^4/s^3$) | 419 | 1900 |
| $H_2S$ (g/s) | 11.08 | 11.08 |
| Hg (g/s) | 0.0081 | 0.0081 |

**Modelling Results and Impact Assessment**

**Hydrogen Sulphide ($H_2S$)**

The highest ground level concentrations (GLCs) as 99.9$^{th}$ percentile 1-hour average for $H_2S$ predicted by the modelling at the sensitive receptors are presented in Table 4.7 below. Sensitive receptors in regard to air quality impacts from the Project include private residences, schools, hospitals, or other areas where people may be potentially exposed to discharges from the site. For the purpose of this assessment representative locations at nearby villages have been selected to predict the level of potential impacts of the discharges.

Isopleth diagrams of the model prediction are presented as Figure 4.1 (for Rankine steam condensing plant option) and Figure 4.2 (for ORC option) below. The isopleth diagrams indicate the main area of impacts from the discharges is predicted to be the west and north-west of the Project site, downwind due to the predominant easterlies. South-easterly winds, while not frequently observed, appear to result in elevated concentrations to the northwest of the Project. These winds are likely to be relatively light, resulting in poorer dispersion of the plume.

The highest predicted MGLC of $H_2S$ as a 99.9$^{th}$ percentile 1-hour average was 1,100 µg/m$^3$ for the steam condensing option and 8,210 µg/m$^3$ for the ORC option, and occurs adjacent to the cooling towers, to the north-west of the laydown area. The difference between the two scenarios is due to the nature of the sources, with the ORC source having a lower discharge height as well as a lower buoyancy which results in higher concentrations near the point of discharge compared to the steam-condensing option. Both scenarios are predicted to result in concentrations that are well below the WHO lowest observable adverse effect level (LOAEL) for $H_2S$ of 15,000 µg/m$^3$, although they are significantly above the NZ MfE Odour-based guideline of 7 µg/m$^3$.

However, the maximum predicted concentrations decrease rapidly with distance from the power plant, and in the main residential areas are below the nuisance odour threshold of 7 µg/m$^3$. The model predictions for the ORC option are significantly lower than for the steam condenser option at the sensitive receptors, despite the ORC predictions being higher near the power plant itself. This is presumably due to differences in release height and estimated buoyancy of the discharges which result in higher concentrations near the power plant, but greater dispersion at further distances.

Predicted 1-hour concentrations of $H_2S$ within the Morne Trois Piton National Park are highest directly north-north-west of the power plant, with highest concentrations being around 85 µg/m$^3$ for the steam condensing option and 28 µg/m$^3$ for the ORC option. The highest concentrations are well below the LOAEL for $H_2S$, and are not likely to result in adverse ecosystem impacts.

It is possible that the operation of the power plant could result in a discernible increase in odour from $H_2S$ discharges at residences nearest to the Project area. However, given the active geothermal nature of the area and the existing baseline levels of $H_2S$ in this area, it is unlikely that these would reach nuisance levels. The level of impact significance is therefore assessed as being of **Negligible** significance.

**Table 4.7 : Predicted MGLCs of 1-hour average $H_2S$ (µg/m$^3$) from 7 MW Geothermal Plant Operation**

| Receptor ID | Description | Predicted 1-hour average (99.9$^{th}$ percentile) $H_2S$ Concentration (µm$^3$) | |
|---|---|---|---|
| | | Rankine steam condensing Option | Binary/ORC Option |
| 1 | Boiling Lake | 0.0003 | 0.006 |
| 2 | Copt Hall | 1. 5 | 0.3 |
| 3 | Fond Cani (north) | 8.0 | 2.3 |
| 4 | Fond Cani (south) | 0.9 | 0.3 |
| 5 | Fresh Water Lake | 0.008 | 0.003 |
| 6 | Laudat_North | 8.8 | 1.1 |
| 7 | Laudat_South | 5.6 | 5.1 |
| 8 | Laudat_West | 14.9 | 2.9 |
| 9 | Morne Prosper | 1.2 | 0.1 |
| 10 | Shawford | 1.7 | 0.5 |
| 11 | Trafalgar_East | 2.7 | 0.5 |
| 12 | Trafalgar_South | 1.2 | 0.2 |
| 13 | Trafalgar_West | 3.5 | 0.9 |
| 14 | Valley of Desolation | 0.008 | 0.007 |
| 15 | Wotten Waven | 0.3 | 0.02 |
| Highest at Morne Trois National Park | | 85 | 28 |
| Highest within modelling domain | | 1110 | 8210 |

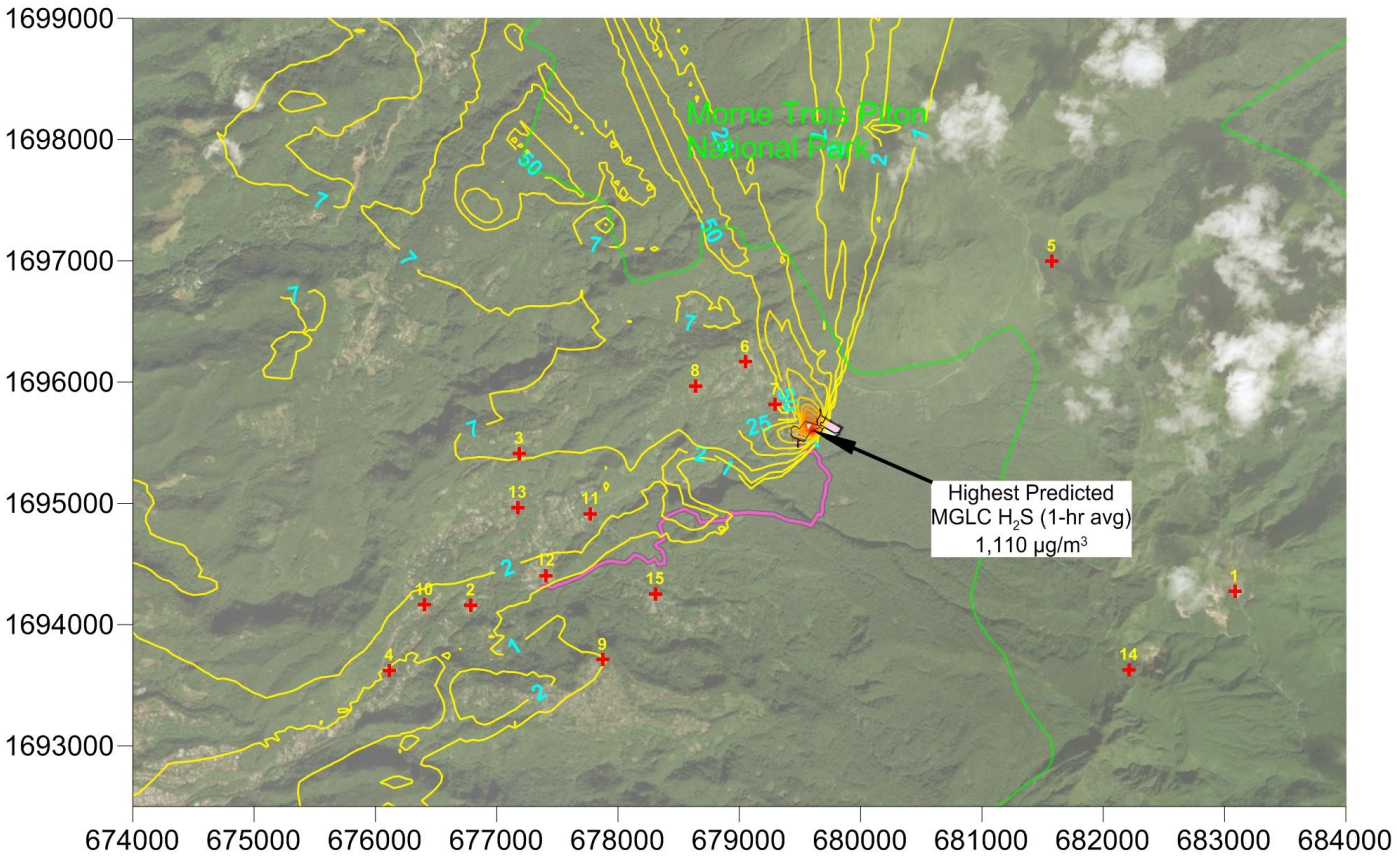


**Figure 4.1 : Predicted MGLCs as a 99.9th %ile 1-hour average of $H_2S$ (µg/m³) from 7 MWe Geothermal Plant Operation (Rankine Steam Condensing Option)**

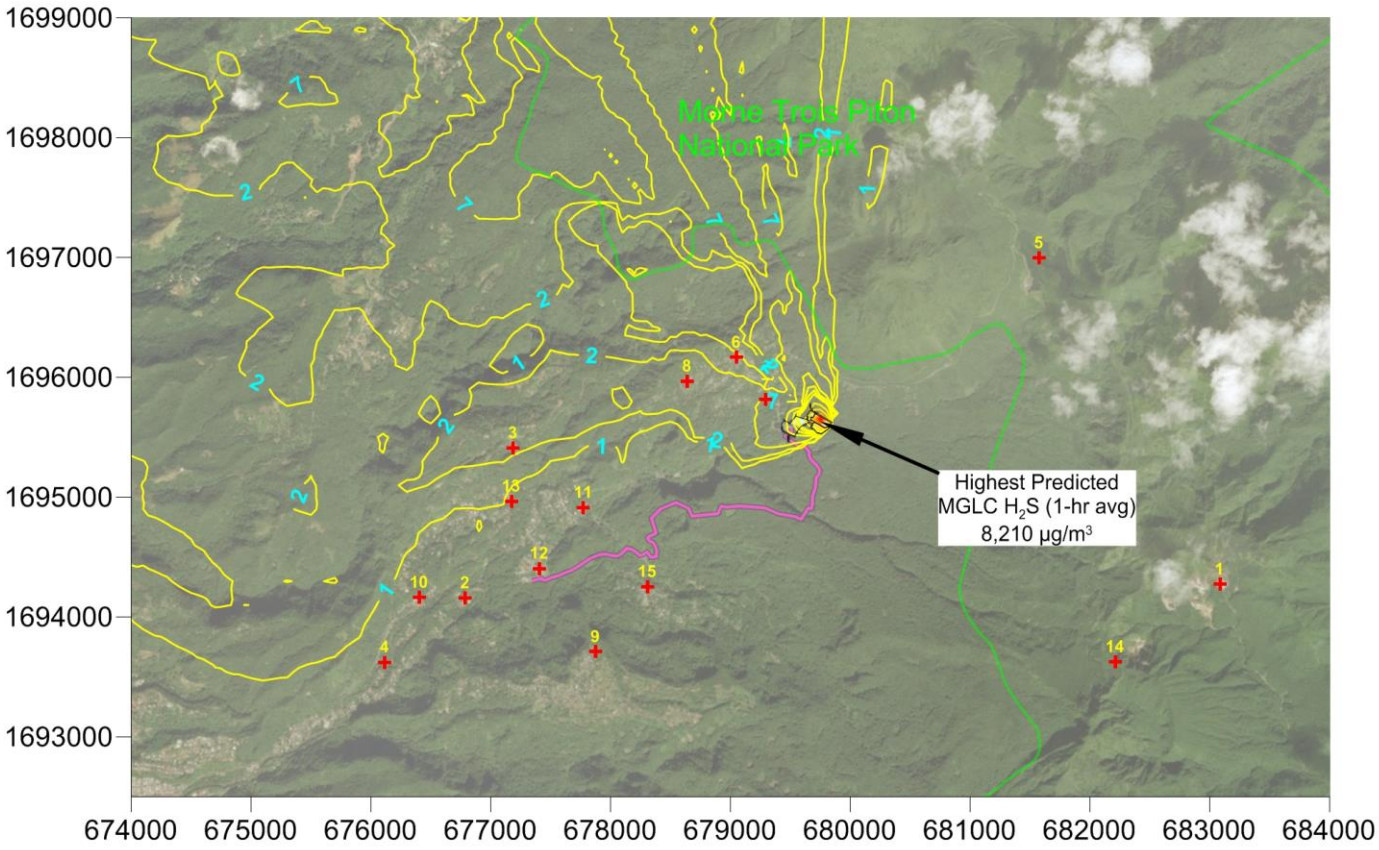


**Figure 4.2 : Predicted MGLCs as a 99.9th %ile 1-hour average of $H_2S$ (µg/m³) from 7 MWe Geothermal Plant Operation (ORC Option)**

Predictions of $H_2S$ as 24-hour averages indicate are provided in Table 4.8 below, and similarly concentrations of $H_2S$ are below the WHO guideline for $H_2S$ of 150 µg/m³ at all sensitive receptors. Concentrations near the power plant are predicted to exceed this guideline value, with the 150 µg/m³ limit exceeded beyond the power plant boundary in a very limited area, but not where there are residences.

Highest predicted 24-hour average concentrations of $H_2S$ at the Morne Trois National Park occur at the boundary to the north northwest of the power plant, with the maximum concentrations being 7 µg/m³ for the ORC option and 23 µg/m³ for the Rankine steam condensing option, see Figure 4.3 and 4.4. This indicates the likelihood of odour impacts at this location from the plant, but health and ecosystem impacts will be low.

**Table 4.8 : Predicted MGLCs of 24-hour average $H_2S$ (µg/m³) from 7 MWe Geothermal Plant Operation**

| Receptor ID | Description | Predicted 1-hour average (99.9th percentile) $H_2S$ Concentration (µm³) | |
|---|---|---|---|
| | | Rankine Steam Condensing Option | Binary/ORC Option |
| 1 | Boiling Lake | 0.03 | 0.14 |
| 2 | Copt Hall | 0.21 | 0.04 |
| 3 | Fond Cani (north) | 2.48 | 0.34 |

| Receptor ID | Description | Predicted 1-hour average (99.9th percentile) $H_2S$ Concentration ($\mu m^3$) | |
|---|---|---|---|
| | | Rankine Steam Condensing Option | Binary/ORC Option |
| 4 | Fond Cani (south) | 0.18 | 0.03 |
| 5 | Fresh Water Lake | 0.05 | 0.05 |
| 6 | Laudat_North | 3.62 | 0.30 |
| 7 | Laudat_South | 0.98 | 1.01 |
| 8 | Laudat_West | 2.72 | 0.50 |
| 9 | Morne Prosper | 0.55 | 0.15 |
| 10 | Shawford | 0.49 | 0.07 |
| 11 | Trafalgar_East | 0.84 | 0.07 |
| 12 | Trafalgar_South | 0.19 | 0.04 |
| 13 | Trafalgar_West | 1.46 | 0.15 |
| 14 | Valley of Desolation | 0.02 | 0.04 |
| 15 | Wotten Waven | 0.18 | 0.03 |
| Highest at Morne Trois Pitons National Park | | 23 | 7 |
| Highest within modelling domain | | 720 | 4110 |

The highest measured background concentration of $H_2S$ measured as part of the baseline assessment is 19 $\mu g/m^3$, which if added to the model predictions results in concentrations that remain well below the LOAEL of 15,000 $\mu g/m^3$ and the 24-hour average guideline of 150 $\mu g/m^3$ at all receptors. This is therefore considered to have a **Negligible** level of potential impact on the surrounding environment.

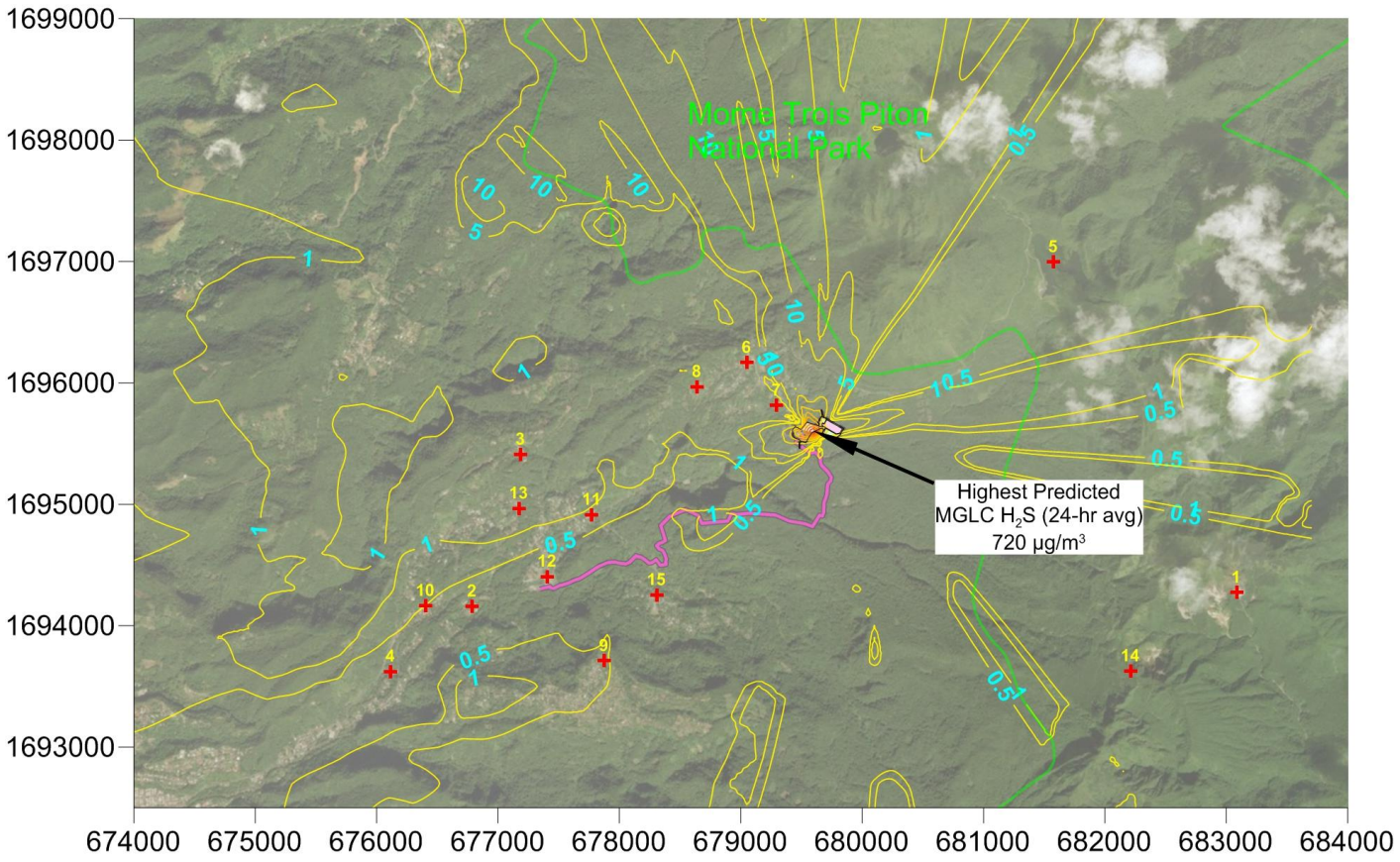


**Figure 4.3 : Predicted MGLCs of 24-hour average $H_2S$ (µg/m³) from 7 MWe Geothermal Plant Operation (Rankine Steam Condensing Option)**

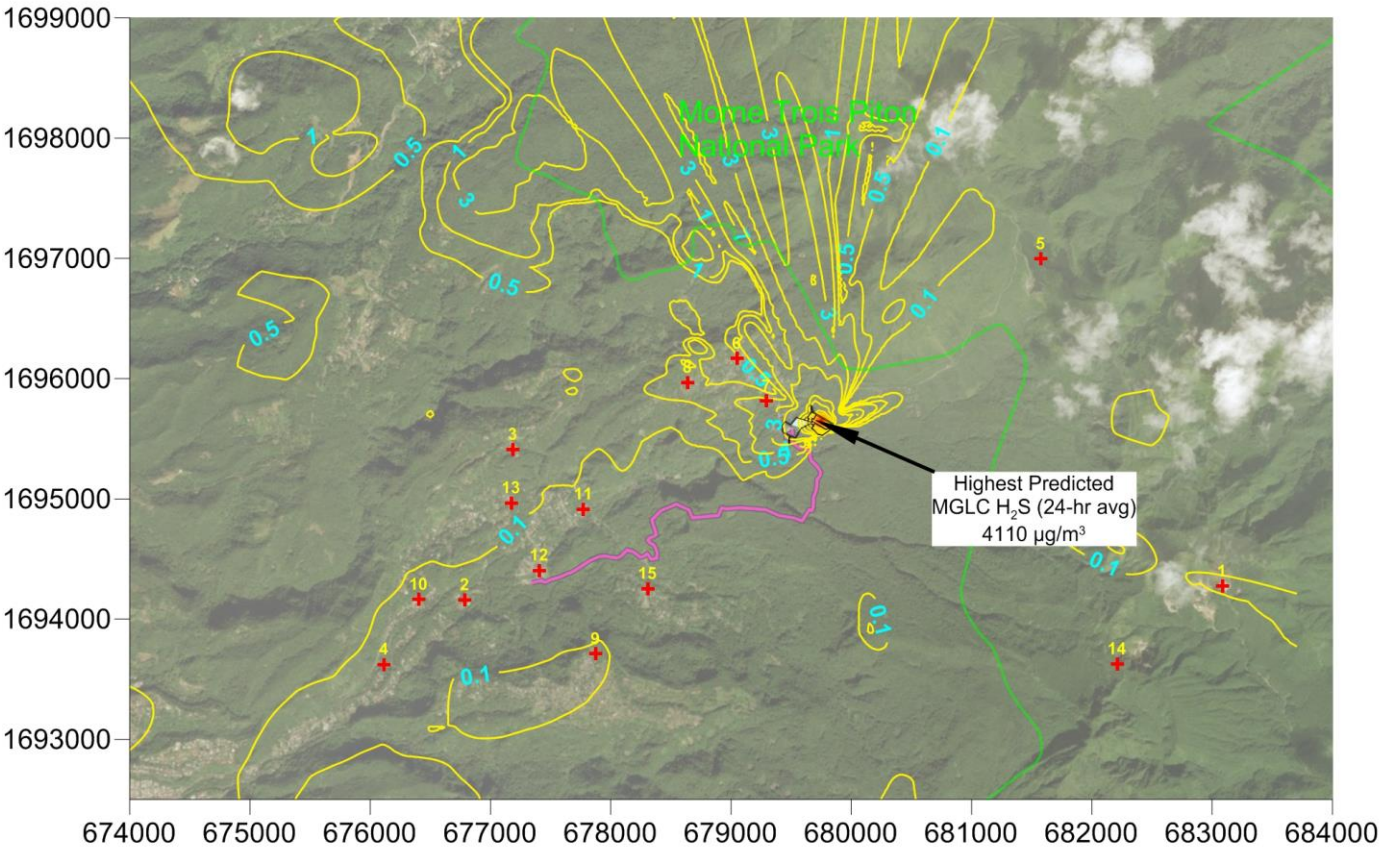


**Figure 4.4 : Predicted MGLCs of 24-hour average $H_2S$ (µg/m³) from 7 MWe Geothermal Plant Operation (ORC Option)**

### Mercury (Hg)

The annual average mercury concentrations predicted by the modelling at the sensitive receptors during operation of the power plant are provided in Table 4.9 below. The highest annual average ground level mercury concentration was predicted to be 0.53 µg/m³, and occurs near the Project boundary. This is below the WHO ambient air guideline for inorganic mercury of 1 µg/m³. Concentrations are much lower at the sensitive receptors, and the MTPNP with the highest predicted concentration at sensitive receptors being 0.003 µg/m³. Given the low concentrations of mercury predicted, which are likely to be significantly lower as the mercury concentrations in the steam is expected to be well below the upper range found in geothermal resources. Mercury discharges are therefore considered to have a **Minor** adverse level of potential impact on the surrounding environment.

**Table 4.9 : Predicted MGLCs of Annual average Mercury (µg/m³) from 7 MWe Geothermal Plant Operation**

| Receptor ID | Description | Predicted 1-hour average (99.9th percentile) $H_2S$ Concentration (µm³) | |
|---|---|---|---|
| | | Rankine Steam Condensing Option | Binary/ORC Option |
| 1 | Boiling Lake | 9.7E-08 | 2.4E-05 |
| 2 | Copt Hall | 4.5E-06 | 1.5E-04 |

| Receptor ID | Description | Predicted 1-hour average (99.9th percentile) $H_2S$ Concentration ($\mu m^3$) | |
|---|---|---|---|
| | | Rankine Steam Condensing Option | Binary/ORC Option |
| 3 | Fond Cani (north) | 4.5E-04 | 1.8E-03 |
| 4 | Fond Cani (south) | 2.9E-06 | 1.3E-04 |
| 5 | Fresh Water Lake | 1.3E-07 | 3.5E-05 |
| 6 | Laudat_North | 3.0E-05 | 2.6E-03 |
| 7 | Laudat_South | 2.2E-05 | 7.2E-04 |
| 8 | Laudat_West | 1.6E-04 | 2.0E-03 |
| 9 | Morne Prosper | 3.1E-06 | 4.1E-04 |
| 10 | Shawford | 9.2E-06 | 3.6E-04 |
| 11 | Trafalgar_East | 2.3E-05 | 6.1E-04 |
| 12 | Trafalgar_South | 3.8E-06 | 1.4E-04 |
| 13 | Trafalgar_West | 6.6E-05 | 1.1E-03 |
| 14 | Valley of Desolation | 7.7E-08 | 1.5E-05 |
| 15 | Wotten Waven | 7.6E-07 | 1.3E-04 |
| Highest at Morne Trois National Park (at park boundary) | | 1.9E-04 | 4.4E-05 |
| Highest within modelling domain | | 3.4E-01 | 5.3E-01 |

**Summary of Impact Assessment**

The predicted highest one-hour maximum ground level $H_2S$ concentration as a 99.9 %ile was 1,200 µg/$m^3$ and this occurs within 50 m downwind from the source. This value is well below the WHO lowest observable adverse effect level (LOAEL), of 15,000 µg/$m^3$ and is considered to have a **Negligible** impact.

Overall, it is considered that there would be **Negligible** impact on receptors with regard to odour, due to the low concentrations predicted at the main residential areas and a likely desensitised local population.

There will be **Negligible** nuisance dust impacts during the operation of the power plant.

Combustion emissions from the operation of the Project will be restricted to occasional use equipment such as emergency generators, firewater pumps, and maintenance vehicles. As such, it is considered that the potential impact on people living and working in the surrounding area from combustion emissions will be of **Negligible** significance.

## 4.4 Mitigation and Monitoring Measures

### 4.4.1 Mitigation

**Construction**

Although the unmitigated impacts of nuisance dust are not considered to be significant in the wider context of the Project, there could be individual residences within closer proximity to construction sites, as well as local use of near-by walking tracks and farming areas. The Project will apply good working practices to minimise potential dust impacts through mitigation techniques such as water suppression, covering or enclosed storage of aggregates (including topsoil and sand) where practical, and limiting dust generation activities in high winds or specific wind directions, if required.

The EPC Contractor will develop an Air Quality Management Procedure that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the document. The Air Quality Management Procedure will include the following measures:

- Construction vehicles will be periodically checked to ensure that they are not emitting excessive pollutants.
- Construction dust will be suppressed with water applied by water sprinklers and/or water carts. For access tracks, it is recommended that water is sprayed on roads at least twice a day during the dry periods.
- Dust on the wheels of vehicles will be removed through wheel washing prior to leaving the site.
- Vehicle speed on the construction site will be set to a maximum of 15 mph to reduce dust release from road surfaces.
- In the event of high winds during dry periods, it may be necessary to cease some construction activities until the wind subsides.
- When transporting material that is prone to wind blow, vehicles will be equipped with a tarpaulin cover when passing through residential areas.
- Windblown material from stockpiles of soil, aggregate, sand etc. will be held in bins or other enclosures, and stockpiles of material including soil, and where practicable covered with a tarpaulin.
- To reduce windblown material, the EPC Contractor will sow grass seed on soil stockpiles that will remain dormant for more than three months.

**Operation**

The O&M Contractor will ensure the following:

- Routine maintenance checks will be undertaken on wellheads and blowout prevention equipment to check it is in operable condition.
- If a wet cooling tower system is to be used for the Project, drift eliminators will be incorporated into the final design to minimise particulate emissions.
- Impacts from the operational station will be dependent on the geothermal fluid chemistry and the plant design. Given the predicted level of effects is predicted to be at an acceptable level, additional measures such as total or partial re-injection of gases with geothermal fluids; and abatement systems to remove hydrogen sulphide emissions from NCGs (e.g. wet/dry scrubbers), are not required.

### 4.4.2 Monitoring

**Construction**

To determine the effectiveness of dust mitigation measures used during construction, the EPC Contractor will ensure that ambient air monitoring is undertaken on the site boundary. DGDC will monitor the performance of the EPC Contractor. Sampling should be conducted for:

- Visual dust inspection of the site on a daily basis during the dry season to gauge the effectiveness of dust mitigation measures will occur at least 400m from construction works.
- The monitoring provides a means of ensuring control systems such as dust suppression sprays are operating correctly and should be undertaken by a qualified laboratory using appropriate sampling equipment. Visual inspections of cleaning truck tyres and road watering activities will also be monitored and recorded. The results will be reported on a monthly basis and included in publicly available reports.

As part of good working practice the EPC Contractor will complete routine checks on dust generation from construction activities, and confirm that dust suppression and appropriate storage is being used where required. In addition, a mechanism for complaints regarding dust will be available to locals, and due regard given to any issues raised.

Safety monitoring systems with warning alarms for high emissions of potentially hazardous gases, including $H_2S$, incorporated at the well sites (e.g. the power plant and reinjection sites), as well as providing direct safety measures in the event of a blowout, will highlight potential H2S emissions issues which could arise during well commissioning and operation. All personnel and local residents will be made aware of the procedure should an alarm be activated.

**Operation**

The O&M Contractor will ensure the following monitoring is undertaken during operation:

- Ambient monitoring for $H_2S$ can be easily undertaken at sensitive locations (e.g. nearby residential areas) using low-level ambient $H_2S$ monitors such as Odalog, which can be deployed at multiple locations for up to two months at a time.
- Safety monitoring systems with warning alarms for high emissions of potentially hazardous gases will continue to operate during the Operation Phase.
- For the Organic Rankine Cycle option, there will be infrared heat detectors and pentane vapour monitors installed at the power plant site around the working fluid condenser/equipment and cooling tower, for early detection of any leaks of pentane or heat sources.
- All heat and pentane sensors if an ORC plant is selected will be checked and calibrated on an annual basis or as per the manufacturer's specifications.

DGDC will monitor the performance of the O&M Contractor.

## 4.5 Assessment of Residual Impacts

Following the application of the mitigation measures described above, the residual impacts from the construction and operation of the power plant and the reinjection pipeline route are expected to be of **Negligible** significance.

# 5. Greenhouse Gas Emissions

## 5.1 Introduction

This section describes the emissions of greenhouse gases (GHGs) from the construction and operation of the Project and associated impacts. One of the benefits of the nature of the Project is the change from the combustive nature of diesel fuelled power of Dominica to production of electricity without the combustion of fossil fuels.

## 5.2 Methodology

### 5.2.1 Greenhouse Gas Accounting

GHGs is a collective term for a range of gases that are known to trap radiation in the upper atmosphere, where they have the potential to contribute to the greenhouse effect (global warming). Creating an inventory or accounting for the likely GHG emissions associated with a Project has the benefit of determining the scale of the emissions and providing a baseline from which to develop and deliver GHG reduction options, if applicable. GHGs include:

- Carbon dioxide ($CO_2$) – by far the most abundant, primarily released during fuel combustion.
- Methane ($CH_4$) – from the anaerobic decomposition of carbon based material (including enteric fermentation and waste disposal in landfills).
- Nitrous Oxide ($N_2O$) – from industrial activity, fertiliser use and production.
- Hydrofluorocarbons (HFCs) – commonly used as refrigerant gases in cooling systems.
- Perfluorocarbons (PFCs) – used in a range of applications including solvents, medical treatments and insulators.
- Sulphur hexafluoride ($SF_6$) – used as a cover gas in magnesium smelting and as an insulator in heavy duty switch gear.

It is common practice to aggregate the emissions of these gases to the equivalent emission of $CO_2$. This provides a simple figure for comparison of emissions against targets. Aggregation is based on the potential of each gas to contribute to global warming relative to $CO_2$ and is known as the global warming potential (GWP). The resulting number is expressed as carbon dioxide equivalents (or $CO_2e$).

### 5.2.2 Emission Sources

During the operation phase, the Project will reduce GHG emissions by displacing a portion of the electricity generated in the Dominica grid, currently produced by diesel generation.

GHG emission quantification is calculated in accordance with the principles of the Greenhouse Gas Protocol (GHG Protocol), with reference to World Bank Performance Standards. These state that a project producing more than 25,000 tonnes $CO_2$-e per year shall quantify direct and indirect emission in accordance with internationally recognised methodologies and good practice. World Bank encourages the Project to publically report when emitting over 25,000 tonnes. This value has been referenced when determining the Project's requirement for GHG emissions reporting.

There are currently no published guidelines for determining the significance of GHG emissions from projects in ESIAs, due to the problematic nature of linking a single power plant to individual climate change impact level on nearby receptors.

The GHG emissions can be split into three categories known as 'Scopes'. Scopes 1, 2 and 3 are defined by the GHG Protocol and can be summarised as follows:

- **Scope 1** – Direct emissions from sources that are owned or operated by a reporting organisation (examples – combustion of diesel in company owned vehicles or used in on-site generators).
- **Scope 2** – Indirect emissions associated with the import of energy from another source (examples – import of electricity or heat).
- **Scope 3** – Other indirect emissions (other than Scope 2 energy imports) which are a direct result of the operations of the organisation but from sources not owned or operated by them (examples include business travel (by air or rail) and product usage).

The GHG Protocol (and many other reporting schemes) dictates that reporting Scope 1 and 2 sources is mandatory, whilst reporting Scope 3 sources is optional. Reporting significant Scope 3 sources is recommended. As guidance, reference has been made to the Equator Principles III (2013), which considers Scope 1 and 2 emissions only and excludes Scope 3 emissions (for example construction works), as these types of emissions are not operationally controlled by the Project. For this reason, construction emissions were not considered as part of this assessment.

## 5.3 Assessment of Impacts

### 5.3.1 Scope 1

The operation of the geothermal power plant will emit $CO_2$ with the potential of very minor $CH_4$ and $H_2S$ emissions. The $CO_2$ emissions will be generated from the specific steam consumption, of which 1.6% of this is predicted to be in the form of NCGs, a natural component of geothermal fluids. Of the NCGs produced, 94% is estimated to be $CO_2$. An emission factor of 1.62 kg $CO_2$ per MW/hr has been calculated based on the 7 MW output of the power plant and the 3 kg/sec/MW of specific steam consumption. Based on this, $CO_2$ emissions have been estimated to be 9,462 tonnes per annum for Scope 1 GHG emissions.

### 5.3.2 Scope 2

The Project's energy consumption is expected to be a small component of the total MW generated by the Project and as such will not require purchase of electricity from the Dominica Grid. It is therefore anticipated that the Project will emit **Negligible** Scope 2 GHG emissions.

## 5.4 Mitigation and Monitoring Measures

The use of a geothermal renewable energy source for power production is itself considered to be a form of mitigation against the use of fossil fuel derived energy generation. Therefore, no additional mitigation measures are deemed necessary.

## 5.5 Assessment of Residual Impacts

Total GHG emissions are estimated to be 9,462 tonnes $CO_2$-e per year for the Project. With reference to the 25,000 tonnes $CO_2$-e per year threshold for the requirement of publically reporting of GHG emissions, it is not considered necessary to report annually on GHG emissions. The total $CO_2$-e per year is considered to be significantly less than a fossil fuel derived energy source and therefore the Project is considered to have **Moderate Beneficial** significant impact.

# 6. Geology, Soils and Groundwater

## 6.1 Introduction

This section describes the potential impacts to geology, soils and groundwater from the construction and operation of the Project and sets out mitigation measures to minimise any impacts.

## 6.2 Methodology

This assessment utilises baseline data on the geology, soils and groundwater that typically occur within Dominica and in particular within the Project area, as described further in Section 3.12. Using the impact identification criteria as set out in Section 2, the assessment will then draw a conclusion on the likely impacts to the proposed Project on geology, soils and groundwater.

## 6.3 Assessment of Impacts

**Construction**

Construction has the potential to have an impact on soils, geology and groundwater through various activities, including the installation of drainage channels, removal of topsoil and through accidental soil contamination:

- Construction of the power plant, laydown and worker's camp areas (estimated to be 32,144 $m^2$ (3.2 ha)) will generally avoid the removal of soil and will utilise cut and fill evenly. Top layers of vegetation and topsoil (estimated to be 350- 500mm) will need to be stripped and reused as landscape bunding on site. As a worst-case scenario, this would require 16,072 $m^3$ of soil required for reuse on the site. Without measures to fix the soil in place potential impacts of soil removal are determined to be of **Minor** significance.
- For the reinjection line the footings for pipe supports and construction of pipe bridges will require soil removal but this will be relatively shallow therefore would not be removed from site. The reinjection line will sit above ground and the foundations would need localised clearing (under 5 $m^2$ each, every 50 m along the pipeline), to ensure they are on even ground to prevent settlement. The route may also need some localised earthworks if it encounters a high or low spot to maintain a relatively constant grade. The Breakfast River Gorge Bridge foundations would be similar to the pipe supports in that they would be relatively localised earthworks. As a worst-case scenario, due to the relatively low volumes of required for removal (estimated to be ~100 $m^3$), this potential impact is determined to be of **Negligible** significance.
- There are no planned discharges of hazardous substances or waste to land during all construction activities. The only potential for hazardous substances and/or waste to enter the environment and cause an impact is if the material is inappropriately used or stored causing an accidental spillage and land contamination. There is potential for hazardous substances or waste to be accidentally discharged to the environment if inappropriately collected and stored on site. Without appropriate mitigation measures in place, this potential impact is determined to be of **Moderate** significance.

**Operation**

With regards to potential operational impacts on soils and geology these all relate to potential contaminants entering the soil from the following infrastructure:

- Brine collection and disposal system – the brine from the separators will pass through a brine collection drum and then onto a disposal network of pipes. The brine will then be discharged into reinjection wells WW-R1 and WW-01 via the brine injection pipeline. The pipeline will also have drain at any low points for draining down the line on shutdown in order to prevent silica polymerising in the lines. These drain points will be connected to lined sumps for subsequent disposal into the reinjection wells WW-03.

- Condensate collection and disposal system – condensate produced in steam pipelines is generally collected via a condensate collection drain pot found at low points along the pipeline route, with this condensate disposed of via a steam trap. The condensate can be pumped to reinjection well WW-03.
- Storage sump – Sumps are normally used to store brine or condensate discharged due to operational upsets. Only one sump is required for this development as the power plant is relatively close to the wellhead. This sump will be lined, with the contents removed via pumps for subsequent disposal into the reinjection wells WW-03.
- Spillage from hazardous chemicals – a range of potentially hazardous material will be stored and used on site including acid, antiscalant, caustic soda, biocide, dispersant and turbine oil. All of these chemicals will be stored in bunded enclosures with any residual material collected following completion of use.

When the power plant is operational, there are a number of potential impact pathways for groundwater as outlined below:

- Drainage of the steamfield piping system due to plant shutdown: during a planned or emergency shutdown, large volumes of brine and condensate will require disposal through reinjection or storage in lined ponds.
- Drawdown in shallow aquifer system during operation of production wells: a decrease in pressure of the deep geothermal reservoir may cause a long term effect on piezometric levels in the shallow aquifer that could lead to a reduction in spring flow.

*Minor Power Plant Discharges*

There are numerous minor power plant discharges that will occur during the life of a station. The majority of these discharges consist of condensate from steam scrubbers, demister, rock muffler drains, and other condensate drains that will flow into the proposed sump. These flows are generally small and will mainly comprise of condensate, and given the low mineralisation of condensate, the impacts of the environment are considered to be of **Negligible** significance for this activity.

**Steamline Discharges**

The steam pipelines are proposed to be designed with drain pots at regular intervals and/or low points to collect any liquid that condenses from the steam during normal operations. Any condensate produced will be dependent on the composition and will be disposed of with power station condensate by injection. The concentration levels of the condensate are significantly less than that of the brine and as such, it is considered that discharge from the steam traps will be of **Negligible** significance.

*Pipeline Drainage*

It is proposed to install sumps along the reinjection pipeline corridor. It will be necessary to drain brine from pipelines in the infrequent event of a prolonged power plant shut-down or for preventative maintenance or inspections. The draining of fluid from the reinjection pipeline and associated vessels is required in order to prevent the build-up of silica scale within the pipe. The number of low points will be kept to a minimum since each low point will require a local lined sump to drain that section of accumulated fluid on shutdown of the steamfield. Discharge to the sumps is infrequent and expected to only occur a few times per annum. As the brine will be drained into a lined sump before disposal into the reinjection well, it is considered that this discharge will be of **Negligible** significance.

**Drawdown in Shallow Aquifer**

There is the potential for a decrease in pressure of the deep geothermal reservoir during production, which could result in decreasing piezometric levels in the shallow aquifer if the two aquifers are hydrologically connected. It is anticipated that any effects of this kind would be localised, with the main potential impact being a reduction in spring flows. However, as no cold water springs have been identified in the vicinity of the proposed power plant, it is considered that this potential impact is of **Negligible** significance.

## 6.4 Mitigation and Monitoring

### 6.4.1 Mitigation

**Construction**

The EPC Contractor will develop an Erosion and Sediment Control Procedure and Hazardous Substances Management Procedure that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the documents.

The EPC Contractor and Subcontractors will ensure that they undertake the following mitigation activities:

- Excavated earth should be strongly compacted and cut-off ditches should be dug in erosion prone areas to divert water away for the earthworks and to settling ponds before discharge to nearby water courses.
- Along the reinjection pipeline route catchment areas will be kept to small sizes with their own temporary drains and specific treatment devices.
- Silt curtains, fibrous mats etc. will be placed across as temporary stormwater drains to reduce the efflux velocity of the water and to aid settling of suspended sediment from the water.
- Spill kits should be located on the construction site to manage and contain any fuel or hazardous substance spillage. If an accident does occur, then contaminated soil should be excavated and replaced with clean fill to minimise (or prevent) groundwater contamination with treatment of any stormwater runoff or process water prior to disposal.
- All wastewater should be collected prior to discharge.
- Oily and/or hazardous waste will be separately collected and disposed of by an appropriately licensed operator.
- All vehicle maintenance should be done in garages.
- The laying of overland flow diversion drains and preload fill should be completed preferable during the dry season and prior to the power plant construction earthworks commencing.
- Drainage water collection and treatment systems should be installed as a priority to prevent discharge to the adjacent rivers and streams.
- The EPC Contractor and Subcontractors will ensure that they undertake the following mitigation activities:
- Excavated topsoil will be transported to, and stockpiled in, designated topsoil storage areas.
- Prior to filling, sub-grade surfaces of depressions will be free of standing water and unsatisfactory soil materials will be removed.
- All unnecessary excavated materials will be transported and deposited outside of the site at an approved facility.
- Where excavated material is suitable to be used for fill and backfill, the material will be segregated and transported to a stockpile location at the construction site.
- Excavated topsoil will be transported to, and stockpiled in, designated topsoil storage areas.
- Prior to filling, sub-grade surfaces of depressions will be free of standing water and unsatisfactory soil materials will be removed.
- All unnecessary excavated materials will be transported and deposited outside of the site at an approved facility.
- Where excavated material is suitable to be used for fill and backfill, the material will be segregated and transported to a stockpile location at the construction site.

**Operation**

The mitigation for soils, geology and groundwater issues will be the same as that stated above during the construction phase, under the management of the O&M Contractor.

### 6.4.2 Monitoring

During the Construction Phase the EPC Contractor will undertake routine monitoring of any spring flows (cold water), both baseline and during development in order to determine any potential effects on the system. DGDC will monitor the performance of the EPC Contractor. This responsibility will pass to the O&M Contractor during the Operation Phase.

## 6.5 Residual Impacts / Summary

Based on the assessment completed, there will be residual impacts on soils, geology and groundwater will be of **Negligible** significance and are therefore not considered significant.

# 7. Hydrology

## 7.1 Introduction

This section describes the potential impacts to the hydrology of the local area from the construction and operation of the Project and sets outs mitigation measures to minimise any impacts.

The hydrology assessment considers two main Projects aspects: the potential impacts of the power plant and reinjection pipeline. It has been assumed that road infrastructure to the site will maintain natural water courses and culvert and fords will be adequately designed (post-Hurricane Maria) to meet the flood flows expected in the region. Hurricane Maria resulted in damage to a number of roads and bridges (DGDC, 2017) and highlights that need for the local government to improve drainage infrastructure on the access roads.

## 7.2 Methodology

The hydrology assessment utilises data collected from previous studies as described in Section 3.5. Significance of impacts are assessed using the general process described above in Section 2.

## 7.3 Assessment of Impacts

### 7.3.1 Key Activities

The following activities are considered in the assessment of potential impacts for hydrology:

**Power Plant Construction**

- Water supply demand for workers (potable), vehicle and equipment washdown and firefighting reserve. Concrete mixing has been assumed to be undertaken off site (brought in via trucks).
- Stormwater management on site (including capture of runoff in sumps, development of diversion drains and treatment/discharge of runoff).

**Reinjection Pipeline Construction**

- Water supply for construction staff and concrete mixing for foundations. Water take will be minimal and will be taken from a local watercourse, mostly likely Roseau River.

**Power Plant Operation**

- Firewater to be stored at site (minimum of 500 $m^3$ as outlined in ESIA Volume 5: Technical Appendices (Process Description).
- Potable and grey water (water for toilets, showers) for up to three staff as outline in ESIA Volume 5: Technical Appendices (Process Description).
- Flooding risk from Titou Gorge Stream.
- Permanent stormwater capture, treatment and discharge.
- Potential for stimulation of well WW-R1 by pumping cold water from the Roseau River to increase well injection capacity. This would require 51,840 $m^3$ of water to be pumped into WW-R1 at a rate of 20 litres/s over a 1 month period.

**Reinjection Pipeline Operation**

- Flooding risk at the various pipeline stream crossings (pipe bridges).

This assessment does not consider the storage or discharge of brine or condensate associated with operation of the power plant. Further descriptions of each of the impacts identified above are documented below.

### 7.3.2 Power Plant Construction

Construction of the proposed plant layout as presented has a land requirement estimate of 20,000 $m^2$ (2 ha), for the binary plant option – including laydown / spoil areas (refer to ESIA Volume 1: Introduction, Section 3.4 – Land Requirements). Approximately 10% of the power plant site will be concreted and the rest covered with gravel. This will occur next to the existing WW-P1/WW-03 site which is ~5,000 $m^2$ (0.5 hectares). The combined area of 2 ha is hereafter referred to as the 'construction pad'.

No permanent water courses appear to exist that drains through the site, while there is evidence of ephemeral stream/spring channels from site visits (see Figure 7.1). During torrential rain it would be expected that an overland flow would occur from the catchment surrounding the power plant across the construction pad. This could lead to difficulties in ground conditions and increased sediment and contaminant discharge to the receiving environment. Inherent design would allow for a diversion drain to divert this water around the site. Compaction of the site and exposed topsoil due to deforestation and land clearing/levelling would be the most direct impact during construction, and would increase runoff and sediment load, thus requiring some form of treatment or retention prior to discharge. The impact of this activity (without treatment) is considered to be of **Moderate** significance.



**Figure 7.1 : Ephemeral stream above proposed power plant location**

During construction, there will be a water demand for workers (potable and toiletry), equipment washdown, concrete mixing and potentially a reserve for fire-fighting. Raw water for construction works shall be drawn from the naturally occurring spring located at a higher elevation above the site. Details of volumes of water required for extraction are provided below in Table 7.1.

**Table 7.1: Proposed Raw Water Supply Information**

| Item | Natural Spring | Unit |
|---|---|---|
| **Raw Water Source Location** | | |
| Latitude | 15°19'58.20" | N |
| Easting | 61°19'34.22" | W |
| Elevation | 623 | mASL |
| **Water take limits** | | |
| Daily | 10,000 | Litres |
| Monthly | 200,000 | Litres |
| Maximum instant | 5 | Litres/s |

Although no flow rates are currently known for the stream, it is estimated that the stream has a flow rate of between 5 – 10 litres/s. Assuming this stream is 5 litres/s, if water is pumped to a 10 $m^3$ plastic tank and at an abstraction rate of one L/s (20% 0f flow rate) then it is estimate that it would take ~167 minutes to fill this tank daily. Based on this and given that there are no known people in the area sourcing water from this stream, the potential impact of abstraction for these activities is considered to be of **Minor** significance.

While there is a risk of flood inundation during construction the likelihood of this occurring is small with the impact considered to be of **Negligible** significance, as construction will be over a short period, will most likely occur in the dry season and will have drainage designs (diversion channels) in place as part of power plant design.

### 7.3.3 Reinjection Pipeline Construction

During construction of the reinjection pipeline, water supply will be the primary hydrological impact. It's likely that potable water potential impacts will be of **Minor** significance, as workers will either bring water from the Roseau or source drinking water from nearby streams. In addition, some pipeline foundations will be concreted and will utilise local supply. Water take will be minimal and will be taken from a local watercourse, mostly likely Roseau River.

Construction of the pipeline near watercourses could cause localised sediment inputs to streams due to soil disturbance. Permanent removal of trees over a proposed 4 m wide and 3.25 km long pipeline route may cause localised increases in surface water runoff due to a lack of canopy storage/interception of rainfall. Due to the temporary nature of these impacts and the high rainfall observed in the Roseau Valley, it is expected that these potential impacts will be of **Minor** significance.

### 7.3.4 Power Plant Operation

Once the power plant is operational, and estimated 2 ha will have a permanent change from soil with forest/scrub cover to a mixture of concrete and gravel pads. The power plants site is anticipated to be 10% concrete and 90% gravel. This will permanently increase localised runoff. The potential impact of this is considered to be of **Moderate** significance, given this leads to a permanent change in runoff characteristics.

The site will most likely have a gradient draining towards a stormwater collection system to prevent surface ponding, which would then be discharged to a nearby water source if the quality is acceptable (likely Titou Gorge Stream). While gravel will be present across a large portion of the site, the compacted pad beneath the gravel will likely have limited capacity infiltration, but some capacity for water storage (depending on the depth of the gravel layer). Higher runoff will occur from the concreted pads and to a lesser extent, the gravel pads, and this increase in discharge would be concentrated into a stormwater drainage channel (as opposed to the natural system being overland flow).

Retention of stormwater prior to discharge downstream may be required to settle any sediments, collect rubbish and act as a temporary holding area for any unforeseen contaminant discharges, (such as oil leaks from vehicles). The discharge following retention could lead to an increase in erosion within the receiving water body and has the potential to affect freshwater habitats. Without appropriate sediment and erosion mitigation in place the potential impact of this is considered to be of **Minor** significance.

Additionally, permanent capture of overland flow from surrounding catchment via diversion drains, which would have been established during construction, will also be required. This will concentrate the overland flow in the diversion drain and discharge this to the receiving environment.

Firewater is to be stored on site in a >500 $m^3$ tank. This would be infrequently filled, and would be abstracted from Titou Gorge Stream. Pumping at a rate that is too high compared to the stream baseflow could lead to the stream running dry for a short period (given spot gauging's show ~50 L/s during the dry season). The potential impact is considered to be of **Minor** significance.

Potable water supply for the workers will be trucked into the plant as bottle water. Grey water for showers, toilets and general washing will be supplied by rainwater collection as advised in ESIA Volume 1: Introduction (Process Description). This negates the requirement for abstraction from Titou Gorge. The potential impact is considered to be of **Negligible** significance.

As outlined in Caraïbes Environnement Développement & Coll (2015a/b), a flood study was undertaken for 10 and 100 year ARI 12 hour storms. The subsequent inundation maps are presented in Figure 7.1. These maps indicate that both events cause flooding from localised tributaries, with a water level depth (above ground) between 0.1–0.25 m. The flood of this magnitude could inundate the power plant and could lead to infrastructure/electrical damage, temporary shutdowns and failure of some systems. Power plant design will incorporate a diversion channel to reduce the likelihood of flooding, however, sizing of the channel is important to capture peak flows. The potential impact of this (on the Project and to the community that rely on the power supply) is considered to be of **Minor** significance.

A risk to the environment in regards to operation of the reinjection pipeline is the unlikely event of a lack in capacity of the reinjection well at full output (WW-R1). Brine is disposed in WW-R1, and if the capacity is inadequate to uptake the brine then a secondary option (following installing a pump station to increase pressures) would be the stimulation of the well with cold water from the Roseau River.

As discussed within ESIA Volume 5: Technical Appendices (Process Description) during operation there may be a requirement to undertake well stimulation in order to increase well injection capacity. This would require 51,840 $m^3$ injected into WW-R1 at a rate of 20 litres/s over a one-month period. The risk of this activity would be a reduction in base flow in the Roseau River which may potentially have adverse impacts on downstream users, ecology and water quality. In the unlikely event that reinjection capacity drops, alternative remedial measures to water abstraction and pumping will be used first. 20 litres/s is ~0.6% of the flow identified in Section 3.5, therefore the risks are considered to be of **Minor** significance, given the likelihood of water abstraction for well stimulation occurring and the minimal flow impacts on the river.

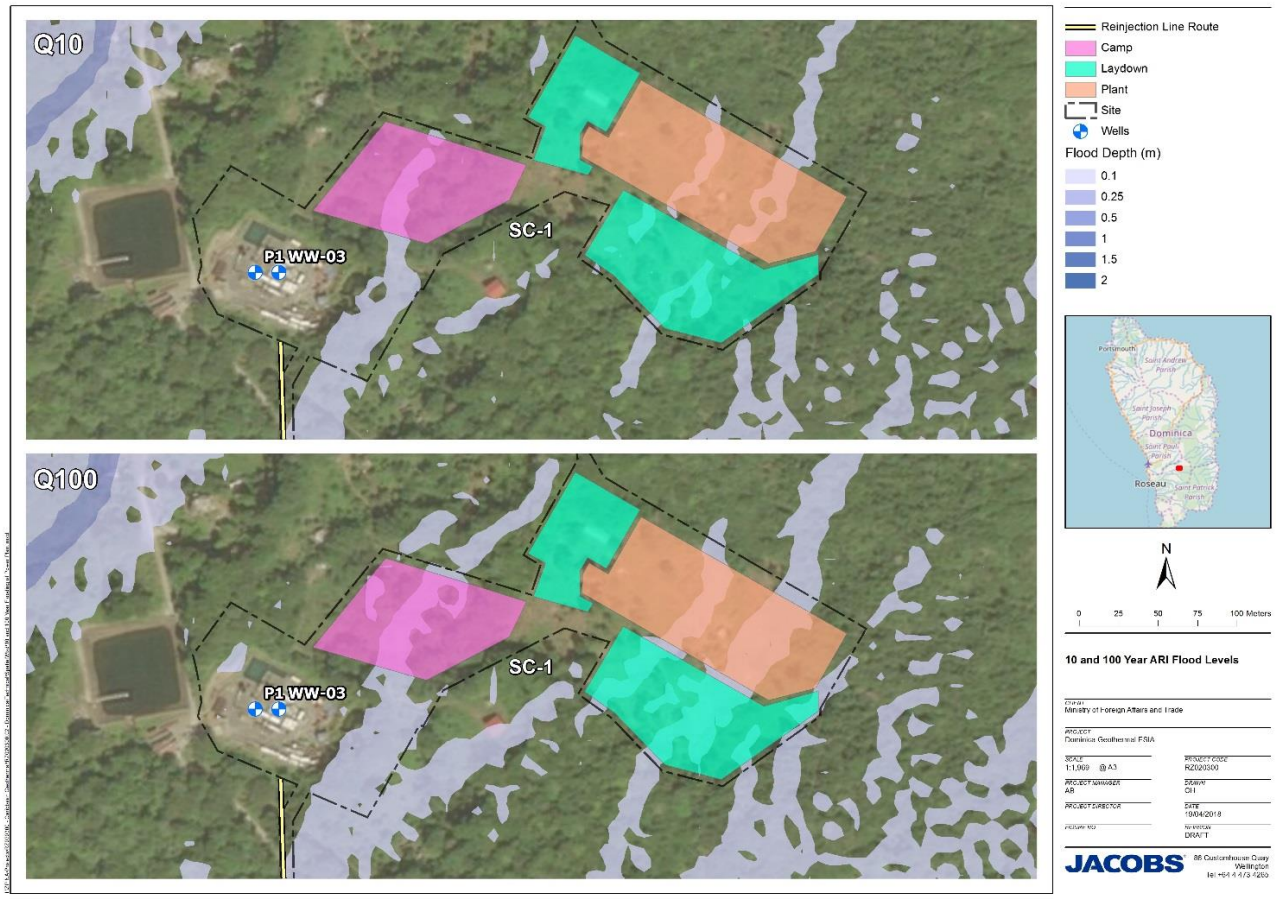


**Figure 7.2 : 10 and 100 yr ARI flood water level maps**

### 7.3.5 Reinjection Pipeline Operation

The primary hydrological risk to the reinjection pipeline will be from flooding. The torrential downpours, annual rainfall >8,000 mm/year (in the upper mountains) and steep nature of the catchments result in a flashy system with high peak flows and velocities.

Subsequently, any pipe crossings (pipe bridges) over waterways will be at risk from potential flood impacts in terms of high water levels and debris carried with these flows. This could cause significant damage or loss of certain areas of the pipeline and is a critical component to the ongoing success of the power plant and energy supply in Dominica. This is a potential impact to the Project's operability and is considered of **Major** significance, given this would critically effect infrastructure and lead to plant shut downs. DGDC (2017) verified that the risk to the re-injection pipeline from debris strike during flooding is of particular importance. Assessment post Hurricane Maria showed the DOMLEC pipeline route from Trafalgar to Padu had been overwhelmed with rocks and river debris, and over 100 m of pipeline was destroyed. A similar fate would have occurred to the geothermal pipeline if it was located in this area and not adequately designed (with sufficient freeboard).

A review of the preferred reinjection pipeline route against the 100 yr ARI flood levels has identified five areas where the pipeline may be affected from flooding or overland flow, with three areas being streams crossings and two being flood inundated areas. These are documented in Figure 7.3. Given the topography is dynamic and the preferred pipeline design may change, the exact levels along the pipeline route have not been reported in this assessment.

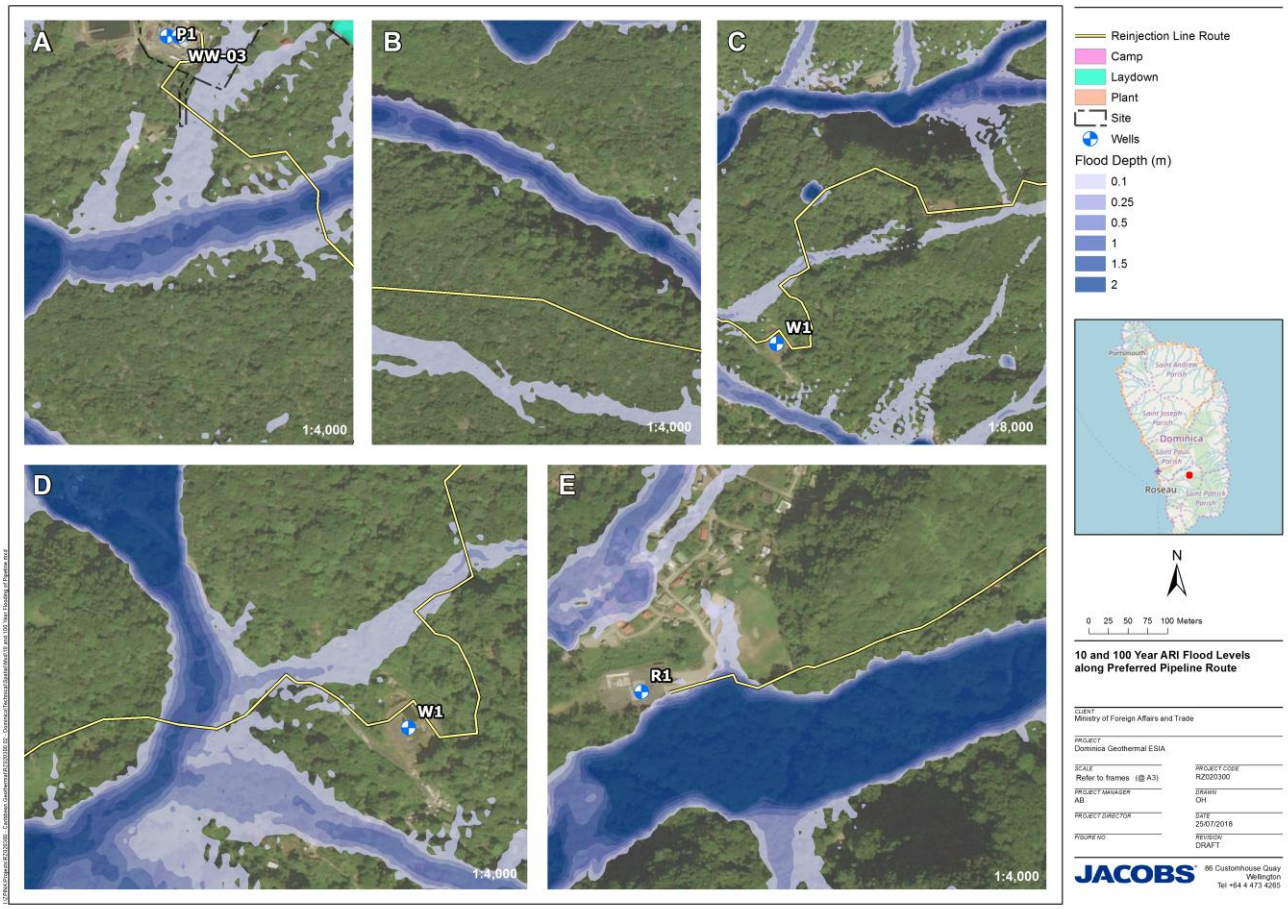


**Figure 7.3 : 100 yr ARI 12 hour flood water levels and the at risk areas of preferred pipeline route.**

## 7.4 Mitigation and Monitoring Measures

### 7.4.1 Power Plant Construction

A Stormwater Management Procedure (SMP) (embedded within the Erosion and Sediment Control Procedure) will be developed by the EPC Contractor before the construction phase. DGDC will be responsible for checking and reviewing the document. All construction mitigation measures outlined below will be the responsibility of the EPC Contractor.

Following surveying of the boundary of the construction pad, diversion drains should be excavated around the perimeter of the site to convey overland flow to appropriate locations downstream. During construction these could be temporary excavations, rock or geotextile lined to reduce erosion.

Direct site runoff from the 3.7 ha should be captured via interceptor ditches and sumps/sediment ponds. In localised areas, sediment runoff could be managed through silt fences. Grading the construction site to ensure runoff is captured and detained in these locations is essential, as its highly likely surface water will be sediment laden and will need some settling before discharge to the nearby Titou Gorge Stream (likely through a decant structure or overflow spillway in a sediment pond).

Any discharges of concentrated flow should be to watercourses that have adequate erosion protection in place to prevent gullying of channels, bank collapse and increased sedimentation downstream. This may require installation of reno mattresses or rock rip rap (adequately sized to convey flows and velocities) at the discharge

point. The remaining channel (if it exists) may require further excavation to convey the increased flows, and subsequently the installation of a permanent channel draining from the construction pad settling ponds to the Titou Gorge Stream would be recommended (a distance of ~250 m). This is documented in Figure 7.3.

Should local water sources be required for meeting some construction demands including vehicle and equipment washdown, the use of a temporary portable storage tank is advised. A 25,000 L plastic tank (3.6 m x 2.8 m) could provide storage for firefighting and water supply, and be topped up from Titou Gorge Stream at low abstraction rates (<2 L/s) to minimise environmental impact. A full assessment of construction water demands will be needed to verify the infrastructure required.

### 7.4.2 Reinjection Pipeline Construction

Minimal impacts to hydrological water courses are expected during the construction of the pipeline. Near stream works will require local sediment controls such as silt fences or downstream sediment traps to reduce the impacts of disturbance. Water supply for concrete mixing will be minimal and infrequent, primarily used for support foundations.

### 7.4.3 Power Plant Operation

All operation mitigation measures outlined below will be the responsibility of the O&M Contractor.

The power plant site and laydown area will require a stormwater system designed to capture and treat any runoff. The diversion drains to divert the overland flow put in place during the construction period will remain and given their permanence, should ideally be enhanced from a temporary channel to one that is lined with concrete or rock rip rap.

For simplicity, the diversion drains could discharge to the permanent channel (see Figure 7.3), as long as the site layout can provide for a grade of <2-3% to reduce velocity. Should this not be the case, a drop structure or more significant erosion prevention mechanism (such as a reno mattress) will be required within the channel.

Initial assessments of topography based off 1 m contour lines and the pad layout in Figure 7.3 show from north to south, there is a 14 m elevation change over ~65 m, indicating that the current linear grade is ~21.3% (>12°). Pad construction will result in benching of the site and subsequent diversion drains.

The power plant's stormwater system should ideally drain through a sump or settling pond. This would capture any runoff from the pad and settle out rubbish and sediment, while reducing flow velocities. Areas of the plant that are at risk of having contaminant discharges (such as oil leaks from vehicles or fluid spills) should be isolated, with their flows first draining through an oil water separator. The outflows from this separator could then drain to the sump/settling pond for further treatment.

Design of the settling pond/sump should take into account the expected rainfall for short duration design storms (i.e. <30 minutes) which will have the highest intensity in a short time period. The settling system would ideally store the volume of a 5 or 10 yr ARI short duration event, however this may vary depending on local design guidelines. Tropical storm Dorothy (August 1970) resulted in 680 mm of rainfall in Fourniols and holds the record for 24 hours of rainfall in the area. The maximum rainfall depth for 10 minutes was 37 mm and for 30 minutes was 92 mm. Monitoring of the effectiveness of the settling pond on sediment should be undertaken during construction and ongoing operations, with spot samples assessed for Total Suspended Solids (TSS) at the inlet and outlet locations. Imhoff settling cones offer a cheap and viable method for quick onsite estimates of TSS from the inlet and outlet.

Outflows from the settling pond could occur through a lined overflow spillway or decant structure into the permanent drainage channel to Titou Gorge. This would be adequately strengthened and sized to maintain regular stormwater flows from both the power plant and the diversion channels. Should steep gradients lead to excessive velocities, a number of mitigations to reduce erosion could be undertaken, including in stream block structures or drop structures.

The final risk to the power plant is from overland flooding. While the power plant design will incorporate diversion drains around the site, the capacity of these drains needs to convey adequate flood events to reduce the likelihood of this occurring. The flood assessment undertaken in Caraïbes Environnement Développement & Coll (2015a/b) indicated some risk of inundation during both storm trials (10 and 100 yr 12 hour event). The rainfall depth of the 100-year event is approximately equivalent to the rainfall during Hurricane Maria as estimated by NASA. This flood assessment utilised a 10 x 10 m digital elevation model (DEM) with an unknown vertical accuracy. This provides some uncertainty around the inundation maps, and could be enhanced using a 1–5 m grid spacing at key sites with the available 1 m contour dataset.

The maximum water depth expected from overland flow at the plant, during the 100 yr event, is 0.25 m above ground level across an area of up to 50 m. Subsequently, the power plant's diversion drains will have to be sized to adequately convey the peak flow expected during this event, from a catchment area of between 5–8 ha.

Initial rational method peak flow assessments were undertaken using the 100 yr ARI storms peak rainfall (147.6 mm/hour) in Caraïbes Environnement Développement & Coll (2015a/b) and a runoff coefficient of 0.6. These indicate:

- 5 ha catchment could have a peak flow of up to 1.2 $m^3/s$; and
- 8 ha catchment could have a peak flow of up to 1.9 $m^3/s$.

Sizing of the drains is a balance between the risk of design storm occurring throughout the project life and the cost/benefit of the infrastructure required to prevent flooding damage from that event. Assuming a 50 year design life, then the risk of occurrence over the project is:

- 9.5% for a 500 year ARI storm;
- 39.5% for a 100 year ARI storm;
- 63.6% for a 50 year ARI storm; and
- 99.5% for a 10 year ARI storm.

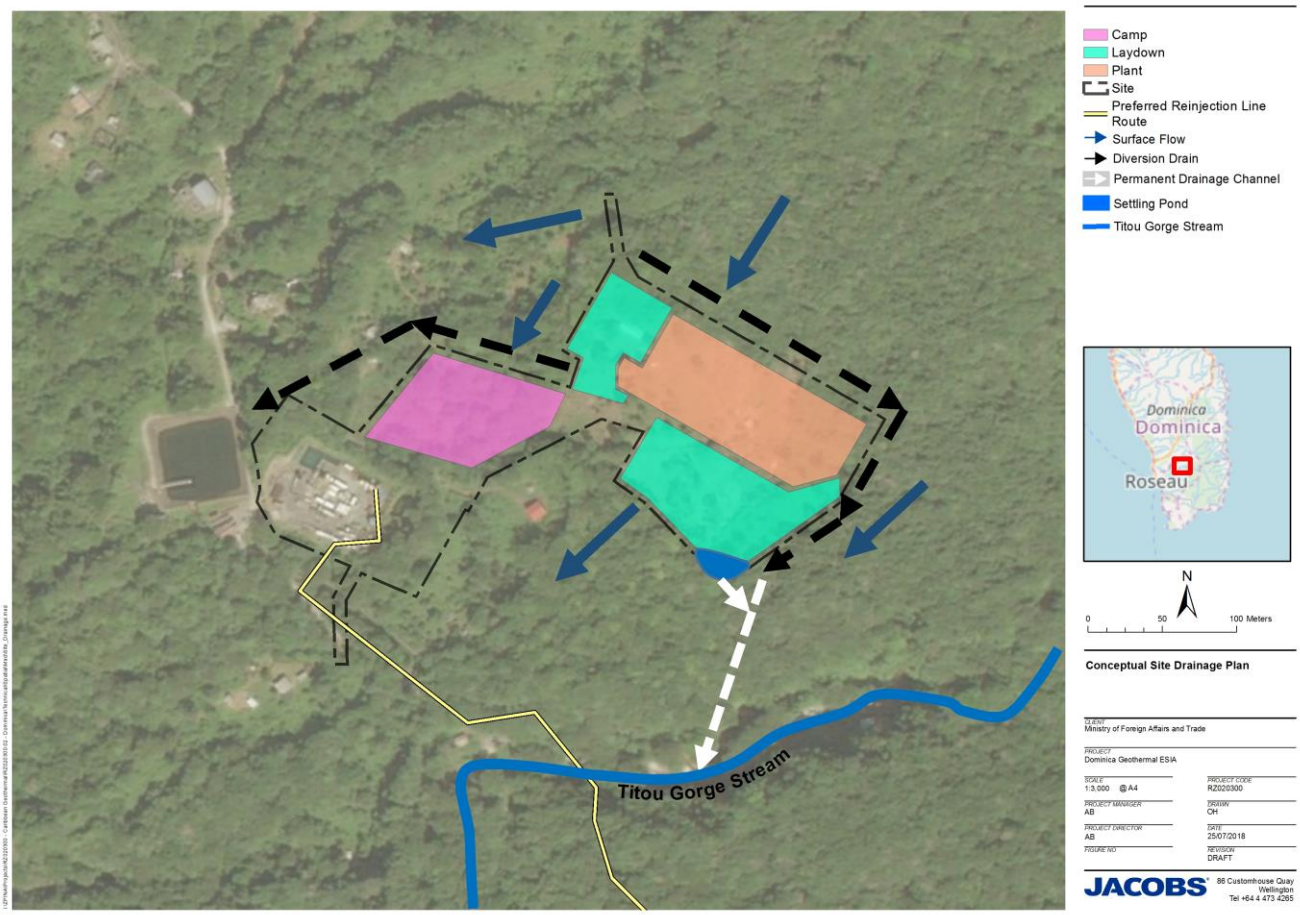


**Figure 7.4 : Conceptual diversion drain and stormwater capture pond**

The final impact from ongoing operations of the power plant will be water supply for firefighting. This will be infrequent, however would require >500 $m^3$ stored in a tank. Pumping from Titou Gorge Stream could be undertaken using a portable pump, however to reduce environmental effects of abstraction, pumping rates should not exceed 3 L/s (equivalent to ~6% of Titou Gorge Streams spot gauging flow). At this rate, it would take ~2 days to fill the fire water tank, but would ensure minimal impact on the stream.

Should abstraction be undertaken from the Roseau River for well stimulation in WW-R1, this should only occur once a suitable baseline flow has been assessed with spot gauging at the abstraction point.

### 7.4.4 Reinjection Pipeline Operation

The primary potential impact on the pipeline once operating is from flooding and debris strike. To manage this issue, the pipeline design should follow ridgelines where suitable, ensuring inundation risks are reduced.

Where the pipeline has been identified as at risk from inundation (see Figure 7.2), the detailed design should ensure:

- A minimum freeboard of 0.3 m above the 100 yr peak water level on all small tributaries that are exhibiting overland flow (i.e. location '*c*' in Figure 7.2).
- A minimum freeboard of 1.5 m above the 100 yr peak water level on all significant stream crossings requiring a pipe bridge. An example of this would be location '*b*' in Figure 7.2.

A larger freeboard for stream crossings is required to ensure they are not damaged by debris. The high velocity and short duration peak flows of Dominica mountain streams would indicate debris strike from trees and landslides is a considerable risk to infrastructure. This is supported by DCDC, (2017).

The 1.5 m minimum freeboard of pipe bridges may be difficult to adopt in some situations depending on the local gradient at each site and designers will need to verify the risk at each major crossing and factor this into the pipeline route. However, should the site allow for a larger freeboard with minimal change to design, this should be adopted.

### 7.4.5 Monitoring

Prior and during construction it is recommended that monitoring of the flow rates be conducted at the small stream used for abstraction of water.

Visual monitoring of stream banks and the construction of diversion channels should be undertaken to identify any areas that may be performing inadequately during both construction and operation (resulting in bank collapses, localised erosion hot spots and scouring).

During operation the O&M Contractor will monitor the effectiveness of the settling pond on sediment should be undertaken during construction and ongoing operations, with spot samples assessed for Total Suspended Solids (TSS) at the inlet and outlet locations. Imhoff settling cones offer a cheap and viable method for quick onsite estimates of TSS from the inlet and outlet.

## 7.5 Assessment of Residual Impacts

### 7.5.1 Power Plant Construction

During construction, if infrequent flows and runoff are controlled through mitigation discussed above (i.e. to reduce sediment and velocity of water entering the Titou Gorge Stream), the residual impact on the receiving environment are expected to be reduced to **Minor** significance.

Local water sources will be required for meeting some construction demands including vehicle and equipment washdown. The mitigation proposed (i.e. provision of storage tanks), residual impacts to watercourses will be of **Minor** significance.

### 7.5.2 Reinjection Pipeline Construction

The use local sediment controls such as silt fences or downstream sediment traps to reduce the residual impacts of disturbance through sedimentation and erosion to a **Negligible** significance.

The most likely residual impacts present during construction of the reinjection pipeline would be the permanent removal of the forest trees where the pipeline will be laid, which reduces canopy storage and interception, and could lead to a small amount of increased surface water runoff. Following mitigation, residual impacts of **Minor** significance will be observed.

### 7.5.3 Power Plant Operation

The primary residual impacts from the power plant will be increased runoff and less recharge to soils/groundwater for the concrete/gravel pad (3.7 ha). Additionally, there will be ongoing increased risk of oils and hydrocarbons entering waterways due to the new development and equipment, however mitigation measures such as bunds, oil spill training, spill kits and oil/water separators will help ensure this is limited. Implementation of the mitigation measures is considered to result in residual impacts of **Minor** significance.

With the appropriate mitigation measures in place to reduce impacts from sourcing water for firefighting activities, the residual impact on the receiving Titou Gorge Stream is considered to be of **Negligible** significance.

Erosion risk around the site and to receiving water bodies can be effectively managed with appropriate mitigation measures (i.e. visual monitoring of stream banks). With the appropriate mitigation measures in place the residual impacts for erosion are anticipated to be of **Negligible** significance.

Baseflow in the river should be a minimum of 1 $m^3$/s before any planned abstraction occurs at the rate of 20 litres/s. This is equivalent to <2% of the rivers flow and as the stimulation would only occur for a short duration, the impacts are considered **Negligible** with proposed mitigation in place.

### 7.5.4 Reinjection Pipeline Operation

With recommended detailed design mitigation measures in place to reduce the risk of flooding and debris strike, residual impacts for the reinjection pipeline are considered to be of **Moderate** significance.

## 7.6 Conclusions

Following the application of the mitigation measures described above, the residual impacts for both the power plant and reinjection pipeline route for hydrology receptors are expected to be reduced to **Minor** or **Negligible**. However, with proposed mitigation in place there remains a significant residual impact of **Moderate** significance for the reinjection pipeline, for risk of flooding and debris strike.

# 8. Water Quality and Freshwater Ecology

## 8.1 Introduction

This section describes the potential impacts to the water quality and freshwater ecology value of the project area from the construction and operation phases of the Project. Mitigation has been identified where necessary to reduce the scale and nature of potential impacts and monitoring has been proposed.

Changes in the flow regimes through abstraction and/or discharges can impact upon freshwater and aquatic ecology receptors. Due to the related nature of topics, this section should be considered closely with Section 7 - Hydrology.

## 8.2 Methodology

This impact assessment is based on survey data collected by Caraïbes Environnement Développement as part of an earlier study (Caraïbes Environnement Développement & Cull, 2015a/b), this report is provided for reference in ESIA Volume 5: Technical Appendices. The indices produced by Caraïbes Environnement Développement & Coll have been used as the basis for assessment of potential impacts associated with the proposed development. This assessment considers the likely baseline environmental quality that exists after Hurricane Maria.

The impact assessment has been conducted in accordance with the assessment methodology outlined in Section 2.

## 8.3 Sensitivity of Watercourses

Sampling was undertaken at four locations:

1) Roseau River Upstream
2) Roseau River Downstream
3) Blanc River Upstream
4) Blanc River Downstream

The sensitivity of the locations based on the results of the sampling as detailed below.

### 8.3.1 Roseau River Upstream and Roseau River Downstream Sites

Given the 'good' water quality and ecology and apparent lack of existing human impact on the riparian environment these sample locations are considered to be of Medium Sensitivity to potential impacts in accordance with the sensitivity assessment methodology used within this ESIA as a *'receptor with little capacity to absorb proposed changes and/or limited opportunities for mitigation*'. This consideration is based on the fact that the macroinvertebrate ecological state is clearly impacted by hydrological variations but has capacity to recover in lower flow periods. Therefore, while it may have capacity to respond to other pressures (such as discharges), it is possible that these could present cumulative pressures and as such degrade the existing ecology.

### 8.3.2 Blanc River Upstream Site

Given the 'good' water quality and the 'very good' ecology classification and apparent lack of existing human impact on the environment the area is considered to be of Medium Sensitivity to potential impacts as a *'receptor with little capacity to absorb proposed changes and/or limited opportunities for mitigation*'.

### 8.3.3 Blanc River Downstream

Given this was observed to have 'good' water quality and demonstrated potential for good quality ecology and existing human modification to the impact the area is considered to be of Medium Sensitivity to potential impacts as a *'receptor with little capacity to absorb proposed changes and/or limited opportunities for mitigation*'. This was determined through the observation that the ecological state is impacted by some activities at times and is represented by species more tolerant of disturbance or change.

## 8.4 Assessment of Impacts

During construction and operation, the proposed power plant would have a number of activities with the potential to impact on the river environments. This includes a range of physical disturbance activities as well as water use and water management processes. Table 8.1 provides an overview of these proposed activities and identifies how they are currently proposed to be managed as outlined through the design in ESIA Volume 5: Technical Appendices (Process Description). In some cases, the proposed management and mitigation measures included in the design is such that no impact is considered to be likely to occur. Those activities considered to be of potential risk as they have the potential to impact upon waterbodies are then assessed in the following sections.

Table 8.1 also identifies the water body that may be potentially impacted by the activities. The assessment of the magnitude of potential impacts is based on the management of the activities as currently proposed in ESIA Volume 5: Technical Appendices (Process Description). Where the impacts are considered to be of a high potential magnitude then additional mitigation has been proposed. The potential magnitude of the residual impacts is then assessed after the additional mitigation has been assumed to be implemented. Monitoring related activities have also been included.

**Table 8.1 : Potential impacts of the proposed development on the river environments**

| Activity | Potential impact |
|---|---|
| **Construction** | |
| *Power plant and laydown area construction:*<br>• Clearing of site vegetation.<br>• Bulk earthworks to level the site, form roads, create temporary construction facilities, formation of drains and create washroom amenities.<br>• Foundations for pipeline and equipment.<br>• Installation of all plant and equipment. | The main potential impact is from erosion of site soils then causing sedimentation impacts upon the Roseau River. |
| *Reinjection pipeline construction:*<br>• Clearing of a 3-5 m wide corridor.<br>• Provision of a gravelled road network to access the steam line and reinjection site.<br>• Earthworks including excavation of foundation holes, drilling and vehicle tracking along route including stream crossing of vehicles during construction.<br>• Construction of the pipeline over a number of waterbodies.<br>• Concrete use for foundation construction.<br>Excavation of sumps for draining line down and collecting condensate. | The main potential impact is from erosion of site soils then causing sedimentation impacts upon tributaries of the Roseau River and within the Blanc River.<br>Direct physical disturbance could also occur at stream crossing locations within the tributaries of the Roseau River and within the Blanc River. |
| *Water supply:*<br>• During construction, there will be a water demand for workers (potable and toiletry), equipment washdown, concrete mixing and potentially a reserve for fire-fighting. Raw water for construction works shall be drawn from the naturally occurring spring located at a higher elevation above the site. | Although no flow rates are currently known for the stream, it is estimated that the stream has a flow rate of between 5 – 10 litres/s. Assuming this stream is 5 litres/s, if water is pumped to a 10 $m^3$ plastic tank and at an abstraction rate of one L/s (20% of flow rate) then it is estimate that it would take ~167 minutes to fill this tank daily. |

| | |
|---|---|
| *Sewage and site amenity wastewater discharge:*<br>• Treatment by package plant then discharged to land via soakaway. | Limited potential discharge to the Roseau River. |
| **Operation** | |
| *Stormwater discharges from site hardstanding, roofs and well pads:*<br>• Stormwater from general roof and hardstand areas will discharge to adjacent waterbodies. | Roseau River from power plant and wellpads plus reinjection site. |
| *Stormwater discharges from process areas:*<br>• Stormwater from areas with oily process operations will be drained through oil interceptors before being discharged to watercourses. | Roseau River from power plant and wellpads plus reinjection site. |
| *Treated sewage discharge:*<br>• Treatment by package plant then discharged to land via soakaway. | Limited potential discharge to the Roseau River. |
| *Process wastewaters (condensate and brine):*<br>• These include condensate captured in sumps along pipeline route and on well pad.<br>• Sumps will also be provided at the wellpads to store brine or condensate that is discharged accidentally.<br>• All brine and condensate wastewaters will be reinjected with no provision for discharge to the environment. | None envisaged as no discharge to the environment planned. |
| *Water supply for showers, cleaning and firefighting:*<br>• Is expected to be delivered drinking water for 2-3 staff with rainwater collection for showers and cleaning. Firefighting water would be kept in a tank onsite. Bore maintenance is expected to use portable or tank water supplies when required. | None envisaged as no direct take from rivers. |
| *Potential water supply for reinjection well stimulation:*<br>• This would require 51,840 $m^3$ of water to be pumped into WW-R1 at a rate of 20 litres/s over a 1 month period. This is 0.6% of the base flow in the Roseau River at the point of take. | A large reduction in base flow could impact on the ecology. The low percent of base flow that is abstracted is considered unlikely to modify the available habitat within the watercourse and would be unlikely to impact on the ecology. |
| *Hazardous Substances Storage:*<br>• Geothermal fluids which will be captured and re-injected.<br>• Working fluid will be stored in bunded tanks.<br>• Acid, antiscalant, caustic soda, biocide, dispersant and turbine lube oil will all be stored and used on site. These would be stored in bunded tanks with any residual material following use of products for cleaning collected. | None envisaged as all products bunded on site. |

### 8.4.1 Construction

**Earthworks during Construction of the Power Plant and Laydown Area**

The power plant, laydown area and access road are located in the Roseau River catchment, which is considered to be of medium sensitivity. The power plant, laydown area and worker's camp will cover an estimated area of (2 ha). There are no proposed diversions of existing watercourses for construction but overland flow paths do travel through the power plant area and it is proposed that these overland flow paths will be diverted around the site.

The power plant, laydown area and their access road are in steep well vegetated terrain with erodible volcanic soils which experience high rainfall. When vegetation is cleared the site soils will be highly susceptible to erosion. The area had comparatively little vegetation damage from Hurricane Maria and as such the clearance of vegetation will expose fresh soil areas. The resulting sediment runoff could impact upon the Roseau River water quality through increasing turbidity, reducing clarity and causing deposition of fine sediments. Indirect impacts could then be brought about for the ecology of the river by a range of processes including directly

smothering species, changes in habitat and direct impacts of sediment upon fish species. Without erosion or sediment controls in place then there is a potential for potential impacts of **Moderate** significance downstream of the proposed works. This relates to the likelihood of there being detectable changes to water quality and ecological health that may be a permanent change if ecological health is compromised for the whole two year construction period. This is probably the activity with the most significant risk on the existing water quality and ecology for the Project.

**Earthworks during Construction of the Reinjection Pipeline**

The proposed reinjection pipeline is approximately 3.25 km long. A width of 3-5 m will be cleared of vegetation along this route thus disturbing approximately 9,750 $m^2$ to 16,250 $m^2$ of land. This cleared land would then be trafficked by vehicles constructing the pipeline. Some areas would be sealed with gravel to provide access to the pipeline during operation. Bare soil areas and trafficked areas would be more susceptible to erosion.

Following the passage of Hurricane Maria and damage to vegetation and soils in the area the pipeline construction will require further vegetation removal than originally expected including removing fallen/dead trees and the proposed need to remove trees in proximity to the pipeline (pipeline fall line) that may fall on the pipeline and risk damaging it in the future.

The pipeline route crosses a number of small tributaries of the Roseau River and the main Blanc River on pipe bridges above the river. The Blanc River is the larger watercourse and at its monitoring site near to the proposed crossing point is considered to be of moderate sensitivity. The Roseau River is considered to be of moderate sensitivity.

The earthworks and stream crossings phases of the pipeline construction are considered to be the higher risk activities to the existing water quality and ecology. This is especially the case with watercourses near to the pipeline route that may be more ecological sensitive/stressed due to vegetation loss and sediment inputs than pre hurricane Maria. The stream crossings will involve the placing of pipe bridges above the watercourses. Uncontrolled eroded soil material will cause direct and indirect sediment impacts, as discussed for the power plant location. Direct physical disturbance and additional sediment generation would also occur at stream crossing points. Unmitigated, this is considered to give rise to a potential impact of a **Moderate** significance.

**Discharge of Sewage and Site Amenity Wastewater during Construction**

During the construction phase there will be an estimated 50 personnel housed on site in the worker's camp area. Amenities will be provided including canteen areas, showers and toilets. Sewage and wastewater from these will be collected into package plant for treatment and disposal. Amenities would be within the worker's camp area and no disposal area has yet been identified. Package plants only provide a basic level of sewage and wastewater treatment compared to a full sewage treatment plant. As such, the effluent is not considered suitable for direct discharge to waterbodies as nutrients would be likely to promote algal growth in the receiving waterbodies. This is especially the case in steep landscapes with higher rainfall where package plant treated effluent could easily pass through land towards surface watercourses. Prior to mitigation, this potential impact is considered to be of **Moderate** significance.

**Water Supply during Construction**

It is estimated that the stream has a flow rate of between 5 – 10 litres/s. Assuming this stream is 5 litres/s, if water is pumped to a 10 $m^3$ plastic tank and at an abstraction rate of one L/s (20% of flow rate) then it is estimate that it would take ~167 minutes to fill this tank daily. The abstraction of water from the stream will not impact on the water quality downstream from the extraction point. Ecological impacts are anticipated to be of **Minor** significance as the extraction rate will provide adequate flow for maintaining the ecological health of the stream.

### 8.4.2 Operation

**Discharge of Stormwater from Site Hardstanding, Roofs and Wellpads**

It is proposed that all stormwater from site hardstanding areas, roofs and well pads will be captured and disposed to surface watercourses through detailed design. These areas are considered to be of low risk of contamination as they do not contain oily waste processes or condensate/brine discharges. During operation the power plant has a small number of operators (~3) and as such site traffic and use would present low risks for contamination.

The Hydrology Impact Assessment (Section 7) recommends additional mitigation of the stormwater discharges that includes their capture into sumps or settling ponds to specific design criteria that mitigate flow effects and would also provide for capture and treatment of floatable and suspended contaminants in the stormwater. Protection of outlets to reduce erosion risk is also proposed.

With the low contamination risk to stormwater it is considered that the potential impact of operational stormwater would be of **Minor** significance.

**Discharge of Stormwater from Process Areas**

Process areas that could give rise to oily waste contaminants within the stormwater would be drained through oil interceptors prior to discharging into the main site stormwater system. This is anticipated to provide for removal of those contaminants to low concentrations where adverse impacts are likely to be of **Minor** significance.

**Discharge of Treated Wastewater during Operation**

Wastewater during operation is proposed to be disposed in a similar manner to during construction through package plants with no specification of the final disposal location or infiltration/final treatment methods. With the number of staff (50 workers) it is considered that a package plants system is acceptable to this phase of work. With an infiltration/final treatment design, the impacts are considered to be of **Negligible** significance.

## 8.5 Mitigation

### 8.5.1 Construction

**Earthworks during Construction of the Power Plant**

The EPC Contractor will develop an Erosion and Sediment Control Procedure (ESCP) that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the documents. The ESCP will aim to manage and mitigate suspended solid discharges to the Roseau River to an acceptable level. This will be managed in accordance with the EHS general Guidelines. The ESCP will include the following mitigation:

- Clean water diversions – Section 7 – Hydrology identifies that an overland flow path crosses the proposed power plant location. This should be diverted around the site area first to minimise clean water ingress to bare earth areas.
- Access road sealing – the access road should be gravelled or sealed as a first stage in construction to minimise erosion.
- Staging – the works should progress in stages where possible to minimise the amount of bare earth. This is likely to include clearing the laydown area first, then providing erosion and sediment control to it before then moving onto the power plant area.
- Reducing catchment sizes – work areas should be created that involve small sub catchments in which flows can be reduced, channelized concentration or water minimised to reduce erosion.

- Installation of temporary stormwater drains through each of the catchment areas to collect and direct stormwater to sedimentation ponds.
- Erosion protection – when flows have been concentrated into channelized flows these should be within protected channels. These could be either temporary protection using geotextiles or more permanent hard protection.
- Sediment retention - Silt fences should be used around all the downstream site earthwork boundaries and within the site around each subcatchment. These will work to slow water flow and retain sediments. Silt fences should also be provided on the downstream side of the access road where earthworks are proposed.
- Sediment settlement – prior to discharge, all collected stormwater shall be directed by temporary drains through sedimentation ponds.

**Earthworks during Construction of the Reinjection Pipeline**

The ESCP recommendations for the power plant location will also apply with the following additional mitigation to manage specific risk activities for the reinjection pipeline:

- Staging – The works should progress in stages where possible to minimise the amount of bare earth. This is likely to include clearing the route in sections with installation of settlement retention features for each section before pipeline construction in that section. The next sections should not be cleared till works are ready to progress.
- Clean water diversions – overland flow paths going through work areas should be directed directly through the pipeline corridor and not allowed to travel down the cleared pipeline route to minimise erosion.
- Sediment retention - Silt fences should be used around all the downstream pipeline route boundaries. These will work to slow water flow and retain sediments. Silt fences should also be provided on the downstream side of the access road where earthworks are proposed.
- Temporary stream crossings – where streams will be regularly crossed temporary protection should be installed (culverts) to minimise direct disturbance and sediment generation. These should be removed after works are complete.

**Discharge of Sewage and Site Amenity Wastewater during Construction**

Package plant treated sewage and wastewater during the construction phase would lead to the potential discharge of wastewater with limited treatment to watercourses. With the use of a proprietary treatment plant or off-site disposal of primary treated wastewater the risk of an impact is considered to be low as the wastewater will either be removed from the environment or have a much higher degree of treatment to remove bacteria, pathogens and nutrients prior to discharge to land and then soaking towards the watercourses.

### 8.5.2 Operation

During operation wastewater will be treated initially in a package plant. The package plant would be to a sand filter or similar medium that allows the treated effluent to infiltrate to ground below the soil surface and receive further treatment. This infiltration system should be located close to the edge of the power plant area to maximise distances to watercourses.

The power plant's stormwater system should ideally drain through a sump or settling pond. This would capture any runoff from the pad and settle out rubbish and sediment, while reducing flow velocities. Areas of the plant that are at risk of having contaminant discharges (such as oil leaks from vehicles or fluid spills) should be isolated, with their flows first draining through an oil water separator. The outflows from this separator could then drain to the sump/settling pond for further treatment.

## 8.6 Monitoring

### 8.6.1 Construction

**Earthworks during Construction of the Power Plant and Reinjection Pipeline**

The EPC Contractor will ensure the following:

- Inspection and maintenance – the ESCP shall specify who is responsible for inspecting all physical elements of the erosion and sediment control measures. These shall be inspected daily to ensure they are installed and working correctly. Any defects shall be rectified before earthworks occur in that area of the site. Accumulated sediment shall be removed from all features when it reaches 25% of the available space. Records of all inspection and maintenance shall be kept.
- Visual inspection of the river - the ESCP shall specify who is responsible for inspecting the river upstream and downstream of the works on a daily basis. The inspection should identify whether any visible change in water clarity or turbidity occurs after the site discharges. If no discharge is occurring the inspection should identify if any sediment builds up is obvious within the channel downstream of the site. If visible changes are observed, then modification of site operations and/or site erosion and sediment control practises should be made to reduce the impact. Records of all inspection and response activities shall be kept.
- The discharge from the sedimentation ponds should be monitored during rain events. At least once per month for total suspended solids for comparison with the discharge limit of 50 mg/l and to determine the effectiveness of the pond.
- Monitoring of treated effluent from the Workers' Accommodation package sewage treatment plant on a monthly basis.
- Prior and during construction it is recommended that water quality and ecological (i.e. aquatic invertebrates) monitoring will be conducted at the small stream used for abstraction of water.

DGDC will monitor the performance of the EPC Contractor.

### 8.6.2 Operation

The O&M Contractor will ensure the following:

- Visual inspection of oil interceptors for visible oil and settling ponds.
- Monitoring of the discharge from oil interceptors and settling ponds every three months (with comparison to WBG EHS Discharge Guidelines).
- Monitoring of effluent discharged from the package plant every six months.

DGDC will monitor the performance of the O&M Contractor.

## 8.7 Assessment of Residual Impacts

The main risk of potential impacts on the water environments is considered to be from discharges during the construction phase of the Project. Erosion and resulting deposition in watercourse as a result of the earthworks and vegetation cleared required are considered to be the main impacts. Mitigation has been proposed with specific measures to reduce erosion and manage sediment and conditions requiring inspection and maintenance of the erosion and sediment control systems. With this mitigation in place the residual impacts are reduced, as detailed below.

### 8.7.1 Construction

**Earthworks during Construction of the Power Plant**

With a well-developed ESCP in place incorporating the elements in Section 7 it is considered that the potential of erosion of soils would be reduced. The proposed settlement should reduce off site losses and the clear identification of inspection and maintenance responsibilities should keep it operational over time. This is likely to reduce the amount of suspended material in site construction discharges. It is considered that site discharges would still contain elevated suspended sediments but after the implementation of good ESCP these would be at concentrations more typical of catchment flows from undeveloped land in larger rainfall events. As such the potential impact on the receiving water quality and ecology would be reduced. With the above additional ESCP mitigation in place it is considered that the magnitude of the impact is likely to be minor, which is it would be a detectable but small change to the existing water quality and ecology. With the proposed mitigation the residual impact from the earthworks should be reduced to **Minor** significance.

**Earthworks during Construction of the Reinjection Pipeline**

With a well-developed ESCP in place incorporating the elements in previously described it is considered that the risks of erosion of soils would be reduced. The proposed staging and silt fences should reduce off site losses. Protection of stream crossings while introducing a temporary barrier to movement of some species during works does provide for reduced direct disturbance and sediment input. The proposed visual inspection and monitoring of the treatment devices and resulting changes to watercourses downstream on a daily basis are key management tools to identify any potential issues in terms of visual impacts on water quality and quickly identify ways to rectify them. This is especially important in the areas along the pipeline route where the water environments are likely to be more stressed and degraded following Hurricane Maria and thus have less ability to absorb changes and be more sensitive to impacts than they may have been when the original baseline data was gathered. Overall, the approaches are likely to reduce the amount of suspended material in site construction discharges. It is considered that site discharges would still contain elevated suspended sediments but after the implementation of ESCP these would be at concentrations more typical of catchment flows from undeveloped land in larger rainfall events. As such the potential impact on the receiving water quality and ecology would be reduced. With the above additional ESCP mitigation in place it is considered that the magnitude of the impact is likely to be minor, which is it would be a detectable but small change to the existing water quality and ecology.

With the proposed mitigation the residual impact from the earthworks should be of **Negligible to Minor** significance.

**Discharge of Sewage and Site Amenity Wastewater during Construction**

With the use of a package plant the risk of an impact is considered to be low as the wastewater will either be removed from the environment or have a much higher degree of treatment to remove bacteria, pathogens and nutrients prior to discharge to land and then soaking towards the watercourses. Overall, this is considered to give rise to a residual impact of **Minor** significance.

### 8.7.2 Operation

**Discharge of Treated Wastewater during Operation**

The use of package plants through discharge to land has been recommended. With the use of a suitable disposal field the risk of an impact is considered to be low and result in a negligible or minor magnitude impact. Overall, this is considered to give rise to a residual impact of **Minor** significance.

## 8.8 Conclusions

Following the application of the mitigation measures described above, the residual impacts for both the power plant and reinjection pipeline route for freshwater ecology and water quality receptors are expected to be reduced to **Minor** or **Negligible** and are therefore not considered significant.

# 9. Landscape and Visual

## 9.1 Introduction

This section describes the potential impacts of the construction and operation of the Project on the existing landscape character and visual amenity of the area and sets out mitigation measures to minimise the impact of the Project.

## 9.2 Methodology

The landscape and visual impacts during construction are not assessed due to their temporary nature and reversibility. Therefore, the assessment considers the potential operational landscape and visual impacts of the operation of the Project only.

The location of the Project is in the Roseau Valley, Dominica. The power plant is located in a valley with forested undulating valley sides. The spatial scope includes a number of viewpoints looking towards the plant.

### 9.2.1 Assessment Criteria

**Baseline Data**

An appraisal of the landscape character and visual amenity has been undertaken through fieldwork and desk study to provide sufficient information against which to predict levels of potential impact and assess the significance of such impacts. Receptor viewpoints were chosen through desk-based and site assessment.

**Impact Significance**

The sensitivity of receptors of the area and magnitude of impact of the Project on visual amenity are categorised/classified using the criteria in Table 9.1 and Table 9.2 below.

**Table 9.1 : Sensitivity of Visual Receptors**

| Sensitivity | Typical character/use |
|---|---|
| High | Permanent occupiers of residential properties and associated outdoor areas (e.g. gardens). Users of nationally protected areas, recreational scenic trails or users of designated tourist routes. |
| Medium | Workers in predominantly outdoor professions (e.g. farmers) and any associated temporary accommodation. Users of secondary or minor roads in scenic areas, schools and outdoor recreational users (e.g. sports grounds). |
| Low | Users of main roads, passengers in public transport or tourists in minibuses using main arterial routes. |

**Table 9.2 : Magnitude of Impact**

| Magnitude of Impact | Typical criteria |
|---|---|
| Major | Total loss or large scale damage to existing character or views, and/or the addition of new but uncharacteristic conspicuous features and elements. |
| Moderate | Partial loss or noticeable damage to existing character or views, and/or the addition of new but uncharacteristic noticeable features and elements. |
| Minor | Slight loss or damage to existing character or views, and/or the addition of new but uncharacteristic features and elements. |
| Negligible | Barely noticeable loss or damage to existing character or views/no noticeable loss, damage or alteration to character or views. |

Using the outputs from Table 9.1 and Table 9.2 above the following matrix has been prepared to assist with determining the overall significance of visual impacts (Table 9.3).

**Table 9.3 : Significance of Visual Impacts**

| | | MAGNITUDE OF IMPACT | | | |
|---|---|---|---|---|---|
| | | NEGLIGIBLE | MINOR | MODERATE | MAJOR |
| SENSITIVITY OF VISUAL RECEPTOR | LOW | Negligible | Low | Moderate - Low | Moderate |
| | MEDIUM | Low | Moderate - Low | Moderate | Moderate – High |
| | HIGH | Moderate - Low | Moderate | Moderate – High | High |

## 9.3 Assessment of Impacts

### 9.3.1 Power Plant

The power plant will be designed to fit into the patterns of the landscape, and provide visual mitigation measures, where appropriate. For example, the turbine hall building of a flash plant can be architecturally designed. Although it is considered a relatively small development, the scale and nature of the power plant is such that it is not possible to mitigate its visual impact entirely. A geothermal power plant is a new feature to the Roseau Valley and without mitigation, will have some impact on the visual character and amenity of the area.

The mechanical draught cooling tower (or air coolers) is likely to have the largest visual impact from the power plant. While air coolers are not as high as mechanical draught cooling tower units they can take up a large area due to the heat rejection surface area required. While the evaporative cooling tower units will have a smaller footprint then an air cooler, it will be a taller structure and it may produce under certain climatic conditions a visual and prominent plume due to evaporating water, unless mist eliminators are installed to avoid this. Cooling towers are designed to be situated to avoid adverse effects (of recirculation) from prevailing wind direction, and to achieve adequate plume rise under stagnant conditions.

Figure 9.1 below shows the Zone of Theoretical Influence (ZTI) for the power plant. It should be noted that these views are a worst case scenario using only topographic data and therefore do not consider any vegetation in the Roseau Valley, which will soften and screen much of the power plant including when viewed from sensitive receptors.

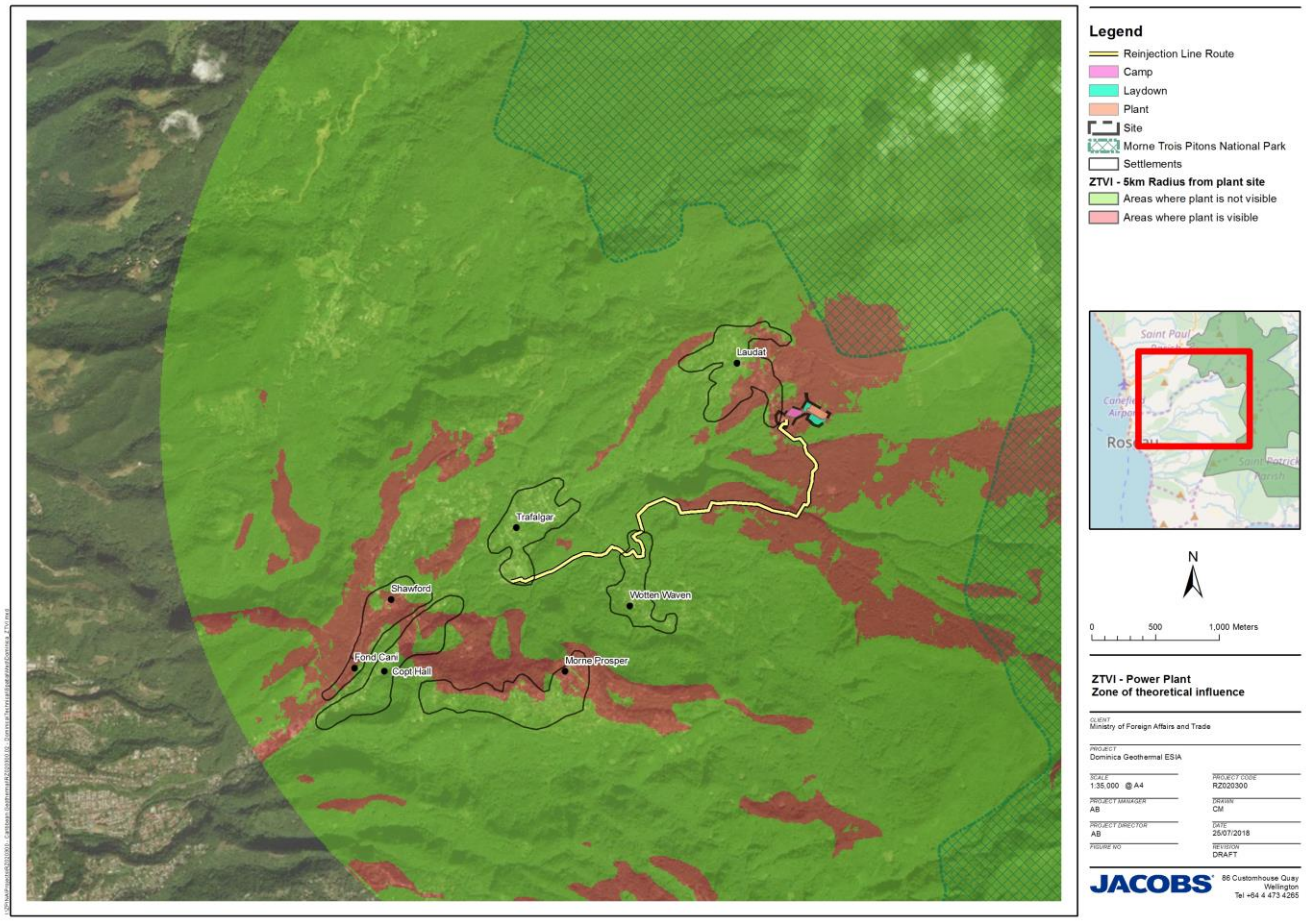


**Figure 9.1 : The ZTI for the Power Plant**

The key areas where the power plant may be seen includes the settlements of Laudat, Morne Prosper and Shawford. As shown in Figure 9.1, the majority of the area surrounding the proposed power plant does not have visual connection with the structure and based on the level of vegetation within the valley. Furthermore, the power plant is likely to be screened from any areas that are shown to have visual connection other than those that are immediately adjacent to the structure.

Using the ZTI, potential impacts are described below in Table 9.4 for the power plant.

**Table 9.4 : Power plant: assessment of potential impacts on visually sensitive receptors**

| Visually Sensitive Receptor (VSR) | Sensitivity of VSR | Magnitude of Change | Significance of Visual Impact | Comment |
|---|---|---|---|---|
| Permanent occupiers of residential properties adjacent to site | High | Moderate | **Moderate - High** | During operation there may be a number of properties surrounding the power plant that experience adverse views of the power plant from their properties or when accessing their properties using the existing access road. However, it is anticipated that these adverse views will reduce over time through vegetation growing up around the perimeter of the power plant. |
| Road users driving past power plant site | Low | Minor | **Low** | During operation, the power plant will be visible to tourists wishing to access the Titou Gorge. Whilst |

| Visually Sensitive Receptor (VSR) | Sensitivity of VSR | Magnitude of Change | Significance of Visual Impact | Comment |
|---|---|---|---|---|
| (i.e. tourists at Titou Gorge) | | | | some people may find the power plant visually unappealing, others may find it interesting and in keeping with Dominica's drive for sustainable energy. |
| Permanent Occupiers in the Settlements of Laudat, Morne Proposer and Shawford | High | Minor | **Moderate** | The power plant is likely to be visually screened by vegetation from the settlements of Laudat, Morne Prosper and Shawford, although there is a possibility that the cooling tower and/or steam emissions may still be visible. |
| Outdoor workers (farmers); and recreational users | Medium | Minor | **Moderate – Low** | During operation, the power plant may be visible to outdoor farmers and recreational users. However, it is likely that with natural screening from vegetation, local people will be unable to view it unless they are working within a close proximity to the plant. |

### 9.3.2 Reinjection Pipeline

Due to the size of the pipeline corridor (3 – 5 m) and the pipeline itself (30 cm), it is unlikely that during operation the pipeline will be visible and have significant impacts on the visual amenity of the area. The route of the reinjection pipeline is relatively far away from any visual receptors such as local communities and passes through mainly isolated areas of bush, some subsistence farming and abandoned access tracks. However, there are sections of the reinjection pipeline that traverse a cliff and therefore, these may be seen from a distance by some villages in the Roseau Valley. It is anticipated that vegetation will likely grow quickly around the pipeline corridor and over time, provide natural screening. There is evidence for rapid vegetation growth in the valley in the time since Hurricane Maria occurred (Figure 3.38).

Potential impacts are described below in Table 9.5 for the reinjection pipeline.

**Table 9.5 : Reinjection Pipeline: assessment of potential impacts on visually sensitive receptors – Operation**

| Visually Sensitive Receptor (VSR) | Sensitivity of VSR | Magnitude of Change | Significance of Visual Impact | Comment |
|---|---|---|---|---|
| Permanent occupiers of residential properties | Medium | Minor | **Moderate – Low** | During operation there may be a number of properties surrounding the reinjection pipeline that experience adverse views of the pipe from their properties. However, it is anticipated that these adverse views will reduce over time through vegetation growing up around the pipe. |
| Outdoor workers (farmers); and recreational users | Medium | Minor | **Moderate – Low** | During operation there may be a number of workers in the vicinity of the reinjection pipeline that may experience adverse views of the pipe from their properties. However, it is anticipated that these adverse views will reduce over time through vegetation growing up around the pipe. |
| Users of main roads or passengers in public transport on main arterial routes | Low | Negligible | **Negligible** | During operation, there is unlikely to be any view of the reinjection pipeline from the road for users of main arterial routes. |

## 9.4 Mitigation and Monitoring Measures

### 9.4.1 Power Plant

**Construction**

- The EPC Contractor will develop a Pest and Weed Management Procedure that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the document.
- Plants used in any landscape planted will be nursery grown and will be sound, healthy, and vigorous and free from insect infestations. Trees and shrubs will be chosen to tolerate weather conditions and other such site characteristics.
- Any lighting requirements will be designed to ensure light spill is directed into the construction site.
- Where possible the selection of neutral/muted cladding and external finishing would aid in limiting the extent of adverse visual impacts.
- After construction works are completed, it is proposed that the power plant site will be landscaped in order to improve visual amenity.
- The soil removed during earthworks for construction will be reinstated and used as topsoil for the proposed landscaping bunds (piles of earth mounted at the Project site boundary that are planted with trees to provide screening and natural noise attenuation for local residents).
- For visual appearance and to limit erosion from surface water during heavy rains, stockpiled topsoil will be used for landscaping and to create 'green zone' areas on the power plant site as soon as practicable.
- Site fencing has the potential to aid in mitigating adverse visual effects of the power plant by partially screening and softening the visual impact of the site and ensuring light spill from the site is minimised.

**Operation**

During operation it is proposed that the power plant site will be landscaped in order to improve visual amenity. Additionally, this will aid in limiting soil erosion at the site during heavy rainfall events. The soil removed during earthworks for construction will be reinstated and used as topsoil for the proposed landscaping.

Plants used for landscaping will be nursery grown and will be healthy and free from insect infestations. Trees and shrubs will be chosen in keeping with prevailing weather conditions and other such site characteristics. Maintenance operations will begin immediately after planting by mulching, watering, pruning, spraying, weeding and other necessary operations of maintenance. Planting beds will be kept free of weed, grass and other undesired vegetation growth. It is anticipated that vegetation will grow up around the power plant site quickly, given the climate and high rainfall in the valley. See Section 13 – Terrestrial Ecology and ESIA Volume 5: Appendices – Terrestrial Ecology Impact Assessment, for more recommendation regarding planting regimes and the use of a Habitat Management Plan.

The following recommendations are proposed for consideration for the buildings and power plant site (completed by the O&M Contractor):

- Any planted beds will be kept free of weeds and other undesired vegetation growth, as per the measures proposed in the Pest and Weed Management Plan.
- Site fencing has the potential to aid in mitigating adverse visual effects of the power plant by partially screening and softening the visual impact of the site and ensuring light spill from the site is minimised.
- Any lighting requirements should be designed to ensure light spill is directed into the construction and operation site.
- Where possible the selection of neutral/muted cladding and external finishing's would aid in limiting the extent of adverse visual impacts.

- Installation of drift elimination, if wet cooling towers options is selected to reduce particulate emissions and plume visibility.

An overall recommendation is to make the public aware that potentially affected parties can use the public grievance mechanism. This will be monitored in accordance with the measures set out in ESIA Volume 3: Social Impact Assessment.

### 9.4.2 Reinjection Pipeline

The reinjection pipeline should be coloured so that it is conspicuous with the surrounding environment. No further mitigation measures are recommended.

## 9.5 Assessment of Residual Impacts

Following the application of the mitigation measures described above, the residual impacts for both the power plant and reinjection pipeline route are expected to be reduced to **Low** or **Negligible** and are therefore not considered significant.

# 10. Natural Geothermal Features

## 10.1 Introduction

The scope of this Section includes an assessment of the potential risks and impacts to the geothermal resource (including natural surface features) during construction and operation and sets out mitigation measures to minimise the impact of the Project.

## 10.2 Methodology

This assessment utilises baseline data on the number and location of existing geothermal features within the area and experience from other operating geothermal fields. It includes an understanding of typical steamfield operation performance issues and how the proposed steamfield operation design addresses these issues. Using the impact identification criteria in Section 2, the assessment will then draw a conclusion on the likely significant residual impacts to local geothermal features from the Project.

## 10.3 Assessment of Impacts

### 10.3.1 The Deep Reservoir

When a geothermal reservoir is utilised for power generation, change can occur that may degrade the resource. These changes include:

- Reservoir pressure drawdown, causing a decline in discharge pressure of production wells and lower power output.
- Pressure decline causing reservoir boiling and expanding steam zones. This may be advantageous in the medium term as it results in higher proportions of steam in well discharges (higher enthalpy), a higher power output and lower brine flow for disposal. In the long term it may result in reduced well output as a result of declining pressure.
- Ingress of groundwater resulting in cooling and reduced power output from production wells.
- Returns of injected brine. If this occurs too quickly, with insufficient time for the brine to re-heat, it may cool the reservoir in the production zone.
- Mineral scaling resulting from changes in the chemistry of the reservoir as a result of the above processes.
- Ingress of acidic fluids causing corrosion to wellbores and plant.

### 10.3.2 Surface Thermal Features

As shown in Figure 3.21, two geothermal resources (that are popular tourist sites) are the Boiling Lake and Valley of Desolation. Both are located over 3 km from the power plant site and outside of the modelled reservoir area. Other surface thermal features within the modelled reservoir area include (Figure 3.21):

- Papillote Natural Hot Pools and Cold Mineral Pools (Trafalgar Falls);
- Screws Sulphur Spa Hot Pool (Wotten Waven);
- Tia's Hot Springs (Wotten Waven); and
- Ti Kwen Glo Cho Hot Springs (Wotten Waven).

When geothermal wells discharge steam and water for power generation the reservoir pressure can fall in the production area. Since the deep reservoir is hydrologically connected to the surface thermal features, pressure decline in the reservoir can cause changes to the thermal features.

Some geothermal fields (such as Wairakei, Ohaaki in New Zealand) have experienced cessation in flow from major hot springs as a result of pressure decline in the deep reservoir caused by production from geothermal power plants. These power plants are typically large relative to the size of the resource available and as a result the pressure decline is large. Pressure decline can also result in increased boiling in the deep reservoir which may increase activity from steam vents and potentially result in hydrothermal eruptions. This was the case at Wairakei where a large increase in steam flow occurred at the Craters of the Moon thermal area.

The degree of reservoir pressure decline depends on a number of factors including the extraction rate of production and the size of the resource. The reservoir temperatures and pressures measured in the existing in-field wells (excluding WW-R1) are nearly uniform and the deep permeability in these wells is generally good so the indicated (measured) reservoir area corresponds to an area of 3 $km^2$ and is considered to be sufficiently proven to be used as a basis for a small development using existing wells. ELC Preliminary Resource Assessment (ELC, 2012) and the Feasibility Study – Small Geothermal Report (ELC, 2013), estimated that there is a 90% probability that the indicated resource is at least 25 MW, and a 50% probability of supporting 41 MW. These estimates provide sufficient confidence for a small scale development using existing wells to be sustainable for 30 years, although there is a low risk that recharge by low temperature or acidic fluids could prematurely reduce the output of the wells.

Temperature and pressure changes also depend on where the waste (cooled) geothermal fluid is injected. The pressure decline in some geothermal fields is exacerbated because little of the produced brine is injected back into the reservoir ("in-field" injection). Often it is injected outside the resource ("out-field" injection) where it is less likely to cool the production zones. In-field injection can help maintain reservoir pressures and preserve surface thermal activity. However, if injection is concentrated too close to the hot springs then it is possible that there will be localised pressure increase resulting in increased flow from hot springs. Optimising the injection strategy to provide good pressure support, without degrading the resource or adversely affecting surface features is a challenge with all geothermal fields, although less so with power plants that are small relative to the resource size.

The proposed Project is currently designed to a 7 MW capacity which is approximately 10% of the total reservoir capacity (reservoir modelling indicates the total reservoir capacity to be 65 MW). Therefore, as the plant is small in size relative to the resource available, impacts to the local geothermal resource are anticipated to be minor. The steamfield design also includes one out-field injection well (WW-R1) and one in-field injection well (WW-01). Well WW-01 will provide some reservoir support but as it is located close to the Wotton Waven thermal area there may be potential for pressure increase here, which could drive increases in spring flow. It may be possible to manage this by adjusting the balance of injection between WW-01 and WW-R1, although there are some physical limits to this, i.e. the low injectivity of WW-R1 and pressure limits on the use of WW-W1. Furthermore, DGDC informed surveyors in March 2018 that many of the natural hot springs in the Roseau Valley are subsurface in nature and therefore do not appear to be connected to the deeper geothermal reservoir. Therefore, it is anticipated that based on the proposed steamfield design, impacts to geothermal features in the area are likely to be a potential impact of **Minor** significance.

Hot springs which have high sodium-chloride concentrations (e.g. springs along River Blanc) are derived from the deep reservoir liquid and could potentially show declining flowrates if reservoir pressures decline. The low-chloride features (e.g. Ti Kwen Glo Cho) are related to boiling and steam-generation from the deeper reservoir. These features could potentially show increases in activity (e.g. higher temperatures, increased flow) as a result of reservoir pressure decline stimulating increased boiling along the outflow to the springs. However, given the small size of the power plant relative to the modelled size of the resource and the siting of injection close to the injection sector (see below) it is possible there will be minimal pressure decline and potential impact of **Minor** significance on the surface features.

## 10.4 Mitigation and Monitoring Measures

As mentioned above, impacts to the geothermal resource will be mitigated primarily through steamfield design. Further mitigation through a Reservoir Management Plan will be implemented by the EPC Contractor and O&M Contractor that considers all possible change that may occur to the deep reservoir and the surface thermal

activity, as described above. It will outline the necessary monitoring to identify this change and present a mitigation plan to limit any adverse impact.

It is essential that the O&M Contractor complete a baseline monitoring programme before the power plant is commissioned, to establish the natural seasonal variability of surface spring activity including flowrate, temperature and fluid chemistry. Springs can change over time so the baseline data is needed for objective assessment, post commissioning. A significant change in spring activity outside the baseline variation, combined with reservoir measurements may show clearly that the impact is due to extraction or injection. During operation reservoir change (pressure, temperature and chemistry) will be monitored by the O&M Contractor through regular testing of production wells.

The Reservoir Management Plan will include a monitoring system (such as slimhole downhole pressure sensors) that will monitor reservoir pressure throughout operation, both at the production and reinjection wells. In the event of any significant changes in reductions in reservoir pressure, in the vicinity of WW-01 that may cause adverse change to thermal features, this will be mitigated in the first instance by adjusting the relative flows to WW-R1 and WW-01.

## 10.5 Assessment of Residual Impacts

The impacts to geothermal following the application of the mitigation incorporated through steamfield design and monitoring as described above, the residual impacts to local geothermal features are expected to be reduced to **Minor or Negligible** and are therefore not significant.

# 11. Natural Hazards

## 11.1 Introduction

The scope of this section includes a review of the seismicity, volcanism, subsidence and flood risk of the area and the assessment of the potential geological risks and impacts during construction and operation, and sets out mitigation measures to minimise the impacts of the Project.

## 11.2 Methodology

This assessment utilises baseline data on the natural hazards that typically occur within Dominica and in particular within the Project area, as described further in Section 3.9. Using the impact identification criteria in Section 2, the assessment will then draw a conclusion on the likely significant impacts to the proposed Project from natural hazards.

## 11.3 Assessment of Impacts

Long term production and injection of geothermal fluids associated with geothermal developments can induce seismicity. Typically, this induced seismicity, associated with the geothermal operations, is limited to small magnitude seismic events (magnitude <3) or micro-earthquakes (MeQs – Magnitude <2). It is standard practice for geothermal fluid to be captured and sent to injection wells for re-injection to support production and reservoir pressures. By supporting reservoir pressures, the likelihood of inducing larger events is reduced. Seismic events of magnitude 3 are rarely felt at the surface and are very unlikely to cause damage. Micro-earthquakes are common in geothermal reservoirs that they are commonly used as an interpretative method to assess reservoir boundary extent, active faults and injection/production area extents. Thus, relative to the baseline seismic risk, the induced seismic potential impact as a result of the Project is considered to be of **Minor** significance.

Extraction of geothermal fluids can also contribute to subsidence. Rates of subsidence in operating geothermal fields vary considerably depending on background rates, the geological setting, and the reservoir management strategy. Subsidence can be very localised and related to water drainage from compressible sediments. It is particularly important to avoid differential subsidence in areas where there is key sensitive plant (e.g. turbine halls). Typically, subsidence occurs slowly in response to operation over months and years. There is potential that the Project may increase subsidence in the Project area as a result geothermal fluid extraction and therefore impacts are considered to be of **Moderate** significance.

Other natural hazards including volcanic activity, landslides, hurricanes and flooding are common to Dominica. The Project has potential to contribute to increased occurrence of flooding and landslides through construction and operation, however, other events such as hurricanes and volcanic eruptions occur independently of the Project. Following Hurricane Maria in September 2017, there is an increased likelihood of landslides during construction activities for the reinjection line in particular.

Based on the location and nature of the proposed Project and natural hazards identified within the vicinity of the project area, overall potential impacts are considered to be of **Moderate** significance.

## 11.4 Mitigation and Monitoring Measures

### 11.4.1 Landslides

Following Hurricane Maria in September 2017, the likelihood of landslides has increased. It is therefore recommended that further studies be undertaken to establish the risk of landslide prior to construction. It is also recommended that a Landslide Management Procedure is prepared within the Erosion and Sediment Control Procedure. This will be implemented by the EPC Contractor during the construction phase.

During construction and operation, the EPC Contractor and O&M Contractor will be able to mitigate its contribution and the scale of impact from existing natural hazards such as flooding and landslides through good practices such as for example: management of soil runoff and soil erosion, ensuring soil stockpiles are covered and water flow off site is reduced. Further mitigation and monitoring in relation to water, is detailed within the Hydrology Impact Assessment (Section 7). Management measures will also be included with soil and erosion management procedures that will be in place during both construction and operation.

Rerouting options should be examined as a primary mitigation measure to avoid areas with large scale and active landslides, since they present a threat to the reinjection line integrity. International best practice is to identify landslide features and avoid by routing along ridge crests and spurs, and minimising the exposure to large and active geohazard landslides, potentially unstable and steep side slopes (Marinos et al., 2016).

Monitoring will be required by the EPC Contractor and O&M Contractor during construction and operation of the pipeline for identified geohazards of moderate or high risk that have not been avoided.

### 11.4.2 Subsidence

During operation the risk of subsidence is largely mitigated by reinjection of the geothermal fluids. There remains the possibility that subsidence could occur in response to development of the reservoir. A Subsidence Management Plan should be prepared and implemented. This will include baseline monitoring by the O&M Contractor of background subsidence prior to the construction of the power plant and monitoring of ground levels during operation. In the event of significant subsidence occurring and shown to be due to the development, a review of the reservoir management strategy should be undertaken alongside numerical modelling of reservoir behaviour and subsidence to guide alternative mitigation measures.

### 11.4.3 Volcanic Eruptions and Hurricanes

Natural hazards such as volcanic eruptions and hurricanes occur independently of the Project and although the Project does not contribute to the occurrence of these hazards there are no mitigation measures that can be implemented to prevent them from occurring. Monitoring for these natural hazards are already undertaken at a national level.

## 11.5 Assessment of Residual Impacts

The impacts from natural hazards as result of the proposed Project following the application of mitigation incorporated through steamfield design and additional mitigation applied during construction and operation as described above, the residual impacts are expected to be reduced to **Minor** and are therefore not significant.

# 12. Noise

## 12.1 Introduction

This section describes the potential impacts to noise nuisance from the construction and operation of the Project and sets out mitigation measures to minimise any impacts. The section summarises the findings of the ESIA Volume 5: Technical Appendices (Noise Impact Assessment).

## 12.2 Methodology

### 12.2.1 Construction

This assessment considers potential construction impacts from the power plant, reinjection pipelines, suspension bridge and tramway carpark.

Potential construction noise impacts were modelled using the CONCAWE algorithm in the SoundPLAN noise modelling software package. The CONCAWE algorithm has been used to predict noise impacts from neutral weather conditions. Meteorological modelling and weather records have shown that temperature inversions are not a feature of the island and as such noise transmission under adverse weather conditions has not been considered. Refer to ESIA Volume 5 – Technical Appendices (Noise Impact Assessment) for further details.

The noise level at the sensitive receiver locations during the construction phase of the plant and associated infrastructure will vary depending on the location of the work within the site, the type and number of equipment operating at any one time, the duration of the activity, and meteorological conditions at the time. In the absence of a complete methodology and to simplify the large number of variables for construction activities around the site, a “typical “construction scenario has been assessed for the Project. The scenario includes all equipment outlined in each phase of Table 12.1, operating for 50% of the time. This is not intended to be a worst case scenario for the construction activities but should serve to provide an indication of the expected levels on a day to day basis. Table 12.1 presents the predicted noise levels for a typical operation scenario noise impact.

Noise levels from equipment types anticipated to be used for different phases of the Project, are detailed in Table 12.1 below.

**Table 12.1 : Representative construction phases and equipment**

| Construction stage | Noisiest equipment | Sound Power Level dB(A) |
|---|---|---|
| **Power Plant** | | |
| Earthworks | D7 Dozer<br>30t Excavator<br>40t Road dump truck<br>20t Vibratory roller | 115 |
| Plant construction | 100T Mobile crane<br>Gas cutter x2<br>Ratchet gun x2 | 109 |
| Building construction | Concrete truck and pump<br>Concrete drill<br>Welder<br>Nail gun<br>Truck mounted crane | 110 |

| Construction stage | Noisiest equipment | Sound Power Level dB(A) |
|---|---|---|
| **Reinjection pipeline** | | |
| Earthworks | Bobcat<br><10t Vibratory roller | 111 |
| Footings | Concrete truck and pump<br>Concrete drill | 109 |
| Placement of pipe sections | 100T Mobile crane<br>Gas cutter<br>Ratchet gun | 107 |
| **Production / Reinjection well** | | |
| Earthworks | Bobcat<br><10t Vibratory roller | 111 |
| Finishing works | 100T Mobile crane<br>Gas cutter<br>Ratchet gun | 107 |
| **Suspension Bridge** | | |
| Earthworks | Bobcat<br><10t Vibratory roller | 111 |
| Footings | Concrete truck and pump<br>Concrete drill | 109 |
| Placement of cables and platform | 100T Mobile crane<br>Gas cutter<br>Ratchet gun | 107 |
| **Tramway carpark** | | |
| Earthworks | 15t Road grader<br>30t Excavator<br>40t Road dump truck<br>2 x 20t Vibratory roller | 116 |
| Asphalting | Asphalt paving machine<br>30T Road dump truck | 110 |

### 12.2.2 Operation

The noise assessment considers the predicted noise impacts at the most affected receiver locations and compares these to the Project noise criteria. The WBG requirements were identified as the limiting condition for noise impact assessment.

The prediction of noise impacts has been undertaken using SoundPLAN noise modelling software, which incorporates specific Project information to predict noise levels at sensitive receiver locations. The assessment of noise impacts from the project has compared the predicted levels at the receiver locations to the noise goals identified to confirm compliance with environmental objectives.

The noise model used the CONCAWE algorithm to predict the $L_{Aeq\ 1\ hour}$ noise level impacts at the nearby residences. Although in practice the noise level from the project may vary depending on demand, these noise

impacts are considered to be constant for both daytime and night time periods. The CONCAWE algorithm has been used to predict noise impacts from both adverse and neutral weather conditions.

## 12.3 Modelling Methodology

The assessment of noise impacts at residential locations nearest to the power plant is based on the prediction of noise levels using a noise model. The noise model for this Project was developed from topographic data for the area and identification of receiver locations from available aerial photography. Precise equipment noise levels and site layouts were not determined at the time of the assessment and as such a combination of typical noise levels and project OHS design specifications have been used for modelled noisy equipment.

To predict the noise impact at the nearby receivers and approximation of the individual contribution from each major source is required. Where necessary, estimates of the contribution have been made based on measurements of similar sources from other sites. The major sources of noise emissions associated with each project component are presented below in Table 12.2. This table is not an exhaustive list of noise sources from the project however the main items of noisy plant have been identified for the noise model.

**Table 12.2 : Representative operational noise sources**

| Component | Equipment | Sound Power Level (SWL) dB(A) |
|---|---|---|
| Power plant – Flash steam condensing unit | Turbine (including exhaust ducting, inlet valves and pipes) | 93 |
| | Evaporative cooling towers | 81 |
| | Steam ejectors | 90 |
| | Pumps | 96 |
| | **TOTAL** | **99** |
| Power Plant – Organic Rankine Cycle unit | Turbine (including exhaust ducting, inlet valves and pipes) | 93 |
| | Air cooled condenser (ACC) fans | 88 |
| | Working fluid feed pumps | 97 |
| | Vapouriser / pre-heater / desuperheater | 76 |
| | **TOTAL** | **99** |
| Steam gathering system | Atmospheric flash tank | 118 |
| | Rock muffler | 80 |
| | Steam inlet pipes and valves inc. pressure control valves | 76 |
| | **TOTAL** | **118** |
| Reinjection wells | Reinjection pumps | 77 |
| Commissioning of both power plant and reinjection wells | Steam pressure releases | 118 |

** Noise levels for these units were unable to be obtained and as such an SWL of 93 has been used in this preliminary assessment, this being the OHS limit of 85dB(A) at a distance of 1m.*

The loudest noise events during operation are likely to be associated with either:

a) the emergency release of steam pressure as a result of a ruptured disk; or

b) steam vented from rock muffler when plant trips out or shuts down.

These events may be up to 140 dB(A), however they will be very short term. Although noise levels from this event may be high, they will not exceed 1hr noise criteria due to their short duration.

The CONCAWE algorithm has been used to predict noise impacts from neutral weather conditions. Meteorological modelling and weather records have shown that temperature inversions are not a feature of the island and as such noise transmission under adverse weather conditions has not been considered.

Modelling of the plant site has assumed all equipment is operating at full capacity at the site boundary. No localised shielding on the project site (for example from buildings or other site equipment) has been included in the model. As such the following noise predictions represent an unlikely 'worst case' forecast of potential noise impacts.

## 12.4 Noise Limits

### 12.4.1 Construction

The risk of adverse impact of construction noise within a community is determined by the extent of its emergence above the existing background noise level, the duration and scheduling of the event and the characteristics of the noise.

There are no specific construction noise impact criteria identified for the Project. However, an increase of 15 dB(A) above daytime background noise levels and 10 dB(A) above night time noise levels has been used as a guideline to determine if mitigation of construction noise is likely to be required. Again, the minimum monitored $L_{Aeq}$ during the tourist down season for each village has been referenced in these calculations.

**Table 12.3: Construction noise guidelines**

| Location (Residential, Institutional Educational receptors) | Existing dB(A) | | Allowance dB(A) | | Construction noise limits dB(A) | |
|---|---|---|---|---|---|---|
| | Day 07:00-22:00 | Night-time 22:00-07:00 | Day 07:00-22:00 | Night-time 22:00-07:00 | Day 07:00-22:00 | Night-time 22:00-07:00 |
| | $L_{Aeq1\ hr}$ | $L_{Aeq1\ hr}$ | $L_{Aeq\ period}$ | $L_{Aeq\ period}$ | $L_{Aeq1\ hr}$ | $L_{Aeq1\ hr}$ |
| Laudat | 38.0 | 42.0 | 15 | 10 | **53.0** | **52.0** |
| Fond Cani North | 36.0 | 37.5 | | | **51.0** | **47.5** |
| Fond Cani West and South | 42.0 | 41.0 | | | **57.0** | **51.0** |
| Morne Prosper | 36.0 | 35.0 | | | **51.0** | **45.0** |
| Wotten Waven | 41.0 | 48.0 | | | **56.0** | **58.0** |
| Trafalgar | 44.0 | 43.5 | | | **59.0** | **53.5** |

### 12.4.2 Operation

The operations of the Project have the potential to impact on residential and other noise sensitive receiver amenity and therefore must be assessed to determine requirements for noise mitigation where necessary. The use of guidelines to define a level of noise emissions from an industrial facility provides the most affected receivers with noise impacts that are within an acceptable range for day to day wellbeing.

The Project specific noise criteria will be taken to be the most stringent of the noise goals of either the World Bank Group (WBG) Environmental Health and Safety (EHS) Guideline or the Dominican regulations.

### Dominican regulations – Environmental Standards for Protection against Noise (June 2003)

This document sets the maximum permissible noise levels for noise produced by fixed and mobile sources. This document presents the following maximum noise levels.

**Table 12.4 : Dominica Environmental Noise Standards**

| Receiver category | Maximum permissible external noise level $L_{Aeq}$(period) dB(A)* | |
|---|---|---|
| | Daytime (07:00 to 21:00) | Night time (21:00 to 07:00) |
| **Area 1 - Zones of tranquillity** | | |
| Hospitals, medical centres, place of worship | 55 | 50 |
| Offices, schools | 60 | 55 |
| Zoos, botanical gardens | 60 | 55 |
| Quiet areas for the preservation of habitat | 60 | 50 |
| **Area 2 – Residential Zones** | | |
| Residential areas | 60 | 50 |
| Residential areas within commercial and/or industrial areas | 65 | 55 |
| **Area 3 – Commercial Zones** | | |
| Industrial zones | 70 | 55 |
| Commercial zones | 70 | 55 |

** As no statistical parameter appears to be presented in this document, it is assumed that these levels are $L_{Aeq}$(period).*

### World Bank Group Environmental, Health and Safety Guidelines

The World Bank Group (WBG) recommends noise limits for residential locations in accordance with its Environmental, Health and Safety (EHS) Guidelines. These guidelines have been adopted from Guidelines for Community Noise, World Health Organization, 1999 and are values for noise levels measured outside a dwelling. The noise level guidelines from the WBG have been reproduced in Table 12.4.

**Table 12.5 : WBG noise guidelines for noise sensitive locations**

| Receptor | Day 07:00-22:00 | Night-time 22:00-07:00 |
|---|---|---|
| | $L_{Aeq1\ hr}$ | $L_{Aeq1\ hr}$ |
| Residential, Institutional Educational | 55 dB(A) | 45 dB(A) |
| Industrial, Commercial | 70 dB(A) | 70 dB(A) |

The guidelines state:

*"Noise impacts should not exceed the levels presented in Table 3.2 or result in a maximum increase in background levels of 3 dB at the nearest receptor location – off site"*

The additional criteria of background plus 3 dB(A) is referred to as a maximum increase in noise levels and is only to be adopted where the guideline levels in the table are already exceeded. For the purposes of these calculations, the minimum monitored $L_{Aeq}$ during the tourist down season for each village will be used.

**Table 12.6 : World Bank EHS noise guidelines for power stations**

| Location (Residential, Institutional Educational receptors) | Initial noise limits dB(A) | | Existing dB(A) | | Final noise limits dB(A) | |
|---|---|---|---|---|---|---|
| | Daytime 07:00-22:00 | Night-time 22:00-07:00 | Daytime 07:00-22:00 | Night-time 22:00-07:00 | Daytime 07:00-22:00 | Night-time 22:00-07:00 |
| | $L_{Aeq1\ hr}$ | $L_{Aeq1\ hr}$ | $L_{Aeq\ period}$ | $L_{Aeq\ period}$ | $L_{Aeq1\ hr}$ | $L_{Aeq1\ hr}$ |
| Laudat | 55 | 45 | 38.0 | 42.0 | 55 | 45 |
| Fond Cani North | | | 36.0 | 37.5 | 55 | 45 |
| Fond Cani West and South | | | 42.0 | 41.0 | 55 | 45 |
| Morne Prosper | | | 36.0 | 35.0 | 55 | 45 |
| Wotten Waven | | | 41.0 | 48.0 | 55 | 51 |
| Trafalgar | | | 44.0 | 43.5 | 55 | 45 |

It can be seen that the WBG EHS noise guidelines are generally applicable, however, for locations in Wotten Waven, the night time noise level is greater than the guidelines and as such the alternative 'background plus 3 dB(A)' criteria may be applied during this period at this location.

**Summary of Operational Noise Criteria**

Given the different criteria applicable to this project, the minimum criteria for each location will be used to assess operational noise associated with the project. These have been set out below in Table 12.7.

**Table 12.7 : Summary of operational noise criteria (LAeq 1 hour)**

| Location | World Bank Base Criteria dB(A) | | World Bank 'Plus 3' Criteria dB(A) | | Dominica Criteria dB(A) | | Final noise criteria dB(A) | |
|---|---|---|---|---|---|---|---|---|
| | Day | Night | Day | Night | Day | Night | Day | Night |
| Laudat | 55 | 45 | 55 | 45 | 60 | 55 | **55** | **45** |
| Fond Cani North | 55 | 45 | 55 | 45 | 60 | 55 | **55** | **45** |
| Fond Cani West and South | 55 | 45 | 55 | 45 | 60 | 55 | **55** | **45** |
| Morne Prosper | 55 | 45 | 55 | 45 | 60 | 55 | **55** | **45** |
| Wotten Waven | 55 | 45 | 55 | 51 | 60 | 55 | **55** | **51** |
| Trafalgar | 55 | 45 | 55 | 45 | 60 | 55 | **55** | **45** |
| Recreational areas | 55 | 45 | 55 | 45 | 60 | 50 | **55** | **45** |

It can be seen that where compliance is shown to meet the World Bank 'Background plus 3' noise criteria, local noise criteria will also be met.

The significance of construction and operational noise impacts can be characterised as the product of the degree of predicted impact (magnitude of impact) and the value of the receiver that is subjected to that impact (sensitivity of receiver). The criteria for the definition of magnitude and sensitivity are presented below.

### 12.4.3 Magnitude of impacts

The definition of the magnitude ratings for the noise impact assessment are explained in Table 12.8 below.

**Table 12.8 : Magnitude rating definition**

| Category | Description |
|---|---|
| Major | An impact that is significant and mitigation must be considered. |
| Moderate | An impact that is significant and mitigation should be considered. |
| Minor | An impact that is significant, but small enough that noise management practices would ensure noise levels are below significance criteria. |
| Negligible | No need to consider in decision making, no mitigation required. |

The magnitude of the noise impact is defined by a series of noise change categories with an associated semantic scale presented in Table 12.9 below.

**Table 12.9 : Magnitude of noise impact criteria**

| Magnitude of impact | Exceedance of operational noise criteria – dB(A) |
|---|---|
| Major | ≥ 5 |
| Moderate | 3.0 – 4.9 |
| Minor | 0.1 – 2.9 |
| Negligible | 0 |

### 12.4.4 Sensitivity of receivers

The definition of the sensitivities of receivers to noise impacts during construction and operation are based on the maximum permissible daytime noise levels, detailed in ESIA Volume 5: Technical Appendices (Noise Impact Assessment Report). The sensitivity of receiver definition is presented in Table 12.10 below.

**Table 12.10 : Sensitivity of receiver definition**

| Category | Description |
|---|---|
| High | Hospitals, medical centres, place of worship |
| Medium | Offices, schools<br>Zoos, botanical gardens<br>Quiet areas for the preservation of habitat<br>Residential areas |
| Low | Residential areas within commercial and/or industrial areas |
| Negligible | Commercial and industrial premises |

### 12.4.5 Evaluating the significance of impacts

The significance of effect is a function of the value or sensitivity of the receptor and the magnitude of the impact. Table 12.11 presents the significance of impact, based on the magnitude of impact in Table 12.9 and the sensitivity of receptors in Table 12.10

.

**Table 12.11 : Significance of noise impact**

| Sensitivity of receiver | | Magnitude of impact | | | |
|---|---|---|---|---|---|
| | | **Major** | **Moderate** | **Minor** | **Negligible** |
| | High | Major | Major | Moderate | Negligible |
| | Medium | Major | Moderate | Minor | Negligible |
| | Low | Moderate | Minor | Negligible | Negligible |
| | Negligible | Minor | Negligible | Negligible | Negligible |

## 12.5 Assessment of Impacts

### 12.5.1 Construction

The predicted construction noise levels are detailed in Table 12.12 below. Construction scenarios are defined using the following abbreviations:

- PPE - Power Plant Earthworks
- PPC - Power Plant Construction
- PPB - Power Plant Building Construction
- RPE - Reinjection Pipeline Earthworks
- RPF - Reinjection Pipeline Footings
- RPP - Reinjection Pipeline Pipe Installation
- WE - Production / Reinjection Well Earthworks
- WF - Production / Reinjection Well Finishing
- SBE - Suspension Bridge Earthworks
- SBF - Suspension Bridge Footings
- SBC - Suspension Bridge Placement of Cables
- TCE - Tramway Carpark Earthworks
- TCA - Tramway Carpark Asphalting

**Table 12.12 : Predicted construction noise levels (Neutral meteorological conditions)**

| Receiver | Daytime Noise criteria dB(A) | Predicted maximum $L_{Aeq}$ during construction stage [dB(A)] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PPE | PPC | PPB | RPE | RPF | RPP | WE | WF | SBE | SBF | SBC | TCE | TCA |
| Laudat (north) | 53.0 | 26 | IA | IA | 25 | IA | IA | IA | IA | IA | IA | IA | 28 | IA |
| Laudat (south) | 53.0 | 53 | 47 | 48 | 37 | 35 | 33 | 43 | 39 | IA | IA | IA | 33 | 27 |
| Laudat (west) | 53.0 | 34 | 28 | 29 | 28 | 26 | IA | 29 | IA | IA | IA | IA | 28 | IA |
| Trafalgar (east) | 59.0 | 27 | IA | IA | 38 | 36 | 34 | 35 | 31 | IA | IA | IA | IA | IA |
| Trafalgar (south) | 59.0 | IA | IA | IA | 59 | 57 | 55 | 53 | 49 | IA | IA | IA | IA | IA |
| Trafalgar (west) | 59.0 | IA | IA | IA | 31 | 29 | 27 | 30 | 26 | IA | IA | IA | IA | IA |
| Copt Hall | 57.0 | IA | IA | IA | 25 | IA | IA | IA | IA | IA | IA | IA | IA | IA |
| Shawford | 57.0 | IA | IA | IA | 29 | 27 | 25 | 29 | IA | IA | IA | IA | IA | IA |
| Fond Cani (north) | 51.0 | IA | IA | IA | 26 | IA | IA | 26 | IA | IA | IA | IA | IA | IA |
| Fondi Cani (south) | 57.0 | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA |
| Morne Prosper | 51.0 | IA | IA | IA | 30 | 28 | 26 | 29 | 25 | IA | IA | IA | IA | IA |
| Wotten Waven | 56.0 | IA | IA | IA | 46 | 44 | 42 | 47 | 43 | IA | IA | IA | IA | IA |
| Boiling Lake* | 55.0 | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA |
| Valley of Desolation* | 55.0 | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA |
| Freshwater lake* | 55.0 | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA |

***BOLD** indicates a potential exceedance of construction noise criteria / IA = Inaudible [less than 20dB(A)]*

*= Major Significance of Impact; = Moderate Significance of Impact; = Minor Significance of Impact; = Negligible Significance of Impact*

**Construction Noise Impacts**

Predicted construction noise levels (based on neutral meteorological conditions) have been assessed as having potential impacts of **Negligible** significance, as described further below and outlined in ESIA Volume 5: Technical Appendices (Noise Impact Assessment).

*Power plant*

Construction works associated with the power plant, i.e. PPE, PPC and PPB, are predicted to comply with the daytime noise limits at all surrounding residential receivers. The predicted maximum noise level of each power plant construction scenario is as follow:

- PPE works is 53 dB(A) at the Laudat (south) residential receiver;
- PPC works is 47 dB(A) at the Laudat (south) residential receiver; and
- PPB works is 48 dB(A) at the Laudat (south) residential receiver.

The power plant construction works have been predicted to be inaudible at most residential receivers, and is considered to have potential impacts of **Negligible** significance.

*Reinjection pipeline*

Works associated with the construction of the reinjection pipeline, i.e. RPE, RPF and RPP, are predicted to comply with the noise limits at all other surrounding residential receivers. The maximum noise level of the reinjection pipeline construction activities are predicted to be as follow:

- RPE works is 59 dB(A) at the Trafalgar (south) residential receiver;
- RPF works is 57 dB(A) at the Trafalgar (south) residential receiver; and
- RPP works is 55 dB(A) at the Trafalgar (south) residential receiver.

Reinjection pipeline works are considered to have potential impacts of **Negligible** significance at all surrounding receivers.

*Reinjection well works*

Works associated with the construction of the reinjection wells, i.e. WE and WF, are predicted to comply with the noise limits at all surrounding residential receivers.

Reinjection well earthworks and finishing works are considered to have potential impacts of **Negligible** significance at all surrounding receivers.

Based on the noise predictions, receivers surrounded will comply with the noise limits where they are least 45 metres from any reinjection wells construction works.

*Bridge and carpark*

Construction works associated with the suspension bridge and tramway carpark, i.e. SBE, SBF, SBC, TCE and PPB, are predicted to comply with the daytime noise limits at all surrounding residential receivers.

Bridge and carpark works are considered to have potential impacts of **Negligible** significance at all surrounding receivers.

### 12.5.2 Operation

Operational scenarios are defined using the following abbreviations:

- PS3 - Power Plant Steam Cycle
- PR3 - Power Plant Rankine cycle
- SGS - Steam Gathering System
- RIW - Production / Reinjection Wells
- COM - Commissioning

The predicted operational noise levels are detailed in Table 12.13 and Table 12.14 below.

**Table 12.13 : Predicted operational noise levels (Neutral meteorological conditions)**

| Receiver | Operational noise criteria | Predicted maximum $L_{Aeq}$ during operation [dB(A)] | | | | |
|---|---|---|---|---|---|---|
| | Night | PS3 | PR3 | SGS | RIW | COM |
| Laudat (north) | 45 | IA | IA | 33 | IA | 33 |
| Laudat (south) | 45 | 40 | 38 | **53** | IA | **53** |
| Laudat (west) | 45 | 25 | 23 | 39 | IA | 39 |
| Trafalgar (east) | 45 | IA | IA | 45 | IA | 45 |
| Trafalgar (south) | 45 | IA | IA | **63** | 22 | **63** |
| Trafalgar (west) | 45 | IA | IA | 40 | IA | 40 |
| Copt Hall | 45 | IA | IA | 32 | IA | 32 |
| Shawford | 45 | IA | IA | 39 | IA | 39 |
| Fond Cani (north) | 45 | IA | IA | 36 | IA | 36 |
| Fondi Cani (south) | 45 | IA | IA | IA | IA | IA |
| Morne Prosper | 45 | IA | IA | 39 | IA | 39 |
| Wotten Waven | 51 | IA | IA | **57** | IA | **57** |
| Boiling Lake* | 45 | IA | IA | IA | IA | IA |
| Valley of Desolation* | 45 | IA | IA | IA | IA | 21 |
| Freshwater lake* | 45 | IA | IA | IA | IA | IA |

***BOLD*** *indicates a potential exceedance of operation noise criteria / IA = Inaudible [less than 20dB(A)]*

*= Major Significance of Impact; = Moderate Significance of Impact; = Minor Significance of Impact; = Negligible Significance of Impact*

**Table 12.14 : Predicted operational noise levels (Enhanced meteorological conditions)**

| Receiver | Operational noise criteria | Predicted maximum $L_{Aeq}$ during operation [dB(A)] | | | | |
|---|---|---|---|---|---|---|
| | Night | PS3 | PR3 | SGS | RIW | COM |
| Laudat (north) | 45 | 22 | 20 | 40 | IA | 40 |
| Laudat (south) | 45 | 44 | 42 | **55** | IA | **55** |
| Laudat (west) | 45 | 29 | 27 | 45 | IA | 45 |
| Trafalgar (east) | 45 | 21 | IA | **50** | IA | **50** |

| Receiver | Operational noise criteria | Predicted maximum $L_{Aeq}$ during operation [dB(A)] | | | | |
|---|---|---|---|---|---|---|
| | Night | PS3 | PR3 | SGS | RIW | COM |
| Trafalgar (south) | 45 | IA | IA | **64** | 23 | **64** |
| Trafalgar (west) | 45 | IA | IA | 45 | IA | 45 |
| Copt Hall | 45 | IA | IA | 36 | IA | 36 |
| Shawford | 45 | IA | IA | 44 | IA | 44 |
| Fond Cani (north) | 45 | IA | IA | 42 | IA | 42 |
| Fondi Cani (south) | 45 | IA | IA | 25 | IA | 25 |
| Morne Prosper | 45 | IA | IA | 45 | IA | 45 |
| Wotten Waven | 51 | IA | IA | **60** | IA | **60** |
| Boiling Lake* | 45 | IA | IA | IA | IA | IA |
| Valley of Desolation* | 45 | IA | IA | IA | IA | 28 |
| Freshwater lake* | 45 | IA | IA | IA | IA | IA |

***BOLD*** *indicates a potential exceedance of operation noise criteria / IA = Inaudible [less than 20dB(A)]*

*= Major Significance of Impact; = Moderate Significance of Impact; = Minor Significance of Impact; = Negligible Significance of Impact*

Steam gathering system and commissioning noise impacts during neutral weather condition are predicted to exceed the noise criteria at Laudat (south), Trafalgar (south) and Wotten Waven, but are predicted to comply with the noise criteria at all other surrounding residential receivers. During enhanced weather conditions, steam gathering system and commissioning noise impacts are predicted to exceed the noise criteria at Laudat (south), Trafalgar (east), Trafalgar (south) and Wotten Waven, but are predicted to comply with the noise criteria at all other surrounding residential receivers. The predicted noise impacts at Laudat (south), Trafalgar (east), Trafalgar (south) and Wotten Waven have been predicted to exceed the noise criteria by 10 dB(A), 5 dB(A), 19 dB(A) and 9 dB(A) respectively during enhanced weather condition. Steam gathering system and commissioning works will potentially have **Major** significance of impact at Laudat (south), Trafalgar (east), Trafalgar (south) and Wotten Waven, but is considered to have **Negligible** significance of impact at all other surrounding receivers. That said, it is understood that commissioning testing will only occur for a relatively short period and is therefore, not considered to be of concern.

The predicted noise levels indicate that the operations of the Rankine steam condensing and ORC power plant at the preferred sites will most likely comply with the noise criteria at all surrounding residential receivers. The predicted noise levels show that operational noise from the Steam or ORC power plant are inaudible at all surrounding receivers except at Laudat (south), Laudat (west) and Trafalgar (east). Operational noise levels of the Steam power plant are predicted to be up to 40 dB(A) during neutral weather condition and up to 44 dB(A) during enhanced weather condition. While operational noise levels of the ORC power plant are predicted to be up to 38 dB(A) during neutral weather condition and up to 42 dB(A) during enhanced weather condition. Based on the predicted operational noise levels of the power plant, it can be seen that the ORC power plant is the quieter option. Operational noise impacts of either Rankine Steam or ORC power plant at the preferred site are considered to have **Negligible** significance of impact at all surrounding receivers.

Operations of the production / reinjection wells are also predicted to comply with the noise criteria at all surrounding residential receivers. The noise modelling results show that production / reinjection wells are inaudible at most receivers except at Laudat (south), Trafalgar (east), Trafalgar (south), Trafalgar (west), Morne Prosper and Wotten Waven. The worst case operational noise impact of production / reinjection wells has been predicted to be 22 dB(A) during neutral weather condition and 23 dB(A) during enhanced weather condition. Both worst case operation noise impacts were predicted at Trafalgar (south). Production / reinjection wells are considered to have **Negligible** significance of impact at all surrounding receivers.

## 12.6 Mitigation

### 12.6.1 Construction

Worse case construction noise impacts are predicted to comply with the noise limits at all surrounding residential receivers. Notwithstanding this finding, it will be important for the contractor to undertake all reasonable and feasible measures to manage noise levels, minimise noise impacts and liaise with affected landowners and local communities.

During the planning and scheduling of construction works the predicted noise levels should be considered in establishing work site locations, construction techniques and on site practises. The following principles and proactive noise management measures should be considered for implementation by the EPC Contractor:

- A Construction Noise Management Plan (CNMP) should be formulated to provide a framework for addressing construction noise levels. Noise control options including site mitigation and the investigation of low noise plant should be detailed and direction provided for the delivery of best practice noise management on site.
- Construction works should adopt Best Management Practice (BMP) and Best Available Technology Economically Achievable (BATEA) practices. BMP includes factors discussed within this report and encouragement of a project objective to reduce noise emissions. BATEA practices involve incorporating the most advanced and affordable technology to minimise noise emissions.
- Limit construction works to daytime hours where reasonable and feasible.
- Locating haul routes as far as possible from residential receivers.
- Using equipment that has been well maintained so that noise emissions are minimised.
- Provide localised noise screening where works are to be conducted within 200 metres (the compliance distance) of any sensitive receivers.
- Where possible, static construction plant such as generators should be located adjacent to on-site structures to impede noise propagation.
- Engines shall not be started and on-site activities shall not be undertaken outside of the daytime construction hours. Non noise generating works can be undertaken at staging areas where works are not adjacent to residential receivers.
- Construction activities should be undertaken in accordance with BS 5228, Code of Practice for Noise Control on Construction and Demolition Sites. All equipment used on site would be required to demonstrate compliance with the noise levels recommended within BS 5228.
- Appropriate use of all plant and equipment, with reasonable work practices applied, including no extended periods of ‘revving’, idling or ‘warming up’ in proximity to existing residential receivers. Any excessively loud activities should be scheduled during periods of the day when general ambient noise levels are greatest. This would reduce the potential for cumulative noise impacts (relating to worst-case elevated operations) and extended periods of off-site annoyance.
- Minimising reversing alarm noise emissions from mobile plant and transport truck operations should be considered, provided occupational health and safety requirements are satisfied. Where practicable, site entry and exit points should be managed to limit the need for reversing.
- Construction plant source noise levels should be confirmed prior to the commencement of works to verify construction noise impacts and noise management measures.
- Provide a summary of required construction noise management practices to all staff and contractors and be included during site inductions. The summary should include, as a minimum, the permitted hours of construction work, work site locations and site ingress/egress.

- Local residents and land owners are to be notified a minimum of 2 weeks prior to the commencement of construction works. The notification would detail proposed construction works, permitted hours of work and potential noise impacts.

### 12.6.2 Operation

Based on the predicted noise levels, it is shown that the ORC type power plant is quieter compared to the Steam type power plant. As the commissioning phase of the power plant has the potential to adversely impact on surrounding residential receivers, it is recommended that the measures be implemented by the O&M Contractor during the commissioning operations of the power plant:

- Steam gathering system operations and commissioning testing should be conducted during daytime periods only.
- Erect temporary localised screening during steam gathering system operations and commissioning testing. Potential noise impact reduction of up to 6 dB(A) is achievable where acoustic screens are located within 5 metres of the construction works, be at least 300 mm above the height of the noise source and provide a solid façade impeding line of sight to nearest receivers – any gaps negate noise reduction performance.
- Notify local residents and landowners prior to any steam gathering system operation and commissioning testing.

## 12.7 Monitoring

### 12.7.1 Construction

The following monitoring measures should be employed during construction by the EPC Contractor:

- Noise monitoring to confirm the actual construction noise levels at representative sensitive receiver locations should be undertaken, for example, adjacent to the power plant site). This monitoring should be carried out at the start of the construction of the Project and on a quarterly basis.
- Direct observation of machine maintenance should also be made to ensure that any noise-creating faults are repaired.

### 12.7.2 Operation

The following monitoring measures should be employed during operation by the O&M Contractor:

- Noise at the power plant will be measured on a quarterly basis at the power plant site and the nearest settlements for a duration of at least 48 hours. Results from this monitoring are to be used to assess compliance with Dominica guidelines (Environmental Standards for Protection against Noise (June 2003)) and the WBG EHS Guidelines and to be reported to the relevant authorities. Noise monitoring data should also be made available for public access.
- Direct observation of machine maintenance should also be made to ensure that any noise-creating faults are treated.

## 12.8 Assessment of Residual Impacts

### 12.8.1 Construction

The impact assessment identified construction noise to have **Negligible** potential impacts. The application of the mitigation measures described above will ensure construction activities are well within the noise management levels and therefore residual impacts are considered to remain at **Negligible** significance.

### 12.8.2 Operation

The impact assessment identified operational noise to be of **Negligible** potential impact except during the commissioning phase, which reported temporary **Major** potential impacts. Following the application of the mitigation measures described above, impacts from commissioning activities residual impacts are considered to reduce to **Minor** significance.

# 13. Terrestrial Ecology

## 13.1 Introduction

This section describes the potential impacts to ecological receptors from the construction and operation of the Project and sets out mitigation measures to minimise any impacts. The section summarises the findings of the ESIA Volume 5: Technical Appendices (Terrestrial Ecology Impact Assessment).

## 13.2 Methodology

The methodology for the terrestrial ecology impact assessment follows the general methodology set out in ESIA Volume 1: Introduction.

## 13.3 Activities Proposed

Since the commencement of exploratory drilling in 2011, five wells have been drilled (WW-P1, WW-R1, WW-01, WW-02 and WW-03). The Project will use the wells which have already been drilled and tested. As such this document assumes no drilling of new wells in advance of operation. If additional 'make-up' wells are required during the lifespan of the Project, a separate ESIA will be undertaken when the requirements are known. Maintenance of the existing wells is, however, considered within this ESIA. Project-related activities expected to be required are set out in Table 13.1. Construction of the Project will take 18 months to two years.

**Table 13.1: Indicative activities required during each phase of the Project**

| |
|---|
| **Construction** |
| • Vegetation clearance for the power plant site, laydown areas, reinjection route and creation/widening of access roads.<br>• Earthworks for the power plant site, laydown areas, reinjection route and creation of access tracks for the reinjection line.<br>• Operation of construction plant.<br>• Increased presence of vehicles.<br>• Increased human presence.<br>• Release of run-off or sediments during construction.<br>• Accidental spillage of chemical or hydrocarbon loads.<br>• Use of water for equipment washdown, workers (potable and sanitary uses), and potentially a reserve for fire-fighting. Water could be abstracted from Titou Gorge Stream (c.150 m south of the plant). |
| **Operation** |
| • Monitoring and maintenance of the geothermal reservoir, including well workovers, as detailed in ESIA Volume 5: Technical Appendices, Technical Report – Detailed Process Description.<br>• Water use - for workers, supply for fire-fighting, and for maintenance and plant cleaning. This would be sourced from surface water sources and/or brought in from off-site.<br>• Water abstraction – possible requirement to pump cold water from the Roseau River to increase well injection capacity.<br>• Increased human presence.<br>• Emissions to air of non-condensable gases.<br>• Air coolers, which do not have a visible plume of water vapour but may exhibit a heat haze OR water cooling towers, which have a visible plume of water vapour when the relative humidity of the atmosphere is high.<br>• Other routine maintenance works.<br>• If Organic Rankine Cycle (ORC) technology is selected, the flammable substance n-pentane will be required (c. 30 tonnes), to be stored in a bunded storage tank in the power plant site, and in the condenser and process lines of the power plant. |
| **Decommissioning** |
| • Activities likely to be similar in nature to those during construction, above, but less extensive and intensive. |

- Plugging and abandoning geothermal wells.

## 13.4 Impact Assessment

For the species and habitats evaluated in the Section 3.12 (Terrestrial Ecology Baseline) as important to this assessment, the activities detailed in Table 13.1 which may impact the feature directly, indirectly and/or cumulatively, are detailed in Table 13.2. Where an impact is initiated in construction but also occurs throughout operation (e.g. permanent habitat removal), it is discussed only within operational impacts.

**Table 13.2: Assessment of significance of impacts in the absence of mitigation**

| Activity | Potential impact | Effect | Significance |
|---|---|---|---|
| **Construction** | | | |
| Construction activities including earthworks, excavations, creation/widening of access roads, and the operation of construction plant | • Noise | Construction noise levels have been modelled for receptor locations around the Project area. Noise levels during construction are predicted to be inaudible or of negligible significance under all 13 construction scenarios. | Negligible |
| | • Harmful air emissions<br>• Dust<br>• Night-time illumination of platforms | Air emissions and dust during construction have been modelled for receptor locations at and around the source points.<br>Dust emissions from 'small'[6] earthworks are considered negligible at distances >200m. As the sensitivity of the area is classified as 'Low', the resulting risk is classified as 'Negligible' for ecological impacts.<br>There is a small potential for cumulative impacts of $SO_2$ and particulate matter, however the effect would be highly localised.<br>Lighting of platforms could cause minor disturbance to animals in the immediate vicinity of the construction area. | Negligible |
| | • Introduction/spread of invasive plant species | The transport of significant quantities of soil on or off site is not expected. Spread of invasive species which may outcompete native species is possible, although based on the scale of the construction area, is unlikely to be significant. | Negligible |
| | • Release of hazardous substances from accidental spillage or major accident | Uncontrolled discharges of geothermal fluids (brine and condensate) can be harmful to the environment, containing substances such as arsenic and boron. Brine is also very hot.<br>Impacts could occur downstream, including damage to plant tissue, necrosis and animal sickness or mortality. Release on a scale which would have a significant effect would be unlikely. | Minor |
| | • Run-off or sedimentation | If not treated, run-off and sedimentation will reduce water quality and increase deposition downstream, potentially contaminating drinking water used by animals, and inhibiting plant growth. Release on a scale which would have a significant effect would be unlikely. | Minor |

[6] As defined in the Institute of Air Quality Management (IAQM) (2011). For details see the ESIA Volume 3: EIA, Chapter 4 - Air Quality.

| Activity | Potential impact | Effect | Significance |
|---|---|---|---|
| Increased presence of vehicles | • Noise and vibration<br>• Dust<br>• Emissions to the air<br>• Collision with animals | Effects from noise, vibration and dust would be as above, but not on a scale greater than negligible.<br>Direct mortality of individuals from collisions or entrapment in uncovered holes, pipes or machinery is unlikely to occur in sufficient numbers to affect the wider population. | Negligible |
| Increased human presence | • Encroachment | An influx of workers in search of employment, and associated businesses and services, may result in settlements growing. This may place increased pressure on resources such as land, water, waste disposal procedures. The Project size and location is unlikely to attract large numbers of job-seekers. Localised inappropriate waste disposal may however occur. | Negligible |
| Temporary removal of terrestrial habitats to accommodate the construction corridor for the reinjection line. During construction, the corridor will be 10 m wide (of which 3-4 m will be permanent loss, see below). | • loss of habitat<br>• reduction of ecological connectivity | Temporary reduction in extent of secondary rainforest and agricultural land, and associated impacts on animal communities associated which rely on these habitats for food, shelter and breeding.<br>Parts of the habitats to be lost could support threatened species but are not considered to be core habitat. The extent of the habitat loss is relatively small, and the vegetation along the reinjection line is expected to regenerate rapidly. | Negligible |
| **Operation** | | | |
| Permanent removal of terrestrial habitats to accommodate footprint of construction. The land required for the power plant site is expected to be between 0.32 ha and 1.42 ha, all of which is Modified.<br>In addition, the 3.25 km pipeline will have a permanent wayleave of 3-4m, with an associated loss of 1.4 ha Modified habitat and 1.7ha Natural habitat | • loss of habitat<br>• reduction of ecological connectivity | Permanent removal of terrestrial habitats to accommodate footprint of construction. The land required for the power plant site is expected to be between 0.32 ha and 1.42 ha, all of which is Modified. | Minor |
| Operation of power plant (including turbines, fans, pumps etc.), reinjection wells, and steam pressure releases during commissioning of both power plant and reinjection wells | • Noise | Operational noise levels have been modelled for 13 locations. Noise levels are predicted to be inaudible or of negligible significance in all scenarios, except one. Under the commissioning scenario, there are exceedances at three locations: Trafalgar, Laudat and Wotten Waven, however it is understood that commissioning testing will only occur for a relatively short period. | Minor |
| | • Harmful air emissions | If of sufficient magnitude, air emissions and dust could result in disturbance to animals, and associated stress and reduction in fecundity.<br>Air emissions such as $H_2S$, $SO_2$ and mercury have been modelled throughout the Project area. Small exceedances may occur close to the emission sources, however concentrations will decrease rapidly with distance and adverse impacts are not expected. | Negligible |

| Activity | Potential impact | Effect | Significance |
|---|---|---|---|
| Maintenance activities including well workovers and cleanouts, which could include small-scale drilling | • Release of toxic gas e.g. hydrogen sulphide<br>• Noise<br>• Vibration | In high concentrations hydrogen sulphide can result in necrosis and mortality.<br>Vibration, noise and lighting may affect fauna, resulting in stress, behavioural changes, reduced breeding success. These activities would be relatively infrequent and short-term and thus not expected to be significant. | Negligible |
| Increased human presence | • Encroachment | A workforce of only two or three workers is expected during operation, therefore no impacts are expected. | Negligible |
| If ORC technology is selected, storage and use of the flammable substance n-pentane | • Leak or rupture of n-pentane storage tank at the power plant | Based on the Areal Locations of Hazardous Atmospheres (ALOHA) modelling detailed within ESIA Volume 2: EIA, Chapter 15, the spatial extent and level of consequence of a three scenarios at the power plant was estimated.<br>The level of impact under this scenario was found to be contained within the power plant, and the level of impact on surrounding areas of Negligible significance. | Negligible |
| | • Leak or rupture of n-pentane storage tank at the power plant resulting in a pool fire in the bund | A burning pool fire which could affect animals and habitats outside the power plant is possible but highly unlikely. The level of impact on the areas surrounding the power plant were assessed as of Negligible significance. | Negligible |
| | • Boiling liquid expanding vapour explosion (BLEVE)[7] | Under the modelled scenario the thermal radiation from this event sufficient to cause pain (to humans) within 60 seconds extends to 413 m from the incident location. Lethal effects may extend to 188 m, with an intermediate category of 2nd degree burns (to humans) extending to 265 m. Such an incident could have substantial and wide-ranging consequences for animals and habitats, but is a very unlikely occurrence. | Minor |
| **Decommissioning** | | | |
| Activities likely to be undertaken will be similar in nature to those during construction but will likely be less extensive and intensive. These activities may include plugging and abandoning geothermal wells. | An indicative operational lifetime for the Project is 30 years. After this point, a programme of activities will be required to decommission the above-ground facilities and remediate the site to an agreed level.<br>Because of the long timescale until this phase of the Project occurs, it is recommended that a separate assessment of impacts is undertaken at that time, including all mitigation and monitoring required to avoid significant adverse impacts. | | |

## 13.5 Mitigation and Monitoring

The important species and habitats identified in the assessment were red-necked parrot, tink frog, Dominican ground lizard, Dominica anole, blue-headed hummingbird, and plumbeous warbler, and their habitats. No likely significant (greater than minor) negative impacts have been identified through the assessment process, and thus no specific mitigation is required for these species.

Part of the reinjection line corridor is currently Natural Habitat (see ESIA Volume 5: Technical Appendices - Appendix H Terrestrial Ecology Impact Assessment). In line with Performance Standard 6, in areas of Natural

[7] A BLEVE is an explosion caused by the rupture of a vessel containing a pressurised liquid above its boiling point. This is a rare event that can occur only if safety measures fail completely or in other very unusual circumstances.

Habitat, mitigation has been designed to achieve No Net Loss of biodiversity, where feasible. This has included / will include the following activities:

- A number of options for the reinjection in route were considered, with consideration for ecological impacts, to avoid sensitive habitats.
- Habitat cleared will be minimum possible, with any way-leave area required of the minimum width necessary. This will contribute to minimising habitat fragmentation.
- The 6-7m of the construction corridor of the reinjection line that is not required permanently will be replanted with native species as soon as possible after construction.
- A biodiversity offset will be created to a minimum extent of 1.7 ha (equivalent to the Natural Habitat lost under the Project Area and where practicable include the Modified Habitat lost to the Project Area). A Habitat Management Plan (HMP) will be developed to establish the biodiversity offset required to achieve No Net Loss of Natural Habitats, with input from local specialists and stakeholders as appropriate. The biodiversity offset will also incorporate the measures identified in Section 6: Post-Hurricane Maria Actions, where appropriate.

A minor impact was identified as a result of fragmentation of habitats by the reinjection line. In order to minimise severance effects, the pipeline will have under/overpasses installed at intervals along its length. The exact nature and positioning of these will be developed during detailed design. In addition, because the pipeline is located above-ground, smaller animals are expected to be able to pass under it.

Furthermore, standard good practice measures such as the following will however help to further minimise adverse impacts. These should be undertaken by the EPC Contractor:

- Implement dust-suppression measures such as covering vehicles transporting materials, ensuring vehicles use wheel wash facilities at site, and use of water spray dust suppression systems.
- Highly noisy activities should be undertaken during daylight hours where possible.
- Inductions/tool-box talks for staff should include reference to measures required to protect biodiversity.
- Appropriate provision should for be made for waste disposal.
- Vegetation clearance activities should commence outside the breeding season for five key threatened species identified, to minimise impacts on breeding animals. The breeding seasons of the three bird species are overlapping, between January and August[8]. The amphibian species are thought to breed year-round, but primarily between May and July
- Use temporary fencing to prevent inadvertent damage outside designated construction areas.
- Avoid piling of clear-felled vegetation on standing live vegetation which would hinder movement of wildlife.
- Any replanting / landscaping should use native or endemic species to prevent the incursion of opportunistic invasive species.
- Machinery and vehicles should be cleaned upon entry/exit, and any soil brought on or off site screened for invasive species or plant pathogens.
- Minimise potential for sedimentation impacts by ensuring good construction site practices are implemented.
- Appropriate disposal of solid and liquid wastes, in line with recommendations in international and national standards, and using designated facilities as required.
- Any effluent discharged to surface watercourses must meet the more stringent of international water quality discharge standards prior to release to remove pollutants.
- Minimise potential for pollutants and surface water run-off to migrate off-site by ensuring standard good construction site practices are implemented.

[8] http://www.iucnredlist.org/ (Accessed September 2017)

- Ensure all standard safe storage measures for n-pentane are implemented, as detailed in ESIA Volume 2: EIA, Chapter 15.

These measures will be included within the Environmental and Social Management Plan (ESMP), to be developed following detailed design of the Project. The Plan will be agreed with input from relevant authorities and implemented prior to construction where appropriate. It will also include mitigation/monitoring measures identified as required in the MTPNP assessment. As detailed above, an HMP will be developed to establish the biodiversity offset required to achieve No Net Loss of Natural Habitats. It should be noted that the additional mitigation and monitoring set out within the MTPNP assessment are of relevance to ecological receptors generally, and should be considered alongside this assessment.

### 13.5.1 Post-Maria Specific Work

DGDC will develop a Habitat Management Procedure (HMP) that will be adhered to be the EPC Contractor and all Subcontractors during all Project construction works. The HMP will aim to provide enhancement measures for post-Maria terrestrial biodiversity of the area:

- Stabilise bare slopes or improve resilience on slopes where trees have fallen – promote tree and shrub planting to stabilise lose soil and rock, prevent further erosion and slips. This could also include supporting local nurseries to grow more trees which in turn could be used by local communities.
- Areas of fallen trees surrounding well pads and other infrastructure – plant native tree species to stabilise ground conditions, improve ecological resilience and reduce rainwater run-off which in turn could pollute water courses and cause soil erosion.
- Restore river courses – remove bulky items where possible such as fallen trees, logs and other detritus and large rocks which could block river flow and cause flooding; destabilise slopes or cause soil erosion to surrounding terrestrial areas.
- Removal of habitat cover – provide hibernacula of log piles, stone/rock piles for amphibians and other animals which might have been lost along with tree canopy cover.
- Exposed ground - plant native grass seed with fertilizer where exposed ground is still visible or where slopes are too steep or where soil has been washed away.

## 13.6 Residual Impacts / Summary

The field surveys and desk study information indicate a relatively low diversity and abundance of important ecological features, with the majority of important habitats and species being instead concentrated within the MTPNP. Whilst the surrounding areas provide important functions in terms of connectivity and supplementary habitat, there is no identified Critical Habitat and the only Threatened species thought to use the area finds its core habitat within the MTPNP. No culturally or socially important plant species were identified.

Impacts identified were notably loss of secondary rainforest and agricultural habitats, and the small likelihood but potentially substantial consequences of a major leak, fire or explosion. None of the impacts identified would be greater than minor significance and thus no specific mitigation was required. A biodiversity offset is proposed to ensure the Project achieves No Net Loss of Natural Habitats, and as close to No Net Loss of all habitats as possible. In addition, a range of standard good practice measures are recommended to minimise adverse impacts further. These measures are consistent with the recommendations of the assessment of impacts on the MTPNP, and will assist in maintaining the values, integrity and protection of that site too.

# 14. MTPNP World Heritage Site

## 14.1 Introduction

This section describes the potential impacts to the MTPNP World Heritage Site from the construction and operation of the Project and sets out mitigation measures to minimise any impacts. The section summarises the findings of the ESIA Volume 5: Technical Appendices (MTPNP Impact Assessment).

## 14.2 Methodology

World Heritage Sites are those places which have been determined by UNESCO to be of "Outstanding Universal Value"[9] (OUV), fulfilling at least 1 of 10 selection criteria, and meeting conditions relating to site integrity, and protection/management systems. Their designation indicates that they are deemed important to the collective interests of humanity.

In addition to the national legislation and financier's requirements regarding Environmental Assessments, as set out in the ESIA Volume 1: Introduction, Chapter 2, this assessment also reflects the requirements of the IUCN World Heritage Advice Note on Environmental Assessment (IUCN, 2013). The Advice Note provides guidance on integrating natural[10] World Heritage Sites, such as the MTPNP, within Environmental Assessments. The guidance is concerned specifically with impacts of the Project on the OUV of the site, rather than all potential impacts.

### 14.2.1 Outstanding Universal Value

OUV has three components:

- values;
- integrity; and
- protection and management.

All development proposals that could affect the OUV of a WHS are required to be submitted by States Party to the World Heritage Committee before a decision on their funding, permitting or implementation is taken. As such, a copy of this ESIA will be provided to the World Heritage Committee for comment.

### 14.2.2 World Heritage Impact Assessment Principles

The World Heritage Advice Note sets out eight Impact Assessment Principles with which the assessment is required to comply. The principles are set out within Table 14.1, and references provided to their location for this development.

**Table 14.1 : World Heritage Impact Assessment Principles**

| No. | Requirement of Environmental Assessment for proposals affecting natural World Heritage Sites | Details / reference where addressed in report |
|---|---|---|
| 1 | Take place as early as possible in the decision-making process. | Consultation between the GoCD and the World Heritage Committee has been ongoing since the inception of the development proposals (as documented in UNESCO Mission Report (UNESCO, 2017b)). |

[9] Defined as *"…natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity."*

[10] World Heritage sites are designated by criteria which categorise them as natural, cultural or mixed.

| No. | Requirement of Environmental Assessment for proposals affecting natural World Heritage Sites | Details / reference where addressed in report |
|---|---|---|
| 2 | Identify and evaluate reasonable alternatives to the proposal. | Provided in ESIA Volume 5: Technical Appendices (MTPNP Impact Assessment), Section 2. |
| 3 | Assess the likely environmental and social effects of the development proposal(s) on the Outstanding Universal Value of the site. | Provided in ESIA Volume 5: Technical Appendices (MTPNP Impact Assessment), Section 3 |
| 4 | Identify adequate mitigation measures for any residual negative impacts on Outstanding Universal Value that cannot be further reduced. | Provided in ESIA Volume 5: Technical Appendices (MTPNP Impact Assessment), Section 4 |
| 5 | Include a separate chapter on World Heritage impacts in the Environmental Assessment report. | Provided in ESIA Volume 5: Technical Appendices (MTPNP Impact Assessment). |
| 6 | Be publicly disclosed and subject to thorough public consultation. | Details of consultation undertaken for the Project are detailed within Stakeholder Engagement Plan (located in ESIA Volume 5: Technical Appendices), and included consideration of the MTPNP. |
| 7 | Propose, implement and independently audit an environmental management plan. | Monitoring and management will be undertaken as detailed in ESIA Volume 5: Technical Appendices (MTPNP Impact Assessment), Section 4. |
| 8 | Effectively integrate the conclusions of the assessment into the decision-making process. | The conclusions of the ESIA as a whole will be taken into consideration by the deciding authorities, as required by national legislation and international standards. |

The guidance requires consideration of all likely effects of the proposal on the OUV of the WHS, including potential direct, indirect and cumulative effects. Potential social issues that could impact on the site's OUV should also be assessed, and a consideration provided of alternative options, including the 'no project' option.

### 14.2.3 Assessment of Impacts

Significance of potential impacts have been classified in accordance with the impact evaluation matrices in Section 2.5 and considers the magnitude and sensitivity of the impact.

### 14.2.4 Mitigation and Residual Impacts

Adequate mitigation measures are identified for potential minor residual negative impacts identified on OUV that cannot be avoided or further reduced. The assessment also notes how these measures will be implemented, who will implement them within what timeframe, and what resources are secured for their implementation.

The assessment presents conclusions on the proposal's potential negative impacts on all relevant aspects of OUV, including on values, integrity and protection and management.

Based on the findings of the assessment and any residual impacts, a preferred development proposal option/scenario is recommended.

## 14.3 Assessment of Potential Impacts

Table 14.2 provides an assessment of the significance of potential impacts on the MTPNP World Heritage Site .

**Table 14.2: Assessment of significance of impact on WHS in the absence of mitigation**

| Activity | Potential impact | Effect | Magnitude | Sensitivity | Significance |
|---|---|---|---|---|---|
| **Construction** | | | | | |
| Vegetation clearance | • Loss of habitat (outside the WHS)<br>• Reduction of ecological connectivity | Habitat loss and resulting fragmentation outside the WHS has a low likelihood of indirectly and/or cumulatively contributing to similar effects within the WHS, including Critical habitat. This is because of the scale of the Project infrastructure and high degree of regeneration post-disturbance.<br>Removal of nests or nesting habitat outside the WHS which would otherwise act as fringe habitat and extend the range of a species, including species which are threatened and/or protected.<br>Reduction of foraging habitat for species which may move in and out of the site. | Minor | Medium | Minor |
| Construction activities including earthworks, excavations, creation/widening of access roads, and the operation of construction plant | • Noise | Construction noise levels have been modelled for three points within the MTPNP: Boiling Lake, Valley of Desolation and Freshwater Lake. Noise levels are predicted to be inaudible (less than 20dB(A)) under all 13 construction scenarios. | Negligible | Medium | Negligible |
| | • Harmful air emissions<br>• Dust<br>• Night-time illumination of platforms | If of sufficient magnitude, air emissions and dust could result in disturbance to animals within the WHS, and associated stress and reduction in fecundity.<br>Air emissions and dust during construction have been modelled for three points within the MTPNP: Boiling Lake, Valley of Desolation and Freshwater Lake.<br>Maximum predicted concentrations of hydrogen sulphide ($H_2S$) decrease rapidly with distance from the power plant and adverse impacts are not expected.<br>Dust emissions from 'small'[11] earthworks are considered negligible at distances >200m. | Negligible | Low | Negligible |

[11] As defined in the Institute of Air Quality Management (IAQM) (2011). For details see the ESIA Volume 3: EIA, Chapter 4 - Air Quality.

| Activity | Potential impact | Effect | Magnitude | Sensitivity | Significance |
|---|---|---|---|---|---|
| | | Works on tracks and the laydown area would be no greater than the exploration activities already undertaken.<br>There is a small potential for cumulative impacts of $SO_2$ and particulate matter, however the effect at the MTPNP would be negligible.<br>Lighting of platforms is unlikely to be sufficiently disturbing at 600m to result in stress, behavioural changes or reduced breeding success. | | | |
| | • Introduction/spread of invasive plant species | Spread of invasive species into the WHS, which may outcompete native species. However, no air-dispersed plant species are known to be of concern in this area. Construction plant and vehicles will not drive onto the WHS so no impacts will occur. | Minor | Medium | Minor |
| | • Release of hazardous substances from accidental spillage or major accident | Uncontrolled discharges of geothermal fluids (brine and condensate) can be harmful to the environment, containing substances such as arsenic and boron. Brine is also very hot.<br>Unless occurring on a major scale, however, release of contaminants is unlikely to result in significant impacts, as the WHS is upstream of the Project site.<br>Uncontrolled discharges of geothermal fluids (brine and condensate | Minor | Medium | Minor |
| | • Run-off or sedimentation | Unless occurring on a major scale, contamination of watercourses is unlikely to result in significant impacts, as the WHS is upstream of the Project site. | Minor | Medium | Minor |
| Increased presence of vehicles | • Noise and vibration<br>• Dust<br>• Emissions to the air<br>• Collision with animals | Effects would be as above, but not on a scale that would be noticeable at the MTPNP.<br>Vehicles would not be present on the MTPNP, and encounters with animals outside the park boundaries are considered unlikely. | Minor | Low | Negligible |
| Increased human | • Encroachment | An influx of workers in search of employment, and | Minor | Low | Negligible |

| Activity | Potential impact | Effect | Magnitude | Sensitivity | Significance |
|---|---|---|---|---|---|
| presence | • Increased access to WHS through improved infrastructure | associated businesses and services, may result in settlements growing. This may place increased pressure on resources such as land, water, waste disposal procedures. Given the Project site is on a small island this is unlikely to occur on scale that would impact the WHS. | | | |
| **Operation** | | | | | |
| Operation of power plant (including turbines, fans, pumps etc.), reinjection wells, and steam pressure releases during commissioning of both power plant and reinjection wells | • Noise | Operational noise levels have been modelled for three points within the MTPNP: Boiling Lake, Valley of Desolation and Freshwater Lake. Noise levels are predicted to be inaudible (less than 20dB(A)) under all 10 operational scenarios, with one exception, which is 21dB(A) at the Valley of Desolation, during steam pressure releases. Noise level changes of 3dB(A) are imperceptible to human receptors and a change of 1dB(A) is therefore negligible, even for sensitive animals. | Negligible | Medium | Negligible |
| | • Harmful air emissions | If of sufficient magnitude, air emissions and dust could result in disturbance to animals within the WHS, and associated stress and reduction in fecundity.<br>Air emissions and dust during construction have been modelled for three points within the MTPNP: Boiling Lake, Valley of Desolation and Freshwater Lake.<br>Maximum predicted concentrations of hydrogen sulphide ($H_2S$) were found to decrease rapidly with distance from the power plant and adverse impacts are not expected. | Negligible | Low | Negligible |
| Maintenance activities including well workovers and cleanouts, which could include small-scale drilling | • Release of toxic gas e.g. hydrogen sulphide<br>• Noise<br>• Vibration | In high concentrations hydrogen sulphide can result in necrosis and mortality.<br>Vibration, noise and lighting may affect fauna, resulting in stress, behavioural changes, reduced breeding success.<br>The above are not expected to be experienced within | Minor | Low | Negligible |

| Activity | Potential impact | Effect | Magnitude | Sensitivity | Significance |
|---|---|---|---|---|---|
| | | the WHS boundaries at a magnitude that would be above negligible. | | | |
| Increased human presence | • Encroachment<br>• Increased access to WHS through improved infrastructure | A workforce of only two or three workers is expected during operation; therefore, no impacts are expected. | Minor | Low | Negligible |
| If ORC technology is selected, storage and use of the flammable substance n-pentane | • Leak or rupture of n-pentane storage tank at the power plant | Based on the Areal Locations of Hazardous Atmospheres (ALOHA) modelling detailed within ESIA Volume 2: EIA, Chapter 15, the spatial extent and level of consequence of a leak or rupture of an n-pentane storage tank at the power plant was estimated for three scenarios.<br>The effects at the WHS boundary under this scenario were negligible. | Minor | Low | Negligible |
| | • Leak or rupture of n-pentane storage tank at the power plant resulting in a pool fire in the bund | Under the modelled scenario, the effects at the WHS boundary were negligible. | Minor | Low | Negligible |
| | • Boiling liquid expanding vapour explosion (BLEVE)[12] | Under the modelled scenario the thermal radiation from this event sufficient to cause pain (to humans) within 60 seconds extends to 413 m from the incident location, which is estimated to be 100 - 150 m from the WHS boundary. Effects at this distance could be sufficient to cause disturbance and damage to plants and animals. | Moderate | Low | Minor |

[12] A BLEVE is an explosion caused by the rupture of a vessel containing a pressurised liquid above its boiling point. This is a rare event that can occur only if safety measures fail completely or in other very unusual circumstances.

## 14.4 Mitigation

### 14.4.1 Mitigation for Minor Impacts

No significant (greater than minor) negative impacts have been identified through the assessment process. Although non-significant, the IUCN guidance requires that “adequate” mitigation is also identified for minor impacts on OUV. Mitigation for minor effects identified in Table 4.1 is detailed in Table 4.2. The HMP outlined above (Section 13.5.1) will also directly contribute towards mitigation for the MTPNP.

### 14.4.2 Performance Standard 6 Mitigation

In line with Performance Standard 6, in areas of Natural Habitat, mitigation has been designed to achieve No Net Loss of biodiversity, where feasible. This has included / will include the following activities:

- A number of options for the reinjection in route were considered, with consideration for ecological impacts, to avoid sensitive habitats.
- Habitat cleared will be minimum possible, with any way-leave area required of the minimum width necessary. This will contribute to minimising habitat fragmentation.
- The 6-7m of the construction corridor of the reinjection line that is not required permanently will be replanted with native species as soon as possible after construction.
- A biodiversity offset will be created to a minimum extent of 1.7 ha (equivalent to the Natural Habitat lost under the Project Area). A Habitat Management Plan (HMP) will be developed to establish the biodiversity offset required to achieve No Net Loss of Natural Habitats, with input from local specialists and stakeholders as appropriate. The biodiversity offset will also incorporate the measures identified in Section 6: Post-Hurricane Maria Actions, where appropriate.

### 14.4.3 Generic Good Practice Mitigation

The following generic good practice mitigation is considered adequate to further minimise adverse impacts, including negligible impacts:

- Implement dust-suppression measures such as covering vehicles transporting materials, ensuring vehicles use wheel wash facilities at site, and use of water spray dust suppression systems.
- Highly noisy activities should be undertaken during daylight hours where possible.
- Inductions/tool-box talks for staff should include reference to measures required to protect biodiversity.
- Proposals for the MTPNP buffer zone should be progressed, and this area maintained as a development-free zone. Activities that would facilitate access to the MTPNP should not be encouraged.
- Standard safe storage for n-pentane includes storage under a nitrogen blanket; incorporation of a Pressure Relief Valve; appropriate bunding; and a deluge fire extinguishment system. Heat and pentane sensors are also fitted around the storage tank and the plant to detect any leaks and heat changes.

### 14.4.4 Implementation of Mitigation

Implementation of mitigation will be prior to the phase in which the corresponding impact is expected to occur. Responsibility for the implementation of mitigation set out in the ESIA will become the responsibility of the appointed EPC Contractor, overseen by DGDC.

## 14.5 Monitoring

The MTPNP supports at least five species considered Threatened by IUCN: giant ditch frog, imperial parrot, red-necked parrot, forest thrush, and a species of tree frog (*Eleutherodactylus amplinympha*). The UNESCO Mission Report (UNESCO, 2017b) considered that habitat loss required for the construction of the power plant and installation of the pipeline could negatively impact the red-necked parrot – and potentially other Threatened

species. Mitigation measures will minimise habitat loss in the vicinity of the Project infrastructure and no habitat loss will take place within the WHS.

In addition, and in line with the UNESCO Mission Report (UNESCO, 2017b) it is recommended that a programme of monitoring be implemented. This should comprise firstly a programme of monitoring for the five key species identified, recommended to be at every six months from pre-construction until the completion of one year of construction, and annually thereafter for a minimum of five years of operation. The programme should also include the ongoing monitoring in the Laudat and Trafalgar area for any other potential impacts on the OUV of the WHS.

Monitoring will be detailed in an Environmental and Social Management Plan (ESMP), to be developed following detailed design of the Project. The Plan will be agreed with input from the MTPNP managing authorities (National Parks Unit of the Division of Forestry, Wildlife and National Parks), and implemented prior to construction where appropriate. The monitoring programme outlined will enhance understanding of the ecology of the MTPNP and surrounding areas, and ensure that if any adverse effects on OUV were to occur, these would be detected in a timely manner and properly mitigated.

Independent third-party auditing of the implementation of the ESMP will be undertaken at regular intervals. The budget for this auditing and its frequency will be specified in the ESMP and verified by the relevant regulators.

## 14.6 Assessment of Residual Impacts

Following the implementation of mitigation measures set out within this document and within the ESIA Volume 4: ESMP, Framework ESMS and Assessment Against WBG Standards, no significant adverse effects on OUV of the MTPNP are predicted (Table 14.2). Due to the sensitivity and importance of the WHS it is also recommended that the monitoring is undertaken.

**Table 14.2 : Mitigation for minor impacts, and resulting residual effects**

| Activity | Potential impact | Potential Impact | Significance | Mitigation | Residual |
|---|---|---|---|---|---|
| Vegetation clearance | • Loss of habitat outside the WHS<br>• Reduction of ecological connectivity | Habitat loss and resulting fragmentation outside the WHS has a low likelihood of indirectly and/or cumulatively contributing to similar effects within the WHS, including Critical habitat.<br>This is because of the scale of the Project infrastructure and high degree of regeneration post- disturbance.<br>Removal of nests or nesting habitat outside the WHS which would otherwise act as fringe habitat and extend the range of a species, including species which are threatened and/or protected.<br>Reduction of foraging habitat for species which may move in and out of the site. | Minor | • Vegetation clearance activities should commence outside the breeding season for five key threatened species identified, to minimise impacts on breeding animals. The breeding seasons of the three bird species are overlapping, between January and August[13]. The amphibian species are thought to breed year-round, but primarily between May and July[14].<br>• Habitat cleared should be the minimum possible, with any way-leave area required of the minimum width necessary.<br>• Use temporary fencing to prevent inadvertent damage outside designated construction areas.<br>• Avoid piling of clear-felled vegetation on standing live vegetation which would hinder movement of wildlife. | Negligible |
| Construction activities including earthworks, excavations, creation/widening of access roads, and the operation of construction plant | • Introduction/spread of invasive plant species | Spread of invasive species into the WHS, which may outcompete native species. However, no air-dispersed plant species are known to be of concern in this area. Construction plant and vehicles will not drive onto the WHS so no impacts will occur. | Minor | • Any replanting / landscaping should use native or endemic species to prevent the incursion of opportunistic invasive species.<br>• Machinery and vehicles should be cleaned upon entry/exit, and any soil brought on or off site screened for invasive species or plant pathogens. | Negligible |
| | • Release of hazardous substances from accidental spillage or major accident | Uncontrolled discharges of geothermal fluids (brine and condensate) can be harmful to the environment, containing substances such as arsenic and boron. Brine is also very hot.<br>Unless occurring on a major scale, however, release of contaminants is unlikely to result in significant impacts, as the WHS is upstream of the Project site. | Minor | • Minimise potential for sedimentation impacts by ensuring good construction site practices are implemented.<br>• Appropriate disposal of solid and liquid wastes, in line with recommendations in international and national standards, and using designated facilities as required.<br>• Any effluent discharged to surface watercourses must meet the more stringent of international water quality discharge standards prior to release to remove pollutants. | Negligible |

[13] http://www.iucnredlist.org/ (Accessed September 2017)
[14] http://www.amphibianark.org/pdf/Husbandry/Leptodactylus%20fallax%20-%20Management%20Guidelines.pdf (Accessed September 2017)

| Activity | Potential impact | Potential Impact | Significance | Mitigation | Residual |
|---|---|---|---|---|---|
| | | Uncontrolled discharges of geothermal fluids (brine and condensate | | | |
| | • Run-off or sedimentation | Unless occurring on a major scale, contamination of watercourses is unlikely to result in significant impacts, as the WHS is upstream of the Project site. | Minor | • Minimise potential for pollutants and surface water run-off to migrate off-site by ensuring standard good construction site practices are implemented. | Negligible |
| Storage and use of the flammable substance n-pentane | • Boiling liquid expanding vapour explosion (BLEVE)[15] | Under the modelled scenario the thermal radiation from this event sufficient to cause pain (to humans) within 60 seconds extends to 462m from the incident location, which is approximately 140m from the WHS boundary. Effects at this distance could be sufficient to cause disturbance and damage to plants and animals. | Minor | • Detailed measures to minimise the likelihood and magnitude of a BLEVE occurring is provided in ESIA Volume 2: EIA, Chapter 15, including:<br>- Installation of pentane sensors and leak detectors;<br>- Fire extinguishing controls<br>- Induction and training;<br>- Standard Operating Procedures;<br>- Routine inspections;<br>- Good record keeping; and<br>- Suitable firefighting equipment. | Negligible |

[15] A BLEVE is an explosion caused by the rupture of a vessel containing a pressurised liquid above its boiling point. This is a rare event that can occur only if safety measures fail completely or in other very unusual circumstances.

# 15. Hazardous Substances and Waste

## 15.1 Introduction

This section describes the following:

- The hazardous substances that will used, stored and disposed of during the construction and operation of the Project, the potential impacts and the management/mitigation measures.
- The solid wastes that will be generated, stored and disposed of during construction and operation of the Project, the potential impacts and the management/mitigation measures.

## 15.2 Methodology

### 15.2.1 Spatial Scope of Assessment

Waste will be generated within the Project AoI and if properly managed, the area impacted will not extend beyond the boundary of the power plant, production and reinjection wellpads and reinjection pipeline. Hazardous substances will be used and stored within the Project AoI and if properly stored, handled and managed will not result in impacts beyond the boundary of power plant, wellpads and reinjection pipeline route. However, if any hazardous substances, wastes or spoil/excavated materials that require special disposal treatment and disposal offsite are not handled and stored properly, there is potential that soil, and/or surface water could become contaminated outside the Project AoI.

### 15.2.2 Impact Assessment

There are a range of impacts which can occur from the mismanagement of waste materials and hazardous substances arising from the construction and operation of a geothermal power plant. Therefore, materials and waste handling impact assessment is primarily about identifying waste streams and adopting an appropriate good practice management approach, which seeks to avoid the generation of waste in the first instance, rather than mitigating potential impacts to a defined baseline environment. After identifying the potential sources and, where possible, quantifying waste arising, the assessment focuses on measures to reduce, reuse and recycle, as well as the solutions available for waste disposal.

For hazardous substances the impact assessment is about identifying volume, types and intrinsic hazards of the different hazardous substances to be used, stored and disposed of during the construction and operation phases. Mitigation measures are then recommended to prevent any mismanagement or misuse which could result in an uncontrolled release to the environment, the frequency and magnitude of such a release and therefore the level of adverse impact.

The assessment of significance has been determined based on a function of the expected sensitivity of the receiving environment / receptor(s) and the resultant magnitude of any identified impact on the receiving environment / receptor(s) should there be a failure of the waste management and hazardous substances management controls.

## 15.3 Assessment of Impacts – Hazardous Substances

### 15.3.1 Hazardous Substances

Hazardous substances can be defined as materials that represent a risk to human health, property, or the environment due to their physical or chemical characteristics. Hazardous substances can be classified according to their hazardous properties such as; explosiveness, flammability, oxidising capacity, corrosiveness, toxicity, and ecotoxicity. A substance is also hazardous if it generates a substance with any one or more of these hazardous properties when it comes into contact with air or water (other than air or water where the temperature or pressure has been artificially increased or decreased) (NZ EPA, 2012).

The overall objective of hazardous substance management is to avoid or, when avoidance is not practicable, minimise uncontrolled releases of hazardous substances or accidents during their handling, storage and use.

### 15.3.2 Types and Quantities - Construction

The construction of the geothermal development will involve the use of various hazardous substances, predominantly liquids, which, if mismanaged or spilt, could cause adverse effects on the environment or present a hazard. Hazardous substances likely to be stored or used during the construction of the project are detailed in Table 15.1 below.

**Table 15.1 : Summary of hazardous substances potentially used during construction**

| Hazardous Substance | Estimated Quantity | Use | Typical Composition | Storage Location |
|---|---|---|---|---|
| Light fuel oil, fuel oil and oil. | To be determined | Used for the operation of machinery, vehicles and other equipment. | Varied | Temporary fuel storage tanks; Secure Hazardous Substances Store |
| Paints, glues and various solvents | To be determined | Used primarily in the erection of buildings and structures on the Project site, including installation and fixing of cladding and roofing, concreting, installation of building linings, plumbing, carpentry, plastering, painting and electrical work. | Varied | Secure Hazardous Substances Store |
| Compressed Gas Cylinders | To be determined | Used for welding and metal cutting. | Acetylene; oxygen | Secure Hazardous Substances Store |

There will be no deliberate discharges of these substances to the natural environment as part of the construction activities. Accidental discharges will be kept to an absolute minimum as part of the housekeeping procedures of the EPC Contractors.

### 15.3.3 Types and Quantities - Operation

The operation of the geothermal development will similarly involve the use of various hazardous substances, predominantly liquids, which, if mismanaged or spilt, could cause adverse impacts on the environment or present a hazard. Hazardous substances likely to be stored or used during the operation of the Project are detailed in Table 15.2 below.

**Table 15.2 : Summary of hazardous substances potentially used during operation**

| Hazardous Substance | Estimated Quantity | Use | Typical Composition | Storage Location |
|---|---|---|---|---|
| Sulphuric acid ($H_2SO_4$). | To be determined. Will be dependent on the nature of the geothermal fluids being produced. | Required to adjust the pH of brine to ensure that Silica Saturation Index (SSI) limits are maintained within appropriate levels. | - | Secure Hazardous Substances Store and bunded tanks on power plant site for working volumes. |
| Biocide | To be determined. Will be dependent on the plant design. | For wet cooling towers biocide dosing is required to prevent build-up of biologic growth such as algae. | Sodium Hypochlorite (NaClO) is typical. | Secure Hazardous Substances Store and/or IBC bunded tanks on power plant site for working volumes. |
| Dispersant | To be determined. Will be dependent on geothermal fluid | Dispersant(s) are chemicals that are used to inhibit or prevent scale formation in the cooling tower. | - | Secure Hazardous Substances Store and bunded tanks on power plant site for working volumes. |

| Hazardous Substance | Estimated Quantity | Use | Typical Composition | Storage Location |
|---|---|---|---|---|
| | chemistry and plant design. | | | |
| Oils | To be determined. | Used for the operation of machinery, vehicles and other equipment. | - | Secure Hazardous Substances Store |
| Transformer oil | To be determined. Will be dependent on plant design. Typically, in the order of 20,000 to 40,000 litres | Provides an insulating and cooling medium for the transformer. | - | Within transformers |
| Turbine lube oil | To be determined. Will be dependent on plant design. | | - | Within turbines |
| Working fluid | Will only be required if ORC plant technology is being used . Approx. 40,000 litres | Used in ORC plant which uses a low boiling point hydrocarbon, or other organic fluid, as the “working” or “motive” fluid for the turbine, rather than using steam. | Most likely n - pentane | Bunded storage tank in the power plant site and in the condenser and process lines of the power plant. The tank may require pressurisation depending on the volatility of the fluid selected. Leakage of hydrocarbon working fluids presents a fire risk and a fire fighting system is normally integrated into the tank design. |

### 15.3.4 Potential Impacts

The storage, use, and transport of hazardous substances during all phases of the Project provide potential pathways by which contamination of sensitive receptors could occur. Impacts which could occur at all phases of the development include:

- Accidental spills from containers, vehicles or ships: Damage to vehicles and ships transporting hazardous substances to and from Dominica and within the Project area have the potential to result in spills which can contaminate soil, groundwater, waterways, and freshwater environments.
- Incorrect disposal of old containers used for hazardous substances and or fuels/oils: if not disposed of correctly could contaminate soil, groundwater, waterways, and freshwater environments.
- Tampering and vandalism: Access to hazardous substances by unauthorised persons leading to spills, which could contaminate soil, groundwater, waterways, and freshwater environments.
- Toxicity and corrosiveness: The toxicity hazards of the substances relates to the potential adverse effects on workers at the site via ingestion/inhalation or dermal/ocular exposure in the case of corrosive liquids. The level of toxicity is variable and relates to the intrinsic properties of the substance and its concentration.
- Fire and explosion: Along with the risk of burns, a fire could also result in toxic by-products (from the combustion of chemicals) being discharged to air.
- Natural hazards: Such as hurricanes, landslips and subsidence. Natural hazards could cause damage to tanks/containers, which may spill their contents. In addition, they could cause concrete paving and bunding to crack resulting in their inability to contain spills of hazardous substances.

Impacts specific to construction and operation of the steamfield, wellpads and power plant are detailed in the following sections.

**Potential Impacts during Construction**

- Fuel spill: The largest potential spill volumes at the during construction will be from the diesel stored in an Aboveground Storage Tank (AST) which will have a potential volume of up to 10,000 litres, which could impact soil, groundwater, and surface water.

**Potential Impacts during Operation**

- Spillages: Operational requirements for sulphuric acid and biocide have the potential to impact on the environment from any containment failures. In addition, there will be transformer and turbine oils and working fluids (as discussed above) with large working volumes. Failure of containment systems is a highly unlikely event.
- Working fluid fire/explosion risk: Leakage of hydrocarbon working fluids presents a fire risk, and substances used will likely burn with a blue/invisible flame. This could result in burns and toxic fumes. Firefighting systems as well as flame detection units will be integrated into the design should ORC plant be used. This risk of n-pentane fire is quantitatively assessed in the following section.

**Potential Impacts from N-Pentane Storage**

Should the ORC option be selected, the storage and use of an n-pentane for the Project poses a potential risk to properties and people working and living in the surrounding area. N-pentane has been selected here as the working fluid as it is the most commonly used working fluid with ORC plants. Pentane is used as the working fluid for heat exchange and power generation in a closed loop system. Temperature and pressures ranges for pentane are considered low to moderate, and range from 30-170°C, and 1-20 bar respectively. It is estimated that there would be approximately 30 tonnes of n-pentane required in the 7 MW plant process loop and in the stock tank which is normally 50% full when the plant is operating.

The main pentane stock tanks are typically horizontal cylindrical tanks, constructed from carbon steel to the relevant international standard. A typical pentane stock tank is shown in Figure 15.1 below. For safety reasons pentane is stored under a nitrogen blanket. A Pressure Relief Valve (PRV) set at 8 bar protects the stock tank in case of fire or engulfment. The n-pentane storage tank will have an approximately 10,000 litre capacity, but storage volumes during operation will be less than this (typically less than half) as much of the pentane resides in the closed loop heat exchange system. The n-pentane stock tank is located in a bund enclosure to contain the spilt liquid. A deluge fire extinguishment system is suppled which when activated will quickly extinguish any fire. Heat and pentane sensors are also fitted around the storage tank and the plant to detect any leaks and heat changes.



**Figure 15.1 : Pentane Stock Tank**

An applied model, the ALOHA (Areal Locations of Hazardous Atmospheres) model, has been used to predict the spatial extent and level of consequence of a leak or rupture of an n-pentane storage tank at the power plant. The ALOHA Model, developed jointly by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Environmental Protection Agency (EPA), is a computer program designed to model potential chemical releases, as well as thermal radiation and overpressure related to toxic chemical releases resulting from, fires, and/or explosions (NOAA and EPA, 2016). A complete technical description of the model can be found in the ALOHA User's Manual (EPA, 2013).

The purpose of the ALOHA Model is to provide predictive estimates of consequence in order to determine the potential impacts to human health and safety for the general public. Model output are in the form of dispersion diagrams of the distance from area of leakage to levels of concern for both flammability risk from the leaking pentane, for heat effects for a scenario in which the n-pentane catches fire, and for an explosion resulting from a Boiling Liquid Expanding Vapour Explosion (BLEVE) scenario. The results of the modelling are presented below. We have assumed in all three scenarios that the tank is approximately 50% full (i.e. contains 5,000 litres of liquid n-pentane), and that all of the pentane in the tank is available for release.

**Scenario 1: Flammable Area of N-pentane Vapour Cloud**

Inputs to ALOHA for a scenario in which the pentane is leaking from a tank are provided below:

*Location: DOMINICA, DOMINICA*
*Building Air Exchanges Per Hour: 0.56 (unsheltered single storied)*

*CHEMICAL DATA:*
*Chemical Name: N-PENTANE*
*CAS Number: 109-66-0 Molecular Weight: 72.15 g/mol*
*PAC-1: 3000 ppm PAC-2: 33000 ppm PAC-3: 200000 ppm*
*IDLH: 1500 ppm LEL: 14000 ppm UEL: 78000 ppm*
*Ambient Boiling Point: 35.4° C*
*Vapor Pressure at Ambient Temperature: 0.96 atm*
*Ambient Saturation Concentration: 985,626 ppm or 98.6%*

*ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)*

*Wind: 2 metres/second from E at 3 metres*
*Ground Roughness: urban or forest Cloud Cover: 5 tenths*
*Air Temperature: 35° C Stability Class: C*
*No Inversion Height Relative Humidity: 50%*

*THREAT ZONE:*
*Threat Modeled: Flammable Area of Vapor Cloud*
*Model Run: Heavy Gas*
*Red : 11 metres --- (8400 ppm = 60% LEL = Flame Pockets)*
*Note: Threat zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.*
*Yellow: 35 metres --- (1400 ppm = 10% LEL)*

The predicted impact of a n-pentane leak at the n-pentane stock tank is predicted to result in a vapour hazard (as 10% of the lower explosive limit or LEL for pentane) 35 m from the point of release. This level of impacts was below the ALOHA threshold for contour plots for the threat zones and will be contained within the power plant. The likelihood of a vapour cloud release is highly unlikely and as the event will be contained with the level of impact on the community located near the power plant is determined to be of **Negligible** significance.

**Scenario 2: Thermal Radiation from Pentane Fire**

Inputs to ALOHA for a scenario in which leaking pentane from the stock tank catches fire and results in a pool fire in the base of the bund are provided below:

*SOURCE STRENGTH:*
*Leak from short pipe or valve in horizontal cylindrical tank*
*Flammable chemical is burning as it escapes from tank*
*Tank Diameter: 1 metres Tank Length: 7 metres*
*Tank Volume: 5,500 liters*
*Tank contains liquid Internal Temperature: 35° C*
*Chemical Mass in Tank: 3,059 kilograms*
*Tank is 91% full*
*Circular Opening Diameter: 5 centimetres*
*Opening is 0 metres from tank bottom*
*Max Flame Length: 17 metres*
*Burn Duration: 17 minutes*
*Max Burn Rate: 142 kilograms/min*
*Total Amount Burned: 3,059 kilograms*
*Note: The chemical escaped as a liquid and formed a burning puddle.*
*The puddle spread to a diameter of 4.9 metres.*

*THREAT ZONE:*
*Threat Modeled: Thermal radiation from pool fire*
*Red : 12 meters --- (10.0 kW/(sq m) = potentially lethal within 60 sec)*
*Orange: 19 meters --- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)*
*Yellow: 32 meters --- (2.0 kW/(sq m) = pain within 60 sec)*

The outputs of the dispersion model show the extent of a potentially flammable area, categorised by ranges of heat output which is out to 32 m. The extent of the plume is superimposed for reference over a map of the Project area plant in Figure 15.2 below. The indicative area of significant heat impacts is also shown to be restricted the power plant site and does not extend beyond the site boundary.

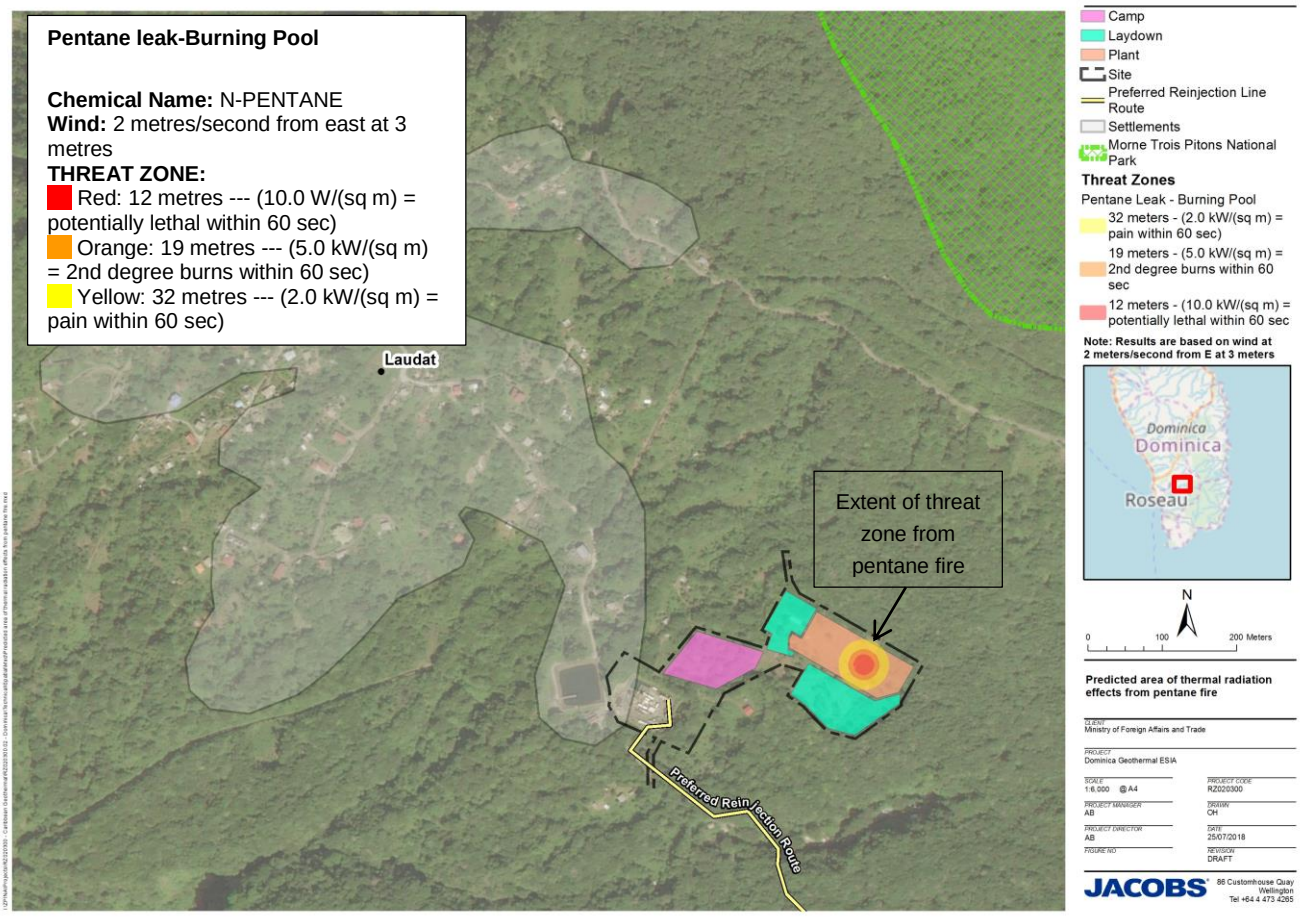


**Figure 15.2 : Predicted area of thermal radiation effects from pentane fire**

The likelihood of an n-pentane leak burning pool fire is highly unlikely and as the event will be contained with the impact the level of impact on the community located near the power plant is determined to have a **Negligible** significance.

### Scenario 3: BLEVE from Pentane Fire

A BLEVE is an explosion caused by the rupture of a vessel containing a pressurised liquid above its boiling point. This is a rare event that is possible only if the pressure relief equipment or system fails completely or if there is some combination of an unusually high vaporisation rate (e.g. due to fire) and some obstruction of the venting and pressure relief system preventing adequate pressure release. This is a rare event due to the extensive requirements for pressure relief including pressure relief valves and burst discs that are built into the design codes. Inputs to ALOHA for a scenario in which the stock tank catches fire and produces a BLEVE are provided below:

*SOURCE STRENGTH:*
*BLEVE of flammable liquid in horizontal cylindrical tank*
*Tank Diameter: 1 metres Tank Length: 7 metres*
*Tank Volume: 5,500 liters*
*Tank contains liquid*
*Internal Storage Temperature: 35° F*
*Chemical Mass in Tank: 3,059 kilograms*
*Tank is 91% full*

*Percentage of Tank Mass in Fireball: 100%*
*Fireball Diameter: 84 metres Burn Duration: 7 seconds*

*THREAT ZONE:*
*Threat Modelled: Thermal radiation from fireball*
*Red : 188 metres --- (10.0 kW/(sq m) = potentially lethal within 60 sec)*
*Orange: 265 metres --- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)*
*Yellow: 413 metres --- (2.0 kW/(sq m) = pain within 60 sec)*

The outputs of the dispersion model show the extent of a potentially flammable area, categorised by ranges of heat output. The extent of the plume is superimposed for reference over a map of the proposed site in Figure 15.3 below. The lethal contour extends out from the point of release a distance of 188 m and for 2nd degree burns out to 265 m. The indicative area of significant heat effects is shown to extend beyond the site boundary, with heat effects extending into part of the Laudat residential area to the northwest of the site. However, a BLEVE is a very rare scenario, and is prevented by basic safety measures in design and as such the level of risk posed by such an event is low. The emergency response requirement, in particular warning nearby residents to such an incident, and their evacuation will form part of the site and community emergency response and preparedness plans.

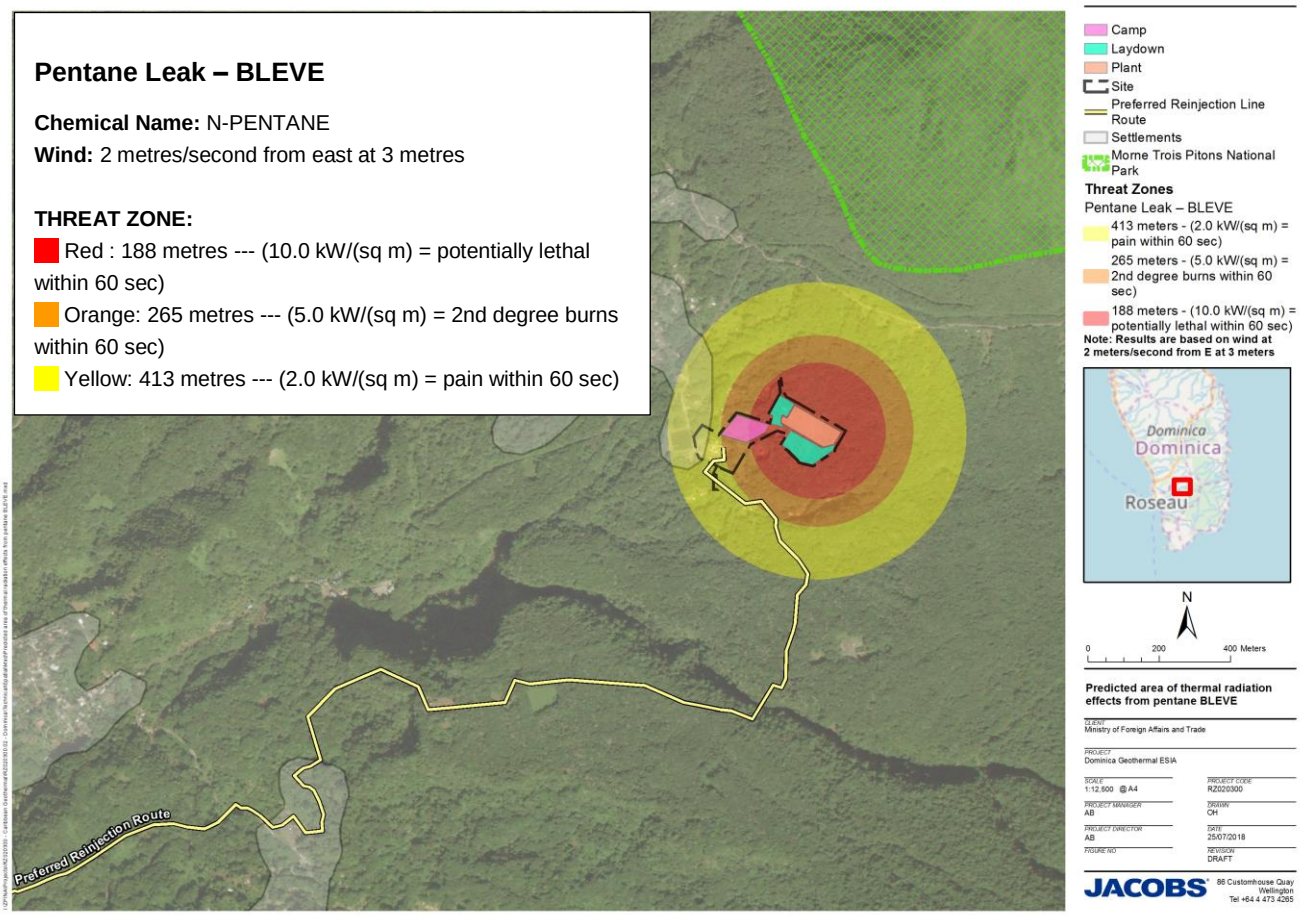


**Figure 15.3 : Predicted area of thermal radiation effects from pentane BLEVE**

### 15.3.5 Management and Mitigation

Hazardous substances will be controlled according to a Hazardous Substances Management Plan for construction and operation (both the EPC Contractor and O&M Contractor). This will include ensuring that the following information must be readily available to employees and employee representatives for all hazardous substances in the workplace:

- A register will be held and maintained onsite during construction and operation, which sets out the types, volumes and locations of all hazardous substances.
- Safety Data Sheets (SDSs) compiled in accordance with the approved code of practice for the preparation of material safety data sheets.
- Labels on containers compiled in accordance with the approved code of practice for the labelling workplace substances.
- Induction and training will be provided to all those employees whose work potentially exposes them to hazardous substances; and those employees who are supervising others who are using hazardous substances at work.
- Hazardous substances storage containers (including gas cylinders) which are unsafe (e.g. damaged, leaking etc) must be clearly marked as 'out of service' to prevent them from being used, until their disposa.
- Designated stores which are appropriately designed and fire rated will be used to store hazardous substances.
- Incompatible substances will be stored separately.
- Appropriate bunding shall be used when there is a risk of leaks, spills or loss of containment. Bunding needs to be provided for:
    - All tanks and other vessels containing materials which can cause an environmental, safety or health hazard.
    - Any other area where spills may occur (e.g. filling stations, decanting areas, drum storage areas etc.).
    - Bunded areas for tanks will be sized to contain 110% of the largest tank in the bund.
- Level protection (including automatic trips) is required to avoid overflow during the filling of tanks.
- Storage areas for hazardous substances (including piping systems) must be inspected on a regular basis to detect spills, leaks and the potential for such occurrences. Any deficiencies found must be recorded and immediately reported to the work area manager in order for the deficiency to be rectified as soon as practicable.
- Standard Operating Procedures (SOPs) and/or guidelines (if appropriate, by means of signage) must be prepared and implemented to cover at least the following:
    - Incompatibility of substances when mixed (e.g. mixing may result in fire or explosion).
    - Precautions when pouring, decanting or transferring substances.
    - Steps to be taken in the event of a spill or exposure.
    - Personal protective equipment to be used with the substance.
- Operations which require the mixing of one or more substances must be assessed by personnel with the appropriate chemical qualifications prior to work commencement.
- Transport of hazardous substances must be carried out in full compliance with the relevant legislative requirements.
- Transport vehicles shall have appropriate signage and carry documentation on the hazardous substances to be transported.

- Arrangements must be in place to ensure that the appropriate spill control equipment for storage and transport (i.e. for water and/or land) is available in sufficient quantities for any foreseeable spills.
- Suitable firefighting equipment must also be available to suit the type/s of substances being transported.
- Any such equipment must be routinely inspected and maintained in good working order and in a state of readiness.
- No chemicals are to be accepted onto the Project sites or off-loaded without the relevant health, safety and emergency information being made available by the supplier. Vehicles and other equipment shall be turned off while fuelling operations takes place.
- Provisions will be made for the containment, collection and disposal of waste oil and spills that are generated as a result of refuelling activities. Provisions may be in the form of a bunded and impervious area, with a spill and effluent collection system. Alternatively, a portable collection sump will be placed underneath the maintenance and refuelling areas to contain any spillage and/or minor leaks.
- Preparation and implementation of emergency response procedures which manage spoils, fires etc., and include warning and evacuation of nearby residences.
- Heat and pentane sensors will be fitted around the pentane storage tank and the plant to detect any leaks and heat changes.
- A deluge fire extinguishment system for the working fluid storage system will be installed which when activated will quickly extinguish any fire.

**Disposal of Hazardous Substances**

All hazardous waste, including used spill response items, oils and residues, including drums and containers which were used to hold hazardous substances, and will need to be collected and transported an appropriate hazardous waste disposal facility for disposal. Some items which cannot be disposed of in Dominica may need to be shipped off-island for treatment and disposal. The feasibility and cost of transporting hazardous waste off the island for disposal will need to be determined by the EPC Contractor and the O&M Contractor as part of developing their Waste Management Procedure.

## 15.4 Waste

A waste is any solid, liquid, or contained gaseous material that is discarded by disposal, recycling, burning or incineration. It can be a by-product of a manufacturing process or an obsolete commercial product that can no longer be used for its intended purpose and requires disposal.

Waste management during construction and operation phases of the Project should follow the waste management hierarchy that consists of prevention, reduction, reuse, recovery, recycling, removal and finally disposal of wastes (see Figure 15.4). The hierarchy states that as far as practicable, the generation of wastes should be avoided or minimised. Where waste generation cannot be avoided it should be reused, recycled or recovered. Where waste cannot be recovered or reused it should be stored, treated and disposed of in an environmentally sound manner.

Geothermal development produces some solid waste and suitable disposal methods need to be found, often in engineered locations. Wastes produced in geothermal developments are as follows:

- Drilling muds;
- Petroleum products and lubricants;
- Cement wastes, including silica flour;
- Cooling tower sludges, which are predominantly sulphur with the possibility of mercury, boron and vanadium (if present in significant quantities) contamination (if $H_2S$ abatement is used);

- Earthworks overburden;
- Domestic waste; and
- Construction and normal maintenance debris including paper, metals, waste oils etc.

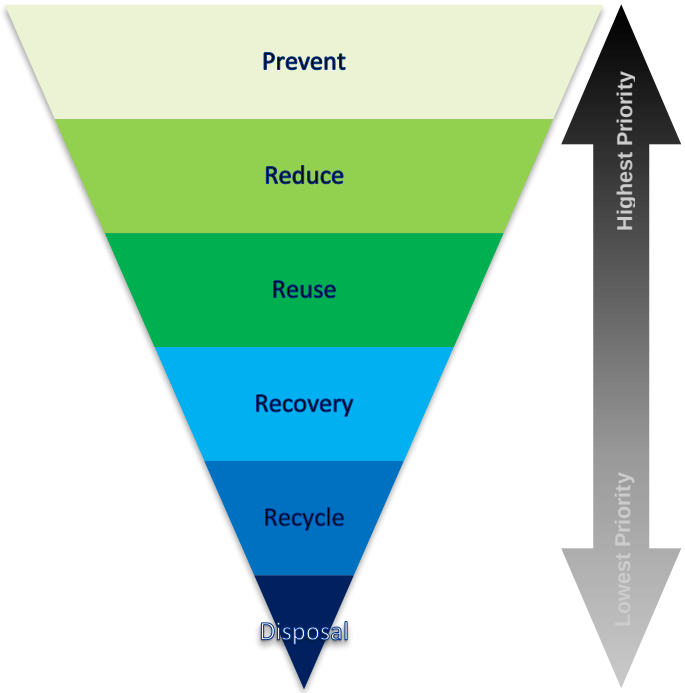


**Figure 15.4 : The waste management hierarchy**

### 15.4.1 Types and Quantities - Construction

Summaries of the wastes produced during the construction phase of the Project are presented in Table 15.3.

**Table 15.3 : Summary of potential construction phase waste generation**

| Waste Material | Estimated Quantity | Generation Point/Use | Composition | Storage Location | Disposal Route |
|---|---|---|---|---|---|
| Bio solids | 6,000 litres per day, with approximately 5.6 kg of solid waste (dry).[16] | Generated by staff. Includes sludge from package plant. | Sludge | Package plant | Sludge from package plants will be collected and disposed of offsite in an appropriate facility. Treated liquid effluent will be allowed to soak into the ground. |

[16] Based on 40 workers producing 150 L per day wastewater, of which 140 g (dry) is solid waste, each.

| Waste Material | Estimated Quantity | Generation Point/Use | Composition | Storage Location | Disposal Route |
|---|---|---|---|---|---|
| Construction Waste | Dependent on the construction process.<br>In general terms it should be assumed that 10% of the total construction material used will be disposed of as waste. | General construction activities at point of use. | This will include excess material and packaging.<br><br>Generally made up of Inorganic substances: cement, broken rock plastic, metal, glass; fabrics, synthetic resins, earth, sand, cardboard, paper, inert and nontoxic waste.<br><br>Hazardous waste may include used containers of chemicals (i.e. solvents, oils, paints) and oily rags. | General Waste Depot | Reuse, Recycling and Disposal |
| Cooling water pipe debris | Less than 10 kg | Cooling water pipes will be flushed and the water will be circulated and Strainers will collect debris. | Small amounts of steel and other material. | General Waste Depot | Reuse, Recycling and Disposal |
| Earthworks overburden | To be determined. Will depend on drill pad locations and power plant site earthworks requirements. | Generated across area<br><br>Formation of the drill pad sites, laydown area, access tracks, and steam pipe tracks may result in overburden. | Local topsoil | Any overburden will be stockpiled and/or revegetated at the edge of the formed area, or laydown area. | Stockpiled for future use, or revegetated as permanent landscaping. |
| General Waste | 20 kg per day[17] | Staff areas | Office Material (paper, small amount of packaging) | General Waste Depot | Recycling and Disposal |

[17] Based on 40 workers producing 0.5 kg waste per day each.

| Waste Material | Estimated Quantity | Generation Point/Use | Composition | Storage Location | Disposal Route |
|---|---|---|---|---|---|
| Geothermal fluid | To be determined. Estimated to be anywhere between 50 and 300 tonnes per hour. | Geothermal fluids will be released from the underground geothermal reservoirs as a result of commissioning and is fundamental to the power plant operation. | Steam, brine (can include heavy metals), and non-condensable gases (NCGs). | Steam and NCGs will be released to the air (in operation it will be dependent on the design). Brine will be collected in sumps during commissioning and most likely reinjected. | During commissioning will be reinjected. |
| Oils | To be determined. Required for operation and maintenance of machinery. | Mostly form maintenance areas and at point of use in the power plant | Oil (lubricants, diesel, petrol) containers with residue, oily rags, used oil filters. | Hazardous Waste Depot. | Disposal at an appropriate facility. |
| Vegetation | To be determined. The majority of exploration area cleared will be suitable for construction. Additional track and footprint for steam piping will be required. | Clearance access tracks, drilling zones, laydown area/power plant site, and steam piping. | Wood and Foliage | Will be moved to the edges of the cleared areas. | On site decomposition, burning, or be recycled as fire wood or building material where possible. |

### 15.4.2 Types and Quantities - Operation

A summary of the wastes produced during the operation phase of the Project are presented in Table 15.4.

**Table 15.4 : Summary of potential operation phase waste generation**

| Waste Material | Estimated Quantity | Generation Point/Use | Composition | Storage Location | Disposal Route |
|---|---|---|---|---|---|
| Bio solids | < 300 litres per day, with 500 grams of solid waste (dry) | Generated by staff. Includes sludge from package plant. | Sludge | Package plant | Sludge from package plants will be collected and disposed of to an appropriate facility. Treated liquid effluent will be allowed to soak into the ground. |

| Waste Material | Estimated Quantity | Generation Point/Use | Composition | Storage Location | Disposal Route |
|---|---|---|---|---|---|
| Condensate | To be determined | Inside of steam piping. | Condensed geothermal fluid. | Collected in drainage pots along steam line. | Dependent on the chemistry of the geothermal fluid will be collected and piped for re-injection. |
| Cooling Tower sludge's | To be determined. Dependent on the plant design. | Formed in the Cooling Towers. | Geothermal condensate can be rich in boron and heavy metals which will tend to accumulate in the cooling tower sludge. | Cooling Tower. | Will be removed as required, and either re-injected or disposed of off Dominica for in an appropriate facility. |
| General Waste | < 1 kg per day. | Staff areas. | Office Material (paper, small amount of packaging). | General Waste Depot. | Recycling and Disposal. |
| Geothermal fluid | To be determined. Dependent on technology option. All fluids will be reinjected or a combination of NCGs and steam may be released. | Geothermal fluids will be released from the underground geothermal reservoirs as a result of the power plant operation. | Steam, brine (can include heavy metals), and non-condensable gases (NCGs). | Steam and NCGs will be released to the air (in operation it will be dependent on the design). Brine will be collected and reinjected during operation. | During operation will be reinjected. |
| Maintenance activities | To be determined. | Across the power plant and associated infrastructure areas. | Includes steel and aluminium scrap, pallets, wood, and plastic containers. | General Waste Depot. | Reuse, Recycling and Disposal. |
| Oils | To be determined. Required for operation and maintenance of machinery. Will also include lubricating oil is used to lubricate the turbine bearings, and other moving parts in small quantities, and oil for transformers and switchgear. | Mostly form maintenance areas and at point of use in the power plant. | Oil (lubricants, diesel, petrol) containers with residue, oily rags, used oil filters. | Hazardous Waste Depot. | Disposal at an appropriate facility. |

### 15.4.3 Potential Impacts

The storage and transport of wastes during the construction and operation of the Project, if inappropriately managed, has a number of potential negative impacts through releases to air, soil and water. Impacts which could occur at all phases of the development include:

- Accidental spills from containers, or vehicles: Damage to vehicles transporting waste and hazardous substances to and from Dominica and within the project area have the potential to result in spills which can contaminate soil, groundwater, waterways, and marine environments.
- Insufficient disposal frequencies or inappropriate storage containers could result in odour concerns.
- Old container used for hazardous substances and or fuels/oils not disposed of correctly could contaminate both streams and groundwater.
- Waste that is stored incorrectly and may blow around the site or offsite. This waste would have the potential to pollute waterways and sensitive habitats.
- Runoff from waste storage areas that is not collected and has the potential to contaminate soil, stormwater, and groundwater.
- Incorrect storage such as storage of incompatible wastes together may lead to items not able to be reused or recycled.
- Incorrect and/or illegal disposal of wastes resulting in breaches of local regulations.
- Erosion of stored soil leading to sedimentation of streams.
- Inappropriately placed/protected soil stockpiles can result in erosion of stored soil which could lead to sedimentation of near-by streams.

Impacts specific to the various Project phases are detailed in the following sections.

**Potential Impacts of Waste during Construction**

- Biosolids from the construction workforce: biosolids can carry harmful micro-organisms that easily contaminate soils and water sources.
- Incorrect handling, separation and storage of construction wastes resulting in soil and water contamination impacts.
- Uncontrolled discharges of geothermal fluids (brine and condensate) as a result of power plant commissioning. Brine can have quantities of heavy metals (such as arsenic) as well as other harmful substances (such as boron). These substances can leach into soils and discharge into nearby water courses.
- Ablutions for the construction workforce: Human wastewater can carry harmful micro-organisms that easily contaminate soils and water sources. Domestic wastewater from amenities at the laydown camp will need be collected and treated in a package plant, or off-site disposal (i.e. portable latrines).

**Potential Impacts of Waste during Operation**

- Uncontrolled/improper discharges of condensate: The condensate can have quantities of heavy metals (such as arsenic) as well as other harmful substances (such as boron). These substances can leach into soils and groundwater and discharge into nearby water courses.
- Uncontrolled/improper discharges of Cooling Tower sludge: This will be dependent on the power plant design including cooling towers. Condensate can have quantities of heavy metals (such as arsenic) as well as other harmful substances (such as boron), which can accumulate in the Cooling Tower sludge. If improperly disposed of they can leach into soils and groundwater, and nearby water sources.
- Incorrect handling, separation and storage of construction and operation wastes resulting in soil and water contamination impacts.

- Incorrect treatment and disposal of liquid and hazardous wastes.

### 15.4.4 Waste Management

Waste Management Procedures for construction and the operation phases will be prepared by the EPC Contractor and O&M Contractor to minimise waste generation and ensure proper disposal methods. Particular attention will be given to the use and re-use of materials to minimize waste and, whenever practicable, using materials and products from sustainable sources. The Waste Management Plan shall include steps to:

- Minimise the amount of waste produced;
- Prepare designated waste storage areas for the wastes which are not able to be immediately disposed of. The waste storage areas should be covered and clearly signed;
- Educate and train staff on separation of wastes and recycling;
- Dispose of hazardous waste via a licensed third party operator; and
- Record the disposal of wastes by “Waste Manifest”.

### 15.4.5 Mitigation of Waste

Waste should be stored so as to prevent or control accidental releases to air, soil, and water resources. The prepared Waste Management Procedure shall include steps to:

- Encourage waste separation and recycling, and waste minimisation at source.
- Store waste in the appropriate place once work has finished for the day.
- Store waste in closed containers away from direct sunlight, wind and rain. Cover the waste storage areas e.g. with lids and/or roofs to prevent rain water from getting in. The waste package should be in good condition, undamaged, corrosion and leak free.
- Preferably store liquid wastes on impermeable surfaces with spill containment systems. Spill containment systems should be constructed with materials appropriate for the wastes being contained and with a drainage and collection system. Spill containment should be included wherever liquid wastes are stored in volumes greater than 220 litres. The available volume of spill containment should be at least 110% of the largest storage container, or 25% of the total storage capacity (whichever is greater), in that specific location.
- Waste signs shall be put on all waste containers and collection areas. Each sign shall be highly visible and easily seen by the person using the waste container or area. Each container or waste area sign shall be labelled as Domestic Waste, Non-Hazardous Waste or Hazardous Waste and include the responsible person with contact information and how to handle the waste. Recyclable waste bins will be designated for metal, plastic, paper, etc.
- Waste should be stored in a manner that prevents the commingling or contact between incompatible wastes. Sufficient space is needed between incompatibles or physical separation such as walls or containment curbs. For example, hazardous waste should be stored separately from other wastes and in a sealed container.
- Hazardous wastes are stored in a separate storage area which is bunded and that hazardous wastes are removed for treated and disposal form the site by an approved licensed third party operator. Destruction certificates are supplied by the operator to indicate how and when the hazardous wastes wren treated ad disposed of.
- Provide adequate ventilation where volatile wastes are stored.
- Record the amount and destination of the wastes, removed and disposed of off-site.

### 15.4.6 Waste Disposal

Solid waste produced during construction and operation of the Project will be collected onsite as outlined above, and then transferred to a designated waste disposal facility, fortnightly or as required.

### 15.4.7 Monitoring

As part of the Waste Management Procedure a monitoring plan will be developed to inspect waste collection skips, to check wastes are being separated correctly and hazardous wastes are not being included with non-hazardous. The inspection should also include a check of the waste skips and bins condition to be sure waste is being held securely and not able to impact the environment through leakage or being blown away.

Records should be kept on the types of wastes generated, the volume generated and the location/volume of waste disposed off-site. Types and volumes of hazardous waste must be recorded and destruction certificates obtained from the hazardous waste removal contractor.

## 15.5 Assessment of Residual Impacts

If the measures identified above for the storage, use, management, disposal and spill management for hazardous substances are well implemented there should be no significant release of hazardous substances to the environment and therefore **Negligible** impact on the environment.

The impact on the environment from wastes during construction will be **Minor** if the waste is appropriately managed at the site.

# 16. Traffic and Access

## 16.1 Introduction

This section considers the impacts that additional traffic that the construction and operation of the Project will generate and the appropriate mitigation that will be put in place.

## 16.2 Methodology

The traffic impact assessment utilises baseline data described in Section 3.14 and in accordance with the ESIA methodology outlined in Section 2. The assessment will draw a conclusion on the likely significant impacts from the Project to existing traffic conditions in the Roseau Valley.

## 16.3 Assessment of Impacts

This section analyses impacts in relation to trip generation and traffic distribution as well as to the network (both temporary and permanent) from the construction, commissioning and operation of the power plant.

### 16.3.1 Road Network

The road network to supply materials and staff for the Project already exists. More roads or tracks will be constructed to steamfield facilities, in particular the reinjection pipeline corridor, as required. These will be used for access by operations staff for inspections, operation and maintenance. The access roads shall be surfaced with gravel but gradients in steeper areas shall be sealed.

### 16.3.2 Port to Site Access

All equipment will be required to be transported by sea to the island. Dominica's main port is at Woodbridge Bay, about 2 km north of Roseau. A transportation assessment by the EPC Contractor will be required to fully understand any potential difficulties in transporting equipment from the port to the Project location (both in terms of roading infrastructure and availability / capacity of equipment transporters).

### 16.3.3 Construction Traffic

During the construction phase various items of equipment will be needed on site, including but not limited to: small drilling rigs, excavators, trucks, rollers, compactors, cranes, portable welders and generators. These are likely to be delivered by large trucks and heavy vehicles, or in some cases there may be an opportunity for equipment to be transferred by helicopter. The drilling work has already been completed and therefore the large number of trucks required for this activity has not been accounted for in this assessment.

Construction equipment will be stored in laydown areas and moved to site when required. One main construction laydown area will be required adjacent to the power plant, with other laydown areas possibly required depending on contractor preferences (such as alongside the main reinjection pipeline corridor for storage of reinjection pipeline construction materials). Transport options will be required between these sites.

Delivery of construction materials will be via cargo ship to Roseau's port and they will then be required to be transported to site on arrival. The type and size of vehicles required will generally be at the EPC Contractor's discretion to transport the equipment to site. There may be an option to store imported equipment in Roseau until it is due for installation at site or to be moved to a laydown area closer to site. This would reduce site laydown area requirements of the site, and would spread the transportation of heavy loads over a longer period (same number of loads, but not coinciding with vessel unloading and transporting heavy loads when there is a high passenger volume cruise ship in the port).

It will not be feasible to expect the construction traffic not to operate when there are cruise ships in port due to the frequencies of cruise ship arrivals during the main cruise ship season, but consideration will need to be taken to try and limit construction traffic on days when there is a high passenger volume cruise ship in port in Roseau. Therefore, it is considered that the construction traffic will only have a potential impact of **Minor** significance on the existing traffic network.

There will also be added light vehicle traffic on the network due to transporting staff and the workforce to the sites. Construction staffing levels are envisaged to be in the order of around 50 staff (including locals) during the construction phase of the main power plant, with around 15-30 staff to be employed during the construction of the reinjection pipeline phase of the Project. Staffing numbers may also increase sporadically due to the use of local labour for the manhandling of materials on site. It is assumed that most workers will be based in the worker's camp however, which will have the capacity for 50 people. It is possible that some workers will be based in Roseau City as this is the most populated area in Roseau Valley and this journeys for workers from here represent a would be a worst case scenario.

It has been assumed that some staff may commute to work either by private vehicle or by a privately owned minivan bus. The privately owned minivans that operate as public transport hold up to 15 passengers. If the equivalent of these were used to transport staff to site, up to four buses could be added to the network (eight trips with four each way), having a **Negligible** impact on the existing traffic.

It is possible that construction activities relating to the power plant and steamfield may interfere with farming and subsistence activities on site. In addition to the local access roads there are existing tracks and routes for both private and public use near the Laudat site and on proposed reinjection pipeline routes. Farm access will need to be maintained as far as practical during construction. It is not anticipated that there will be prolonged issues with access and therefore this is considered to be a **Minor** impact.

### 16.3.4 Operational Traffic

Traffic levels generated by routine operations are expected to be minimal, and a slightly increased vehicle count will occur during planned or unplanned maintenance activities and during any future well drilling. These events however will be once or twice per year, for maintenance, and as infrequent as once every couple of years at most for future well drilling requirements. Therefore, it is considered that the operational traffic will have a potential impact of **Negligible** significance on the existing traffic network.

### 16.3.5 Public Transport Network

Due to the limited knowledge of the public transport system, it is difficult to understand the impacts. It is likely that staff will be able to use the public transport network to move between their homes and the sites.

### 16.3.6 Pedestrians and Cyclists

There is a distinct lack of pedestrian facilities along the roads that will be used for site access. The exception to this is the Waitukubuli National Trail, which intersects the proposed reinjection line route adjacent to WW-01 (Figure 3.35). During construction, there will be temporary potential impacts on pedestrians wishing to utilise the trail, leading to potential impacts of **Moderate** significance. However, as the reinjection pipeline will pass underneath the road, there will be no impacts on users of the trail during operation.

During construction, pedestrians and cyclists will be disadvantaged by the general increased level of traffic along the roads being used. This may lead to temporary diversions and minor delays, resulting to potential impacts of **Moderate** significance. However, during operation there will be no impacts on pedestrians and cyclists.

## 16.4 Mitigation and Monitoring

Table 16.1 below, outlines the recommended mitigation and monitoring measures resulting from this traffic impact assessment.

**Table 16.1 : Mitigation and Monitoring**

| Mitigation / Monitoring | Detail |
|---|---|
| Traffic Management Plan (TMP) for movement of large construction equipment. | This is the responsibility of the EPC Contractors. Over the suggested two year construction phase, trucks and other vehicle movements have a potential to impact the surrounding area and road network. It is important that measures are put in place to minimise the potential impacts of the construction traffic. These measures are typically identified through the requirement for a traffic management plan. Where required this may seek to control the times of operation (e.g. avoiding peak periods or when large cruise ships arrive at Roseau Port) or routes used.<br><br>In the TMP, measures will be provided to ensure that the existing road network continues to provide safe and convenient access to all road users including pedestrians and cyclists. For the purpose of pedestrian safety, it is important to liaise with road controlling authorities, schools, residents, businesses, sports facilities, major events organisers and emergency services. Consideration may need to be given to the speed at which the vehicles are permitted to travel on the public road network, especially in rural areas. |
| Travel Plan for the project. | It is recommended that a Travel Plan is written and distributed to staff to inform them of the best ways to travel to the sites of the Project. Staff should be encouraged to take public transport, car pool or that the contractor provides transport for them. During construction, this will be the responsibility of the EPC Contractor and during operation this will be the responsibility of the O&M Contractor. |
| Worker's camp | A worker's camp will be constructed next to the power plant construction site. This will provide accommodation for an estimated 50 workers and will significantly help to reduce traffic impacts on the local road network by reducing the number of trips taken to and from the site from Roseau City. |
| New Traffic Impact Assessment for decommissioning phase. | The decommissioning phase is likely to attract high volumes of traffic to the area. As this phase is likely to be a number of years away, a new traffic impact assessment should be undertaken then. |
| Waitukubuli National Trail Management Plan | The Waitukubuli National Trail Management Plan will set out how the movement of pedestrians along the Waitukubuli National Trail will be maintained during construction (i.e. health and safety measures, protection barriers, detailed diversion designs). |
| Local community education should be undertaken. | A vehicle awareness program would be beneficial for the locals most likely to be impacted, with the aim of warning them of increased vehicle movements and the hazards posed due to the Project.<br>With larger vehicles being used to transport construction equipment than what is currently likely on the road, it is important that any impacts on pedestrians are included in any TMP created. |
| Continued monitoring of the impacts. | It is important that once the Project commences, continual monitoring is carried out to ensure the impacts are as expected and to determine if further mitigation is required. This will be done through visual observations and counting of vehicles using the site and monitoring of the grievance mechanism in relation to any complaints surrounding access within the Roseau Valley. |

## 16.5 Assessment of Residual Impacts

The impacts from construction and operational traffic as result of the proposed project and following the application of design mitigation and additional mitigation detailed in Table 16.1 above, the residual impacts are expected to be **Negligible** and are therefore not significant.

# 17. Working Conditions, and Occupational Health and Safety

## 17.1 Introduction

The occupational health and safety issues during the construction and operation of the Project are common to those of large industrial facilities and their prevention and control is discussed in the WBG EHS General Guidelines and the EHS Geothermal Power Guidelines. These include exposure to physical hazards, trip and fall hazards, exposure to dust and noise, falling objects, working at heights, working in confined spaces, exposure to hazardous material and exposure to electrical hazards.

To protect workers from potential hazards, as well as ensuring that appropriate measures are put in place to deal with any disputes that may arise between workers and the employer, it is anticipated that detailed labour, health and safety documents will be prepared by the EPC Contractors prior to commencement of Project construction works and by DGDC prior to commissioning the power plant. These would cover hazard identification, safe work practices, emergency response plans, incident/accident management, auditing and review.

Occupational health and safety performance should be evaluated against internationally published exposure guidelines, of which examples include:

- Threshold Limit Value (TLV) occupational exposure guidelines and Biological Exposure Indices (BEIs) published by American Conference of Governmental Industrial Hygienists (ACGIH) (various dates);
- Pocket Guide to Chemical Hazards published by the United States National Institute for Occupational Health and Safety (NIOSH) (2007);
- Permissible Exposure Limits (PELs) published by the Occupational Safety and Health Administration of the United States (OSHA) (various dates);
- Indicative Occupational Exposure Limit Values published by European Union member states (2017);
- or other similar sources.

Further detail is provided in the Technical Report - Working Condition, Occupational Health and Safety Assessment (ESIA Volume 5: Appendices).

## 17.2 Overarching Site Safety Management and Awareness

The following general safety measures will be applied during the construction, operation and maintenance of the Project (more detail found in Technical Report - Working Condition, Occupational Health and Safety Assessment (ESIA Volume 5: Technical Appendices):

- Establishment of Health and Safety Management Systems for construction and operation including safety management organisation / reporting chain; construction methodology; hazard / risk assessment and proposed mitigation measures; and safety checklists.
- Development of a Health and Safety Risk Register and hazard identification and assessment procedures.
- Training and distribution of Personal Protective Equipment (PPE) to all staff on site.
- Safe Work Rules and Procedures designed to be generic rules provided within employment contracts and task specific procedures will be communicated during tool box talks and displayed on machinery or within hazardous work areas.
- Permits to Work for hazardous activities.
- Use of site safety facilities such as first-aid equipment and stations, emergency response equipment etc.

- Health and Safety Meetings such as daily tool box talks, weekly HSE meetings and the creation of a Safety and Health Committee which includes worker representatives.
- Regular safety inspections and monitoring of exposure to hazards.
- Security Procedures on site.
- Emergency Response Procedures for managing incidents onsite and where they may have offsite impacts.
- Accident /incident reporting and investigation.
- Monitoring of Health and Safety Management Systems.

### 17.2.1 Occupational Health and Safety Plans

DGDC and the EPC Contractors will both be required to develop Occupational Health, and Safety Plans (OHS) for the construction and operation activities for the Project, which will apply to all personnel involved in the Project, including Subcontractors and part-time workers. The primary health and safety objectives will be to ensure effective measures and management of occupational health and safety to minimise workplace accidents and injuries. All Occupational Health and Safety (OHS) systems for the development will need to meet the requirements of the Equator Principles (EPs), the WBG EHS Guidelines and any other relevant international or national legislation.

The OHS Plans will outline the procedures essential for the protection of personnel during construction and operation. They will be designed to assist all those who deal with OHS as a functional responsibility within the context of their job.

In particular, they will include:

- Demonstration of compliance with Dominican and WBG health and safety requirements (i.e. Section 1.2 of the WBG EHS Guidelines – Geothermal Power Plants (2007) and Section 1.2 of the WBG EHS Guidelines – Electric Power Transmission and Distribution (2007)), including consideration of the following risk that are directly related to geothermal developments:
  - Geothermal gas exposure;
  - Confined Spaces;
  - Heat;
  - Live power lines;
  - Working at height on poles and structures;
  - Electric and magnetic fields;
  - Exposure to chemicals; and
  - Noise.
- OHS responsibility / reporting structure;
- Details of site inductions and ongoing training;
- Hazard identification and risk assessment;
- Mitigation measures including mandatory personal protection equipment (PPE);
- Safe working procedures and safety rules (includes permit-to-work procedures, working at height, etc);
- Response to health and safety incidents, including investigation and reporting;
- Emergency response plans;
- Reporting and record keeping systems;

- Scheduled HS meetings; and
- Inspection and auditing procedures.

The key goal of the plans will be to instil a safety culture within the site employees through education, good communication, a motivated workforce, recognition of individual/team effort and safety incentive programmes.

### 17.2.2 Roles and Responsibilities

DGDC and the EPC Contractors will establish a hierarchy of responsibility with regards for the provision of health and safety. The precise titles and roles of each member will be determined by DGDC and the EPC Contractors prior to work on the site

Management of OHS during construction will primarily be the responsibility of the EPC Contractor. The EPC Contractor's HSE Plan will be implemented at the Project site taking into account the management, mitigation and monitoring requirements contained in the Project ESIA/ESMP. During the construction phase, DGDC will review and monitor EPC Contractor's performance in accordance with their HSE Plan to ensure alignment with the Project ESMS. DGDC is responsible for reporting findings every six months to relevant authorities.

During the operational period, it is proposed that DGDC will prepare an OHS Plan based upon the Project ESMS.

Significant aspects of health and safety during operations will be borne by the operating Contractor(s) who will operate the Project. DGDC will prepare the O&M Health and Safety Management System (HSMS) and manage O&M work, with an advisory agreement with the operating Contractor to provide technical assistance in establishing the O&M platform (including O&M HSMS) and supporting DGDC in preparing the O&M HSMS and managing O&M work at the Project site.

## 17.3 Labour and Working Conditions

All works will be undertaken in accordance with the laws and regulations pertaining to employment, human rights and worker rights in Dominica. Furthermore, the Project policy for its own employees will also follow the laws and regulations of the GoCD and an employment policy framework will be developed which will comply with International Labour Organisation (ILO) Conventions (listed in full in Section 2 of ESIA Volume 1: Introduction).

A Human Resource Policy will be developed prior to commencement of any work by employees of the either DGDC or the EPC Contractor on the Project, compliant with the Dominica Labour Legislation and the World Bank EHS Guidelines. This will be supplied to the local labour authority and regularly reviewed as the Project progresses.

### 17.3.1 Worker Contracts

All employees working on the Project will have a mutually agreed Contract of Employment and will be provided with regular health assessments and the appropriate health and safety training. The EPC Contractors will issue all Project staff with an individual contract of employment detailing their rights and conditions in accordance with the national law and WBG requirements related to hours of work, wages, overtime, compensation and benefits such as maternity or annual leave, and update the contract when material changes occur. DGDC have not established a Human Resource Policy for this Project yet, but all employment matters shall meet the laws and regulation of Dominica.

### 17.3.2 Workers Grievance Mechanism

A worker's grievance mechanism will be established for the construction and operation phases by DGDC and its contractors. This grievance mechanism is set out in Volume 5: Technical Appendices (Technical Report

Working Conditions, Occupational Health and Safety). It has been designed to receive and facilitate resolution of concerns and grievances about the Project's working conditions and safety performance. It will be scaled to the risks and impacts of the Project and have workers as its primary user. It will seek to resolve concerns promptly, using an understandable and transparent consultative process that is culturally appropriate, readily accessible, at no cost, and without retribution to the party that originated the issue or concern. The mechanism should not impede access to judicial or administrative remedies. DGDC will inform the workers about the mechanism in the course of the workers engagement and induction process.

# 18. Associated Facilities and Cumulative Impacts

## 18.1 Introduction

This section provides discussion of potential impacts for associated infrastructure for the Project. Furthermore, it provides an assessment of cumulative impacts associated with the construction and operation of the Project and takes into account any other known present and planned developments in the AoI.

## 18.2 Associated Facilities

The impacts of associated facilities as defined by Performance Standard 1 which states "*Associated facilities, which are facilities that are not funded as part of the project and that would not have been constructed or expanded if the project did not exist and without which the project would not be viable*" have been considered.

The new geothermal power plant will evacuate power at 11 kV through three new underground cables that will connect to the existing 11 kV switchgear at Luadat Hydropower Station (LHS). These three new underground cables will run through land to be acquired for the power plant and through land owned by DOMLEC. They will be run under or directly alongside the proposed access road into the Project site. The length of this route is approximately 440 m. The proposed connection arrangement is provided in Figure 3.21.

For installation, trenches will have to dug in which the cables will be laid in and backfilled. There is the potential to create sediment containing run-off when the trenches are open. This run-off will be handled as part of the mitigation measures proposed for civil construction works in general. Once installed, there will be no visual impact, nor impact on the use of the roads or amenities as they are underground. Therefore, no mitigation specific measures are required.

In addition to the 11 kV underground cable connection to the LHS, DOMLEC are to also carry out ancillary works on the network. This includes the rebuild of the existing transmission line from Trafalgar Hydropower Station (THS) to Fond Cole Power Station which was destroyed by Hurricane Maria. As it represents an opportunity to build back better, DOMLEC have opted to upgrade the line to be capable to operating at 33 kV as part of this rebuild. That entails fitting slightly longer insulators which suspend the transmission wires from the poles. Also, they will extend the line from THS to LHS as a 2nd circuit on the existing transmission poles from THS to LHS. These measures are to improve DOMLEC's network capacity, capability and flexibility and will be carried out even if the geothermal power plant is not developed. The rebuild of the DOMLEC transmission lines is therefore not considered to be an associated facility as defined under Performance Standard 1 and as such the impacts associated with this activity are not assessed in this ESIA.

The construction method to be used for the rebuild will be determined by DOMLEC who will be responsible for upgrading the lines. For overhead lines with step changes in vertical height, a number of options are available, such as utilising a helicopter to carry the line or manually hauling the line. It is anticipated that only minor vegetation clearance / trimming will be required for DOMLEC's construction activities for the upgraded connections.

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## 18.3 Assessment of Cumulative Impacts

### 18.3.1 Introduction

Cumulative Impacts can be defined as those impacts that may result from the combination of past, present or future actions of existing or planned activities in the Project's AoI. While a single activity may not itself result in a significant impact, it may, when combined with other impacts in the same geographical area and occurring at the same time, result in a cumulative impact (beneficial or adverse) that is significant.

### 18.3.2 Future Geothermal Power Plants

Whilst it is a possibility, at this stage of preparing this ESIA there are no confirmed plans to develop further geothermal power plants in the Roseau Valley in the future. Therefore, consideration of the cumulative impacts of additional power plants is not applicable for this Project as the size, scale and location of such plants is not known.

### 18.3.3 Cumulative Impact Assessment

Given the nature of the receiving environment and industrial activities undertaken in the Roseau Valley, the potential for cumulative impacts is limited. The cumulative impact assessment can be summarised as follows:

- The impacts of increases in $H_2S$ generated by the power plant are not deemed to have significant cumulative impacts, given the nature of the naturally high levels of $H_2S$ in the geothermal region.
- The main potential cumulative impact with the DOMLEC hydropower plant relates to noise, however, the hydropower plant's turbine hall is located ~980m from the power plant down the valley, and the upper scheme uses gravity to transport the water to the penstocks, so there is no pumping required. As such, it has been determined that there are no cumulative noise impacts associated with DOMLEC's hydropower plant and the proposed geothermal power plant.
- The impacts of the power plant and reinjection pipeline are not considered to generate a cumulative impact on the landscape character and visual amenity with the existing DOMLEC hydropower plant penstocks. This is because the penstock pipeline runs through a different ridgeline to that proposed for the reinjection pipeline and as such they are located in separate viewscapes.

# 19. Summary of Environmental Impact Assessments

## 19.1 Construction Impacts

During construction, the majority of residual impacts (i.e. following the use of proposed mitigation and monitoring measures) are considered to be of **Negligible** or **Minor** significance and are discussed below:

### 19.1.1 Power Plant

The following residual impacts have been identified during the construction of the power plant:

- Compaction of the site and exposed topsoil due to deforestation and land clearing/levelling during construction could increase runoff and sediment load, thus requiring some form of treatment or retention of water prior to discharge. The impact of this (without treatment) is considered to be of **Moderate** significance. However, following the implementation of mitigation designed to reduce the impacts of runoff and sediment load (i.e. interceptor ditches/sumps/silt fences etc.), this impact will reduce to **Minor** significance**.**
- When vegetation is cleared for the power plant the site soils will be highly susceptible to erosion. The resulting sediment runoff could impact upon the Roseau River water quality through increasing turbidity, reducing clarity and causing deposition of fine sediments. Indirect impacts could also affect the ecology of the river by a range of processes including directly smothering species, changes in habitat and direct impacts of sediment upon fish species. Without erosion or sediment controls in place then there is a potential for potential impacts of **Moderate** significance downstream of the proposed works, through detectable changes to water quality and ecological health. With a well-developed Erosion and Sediment Control Procedure in place (incorporating elements such as staging, clean water diversions, sediment retention etc.), as well as other proposed mitigation measures, it is considered that the residual impacts resulting from of erosion of soils would be reduced to a **Minor** significance.
- There is potential for hazardous substances or waste to be accidentally discharged to the environment if inappropriately collected and stored on site. However, following the development of mitigation such as the Hazardous Substances and Waste Management Plan, this impact will be reduced to **Negligible** significance.
- With proposed mitigation in place, there will be **Negligible** adverse residual impacts on the MTPNP World Heritage site.

### 19.1.2 Reinjection Pipeline

The following residual impacts have been identified during the construction of the reinjection line:

- The earthworks and stream crossings phases of the pipeline construction are considered to be the higher risk activities to the existing water quality and ecology. The stream crossings will involve the placing of pipe bridges above the watercourses. Uncontrolled eroded soil material will cause direct and indirect sediment impacts, as discussed for the power plant location. Direct physical disturbance and additional sediment generation would also occur at stream crossing points. Unmitigated, this is considered to give rise to a potential impact of a **Moderate** significance. With a well-developed ESCP in place (incorporating elements such as staging, clean water diversions, sediment retention etc.), as well as other proposed mitigation measures, it is considered that the residual impacts resulting from of erosion of soils would be reduced to a **Negligible to Minor** significance.
- The Waitukubuli National Trail will be intersected by the proposed reinjection line route adjacent to WW-01. During construction, there will be temporary potential impacts on pedestrians wishing to utilise the trail, leading to potential impacts of **Moderate** significance. Following the implementation of mitigation (such as the development of a Traffic Management Plan), residual impacts on non-motorised users of the Waitukubuli National Trail will reduce to **Negligible** significance.

- The construction of the reinjection line will involve temporary removal of terrestrial habitats in an 10 m wide corridor. 3-4 m of this corridor wide will be permanently lost. Preparing the corridor will include the felling of trees which can cause fragmentation. Parts of the habitats to be lost could support threatened species but are not considered to be core habitats resulting in a potential impact of **Moderate** significance. The extent of the habitat loss is relatively small, and then vegetation along the reinjection line is expected to regenerate rapidly, resulting in **Negligible** significance.
- A minor impact was identified as a result of fragmentation of habitats by the reinjection line. In order to minimise severance effects, the pipeline will have under/overpasses installed at intervals along its length. The exact nature and positioning of these will be developed during detailed design. In addition, because the pipeline is located above-ground, smaller animals are expected to be able to pass under it.
- During construction, pedestrians and cyclists will be disadvantaged by the general increased level of traffic along the roads being used. This may lead to temporary diversions and minor delays, resulting to potential impacts of **Moderate** significance. Following the implementation of mitigation (such as the development of a Traffic Management Plan), residual impacts on non-motorised users of the road network will reduce to **Negligible** significance.

## 19.2 Operational Impacts

During operation, the majority of residual impacts (i.e. following the use of proposed mitigation and monitoring measures) are considered to be of **Negligible** or **Minor** significance and are discussed below.

### 19.2.1 Power Plant

The following residual impacts have been identified during the operation of the power plant:

- There is potential that the Project may increase subsidence in the Project area as a result geothermal fluid extraction and therefore, prior to mitigation potential impacts are considered to be of **Moderate** significance. Overall, natural hazards including volcanic activity, landslides and hurricanes present potential impacts to the Project of **Moderate** significance. However, following the application of mitigation incorporated through steamfield design and additional mitigation applied during construction and operation (i.e. Subsidence Management Procedure), the residual impacts are expected to be reduced to **Minor.**
- Once the power plant is operational, ~2 ha will have a permanent change from soil with forest/scrub cover to a mixture of concrete and gravel pads. The power plants site is anticipated to be 10% concrete and 90% gravel. This will permanently increase localised runoff and this potential impact is considered to be of **Moderate** significance, given this will lead to a permanent change in runoff characteristics. However, with additional design mitigation in place, such as stormwater management and drainage, the residual impact will reduce to **Minor** significance.
- During operation there may be a number of properties surrounding the power plant that experience adverse views of the power plant from their properties or when accessing their properties using the existing access road. The adverse impact of this is expected to be of **Moderate – High** significance. However, it is anticipated that these adverse views will reduce over time through vegetation growing up around the perimeter of the power plant. Following mitigation measures such as planting regimes and site fencing, the residual impacts for both the power plant are expected to be reduced to **Low** or **Negligible** significance.
- During commissioning works there will be noise impacts of **Major** significance of impact at Laudat (south), Trafalgar (east), Trafalgar (south) and Wotten Waven. However, it is understood that commissioning testing will only occur for a relatively short period and following the application of the mitigation measures, impacts from commissioning activities residual impacts are considered to reduce to **Minor** significance.
- There is anticipated to be an increase release in $H_2S$ as a result of the Project's activities, however, it is considered that there would be **Negligible** impact on receptors with regard to odour, due to the low concentrations predicted at the main residential areas and a likely desensitised local population. Despite

this, ambient monitoring has been recommended to monitor for $H_2S$ during operations, at sensitive locations (e.g. nearby residential areas), using low-level ambient $H_2S$ monitors such as Odalog, which can be deployed at multiple locations for up to two months at a time.

- With proposed mitigation in place, there will be **Negligible** adverse residual impacts on the MTPNP World Heritage site.
- For GHG emissions, the total $CO_2$-e per year is considered to be significantly less than a fossil fuel derived energy source and therefore the Project is considered to have **Moderate Beneficial** significant impact.

### 19.2.2 Reinjection Pipeline

The following residual impacts have been identified during the operation of the reinjection pipeline:

- The primary hydrological risk to the reinjection pipeline will be from flooding. The torrential downpours, annual rainfall >8,000 mm/year (in the upper mountains) and steep nature of the catchments result in a flashy system with high peak flows and velocities. Subsequently, any pipe crossings (pipe bridges) over waterways will be at risk from potential flood impacts in terms of high water levels and debris carried with these flows. This could cause significant damage or loss of certain areas of the pipeline and is a critical component to the ongoing success of the power plant and energy supply in Dominica. This is a potential impact to the Project's operability and is considered of **Major** significance, given this would critically effect infrastructure and lead to plant shut downs. With recommended detailed design mitigation measures in place to reduce the risk of flooding and debris strike, residual impacts for the reinjection pipeline are to reduce to **Moderate** significance.

## 19.3 Natural Hazards – All Phases of Project Development

Of particular note when considering natural hazards is the devastating effects that Hurricane Maria brought to Dominica and the increased likelihood of landslides following the event. Based on the location and nature of the proposed Project and natural hazards identified within the vicinity of the Project area, overall potential impacts are considered to be of **Moderate** significance. The impacts from natural hazards as result of the proposed Project following the application of mitigation incorporated through steamfield design and additional mitigation applied during construction and operation (i.e. an ESCP including a Landslide Management Procedure), the residual impacts are expected to be reduced to **Minor** and are therefore not significant.

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Dominica Geothermal Development Company Limited
*Powering a New Generation...*

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# Dominica Geothermal Development - Environmental and Social Impact Assessment

NZ Ministry of Foreign Affairs & Trade

## ESIA Volume 3: Social Impact Assessment

RZ020300-0002-NP-RPT-0006 | V2

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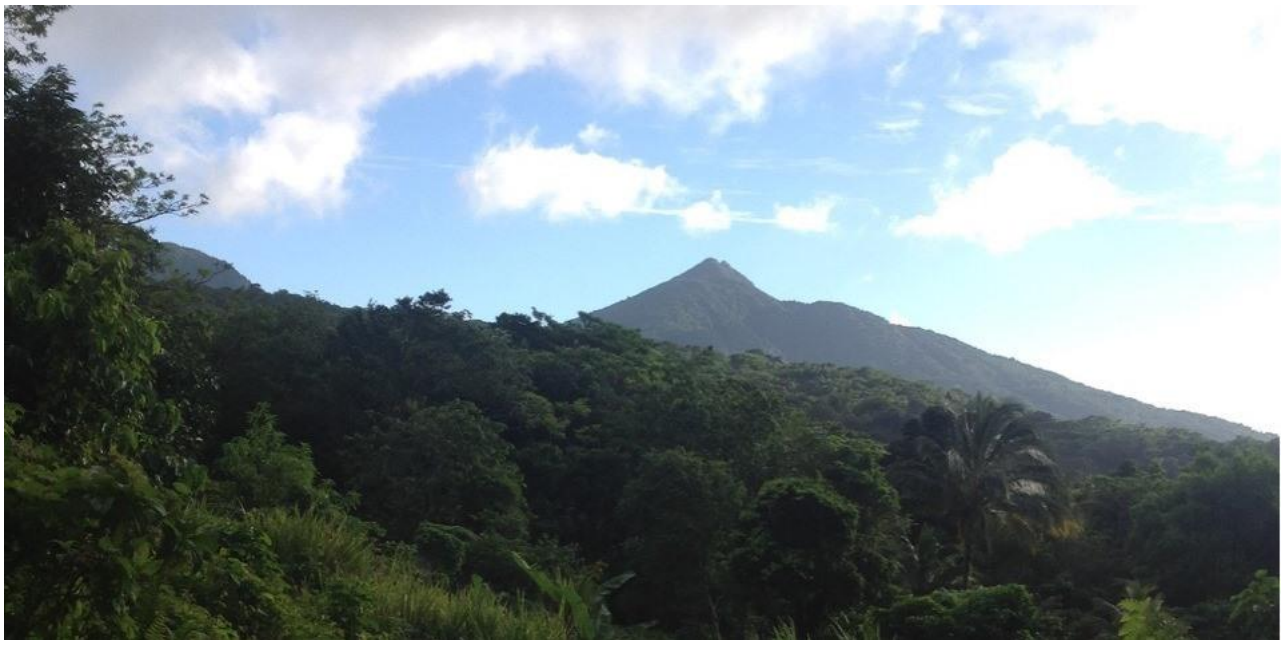

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# Glossary

| Acronym | Term | Definition |
|---|---|---|
| AoI | Area of Influence | The project AoI is defined through consideration of the project footprint including all ancillary project components and also considering project impacts on various environmental and social components. A number of project areas of influence may result but is best to amalgamate them into an overall project area of influence. In addition to the area of geographical or spatial influence, temporal influence should also be determined. A geographical information system is a useful tool for this purpose. |
| - | Cumulative Effects | Cumulative effects (or impact) are changes to the environment that are caused by an action in combination with other past, present and future human actions. The assessment of these effects is called a cumulative effects assessment (CEA) or cumulative impact assessment (CIA). |
| - | Cut-off date | Date of completion of the census and assets inventory of persons affected by the project. Persons occupying the project area after the cutoff date are not eligible for compensation and/or resettlement assistance. Similarly, fixed assets (such as built structures, crops, fruit trees, and woodlots) established after the date of completion of the assets inventory, or an alternative mutually agreed on date, will not be compensated. |
| - | Economic Resettlement | Loss of income streams or means of livelihood, resulting from land acquisition or obstructed access to resources (land, water, or forest) resulting from the construction or operation of a project or its associated facilities. |
| ESIA | Environmental and Social Impact Assessment | Identifies and assesses risks and the impacts associated with the project and provides a series of mitigation measures that when implemented will ensure the project complies with the standards and guidelines it has be evaluated against. |
| ESMP | Environmental and Social Management Plan | Summarises the client's commitments to address and mitigate risks and impacts identified as part of the Assessment, through avoidance, minimisation, and compensation/offset. This may range from a brief description of routine mitigation measures to a series of more comprehensive management plans (e.g. water management plan, waste management plan, resettlement action plan, indigenous peoples plan, emergency preparedness and response plan, decommissioning plan). |
| ESMS | Environmental and Social Management System | The ESMS is the overarching environmental, social, health and safety management system which may be applicable at a corporate or Project level. The system is designed to identify, assess and manage risks and impacts in respect to the Project on an ongoing basis. |
| - | Involuntary resettlement | Resettlement is involuntary when it occurs without the informed consent of the displaced persons or if they give their consent without having the power to refuse resettlement. |
| IP | Indigenous People | Social groups with identities that are distinct from mainstream groups in national societies, are often among the most marginalized and vulnerable segments of the population. In many cases, their economic, social, and legal status limits their capacity to defend their rights to, and interests in, lands and natural and cultural resources, and may restrict their ability to participate in and benefit from development. |
| - | Land Acquisition | Land acquisition includes both outright purchases of property and acquisition of access rights, such as easements or rights of way. |
| - | Legal and regulatory framework | The national legal and institutional framework applicable to the project should be defined. This should also include any additional lender requirements and any international agreements or conventions that may also apply. |
| - | Livelihood | Refers to the full range of means that individuals, families, and communities utilize to make a living, such as wage-based income, agriculture, fishing, foraging, other natural resource-based livelihoods, petty trade, and bartering. |

| Acronym | Term | Definition |
|---|---|---|
| LRP | Livelihood Restoration Plan | The document in which a project sponsor or other responsible entity specifies the procedures that it will follow and the actions that it will take to mitigate adverse effects, compensate losses, and provide development benefits to persons and communities affected by an investment project. The LRP relates specifically to cases where Project Affected Persons (PAPs) are economically displaced. |
| - | Physical displacement | Loss of shelter and assets resulting from the compulsory acquisition of land associated with a project that requires the affected person(s) to move to another location. |
| PAP | Project Affected Persons | Any person who, as a result of the implementation of a project, loses the right to own, use, or otherwise benefit from a built structure, land (residential, agricultural, or pasture), annual or perennial crops and trees, or any other fixed or moveable asset, either in full or in part, permanently or temporarily. |
| - | Project Description | A project description should be provided as early as possible that describes all project activities that could impact on environmental and social components within the project area of influence. Ideally the project description should be prepared by the project front end engineering team in association with the ESIA team. It should consider all project phases from pre-construction, construction, operation and decommissioning. The project description should be as detailed as possible in order to identify the environmental aspects resulting from project activities. |
| ARAP | Abbreviated Resettlement Action Plan | The document in which a project sponsor or other responsible entity specifies the procedures that it will follow and the actions that it will take to mitigate adverse effects, compensate losses, and provide development benefits to persons and communities affected by an investment project. The ARAP relates specifically to cases where Project Affected Persons (PAPs) are physically displaced. |
| - | Resettlement | The settlement of people in a different place. |
| - | Screening | Categorization of the project should be undertaken depending on the expected severity of project impacts, which determine the level of environmental and social impacts. Categories (ABC) should be established as per IFC Performance Standards. |
| ToR | Terms of Reference | The ToR provides a guide as to how an environmental and social assessment should be conducted and the level of detail that is required. Normally the ToR is prepared by the responsible environmental authority. In some cases, the ToR may be circulated in draft form for public review and comment before being defined. |
| - | Vulnerable groups | People who by virtue of gender, ethnicity, age, physical or mental disability, economic disadvantage, or social status may be more adversely affected by resettlement than others and who may be limited in their ability to claim or take advantage of resettlement assistance and related development benefits. |

# List of Abbreviations

| Acronym | Meaning |
|---|---|
| AoI | Area of Influence |
| ARAP | Abbreviated Resettlement Action Plan |
| DGDC | Dominica Geothermal Development Company Limited |
| DOMLEC | Dominica Electricity Services Limited |
| DOWASCO | Dominica Water and Sewerage Company Limited |
| DSWMC | Dominica Solid Waste Management Corporation |
| EIA | Environmental Impact Assessment |
| EHS | Environmental Health and Safety |
| EPC | Engineer, Procure and Construct |
| ESIA | Environmental and Social Impact Assessment |
| ESMP | Environmental and Social Management Plan |
| ESMS | Environmental and Social Management System |
| GDP | Gross Domestic Product |
| GoCD | Government of the Commonwealth of Dominica |
| HSE | Health, Safety and Environment |
| IFC | International Finance Corporation |
| kV | Kilovolt |
| kW | Kilowatt |
| LRP | Livelihood Restoration Plan |
| MTPNP | Morne Trois Pitons National Park |
| MW | Mega Watt |
| MWe | Mega Watt Electric |
| PAP | Project Affected Persons |
| PPE | Personal Protective Equipment |
| PS | Performance Standard |
| RPF | Resettlement Policy Framework |
| SEP | Stakeholder Engagement Plan |
| SIA | Social Impact Assessment |
| ToR | Terms of Reference |
| WB | World Bank |
| WBG | World Bank Group |
| WHO | World Health Organisation |

# Important note about your report

The sole purpose of this report and the associated services performed by Jacobs New Zealand Limited ("Jacobs") is to describe the Environmental and Social Impact Assessment (ESIA) for the Dominica Geothermal Power Project in accordance with the scope of services set out in the contract between Jacobs and the New Zealand Ministry of Foreign Affairs and Trade (the Client). That scope of services, as described in this report, was developed with the Client, the Government of the Commonwealth of Dominica (GoCD) and the Developer (Dominica Geothermal Development Company (DGDC) established and owned by the GoCD).

Jacobs has been contracted by the Client to undertake the conceptual design and overall project definition through their engineering team. In preparing this ESIA report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided. Except as otherwise stated in the ESIA report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced as noted in the ESIA volumes and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

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# 1. Introduction

## 1.1 Overview

The ESIA Volume 3: Social Impact Assessment (SIA) assesses how people and communities may be affected as a result of the Project in terms of the way they live, work and interact. The broad objectives of this SIA are to ensure that key potential socio-economic and community impacts have been identified, assessed, mitigated and managed in a constructive manner. Social, economic and biophysical impacts are interrelated. The human environment will be the receptor of impacts such as noise, dust, waste and traffic. These impacts are identified and taken into account in this SIA, but are addressed in detail in the ESIA Volume 2: Environmental Impact Assessment and other Technical Reports located in ESIA Volume 5: Technical Appendices.

This SIA follows the principles defined in the Social Impact Assessment: Guidance for Assessing and Managing the social impact of Projects and, as the Project is considered a private sector led economic development Project, this assessment was carried out to meet the requirements of World Bank Group Performance Standards (described in Section 2).

Social and community impacts have been assessed and identified as potentially significant in relation to resettlement, community health and safety and livelihood restoration. Consideration has also been given to employment impacts. Environmental impacts from construction activities could also have community impacts, however, to avoid double counting of impacts these have been addressed within Volume 2 and are not covered again here.

A draft of the SIA of was issued in September 2017 prior to Hurricane Maria. This SIA has been updated following Hurricane Maria, which devastated the island in September 2017. It was reported that the majority of the island's inhabitants have been affected by the Hurricane. Impacts include loss of homes, business, schools, social infrastructure and basic amenities such as water and electricity. Further discussion on the baseline impacts following Hurricane Maria are presented in Section 4.

## 1.2 Structure of Volume 3

This ESIA Volume 3: SIA is structured in the following way:

- Section 2 – Legal and Regulatory Framework
- Section 3 – Impact Assessment Methodology
- Section 4 – Social and Economic Baseline
- Section 5 – Stakeholder Engagement
- Section 6 – Social Impact Assessment
- Section 7 – Cultural Heritage
- Section 8 – Mitigation, Monitoring, Enhancement Measures and Residual Impacts
- Section 9 – References

# 2. Legal and Regulatory Framework

## 2.1 Introduction

The purpose of this section is to set out the requirements that apply to SIA for the Project. It is important that the Project meets local and internationally accepted environmental and social safeguard standards to ensure that community benefits are maximised and that potential adverse environmental and social impacts are minimised. Relevant national and international requirements are summarised below.

## 2.2 National Requirements

There are a number of Dominican national policies, laws, regulations and guidelines that guide relevant environmental, social and economic issues (discussed in detail in ESIA Volume 1: Introduction, Section 2). The laws and regulations also provide the relevant instruments for the effective management of land acquisition and proper institutional coordination. These regulations, policies, laws and guidelines identified include the following:

### 2.2.1 Land Acquisition Act

The Land Acquisition Act, Chapter 53:02 deals with the acquisition of land by the state and clearly outlines procedures in acquiring private lands for state use. The Act covers the following areas:

i. Acquisition of land and abandonment of acquisition

ii. Appointment and powers of Board of Assessment

iii. Determination of Small Claims for Compensation

iv. Provisions Governing Assessment of Compensation

v. Miscellaneous

   a) Absentee owners

   b) Compensation to persons interested in adjacent land

   c) Special provisions as to leases

   d) Persons in possession to be deemed owners

   e) Fees and expenses of Board

   f) Conveyancing etc.

   g) Payment of compensation

   h) Exemption from stamp duty and fees

   i) Limitation of time for making claims

   j) Assaulting or obstructing officer

   k) Saving

The Act includes the determination of how compensation should be determined. The general process of compulsory land acquisition under the Land Acquisition Act, Chapter 53:02 is described below in Figure 2.1.

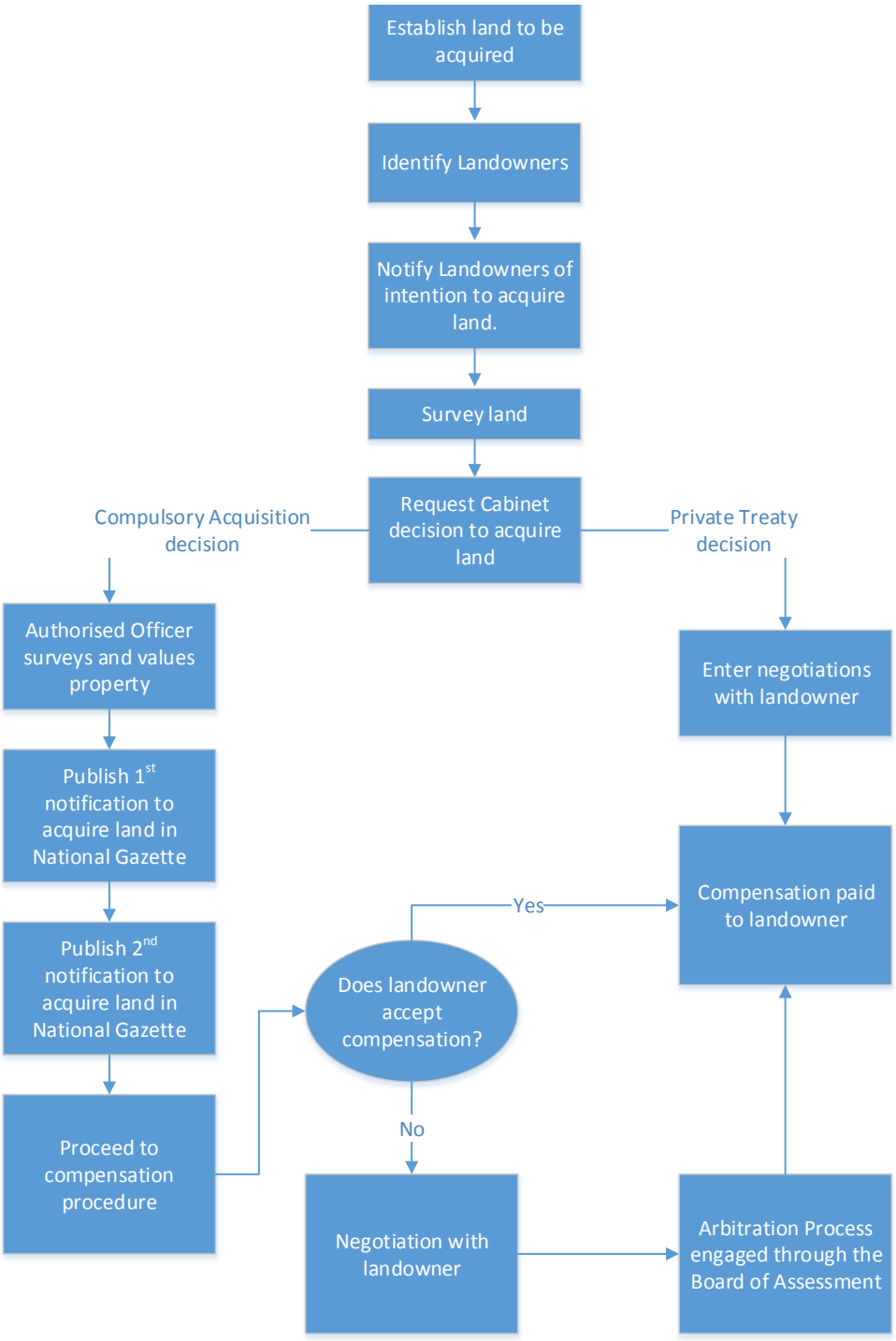


**Figure 2.1 : The general process of acquiring land through compulsory acquisition in Dominica**.

## 2.3 International Requirements

### 2.3.1 World Bank Group Operational Policies

This study was conducted taking into account Dominica's regulations and the requirements of lenders, in this case the World Bank Group (WBG). This includes examination and verification of the project's compliance with WBG's Operational Policies. The applicable policies to this project are: OP4.03 (World Bank Group Performance Standards for Private Sector Activities) and OP4.12 (Involuntary Resettlement). Under OP4.03, the applicable performance standards are:

- Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts;
- Performance Standard 2: Labour and Working Conditions;
- Performance Standard 3: Resource Efficiency and Pollution Prevention;
- Performance Standard 4: Community Health, Safety, and Security
- Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources;
- Performance Standard 7: Indigenous Peoples; and
- Performance Standard 8: Cultural Heritage.

PS 7 - Indigenous People does not apply to the Project. People living in the Project area are not categorized as Indigenous People. They are part of the mainstream Dominican society, and do not have any specific economic or cultural activity different from the rest of the society. They participate fully in the socioeconomic life of the society.

### 2.3.2 OP 4.12- Involuntary Resettlement

According to OP 4.12, involuntary resettlement may cause severe long-term hardship, impoverishment, and environmental damage unless appropriate measures are carefully planned and carried out. For these reasons, the overall objectives of the Bank's policy on involuntary resettlement are the following:

(a) Involuntary resettlement should be avoided where feasible, or minimized, exploring all viable alternative project designs.

(b) Where it is not feasible to avoid resettlement, resettlement activities should be conceived and executed as sustainable development programs, providing sufficient investment resources to enable the persons displaced by the project to share in project benefits. Displaced persons should be meaningfully consulted
and should have opportunities to participate in planning and implementing resettlement programs.

(c) Displaced persons should be assisted in their efforts to improve their livelihoods and standards of living or at least to restore them, in real terms, to pre-displacement levels or to levels prevailing prior to the beginning of project implementation, whichever is higher.

OP 4.12 covers direct economic and social impacts that both result from Bank-assisted investment projects and are caused by:

(a) the involuntary taking of land resulting in relocation or loss of shelter;

(1) loss of assets or access to assets; or

(2) loss of income sources or means of livelihood, whether or not the affected persons must move to another location; or

(3) the involuntary restriction of access9 to legally designated parks and protected areas resulting in adverse

(b) impacts on the livelihoods of the displaced persons.

### 2.3.3 General and Industry Specific Environmental Health and Safety (EHS) Guidelines

The World Bank Group (WBG) General EHS Guidelines contain information on overall project environmental, health, and safety issues applicable to all industry sectors. These guidelines should be used together with the relevant Industry Sector Guideline(s), which in the case of the Project include:

- Geothermal Power Generation, and
- Electric Power Transmission and Distribution.

Further discussion of General and Industry Specific EHS Guidelines can be found in ESIA Volume 1: Introduction, Section 2.

# 3. Impact Assessment Methodology

## 3.1 Introduction

The objective of the SIA is to determine the potential impacts of the Project on social and economic factors that influence the socio-economic well-being of the communities where the Project is proposed. To measure the influence of the Project on these factors, a socio-economic baseline is presented to establish existing characteristics of the community. This is followed by a discussion of the potential positive and negative impacts that could result from implementation of the Project including proposed measures to mitigate any potential negative impacts. The SIA methodology has been completed in accordance with both national and international requirements.

## 3.2 Baseline Conditions

Baseline data collection refers to the collection of background data in support of the SIA. Ideally baseline data should be collected prior to development of a project, but often this is not possible. Baseline data collection can also occur throughout the life of a project as part of ongoing monitoring of environmental and social conditions.

World Bank (1999) guidance on identification of baseline data states that it *'…describes relevant physical, biological, and socioeconomic conditions, including any changes anticipated before the project commences. Also takes into account current and proposed development activities within the project area but not directly connected to the project. Data should be relevant to decisions about project location, design, operation, or mitigatory measures. The section indicates the accuracy, reliability, and sources of the data.'*

The baseline data was gathered through social baseline studies conducted between November 2016 until March 2018 and supplementary data from earlier Project related studies detailed below. It should be noted that the impacts described in the impact assessment are for those that exist in the 'post-Maria' environment (i.e. impacts on the current baseline).

### 3.2.1 Previous Studies

The Project benefits from having a wealth of environmental studies data collected for environmental assessments for exploration and drilling phases. To date the following environmental and social studies have been completed:

- Caraïbes Environnement Développement & Coll (2009) Regulatory Impact Assessment on the Initial Environment - Environmental Feasibility Study.
- Caraïbes Environnement Développement & Coll (2011). Stage 1: Exploration Drilling Process – Environmental Impact Assessment.
- Caraïbes Environnement Développement & Coll (2013) Stage 2: Preliminary Environmental Impact Assessment of Geothermal Production and Re-Injection Drilling Wells in Dominica – Environmental Impact Assessment.
- To support the preparation of an ESIA for the exploration phase of the geothermal development, baseline surveys of the social, physical and biological environment within the Roseau Valley were completed between October 2013 and April 2015. These were summarised in the following reports (collectively referred to as the 'Baseline Study'):
    - Caraïbes Environnement Développement & Coll (2015a). Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production. Final report, May 2015. Section 3 Biodiversity / Terrestrial Flora and Fauna.

- Caraïbes Environnement Développement & Coll (2015b). Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production. Final summary report.

As part of the ESIA Terms of Reference (ToR), (Jacobs, 2017) a review of these previous studies was carried out. The findings of this review were presented along with any further baseline data collection proposed in the ToR. In addition, a review of the situational analysis prepared by the WB was carried out.

## 3.3 Aspects Identification

The key E&S aspects considered in detail in this SIA have been determined from the ESIA Terms of Reference (ToR) (Jacobs, 2017). As a result of the scoping assessment the following baseline socio-economic topics are covered in this SIA:

- Demographic Overview;
- Land Use;
- Religion;
- Ethnicity and Culture;
- Gender Relations;
- Indigenous People;
- Ecosystem Services;
- Economic Profile;
- Educational Profile;
- Health Profile;
- Access to Community Services and Infrastructure; and
- Quality of Life.

The following key issues have been technically assessed in this SIA:

- Physical Displacement/Resettlement as a result of the Project;
- Economic Displacement and Livelihood Impacts, including those to Ecosystem Services;
- Employment benefits; and
- Economic benefits.

## 3.4 Impact Identification

The impact assessment predicts and assesses the Project's likely positive and negative impacts, in quantitative terms to the extent possible. For each of the environmental aspects listed above, the assessment identifies impacts and reports the likely significant environmental impacts. An ESIA will always contain a degree of subjectivity, as it is based on the value judgment of various specialists and ESIA practitioners. The evaluation of significance is thus contingent upon values, professional judgement, and dependent upon the environmental context. Ultimately, impact significance involves a process of determining the acceptability of a predicted impact.

In broad terms, impact significance can be characterised as the product of the degree of change predicted (the magnitude of impact) and the value of the receptor/resource that is subjected to that change (sensitivity of receptor). For each impact the likely magnitude of the impact and the sensitivity of the receptor are defined. Generic criteria for the definition of magnitude and sensitivity are summarised below.

### 3.4.1 Direct vs Indirect Impacts

A direct impact, or first order impact, is any change to the environment, whether adverse or beneficial, wholly or partially, resulting directly from an environmental aspect. An indirect impact may affect an environmental, social or economic component through a second order impact resulting from a direct impact.

### 3.4.2 Magnitude Criteria

The assessment of impact magnitude is undertaken by categorising identified impacts of the Project as beneficial or adverse. Then impacts are categorised as 'major', 'moderate', 'minor' or 'negligible' based on consideration of parameters such as:

- Duration of the impact – ranging from 'well into operation' to 'temporary with no detectable impact'.
- Spatial extent of the impact – for instance, within the site boundary, within district, regionally, nationally, and internationally.
- Reversibility – ranging from 'permanent thus requiring significant intervention to return to baseline' to 'no change'.
- Likelihood – ranging from 'occurring regularly under typical conditions' to 'unlikely to occur'.
- Compliance with legal standards and established professional criteria – ranging from 'substantially exceeds national standards or international guidance' to 'meets the standards' (i.e. impacts are not predicted to exceed the relevant standards) presents generic criteria for determining impact magnitude (for adverse impacts). Each detailed assessment will define impact magnitude in relation to its environmental or social aspect.
- Any other impact characteristics of relevance.

Table 3.1 below presents generic criteria for determining impact magnitude (for adverse impacts). Each detailed assessment will define impact magnitude in relation to its environmental or social aspect.

**Table 3.1 : Magnitude criteria**

| Magnitude (beneficial or adverse) | Definition (considers likelihood, duration, number of people affected, spatial extent and local benefit sharing) |
|---|---|
| Major | A highly likely impact that would have implications beyond the Project's life affecting the wellbeing of many people across a broad cross-section of the population and affecting various elements of the local communities', or workers', resilience. |
| Moderate | A likely impact that continues over a number of years throughout the Project's life and affects the wellbeing of specific groups of people and affecting specific elements of the local communities', or workers', resilience. |
| Minor | A potential impact that occurs periodically or over the short term throughout the life of the Project affecting the wellbeing of a small number of people and with little effect on the local communities', or workers', resilience. |
| Negligible | A potential impact that is very short lived so that the socio-economic baseline remains largely consistent and there is no detectable effect on the wellbeing of people or the local communities' or workers', resilience. |

### 3.4.3 Sensitivity Criteria

The significance of an impact has been determined by the interaction between its magnitude, and the sensitivity of receptors affected. Professional judgement has been used by appropriately qualified social scientists when assigning significance. The use of these two concepts for this assessment is outlined below.

The sensitivity of receptors has been estimated through consideration of their socio-economic vulnerability, measured by their capacity to cope with social impacts that affect their access to or control over additional or alternative social resources of a similar nature, ultimately affecting their wellbeing. Sensitive or vulnerable receptors are generally considered to have less means to absorb adverse changes, or to replicate beneficial changes to their resource base than non-sensitive or non-vulnerable receptors.

When considering sensitivity, the type of resources in question varies between receptors. For example, a community's vulnerability has generally been measured in terms of its resilience to loss of community facilities, whereas an individual's vulnerability has generally been considered in relation to their resilience to deprivation and loss of livelihood assets or opportunities (such as jobs, productive land or natural resources). Impacts that increase impoverishment risks contribute to vulnerability. Impoverishment risks include landlessness, joblessness, homelessness, marginalisation, increased morbidity and mortality, food insecurity, loss of access to common property resources and social disarticulation, which are likely to have increased post-Hurricane Maria. Table 3.2 below presents the guideline criteria that have been used to categorise the sensitivity of receptors.

**Table 3.2 : Sensitivity criteria**

| Category | Description |
|---|---|
| High | An already vulnerable social receptor with very little capacity and means to absorb proposed changes or with very little access to alternative similar sites or services. |
| Medium | An already vulnerable social receptor with limited capacity and means to absorb proposed changes or with little access to alternative similar sites or services. |
| Low | A non-vulnerable social receptor with some capacity and means to absorb proposed changes and with some access to alternative similar sites or services. |
| Negligible | A non-vulnerable social receptor with plentiful capacity and means to absorb proposed changes and with good access to alternative similar sites or services. |

### 3.4.4 Impact Evaluation

The determination of impact significance involves making a judgment about the importance of project impacts. This is typically done at two levels:

- The significance of project impacts factoring in mitigation inherently within the design of the project; and
- The significance of project impacts following the implementation of additional mitigation measures, referred to as residual impact.

Likely impacts are evaluated taking into account the interaction between the magnitude and sensitivity criteria as presented in the impact evaluation matrix in the table below.

**Table 3.3 : Impact Evaluation Scale**

| | | Magnitude | | | |
|---|---|---|---|---|---|
| | | **Major** | **Moderate** | **Minor** | **Negligible** |
| **Sensitivity** | **High** | Major | Major | Moderate | Negligible |
| | **Medium** | Major | Moderate | Minor | Negligible |
| | **Low** | Moderate | Minor | Negligible | Negligible |
| | **Negligible** | Minor | Negligible | Negligible | Negligible |

## 3.5 Mitigation

Mitigation measures are actions taken to avoid or minimise negative environmental or social impacts. Mitigation includes those embedded within design (as already considered as part of the impact evaluation) and any additional mitigation required thereafter. Additional mitigation will be implemented to reduce significance impacts to an acceptable level, this is referred to as the residual impact. The mitigation hierarchy should be followed: prevent or avoid, minimise, restore or remedy, offset, compensate. Mitigation measures should be clearly identified and linked to environmental and social management plans.

## 3.6 Monitoring

Monitoring is not linked to the impact evaluation but is an important component of the ESIA and allows for evaluation of the effectiveness of mitigation measures. Monitoring and follow-up actions should be completed to:

- Continue the collection of data throughout construction, operation and later decommissioning.
- Evaluate the success of mitigation measures, or compliance with project standards or requirements.
- Assess whether there are impacts occurring that were not previously predicted.
- In some cases, it may be appropriate to involve local communities in monitoring efforts through participatory monitoring. In all cases, the collection of monitoring data and the dissemination of monitoring results should be transparent and made available to interested project stakeholders.

## 3.7 Residual Impacts

Those impacts that remain once mitigation has been put in place will be described as residual impacts, using Table 3.3 set out above.

## 3.8 Cumulative Impacts

The assessment of cumulative impacts will consider the combination of multiple impacts that may result when:

- The Project is considered alongside the existing facilities.
- The Project is alongside other existing or proposed projects in the same geographic area or similar development timetable.
- Impacts identified in different environmental and social aspects of the ESIA combine to affect a specific receptor.

The assessment of cumulative impacts will identify where particular resources or receptors would experience significant adverse or beneficial impacts as a result of a combination of projects (inter-project cumulative impacts). In order to determine the full combined impact of the development, potential impacts during construction and operational phases have been assessed where relevant.

# 4. Social and Economic Baseline

## 4.1 Introduction

The Project's socio-economic baseline includes information from:

- Previous Environmental Impact Assessments (EIA) (2009 and 2011) (see Section 2.1);
- A Gap Analysis carried out by the WB in early 2013;
- A subsequent ESIA social baseline study carried out by Jacobs and the Dominica Geothermal Development Company Limited (DGDC) between 2016 and 2017;
- Post Disaster Needs Assessment Hurricane Maria, September 18, 2017, carried out by the Government of the Commonwealth of Dominica.

Public meetings and one to one engagements were conducted for the drilling phase of the project between 2012 and 2015. Public meetings for the current phase of the Project which includes development of the Power Plant and reinjection pipeline route have been held during 2016 – 2017, focused around the three communities of Laudat, Trafalgar and Wotten-Waven. Focus group meetings were held with specific vendor and women's groups in Laudat, Trafalgar and Wotten-Waven in March 2018, following the devastation of the island by Hurricane Maria. Baseline data collected included approximately 35 surveys in the affected community and data collected from focus groups responses. Further details of consultation conducted for the Project are included in Section 5.

## 4.2 General Setting

The Commonwealth of Dominica is a small island developing state in the Caribbean Sea with a population of approximately 72,000 people and a land area of approximately 750 $km^2$. The island is the largest and most northerly of the Windward Islands in the Lesser Antilles, lying between Guadeloupe and Martinique. The island measures 40 km by 22 km, extending from 15º10'N-15º40'N and 61º15'W-61º30'W (Caribbean Community Climate Change Centre, 2011). An estimated 60% of the land is classified as the Morne Trois Piton National Park (MTPNP) World Heritage site by UNESCO, due to its rich biodiversity. The capital Roseau is located to the south-west of the island and has a population of around 15,000 people (Figure 4.1).

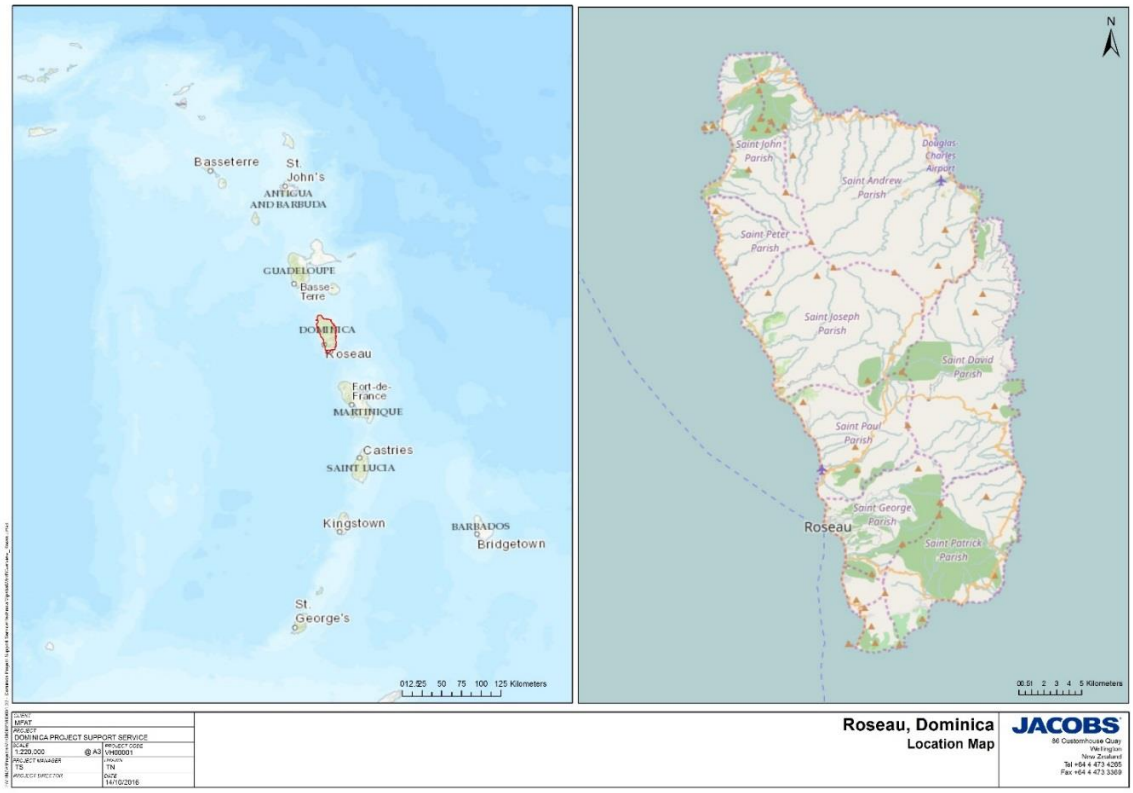


**Figure 4.1 : Dominica's location in the Caribbean**

The Roseau Valley lies inland from the coast, bordering the capital city of Roseau. An overview of the Roseau Valley is provided in Figure 4.2.

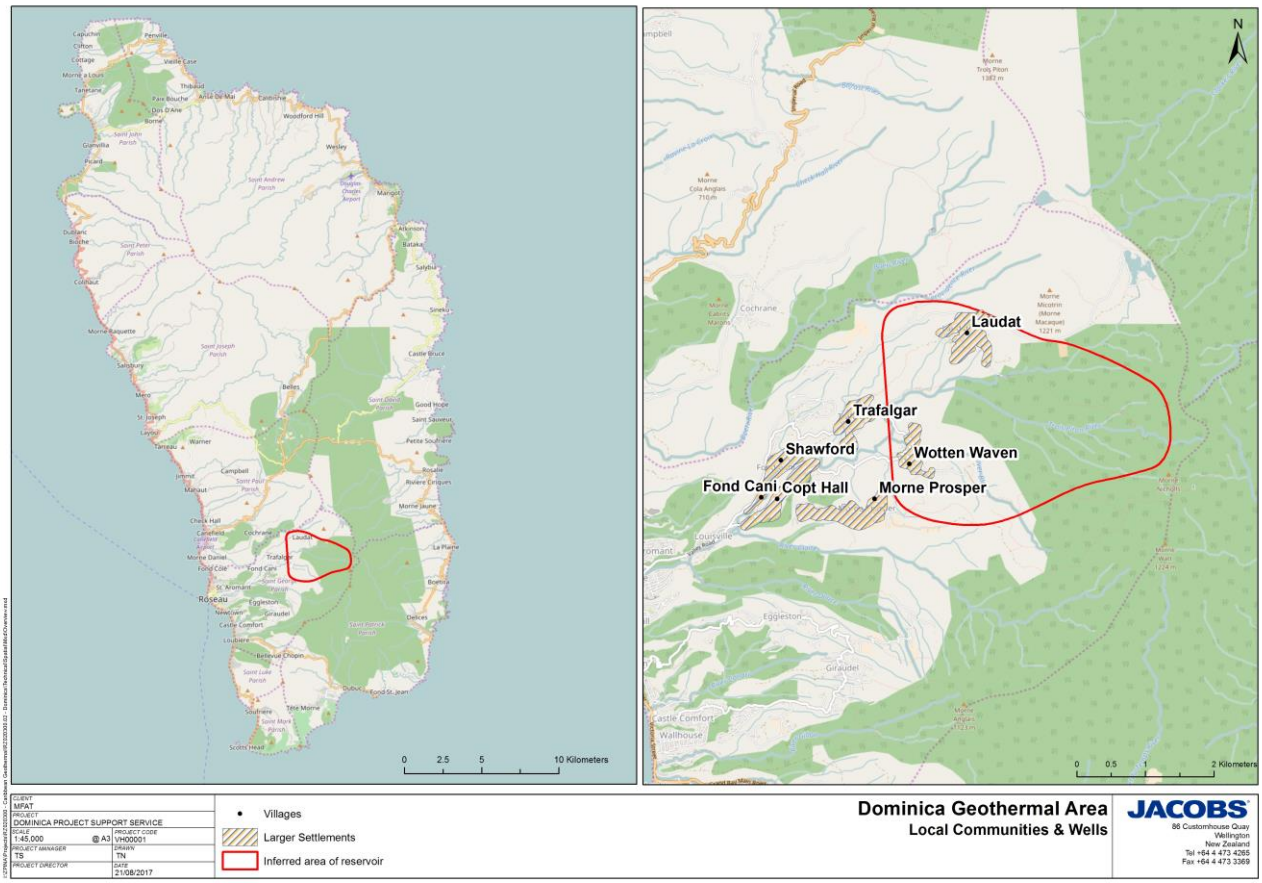


**Figure 4.2 : Location of Roseau Valley (Site of proposed Geothermal Power Plant)**

The proposed Project is located in the Roseau Valley in the Wotten Waven Geothermal System. Three well pads will be used for the Project: WW-P1, WW-01 and WW-R1. WW-01 is located near Wotten Waven, reinjection site WW-R1 is near the village of Trafalgar, and WW-P1 is located in Laudat.

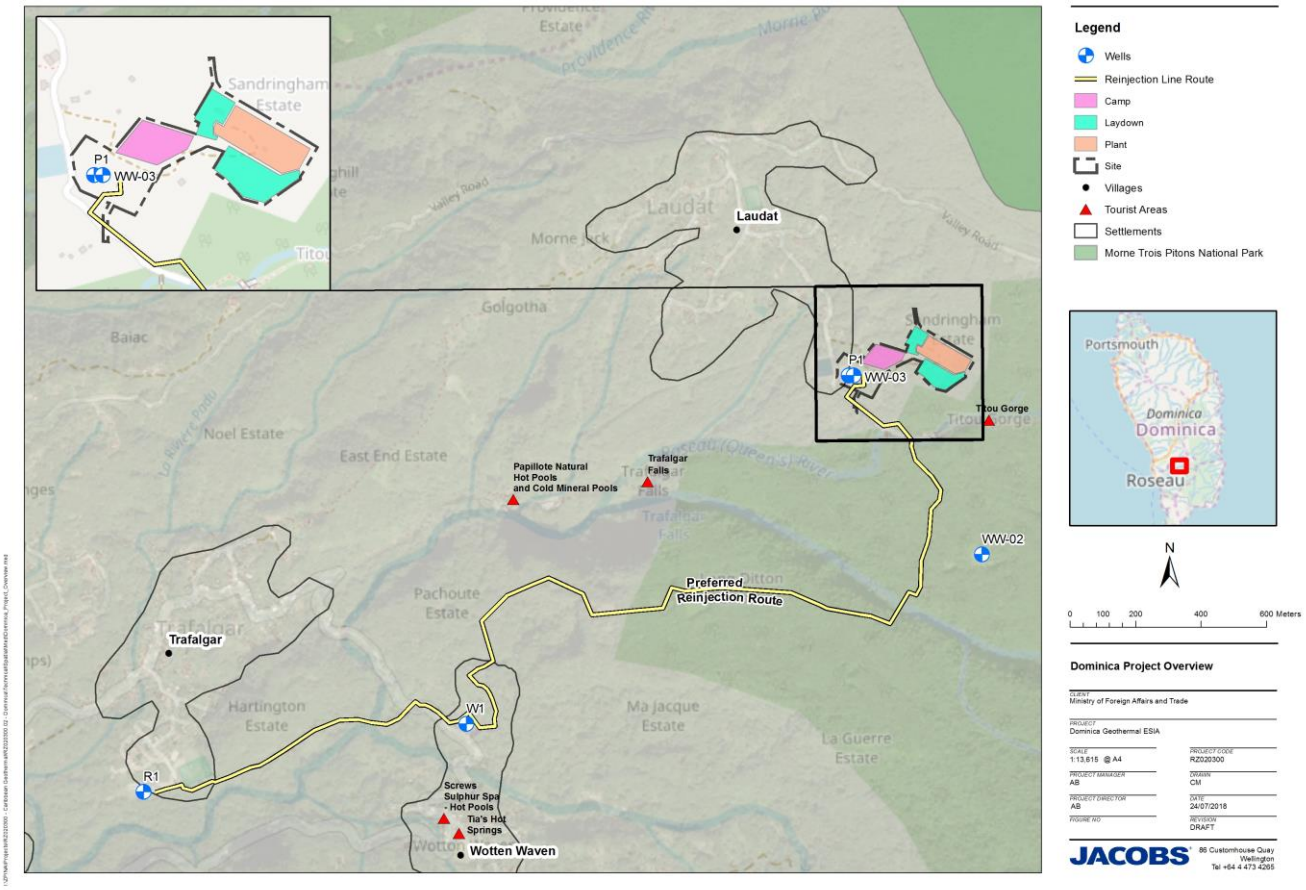


**Figure 4.3 : Project Overview**

The power plant is proposed to be located in the village of Laudat. Three well pads will be used for the Project with a production well and reinjection well for condensate at Laudat by the power plant and two further reinjection wells at Wotten Waven and Trafalgar. The preferred injection line route will be finalised in close co-ordination with process engineering, mechanical, geotechnical and civil engineering design disciplines, along with the Government, Land and Survey Division and environmental and social scientists. An overview of the Project area is provided in and Figure 4.5.

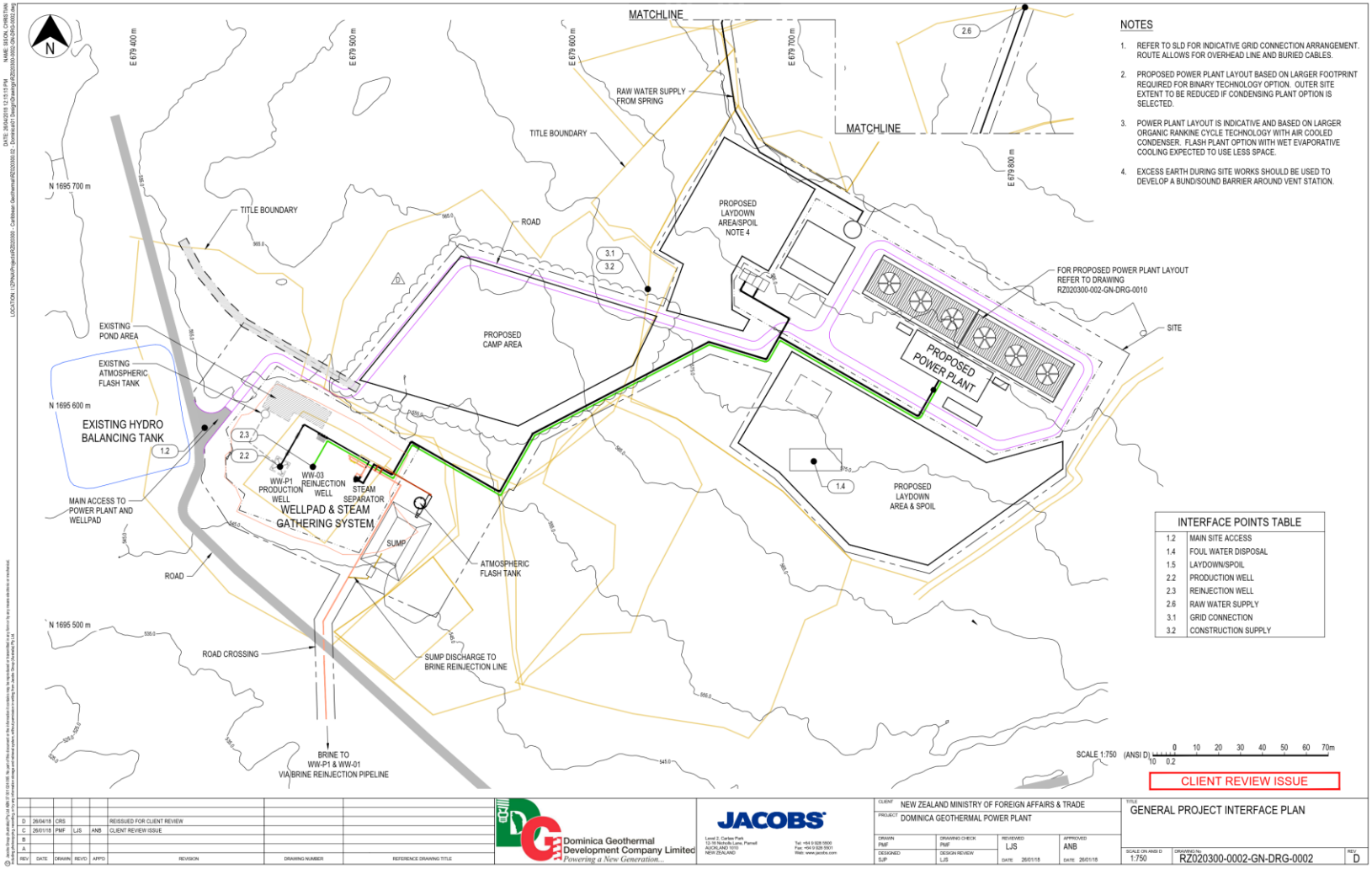


**Figure 4.4 : Proposed Power Plant Site, Worker's Camp and Production Steamfield Layout**

The area proposed for Project development is generally sparsely populated, characterised by some agroforestry and naturally vegetated areas. The proposed re-injection pipeline route is in generally hilly terrain, and is unlikely to be heavily populated. Brief descriptions of the main locations of Project infrastructure are as follows:

- Power plant comprising 2 x 3.5 MW units (either single flash steam condensing cycle or organic Rankine cycle units (binary turbine), which will be adjacent to wells WW-P1 and WW-03. The binary power plants may use wet cooling or dry cooling;
- Production well WW-P1 – The existing geothermal production well at Laudat is indicated to have potential to generate 6 to 9 MW and will be the sole production well for the project;
- Reinjection wells WW-R1 (located in Trafalgar) and WW-01 (located in Wotten Waven) – The used geothermal fluid (brine and possibly some steam condensate) produced from production well WW-P1 would be disposed of into reinjection wells WW-R1 and WW-01 via a 250 to 300 mm diameter reinjection pipeline of up to 3.5 km in length;
- Steamfield infrastructure including two phase piping, steam separator, atmospheric flash tank, brine collection and disposal system, condensate collection and disposal system, pressure relief system, storage sump and rock muffler;
- A Worker's Camp will be constructed during the construction phase will be located on site (see Figure 4.4), which will house an estimated 50 workers and will contain:
  - Canteen and showers with hot water facilities;
  - Sleeping quarters;
  - Recreational/games room;
  - Potable water supplies from either a tanker-supplied storage tank, or a dedicated treatment plant; and
  - Packaged sewage system treatment plant.
- Supporting infrastructure including existing well pads, turbine building, primary and ancillary equipment, cooling system, and water supply; and
- 11 kV interconnection to the DOMLEC electricity grid at the power plant site.



**Figure 4.5 : Reinjection Site (WW-R1) and Surrounding Area (Caraïbes Environnement Développement & Coll , 2013)**

## 4.3 Project Area of Influence

Within the Roseau Valley, three main communities of Trafalgar, Wotten Waven and Laudat were considered as the primary area of influence (Aol) for this SIA because they were in closest proximity to the proposed Project and represent the main communities that to would be likely to be impacted by any employment, resettlement, community health and safety issues. All of these fall within the Roseau Valley and data from the Roseau Valley itself is utilised where appropriate and when more detailed data for each community is not available. Figure 4.5 shows the location of Trafalgar, Wotten Waven and Laudat**.**

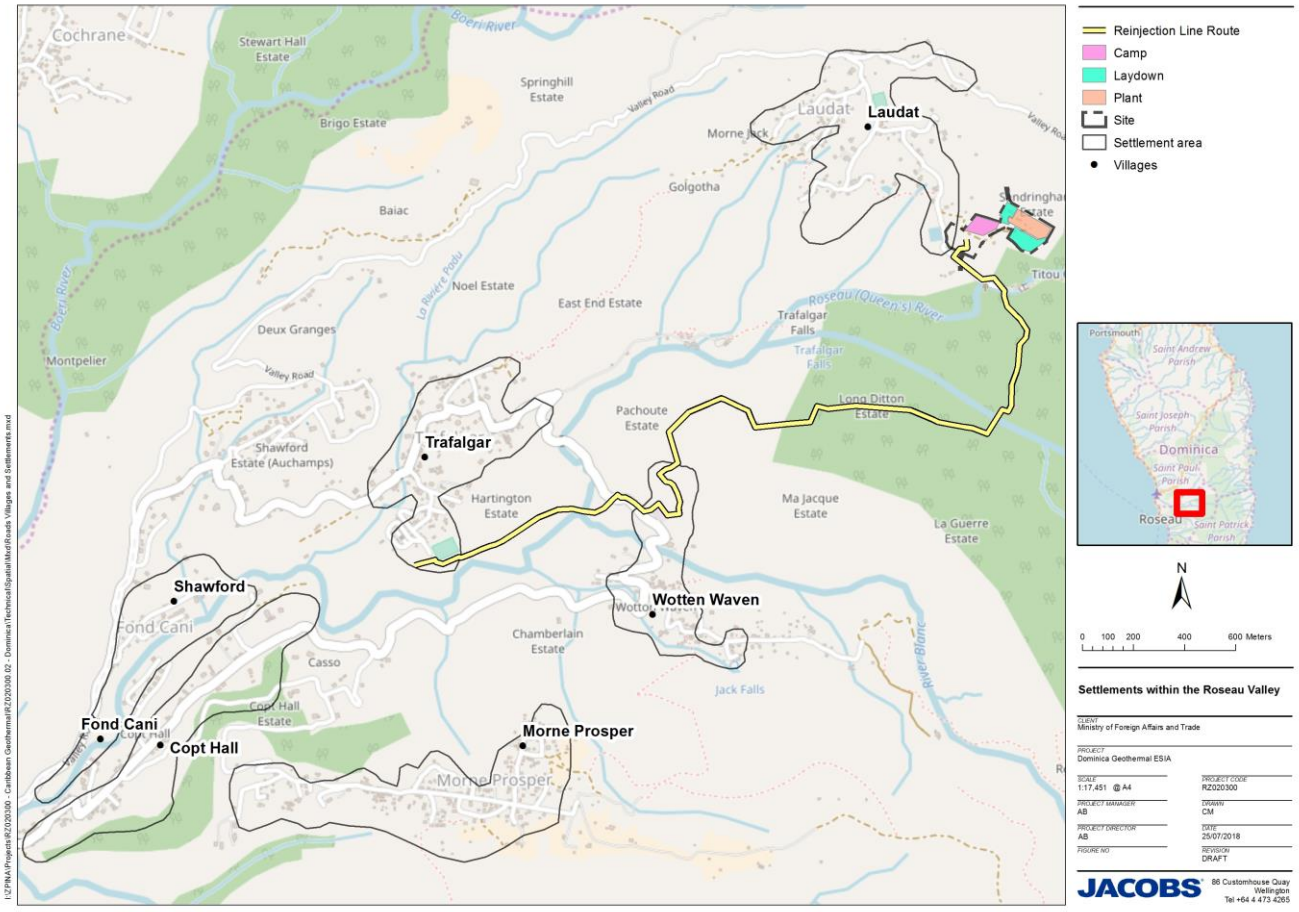


**Figure 4.6 : Settlements within the Roseau Valley**

### 4.3.1 Trafalgar

Trafalgar is located in the eastern portion of the Roseau Valley. The bulk of the population (959) in the valley reside in this area and it includes the most residentially developed of the three affected areas. The area is characterised by brightly coloured concrete houses and includes a health centre and a primary school. At the bottom of the valley, the Trafalgar area is used for agriculture including vegetables, herbs and fruit orchards. Trafalgar Falls is also a tourist destination. The community generally has pride in their natural resources and expressed some mild complaints about the increased rate of rust on metal structures in the community from the steam/sulphur in the area.



**Figure 4.7 : Trafalgar Ecotourism Business (left) (Jacobs, 2017) and Wotten Waven Community (left) (Source: Jacobs, 2017)**

### 4.3.2 Wotten Waven

Wotten Waven is well known for its natural hot sulphur springs and is located in a steep, inaccessible area. The wider area surrounding Wotten Waven area is characterised by agriculture including vegetables, herbs and fruit orchards. The area also includes some residences (population is 313), a health centre and a primary school. Since the 1990s there has been a considerable development in tourism services in the Roseau Valley. This is centred on hiking and the hot sulphur water spas in Wotten Waven.

### 4.3.3 Laudat

Laudat is a small village nestled between 3 mountains: Morne Watt, Morne Micotrine, and Morne Trois Pitons. Laudat, contains a sector of rainforest where numerous trees are felled for economic development. Laudat also includes a small population of 321, a health centre and a primary school.



**Figure 4.8 : Typical Laudat Household (left) (Source: Jacobs, 2017)**

## 4.4 Land Use and Tenure

### 4.4.1 Dominica Overview

The territory of Dominica is estimated to be 74,851 hectares. The Physical Planning Department estimates that approximately 53% of the land is covered by forests or protected areas, 34% is used for agriculture; 7% for construction and 6% is classified as wasteland (Jacobs, 2017).

Urban development in Dominica is concentrated on the narrow coastal plain extending from Roseau. The capital is situated on the oceanfront around the Roseau River. Its industrial and commercial activity zones are located mainly to the north on the way to Canefield Airport (a private airport). Urban expansion is taking place along the coast and tends to form continuous urban stretches between the steep foothills and the sea. Secondary urban areas are located just behind the coastline, infiltrating the secondary valleys that are perpendicular to the sea and parallel to each other. Most of the houses observed on the roads to the Roseau Valley were built recently. A trend of the subdivision of large agricultural plots for individual residential developments was also observed. There are no official records of house prices in Dominica. However, based on some property listings, two to three-bedroom houses can be bought for an average price of US $500,000, depending on the location, area, quality of construction materials and other factors (Global Property Guide Website, 2017).

### 4.4.2 The Roseau Valley

The Roseau Valley (about 1,500 hectares) mainly consists of forest and plantation. The eastern part of the valley tends to be agricultural land (including Wotten Waven and Laudat). The urban areas in the Roseau Valley are particularly concentrated at the entrance to the valley and in the eastern part of the valley. Also see Section 3.7, ESIA Volume 2: EIA for further details of the baseline of the landscape of Dominica.

Eight urban communities exist in the Roseau Valley, organised into independent urban areas: Laudat, Morne Prosper (at the Southern boundary of the study area), Wotten Waven, Trafalgar-Shawford, Fond Canie, Copt Hall, Louisville and Silver Lake. Each urban area is organised around a main road with houses distributed along the streets directly leading off. In many cases, well-kept gardens can be seen. An example of a property within Laudat is shown below in Figure 4.8.

The roads throughout the Roseau Valley are generally narrow, cutting through the districts (for further details of the road network reference should be made to ESIA Volume 2: EIA, Section 3.14 – Traffic). Tourist accommodation is scattered throughout the valley, notably in Wotten Waven. The urban areas are not scattered sporadically throughout the Roseau Valley and the houses are not aligned but rather distributed between forests, river and roads with varying orientations. There are local shops at crossroads and some informal dwellings (sheet metal and wooden cabins) that may not be properly permitted are regularly observed.



**Figure 4.9 : Example property in Laudat (source: Jacobs, 2016)**

### 4.4.3 Land Tenure in the Project Vicinity

**Drilling Phase**

During the exploration drilling campaign the Government acquired four plots of land through compulsory acquisition to be used as well pads and leased one:

- Two plots of land for two exploratory wells, WW-01 in Wotten Waven and WW-03 in Laudat. Production well WW-P1 is also located on WW-03;
- Two plots of land (same owner) for one reinjection well WW-R1 in Trafalgar; and
- One plot was leased for WW-02 in Laudat.

No households were physically displaced and a review of the acquisition and resettlement process and subsequent action plan has been developed as part of this ESIA process. The surveys conducted with each property owner showed that two of the property owners are deceased, one is an operating business parcel and the last is an unutilised plot owned by a family. Table 4.1 below provides a breakdown of the affected properties.

**Table 4.1 : Properties Affected During the Drilling Phase**

| Resource | WW-01 | WW-02 | WW-03 | WW-R1 |
|---|---|---|---|---|
| Land owner | Parcel 1 | Parcel 2 | Parcel 3 | Parcel 4 and Parcel 5 |
| Lot Size | 1.06 acres | 1 acre (leased) | 3.852 acres | Two lots measuring 3.958 and 4.145 acres |

| Resource | WW-01 | WW-02 | WW-03 | WW-R1 |
|---|---|---|---|---|
| Current Ownership/Land Arrangements | Acquired via compulsory acquisition by the Government. | Leased from the owner since 2011. | Acquired via compulsory acquisition by the Government. | Acquired via compulsory acquisition by the Government. |
| Land Use prior to Drilling Phase | Unoccupied. | Business. | Unoccupied. | Unoccupied. |

**Landowners in the Project Vicinity**

A total of 88 properties were identified from aerial images within 200 m of the power plant and reinjection pipeline route (Figures 4.10 and 4.11). As these properties were identified from aerial imagery, it is not known whether they are occupied. There are seven private property owners for parcels that are directly adjacent to and occupying the Power Plant site and laydown area. As a minimum only two parcels of land are required for the power plant site and laydown area, with potential easements for water pipelines required form two other parcels. Six to nine potentially affected parcels of land have been identified for the development of the reinjection pipeline route. It should be noted that the Project only requires sufficient land for a pipeline corridor (maximum width being 10m) for the reinjection line. The final number of parcels of land and the location of the reinjection line will be confirmed as part of detailed design process. DGDC is currently finalising land acquisition needs for government purchase for the power plant and reinjection pipeline route. All Project components and associated properties identified for future negotiations shall be completed in accordance with the Abbreviated Resettlement Action Plan (ARAP included in Volume 5 of this ESIA – Technical Appendices.

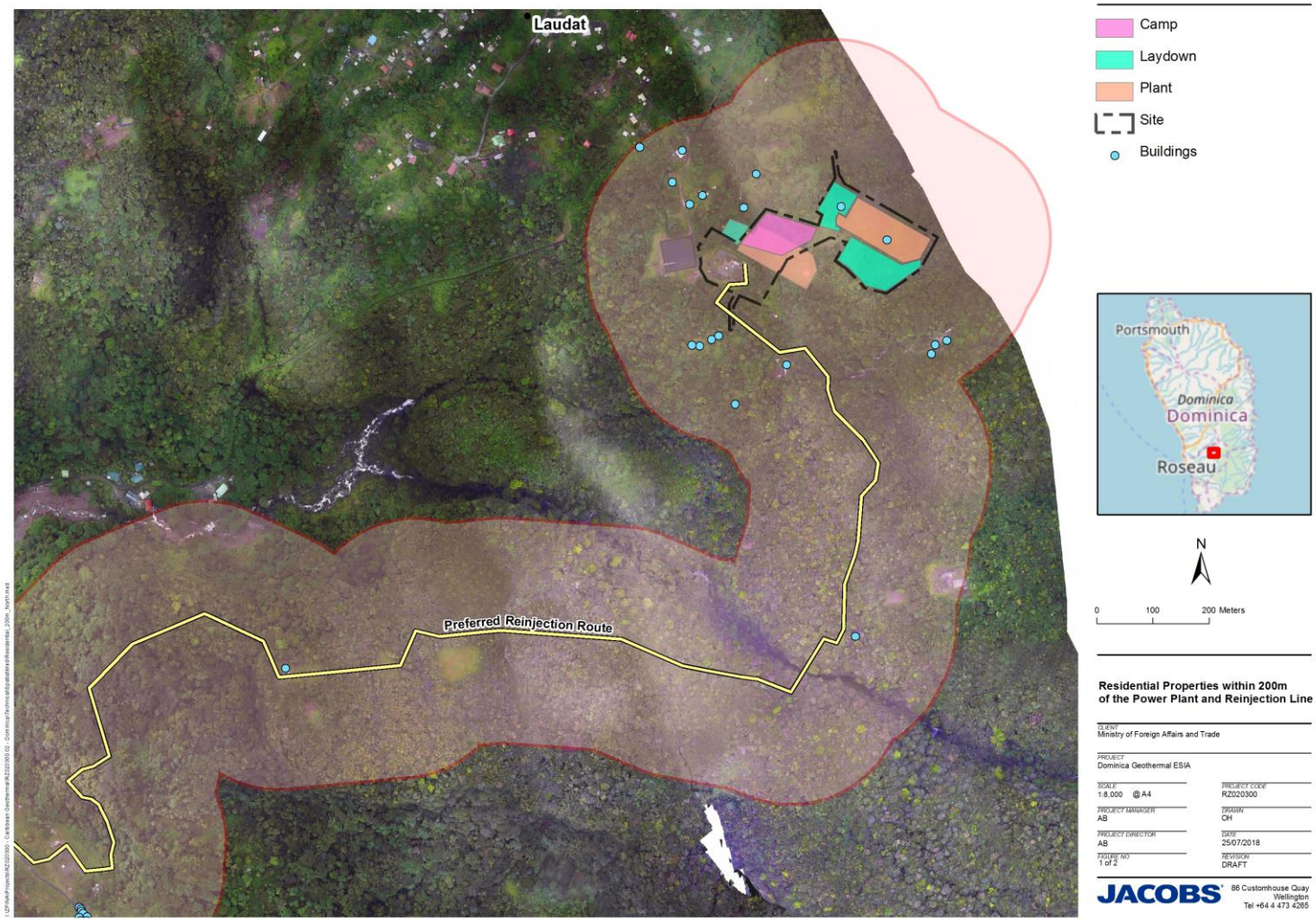


**Figure 4.10 : Buildings within 200 m of the power plant and reinjection pipeline (northern end)**




**Figure 4.11 : Buildings within 200 m of reinjection pipeline (southern end)**

## 4.5 Demographic Overview

According to the Population and Housing Census of 2011, Dominica's population was 71,293 (Commonwealth of Dominica Central Statistical Office, 2011). Between 1991 and 2001, the population of the main townships of Dominica declined, including within the capital Roseau. The population of Dominica shows little increase in general, due to the exodus of people to other countries such as the more prosperous West Indies islands, the United States, the United Kingdom and Canada.

According to the CIA World Factbook the population age stratification consists of the following (shown in Figure 4.11) (CIA World Factbook Website, 2018):

- 0-14 years: 21.72% (male 8,210/female 7,843);
- 15-24 years: 15.14% (male 5,758/female 5,428);
- 25-54 years: 42.2% (male 15,809/female 15,372);
- 55-64 years: 9.81% (male 3,860/female 3,387); and
- 65 years and over: 11.14% (male 3,679/female 4,551) (2017 est.)

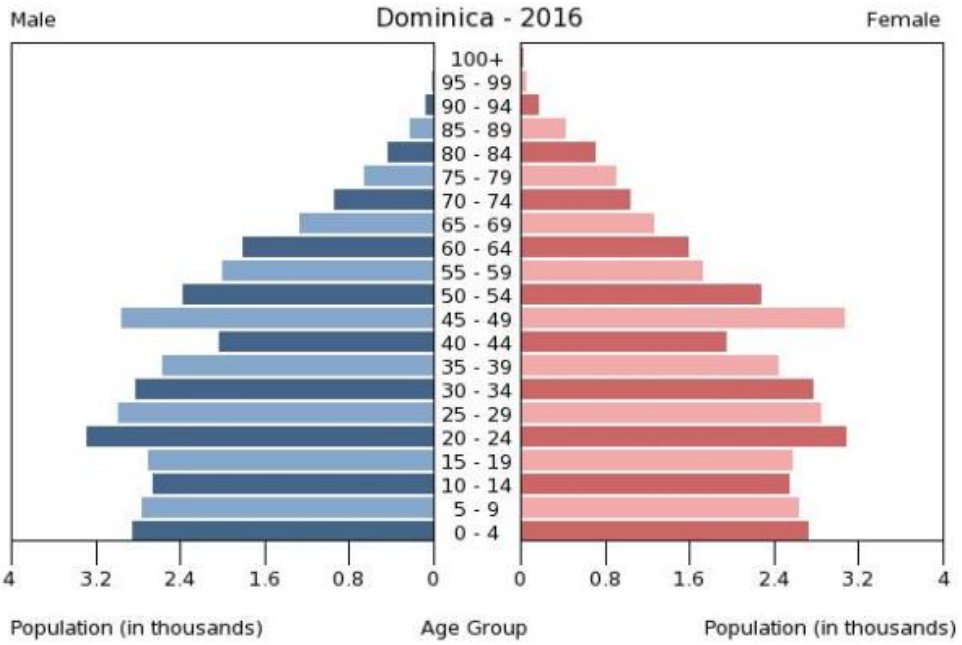


**Figure 4.12 : Age Breakdown in Dominica 2016 (Source: Central Intelligence Agency World Factbook Website (2018))**

Approximately 1,800 people live in the Roseau Valley, of which nearly 1,000 live in Trafalgar and Shawford, and the remaining in the hamlets of Wotten Waven/Casseau, Copthall, and Laudat. According to the 2011 census, the Roseau Valley gained 500 inhabitants between 2001 and 2011, i.e. a substantial increase of 32% (Commonwealth of Dominica Central Statistical Office, 2011). According to the Central Statistical Office, average household size in the Roseau Valley is 2.7. Post Hurricane-Maria, the demographics of the area have changed, as people move to the larger cities or outside of the country following the loss of their homes, infrastructure and employment. The demographics may have also altered where younger generations may have moved away from the smaller towns and the country to seek opportunities elsewhere. Post-Hurricane Maria, it is understood that many Dominicans have emigrated to other countries for work, thus splitting up families. This may make many households more susceptible to vulnerability in the future.

## 4.6 Religion

Religion is important aspect of life for many Dominicans: the majority consider themselves as Catholic (61.4%); 7-8% of the population practice other types of Christianity; 7% are not religious; 6% of the population are 7th day Adventists; 5% Pentecostal; 4% Baptist; 3% Methodist; and approximately 1-3% identify as Rastafarian, Church of God, or other religions. There are several churches in the Roseau Valley representing various religions. They are well-attended and play an important role in the island's social life.

## 4.7 Ethnicity and Language

The great majority of the population is of African descent. English is the official language and is understood by everyone, but due to historical French influence, a French-based Creole language is widely spoken. The island is also the home of the last remaining indigenous population of the West Indies – the Caribs – who number 3,000, but are located an estimated 15 km north-east (the Carib Territory) from the Project site.

Dominica is marked by the Creole culture: 80% of the population speak Creole despite English remaining the official language. The valley enjoys dual English and French-speaking heritage. The current villages correspond to small settlements started by the French colonists as per the December 2013 field surveys.

## 4.8 Gender

Dominica's population is 49% women and 51% male. Women represent 39% of head of households in Dominica. In addition to their role in household leadership, women continue logging an average of 16.14 hours per week in unpaid care work, which is more than half of the time spent by men (7 hours). Female unemployment is slightly higher than male unemployment, with 2,950 unemployed females to 2,774 males pre-Hurricane Maria. As of 2016, there were more men than women in the formal labour force, 70.6% male to 59.5% female. There is a gender division of labour in Dominica, with women overrepresented in the services sector (both government and commercial).

The breakdown of the population by gender in the Roseau Valley is similar to national averages (48% of females and 52% of males, compared to 49% and 51% respectively for Dominica as a whole). There are, nevertheless, a few differences in certain communities such as a slightly higher proportion of females in Copthall (52%) and fewer at Wotten Waven (44%).

Hurricane Maria has exacerbated the challenges the country faces in terms of gender equality. These challenges include, but are not limited to, access to resources for women farmers, access to health care for women and men, increasing levels of gender based violence (GBV) and economic empowerment for women, especially those in lower socio-economic sectors.

In addition, per the 2018 focus group discussions conducted for the Project post Hurricane Maria, women reported effects on farming, damages to houses and roofs; unemployment and loss of business, and general shock within the community. When asked about priority needs 'post-Maria'. the responses were related to:

- Rehabilitation of their houses;
- Restoring basic livelihood;
- Road repairs; and
- Counselling for people who are still traumatized.

## 4.9 Indigenous People

According to the WB Performance Standard 7, Indigenous Peoples are defined as social groups with identities that are distinct from mainstream groups. As such, they may be more vulnerable to the adverse impacts associated with project development and their needs must be carefully considered and protected accordingly.

There are no indigenous communities located in the geothermal Project area of influence, with the nearest community being an estimated 15 km north-east (the Carib Territory). Therefore, impacts upon indigenous communities are not considered relevant and have been screened out of the ESIA.

## 4.10 Ecosystem Services

Ecosystem services are defined by the WB/International Finance Corporation (IFC) (2012) as the benefits that people, including businesses, derive from ecosystems. They are organised into four types: (1) provisioning services (the products people obtain from ecosystems); (2) regulating services (the benefits people obtain from the regulation of ecosystem processes); (3) cultural services (the nonmaterial benefits people obtain from ecosystems); and (4) supporting services (the natural processes that maintain the other services). These would be relevant to the Project in terms ecotourism including thermal spas, medicinal plants, handicrafts, and water related resources in the Trafalgar and Wotten Waven areas. Access to ecosystem services may have been affected by Hurricane-Maria. Much of the area has been destroyed and lands which would have previously been accessible are now reportedly covered in fallen trees, shrubs and bushes, making access challenging.

## 4.11 Economic Profile

Gross Domestic Product (GDP) estimated in 2017 (pre-Hurricane Maria) was 851 million dollars according to the CIA World Factbook. The economy in Dominica used to be primarily driven by agriculture, but in recent years shifted towards tourism as the Government promoted Dominica as a tourist destination. The income of the residents of Trafalgar, Wotten Waven and Laudat was primarily derived from agriculture, which is comprised of family-based farming for both local consumption and commercial purposes, and tourism. In 2016, it was reported that most of the Roseau Valley residents have several jobs, including employment in the town of Roseau. A breakdown of historic occupations in the Roseau Valley is provided in Figure 4.13 below as recorded in the Caraïbes Environnement Développement & Coll, 2013 report. Figure 4.14 below also shows gender equality indicators for labour across the various sectors.

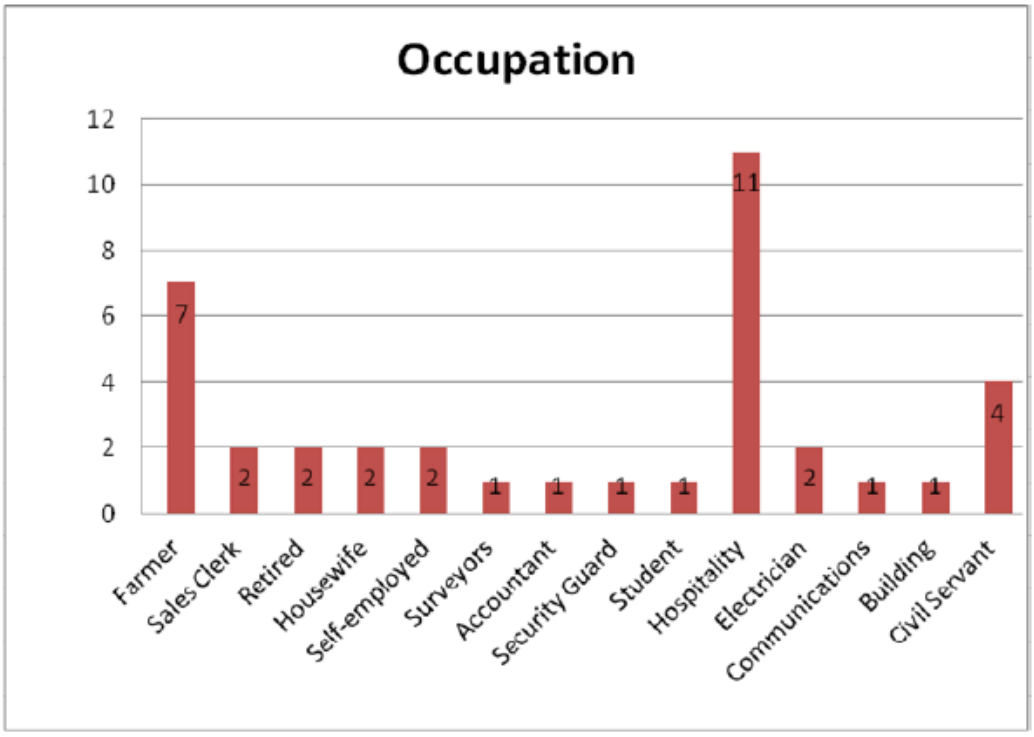

**Figure 4.13 : Valley Residents Occupations Caraïbes Environnement Développement & Coll (2013)**

There are more men than women in the formal labour force, 70.6% male to 59.5% female. As of 2010, the main sectors of the economy represented as a percentage of the GDP are as follows:

- Government services - 19.2%;
- Tourism - 18%;
- Agriculture - 17.4%;
- Commercial services - 38.9%; and
- Manufacturing - 3.79%.

There is a gender division of labour in Dominica, with women overrepresented in the services sector (both government and commercial). Women in the formal economy are primarily in government services 55.7%, commercial services sector 55.3% followed by the agricultural sector 20.1%. Men represent 79.9% of the formal agricultural sector, and manufacturing.

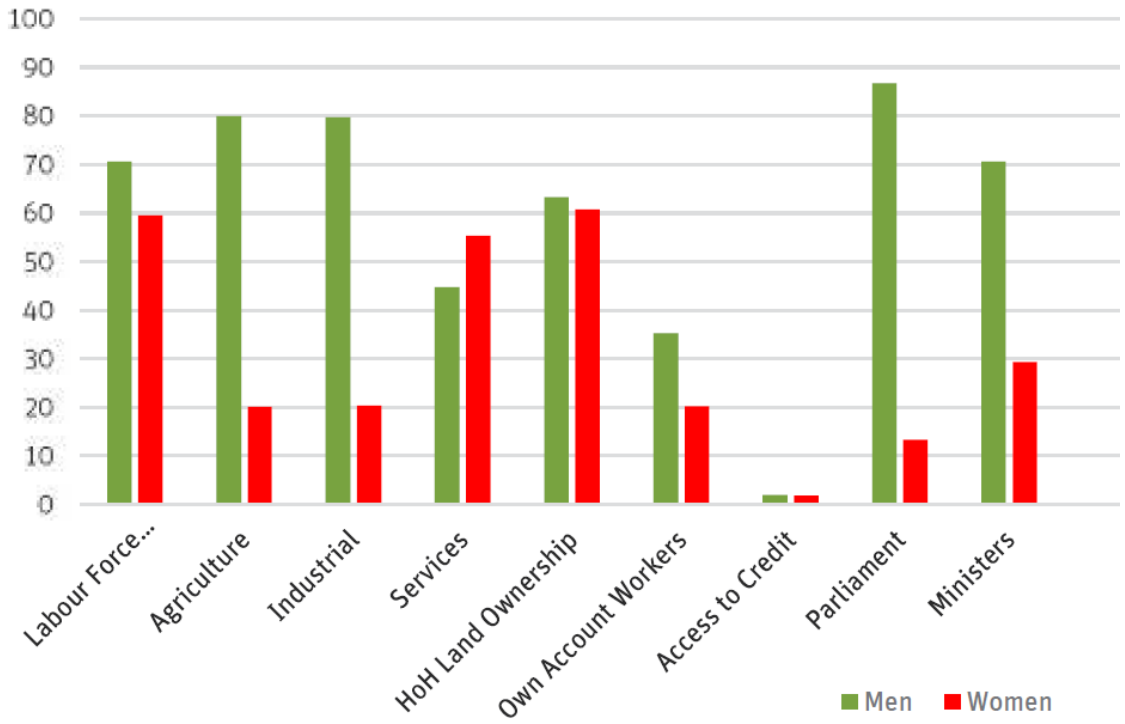


**Figure 4.14 : Key Baseline Data for the Sector, CARICOM Gender Equality Indicators: Dominica, WB PNDA**

Pre Hurricane-Maria, the villagers were trying to develop regional tourism involving exploration of the wildlife and geothermal resources. Several guest houses and self-catering holiday homes had opened in recent years. Tourist attractions were small in size and employed only a small number of persons. According to the Post-Maria disaster assessment conducted by the WB, 39 percent of hotel/guest rooms are considered severely damaged and will not be back in service at least for a year post the Hurricane. Hotel staff and support personnel have been directly impacted as they deal with the strain of unemployment and the concurrent need to rehabilitate their own properties.

In 2016 according to the CIA World Factbook, the average unemployment rate in Dominica was about 23%. Now post Hurricane-Maria the Post Disaster Report stated that a "significant" proportion of the labour force is unemployed. The report does not quantify what is considered "significant". However, it could be assumed that the unemployment rate post Hurricane Maria, is greater than 23% and the livelihoods of its population may have altered as a result.

### 4.11.1 Tourism

**Jobs and the Tourism Economy**

According to the Caribbean Development Bank revenues from tourism in Dominica reached US$49 million in 2006 (The Caribbean Development Bank, 2006). It is difficult to precisely estimate the tourism sector's share of the country's GDP, but it may be between 13 to 19% according to calculations (based on an interview with Discover Dominica Authority in December 2013). An estimated 600 – 1,800 jobs were directly related to tourism, i.e. 7% of the 24,000 jobs in Dominica. According to the Tourism Board, in 2008 approximately 590,000 people visited Dominica and the Roseau Valley on one-day organised tours. Total damage and losses to the tourism industry post-Maria are estimated at EC$ 245M (US$ 116.66 million). Damage to destinations, particularly parks and natural areas will significantly impact the recovery of the tourism sector.[1]

**Key Tourist Locations**

The Roseau Valley was a popular tourism site due to its proximity to the MTPNP: a UNESCO Natural World Heritage Site covering 17,000 hectares of National Park and its volcanic cirque. According to the Ministry of Tourism, tourism was the main source of income for around 60% of the population. In addition, many cruise ships that stopped for the day in the Port of Roseau allowed visitors to visit the Aerial Tram in the Roseau Valley.

The Roseau Valley also includes the Boiling Lake, Waitukubuli National Trail, Middleham Falls, Freshwater Lake and Boeri Lake, the "Dragon's Mouth" (an accessible cave with hot water) and Twin Falls and Middleham Falls in Trafalgar, Titou Gorge, the freshwater lakes, and the various hot springs in Wotten Waven and Papillote, the tropical gardens in the rainforest, and outdoor adventure activities among other attractions.

[1] WBG Post-Disaster Needs Assessment, Hurricane Maria, September 18, 2017 completed November 7, 2017.

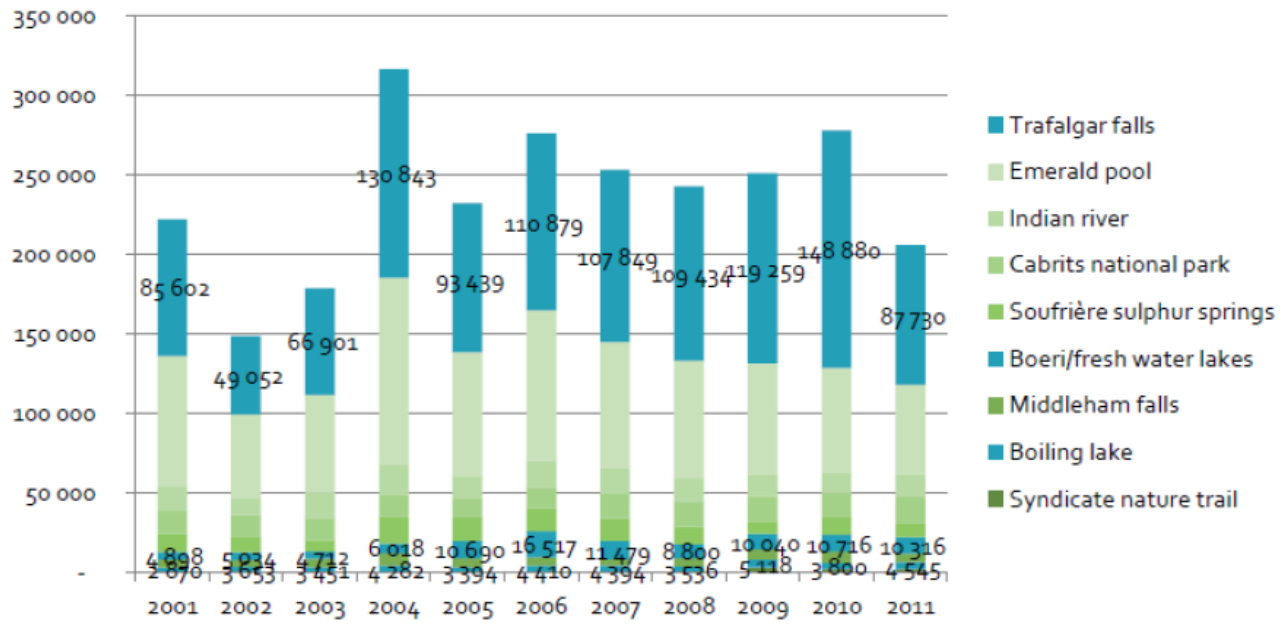


**Figure 4.15 : Visitor numbers at the main nature sites for tourism in Dominica between 2001 and 2011 - Roseau Valley sites in blue (Central Statistical Office, 2012)**

A summary of the key tourist locations in the Roseau Valley is provided below:

- Trafalgar Falls – A 20 minute drive from Roseau, these popular twin waterfalls are a 15 minute walk where tourists may swim in the warm water springs.
- Sulphur Springs – A 10 minute drive from Trafalgar Falls, sulphur pools and springs can be visited at Tia's Bamboo Cottages, Ti Kwen Cho and Shangri-La Resort, or the Screws Sulphur spa.
- Titou Gorge – A swim from the base of the waterfalls through a 'gorge' which was formed by high cliff walls canopied by interlaced trees.
- Fresh Water Lake – Only 2.5 miles from the village of Laudat high in the MTPNP, this lake is the source of the Roseau River; the freshwater lake is one of two of Dominica's lakes, situated in the area of Laudat. The freshwater lake can be accessed by foot or by guide.
- Waitukubuli National Trail - The Waitukubuli National Trail was officially declared as an eco-tourism site on May 10, 2013, in accordance with the Commonwealth of Dominica Statutory Rules and Orders No. 7 of 2013 National Parks and Protected Areas Regulations (Waitukubuli National Trail Website, 2017). See ESIA Volume 2: EIA for further details.

**Tourist Accommodation**

According to the Ministry of Tourism, the Valley includes 11 holiday residences (guest houses, cottages). These guest houses provide 94 bedrooms, plus an eventual 22 extra bedrooms, (i.e. 9-12% of bedroom accommodations on the island). Most of the tourism businesses in the Roseau Valley are small (less than 20 employees) and most had fewer than 10 full-time workers. Many of the accommodation businesses interviewed in the area (in 2016) reported having been in business for 20 years or more with hundreds to thousands of visitors per year. Roadside craft vendors reported making 300-500 per month during the high tourist season. Hurricane Maria has caused major impacts to the hotel industry in the Roseau Valley and rendered many of the spas and tourist businesses non-functional or inaccessible. The Post Disaster Report states that 395 of the hotel room stock in Dominica are considered severely damaged. It is considered likely that Hurricane-Maria has reduced or eliminated business in the guest houses in the Roseau Valley, if they are still operating.

### 4.11.2 Agriculture

Agriculture general accounts for about 20% of GDP in Dominica and employs about 40% of the labour force. As of late 2017 pre-Hurricane Maria, there were about 2,000 hectares (4,900 acres) of land being used as pasture land for animal husbandry, comprising 2.7% of the total land area. In addition to tourism, residents of the Roseau Valley were engaged in crop cultivation and agroforestry. Many properties in the study area included the growth of citrus, other fruits, vegetables, and some root crops for consumption and for sale.

Agriculture is the second highest income-earner for the Roseau Valley's residents after tourism. However, in 2017 farmers were increasingly turning towards tourism which was considered more profitable.

Some villages in the valley were involved in commercial farming in 2017:

- Morne Prosper: mainly vegetables (the land is relatively flat).
- Wotten Waven: more diverse production of flowers, subsistence farming, tubers.
- Trafalgar: smaller-scale production more geared to tourism as well as tubers. There were also 2 small poultry farms.
- Laudat: tuber production, vegetables and subsistence farming.

In 2016 it was reported that there was a reduction in agriculture in most villages, especially Laudat and Trafalgar due to growth in tourism. In 2016, in the Roseau Valley, those working in agriculture are mainly women (in vegetable farming in Morne Prosper and Wotten Waven). Most farms were small production units comprising short-term and small-scale operations (¼ - 1 acre, or 1,000 – 4,000 $m^2$). Few farmers had larger lots of land, i.e. in excess of 5 acres, or just over 20,000 $m^2$.

Hurricane Maria caused substantial damage to agriculture in Dominica, including loss and damages to animals, crops, buildings, infrastructure and equipment. Damage to forest resources was also reported, with further impacts to agriculture. The greatest losses were sustained in the agriculture sector (32 percent), followed by the tourism (19 percent) and transport sector (14 percent).[2] It is probable that income from agriculture in the Roseau Valley has been significantly impacted.

## 4.12 Educational Profile

National school enrolment rates were quite high in Dominica at 97.5% for 5-9 year olds and 98.3% for 10-14 year olds (The Caribbean Development Bank, 2010). According to the Ministry of Education, in 2014, 75 pupils from the Roseau Valley were attending primary school. Approximately 224 students from the Roseau Valley were in Secondary School in 2014. Every village in the Roseau Valley had its own primary school, but pupils must travel to Roseau once they reach secondary school age. This can represent a significant cost for parents, especially for transport. Impacts to social infrastructure such as schools post Hurricane-Maria includes damage to school buildings and infrastructure. Educational facilities on the island, including day-care centres, suffered varying degrees of damage as a result of the storm. Of a total of 163 facilities, 67 (41 percent) suffered major damage and will require reconstruction.

School enrolment pre-Hurricane Maria was slightly higher for males than females, according to the Education Digest from 2015/16 as shown in Figure 4.16 below.

[2] WBG Post-Disaster Needs Assessment, Hurricane Maria, September 18, 2017 completed November 7, 2017.

| Cycle | No. | Duration | Age | boys | Girls | total |
|---|---|---|---|---|---|---|
| Day care centers | 17 | 3 yrs. | 0-3 | 122 | 120 | 242 |
| ECD centres | 73 | 2 yrs. | 3-4+ | 728 | 714 | 1442 |
| Primary | 58 | 7 yrs. | 5-11 | 3,685 | 3,375 | 7,060 |
| Secondary | 15 | 5 yrs. | 12-16 | 2,568 | 2,505 | 5,073 |
| Tertiary | 1 | 2 yrs. | 17+ | | | 1,747 |
| TOTAL | | | | | | 15,564 |

**Figure 4.16 : Existing Educational Facilities and Enrolment in Dominica 2015/16**

## 4.13 Health Profile

According to 2017 data from the Ministry of Health, 5.5-6% of births in the country were born to residents of the Roseau Valley in 2015-2016. In 2016, 162 people were seen at the Roseau Valley health clinic for issues ranging from hypertension, diabetes, asthma and colds to heart disease and anaemia. Approximately 75% of these patients were women. The death rate in Dominica is relatively low, 8.1-9.5 per 1,000 live births between 2010 to 2015. Life expectancy is 77 years (81 for women and 74 for men). The infant mortality rate was 20.8 per 1,000 live births in 2015. There were relatively few deaths in the Roseau Valley in 2015, 19 in total. Chronic illnesses recorded in the valley in 2015 included cancer, pneumonia, pregnancy related illness, hypertension, heart disease, motor neuron disease, birth defect, and diseases of the urinary system. Incidences of each were between 1-2 people. Malaria is not typically present in Dominica, but Chikungunya and Dengue fever are health concerns. At least 30 cases of Zika virus were confirmed in Dominica in 2016. According to the CIA Factbook, in 2014, 5.5% of GDP was spent on health (Central Intelligence Agency World Factbook Website (2017).

There are three health centres in the valley one in each of the potentially affected communities (Trafalgar, Wotten Waven and Laudat). The Valley is also close to the capital of Roseau and its health facilities including the Princess Margaret Hospital, which is the country's top health care establishment. The hospital has 224 beds (including 56 in a psychiatric unit) and was recently expanded (Caraïbes Environnement Développement & Coll, May, 2015a/b).

Damage and losses to healthcare facilities post-Maria were estimated at EC$ 48.3M (US$ 17.85M). The Princess Margaret Hospital, Roseau, the only referral hospital in the health care system, sustained severe damage with 15 percent of its buildings totally destroyed leaving only 53 percent functional. Central medical stores lost the majority of medical supplies due to water damage but most medications were spared. Bed capacity was decreased by 95 beds.

## 4.14 Community Facilities and Utilities

### 4.14.1 Water

The drinking water system in Dominica is fairly comprehensive and generally covers the main inhabited areas. Potable water (for household, commercial and industrial use) and non-potable water (for agriculture, laundries, fishing industries, leisure activities, etc.) are provided by Dominica Water and Sewerage Company Limited (DOWASCO). To meet the demand for drinking water, DOWASCO extracts resources from 47 rivers, representing 10 million gallons per day (45,460 $m^3$/day). The Roseau River is one of the 10 largest rivers. Its annual average flow rate is 10 million gallons (45,460 $m^3$). The capacity of available drinking water is 4.3 million gallons per day (19,547 $m^3$) for Roseau and its environs. The rate of access to drinking water in Dominica was 97% per the CIA World Factbook (2006) (Central Intelligence Agency World Factbook Website (2017).

The 41 water supply areas on the Island were damaged by strong winds, flooding, landslides, falling trees and power outage, 16 were heavily damaged and 21 moderately damaged by Hurricane Maria. Production and distribution pipelines were damaged or washed away, intake systems were blocked with sand and debris, and storage tanks, pumps, physical structures and access roads were damaged. Estimated damage to water supply infrastructure post-Maria is EC$53.6 million (US$19.85M).

### 4.14.2 Waste

The Roseau Valley has no formal wastewater disposal system. Some, but not all homes have septic tanks. Nationally, a quarter of households used pit toilets in 2009. The Dominica Solid Waste Management Corporation (DSWMC), established on the 1 July 1997, deals with solid waste management facilities for storage, collection, treatment and disposal of solid waste

### 4.14.3 Electricity

All homes in the Roseau Valley have electricity through the Rural Electrification Programme, which has helped improve access for the whole country. Only a few isolated houses are not connected to the network. Electricity consumption in Dominica is generally low (100 kWh per customer/month) with a slight rise (1% per year). A pre-payment system has been introduced to ensure bills are paid and to enable the population to better manage their expenditure.

Post-Hurricane Maria, electricity service failed due to widespread damages to the transmission and distribution network. At least 75 percent of the network is down as of late 2017, although part may be recoverable, 80 to 90 percent of the transformers inspected are badly damaged and cannot be repaired. Damage to generation sites vary from moderate to severe. The Trafalgar hydro- generation plant experienced only minor damages to the building structure and Laudat is intact.

## 4.15 Quality of Life

According to the MIT Press article, by Daniel J. Slottje, entitled ‘Measuring the Quality of Life Across Countries,’ Dominica ranks 30th internationally among the 126 countries evaluated. This is relatively high, above countries like Italy, Spain and France. According to the 2015 social surveys, “The residents appreciate their valley, its calm, the fact that most people know each other and the luxuriant natural environment close to the town.” In addition, residents stated that “The standard of living in Roseau Valley is relatively higher than the rest of the country.” Post-Hurricane findings suggest as much as a 20-36 percent decline in the quality of life in some in villages throughout the island. Unless every effort is made to reduce the geographic inequalities during the recovery period, the rural to urban drift may hasten, and the strong tendency towards out migration may increase.

## 4.16 Vulnerability

In 2016 the social survey respondents, focus groups and wider community expressed that there were no specific vulnerable groups in the Roseau Valley. However, during the surveys disabled members of the community were observed including an amputee, blind, and deaf members of the community who were without support services. Disabled members of the community would be considered vulnerable. Elderly members of the community that could be isolated and widows would also be considered vulnerable. In addition, residents of the Roseau Valley that have been unemployed for a significant length of time (2 years or more) could also be considered vulnerable.

Post-Hurricane Maria, new vulnerable groups are emerging. Surveys in the Project affected communities suggest that 90% of the respondents have lost the roofs of their houses, and 95% of the respondents have lost

their livelihoods.[3] Among the non- salaried economically active population 3.1 million work days were lost post-Maria. The respective loss in work days and income resulting from the Hurricane, is likely to result in a 25 percent decline in consumption, which could translate into an increased poverty rate of 36.2% (from 28.9% as reported in 2009). This may, in turn, have the undesirable effect of increasing income inequality, which researchers argue could lead to an increase in violence and crime[3].Those community members previously considered vulnerable e.g. elderly or disabled, maybe have been adversely affected by the Hurricane and the damage it has caused, increasing their vulnerability. All of the parties directly affected by the Project were affected by the Hurricane.

[3] WBG Post-Disaster Needs Assessment, Hurricane Maria, September 18, 2017 completed November 7, 2017.

# 5. Stakeholder Engagement

## 5.1 Stakeholder Engagement Plan

Building on stakeholder engagement that has already been completed during the drilling phase, a process of identifying relevant stakeholders that may be directly or indirectly affected by the project was completed. A Stakeholder Engagement Plan (SEP) was prepared for the Project to guide engagement activities for the Project. The objectives of this SEP are to:

- Identify the local legal framework of consultation activities and disclosure requirements, particularly in respect of those public consultation activities that are directly required under the local permitting process;
- Identify potential stakeholders in the area of influence, as well as relevant interested parties such as government agencies and other key stakeholders. Vulnerable groups (elderly, disabled, unemployed) will are also identified as stakeholders
- Record all consultation activities, including those prior to the commencement of the ESIA process;
- Describe how concerns or grievances will be handled via a Grievance Mechanism;
- Provide an action plan for further consultation including at least two meetings bi-annually in each affected community during preparation, construction and operational phases of the Project, including details on appropriate formats for effective and culturally meaningful interaction with the community and relevant stakeholders; and
- Provide a disclosure plan, including the identification of any locations where relevant project documentation will be available locally and elsewhere as well as languages to be used.

The SEP will be revised and updated periodically including upon completion of the ESIA to assist with ongoing engagement throughout the Project. A copy of the SEP which includes the Grievance Mechanism is provided in Volume 5 – Technical Appendix L.

## 5.2 Public Engagement to Date

### 5.2.1 Public Meetings

During the geothermal drilling phase, eleven general public meetings were held in the potentially affected communities in November and December 2013 and January 2014. Five were held in Laudat, three in Trafalgar and three in Wotten-Waven. A visit to the current geothermal power plant in Guadeloupe was also conducted in 2012 with members of the community to experience first -hand the workings of an operational plant. Additionally, school visits were conducted in February and March 2012 from the Wotten Waven Primary School, Trafalgar Primary School, Morne Prosper Primary School, Laudat Primary School, and Laudat Primary School where students and staff toured the drilling sites. In addition to the recent public engagement, the Grievance Mechanism was socialised within the community during the 2017 social baseline survey process.



**Figure 5.1 : School Visit to Drilling Site**

During the current Project development phase, a town hall meeting was held in Trafalgar in December 2016 with approximately 40 in attendance to discuss the current project and ESIA. Another town hall meeting was held in Laudat in July 2017 with 43 in attendance. A third town hall meeting was held in Wotten Waven in August 2017. A final townhall meeting will be held to present the findings of the ESIA in May or June 2018. In order to facilitate further understanding of community needs and conditions, focus group meetings were held in 2016, 2017 and 2018 in Wotten Waven, Trafalgar and Laudat, described in further detail below. Because the total population of the Project AOI is relatively small (approximately 1,600), and given that the general public and many of the focus groups and landowners that would be affected by the Project are the same parties, the four formal public meetings and 15 informal forums held on the Project were considered representative of the community.

### 5.2.2 Focus Groups

A total of 15 focus group meetings were held as part of the ESIA baseline data collection. A meeting with six representative community leaders from all of the potentially affected communities was held in Trafalgar in November 2016 to discuss the Project and the most effective means of stakeholder engagement. Focus groups meetings were also held in June, July and August of 2017 including meetings with representatives of local hotels and resorts, handicraft vendors, hot springs businesses, and unemployed parties in the area. Groups consisted of 5-15 people and targeted questions were asked and recorded.

Five focus group meetings were held in the communities in March 2018 following Hurricane Maria. These included meetings with the community women in Laudat, Wotton Waven and Trafalgar, and vendor meetings in Wotton Waven and Trafalgar, to identify the impacts on the community of Hurricane Maria which hit Dominica in September 2017 and to understand how conditions in the Project area have changed since the ESIA baseline data was collected pre-Hurricane Maria. Table 5.1 sets out the range of comments and concerns raised during the ESIA Consultation Activities and where subsequent responses can be found in the ESIA is included below.

**Table 5.1 : Summary of Consultation Comments and where Further Information can be Found in the ESIA**

| Consultation | Comment Category | ESIA Reference | Response |
|---|---|---|---|
| Laudat Community at Laudat Primary School (29/06/2017)<br>Papillote Wilderness Retreat (30/06/2017)<br>Wotton Waven Spa Operators | Noise level of the project and effect on the community | ESIA Volume 2: EIA, Section 12 – Noise (Section 12.5 – Assessment of Impacts). | Operational noise will be within acceptable community noise standards. Noise from construction will be reduced to the extent feasible using best practice mitigation measures. |
| Laudat Community at Laudat Primary School (29/06/2017)<br>Papillote Wilderness Retreat (30/06/2017)<br>Wotton Waven Spa Operators | Community benefits | ESIA Volume 3: SIA, Employment and community benefits, Section 6.1.1 – Assessment of Impacts and Section 8.1.1 Employment and Tourism. | The GoCD is committed to providing a community benefits package for this Project. There are several ideas for community benefit/investment options detailed in the ESIA. |
| Papillote Wilderness Retreat (30/06/2017) | Will there be a social/community development fund | ESIA Volume 3: SIA Employment and community benefits, Section 6.1.1 – Assessment of Impacts and Section 8.1.1 Employment and Tourism. | The GoCD is committed to providing a community benefits package for this Project. There are several ideas for community benefit/investment options detailed in the ESIA. |
| Laudat Community at Laudat Primary School (29/06/2017) | Will the re-injection pipeline pass through villages? | ESIA Volume 3: SIA, Preferred route of re-injection pipeline, Figure 4.3 - Location of Power Plant and Reinjection Pipeline. | The re-injection route pipeline has been selected with the intent of avoiding settlements to the extent feasible. |
| Papillote Wilderness Retreat (30/06/2017) | What will be the visual impact of the project | ESIA Volume 2: EIA, Section 9 – Landscape and Visual (Section 9.3 – Assessment of Impacts). | The Project is expected to have minor visual impacts with the exception of those living immediate adjacent to the power plant. |
| Papillote Wilderness Retreat (30/06/2017) | What will the impact on tourism be? Concerns that it will have a negative impact | ESIA Volume 3: SIA, Tourism impacts: Section 6.2.5 Impacts to Tourism.<br>ESIA Volume 3: SIA, Tourism enhancement and mitigation, Section 8.1.1 Employment and Tourism. | Impacts are tourism including thermal spas, etc are considered to be minor. The thermal resource is not likely to be reduced as a result of the Project and the Project could become and educational tourist destination. |
| Papillote Wilderness Retreat (30/06/2017)<br>Wotton Waven Spa Operators | Traffic impacts on the community and local businesses | ESIA Volume 2: EIA, Traffic impacts, Section 16 – Traffic and Access (Section 16.3 Assessment of Impacts). | Traffic congestion could result during construction and will be mitigated to the extent feasible. Long-term traffic increases are considered minor. |
| Papillote Wilderness Retreat (30/06/2017)<br>Wotton Waven Spa Operators | Air quality impacts | ESIA Volume 2: EIA, Air Quality impacts, Section 4 – Air Quality (Section 4.3 Assessment of Impacts). | Air quality emissions will be within acceptable community standards. Dust from construction will be reduced to the extent feasible using best practice mitigation measures. |

| Consultation | Comment Category | ESIA Reference | Response |
|---|---|---|---|
| Papillote – Community Leaders of the Roseau Valley<br>Papillote Wilderness Retreat (30/06/2017)<br>Wotton Waven Spa Operators | Resettlement and land acquisition impacts and plans for the community and businesses | ESIA Volume 3: SIA, Resettlement mitigation plans, Section 8.1.2 Physical and Economic Displacement.<br>ESIA Volume 3: SIA, Land acquisition impacts, Section 6.2 Land Acquisition, Physical Displacement and Resettlement Impacts. | Impacted land owners will be properly consulted and compensated in accordance with International Standards. |
| Wotton Waven Spa Operators | What happen if the reinjection pipe has a leak and dangerous fluids are flowing on the surface? | ESIA Volume 2: EIA, Section 15, Hazardous Substances and Waste and ESIA Volume 3: SIA, Emergency Response Plan. | An Emergency Response and Disaster Management Plan will be developed and implemented for the Project in line with best practice. |
| Laudat Community at Laudat Primary School (29/06/2017) | When and how will payment be made for property and land acquisitions? | See the ARAP. | Impacted land owners will be properly consulted and compensated by the GoCD in accordance with International Standards prior to the commencement of any construction activity. |
| Laudat Community at Laudat Primary School (29/06/2017)<br>Papillote Wilderness Retreat (30/06/2017) | Potential for community shares in the Project | Outside of the scope of ESIA. | This is outside of the scope of ESIA. |
| Papillote Wilderness Retreat (30/06/2017) | Why was solar power not considered? | ESIA Volume 2: Introduction, Section 4, Project Alternatives. | This Project evolved on the basis of the geothermal resource. |
| Papillote Wilderness Retreat (30/06/2017) | Why was this type of consultation not done before decision was made to drill? | See SEP for a full list of consultation activities in Appendix C of the ESIA. | Consultation has been conducted throughout the development of the Project. |
| Papillote Wilderness Retreat (30/06/2017) | Total cost of the Project | Outside of the scope of ESIA. | This is outside of the scope of ESIA. |
| Wotton Waven Spa Operators | Project start date and duration | ESIA Volume 2: Introduction, Section 3, Project Description. | Construction date estimated to be first quarter 2019. Estimated 18 -24 months for construction of Project. |

### 5.2.3 Socioeconomic Data

Baseline information was also collected by Caraïbes Environnement Développement & Coll in 2015 including data collected via some desktop study and approximately 30 interviews with local stakeholders. In addition, targeted surveys were conducted in July and August 2017 with specialised groups such as land owners in the site vicinity and representatives of tourism industry that could be affected. A total of 30 additional surveys were conducted and findings are incorporated in the SIA (September 2017). This data included socioeconomic data from the directly affected communities, data from tourism providers, small businesses and potentially vulnerable members of the community. However, there were some limitations to this data, including reluctance on the part of participants to answer questions about income. In addition, some of the surveys were supplemented by

observation (e.g. community described that no vulnerable groups were present and some were observed). Further socio-economic surveys have been completed post Hurricane-Maria in March 2018. From the data collected, it is apparent that there may be more social concerns as the island now has a more fragile economy. However, as with the 2017 surveys there was reluctance from participants to answer questions about income.

## 5.3 Community Perceptions of Project

Public perceptions of the Project were varied throughout the stakeholder engagement process. Everyone that was spoken to was familiar with the Project and many had been involved in Project related meetings for many years. The 2015 data showed the community had a number of concerns about the Project, but in 2017 most community members expressed support for the Project (approximately 80%). Concerns expressed in 2017 included:

- Health concerns about the steam and air quality emissions associated with the plant;
- Concerns about odours and impacts on the economy from the Project, particularly the tourism industry;
- Noise concerns; and
- Concerns about proper compensation for land to be acquired.

Post-hurricane Maria, concerns now include:

- Natural disasters;
- Improvement of infrastructure;
- Livelihood and tourism impacts;
- Emergency response planning; and
- Cultural impacts from influx of workers during construction.

At public meetings, many questions also arose about public shares in the Project Company (DGDC) and the likelihood of adverse effects on the geothermal resource impacting on tourist businesses. Local residents also expressed concerns about plant emergencies and interface with storms and natural disasters. The ESIA process was explained and the methodology to be undertaken for analysis of relevant topics and plans and expectations for the company were also addressed. A Project Grievance Mechanism has also been disclosed to the local community and several complaints have been recorded and addressed to date (the Grievance Mechanism can be found in Stakeholder Engagement Plan ESIA Volume 5: Technical Appendix L). Details of consultation events with the communities and feedback from these meetings is presented in Appendix C, of the Stakeholder Engagement Plan.

### 5.3.1 ESIA Disclosure

The ESIA Non-Technical Summary was disclosed to the communities of the Roseau Valley via three public meetings: one in Laudat, one in Trafalgar, and one in Wotten Waven in the first week of July. Meetings were attended by Jacobs, DGDC, and approximately 20 members of each community. The community had another opportunity to express concerns and ask questions about the Project and ESIA findings. Concerns generally included community health and safety issues, natural hazards, employment and construction impacts. A summary of the issues raised by each community is provided below.

#### 5.3.1.1 Laudat

In Laudat, a community meeting was held on Tuesday 4th July 2018. Concerns expressed by the community included technical questions about the pipeline and public health considerations associated with operations of the plant. Community members also voiced concerns about the risks associated with volcanic activity near the project, equipment failure, and other natural disasters. Community members also expressed the desire to see policy changes associated with the Project and the need for some community benefit projects that would be

realised in the community. They also asked about land acquisition and noted that Laudat has been the location for several other projects where few benefits were realised in the local community. The DGDC Team explained the costs and the benefits of the project and the ESIA findings in terms of H2S. DGDC also explained the technology being utilised in the plant and the low risks associated with this type of equipment. The DGDC Team further explained the risks and the planning and design measures that were selected for this project given the topography, risk of landslides and recent flooding from Hurricane Maria and the EPC Contractor requirements that will be put in place to reduce nuisance and community health and safety impacts such as the emergency response and other planning procedures. The current status of land acquisition was also explained and the need to complete compensation before construction can begin, as per OP 4.12. Ongoing monitoring and preventative measures such as the traffic management plan and erosion control measures were also explained. Comments on policy and community benefits were noted, but it was explained that this is ultimately under the control of government and policymakers, rather than the project.

#### 5.3.1.2 Trafalgar

In Trafalgar, a community meeting was held on Wednesday 5th July 2018. Fewer comments were made at this meeting than in Laudat or Wotten Waven, likely because the community is further from the power plant site. The community asked a few technical questions about the distance of the pipeline and natural hazards that could affect the project. They also asked about the proximity to the nearby communities from the power plant and emergency response. The DGDC Team explained the risks and the planning and design measures that were selected given the topography, risk of landslides and recent flooding from Hurricane Maria. DGDC also explained the emergency response and planning procedures that will be put in place for the Project. Examples of other projects where a geothermal plant was located in close proximity to the community were given.

#### 5.3.1.3 Wotten Waven

In Wotten Waven, a community meeting was held on Thursday 6th July 2018. A lot of concern was expressed at the meeting particularly about public health issues, employment, and direct benefits to the community. Specifically, people asked about job requirements, accidents at the plant and/or the pipeline, detrimental effects on thermal spas, the expected lifespan of a well, consumer benefits on electricity bills, health impacts of construction and noise, and property acquisition. A community member also suggested the need for a weekly briefing in the community during the construction phase. The DGDC Team explained the design of the plant and reinjection route given the topography, risk of landslides and recent flooding from Hurricane Maria and to reduce noise and visual affects at properties near the power plant. DGDC also explained the technology being utilised in the plant and the low risks associated with this type of equipment. The lack of changes anticipated for the thermal surface features were also explained given the depth of the wells and associated activity and the plan to conduct ongoing monitoring of these features was also shared. The DGDC Team further explained in detail the noise associated with the steam blowing phase and the limited timeframe for this testing. The current status of land acquisition was also explained and the need to complete compensation before construction as per OP 4.12.

Following the disclosure of the NTS, the full ESIA will be made available to the community in August 2018 via the internet, a hard copy will be available at DGDC's offices, and additional public meetings will be held and publicised by the DGDC.

# 6. Social Impact Assessment

## 6.1 Employment

### 6.1.1 Assessment of Impacts

Employment impacts arising from the construction and operations phases of the Project would include:

- Generation of direct employment by the Project; and
- Economic development created as a result of indirect employment by suppliers of goods and services to the Project.

Direct employment created during construction is considered a beneficial impact of the Project. Employment estimates provided by Jacobs Project Engineer in July 2017 consist of the following:

- During operation it is anticipated that there will be approximately 12 permanent employees.
- At the height of construction, approximately 50-60 employees would be employed on-site, which would result in beneficial employment and indirect employment impacts for suppliers including goods and services providers for the project such as food vendors and building materials companies. The construction period will last approximately two years, commencing in 2018.

It is likely that 30 to 40 workers will be the power plant site at the peak of construction and a team of 10 to 15 working on the pipeline. These workers are likely to be sourced from outside of Dominica, depending on the selection of the final EPC Contractor. This total could be slightly larger at times if more locals are required to support with construction equipment in difficult locations. As described above, a worker's camp is also proposed on site that would house up to 50 workers throughout the construction phase.

The majority of employment during construction is likely to be short-term and significant employment opportunities for local communities would be limited. The unskilled and semi-skilled workforce is anticipated to generally come from the local area, but accommodation in the form of a worker's camp will be developed on the site to house mainly expat and out of town workers for the duration of construction to minimise traffic trips to the site from Roseau. There is the potential for women to be disproportionately affected as many of the construction jobs will be geared towards men.

**Direct Employment**

The Project will have a **Moderate Beneficial** impact on employment during construction, both in the Project AoI and in the wider Roseau Valley. The level and range of skills and applicable working experience available in the adjacent communities may be limited by education and relevant skills training. As a result, the ability to acquire a position, and successful performance once hired, will favour experienced (skilled) personnel for professional roles, the majority of whom would likely come from abroad. Therefore, operational employment opportunities are likely to be sourced from outside the local community. As the Project moves towards decommissioning and closure, there will be a subsequent decrease in the workforce requirements.

**Indirect Employment**

Plant staff and contractors will require various vendors, suppliers and service providers to meet the daily operating needs of the Project, needs of the worker's camp, and the domestic needs of its employees. This could include goods and services include food vendors, laundry, supply of vehicles and transportation services, security patrols, as well as some construction equipment.

In addition, the Project will induce secondary/tertiary economic activity due to presence of construction workers, construction worker's camp, and a few operational staff that will require some housing during operations, food,

and other types of resources and services. There will be opportunities for utilising local goods and services for the Project and related activities.

Typically, 3.2-3.5 jobs in service and supply sectors are created for each direct job generated by oil and gas projects (NPC, 2011). Assuming that oil and gas job generation is expected to be slightly higher than geothermal development, the Project may result in approximately 20-30 additional jobs. At the local and regional levels, this is likely to stimulate some minor growth for local agricultural producers, as well as induce growth in other industries such as retail, hospitality, transportation, etc. The additional jobs created indirectly would be considered a **Minor Beneficial** impact.

Post Hurricane-Maria the Project would benefit by providing support in re-development of essential infrastructure as well as the provision of new jobs for local residents, indirect economic development impacts, collaboration and public involvement opportunities such as trips to other power facilities, and potential opportunities for education and industry diversification. Women, in particular, tend to work as vendors in the tourism industry and would benefit from opportunities that bring more potential clients into the community. Per the focus groups conducted with the local communities in March 2018, some women saw the Project as a potential tourism attraction through which they envisaged increased tourist arrivals and increased business generated from tourism including vending food and beverages. In addition, the Project proposes to implement community development initiatives through a Community Development Fund. During the community engagement program conducted in 2017 for this ESIA, the following initiatives were proposed for development:

- Educational fund;
- Basketball court in Wotten Waven;
- Healthcare fund and database;
- Local park in the Trafalgar area;
- Visitor centre at power plant site;
- Recording studio; and
- A flower cutting and export business.

Post-Maria community initiatives suggested have a slightly different focus:

- Infrastructure improvements including roads and bridges;
- More extensive community wide disaster and emergency planning;
- The establishment of a skills development fund for the community with a particular focus on young people;
- Scholarships for children in the affected communities for study in related fields;
- A community centre.

Although details of total funding, projects, and timeframe for fund allocation have not been finalised, the GoCD has committed to funding some community development initiatives along with development of the power plant. As a result, all impacts associated with employment and subsequent community development would be anticipated to be beneficial to the community.

**Conclusions**

Employment impacts are anticipated to result in approximately 40 jobs (direct and indirect) during operations and approximately 60-80 during construction. Given that two of the local communities are made up of approximately 300 people, this would be considered a **Moderate Beneficial** impacts in the Project AoI and in the wider Roseau Valley. Opportunities could be enhanced via training and local job readiness programmes. In the long-term, direct employment impacts are expected to decrease as opportunities focus more around a few skilled positions which are likely to come from outside the community. However, some **Minor Beneficial**

indirect impacts from employment would still be anticipated from suppliers and other businesses in the community. Enhancement measures for employment are detailed below.

## 6.2 Land Acquisition, Physical Displacement, and Resettlement Impacts

### 6.2.1 Land Acquisition

**Power Plant**

Construction and operation of the plant will require the acquisition of land for the power plant itsouelf and for associated infrastructure.

- For construction of the power plant, approximately seven properties are planned to be acquired (two within the proposed Project footprint and five that would be substantially impacted by noise, visual, and construction impacts). All of these properties are currently privately owned and include structures, two of which have been identified as residences, one as a possible residence (currently a goat shelter) and one a rabbit hutch. Some small scale farm activities of animal husbandry and cultivation of fruit trees and other crops is presently occurring on at least five of the proposed sites.

**Reinjection Pipeline Route**

Construction of the reinjection pipeline route corridor would consist of an approximately 10 m wide corridor. Future land requirements include:

- The re-injection route would involve acquisition of some portion of six properties. Most of these affected properties would consist of small portions of parcels, and would not impact on any structures. One tenant farmer would be affected by the development of the pipeline.

### 6.2.2 Efforts to Avoid or Minimise Displacement - Alternative Sites and Reinjection Pipeline Route

Several power plant sites and reinjection pipeline route options were considered as part of the Project (refer to ESIA Volume 1: Introduction). Multiple sites were considered for the power plant once the geothermal resource was identified. The site was gradually moved south-east to create distance from the concentrated local population and reduce noise impacts. In terms of the reinjection pipeline route, four options were considered. One proposed route through Laudat was ultimately rejected to avoid displacement/disruption and another route was rejected as it was scheduled to rely on DOMLEC infrastructure, which presented coordination challenges for the Project. The third option was rejected because it was considered technically too difficult due to topography e.g. steep ravines. Ultimately, the power plant site location and preferred reinjection pipeline route were chosen to avoid disruption to the community and in consideration of economic and technical constraints.

### 6.2.3 Physical Displacement and Resettlement Impacts

For construction of the power plant and re-injection route pipeline, approximately 13 properties would need to be acquired including some structures, in consisting of 2-3 residences. Some farming is presently occurring at six of the proposed sites.

Of the potential 13 properties to be acquired, physical displacement of structures in approximately three affected properties are predicted to occur as a result of the Project, which will be permanent and considered to be of **Minor** significance. Impacts of this nature can result in poverty and / or dislocation of communities and the severance of extended support networks. Post-Hurricane Maria, impacts to any vulnerable parties may be even more severe. If not mitigated appropriately and early, resettlement impacts can cause great controversy and result in significant public objections, time delays and considerable cost overruns for the Project.

As part of due diligence for legacy Project activities to ensure that resettlement and land acquisition impacts from the drilling phase have been addressed in line with WB requirements for involuntary resettlement, a Land

Acquisition Review and Action Plan was conducted in 2017 including an Action Plan to address any gaps between WB and national standards for land acquisition and resettlement. For proposed land acquisitions and resettlement associated with the Project, an Abbreviated Resettlement Action Plan (ARAP) is being developed in consultation with affected parties. The ARAP will provide resettlement sites where appropriate and / or cash compensation and livelihood restoration measures including consideration of those considered to be severely affected and or vulnerable.

In the long-term, impacts are expected to decrease further as affected people realise some of the benefits of compensation and livelihood restoration initiatives, and as the other mitigation and monitoring measures are implemented along with community development initiatives.

### 6.2.4 Economic Displacement and Livelihood Impacts

Along with experiencing physical displacement, six of the parties affected by resettlement for the proposed power plant site and the reinjection pipeline route will experience economic displacement effects as many of the affected properties include agricultural crops, livestock, and trees. In particular, surveys show that some potentially affected parties for the power plant site are presently growing citrus, raising sheep or rabbits, and cultivating medicinal plants on their property. On the proposed power plant site, two farming structures have been identified that would likely be displaced as a result of the project. In addition to these directly affected structures there are six properties that contain crops, fruit trees or livestock.

The Project would also potentially impact ecosystem services in the Project area. The key ecosystem services which have the potential to be significantly affected by the Project are the ecotourism resources including thermal spas, medicinal plants, handicrafts, and water related resources. The Project could potentially have a negative impact on water resources in the area, which would in turn affect ecosystem services. Post-Hurricane Maria, impacts to any vulnerable parties may be even more severe.

Many of the concerns raised in stakeholder engagement activities were about perceived loss of habitat or impact on water resources rather than physical effects anticipated by the Project. According to ESIA Volume 2: EIA, Terrestrial Ecology (Section 13) with regards to residual impacts for terrestrial habitats that may provide ecosystem services there will be limited impacts from the Project in the Roseau Valley. According to the hydrology section of the ESIA, the most likely impact would be the permanent removal of the forest trees where the pipeline will be laid, which reduces canopy storage and interception, and could lead to a small amount of increased surface water runoff**.** The additional livelihood impacts that could result from impacts to agriculture and livestock as well as ecosystem services would be considered **Minor** significance prior to mitigation.

### 6.2.5 Impacts to Tourism

Project impacts to tourism could result from:

- Roadway access restrictions during construction restricting access for visitors in the Valley;
- Potentially adverse effects to the World Heritage site or geothermal features in the Roseau Valley; and
- Any potentially beneficial impacts to local tourism businesses due to increased activity during construction and operations in the AoI.

As discussed in the traffic section of ESIA Volume 2: EIA, Section 16, minor access restrictions are anticipated during construction, which would last up to two years. However, because of hurricane damage to the roadway and many of the spas and hotels, business and access to these communities has already been significantly reduced and very few tourism businesses in Wotten Waven and Trafalgar are still operating. Although these impacts would be short-term, it could result in a minor reduction in local tourism business. In addition, tourism businesses such as local hotels, restaurants, and vendors would be expected to experience a minor increase in local business due to the presence of construction and operational employees in the Valley.

The proposed Project is located approximately 500 m from the World Heritage site boundary and no air quality or noise impacts are expected to occur in the World Heritage site as a result of the Project (see ESIA Volume 2: EIA, Sections 4 and 12 on Air Quality and Noise). As outlined in Section 14 of the ESIA, no changes to the protection and management of the of the World Heritage site are part of the Project proposals, thus no adverse impacts on the Outstanding Universal Value of the World Heritage site are anticipated. In addition, as outlined in ESIA Volume 2: EIA Section 10 of the ESIA, Project impacts on geothermal resource such as hot springs could potentially result in an increase or a decrease in flow. However, given the small size of the power plant relative to the modelled size of the resource (the proposed Project is currently designed to a 7 MWe capacity which is approximately 10% of the total reservoir capacity) and the siting of injection close to the injection sector impacts to the local geothermal resource are anticipated to be **Minor or Negligible**. Post-Hurricane Maria as severe damage has occurred involving many of the islands eco-tourism and natural resources, impacts would be considered to be even fewer.

Women, in particular, tend to work as vendors in the tourism industry and may be disproportionately impacted by any effects on the tourist industry that would result from the Project. As such, it will be particularly important that any proposed mitigation measures specifically consider additional opportunities for women.

As a result of all of the above both adverse and beneficial impacts to tourism combined, a **Minor** impact on tourism businesses in the community would still be anticipated. Mitigation measures for employment and tourism are detailed in Section 7.

## 6.3 Community Health, Safety and Security Impacts

### 6.3.1 Assessment of Impacts

Health and safety impacts arising from the construction, operations and decommissioning of the Project are likely to include the following:

- Increased risk of traffic hazards and incidents associated with the construction routes (see Section 6.25 above);
- Exposure to hydrogen sulphide gas, leakage, and well blow outs;
- Major accidents associated with the storage, use of working fluid (typically n-pentane) for Binary Plant;
- Exposure to Project-related hazards associated with construction and operational activities;
- Site security issues including public access to the power plant, the reinjection route pipeline and potential traffic accidents with the pipeline;
- Increase in communicable diseases and social conflicts;
- Community health impacts related to dust emission during construction that will exacerbate existing or cause new conditions (e.g. respiratory, eye, skin diseases); and
- Health and safety risks associated with ponds, confined spaces and risk of fire.

Emergency response for potential accidents will also be an important consideration. Accidental gas leakages and explosions though extremely rare occurrences, could lead to fire outbreaks which may result in the loss of human lives, loss of wildlife, damaged properties and other serious health implications. Accidental release of fumes and other toxic emissions emanating from the power generation process implicate respiratory infections to workers as well as residents around the Project site. In the event of any explosions or leakages, local livelihoods could also be affected.

Dust and noise related nuisance impacts from construction are anticipated to be **Minor** and **Negligible** respectively and short-term. $H_2S$ concentrations during operations are predicted to be well below World Health Organisation (WHO) thresholds of observed adverse effect levels. Overall health impacts of the Project are

therefore considered to be **Negligible** and the life expectancy of 77 years in Dominica is not anticipated to change as a result of the proposed Project.

The Project is anticipated to include influx of 50-60 workers during construction and 12 permanent employees during operations, which can involve exposure to communicable diseases and potential community conflicts. Construction workers anticipated to predominantly be sourced from outside of Dominica and therefore mitigation measures will be implemented to ensure that health, safety, and security risks from Project workers remain low (refer to Section 8.3.1 below).

Community safety impacts from increased roads and traffic and associated safety risks would be considered to have a potential impact of **Moderate** significance. However, impacts would likely be short-term and localised and risks would be highest during the peak construction period. Children and other vulnerable people and livestock may be more susceptible to traffic risks as elderly, children, and those with existing health problems would likely be most susceptible to the community health risks.

## 6.4 Cumulative Impacts Assessment

There are not many major developments of this type in the area and impacts of the Project are anticipated to be fairly unique to the development itself. Although there are other power sources on the island, the Project area is largely isolated and development of a 7 MW power plant is not anticipated to result in significant cumulative social impacts.

However, given the relatively pristine nature of the Roseau Valley, the importance of ongoing proper stakeholder engagement and understanding of community concerns, and the provision of (where possible and appropriate) training and employment opportunities to community members becomes even more paramount.

The mitigation and enhancement measures proposed below would ensure that long-term impacts would be at worst, of **Minor** adverse significance. However, careful monitoring of these measures and their effectiveness will be crucial to ensure that cumulative impacts remain **Minor** adverse or less. See Section 8 for mitigation measures.

# 7. Cultural Heritage

## 7.1 Introduction

Assessment of Project's impacts on cultural heritage identifies the following aspects for consideration:

- Above ground sensitive features;
- Potential for survival of archeologically artefacts;
- National or international designated features of cultural significance; and
- Intangible cultural heritage resources.

The method of assessing impacts is as described above in Section 3.

## 7.2 Baseline

Current baseline information collected by Caraïbes Environnement Développement & Coll in 2015 identified some culturally significant aspects in the Roseau Valley, including those related to agricultural heritage and architectural heritage. The complex and ancient history of human occupation of the island has led to numerous influences on current and past architecture in the Roseau Valley. One example from Wotten Waven includes a water mill dating from the 18th century. However, it is generally considered that the Roseau Valley has few examples of extant historical heritage.

Despite the rich and complex history of the island, with its multitude of anthropogenic influences long before the arrival of Europeans in the 15th century, few physical traces are still present. To date, there are no known significant archaeological sites in the Roseau Valley (Caraïbes Environnement Développement & Coll in 2015).

During consultation meetings with community members and stakeholders, no issues of cultural heritage concern were raised.

## 7.3 Impact Assessment

**Negligible** potential impacts are anticipated on physical cultural heritage as all known cultural artefacts are located away from the Project boundaries. It is also very unlikely that any cultural artefact will be found during earthworks activities. However, a Chance Find Procedure will be implemented by the Engineer, Procure and Construct (EPC) Contractor and all its sub-contractors to address the risk of finding cultural heritage artefacts.

## 7.4 Chance Find Procedure

'Chance finds' are defined as physical cultural resources encountered unexpectedly during project implementation. 'Physical cultural resources' (PCR) are defined as movable or immovable objects, sites, structures, groups of structures, and natural features and landscapes that have archaeological, paleontological, historical, architectural, religious, aesthetic, or other cultural significance. Their cultural interest may be at the local, municipal, department or international level. The requirements for the chance finds will follow the recommendations of the WB PS8, which defines Chance Finds as, *"Tangible cultural heritage encountered unexpectedly during project construction or operation"*. Neither the DGDC nor the EPC will disturb any chance finds further until a competent specialist appointed by either the Ministry of Youth, Sports, Culture and Constituency Empowerment, or the Dominica Museum has assessed the situation and actions identified the appropriate measures to be taken. The DGDC will liaise closely with the GoCD and the EPC to ensure that the assessment and recommended actions are carried out in a manner that will not be prejudicial to the planned works.

Upon discovery of a physical artefact work will be stopped, the site will be fenced and procedures for reporting will commence. Following internal reporting, the first external notification will be to the GoCD Ministry of Youth, Sports, Culture and Constituency Empowerment, followed by the Dominica Museum in Roseau.

# 8. Mitigation, Enhancement Measures and Residual Impacts

## 8.1 Mitigation and Enhancement Measures

### 8.1.1 General

The EPC Contractor and all Subcontractors will respect and apply industrial good practices as highlighted in WBG EHS Guidelines. This includes among others: no operation during night time near inhabited settlements, implementation of noise and dust control measures, low speed limits for the Project's vehicles in inhabited areas. DGDC will ensure that this is being completed through regular site visits and auditing of reports.

### 8.1.2 Grievance

DGDC will implement regular consultations with PAPs, their grievances will be lodged, treated and addressed. The GoCD will be responsible for grievances related to land acquisition in accordance with the Stakeholder Engagement Plan (SEP). The Grievance Mechanism defined in the SEP will be disclosed by DGDC to the neighbouring communities and implemented, and grievances registered and addressed on a case by case basis. Note: The Grievance Mechanism was disclosed to Laudat, Trafalgar and Wotten Waven communities in July 2017. It will be disclosed again to these communities at least six months before the start of construction.

### 8.1.3 Employment and Tourism

It is important that the employment process is well managed and that the local community is able to actively participate to the extent feasible. Impacts to local businesses would also require rapid action to be properly addressed. The following measures will contribute to this:

- Ensure a transparent hiring process is conducted help the community to understand strategic staffing decisions for the Project.
- Develop a Workforce Development Strategy – a commitment to maximise employment and skills opportunities for local people.
- Develop a training and skills programme to impart best practice in the skilling of local people for construction jobs.
- Encourage contractors to provide apprenticeship opportunities to local people and encourage supply chain partners to recruit local people.
- Establish a local job readiness programme and encourage the construction supply chain to continue to invest in workers.
- Focus a portion of community development investment on girls' and women's education and health;
- Ensure that women working in the tourism industry have access to capital and to the formal sector employment it creates via the development of microfinance/microcredit groups in the affected community;
- Establish a local employment brokerage that will publicise job vacancies and put in place initiatives to ensure employment opportunities for hard to reach groups.
- The tourism providers in the Roseau Valley will be contacted immediately prior to the construction stages. Activities adjacent to local businesses will be restricted to the extent feasible.
- Development of a Community Development Fund to undertake a range of community development initiatives including tourism related activities as described above in Section 6.2.5.
- Ensure that any grievances raised by tourism providers or other local businesses will be managed in an appropriate and timely manner. Where corrective actions are required; they will be implemented effectively and in a timely manner. The Project should ensure that workers are aware of how and where to make complaints using the Project Grievance Mechanism.

### 8.1.4 Physical and Economic Displacement

For future land acquisitions and resettlement associated with the power plant footprint, noise impacts, and the reinjection pipeline, an Abbreviated Resettlement Action Plan (ARAP) is presently being developed in consultation with affected parties. The ARAP developed in line with WB involuntary resettlement requirements considers resettlement sites where appropriate and / or cash compensation and livelihood restoration measures including consideration of those considered to be severely affected and or vulnerable.

Mitigation measures for physical and economic displacement are likely to include the following:

- Ensuring that the Action Plan from the Land Acquisition Review completed for the drilling phase has been properly implemented.
- Developing an ARAP that considers livelihood restoration, impacts to ecosystem services and the requirements of WB involuntary resettlement.
- Implement the ARAP prior to commencement of Project construction. Continue consultation with the Affected Community and ensure that the Stakeholder Engagement Plan for the Project continues to meet the requirements of WB PS 1.
- The Government of Dominica shall invest in and complete some of community development projects that are identified by that community, which contribute to the welfare of the local community.

### 8.1.5 Community Health and Safety

The following mitigation measures are recommended to reduce potential community health and safety impacts:

- The Project will be developed in line with WBG General EHS Guidelines and the Industry Specific Guidelines for Geothermal Power Generation and Electric Power Transmission and Distribution.
- A Worker Policy and Code of Behaviour shall be developed which includes guidance on visits, prescribed actions for conduct violations and a grievance mechanism for complaints.
- Provide a cultural education programme for workers from outside the area to help reduce community conflict.
- Work camp regulations shall also be developed to minimise local nuisance.
- Provide opportunities for women and women's groups to participate in the work force to the extent safe and practical, and assist them in having good quality work standards so they can train others and are able to work with other companies in the future.
- The EPC contractor shall involve external stakeholders (i.e. police or local authorities) in any on or off-site security incidents and ensure that appropriate incident response procedures are implemented. A Worker Policy and Code of Behaviour shall be developed which includes guidance on visits, prescribed actions for conduct violations and a grievance mechanism for complaints.
- An HIV/AIDS awareness and prevention program shall be implemented to provide the community with tools and education materials to reduce the spread of HIV/AIDS.
- An important aspect of minimising the spread of communicable diseases within the community is worker health screening, particularly as many workers are local people. A worker health screening programme shall be developed and implemented.
- The Project will provide adequate and sufficient sanitation facilities for both female and male workers.
- Worker accommodation plans will be developed according to international requirements under WB PS 2 international requirements under IFC Performance Standard 2.
- Develop and implement a Workforce Code of Conduct that addresses issues such as anti-social behaviour, drug and alcohol consumption, banning weapons, and including respect for women.

- Onsite health care shall be provided to ensure prompt medical attention.
- An important aspect of minimising the spread of communicable diseases within the community is worker health screening, particularly as many workers are anticipated to be sourced from outside of Dominica. A worker health screening programme shall be developed and implemented during the peak construction period.
- A Security Management Plan shall be developed in accordance with national law and the principles of good international industry practice. Access to the site will be controlled.
- The Project will train the security guards on Human Rights issues. The security guards will not be armed. They will coordinate with local government security forces in case of need and will ensure that security and human rights of local communities' members are respected.
- Community Emergency Response Plans will be developed and tested including consideration of workers and nearby residents in the vicinity of Project-related traffic. These will include emergency response related to traffic accidents and potential releases of chemicals and other hazardous materials.
- Workers shall receive proper Personal Protective Equipment (PPE) and associated health and safety training including procedures for emergency response.

## 8.2 Monitoring

The following monitoring strategies should be implemented:

- During construction and operation of the development the number of people being employed by the Project should be monitored from: 1) the three key Villages (Laudat, Trafalgar and Wotten Waven) and 2) the wider Roseau Valley, against predicted numbers of employees.
- During construction and operation, surveys should be conducted to determine the number of new businesses and increase or decrease in tourism businesses generated by the development and the level of indirect employment.
- A DGDC Community Liaison Officer will be responsible for updating and monitoring the implementation of the ARAP and Grievance Mechanism defined in the SEP, with the exception of land acquisition issues which shall be managed by the GoCD.
- Throughout the construction ongoing consultation and communication with the local community will be required particularly with PAPs, vulnerable groups and key stakeholder groups. The minutes of meetings and signed lists of attendees will be completed and documented.
- An independent third party review is recommended of the effective implementation of the ARAP, one year after civil construction works commence at the power plant and reinjection line.
- The following will be monitored through on-site visits on a quarterly basis:
  - effectivity of the implementation of good practices as per World Bank Health Safety and Environment (HSE) Guidelines;
  - existence of access control;
  - number of sanitation facilities available for men and for women at each construction site; and
  - effectivity of access restriction measures along the transmission line and its towers.
- The DGDC Human Resources Department will monitor the following on a quarterly basis:
  - effectivity of the implementation of good practices as per World Bank HSE Guidelines
- The records are to be reported to DGDC and any applicable regulatory authorities who then can document and respond to this information as part of their responsibilities.
- During the first four years of operation, on a quarterly basis, DGDC's department responsible for Corporate Social Responsibility (CSR) will record the number of inhabitants of the three villages affected by the power

plant to have received training, and nature of training received, disaggregated by age, sex and village/block.

- During the first four years of operation, the number of consultations with local communities will be recorded through minutes of meetings and signed lists of attendees.
- Grievance resolutions and database will be monitored for the first four years with progress reported on a quarterly basis.

# 9. Residual Impacts

### 9.1.1 Employment

With the measures described above, the residual significance is expected to remain of **Moderate Beneficial** significance. In the long-term, employment impacts are anticipated to decrease, but remain of **Minor Beneficial** significance.

### 9.1.2 Physical and Economic Displacement

With the measures described above, the residual impacts are expected to be remain of **Minor** significance. In the long-term, impacts are expected to decrease and conditions to improve as a result of ARAP compensation, resettlement and livelihood restoration measures proposed mitigation, but would still be considered **Minor** as resettlement impacts would be permanent.

### 9.1.3 Community Health and Safety

With the mitigation measures described above, the residual impacts are expected to be reduced to **Minor** significance.

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Dominica Geothermal Development Company Limited
*Powering a New Generation...*

JACOBS

# Project Name

NZ Ministry of Foreign Affairs & Trade

## ESIA: Volume 4 – ESMP, Framework ESMS and Assessment Against WBG Standards

RZ020302-0002-NP-RPT-0007 | V2

July 2018



## Project Name

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### Document history and status

| Revision | Date | Description | By | Review | Approved |
|---|---|---|---|---|---|
| A | August 2017 | First Draft of ESIA Volume 4 | A Kubale<br>P Gabriel | B Clarke | B Clarke |
| B | September 2017 | Update following MTNP and Terrestrial Ecology Reports | P Gabriel | | |
| C | April 2018 | Revisions following Hurricane Maria – for DGDC/MFAT comment | P Gabriel | B Clarke | B Clarke |
| V1 | June 2018 | Revisions following World Bank Comments – FINAL FOR ISSUE | P Gabriel | B Clarke | B Clarke |
| V2 | July 2018 | Revision following World Bank RSA Comments – Issue for Disclosure | C Duncan | B Clarke | B Clarke |
| | | | | | |

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# Important note about your report

The sole purpose of this report and the associated services performed by Jacobs New Zealand Limited ("Jacobs") is to describe the Environmental and Social Impact Assessment (ESIA) for the Dominica Geothermal Power Project in accordance with the scope of services set out in the contract between Jacobs and the New Zealand Ministry of Foreign Affairs and Trade (the Client). That scope of services, as described in this report, was developed with the Client, the Government of the Commonwealth of Dominica (GoCD) and the Developer (Dominica Geothermal Development Company (DGDC) established and owned by the GoCD).

Jacobs has been contracted by the Client to undertake the conceptual design and overall project definition through their engineering team. In preparing this ESIA report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided. Except as otherwise stated in the ESIA report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced as noted in the ESIA volumes and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

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# 1. Introduction

## 1.1 Overview

The ESIA Volume 4: ESMP, Framework ESMS and Assessment Against WBG Standards provides the following:

- An Environmental and Social Management Plan (ESMP) – Summarises the mitigation and monitoring measures that should be employed during construction and operation for the Project. The ESMP will summarise the DGDC's commitments to address, mitigate and monitor risks and impacts identified as part of the ESIA, through avoidance, minimisation and compensation/offset.
- A Framework Environmental and Social Management System (ESMS) - The Framework ESMS provides a framework of the key elements for developing and implementing an Overarching ESMS which sets out how the mitigation and monitoring will be implemented, checked and reviewed for the life of the Project.
- Assessment Against WB Standards Assessment – The assessment provides a summary of how the Project conforms to the requirements of World Bank Performance Standards for Private Sector Activities, OP 4.03 (2013).

The findings of the ESIA (ESIA Volume 1: Introduction, ESIA Volume 2: EIA and ESIA Volume 3: SIA) are used to develop associated documentation, such as the ESMP and Framework ESMS, as shown below in Figure 1.1.

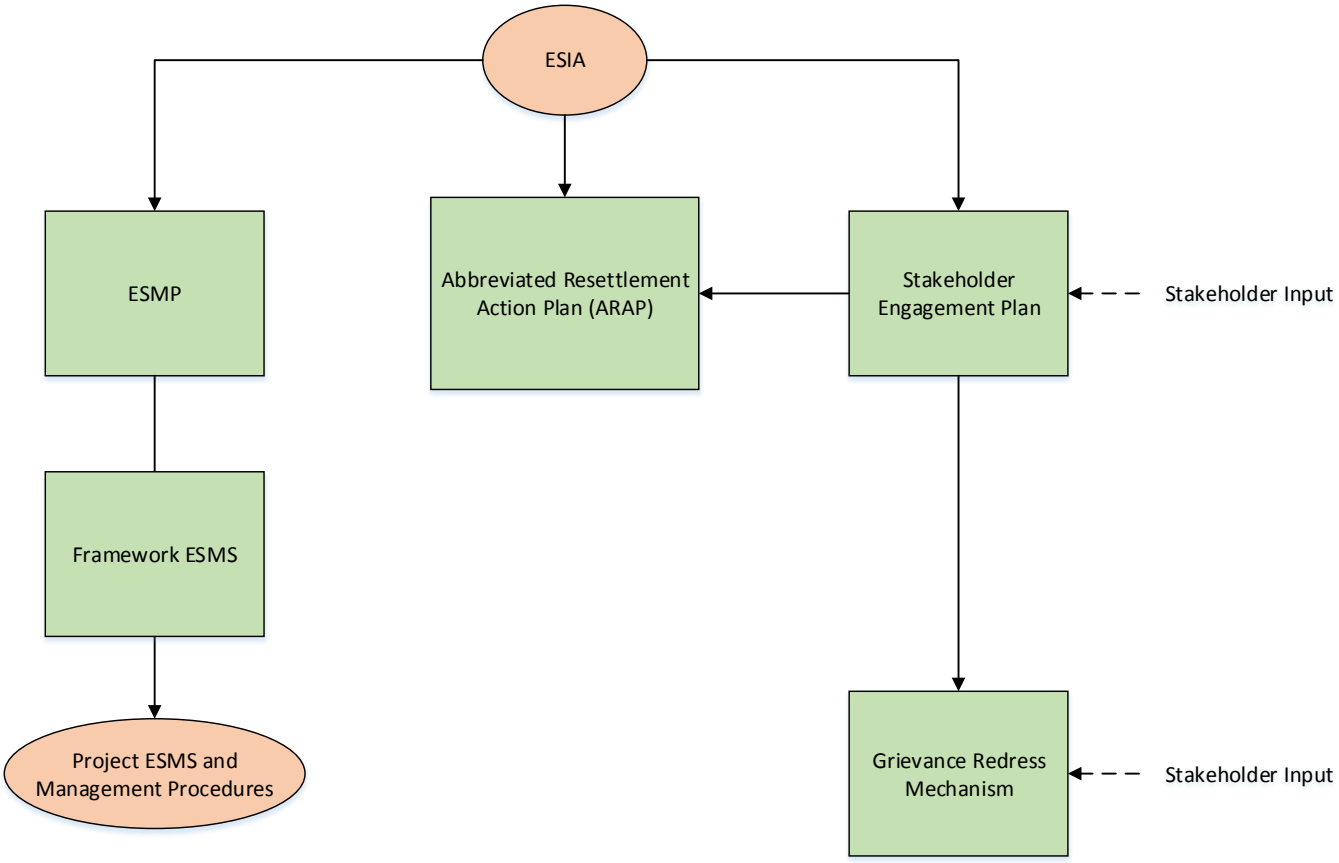


**Figure 1.1 : Flow diagram showing how ESMS is developed from the ESIA and how the documents are interrelated**

## 1.2 Structure of Volume 4

Volume 4 of the ESIA is structured as follows:

- Section 2 – Environmental and Social Management Plan (ESMP)
- Section 3 – Framework Environmental and Social Management System (ESMS)
- Section 4 – Assessment Against WB Standards

# 2. Environmental and Social Management Plan

## 2.1 Introduction

The ESMP describes and prioritises the actions needed to implement mitigation measures, corrective actions and monitoring measures necessary to manage the impacts and risks identified in this ESIA related to the Project. Implementation of the ESMP will take place under the broader framework of the ESMS and will be implemented and managed by Dominica Geothermal Development Company (DGDC). The EPC Contractor and operation maintenance contractor will also adhere to the procedures and requirements as set out in the ESMS.

The mitigation measures and action plans covered in this section therefore relate only to pre-construction, construction and operation stages for the Project. Where necessary, mitigation measures have been proposed to meet the requirements of the World Bank Safeguard, World Bank Performance Standards, World Bank Group (WBG) EHS Guidelines and to comply with Government of Commonwealth of Dominica (GoCD) law and regulations.

## 2.2 Mitigation Measures – Pre-Construction

There are a range of potential environmental and social impacts associated with the pre-construction phase of the Project. The key mitigation measures are summarised below:

- An Abbreviated Resettlement Action Plan (ARAP) has been developed prior to construction commencing. The ARAP contains the procedures that will be implemented to restore the livelihoods of people who have been resettled as a result of the Project. The ARAP has been prepared to complement the legal process of land acquisition and to comply with the principles and objectives of the Performance Standard (PS) 5 Land Acquisition and Involuntary Resettlement. The ARAP is contained in ESIA Volume 5: Technical Appendices.
- The resettlement action measures will be defined in a participatory manner with the affected people.
- The land acquisition process will be completed prior to construction commencing.
- DGDC will require the EPC Contractor and Subcontractor to actively employ locals in the construction phase.
- The Grievance Mechanism defined in the Stakeholder Engagement Plan has been disclosed to the neighbouring communities and implemented, and grievances registered will be addressed on a case by case basis.
- DGDC will undertake vocational training to assist local people in obtaining jobs with the Project.
- The Project will adapt the final design to avoid as much as possible destruction of houses and/or buildings. In particular, inhabited houses will be avoided as much as possible to minimise any potential physical displacement.
- Regular direct meetings with the local communities will be undertaken to update them on the progress of the work and to give them the opportunity to voice their concerns.
- Following Hurricane Maria in September 2017, the likelihood of landslides has increased. It is therefore recommended that further studies be undertaken to establish the risk of landslide prior to construction. It is recommended that a geotechnical study is carried out for all areas where major construction activities are taking place for the Project. This will be organised by DGDC.
- Rerouting options should be examined as a primary mitigation measure to avoid areas with large scale and active landslides, since they present a threat to the reinjection line integrity. International good practice is to identify landslide features and avoid by routing along ridge crests and spurs, and minimising the exposure to large and active geo-hazard landslides, potentially unstable and steep side slopes (Marinos et al., 2016).

## 2.3 Mitigation Measures – Construction and Operation

There are a range of potential environmental and social impacts associated with the construction phase of the Project (Refer to ESIA Volume 2: EIA and ESIA Volume 3: SIA). During construction of the geothermal power plant, reinjection line and access roads, the following mitigation measures are proposed in Table 2.1 for construction and Table 2.2 for operation. It should also be noted that it is anticipated that construction mitigation measures will also be implemented by DOMLEC during the construction and upgrading of Associated Infrastructure (see ESIA Volume 2: EIA, Section 18).

**Table 2.1 : Summary of proposed mitigation during construction**

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| Air quality | All Project construction works – emissions and dust control | The EPC Contractor will develop an Air Quality Management Procedure that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the document. The Air Quality Management Procedure will include the following measures:<br>• Construction vehicles will be periodically checked to ensure that they are not emitting excessive pollutants.<br>• Construction dust will be suppressed with water applied by water sprinklers and/or water carts. For access tracks, it is recommended that water is sprayed on roads at least twice a day during the dry periods.<br>• Dust on the wheels of vehicles will be removed through wheel washing prior to leaving the site.<br>• Vehicle speed on the construction site will be set to a maximum of 15 mph to reduce dust release from road surfaces.<br>• In the event of high winds during dry periods, it may be necessary to cease some construction activities until the wind subsides.<br>• When transporting material that is prone to wind blow, vehicles will be equipped with a tarpaulin cover when passing through residential areas.<br>• Windblown material from stockpiles of soil, aggregate, sand etc. will be held in bins or other enclosures, and stockpiles of material including soil, and where practicable covered with a tarpaulin.<br>• To reduce windblown material, the EPC Contractor will sow grass seed on soil stockpiles that will remain dormant for more than three months. |
| Cultural Heritage | All Project construction works | • The EPC Contractor will implement a Chance Find Procedure as set out in Volume 3: SIA during all Project construction works. DGDC will be responsible for checking and reviewing the document. The Chance Find Procedure outlines the measures taken during construction if an artefact of cultural heritage significance is found (i.e. documentation of the artefact, informing local museum).<br>• The EPC Contractor's Worker's Code of Conduct will include a section on Cultural Heritage and respect of local beliefs and traditions in the local communities. All workers will be made aware of the EPC Contractor's Worker's Code of Conduct and awareness sessions will be organised for all new recruits. DGDC will be responsible for checking and reviewing the document. |
| Environmental and Social Management Systems (ESMS) | All Project construction works | • Management of environmental and social risks and impacts during construction will primarily be the responsibility of the EPC Contractor through the EPC Contract.<br>• During the construction phase, DGDC will review and monitor EPC Contractor's performance in accordance with their Health, Safety and Environment (HSE) Plans and related management plans/procedures to ensure alignment with the overarching Project ESMS. Management of environmental and social aspects associated with the Project will be carried out in accordance with the ESMS. The ESMS will consist of a set of sub-ordinate plans and procedures, which may include, but are not limited to, the following topics:<br>- Construction environmental management;<br>- Pest and weed management; |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| | | - Biodiversity restoration;<br>- Waste management;<br>- Hazardous substance management;<br>- Soil and erosion management;<br>- Air quality/dust management;<br>- Environmental and social monitoring;<br>- Stakeholder engagement;<br>- Grievance mechanism (community and workers);<br>- Emergency preparedness and response;<br>- Noise and vibration management;<br>- Recycling plan;<br>- Landscape management;<br>- Chance find procedure;<br>- Subsidence risk management;<br>- Landslide stabilisation risk management;<br>- Occupational safety and health management; and<br>- Traffic management.<br>• Key personnel will be responsible for ensuring good environmental practice on site during construction. These will include the DGDC Project Manager and the EPC Contractor Site Manager.<br>• Staff will be trained in environmental management, auditing and monitoring procedures as per the framework that has been outlined in the Framework Environmental and Social Management System (see Section 3).<br>• Reporting of mitigation activities will be issued by DGDC to the Lenders every 6 months in the Biannual Environmental and Social Report. |
| Existing Infrastructure | All Project construction works | Construction activities will be operated in a way that will not encroach into the existing infrastructure facilities (e.g. electricity lines, information system, water supply system, offices, etc.). |
| | All Project construction works – | • The EPC Contractor will develop a Waste Management Procedure that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the document. Particular attention should be given to the use and re-use of materials to minimise |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| Hazardous Substances and Waste | general measures for waste | waste and, whenever practicable, using materials and products from sustainable sources. The Waste Management Procedure will be prepared in accordance with the waste hierarchy and include the following steps:<br>• Consideration will be given to recycling to minimise waste disposal; and<br>• Waste will be stored in closed containers away from direct sunlight, wind and rain. Waste packaging will be in good condition, undamaged, corrosion and leak free.<br>• Waste will be stored so as to prevent or control accidental releases to air, soil, and water resources.<br>• Waste signs will be put on all waste containers and collection areas. Each sign will be highly visible and easily seen by the person using the waste container or area. Each container or waste area sign will be labelled as Domestic Waste, Non-Hazardous Waste or Hazardous Waste and include the responsible person with contact information and how to handle the waste.<br>• Waste will be stored in a manner that prevents the commingling or contact between incompatible wastes. Sufficient space is needed between incompatibles or physical separation such as walls or containment curbs.<br>• Solid waste produced during construction will be disposed of in compliance with the regulations and will be outlined in the Waste Management Procedure.<br>• When entrusting wastes for disposal, the Site Manager or Environmental Manager shall:<br>- Select proper waste disposal companies certified by GoCD for the type of waste being disposed of;<br>- Prepare all required documentation and permits if required by Dominican law for the type of waste being disposed of; and<br>- Ensure the waste is disposed of by the third party waste contractor to the agreed disposal facility. |
| | All Project construction works - hazardous substances use and disposal of hazardous waste | • The EPC Contractor will develop a Hazardous Substances Management Procedure that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the document.<br>• Under the Hazardous Substances Management Procedure, the EPC Contractor will induct the workforce to be made aware of hazardous substances, with reference to the applicable Safety Data Sheets (SDS). They will also attend mandatory safety training in the correct way to use and handle the hazardous substances. Training must be adjusted to be compliant with the laws of Dominica and any other relevant regulations prescribed by the competent authorities.<br>• Workers will be provided with the appropriate Personal Protective Equipment (PPE) for the handling and use of hazardous substances.<br>• Emergency facilities, first aid points, clinics, eye wash fountains, emergency showers will be identified/provided where required.<br>• Other facilities that will be available include fire extinguishers, first aid, communication equipment, emergency doors and alarms.<br>• Smoking will be restricted to designated areas and all flammable liquids will be kept away from hot work areas.<br>• Oil, fuel and lubricants storage and dispensing stations will be restricted to established locations. Dispensing area should be located on an impervious surface and under shelter where possible. |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
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| | | • Storage areas will be identified and unauthorised entry will be controlled by use of barriers warning signs and close supervision. All hazardous substances will be stored away from construction activities under covered stores. 'No Smoking' signs will be placed at these locations and all storage areas shall have minimum one dry powder type fire extinguisher.<br>• Hazardous and toxic wastes stored on site will be minimised by increasing the frequency of pick-ups where necessary. The producer of hazardous waste may store hazardous and toxic waste on-site for a maximum of 90 days. This period may be extended if the amount that is produced is less than 50 kg/day.<br>• Adequate ventilation will be provided where volatile wastes are stored.<br>• Secondary containment should be included wherever liquid wastes and hazardous substance are stored in volumes greater than 220 litres. The available volume of secondary containment should be at least 110% of the largest storage container, or 25% of the total storage capacity (whichever is greater), in that specific location.<br>• Triple rinsing must be undertaken before empty chemical containers can be treated as non-hazardous solid wastes.<br>• Hazardous waste will be collected by a licensed contractor and treated, reclaimed or disposed offshore.<br>• Wherever possible, less hazardous substances will be obtained as substitutes. |
| | All Project construction works - spill management | • The EPC Contractor will develop an Emergency Response Plan that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the document. The EPC Contractor, alongside DGDC will communicate the plan with the local community. Further details of the outline of an Emergency Response Plan are located in ESIA Volume 5: Technical Appendices, Technical Report - Occupational Health and Safety and Working Conditions.<br>• Vehicles will only be fuelled in designated locations where the area is hard paved and the collection sump is connected to the wastewater treatment system.<br>• In the event of a spill during construction, spill containment and clean up equipment will be located onsite. This will include equipment for:<br>- Containing and cleaning any spill such as a shovel, broom, drain covers, sandbags, booms and absorbent material. All spills will be handled with compatible materials.<br>- Storing and disposing of spilled material such as safe containers, bags, and drums.<br>- Protecting the safety of staff through PPE.<br>- Any spills will be contained and cleaned up immediately and disposed of at an approved facility. Incidents will be recorded and reported following the accident reporting system as detailed in the HSE Plan. This includes the preparation of an Accident/Incident Report. |
| Landscape | All Project construction works | • The EPC Contractor will develop a Pest and Weed Management Procedure that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the document.<br>• Plants used in any landscape planted will be nursery grown and will be sound, healthy, and vigorous and free from insect infestations. Trees and shrubs will be chosen to tolerate weather conditions and other such site characteristics. |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
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| | | • Any lighting requirements will be designed to ensure light spill is directed into the construction site.<br>• Where possible the selection of neutral/muted cladding and external finishing would aid in limiting the extent of adverse visual impacts.<br>• After construction works are completed, it is proposed that the power plant site will be landscaped in order to improve visual amenity.<br>• The soil removed during earthworks for construction will be reinstated and used as topsoil for the proposed landscaping bunds (piles of earth mounted at the Project site boundary that are planted with trees to provide screening and natural noise attenuation for local residents).<br>• For visual appearance and to limit erosion from surface water during heavy rains, stockpiled topsoil will be used for landscaping and to create 'green zone' areas on the power plant site as soon as practicable.<br>• Site fencing has the potential to aid in mitigating adverse visual effects of the power plant by partially screening and softening the visual impact of the site and ensuring light spill from the site is minimised. |
| Hydrology | Power plant construction | A Stormwater Management Procedure (SMP) (embedded within the Erosion and Sediment Control Procedure) will be developed by the EPC Contractor before the construction phase. DGDC will be responsible for checking and reviewing the document.<br>• Following surveying of the boundary of the construction pad, diversion drains should be excavated around the perimeter of the site to convey overland flow to appropriate locations downstream. During construction these could be temporary excavations, rock or geotextile lined to reduce erosion.<br>• Direct site runoff should be captured via interceptor ditches and sumps/sediment ponds. In localised areas, sediment runoff could be managed through silt fences. Grading the construction site to ensure runoff is captured and detained in these locations is essential, as its highly likely surface water will be sediment laden and will need some settling before discharge to the nearby Titou Gorge Stream (likely through a decant structure or overflow spillway in a sediment pond).<br>• Any discharges of concentrated flow should be to watercourses that have adequate erosion protection in place to prevent gullying of channels, bank collapse and increased sedimentation downstream. This may require installation of reno mattresses or rock rip rap (adequately sized to convey flows and velocities) at the discharge point. The remaining channel (if it exists) may require further excavation to convey the increased flows, and subsequently the installation of a permanent channel draining from the construction pad settling ponds to the Titou Gorge Stream would be recommended (a distance of ~250 m).<br>• Should local water sources be required for meeting some construction demands including vehicle and equipment washdown, the use of a temporary portable storage tank is advised. A 25,000 L plastic tank (3.6 m x 2.8 m) could provide storage for firefighting and water supply, and be topped up from Titou Gorge Stream at low abstraction rates (<2 L/s) to minimise environmental impact. A full assessment of construction water demands will be needed to verify the infrastructure required. |
| | Reinjection pipeline construction | • Near stream works will require local sediment controls such as silt fences or downstream sediment traps to reduce the effects of disturbance. Water supply for concrete mixing will be minimal and infrequent, primarily used for support foundations. |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
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| Noise and Vibration | All Project construction works | The EPC Contractor will be responsible for the following mitigation measures during construction:<br>• A Construction Noise Management Plan (CNMP) should be formulated to provide a framework for addressing construction noise levels. Noise control options including site mitigation and the investigation of low noise plant should be detailed and direction provided for the delivery of best practice noise management on site.<br>• Construction works should adopt Best Management Practice (BMP) and Best Available Technology Economically Achievable (BATEA) practices. BMP includes factors discussed within this report and encouragement of a project objective to reduce noise emissions. BATEA practices involve incorporating the most advanced and affordable technology to minimise noise emissions.<br>• Limit construction works to daytime hours where reasonable and feasible.<br>• Locating haul routes as far as possible from residential receivers.<br>• Using equipment that has been well maintained so that noise emissions are minimised.<br>• Provide localised noise screening where works are to be conducted within 200 metres (the compliance distance) of any sensitive receivers.<br>• Where possible, static construction plant such as generators should be located adjacent to on-site structures to impede noise propagation.<br>• Engines shall not be started and on-site activities shall not be undertaken outside of the daytime construction hours. Non noise generating works can be undertaken at staging areas where works are not adjacent to residential receivers.<br>• Construction activities should be undertaken in accordance with BS 5228, Code of Practice for Noise Control on Construction and Demolition Sites. All equipment used on site would be required to demonstrate compliance with the noise levels recommended within BS 5228.<br>• Appropriate use of all plant and equipment, with reasonable work practices applied, including no extended periods of 'revving', idling or 'warming up' in proximity to existing residential receivers. Any excessively loud activities should be scheduled during periods of the day when general ambient noise levels are greatest. This would reduce the potential for cumulative noise impacts (relating to worst-case elevated operations) and extended periods of off-site annoyance.<br>• Minimising reversing alarm noise emissions from mobile plant and transport truck operations should be considered, provided occupational health and safety requirements are satisfied. Where practicable, site entry and exit points should be managed to limit the need for reversing.<br>• Construction plant source noise levels should be confirmed prior to the commencement of works to verify construction noise impacts and noise management measures.<br>• Provide a summary of required construction noise management practices to all staff and contractors and be included during site inductions. The summary should include, as a minimum, the permitted hours of construction work, work site locations and site ingress/egress.<br>• Local residents and land owners are to be notified a minimum of 2 weeks prior to the commencement of construction works. The notification would detail proposed construction works, permitted hours of work and potential noise impacts. |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
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| Landslides | All Project construction works | • It is also recommended that the EPC Contractor develop an Erosion and Sediment Control Procedure that will incorporate a Landslide Management Procedure, which will contain measures to reduce potential impacts of landslides (slope stabilisation, planting, sandbags etc.). DGDC will be responsible for checking and reviewing the document. |
| Social / Economic | All Project construction works | *General*<br>• The EPC Contractor and all Subcontractors will respect and apply industrial good practices as highlighted in WBG EHS Guidelines. This includes among others: no operation during night time near inhabited settlements, implementation of noise and dust control measures, low speed limits for the Project's vehicles in inhabited areas. DGDC will ensure that this is being completed through regular site visits and auditing of reports.<br>*Grievance*<br>• DGDC will implement regular consultations with PAPs, their grievances will be lodged, treated and addressed.<br>• The Grievance Mechanism defined in the Stakeholder Engagement Plan will be disclosed by DGDC to the neighbouring communities and implemented, and grievances registered and addressed on a case by case basis. Note: The Grievance Mechanism was disclosed to Laudat, Trafalgar and Wotten Waven communities in July 2017. It will be disclosed again to these communities at least six months before the start of construction.<br>*Jobs / Employment*<br>• DGDC, the EPC Contractor and all Subcontractors will ensure a transparent hiring process is conducted to help the community to understand strategic staffing decisions for the Project.<br>• DGDC will establish a local employment brokerage that will publicise job vacancies and put in place initiatives to ensure employment opportunities for hard to reach groups.<br>• DGDC will make efforts to facilitate the growth and development of new entrepreneurs, both individuals and groups originating from affected communities.<br>• DGDC will provide opportunities for women and women's groups to participate in the work force to the extent safe and practical, and assist them in having good quality work standards so they can train others and are able to work with other companies in the future.<br>• DGDC will define targets for women employment (at all levels and skills). It will be disclosed that recruitment is also open to women in the local communities. Specific recruitment strategies targeting women will be defined.<br>*Skills and Training*<br>• DGDC will develop a Workforce Development Strategy – a commitment to maximize employment and skills opportunities for local people which the EPC Contractor will follow.<br>*Community Development*<br>• DGDC will develop a Community Development Fund to undertake a range of community development initiatives. |

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| | | • DGDC will develop Corporate Social Responsibility (CSR) programmes implemented in partnership with local governments to create business opportunities for the local workforce that is no longer involved in the construction of the Project. CSR programmes will also seek to improve levels of education and skills for people affected by the Project.<br>*Health and Social Initiatives*<br>• To prevent social tensions between the workforce and the local population, the EPC Contractor will develop a Worker's Code of Conduct, which will be checked and verified by DGDC. The Worker's Code of Conduct will address issues such as anti-social behaviour, drug and alcohol consumption, banning weapons, and including respect for women.<br>• The EPC Contractor will provide free and anonymous health surveillance and active screening and treatment of workers including sexually transmitted diseases. Onsite health care shall be provided to ensure prompt medical attention.<br>• The EPC Contractor will prevent illness among workers in local communities by undertaking health awareness and education amongst the workforce and in the neighbouring communities. An important aspect of minimising the spread of communicable diseases within the community is worker health screening, particularly as many workers are anticipated to be sourced from outside of Dominica. A worker health screening programme shall be developed and implemented during the peak construction period.<br>• The EPC Contractor will prepare and implement a Sexually Transmitted Disease (STD) Management Plan. DGDC will be responsible for checking and reviewing the document.<br>• DGDC and the EPC Contractor will collaborate with local authorities to enhance access to public health services and promote immunisation.<br>• DGDC will define vector-borne diseases prevention measures (such as avoidance of stagnant water, measures to avoid mosquito development) which the EPC Contractor will implement.<br>• The EPC Contractor will provide adequate and sufficient sanitation facilities for both female and male workers.<br>*Access and Security*<br>• The EPC Contractor will control access to all construction sites with no unauthorised access from local communities permitted.<br>• The EPC Contractor will train the security guards on human rights issues. The security guards will not be armed. They will coordinate with local government security forces in case of need and will ensure that security and human rights of local communities' members are respected.<br>• For the reinjection line, access restriction and safety measures of the general public will be defined implemented along the Right of Way (RoW) during pipeline construction. |
| Soils, Geology and Groundwater | All Project construction works - soil erosion | • The EPC Contractor will develop an Erosion and Sediment Control Procedure and Hazardous Substances Management Procedure that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the documents.<br>• The EPC Contractor and Subcontractors will ensure that they undertake the following mitigation activities: |

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| | | - Excavated earth should be strongly compacted and cut-off ditches should be dug in erosion prone areas to divert water away for the earthworks and to settling ponds before discharge to nearby water courses.<br>- Along the reinjection pipeline route catchment areas will be kept to small sizes with their own temporary drains and specific treatment devices.<br>- Silt curtains, fibrous mats etc. will be placed across as temporary stormwater drains to reduce the efflux velocity of the water and to aid settling of suspended sediment from the water. |
| | All Project construction works - soil and groundwater pollution | The EPC Contractor and Subcontractors will ensure that they undertake the following mitigation activities:<br>• Spill kits should be located on the construction site to manage and contain any fuel or hazardous substance spillage. If an accident does occur, then contaminated soil should be excavated and replaced with clean fill to minimise (or prevent) groundwater contamination with treatment of any stormwater runoff or process water prior to disposal.<br>• All wastewater should be collected prior to discharge.<br>• Oily and/or hazardous waste will be separately collected and disposed of by an appropriately licensed operator.<br>• All vehicle maintenance should be done in garages.<br>• The laying of overland flow diversion drains and preload fill should be completed preferable during the dry season and prior to the power plant construction earthworks commencing.<br>• Drainage water collection and treatment systems should be installed as a priority to prevent discharge to the adjacent rivers and streams. |
| | All Project construction works - excavated material | The EPC Contractor and Subcontractors will ensure that they undertake the following mitigation activities:<br>• Excavated topsoil will be transported to, and stockpiled in, designated topsoil storage areas.<br>• Prior to filling, sub-grade surfaces of depressions will be free of standing water and unsatisfactory soil materials will be removed.<br>• All unnecessary excavated materials will be transported and deposited outside of the site at an approved facility.<br>• Where excavated material is suitable to be used for fill and backfill, the material will be segregated and transported to a stockpile location at the construction site. |
| Terrestrial Ecology | All Project construction works | The EPC Contractor and Subcontractors will ensure that they undertake the following mitigation activities:<br>• Implement dust-suppression measures such as covering vehicles transporting materials, ensuring vehicles use wheel wash facilities at site, and use of water spray dust suppression systems.<br>• Highly noisy activities will be undertaken during daylight hours where possible.<br>• Inductions/tool-box talks for staff will include reference to measures required to protect biodiversity.<br>• Appropriate provision will for be made for waste disposal. |

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| | | • Vegetation clearance activities should commence outside the breeding season for five key threatened species identified, to minimise impacts on breeding animals. The breeding seasons of the three bird species are overlapping, between January and August[1]. The amphibian species are thought to breed year-round, but primarily between May and July.<br>• Habitat cleared will be the minimum possible, with any way-leave area required of the minimum width necessary.<br>• Use temporary fencing to prevent inadvertent damage outside designated construction areas.<br>• Avoid piling of clear-felled vegetation on standing live vegetation which would hinder movement of wildlife.<br>• Any replanting / landscaping will use native or endemic species to prevent the incursion of opportunistic invasive species.<br>• Machinery and vehicles should be cleaned upon entry/exit, and any soil brought on or off site screened for invasive species or plant pathogens.<br>• Minimise potential for sedimentation impacts by ensuring good construction site practices are implemented.<br>• Appropriate disposal of solid and liquid wastes, in line with recommendations in international and national standards, and using designated facilities as required.<br>• Any effluent discharged to surface watercourses must meet the more stringent of international water quality discharge standards prior to release to remove pollutants.<br>• Minimise potential for pollutants and surface water run-off to migrate off-site by ensuring standard good construction site practices are implemented.<br>• Ensure all standard safe storage measures for n-pentane are implemented, as detailed in ESIA Volume 2: EIA, Chapter 15.<br>• The 6-7m of the construction corridor of the reinjection line that is not required permanently will be replanted with native species as soon as possible after construction.<br>• A Habitat Management Plan (HMP) will be developed that sets out the establishment and maintenance required for a biodiversity offset, to be created with minimum extent 1.7 ha (equivalent to the Natural habitat lost under the Project Area). This will be developed with input from local specialists and stakeholders as appropriate and will incorporate measures identified in *Post-Hurricane Maria Specific Actions* below, as appropriate.<br>• It is expected that the pipeline will be designed such that smaller animals can pass under it. In addition, the pipeline will have under/overpasses installed at intervals along its length to minimise fragmentation effects and allow passage of animals across the corridor. |
| | All Project construction works - Post-Hurricane Maria Specific Actions | DGDC will develop a Habitat Management Procedure (HMP) that will be adhered to be the EPC Contractor and all Subcontractors during all Project construction works. The HMP will aim to provide enhancement measures for post-Maria terrestrial biodiversity of the area:<br>• Stabilise bare slopes or improve resilience on slopes where trees have fallen – promote tree and shrub planting to stabilise lose soil and rock, prevent further erosion and slips. This could also include supporting local nurseries to grow more trees which in turn could be used by local communities. |

[1] http://www.iucnredlist.org/ (Accessed September 2017)

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| | | • Areas of fallen trees surrounding well pads and other infrastructure – plant native tree species to stabilise ground conditions, improve ecological resilience and reduce rainwater run-off which in turn could pollute water courses and cause soil erosion.<br>• Restore river courses – remove bulky items where possible such as fallen trees, logs and other detritus and large rocks which could block river flow and cause flooding; destabilise slopes or cause soil erosion to surrounding terrestrial areas.<br>• Removal of habitat cover – provide hibernacula of log piles, stone/rock piles for amphibians and other animals which might have been lost along with tree canopy cover.<br>• Exposed ground - plant native grass seed with fertilizer where exposed ground is still visible or where slopes are too steep or where soil has been washed away. |
| Morne Trois Piton National Park World Heritage Site | All Project construction works | Alongside the HMP described above, the EPC Contractor and Subcontractors will ensure that they undertake the following mitigation activities:<br>• Implement dust-suppression measures such as covering vehicles transporting materials, ensuring vehicles use wheel wash facilities at site, and use of water spray dust suppression systems.<br>• Highly noisy activities will be undertaken during daylight hours where possible.<br>• Inductions/tool-box talks for staff will include reference to measures required to protect biodiversity.<br>• Proposals for the MTPNP buffer zone should be progressed, and this area maintained as a development-free zone. Activities that would facilitate access to the MTPNP should not be encouraged.<br>• Any replanting / landscaping will use native or endemic species to prevent the incursion of opportunistic invasive species.<br>• Machinery and vehicles should be cleaned upon entry/exit, and any soil brought on or off site screened for invasive species or plant pathogens.<br>• Minimise potential for sedimentation impacts by ensuring good construction site practices are implemented.<br>• Appropriate disposal of solid and liquid wastes, in line with recommendations in international and national standards, and using designated facilities as required.<br>• Vegetation clearance activities will commence outside the breeding season for five key threatened species identified, to minimise impacts on breeding animals. The breeding seasons of the three bird species are overlapping, between January and August[2]. The amphibian species are thought to breed year-round, but primarily between May and July[3].<br>• Habitat cleared will be the minimum possible, with any way-leave area required of the minimum width necessary.<br>• Use temporary fencing to prevent inadvertent damage outside designated construction areas. |

[2] http://www.iucnredlist.org/ (Accessed September 2017)
[3] http://www.amphibianark.org/pdf/Husbandry/Leptodactylus%20fallax%20-%20Management%20Guidelines.pdf (Accessed September 2017)

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
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| | | • Avoid piling of clear-felled vegetation on standing live vegetation which would hinder movement of wildlife.<br>• Minimise potential for sedimentation impacts by ensuring good construction site practices are implemented.<br>• Appropriate disposal of solid and liquid wastes, in line with recommendations in international and national standards, and using designated facilities as required.<br>• Minimise potential for pollutants and surface water run-off to migrate off-site by ensuring standard good construction site practices are implemented.<br>• Detailed measures to minimise the likelihood and magnitude of a BLEVE occurring is provided in ESIA Volume 2: EIA, Chapter 15, including:<br>- Induction and training;<br>- Standard Operating Procedures;<br>- routine inspections;<br>- good record keeping; and<br>- suitable firefighting equipment. |
| Traffic Management and Access | All Project construction works | The EPC Contractor will develop a Traffic Management Procedure (TMP) that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the documents. The TMP will:<br>• Identify routes within the site and from Roseau and the port to the site;<br>• Identify weight/height restrictions and alternative routes;<br>• Develop a signing strategy for the routes;<br>• Ensure controls to mitigate for any obstruction to walkers using the Waitukubi National Trail route: and<br>• Formulate mechanisms for vehicle control.<br>The EPC Contractor and Subcontractors will ensure that they undertake the following mitigation activities:<br>• All routes must be clearly signed from the main highway, and through to the catchment areas. The signing strategy must allow unique identification of each route, along with speed and other restrictions. All drivers should have access to a schedule of the routes and a delivery control mechanism put in place to ensure all goods and material deliveries are clearly routed.<br>• The strategy may also include further restrictions such as a restriction upon the time during which vehicles may operate and the use of hazard warnings.<br>• Signs must clearly indicate that they relate to vehicles serving the power plant construction so that they are not misunderstood by other road users.<br>• Work at night should be avoided for safety reasons. |

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| | | • The EPC Contractor will provide safe access for pedestrians and cyclists throughout the duration of construction phase of the Project.<br>• Consideration will be given to the speed at which the vehicles are advised to travel on the public road network and especially in rural areas.<br>• A vehicle awareness program could be conducted with the villagers most likely to be impacted, which will warn them of increased vehicle movements and the hazards posed due to the Project.<br>• Construction traffic drivers will be asked to reduce speeds in built up areas and ensure that braking distances are acceptable.<br>• Operators of the vehicles should regularly maintain vehicles to reduce excessive emissions.<br>• Drivers of all vehicles leaving the site should wash their wheels at the facility before entering the main road (refer to Air Quality mitigation strategies above)<br>• Other procedures to prevent the deposition of slurry, clay or other materials on roads by vehicles leaving the site will include:<br>- use of asphalt millings to surface the internal site haul road;<br>- provision of cleaning facilities including hoses, brooms and shovels;<br>- twice daily monitoring, and education of all construction staff/drivers to monitor for any material which may be accidently spilt onto public roads from construction traffic; and<br>- maintaining a contingency of sweeper equipment on call at all times to clean up material which may be accidently spilt onto public roads.<br>• Adherence to the TMP will be included within site induction and weekly toolbox meetings as required to ensure all site staff are aware and practice the required clean roads protocols.<br>The TMP should outline methods for controlling noise and vibration associated with construction traffic.<br>• It is recommended that a Travel Plan is written and distributed to staff to inform them of the best ways to travel to the sites of the Project. Staff should be encouraged to take public transport, car pool or that the contractor provides transport for them. |
| Working Conditions, Occupational Health and Safety | All Project construction works | • DGDC will be required to develop an Occupational Health Safety (OHS) Plans for the construction activities at the Project site, which will apply to all personnel involved in the Project, including EPC Contractors, Subcontractors and part-time workers. The primary health and safety objectives will be to ensure effective measures and management of occupational health and safety to minimise workplace accidents and injuries. The health and safety procedures within the OHS Plans will comprise a comprehensive Health and Safety Management System HSMS. They will meet the requirements specified in the WBG EHS Environmental, Health and Safety Guidelines pertaining to occupational safety and health. In addition, any Subcontractors appointed by the EPC Contractors will be required to submit their own OHS Plans/Health and Safety Management System. Further details for the requirements of OHS Plans are presented in ESIA Volume 5: Technical Appendices, Technical Report – OHS and Working Conditions.<br>• The EPC Contractor will develop an Occupational Health Safety Management System which covers their staff and sets out the safety performance standards which the EPC Contractor and its subcontractors will meet. The EPC Contractor will actively monitor and audit the safety performance of its subcontractors. |

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| | | • As well as the main OHS Plans, specific Safety Management System procedures shall be developed for each element of the Project, including the following:<br>  - safety management organisation / reporting chain;<br>  - construction methodology;<br>  - hazard / risk assessment and proposed mitigation measures; and<br>  - safety checklists.<br>• The Safety Management System will have a procedure for identifying all hazards associated with the activity in question. A hazard in this context is defined as any aspect of the Project activities which could result in harm to onsite personnel.<br>• The EPC Contractors and Subcontractors will be made aware of their role in ensuring the Project meets international standards related to labour and working conditions, and will be contractually obliged to do so. The EPC Contractor will establish a hierarchy of responsibility with regards for the provision of health and safety.<br>• DGDC and the EPC Contractors will establish a hierarchy of responsibility with regards for the provision of health and safety. The precise titles and roles of each member will be determined by DGDC and the EPC Contractors prior to work on the site.<br>• A DGDC and the EPC Contractor Health and Safety Management Committee will be appointed to evaluate health and safety at the site and to assess and recommend changes to equipment, policy and/or procedures where required by health and safety issues.<br>• Staff will be trained in safety procedures and provided with Personal Protective Equipment (PPE). Working conditions and occupational safety and health procedures framework has been outlined in ESIA Volume 5: Appendices, Technical Report – Working Conditions and Occupational Health.<br>• The EPC Contractors will issue all Project staff with an individual contract of employment detailing their rights and conditions in accordance with the national law and WBG requirements related to hours of work, wages, overtime, compensation and benefits such as maternity or annual leave, and update the contract when material changes occur.<br>• Generic rules shall be provided within employment contracts and task specific procedures will be communicated during tool box talks and displayed on machinery or within hazardous work areas.<br>• All hazardous work shall require the completion of a permit-to-work form and approval by the OHS Manager prior to commencement.<br>• A security procedure shall be included within the OHS Plan covering areas of security control, working hours etc.<br>• Emergency Response Procedures will form an integral part of the OHS Plans/HSMS. As part of these, an Emergency Response Plan shall be prepared to address emergencies of all scales. Further details of the outline of an Emergency Response Plan are located in ESIA Volume 5: Technical Appendices, Technical Report - Occupational Health and Safety and Working Conditions.<br>• A worker's grievance mechanism will be established. In compliance with World Bank Group Standards, this grievance mechanism will be designed to receive and facilitate resolution of concerns and grievances about the Project's working conditions and safety performance. |

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| | Worker's Accommodation Camp | • The Worker's Accommodation Camp on site will be kept clean, tidy and pest-free.<br>• The EPC Contractor will ensure that standards are kept in accordance with the guidance document 'Workers' accommodation: processes and standards' (IFC and EBRD, 2009).<br>• Provide a cultural education programme for workers from outside the area to help reduce community conflict.<br>• Work camp regulations shall be developed to minimise local nuisance.<br>• |
| Water Quality and Freshwater Ecology | Power Plant - earthworks during construction | The EPC Contractor will develop an Erosion and Sediment Control Procedure (ESCP) that they and all Subcontractors will implement during all Project construction works. DGDC will be responsible for checking and reviewing the documents. The ESCP will aim to manage and mitigate suspended solid discharges to the Roseau River to an acceptable level. This will be managed in accordance with the EHS general Guidelines. The ESCP will include the following mitigation:<br>• Clean water diversions – An overland flow path crosses the proposed power plant location. This should be diverted around the site area first to minimise clean water ingress to bare earth areas.<br>• Access road sealing – the access road should be gravelled or sealed as a first stage in construction to minimise erosion.<br>• Staging – the works should progress in stages where possible to minimise the amount of bare earth. This is likely to include clearing the laydown area first, then providing erosion and sediment control to it before then moving onto the power plant area.<br>• Reducing catchment sizes – work areas should be created that involve small sub catchments in which flows can be reduced, channelized concentration or water minimised to reduce erosion.<br>• Installation of temporary stormwater drains through each of the catchment areas to collect and direct stormwater to sedimentation ponds.<br>• Erosion protection – when flows have been concentrated into channelized flows these should be within protected channels. These could be either temporary protection using geotextiles or more permanent hard protection.<br>• Sediment retention - Silt fences should be used around all the downstream site earthwork boundaries and within the site around each subcatchment. These will work to slow water flow and retain sediments. Silt fences should also be provided on the downstream side of the access road where earthworks are proposed.<br>• Sediment settlement – prior to discharge, all collected stormwater shall be directed by temporary drains through sedimentation ponds.<br>• To minimise any potential adverse environmental effects from flooding or erosion (inclusive of land or watercourses) from the stormwater discharge from the operation of the steamfield and plant. |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| | Power Plant – Worker's Camp | A package plant will be used by the EPC Contractor that will treat sewage and wastewater during the construction phase. |
| | Reinjection pipeline construction activities - earthworks during construction | The ESCP recommendations for the power plant location will also apply with the following additional mitigation to manage specific risk activities for the reinjection pipeline:<br>• Staging – The works should progress in stages where possible to minimise the amount of bare earth. This is likely to include clearing the route in sections with installation of settlement retention features for each section before pipeline construction in that section. The next sections should not be cleared till works are ready to progress.<br>• Clean water diversions – overland flow paths going through work areas should be directed directly through the pipeline corridor and not allowed to travel down the cleared pipeline route to minimise erosion.<br>• Sediment retention - Silt fences should be used around all the downstream pipeline route boundaries. These will work to slow water flow and retain sediments. Silt fences should also be provided on the downstream side of the access road where earthworks are proposed.<br>• Temporary stream crossings – where streams will be regularly crossed temporary protection should be installed (culverts) to minimise direct disturbance and sediment generation. These should be removed after works are complete. |
| | Reinjection pipeline construction activities - discharge of sewage and site amenity wastewater | • Portable toilets will be installed and used by workers to prevent contamination of waterways. |

## 2.4 Operational Mitigation

**Table 2.2 : Summary of proposed mitigation during operation**

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| Air quality | All power plant operation activities related to emissions and dust control | The O&M Contractor will ensure the following:<br>• Routine maintenance checks will be undertaken on wellheads and blowout prevention equipment to check it is in operable condition.<br>• If a wet cooling tower system is to be used for the Project, drift eliminators will be incorporated into the final design to minimise particulate emissions.<br>• Impacts from the operational station will be dependent on the geothermal fluid chemistry and the plant design. Given the predicted level of effects is predicted to be at an acceptable level, additional measures such as total or partial re-injection of gases with geothermal fluids; and abatement systems to remove hydrogen sulphide emissions from NCGs (e.g. wet/dry scrubbers), are not required. |
| Cultural Heritage | All Project operation activities | The O&M Contractor will ensure the following:<br>• The mitigation measures employed during operation will be the same as those described above for construction (Table 2.1), namely the implementation of the Chance Find Procedure if an asset of cultural heritage value is discovered as part of the operational activities of the power plant or transmission line<br>• The Worker's Code of Conduct used during operation will also include a section on the importance of cultural heritage preservation and understanding. |
| Environmental and Social Management Systems (ESMS) | All Project operation activities | • The O&M Contractor will operate the power plant and will be responsible for recordkeeping and reporting, maintenance inspections, execution of routine maintenance, periodical maintenance and major overhaul in accordance with the Project ESMS, and emergency stop of operation and incident reporting. The O&M Contractor will prepare separate operation management plans and procedures that align with the Project ESMS. The O&M Contractor will also develop an overall organisational structure for environmental responsibilities on site. DGDC will have responsibility for reviewing and auditing the O&M Contractor's documents.<br>• The O&M Contractor, in collaboration with DGDC, will establish, maintain, and strengthen as necessary an organisational structure that defines roles, responsibilities and authority to implement the ESMS and ESMP. Specific personnel with clear lines of responsibility and authority are designated in this section. Key ESMS responsibilities are defined and will be communicated to the relevant personnel and to the rest of the O&M Contractor workforce as well as DGDC and any Subcontractors. Sufficient management sponsorship and human and financial resources will be provided on an ongoing basis to achieve effective and continuous ESMS performance.<br>• Reporting of mitigation activities will be issued by DGDC to the Lenders every 6 months in the Biannual Environmental and Social Report. |
| Geothermal Resource | All Project operation works | The O&M Contractor will ensure that the Reservoir Management Procedure will be implemented during operation that considers all possible change that may occur to the deep reservoir and the surface thermal activity. |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| Hydrology | Power plant operation activities | The O&M Contractor will ensure the following:<br>• Power plant site and laydown area will have a stormwater system designed to capture and treat any runoff.<br>• The power plant's stormwater system will drain through a sump or settling pond. This would capture any runoff from the pad and settle out rubbish and sediment, while reducing flow velocities.<br>• Diversion drains will be installed around the site, the capacity of these drains needs to convey adequate flood events to reduce the likelihood of this occurring.<br>• Sourcing a water supply for firefighting will be infrequent, however would require >500 $m^3$ stored in a tank. |
| Hazardous Substances and Waste | All Project operation activities | The O&M Contractor will ensure the following:<br>• Heat and pentane sensors will be fitted around the storage tank and the plant to detect any leaks and heat changes.<br>• A deluge fire extinguishment system is suppled which when activated will quickly extinguish any fire. |
| Natural Hazards | All Project activities – subsidence | The O&M Contractor will ensure a Subsidence Management Plan will be prepared and implemented. |
| Noise and Vibration | Power plant operation activities | The O&M Contractor will ensure the following:<br>• Commissioning testing should be conducted during daytime periods only.<br>• Erect temporary localised screening during commissioning testing. Potential noise impact reduction of up to 6 dB(A) is achievable where acoustic screens are located within 5 m of the construction works, be at least 300 mm above the height of the noise source and provide a solid façade impeding line of sight to nearest receivers – any gaps negate noise reduction performance.<br>• Notify local residents and landowners prior to any commissioning testing. |
| Landscape and Visual | All Project operation works | During operation it is proposed that the power plant site will be landscaped in order to improve visual amenity. Additionally, this will aid in limiting soil erosion at the site during heavy rainfall events. The soil removed during earthworks for construction will be reinstated and used as topsoil for the proposed landscaping.<br>Plants used for landscaping will be nursery grown and will be healthy and free from insect infestations. Trees and shrubs will be chosen in keeping with prevailing weather conditions and other such site characteristics. Maintenance operations will begin immediately after planting by mulching, watering, pruning, spraying, weeding and other necessary operations of maintenance. Planting beds will be kept free of weed, grass and other undesired vegetation growth. It is anticipated that vegetation will grow up around the power plant site quickly, given the climate and high rainfall in the valley. See Section 13 – Terrestrial Ecology and ESIA Volume 5: Appendices – Terrestrial Ecology Impact Assessment, for more recommendation regarding planting regimes and the use of a Habitat Management Plan.<br>The following recommendations are proposed for consideration for the buildings and power plant site:<br>• Any planted beds will be kept free of weeds and other undesired vegetation growth, as per the measures proposed in the Pest and Weed Management Plan. |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| | | • Site fencing has the potential to aid in mitigating adverse visual effects of the power plant by partially screening and softening the visual impact of the site and ensuring light spill from the site is minimised.<br>• Any lighting requirements should be designed to ensure light spill is directed into the construction and operation site.<br>• Where possible the selection of neutral/muted cladding and external finishing's would aid in limiting the extent of adverse visual impacts.<br>• Installation of drift elimination, if wet cooling towers options is selected to reduce particulate emissions and plume visibility.<br>The reinjection pipeline should be coloured so that it is conspicuous with the surrounding environment.<br>An overall recommendation is to make the public aware that potentially affected parties can use the public grievance mechanism. This will be monitored in accordance with the measures set out in ESIA Volume 3: Social Impact Assessment. |
| Social / Economic | All Project operation works | The mitigation for social and economic issues will be the same as that stated above during the construction phase, under the management of the O&M Contractor. |
| Soils, Geology and Groundwater | Power plant operation activities | The mitigation for soils, geology and groundwater issues will be the same as that stated above during the construction phase, under the management of the O&M Contractor. |
| Terrestrial Ecology | All operation activities | The O&M Contractor will ensure the following:<br>• Appropriate disposal of solid and liquid wastes, in line with recommendations in international and national standards, and using designated facilities as required.<br>• Any effluent discharged to surface watercourses must meet the more stringent of international water quality discharge standards prior to release to remove pollutants.<br>• Machinery and vehicles should be cleaned upon entry/exit, and any soil brought on or off site screened for invasive species or plant pathogens.<br>• Ensure all standard safe storage measures for n-pentane are implemented, as detailed in ESIA Volume 2: EIA, Chapter 15. |
| | All Project operation works - Post-Hurricane Maria Specific Actions | DGDC will implement a Habitat Management Procedure for the Project that will aim to provide enhancement measures for post-Maria terrestrial biodiversity. The Habitat Management Procedure will be the same as that set out above in Table 2.1. The O&M Contractor will assist in the facilitation of this Habitat Management Procedure. |
| MTPNP World Heritage Site | All operation activities | Mitigation measures are the same as those outlined above during construction, with the exception of the following (the O&M Contractor will be responsible for this):<br>• Standard safe storage for n-pentane includes storage under a nitrogen blanket; incorporation of a Pressure Relief Valve; appropriate bunding; and a deluge fire extinguishment system. Heat and pentane sensors are also fitted around the storage tank and the plant to detect any leaks and heat changes. |

| Issue | Location of Mitigation Measures | Proposed Mitigation Measures |
|---|---|---|
| Traffic Management | Power plant operation activities | • The O&M Contractor will implement a Traffic Management Plan will be distributed to staff to inform them of the best ways to travel to the sites of the Project. Staff should be encouraged to take public transport, car pool or that the contractor provides transport for them. |
| Working Conditions, Occupations and Safety | All operation activities | • The O&M Contractor will be required to develop an Occupational Health and Safety (OHS) Plans for the operation and maintenance of the Project, which will apply to all personnel involved in the Project, including subcontractors and part-time workers. The primary health and safety objectives will be to ensure effective measures and management of occupational health and safety to minimise workplace accidents and injuries. The health and safety procedures within the OSH Plans will comprise a comprehensive Health and Safety Management System. They will meet the requirements specified in the WBG Environmental, Health and Safety Guidelines pertaining to occupational safety and health. DGDC will be responsible for auditing and reviewing the document. Further details for the requirements of OHS Plans are presented in ESIA Volume 5: Technical Appendices, Technical Report – OHS and Working Conditions.<br>• As well as the main OHS Plans, specific Safety Management Systems shall be developed for each element of the Project, including the following:<br>- safety management organisation / reporting chain;<br>- construction methodology;<br>- hazard / risk assessment and proposed mitigation measures; and<br>- safety checklists.<br>• Each Safety Management System will have a procedure for identifying all hazards associated with the activity in question. A hazard in this context is defined as any aspect of the Project activities which could result in harm to onsite personnel.<br>• The O&M Contractor will establish a hierarchy of responsibility with regards for the provision of health and safety.<br>• Health and Safety Management Committee will be appointed by the O&M Contractor to evaluate health and safety at the site and to assess and recommend changes to equipment, policy and/or procedures where required by health and safety issues.<br>• O&M Contractor staff will be trained in safety procedures and provided with Personal Protective Equipment. Working conditions and occupational safety and health procedures framework has been outlined in the ESIA Volume 5: Appendices, Technical Report - Working Conditions, Occupational Safety and Health.<br>• The O&M Contractor's Worker's Grievance Mechanism and Worker's Code of Conduct will continue to run throughout operational period. |
| Water Quality and Aquatic Ecology | Power plant operation activities – discharge of treated wastewater | • During operation wastewater will be treated initially in a package plant. The package plant would be to a sand filter or similar medium that allows the treated effluent to infiltrate to ground below the soil surface and receive further treatment. This infiltration system should be located close to the edge of the power plant area to maximise distances to watercourses.<br>• The power plant's stormwater system should ideally drain through a sump or settling pond. This would capture any runoff from the pad and settle out rubbish and sediment, while reducing flow velocities. Areas of the plant that are at risk of having contaminant discharges (such as oil leaks from vehicles or fluid spills) should be isolated, with their flows first draining through an oil water separator. The outflows from this separator could then drain to the sump/settling pond for further treatment. |

### 2.4.1 Monitoring

A recommended monitoring program is set out in the ESMP which is designed to conduct sufficient monitoring in order to demonstrate compliance with GoCD regulatory discharge limits and ambient standards and the applicable WBG EHS Guidelines standards specified for the receiving environments (air, water, soil, etc.) and to assess the performance of containment and treatment systems at the power plant during construction and operation and for the construction of the reinjection line.

The Monitoring Procedures will set out the location of the sampling points, sampling methodology to be used (grab samples, automated etc.), number of samples to be collected each round, frequency of sampling, sample handling and preservation, parameters to be analysed for and analytical methods, and reporting requirements. This monitoring will include, but will not be limited to:

- Wastewater effluent-quality monitoring to ensure that effluent continues to meet the relevant WBG EHS Guidelines;
- Regular monitoring of water quality of stormwater discharged into the environment from the stormwater sumps, during all seasons;
- Biodiversity monitoring along reinjection route, wellpads and power plant;
- Slope stability and subsidence monitoring;
- Monitoring of geothermal features linked to the reservoir supplying the power plant;
- Noise and ambient air quality; and
- Social surveys and changes monitoring.

This environmental monitoring for the construction and operation phases is set out in Table 2.3 and Table 2.4. It should also be noted that it is anticipated that construction monitoring measures will also be implemented by DOMLEC during the construction and upgrading of Associated Infrastructure (see ESIA Volume 2: EIA, Section 18).

## 2.5 Construction Monitoring

**Table 2.3 : Monitoring activities during construction**

| Issue | Location of Monitoring | Proposed Monitoring Measures |
|---|---|---|
| General | All construction works | • Independent third-party auditing of the implementation of the ESMP will be undertaken at regular intervals. The budget for this auditing and its frequency will be specified in the ESMP and verified by the relevant regulators. |
| Air quality | All construction works | • To determine the effectiveness of dust mitigation measures used during construction, the EPC Contractor will ensure that ambient air monitoring is undertaken on the site boundary. DGDC will monitor the performance of the EPC Contractor. Sampling should be conducted for:<br>- Visual dust inspection of the site on a daily basis during the dry season to gauge the effectiveness of dust mitigation measures will occur at least 400m from construction works.<br>- The monitoring provides a means of ensuring control systems such as dust suppression sprays are operating correctly and should be undertaken by a qualified laboratory using appropriate sampling equipment. Visual inspections of cleaning truck tyres and road watering activities will also be monitored and recorded. The results will be reported on a monthly basis and included in publicly available reports.<br>• As part of good working practice the EPC Contractor will complete routine checks on dust generation from construction activities, and confirm that dust suppression and appropriate storage is being used where required. In addition, a mechanism for complaints regarding dust will be available to locals, and due regard given to any issues raised.<br>• Safety monitoring systems with warning alarms for high emissions of potentially hazardous gases, including $H_2S$, incorporated at the well sites (e.g. the power plant and reinjection sites), as well as providing direct safety measures in the event of a blowout, will highlight potential H2S emissions issues which could arise during well commissioning and operation. All personnel and local residents will be made aware of the procedure should an alarm be activated. |
| Cultural Heritage | All construction works | No monitoring measures are proposed during construction, with the exception of the EPC Contractor ensuring implementation of the Chance Find Procedure. |
| Environmental and Social Management System (ESMS) | All construction works | • The ESMS will set out DGDC's policies and procedures for managing, mitigating and monitoring environmental and social impacts. Monitoring will be carried out in order to determine whether environmental and social outcomes are being achieved. Monitoring requirements will be specified in a monitoring plan (or plans), which identify:<br>- The type of monitoring that is to be carried out including monitoring the performance of the EPC Contractor;<br>- Where monitoring is to take place;<br>- How frequently monitoring will be carried out;<br>- The parameters that will be tested for;<br>- The applicable objectives and performance standards; and<br>- Staff responsible for conducting the monitoring. |

| Issue | Location of Monitoring | Proposed Monitoring Measures |
|---|---|---|
| | | • DGDC will undertake reviews of the ESMS will be conducted throughout construction and operation of the Project and where necessary changes should be made to the documentation to ensure that it remains relevant. For instance, once construction has been completed, the construction related environmental and social aspects will no longer be relevant.<br>• DGDC will be responsible for overall monitoring and reporting every six months to relevant authorities regarding the findings of the reports.<br>• Reporting of monitoring activities will be issued by DGDC to the Lenders every 6 months in the Biannual Environmental and Social Report. |
| Hazardous Substances and Waste | All construction works | The EPC Contractor will ensure that:<br>• The amount and destination of the wastes will be recorded and monitored.<br>• A record of all spillages will be maintained.<br>• All bund enclosures will be regularly inspected for water and sheens prior to the collected water being discharged.<br>• Regular inspection of storage facilities to check for leaks, spills and inappropriate storage practices.<br>• As part of the Waste Management Procedure a monitoring plan will be developed to inspect waste collection skips, to check wastes are being separated correctly and hazardous wastes are not being included with non-hazardous. The inspection should also include a check of the waste skips and bins condition to be sure waste is being held securely and not able to impact the environment through leakage or being blown away.<br>• Regular inspections to check that wastes are being separated and deposited in the correct bins for recycling and disposal.<br>DGDC will monitor the performance of the EPC Contractor. |
| Hydrology | All construction works | The EPC Contractor will ensure that visual monitoring is undertaken at stream banks and the construction of diversion channels to identify any areas that may be performing inadequately (resulting in bank collapses, localised erosion hot spots and scouring). DGDC will monitor the performance of the EPC Contractor.<br>Prior and during construction it is recommended that monitoring of the flow rates be conducted at the small stream used for abstraction of water. |
| Geothermal Resource | Key geothermal sites | A Reservoir Monitoring Procedure (RMP) will be developed by DGDC and monitoring undertaken by DGDC staff. The RMP will consider all possible changes that may occur to the deep reservoir and the surface thermal activity. DGDC will ensure that a baseline monitoring programme is undertaken at selected natural geothermal features before the power plant is commissioned, to establish the natural seasonal variability of surface spring activity including flowrate, temperature and fluid chemistry. Springs can change over time so the baseline data is needed for objective assessment, post commissioning. |
| Natural Hazards | All construction works – risk of landslide | • The EPC Contractor will undertake monitoring during construction for identified geo-hazards of moderate or high landslide risk that have not been avoided. |
| Noise and Vibration | All construction works | • The EPC Contractor will undertake noise monitoring to confirm the actual construction noise levels at representative sensitive receiver locations should be undertaken, for example, adjacent to the power plant site). This monitoring should be carried out at the start of the construction of the Project and on a quarterly basis. DGDC will monitor the performance of the EPC Contractor. |

| Issue | Location of Monitoring | Proposed Monitoring Measures |
|---|---|---|
| | | • Direct observation of machine maintenance should also be made to ensure that any noise-creating faults are repaired. Direct observation of machine maintenance should be made to ensure that any noise-creating faults are repaired. |
| Water Quality and Aquatic Ecology | All construction works | The EPC Contractor will ensure the following:<br>• Inspection and maintenance – the ESCP shall specify who is responsible for inspecting all physical elements of the erosion and sediment control measures. These shall be inspected daily to ensure they are installed and working correctly. Any defects shall be rectified before earthworks occur in that area of the site. Accumulated sediment shall be removed from all features when it reaches 25% of the available space. Records of all inspection and maintenance shall be kept.<br>• Visual inspection of the river - the ESCP shall specify who is responsible for inspecting the river upstream and downstream of the works on a daily basis. The inspection should identify whether any visible change in water clarity or turbidity occurs after the site discharges. If no discharge is occurring the inspection should identify if any sediment builds up is obvious within the channel downstream of the site. If visible changes are observed, then modification of site operations and/or site erosion and sediment control practises should be made to reduce the impact. Records of all inspection and response activities shall be kept.<br>• The discharge from the sedimentation ponds should be monitored during rain events. At least once per month for total suspended solids for comparison with the discharge limit of 50 mg/l and to determine the effectiveness of the pond.<br>• Monitoring of treated effluent from the Workers' Accommodation package sewage treatment plant on a monthly basis.<br>• Prior and during construction it is recommended that water quality and ecological (i.e. aquatic invertebrates) monitoring will be conducted at the small stream used for abstraction of water.<br>DGDC will monitor the performance of the EPC Contractor. |
| Social | All construction works | • DGDC will monitor the number of people being employed by the Project in: 1) the three key villages (Laudat, Trafalgar and Wotten Waven) and 2) the wider Roseau Valley, against predicted numbers of employees.<br>• DGDC will undertake surveys to determine the number of new businesses generated by the development and the level of indirect employment.<br>• A DGDC Community Liaison Officer will be responsible for updating and monitoring the implementation of the RAP and Grievance Mechanism defined in the Stakeholder Engagement Plan.<br>• DGDC will undertake ongoing consultation and communication with the local community will be required particularly with PAPs, vulnerable groups and key stakeholder groups. The minutes of meetings and signed lists of attendees will be completed and documented.<br>• An independent third party review is recommended of the effective implementation of the RAP, one year after civil construction works commence at the power plant and reinjection line.<br>• The following will be monitored through on-site visits by DGDC on a quarterly basis:<br>- effectivity of the implementation of good practices as per World Bank HSE Guidelines;<br>- existence of access control;<br>- number of sanitation facilities available for men and for women at each construction site; and |

| Issue | Location of Monitoring | Proposed Monitoring Measures |
|---|---|---|
| | | - effectivity of access restriction measures along the transmission line and its towers.<br>• The DGDC Human Resources Department will monitor the following on a quarterly basis:<br>- effectivity of the implementation of good practices as per World Bank HSE Guidelines.<br>• The records are to be reported to DGDC and any applicable regulatory authorities who then can document and respond to this information as part of their responsibilities. |
| Soils and Groundwater | All construction works | • The EPC Contractor will undertake routine monitoring of any spring flows (cold water), both baseline and during development in order to determine any potential effects on the system. DGDC will monitor the performance of the EPC Contractor. |
| Terrestrial Ecology | All Project construction works - Post-Hurricane Maria Specific Actions | The Habitat Management Procedure (developed by DGDC) will provide baseline terrestrial biodiversity monitoring recommendations for the site. Although detrimental in general terms, the recent decimation of local habitats and ecosystems at least provides a clear baseline to develop a monitoring programme especially for forest recovery and the key animal groups that use it along with monitoring improvements of aquatic species in water courses. DGDC will be responsible for monitoring of the Habitat Management Procedure. |
| MTPNP World Heritage Site | All construction activities | • DGDC will develop a MTPNP monitoring programme will be implemented for the five key species considered Threatened by IUCN: giant ditch frog, imperial parrot, red-necked parrot, forest thrush, and a species of tree frog (*Eleutherodactylus amplinympha*), recommended to be at every six months from pre-construction until the completion of one year of construction, and annually thereafter for a minimum of five years of operation. The programme should also include the ongoing monitoring in the Laudat and Trafalgar area for any other potential impacts on the OUV of the WHS.<br>• The MTPNP monitoring programme will be agreed with input from the MTPNP managing authorities (National Parks Unit of the Division of Forestry, Wildlife and National Parks), and implemented prior to construction where appropriate. The monitoring programme outlined will enhance understanding of the ecology of the MTPNP and surrounding areas, and ensure that if any adverse effects on OUV were to occur, these would be detected in a timely manner and properly mitigated. |
| Traffic Management | All construction works | The EPC Contractor will undertake monitoring of construction traffic and traffic management measures to ensure compliance with the traffic management requirements outlined within the TMP. Activities to be monitored include:<br>• Construction traffic movements to ensure truck drivers use the designated routes;<br>• Traffic incidents/complaints from the public or officials to ensure that unpredicted changes in travel time due to incidents such as, for example traffic accidents, emergencies, natural disasters can be managed by specially trained personnel; and<br>• Public roads to ensure that the roads in the vicinity of the site are clean at all times of clay, slurry or materials from the site.<br>DGDC will monitor the performance of the EPC Contractor. |
| Working Conditions, Occupations and Safety | All construction works | • The EPC Contractor will undertake a schedule of regular safety inspections and monitoring of exposure to hazards. This will include the state of the site as well as the maintenance of equipment and a comparison to internationally published exposure guidelines.<br>• The EPC Contractor Site Manager shall instigate measures to correct non-conformance in safety performance found during safety checks and inspections. A record of the safety checks and inspections, and resulting actions, shall be provided to the Health and Safety Management Committee every month. |

| Issue | Location of Monitoring | Proposed Monitoring Measures |
|---|---|---|
| | | • DGDC, as principals, undertake independent audits of the EPC Contractor and their Subcontractor's Health and Safety performance to ensure that the health and safety practices as set out in their health and safety plans are being complied with. The audits will also check that no unsafe practices are being carried out at site. If unsafe practices are identified during the audits, work at the site should cease. The audits should be carried out once every two months.<br>• All staff at DGDC and the EPC Contractor should be notified of all incidents/accidents which result in first aid treatment during the soil improvement programme and the construction of the power plant. Minor incidents along with the incident/accident investigation report should be supplied to DGDC once a month. Serious accidents that are Lost Time Incidents, or result in serious harm or a fatality should be reported immediately to DGDC.<br>• Notification of accidents and incidents at the site during soil improvement and construction provide another means of monitoring the Contractor's safety performance.<br>DGDC will monitor the performance of the EPC Contractor. |

## 2.6 Operational Monitoring

**Table 2.4 : Monitoring activities during operation**

| Issue | Location of Monitoring | Proposed Monitoring Measures |
|---|---|---|
| Air quality | Power Plant operation activities | The O&M Contractor will ensure the following monitoring is undertaken during operation:<br>• Ambient monitoring for $H_2S$ can be easily undertaken at sensitive locations (e.g. nearby residential areas) using low-level ambient $H_2S$ monitors such as Odalog, which can be deployed at multiple locations for up to two months at a time.<br>• Safety monitoring systems with warning alarms for high emissions of potentially hazardous gases, including $H_2S$, incorporated at the well sites (e.g. the power plant and reinjection sites), as well as providing direct safety measures in the event of a blowout, will highlight potential $H_2S$ emissions issues which could arise during well commissioning and operation. All personnel and local residents will be made aware of the procedure should an alarm be activated.<br>• For the Organic Rankine Cycle option, there will be infrared heat detectors and pentane vapour monitors installed at the power plant site around the working fluid condenser/equipment and cooling tower, for early detection of any leaks of pentane or heat sources.<br>• All heat and pentane sensors if an ORC plant is selected will be checked and calibrated on an annual basis or as per the manufacturer's specifications.<br>DGDC will monitor the performance of the O&M Contractor. |
| Environmental and Social Management Systems (ESMS) | All Project operation activities | During operation, DGDC will monitor and audit the operational ESMS, as described above for construction activities. Reporting of monitoring activities will be issued by DGDC to the Lenders every 6 months in the Biannual Environmental and Social Report. |
| Geothermal Resource | Key geothermal sites | • The O&M Contractor will conduct regular a monitoring programme of selected natural geothermal features to determine any changes to that measured in the baseline monitoring outside seasonal variations. Springs can change over time so there is a need for objective assessment, post commissioning.<br>• During operation reservoir change (pressure, temperature and chemistry) will be monitored by O&M Contractor for regular testing of production wells.<br>• The Reservoir Management Plan will include a monitoring system (such as slimhole downhole pressure sensors) that will monitor reservoir pressure throughout operation, both at the production and reinjection wells. In the event of any significant changes in reductions in reservoir pressure, in the vicinity of WW-01 that may cause adverse change to thermal features, this will be mitigated in the first instance by adjusting the relative flows to WW-R1 and WW-01.<br>DGDC will monitor the performance of the O&M Contractor. |
| Hydrology | Settling ponds | The O&M Contractor will monitor the effectiveness of the settling pond on sediment should be undertaken during construction and ongoing operations, with spot samples assessed for Total Suspended Solids (TSS) at the inlet and outlet locations. Imhoff settling cones offer a cheap and viable method for quick onsite estimates of TSS from the inlet and outlet. |

| Issue | Location of Monitoring | Proposed Monitoring Measures |
|---|---|---|
| Hazardous Substances and Waste | Power plant operation activities | • To ensure the processes and procedures are operating effectively, the O&M Contractor will conduct regular audits of hazardous substance storage and the operation of the Hazardous Substance Management Plan. Audits will involve reviewing storage procedures, ensuring staff are appropriately trained and supervised, ensuring materials are stored and used in accordance with good international industrial practice, and identifying and recommending any areas for continual improvement.<br>• As part of the Waste Management Procedure a monitoring plan will be developed to inspect waste collection skips, to check wastes are being separated correctly and hazardous wastes are not being included with non-hazardous. The inspection should also include a check of the waste skips and bins condition to be sure waste is being held securely and not able to impact the environment through leakage or being blown away.<br>• Regular inspections to check that wastes are being separated and deposited in the correct bins for recycling and disposal.<br>DGDC will monitor the performance of the O&M Contractor. |
| Noise and Vibration | Power plant operation activities | • The O&M Contractor will measure noise levels on a quarterly basis at the power plant site and the nearest settlements for a duration of at least 48 hours. Results from this monitoring are to be used to assess compliance with Dominica guidelines (Environmental Standards for Protection against Noise (June 2003)) and the WBG EHS Guidelines and to be reported to the relevant authorities. Noise monitoring data should also be made available for public access.<br>• Power plant workers will make direct observation of machine maintenance should also be made to ensure that any noise-creating faults are treated. |
| Water Quality and Aquatic Ecology | Power plant operation activities | The O&M Contractor will ensure the following:<br>• Visual inspection of oil interceptors for visible oil and settling ponds.<br>• Monitoring of the discharge from oil interceptors and settling ponds every three months (with comparison to WBG EHS Discharge Guidelines)<br>• Monitoring of effluent discharged from the package plant every six months.<br>DGDC will monitor the performance of the O&M Contractor. |
| Social | All Project operation activities | The O&M Contractor and DGDC will ensure that the number of people being employed by the Project will be recorded and monitored from: 1) the three key Villages (Laudat, Trafalgar and Wotten Waven) and 2) the wider Roseau Valley, against predicted numbers of employees.<br>• Surveys should be conducted to determine the number of new businesses generated by the development and the level of indirect employment.<br>• A DGDC Community Liaison Officer will be responsible for updating and monitoring the implementation of the RAP and Grievance Mechanism defined in the Stakeholder Engagement Plan.<br>• Ongoing consultation and communication with the local community will be required particularly with PAPs, vulnerable groups and key stakeholder groups. The minutes of meetings and signed lists of attendees will be completed and documented.<br>• During the first four years of operation, on a quarterly basis, DGDC's department responsible for CSR will record the number of inhabitants of the three villages affected by the power plant to have received training, and nature of training received, disaggregated by age, sex and village/block.<br>• During the first four years of operation, on a quarterly basis, the number of regular and ad-hoc meetings with communities will be recorded, as well as the minutes of meetings and signed lists of attendees. |

| Issue | Location of Monitoring | Proposed Monitoring Measures |
|---|---|---|
| | | • During the first four years of operation, the number of consultations with PAPs and number grievances received, treated and solved will be recorded through minutes of meetings and signed lists of attendees.<br>• The Grievance database will be monitored with progress reported on a quarterly basis. |
| Soils and Groundwater | Power plant operation activities | The O&M Contractor will ensure routine monitoring of any spring flows (cold water) to be undertaken, both baseline and during development in order to determine any potential effects on the system. DGDC will monitor the performance of the O&M Contractor. |
| Terrestrial Ecology | All Project operation works - Post-Hurricane Maria Specific Actions | DGDC will develop a Habitat Management Procedure that will provide baseline terrestrial biodiversity monitoring recommendations for the site. |
| MTPNP World Heritage Site | All operation activities | • The monitoring programme during operation will be the same as that outlined above for construction. DGDC will be responsible for this monitoring programme. |
| Working Conditions, Occupational Health and Safety | All operation works activities | • The O&M Contractor OHS Plans and Health and Safety Management System will include a schedule of regular safety inspections and monitoring of exposure to hazards. This will include the state of the site as well as the maintenance of equipment and a comparison to internationally published exposure guidelines. Further details for the requirements of OHS Plans are presented in ESIA Volume 5: Technical Appendices, Technical Report – OHS and Working Conditions.<br>• The O&M Contractor Site Manager shall instigate measures to correct non-conformance in safety performance found during safety checks and inspections. A record of the safety checks and inspections, and resulting actions, shall be provided to the Health and Safety Management Committee every month.<br>• DGDC will undertake audits to check that no unsafe practices are being carried out at site. If unsafe practices are identified during the audits, work at the site should cease. The audits should be carried out once every two months.<br>• All staff at the O&M Contractor should be notified of all incidents/accidents which result in first aid treatment during the soil improvement programme and the construction of the power plant. Minor incidents along with the incident/accident investigation report should be supplied to DGDC once a month. Serious accidents that are Lost Time Incidents, or result in serious harm or a fatality should be reported immediately to DGDC.<br>• Worker occupational monitoring such as hearing and vision will be undertaken on an annual basis.<br>• All heat and pentane sensors if an ORC plant is selected will be checked and calibrated on an annual basis or as per the manufacturer's specifications.<br>• DGDC, as principals, undertake independent audits of the O&M Contractor Health and Safety performance to ensure that the health and safety practices as set out in their health and safety plans are being complied with. The audits will also check that no unsafe practices are being carried out at site. If unsafe practices are identified during the audits, work at the site should cease. The audits should be carried out once every two months. |

## 2.7 Budget for Implementation

The implementation responsibility and estimated budgets for each required management plan (where available) and action are provided in Table 2.5. The management procedures/plans to be implemented during construction by the EPC Contractor will be developed for reviews by DGDC; whereby commitments have been made in to adhere to the Applicable Standards and mitigations set out in this ESIA. As such Table 2.5 only sets out additional costs to be incurred by DGDC over the 18-month construction schedule. The below estimates include budgets for resources and equipment to implement the ESMP as well as conduct training, environmental and social monitoring, analysis and reporting. Estimates for the Operation Phase are provided on the assumption that the O&M contract is for 20 years.

**Table 2 5: Budget for ESMP Implementation**

| Item | Management Plan/Action | Responsibility | Estimate (EC $) |
|---|---|---|---|
| Pre-Construction | | | |
| 1 | Overarching Environmental and Social Management Systems preparation, institutional strengthening and implementation | DGDC | ~300,000.00. Note: this is funded under AfD grant |
| 2 | Construction Environmental and Social Management System/Plan | EPC | Under EPC Contract |
| 3 | Air Quality Management Procedure and Air Quality Monitoring | EPC | Under EPC Contract |
| 4 | Chance Find Procedure | EPC | Under EPC Contract |
| 5 | Health, Safety and Environmental Plans | EPC | Under EPC Contract |
| 6 | Waste Management Procedure including recycling | EPC | Under EPC Contract |
| 7 | Hazardous Substance Management Procedure | EPC | Under EPC Contract |
| 8 | Emergency Response Plan | EPC | Under EPC Contract |
| 9 | Pest and Weed Management Procedure | EPC | Under EPC Contract |
| 10 | Stormwater Management Procedure | EPC | Under EPC Contract |
| 11 | Construction Noise Management Procedure and Noise Monitoring | EPC | Under EPC Contract |
| 12 | Erosion and Sediment Control Procedure | EPC | Under EPC Contract |
| 13 | Habitat Management Procedure and monitoring | DGDC | |
| 14 | Traffic Management Procedure | EPC | Under EPC Contract |
| 15 | Occupational Health and Safety Management System preparation | Jacobs OE | ~20,000.00 |
| 16 | Construction Occupational Health and Safety Management System/Plan | EPC | Under EPC Contract |
| 17 | Stakeholder Engagement Plan, ongoing community consultation and grievance mechanism management | DGDC/EPC | Part of DGDC normal operational costs which is ~ 850,000 per annum |
| 18 | Monitoring and Inspection of EPC Contractor ESHS Performance | Jacobs OE | Under OE Contract |
| 19 | Workers Code of Conduct | EPC | Under EPC Contract |

| Item | Management Plan/Action | Responsibility | Estimate (EC $) |
|---|---|---|---|
| 20 | Landscape Management Plan and Biodiversity Restoration | EPC | Under EPC Contract |
| 21 | Landslide Stabilisation Risk Management | EPC | Under EPC Contract |
| 22 | Subsidence Management lan | EPC | Under EPC Contract |
| 23 | Community Development Fund | DGDC | TBA |
| 24 | Workforce Development Strategy | DGDC | Part of DGDC normal operational costs which is ~ 850,000 per annum |
| 25 | Corporate Social Responsibility Programme | DGDC | Part of DGDC normal operational costs which is ~ 850,000 per annum |
| 26 | Sexually Transmitted Disease Management Plan | EPC | Under EPC Contract |
| 27 | Monitoring implementation of ARAP and Grievance Mechanism | DGDC | Part of DGDC normal operational costs which is ~ 850,000 per annum. Additional support to be funded by A\fD. |
| 28 | Cultural Education Programme | EPC | Under EPC Contract |
| 29 | Baseline Monitoring of Natural Geothermal Features | DGDC | Part of DGDC normal operational costs which is ~ 850,000 per annum |
| 30 | MTPNP Monitoring Programme | DGDC | ~20,000.00 |
| 31 | Biannual Environmental and Social Reports | DGDC | Part of DGDC normal operational costs which is ~ 850,000 per annum |
| 32 | Third Party Auditing of ARAP implementation | DGDC | ~50,000.00 |
| Operation | | | |
| 1 | Subsidence Management Plan | O&M | Under O&M Contract. O&M costs to be funded from tariff estimated at USD 1 to 1.4m PA |
| 2 | Traffic Management Plan | O&M | Under O&M Contract. O&M costs to be funded from tariff estimated at USD 1 to 1.4m PA |
| 3 | Operation ESMS | O&M | Under O&M Contract. O&M costs to be funded from tariff estimated at USD 1 to 1.4m PA |
| 4 | Operation Occupational Health and Safety Plans | O&M | Under O&M Contract. O&M costs to be funded from tariff estimated at USD 1 to 1.4m PA |
| 5 | Annual Environmental and Social Reports | DGDC | Part of DGDC normal operational costs estimated at ~850,00 per annum. |
| 6 | Ongoing Consultation and Communication with Local Communities and Monitoring of Grievance Mechanism | DGDC | Part of DGDC normal operational costs estimated at ~850,00 per annum. |

| Item | Management Plan/Action | Responsibility | Estimate (EC $) |
|---|---|---|---|
| 7 | Monitor O&M Contractor ESHS Performance | DGDC | Part of DGDC normal operational costs estimated at ~850,00 per annum. |
| 8 | Routine Monitoring of Natural Geothermal Features | O&M | Under O&M Contract |
| 9 | Habitat Management Procedure and monitoring (once every 5 years) | DGDC | ~20,000.00 |
| 10 | MTPNP Monitoring (once 5 years after construction) | DGDC | ~20,000.00 |
| 11 | H&S Audits | DGDC | Part of DGDC normal operational costs estimated at ~850,00 per annum. |
| 12 | Worker Occupational Monitoring | O&M | Under O&M Contract |
| 13 | Air Quality Monitoring | O&M | Under O&M Contract |
| 14 | Reservoir Monitoring | O&M | Under O&M Contract |
| 15 | Noise Monitoring | O&M | Under O&M Contract |

## 2.8 UPDATING OF ESMP

This ESMP will be updated, revised and reviewed internally on regular basis as set out in the ESMS to ensure the management plans remain relevant and are effectively mitigating the risks set out in this ESIA.

The ESMP will be monitored and reviewed on a bi annual basis. Furthermore in the event of an unforeseen impact and design change with respect to the Project Standards (including the GOCD and World Bank), the ESMP would be updated as necessary.

# 3. Framework Environmental and Social Management System

## 3.1 Introduction

This section provides a framework for the Environmental and Social Management System (referred to hereafter as 'the ESMS') that establishes a methodological approach to managing environmental and social risks and impacts in a structured way, on a continuous basis. DGDC will be responsible for implementing the ESMS ensuring compliance with national regulatory and Project Sponsor requirements.

The ESMS ensures there are appropriate environmental and social policies and procedures in place and that people consistently follow them. A key feature is continual improvement – an ongoing process of reviewing, correcting and improving the system. The most common method is the Plan-Do-Check-Act cycle (PDCA), shown below in Figure 3.1.

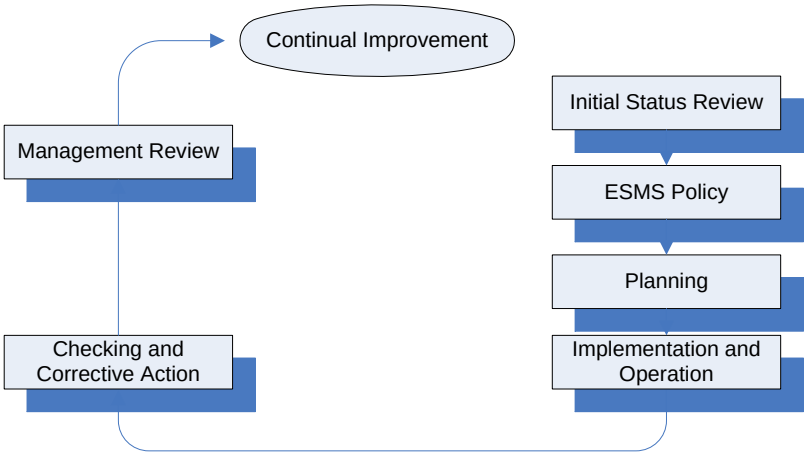


**Figure 3.1: Elements of the Programme ESMS**

The resources needed are planned, provided and managed to support the management plans and programs implemented during the project's lifecycle. Monitoring and measurements are done in order to track DGDC's and EPC Contractor's environmental and social performance, as well as feedback from the stakeholders. Information will be gathered from monitoring and measurements are analysed and presented to the DGDC Management Team. The DGDC Management Team will review and implement the Project ESMS and prepare plans for continual improvement of Project Sponsor's environmental and social performance.

The ESMS will be set out as follows:

- Overview of the ESMS;
- Organisational Roles and Responsibilities;
- Policies, Legal and Other Requirements;
- Identification of Risks and Impacts;
- Management programmes;
- Monitoring and Review;
- Stakeholder Engagement;
- Training; and
- Administration.

## 3.2 Structure of the ESMS

ESMSs are designed to establish a methodological approach to managing environmental and social risks and impacts in a structured way on a continuous basis. The structure of the ESMS that will be implemented for the construction and operation of the Project is shown in Figure 3.2 below:

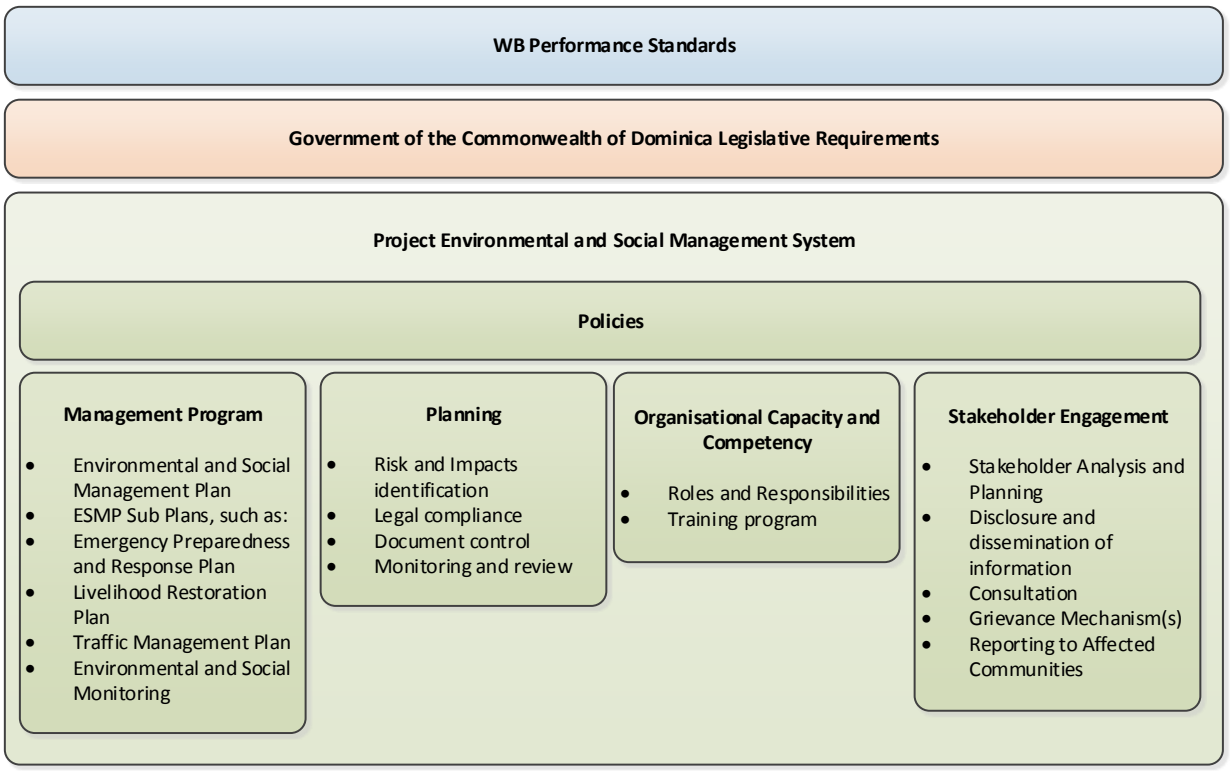


**Figure 3.2: Structure of ESMS**

## 3.3 Policies

### 3.3.1 DGDC's Environmental, Social, Health and Safety Policies

*DGDC is committed to protect the health and safety of those who play major parts in our operations, and those who live in areas where they operate or use our products. Wherever we operate, we will conduct our business with respect and care for both the local and global environment and systematically manage risks so as to ensure a sustainable business growth. We will not be satisfied until we manage to eliminate any injury, occupational illness, unsafe practices and incidents of environmental harm from our activities.*

*To fulfil this commitment DGDC will ensure the social, environmental and health and safety statements outlined below are implemented and adhered to.*

***Social***

- *Support the long-term development of the communities DGDC serve.*
- *A work environment free of harassment or discrimination on the basis of gender, physical or mental state, race, nationality, religion, age, family status or sexual orientation, or any other attribute recognised by the laws of the country in which the Company operates.*

- *A culture of respect, trust and mutual understanding fostered through open, two-way communication, positive encouragement of employees' participation in discussions and willingness to discuss issues and concerns raised at any level in the organisation.*

***Environment***

- *Comply fully with all applicable environmental laws and regulations.*
- *Ensure that all key environmental impacts are identified and managed in a responsible manner.*
- *Continuously improve our environmental performance.*
- *Monitor and report the environmental performance of our business.*
- *Provide the training and resources necessary to meet our environmental responsibilities.*

***Health and Safety***

- *That all employees and contractors understand that working safely is a condition of employment, and they are responsible for their own safety and safety of those around them.*
- *Manage all projects through their life-cycles in a way that protects safety and health and minimizes their impacts on the environment.*
- *Work with governments and stakeholders where we operate in order to develop regulations and standards aiming at improving people's safety and health and the environment.*
- *Maintain a secure work environment to protect ourselves, our contractors and company's assets from injury, property loss or damage resulting from hostile acts.*
- *Communicate our commitment in this policy to our contractors.*

Separate plans relating to assessment, monitoring and control of environmental and social aspects will be prepared by the EPC Contractor, once they are appointed. These plans will align with DGDC's ESMS, which will cover both construction and operation phases.

## 3.4 Alignment with the World Bank Performance Standard

In accordance with World Bank Performance Standard 1 the structure of the ESMS incorporates the following elements, as shown in Table 3.1:

**Table 3.1: Alignment with the World Bank Performance Standard (PS) 1**

| WLG PS 1 for ESMS | Description |
|---|---|
| Policy | Policies that define DGDC's environmental and social commitment/objectives and the principles that guide the project to achieve sound environmental and social performance are described in Section 3.4. |
| Identification of Risks and Impacts | The process for identifying and assessing environmental and social risks is described in ESIA Volume 1: Introduction, ESIA Volume 2: EIA and ESIA Volume 3: SIA. The primary mechanism is the completion of an Environmental and Social Impact Assessment for the construction and operation of the Project. |
| Management Programmes | The management programmes used to mitigate potential environmental and social risks and impacts are described in ESIA Volume 4: ESMP, Framework ESMS and Assessment Against WB Standards. This includes preparation of an ESMP, which will contain procedures/plans to address specific issues in the appropriate level of detail. |
| Capacity/Competency | The roles, responsibilities and authorities for implementation of the ESMS are defined in Section 3.5 and training requirements are described in Section 3.11. |
| Emergency Preparedness/Response | Emergency preparedness and response is addressed in ESIA Volume 5: Technical Appendices, Technical Report – Working Conditions, Occupational Health and Safety, as part of the Management Programmes that are applicable to the construction and operation of the Project. |

| WLG PS 1 for ESMS | Description |
|---|---|
| Monitoring and Review | Section 3.9 describes the monitoring that will be carried out to ensure environmental and social performance standards are being met and the ESMS is being implemented effectively. |
| Stakeholder Engagement<br>Communications and Grievances<br>Reporting to Affected Communities | An overview of stakeholder engagement is provided in Section 3.10, which addresses:<br>• Stakeholder analysis and planning<br>• Disclosure and dissemination of information<br>• Consultation and participation<br>• Grievance mechanism<br>• Reporting to affected communities. |

The ESMS is a 'living' document, which will be reviewed and updated in accordance with the ESMS Management Review Procedure to ensure it maintains its relevance. At a minimum the ESMS will be reviewed before commencing each new phase of work and on an annual basis.

## 3.5 Roles and Responsibilities

### 3.5.1 Construction Phase

Management of environmental and social risks and impacts during construction will primarily be the responsibility of the EPC Contractor through the EPC Contract.

During the construction phase, DGDC will review and monitor the EPC Contractor's performance in accordance with the DGDC's Occupational Health and Safety (OHS) performance standards and related management plans/procedures to ensure alignment with the overall Project ESMS. Further details for the requirements of OHS Plans are presented in ESIA Volume 5: Technical Appendices, Technical Report – OHS and Working Conditions. DGDC is responsible for reporting every six months to relevant authorities regarding the findings of the reports.

The key personnel responsible for ensuring good environmental practice on site during construction will be confirmed once the EPC Contractor has been appointed.

### 3.5.2 Operation and Maintenance (O&M) Phase

The O&M Contractor will operate the power plant and will be responsible for recordkeeping and reporting, maintenance inspections, execution of routine maintenance, periodical maintenance and major overhaul in accordance with the Project ESMS. The O&M Contractor will prepare separate operation management plans and procedures that align with the Project ESMS. he O&M Contractor will also develop an overall organisational structure for environmental responsibilities on site.

he O&M Contractor will establish, maintain, and strengthen as necessary an organisational structure that defines roles, responsibilities and authority to implement the ESMS and ESMP. Specific personnel with clear lines of responsibility and authority are designated in this section. Key ESMS responsibilities are defined and will be communicated to the relevant personnel and to the rest of the O&M Contractor team. Sufficient management sponsorship and human and financial resources will be provided on an ongoing basis to achieve effective and continuous ESMS performance.

Example roles and responsibilities are described in Table 3.2. However, these will need to be confirmed prior to construction/operation of the Project.

**Table 3.2: Example roles and responsibilities for implementation of ESMS**

| Role | Responsibilities |
|---|---|
| Project Manager | • Review and approve strategic Project HSE Policy and Objectives.<br>• Approve the Project environmental protection plan and other procedures.<br>• Define roles, responsibilities and provide resources for ensuring that environmental requirements are implemented and maintained in all areas of Project activities.<br>• Ensure that Project Environmental Management System is managed in a structured manner throughout the site organization.<br>• Ensure sufficient resources are available to support the implementation of the Project Environmental Management System.<br>• Review suitability and effectiveness of the Project Environmental Management System, etc. |
| Environmental Control Supervisor | • Ensure that the environmental requirements are established, implemented and maintained across the Project site activities, specifically including:<br>  • Identification and assessment of environmental aspects.<br>  • Environmental objectives, targets and environmental management program.<br>• Develop and maintain environmental documents (e.g. Project environmental plan and control plans or procedures) and records.<br>• Monitor adherence to the Project environmental policy & objectives, alerting management of non-compliance, and providing advice on remedial actions, through environmental audits, reviews, inspections etc.<br>• Monitor and verify closeout of actions arising from environmental audits.<br>• Report periodically to the Project management on the performance of the Project environmental management system. |
| HSE Manager | • The HSE Manager has an overarching responsibility for the management, monitoring, inspection, and reporting of HSE aspects during construction/operation. The HSE Manager will have the knowledge, skills, and experience necessary to perform their work, including up-to-date knowledge of GoCD legislation and the international requirements as listed in Legal Requirements Register. The HSE Manager will also possess the knowledge, skills, and experience to implement the specific measures and actions required under the ESMS. |

| Role | Responsibilities |
|---|---|
| Operations Manager | The Operations Manager has overall responsibility for the construction of the Project and associated infrastructure. In particular, the Operations Manager will:<br>• Maintain an awareness of the applicable GoCD legal requirements, potential HSE implications, and relevant operational controls among the construction workers.<br>• Manage implementation of standard operational procedures for implementing the ESMS.<br>• Communicate the latest work programme to the HSE Manager on a daily basis to effectively manage and monitor the potential HSE risks and impacts associated with the upcoming works.<br>• Ensure the ESMS is communicated, implemented, and maintained by the Operations Contractor and any Subcontractors. This includes:<br>a) Reviewing and approving training plans.<br>b) Ensuring appropriate training is carried out for employees.<br>c) Reviewing and approving the site's Emergency Preparedness and Response Plan. Further details of the outline of an Emergency Response Plan are located in ESIA Volume 5: Technical Appendices, Technical Report - Occupational Health and Safety and Working Conditions.<br>d) Reviewing and approving the monitoring programme and HSE mitigation measures onsite, and implementing corrective and/or preventive actions in accordance with the operational control procedures.<br>e) Monitoring compliance with the ESMS Periodically evaluating the effectiveness of the ESMS.<br>f) Delegating a clear line of responsibility for HSE protection to the EPC Contractor and any.<br>g) Subcontractors |
| Community Liaison Officer | The Community Liaison Officer will act as DGDC's representative to the affected communities and external stakeholders. DGDC will establish a clear reporting structure among the Community Liaison, Project Manager, Site Manager, HSE Manager and other relevant senior staff to effectively respond to stakeholder concerns and to manage reputational risks for the Project. |
| All other employees | All personnel employed for the operation of the Project are responsible for carrying out their roles in accordance with the ESMS. |

## 3.6 Legal and Other Requirements

An important component of identifying and evaluating relevant environmental and social risks and impacts is defining the legislative framework within which the Project will operate. This includes Dominica National legislation and international requirements such as the World Bank Performance Standards. Details on these standards are provided within Volume 1 of the ESIA.

## 3.7 Identification of Risks and Impacts

To appropriately manage the Project, an understanding of the potential risks and impacts that may affect the environmental, social, health and safety aspects is required. The outcomes of this ESIA will be incorporated into the ESMS.

During construction and operation of the Project there will be ongoing monitoring of environmental and social aspects, reviews of compliance with the ESMS and an evaluation of the effectiveness of the ESMS. These monitoring events and reviews provide opportunities to review the environmental and social aspects of the project, determine whether the appropriate controls are working or need to be improved. In addition, they will help to identify any new aspects. This process is summarised in Figure 3.3.

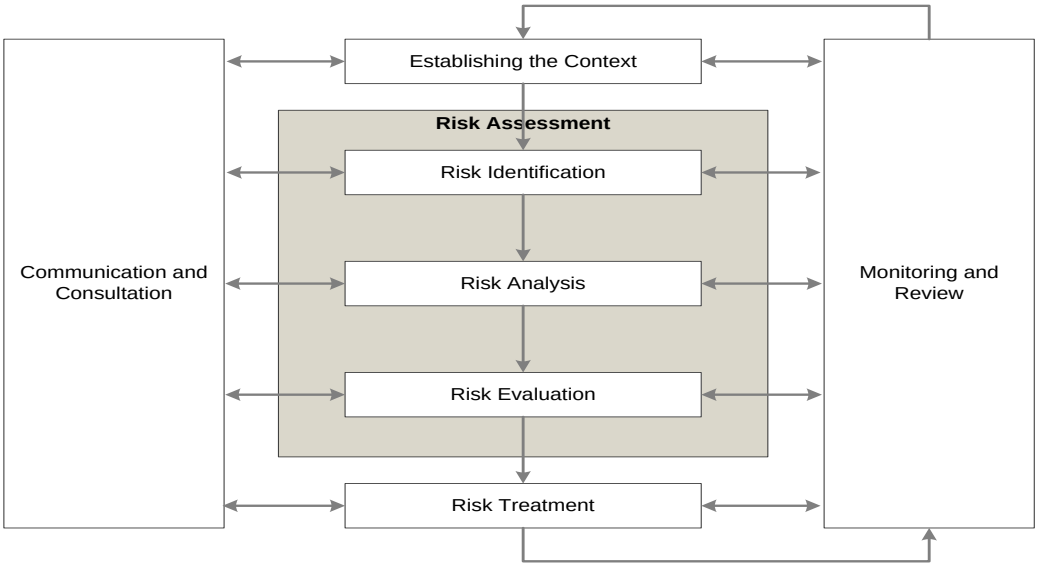


**Figure 3.3 : Risk Assessment Process**

All relevant project environmental and social aspects will be captured in the Aspect Registers: an example of this is provided in ESIA Volume 5: Technical Appendices. Any new aspects that are identified can then be assessed and rated in accordance with the risk rating systems described in ESIA Volume 5: Technical Appendices, and added to the Aspect Registers.

## 3.8 Management Programmes

### 3.8.1 Environmental and Social Management Plan

The Environmental and Social Management Plan (ESMP) as outlined in Section 2 of this Report, describes and prioritises the actions needed to implement mitigation measures, corrective actions and monitoring measures necessary to manage the impacts and risks identified in this ESIA relevant to the Project.

### 3.8.2 Procedures

The ESMS provides a structure and procedures as to how the mitigation and monitoring measures as set out in the ESMP will be implemented. Procedures may include existing documents developed by the DGDC, or be developed by external parties. Procedures may include the following (as outlined in Figure 3.2):

- Environmental and social management;
- Planning;
- Health and safety;
- Organisational capacity and competency; and/or
- Stakeholder engagement.

**General Structure of Procedures**

The following general structure should be applied to all ESMS Procedures:

1) **Project Sponsor Statement:** Outlines the commitment of the Project Sponsors to good environmental and social practices. May make reference to existing statements, policies or procedures.

2) **Project Context:** Outlines the overall context of the project and the purpose of the procedure.
3) **Purpose of Procedure:** Outlines the purpose of the procedure and which other related documents should be read alongside it.
4) **Scope of Procedure:** Outlines the mitigation measures proposed by the procedure and what specific tasks the management, mitigation and or monitoring covers.
5) **Procedure Details:** Provides detailed guidance including the following:
    a) Roles and responsibilities in relation to activities for both the Project Sponsors and any subcontractors;
    b) Definition of keys terms;
    c) Schedule of works;
    d) Verification and monitoring;
    e) Reporting of non-conformities;
    f) Details of training in relation to the procedure;
    g) Any forms that will accompany the procedure; and
    h) Auditing of procedure.

### 3.8.3 Contract Management

A Contractor Management Procedure is required that establishes the necessary environmental, social and health and safety criteria for EPC Contractors, Subcontractors and contracted services. This is very important given that the construction will be contracted to an external party and the operation and maintenance of the Project will be partly contracted to external service providers. Recommended procedural information for reporting includes:

- Contract Risk Assessment;
- Contract Pre-Qualification;
- Contractor Safety, Health, Environment, and Community Management;
- Contractor Register; and
- Contract Close-out.

These should be supported by a register of contractors, which includes information on pre-qualification requirements and contractor approvals.

## 3.9 Monitoring and Review

### 3.9.1 Monitoring of Environmental and Social Aspects

The ESMS will set out DGDC's policies and procedures for managing, mitigating and monitoring environmental and social impacts. Monitoring will be carried out in order to determine whether environmental and social outcomes are being achieved. Monitoring requirements will be specified in a monitoring plan (or plans), which identify:

- The type of monitoring that is to be carried out;
- Where monitoring is to take place;
- How frequently monitoring will be carried out;
- The parameters that will be tested for;
- The applicable objectives and performance standards; and

- Who will conduct the monitoring.

### 3.9.2 ESMS Review

Reviews of the ESMS will be conducted throughout construction and operation of the Project and where necessary changes should be made to the documentation to ensure that it remains relevant. These reviews as a minimum should be undertaken very six months during construction and annually for the operation phase.

### 3.9.3 ESMS Auditing

Routine auditing will be carried out to determine the level of compliance with the ESMS and evaluate the effectiveness of the ESMS. A procedure will be developed along with an auditing programme to define:

- Timing;
- Scope;
- Audit criteria;
- Reporting of audit findings; and
- Process for implementing corrective actions.

An audit checklist should be produced to maintain consistency if different auditors are utilised.

## 3.10 Stakeholder Engagement

The purpose of stakeholder engagement is primarily for transparency to the community, to inform them of the Project and associated construction activities, and the impacts it has on them and the environment. This provides an avenue for stakeholders to understand the Project impacts, how the impacts are being managed. A key aim of the stakeholder engagement is to provide stakeholder the opportunity for comment. Their comments/views will be considered by DGDC.

A Stakeholder Engagement Plan (SEP) has been prepared for the Project (refer to ESIA Volume 3: Social Impact Assessment). These will address the requirements described in the following sections.

### 3.10.1 Stakeholder analysis and planning

In order to conduct effective engagement some analysis is required of the type of stakeholders and the best means of communication with them with regards to the project and its potential impacts. Particular attention should be paid to vulnerable or disadvantaged groups.

### 3.10.2 Disclosure and dissemination of information

Disclosure of relevant project information helps potentially affected communities understand the potential risks, impacts and opportunities of the project. DGDC should provide such people with access to relevant information on:

- The purpose, nature, and scale of the project;
- The duration of proposed project activities;
- Any risks to and potential impacts on such communities and relevant mitigation measures;
- The envisaged stakeholder engagement process; and
- The grievance mechanism.

In addition, DGDC will need to prepare and maintain a procedure for external communications that includes methods to

- Receive and register external communications from the public;
- Screen and assess the issues raised and determine how to address them;
- Provide, track, and document responses, if any; and
- Adjust the management program, as appropriate.

DGDC are also encouraged to make publicly available periodic reports on their environmental and social sustainability.

### 3.10.3 Consultation and participation

Consultation with potentially affected communities and individual stakeholders will ensure they have an opportunity to provide input on the Project, its potential impacts, possible alternatives and the proposed mitigation and monitoring measures. The extent and nature of engagement activities will depend upon the nature of degree of effects.

### 3.10.4 Grievance mechanism

A grievance mechanism should be established to enable potentially affected communities to air their concerns and grievances about the DGDC's environmental and social performance. The grievance mechanism should be scaled to the risks and adverse impacts of the Project; should seek to resolve concerns promptly, using an understandable and transparent consultative process that is readily accessible, and at no cost to such affected communities. The mechanism should also ensure there is no retribution to the party that originated the issue or concern.

### 3.10.5 Reporting to affected communities

DGDC should provide periodic reports to the potentially affected communities describing progress in implementation of project actions that involve or may impact on them as well as addressing issues that the communities have raised.

## 3.11 Training

DGDC shall identify the knowledge and skills necessary for implementation of the ESMS and identify training requirements for its personnel and contractors engaged during the construction and operation of the Project.

All persons responsible for undertaking work during the life of the project must be trained on the contents of the ESMS. Training shall include, but is not limited to:

- Definition of the environment;
- Need for environmental protection and conservation;
- Impacts of construction activities on the environment;
- Adequate mitigation measures against such impacts;
- Emergency preparedness and response plan (further details of the outline of an Emergency Response Plan are located in ESIA Volume 5: Technical Appendices, Technical Report - Occupational Health and Safety and Working Conditions);
- Social responsibility during construction e.g. being considerate to local residents;
- Project ESMS policy and objectives;
- The Project ESMP;
- Health and Safety Management System; and

- Current applicable laws and regulations.

A Training Procedure should be developed that includes:

- Inductions (identifying different types that may be required);
- Training needs identification;
- Training schedule;
- Assessment of competency;
- Recognition of prior learning;
- Evaluation of training; and
- Records.

All training information, records and certificates should be properly documented and filed. An audit of the ESMS is likely to seek verification that all project personnel have been given the appropriate training. This will require a comprehensive training/induction register.

## 3.12 Administration

### 3.12.1 Human Resources

DGDC shall develop human resources (HR) policies and procedures which are consistent with the requirements of World Bank Performance Standards and Dominica national labour laws. The HR policy and manual will provide standard compliance with local labour laws, a description of functions/positions and requirements, general benefits, and give guidance on employee's selection, hiring and promoting procedures.

All employees will receive a copy of this manual at their first day at work. The HR manual will include:

- Prohibition of any type of child and/or forced labour;
- The implementation of equal opportunity and non-discriminatory hiring and promotion policies;
- Description and full disclosure of the worker's/employees' rights and duties, including freedom of association and collective bargaining; and
- A non-retaliatory grievance mechanism to receive and process any complaints from employees on work related conflicts or issues.

Compliance with these policies and procedures will also be mandatory to all contractors, suppliers, and sub-contractors.

### 3.12.2 Document Control

Document control will be carried out in accordance with a Document Control Procedure, which will address the following:

- Controlled documents;
- Controlled document preparation;
- Document reference notation (document numbering);
- Review of documents;
- Approval of documents; and
- Document recording and removal.

A document register will be prepared to capture all relevant ESMS documents, spreadsheets, registers and maps.

### 3.12.3 ESMS Review and Auditing

As identified in Sections 3.9.2 and 3.9.3 there will be periodic reviews and audits of the ESMS. Any changes to ESMS documentation that result from these shall be made in accordance with the Document Control Procedure outlined in Section 3.12.2.

### 3.12.4 Reporting

DGDC shall report to the relevant financial institutions and government authorities on the implementation of ESMS as required. Progress reporting by the EPC Contractor to DGDC will also be carried out as required.

## 3.13 Environmental Aspects Register

The environmental aspects will be scored using the rating system set out in the Tables 3.1-3.3 below. Each aspect is assigned a rating for likelihood and another for consequence, which are used to determine the significance. An example of an Aspects Register is included in Table 3.4: it is anticipated that this will be used as a template for the full Aspects Register to be included in the Project ESMS.

**Table 3.1 : Likelihood**

| Descriptor | Probability | Frequency | Historical |
|---|---|---|---|
| Almost Certain | >1 in 10 | Several times per year | Has occurred frequently in the company |
| Likely | Between 1 in 10 and 1 in 100 | About once per year | Has occurred once or twice in the company |
| Possible | Between 1 in 100 and 1 in 1,000 | Once in 1-10 years | Has occurred many times in the industry |
| Unlikely | Between 1 in 1,000 and 1 in 10,000 | Once in 10-100 years | Has occurred once or twice in the industry |
| Rare | <1 in 10,000 | < Once in a 100 years | Unheard of in the industry |

**Table 3.2: Consequence Rating**

| Descriptor | Safety | Cost | Schedule | Environment | Reputation |
|---|---|---|---|---|---|
| Catastrophic | 1 or more fatalities or total permanent disability | >$10M | >2 years change to schedule | Permanent impact, long term (decades) regional impact | Adverse global media coverage. Major stakeholders terminate. Company at stake. |
| Major | 1 or more partial disabilities | $1M-10M | 1-2 years to change to schedule | Long term (decades) local area impact. Medium term (years) regional impact | Adverse national media coverage. Company on notice |
| Moderate | Lost time injury | $100k-$1M | 6-12 months change to schedule | Medium term (years) local area impact. Short term(months) regional impact | Long term (weeks), local media and local interest |
| Minor | Medical attention, light duties | $10k-$100k | 2-6 months change to schedule | Short term (months) local area impact | Short term (days), local media and local interest |

| | | | | | |
|---|---|---|---|---|---|
| Insignificant | Minor injury/illness. First aid needed. No lost time injury | $0-$!0k | <2 months change to schedule | Temporary impact (days/weeks) to immediate area | Local interest only, quickly forgotten |

**Table 3.3: Significance Rating**

| Likelihood | Insignificant | Minor | Moderate | Major | Catastrophic |
|---|---|---|---|---|---|
| **Almost Certain** | Medium | High | High | Very High | Very High |
| **Likely** | Medium | Medium | High | High | Very High |
| **Possible** | Low | Medium | Medium | High | High |
| **Unlikely** | Low | Low | Medium | Medium | Medium |
| **Rare** | Low | Low | Low | Medium | Medium |

**Table 3.4: Example Aspects Register**

| Aspect/Activity | Impact | Location | Likelihood | Consequence | Significance | Mitigation | Likelihood | Consequence | Treated Significance |
|---|---|---|---|---|---|---|---|---|---|
| Vehicle transport of equipment and personnel | Emission of greenhouse gases through combustion of fossil fuel | Project site | Almost Certain | Insignificant | Low | Minimise vehicle movements. | Likely | Insignificant | Low |
| | Contamination of land, surface and groundwater from leaking fuel | Project site | Possible | Minor | Medium | Maintain vehicles in good working order to prevent leaks of oil and fuel | Unlikely | Insignificant | Low |
| | | | | | | Vehicles to carry spill kits | | | |
| | | | | | | All personnel to be provided spill response training as part of site induction. | | | |
| | Damage to terrestrial flora and fauna | Project site | Possible | Minor | Medium | Vehicles to travel along designated access tracks and avoid disturbing new areas as much as possible | Unlikely | Minor | Low |

| Aspect/Activity | Impact | Location | Likelihood | Consequence | Significance | Mitigation | Likelihood | Consequence | Treated Significance |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Minimise vehicle movements.<br>Note the location, number and state (alive/dead) of any threatened species so that these may be clearly marked on a map | | | |
| | | | | | | Advise project staff during induction of the species that should be noted if encountered | | | |
| | Noise disturbance | Project site | Almost Certain | Insignificant | Medium | Vehicles primarily used during daylight hours | Possible | Insignificant | Low |
| | Disturb/displace community activities | Project site | Possible | Moderate | Medium | Regular/routine community consultation/communication to ensure awareness of works programme amongst villagers. | Possible | Minor | Medium |
| Vehicle transport of hazardous substances and waste | Spill/leak of hazardous substances (in particular n-pentane) and waste onto land or into water | Project site | Possible | Minor | Medium | Hazardous substances and waste to be transported in sealed containers | Unlikely | Minor | Low |
| | | | | | | Hazardous substances and waste placed in drip trays to | | | |

| Aspect/Activity | Impact | Location | Likelihood | Consequence | Significance | Mitigation | Likelihood | Consequence | Treated Significance |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | contain minor leaks/spills | | | |
| | | | | | | Vehicles to carry spill kits | | | |
| | | | | | | Prepare Spill Response Plan | | | |
| | | | | | | All personnel to be provided spill response training as part of site induction | | | |
| Travel on foot | Damage to flora and fauna | Project site | Possible | Insignificant | Low | Limit personnel to designated tracks and project areas where possible | Unlikely | Insignificant | Low |
| | | | | | | Instruct personnel not to interfere with local wildlife or vegetation | | | |
| | | | | | | Advise project staff during induction of the species that should be noted if encountered | | | |
| Vegetation clearance | Damage to flora and fauna | Project site, reinjection line & access tracks | Almost Certain | Moderate | Medium | Minimise vegetation clearance by using existing tracks where possible | Likely | Minor | Low |
| | | | | | | Advise project staff during induction of the species that should be noted if encountered | | | |

| Aspect/Activity | Impact | Location | Likelihood | Consequence | Significance | Mitigation | Likelihood | Consequence | Treated Significance |
|---|---|---|---|---|---|---|---|---|---|
| | Reduced visual amenity | Project site, reinjection line & access tracks | Likely | Minor | Medium | Minimise vegetation clearance by using existing tracks where possible | Possible | Minor | Medium |
| | Noise disturbance | Project site, reinjection line & access tracks | Likely | Minor | Medium | Regular/routine community consultation/communication to ensure awareness of works programme amongst villagers.<br>The use of machinery to create access tracks will be limited to daylight hours | Likely | Insignificant | Low |
| | Contamination of land, surface and groundwater from leaking fuel | Project site, reinjection line & access tracks | Possible | Minor | Medium | Maintain vehicles in good working order to prevent leaks of oil and fuel<br>Vehicles to carry spill kits<br>All personnel to be provided spill response training as part of site induction | Unlikely | Minor | Low |
| Earthworks | Reduced visual amenity | Project site, reinjection line & access tracks | Possible | Minor | Medium | Install screening measures | Possible | Insignificant | Low |
| | Erosion and sedimentation | Project site, reinjection line | Almost Certain | Minor | High | Prepare Erosion and Sediment Control Plan | Possible | Minor | Medium |

| Aspect/Activity | Impact | Location | Likelihood | Consequence | Significance | Mitigation | Likelihood | Consequence | Treated Significance |
|---|---|---|---|---|---|---|---|---|---|
| | | & Project site, reinjection line & access tracks | | | | Seeding of stockpiled soil to stabilise<br>Following completion of the exploration activities, assess whether disturbed areas such as access tracks are required for long term operations. Rehabilitate all disturbed areas not required for long-term operations using sterile seed mixes | | | |
| | Dust generation | Project site, reinjection line & access tracks | Almost Certain | Minor | High | Seeding of stockpiled soil to stabilise<br>Carry out watering of exposed areas and stockpiles as required to suppress dust.<br>Minimise size of exposed areas and stockpiles | Unlikely | Minor | Low |
| | Noise disturbance | Project site, reinjection line & access tracks | Likely | Minor | Medium | Regular/routine community consultation/communication to ensure awareness of works programme amongst villagers. | Likely | Insignificant | Medium |

| Aspect/Activity | Impact | Location | Likelihood | Consequence | Significance | Mitigation | Likelihood | Consequence | Treated Significance |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | The use of machinery to create access tracks will be limited to daylight hours | | | |
| | Contamination of land, surface and groundwater from leaking fuel | Project site, reinjection line & access tracks | Possible | Minor | Medium | Maintain vehicles in good working order to prevent leaks of oil and fuel<br>Vehicles to carry spill kits<br>All personnel to be provided spill response training as part of site induction | Unlikely | Minor | Low |
| Vegetation clearance | Damage to flora and fauna | Project site, reinjection line & access tracks | Likely | Minor | Medium | Minimise vegetation clearance<br>Rehabilitate all disturbed areas not required for long-term operations using sterile seed mixes | Possible | Insignificant | Low |
| | Wood wastage | Laydown Area and Power Plant | Unlikely | Minor | Low | Remove felled trees from the area and stockpile in an area where landowners and local communities can access them for building materials. | Unlikely | Minor | Low |
| | Reduced visual amenity | Project site, reinjection line | Likely | Minor | Medium | Minimise vegetation clearance | Possible | Insignificant | Low |

| Aspect/Activity | Impact | Location | Likelihood | Consequence | Significance | Mitigation | Likelihood | Consequence | Treated Significance |
|---|---|---|---|---|---|---|---|---|---|
| | | & access tracks | | | | | | | |
| | Disturb/displace community activities | Project site, reinjection line & access tracks | Likely | Minor | Medium | Identify and compensate landowners for use of their land<br>Regular/routine community consultation/communication to ensure awareness of works programme amongst villagers. | Likely | Insignificant | Medium |
| | Noise disturbance | Project site, reinjection line & access tracks | Likely | Minor | Medium | Regular/routine community consultation/communication to ensure awareness of works programme amongst villagers.<br>The use of machinery for vegetation clearance will be limited to daylight hours | Likely | Insignificant | Medium |
| | Contamination of land, surface and groundwater from leaking fuel | Project site, reinjection line & access tracks | Possible | Insignificant | Low | Maintain vehicles in good working order to prevent leaks of oil and fuel<br>Vehicles to carry spill kits | Unlikely | Insignificant | Low |

| Aspect/Activity | Impact | Location | Likelihood | Consequence | Significance | Mitigation | Likelihood | Consequence | Treated Significance |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | All personnel to be provided spill response training as part of site induction | | | |
| Construction / installation of temporary buildings | Reduced visual amenity | Laydown Area and Power Plant | Possible | Insignificant | Low | Introduce screening measures | Possible | Insignificant | Low |
| | Noise disturbance | Laydown Area and Power Plant | Likely | Minor | Medium | The use of machinery to construct temporary buildings will be limited to daylight hours | Possible | Insignificant | Low |
| Lighting | Disturb local residents and fauna | Laydown Area and Power Plant | Almost Certain | Insignificant | Medium | Position lighting to shield adjacent dwelling as much as possible | Possible | Minor | Low |
| | | | | | | Turn off all unnecessary lighting at night to avoid attracting migratory birds | | | |
| Storage of equipment and machinery | Contamination of land and/or groundwater from fuel leaking from vehicles | Laydown Area and Power Plant | Possible | Minor | Medium | Maintain vehicles in good working order to prevent leaks of oil and fuel | Unlikely | Minor | Low |
| | | | | | | Drip trays placed under fuel tanks | | | |
| | | | | | | All personnel to be provided spill response training as part of site induction | | | |

| Aspect/Activity | Impact | Location | Likelihood | Consequence | Significance | Mitigation | Likelihood | Consequence | Treated Significance |
|---|---|---|---|---|---|---|---|---|---|
| | Reduced visual amenity | Laydown Area and Power Plant | Possible | Insignificant | Low | Low | Introduce screening measures | Insignificant | Low |
| Storage of hazardous substances | Spill/leak of hazardous substances causing contamination of land and/or groundwater | Laydown Area and Power Plant | Possible | Moderate | Medium | Hazardous substances stored in a location where they are:<br><br>1) Secure<br>2) Covered<br>3) In sealed containers<br>4) Inside a bunded container with sufficient capacity to contain a spill | Unlikely | Minor | Low |
| | | | | | | Spill response plan in place | | | |
| | | | | | | All personnel provided spill response training as part of site induction | | | |
| | | | | | | Spill kits available in all locations where hazardous substances are kept. | | | |
| | Fire resulting in explosion | Laydown Area and Power Plant | Possible | Moderate | Medium | Store flammable substances away from ignition sources | Unlikely | Moderate | Medium |

| Aspect/Activity | Impact | Location | Likelihood | Consequence | Significance | Mitigation | Likelihood | Consequence | Treated Significance |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Smoking prohibited when in close proximity to hazardous substances | | | |
| | Reaction of hazardous substances causing explosion | Laydown Area and Power Plant | Possible | Moderate | Medium | Store incompatible substances separately | Unlikely | Moderate | Medium |
| Storage of general waste | Poor waste management may lead to littering and contamination of land | Laydown Area and Power Plant | Likely | Minor | Medium | Install bins to collect general waste<br>Separate food waste and provide to locals as animal feed if desired. If not, food waste is to be buried | Unlikely | Minor | Low |
| Storage of hazardous waste | Spill/leak of liquid waste causing contamination of land and/or groundwater | Laydown Area and Power Plant | Possible | Minor | Medium | Separate hazardous waste from general waste<br>Hazardous waste stored in a location where it is:<br><br>1) Secure<br>2) Covered<br>3) In sealed containers<br>4) Inside a bunded container with sufficient capacity to contain a spill | Unlikely | Minor | Low |

| Aspect/Activity | Impact | Location | Likelihood | Consequence | Significance | Mitigation | Likelihood | Consequence | Treated Significance |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Spill response plan in place<br>All personnel provided spill response training as part of site induction<br>Spill kits available in all locations where hazardous substances are kept. | | | |
| Washing down vehicles, equipment and drilling casings | Contamination of land and/or groundwater | Laydown Area and Power Plant | Likely | Minor | Medium | Use biodregadable cleaning agents where necessary | Unlikely | Minor | Low |
| Refuelling | Contamination of land, surface and groundwater | Laydown Area and Power Plant | Possible | Moderate | Medium | Refuel in designated refuelling areas only<br>Drip trays and bunding to be in place at refuelling areas at all times<br>Personnel instructed in use/handling of substances and in spill response.<br>Spill kits to be held at refuelling location(s) | Unlikely | Moderate | Medium |
| Domestic camp activity | Noise disturbance | Laydown Area and Power Plant | Likely | Insignificant | Medium | All personnel to behave in accordance with code of conduct | Unlikely | Insignificant | Medium |

| Aspect/Activity | Impact | Location | Likelihood | Consequence | Significance | Mitigation | Likelihood | Consequence | Treated Significance |
|---|---|---|---|---|---|---|---|---|---|
| Use of generators | Emission of greenhouse gases through combustion of fossil fuel | Laydown Area and Power Plant | Almost Certain | Insignificant | Medium | Minimise the number of generators<br>Minimise use of generators by switching them off where possible | Likely | Insignificant | Medium |
| | Noise disturbance | | Almost Certain | Insignificant | Medium | Minimise the number of generators<br>Provision of manufacturer specified mufflers. | Likely | Insignificant | Medium |
| Ablutions | Contamination of land, surface and groundwater | Laydown Area and Power Plant | Almost Certain | Insignificant | Medium | Install and maintain septic tank | Unlikely | Insignificant | Low |

# 4. Assessment Against with World Bank Performance Standards

The purpose of the ESIA is to identify and assess key environmental and social impacts of the Project. The technical data provided within the ESIA, will also provide the basis for assessing the Project against and the World Bank Performance Standards for Private Sector Activities (2013), and they are shown in Table 4.1 below.

**Table 4.1 : Assessment of the Project against the WBG Performance Standards for Private Sector Activities (2013)**

| Performance Standard | Objectives | Comment |
|---|---|---|
| 1. Assessment and Management of Environmental and Social Risks and Impacts | • To identify and evaluate environmental and social risks and impacts of the project.<br>• To adopt a mitigation hierarchy to anticipate and avoid, or where avoidance is not possible, minimize, and, where residual impacts remain, compensate/offset for risks and impacts to workers, Affected Communities, and the environment.<br>• To promote improved environmental and social performance of clients through the effective use of management systems.<br>• To ensure that grievances from Affected Communities and external communications from other stakeholders are responded to and managed appropriately.<br>• To promote and provide means for adequate engagement with Affected Communities throughout the project cycle on issues that could potentially affect them and to ensure that relevant environmental and social information is disclosed and disseminated. | • The ESIA has been undertaken in accordance with PS1.<br>• The ESIA provides a summary of a large amount of technical assessment work assessing the environmental and socio-economic impacts and risks of the Project.<br>• Where possible, environmental impacts have been minimized and avoided in the design through technology choice, power plant siting and route selection for the reinjection line, as discussed in ESIA Volume 1: Introduction, Section 4.<br>• A Grievance Mechanism has been proposed to enable effective and efficient response to grievances raised, as provided in the SEP which is contained in ESIA Volume 5: Technical Appendices.<br>• The Grievance Mechanism was socialised within the community during the 2017 community consultation meetings.<br>• Consultation with Affected Communities is being undertaken in accordance with the SEP for the Project (refer to ESIA Volume 3: SIA, Section 5 and ESIA Volume 5: Technical Appendices). Affected Communities will also be consulted with as part of the Abbreviated Resettlement Action Plan (ARAP) (ESIA Volume 5: Technical Appendices). |
| 2. Labour and Working Conditions | • To promote the fair treatment, non-discrimination, and equal opportunity of workers.<br>• To establish, maintain, and improve the worker-management relationship.<br>• To promote compliance with national employment and labour laws.<br>• To protect workers, including vulnerable categories of workers such as children, migrant workers, workers engaged by third parties, and workers in the client's supply chain.<br>• To promote safe and healthy working conditions, and the health of workers.<br>• To avoid the use of forced labour. | • All Occupational Health and Safety (OHS) systems for the Project will be developed and implement that meet the requirements of Performance Standard 2.<br>• Technical Report – Working Conditions, Occupational Safety and Health (ESIA Volume 5: Technical Appendices) outlines the working conditions and occupational health and safety procedures for the Project.<br>• Working conditions will comply with local regulatory requirements, International Labour Organisation Guidelines, as well as any additional initiatives that are part of the normal approach adopted by the organisation involved at each phase of the Project.<br>• OHS systems will contribute towards improved working conditions.<br>• A Worker's Grievance Mechanism has been prepared and will be implemented for the construction and operation phases. This is contained in Technical Report – |

| Performance Standard | Objectives | Comment |
|---|---|---|
| | | Working Conditions, Occupational Safety and Health (ESIA Volume 5: Technical Appendices)<br>• Labour will be employed in accordance with Dominica labour laws, which prohibit the use of force and child labour. |
| 3. Resource Efficiency and Pollution Abatement | • To avoid or minimize adverse impacts on human health and the environment by avoiding or minimizing pollution from project activities.<br>• To promote more sustainable use of resources, including energy and water.<br>• To reduce project-related GHG emissions. | • Resource efficiencies have been summarised in ESIA Volume 1: Introduction, Section 4 regarding Project justification, and have been considered throughout the Project design and technology selection decisions.<br>• Environmental and social impacts associated with pollution have been assessed in ESIA Volume 2: EIA and ESIA Volume 3: SIA of this ESIA and mitigation measures have been proposed.<br>• GHG reduction measures are outlined in ESIA Volume 2: EIA, Section where total GHG emissions are estimated to be 9,462 tonnes CO2-e per year for the Project. With reference to the 25,000 tonnes CO2-e per year threshold for the requirement of publically reporting of GHG emissions, it is not considered necessary to report annually on GHG emissions. The total CO2-e per year is considered to be significantly less than a fossil fuel derived energy source and therefore the Project is considered to have Moderate Beneficial significant impact. |
| 4. Community Health, Safety and Security | • To anticipate and avoid adverse impacts on the health and safety of the Affected Community during the project life from both routine and non-routine circumstances.<br>• To ensure that the safeguarding of personnel and property is carried out in accordance with relevant human rights principles and in a manner that avoids or minimizes risks to the Affected Communities. | • The health, safety and security of Affected Communities could potentially be impacted by the Project. This ESIA has been prepared with consideration to the impacts on these Affected Communities.<br>• Incidents in the construction and operation of the power plant that have the potential for offsite consequences have been assessed and are regarded as being acceptable (refer to ESIA Volume 2: EIA).<br>• ESIA Volume 3: SIA outlines the potential impacts, and a range of mitigation measures have been recommended to reduce impacts on communities to a Minor (acceptable) significance level, including controlling access, developing emergency response procedures, and implementing disease prevention measures.<br>• Under the recommended mitigation measures, Security Guards will be trained on human rights issues, and the Project will coordinate with local government security forces on human rights and security matters. |

| Performance Standard | Objectives | Comment |
|---|---|---|
| 5. Land Acquisition and Involuntary Resettlement | • To avoid, and when avoidance is not possible, minimize displacement by exploring alternative project designs.<br>• To avoid forced eviction.<br>• To anticipate and avoid, or where avoidance is not possible, minimize adverse social and economic impacts from land acquisition or restrictions on land use by (i) providing compensation for loss of assets at replacement cost and (ii) ensuring that resettlement activities are implemented with appropriate disclosure of information, consultation, and the informed participation of those affected.<br>• To improve, or restore, the livelihoods and standards of living of displaced persons.<br>• To improve living conditions among physically displaced persons through the provision of adequate housing with security of tenure at resettlement sites. | • Construction and operation of the plant will require the acquisition of land for the power plant itself and for associated infrastructure.<br>• Development of the power plant site and reinjection route pipeline will result in the acquisition of up to 11 properties either partially or in their entirety, and as a result cause physical displacement of three households and economic displacement of four farmers.<br>• For construction of the power plant, reinjection route and associated infrastructure, two full properties at the power plant and a portion of six other properties along the reinjection line would need to be acquired. This would include three structures, one of which is residential, one intended for residential use and one used for livestock. These properties would be directly displaced by the Project footprint. In addition, three of the properties are in close proximity to the power plant site expected to be affected by noise, construction and visual impacts and are thus being considered for resettlement.<br>• The six properties impacted by the construction of the reinjection route would only require acquisition of a portion of the property to accommodate a 10 m corridor. As the percentages required of each property are generally small, there is still an opportunity to minimise resettlement/livelihoods impacts during the design phase by placing the reinjection line route in the areas of least impact within each property.<br>• Along with experiencing physical displacement, some of the parties affected by resettlement for the proposed power plant site and the reinjection pipeline route may experience economic displacement effects as many of the affected properties include agricultural crops, livestock, and trees.<br>• For land acquisitions and resettlement associated with the power plant footprint, noise impacts, and the reinjection pipeline, an Abbreviated Resettlement Action Plan (ARAP) has been prepared which will provide guidance for addressing land acquisition and resettlement impacts, in line with WB Performance Standard 5.<br>• The ARAP has been developed in consultation with affected parties and as well as providing where appropriate and / or cash compensation and livelihood restoration measures including consideration of those considered to be severely affected and or vulnerable. |

| Performance Standard | Objectives | Comment |
|---|---|---|
| | | • The ARAP has also addressed any impacts associated with livelihood restoration (i.e. those affected through economic displacement).<br>• The process will be undertaken in accordance with the disclosure methods stipulated in the SEP. |
| 6. Biological Conservation and Sustainable Management of Living Natural Resources | • To protect and conserve biodiversity.<br>• To maintain the benefits from ecosystem services.<br>• To promote the sustainable management of living natural resources through the adoption of practices that integrate conservation needs and development priorities. | • This ESIA has assessed the impacts of the Project on biodiversity, including freshwater and terrestrial ecology in ESIA Volume 2: EIA and ESIA Volume 5: Technical Appendices, (MTPNP Impact Assessment and Terrestrial Ecology Impact Assessment).<br>• The proposed geothermal development is located approximately 450 m from the WHS boundary at the closest point. As such, an assessment of potential impacts on the WHS is required, consistent with the International Union for the Conservation of Nature (IUCN) World Heritage Advice Note on Environmental Assessment (IUCN, 2013). The ESIA contains a separate report to address this in ESIA Volume 5: Technical Appendices, (MTPNP Impact Assessment).<br>• A range of measures have been incorporated in the Project design, mitigation and monitoring to promote sustainable management of living resources, including minimizing habitat destruction through site and route identification; design and implement control procedures sediment, dust and noise impacts; and the design of a MTPNP monitoring programme will be implemented for the five key species considered Threatened by IUCN: giant ditch frog, imperial parrot, red-necked parrot, forest thrush, and a species of tree frog (*Eleutherodactylus amplinympha*). |

| Performance Standard | Objectives | Comment |
|---|---|---|
| 7. Indigenous Peoples | • To ensure that the development process fosters full respect for the human rights, dignity, aspirations, culture, and natural resource-based livelihoods of Indigenous Peoples.<br>• To anticipate and avoid adverse impacts of projects on communities of Indigenous Peoples, or when avoidance is not possible, to minimize and/or compensate for such impacts.<br>• To promote sustainable development benefits and opportunities for Indigenous Peoples in a culturally appropriate manner.<br>• To establish and maintain an ongoing relationship based on Informed Consultation and Participation (ICP) with the Indigenous Peoples affected by a project throughout the project's life-cycle.<br>• To ensure the Free, Prior, and Informed Consent (FPIC) of the Affected Communities of Indigenous Peoples when the circumstances described in this Performance Standard are present. | • As discussed in the ESIA Volume 3: SIA, PS7 is not considered to apply to the Project. This is because people living in the Project area are not categorised as indigenous. They are part of the mainstream society, and do not have any specific economic or cultural activity different from the rest of the society. They participate fully in the socioeconomic life of the society. |
| 8. Cultural Heritage | • To protect cultural heritage from the adverse impacts of project activities and support its preservation.<br>• To promote the equitable sharing of benefits from the use of cultural heritage. | • This ESIA assesses the impact of the Project on cultural heritage, and specifically in ESIA Volume 3: SIA, Section 7.<br>• No direct impacts on physical cultural heritage are anticipated as all known cultural artefacts are located outside the Project boundaries. It is also very unlikely that any cultural artefact will be found during earthworks activities.<br>• A Chance Find Procedure will be implemented by the EPC contractor and all its Subcontractors to address the risk of finding cultural heritage artefacts. A Code of Conduct for workers will also be developed by the EPC Contractor. |

## 4.1 Conclusion

This ESIA summarises a large amount of technical work undertaken to assess the impacts of the proposed Project. The ESMP sets out mitigation and monitoring actions that address the key environmental and social impacts identified in the analysis. Implementation of the mitigation, management and monitoring measures in the ESMP for each phase of the Project will ensure that the environmental and social impacts of the Project overall will be acceptable.

Dominica Geothermal Development Company Limited
*Powering a New Generation...*

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# Dominica Geothermal Development – Environmental and Social Impact Assessment

NZ Ministry of Foreign Affairs & Trade

## ESIA Volume 5: Technical Appendices

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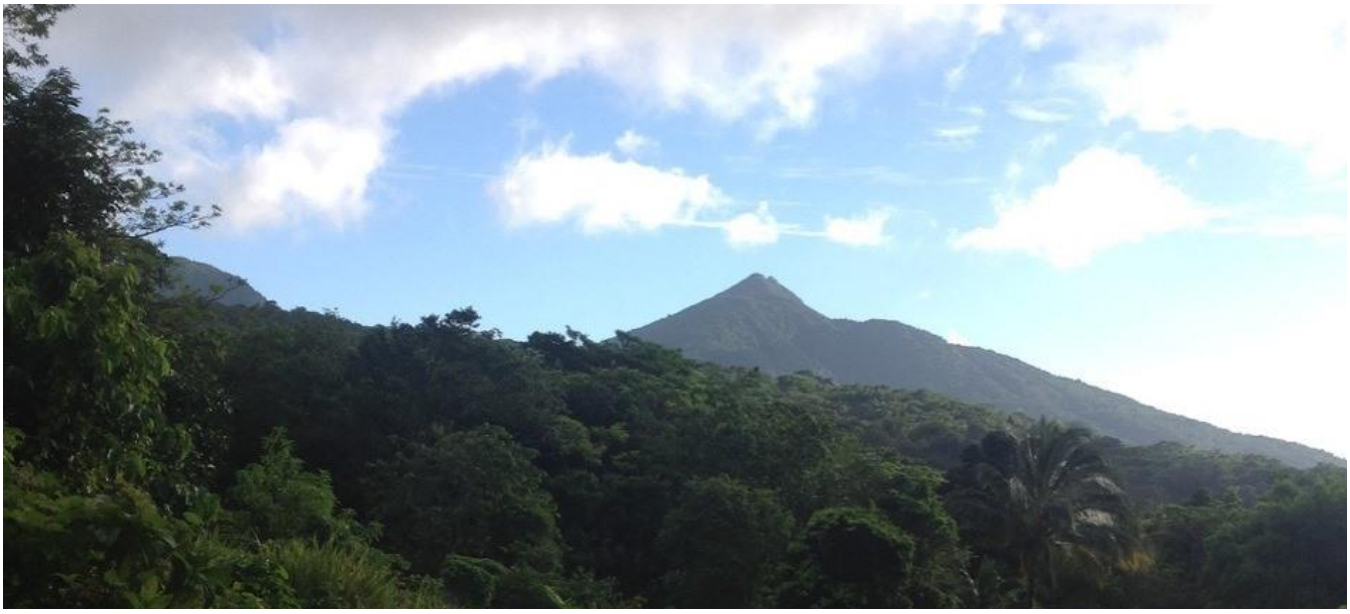

# Dominica Geothermal Development – Environmental and Social Impact Assessment

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# Introduction

ESIA Volume 5 provides Technical Appendices relevant to this ESIA and as referenced within ESIA Volume 1: Introduction, ESIA Volume 2: EIA, ESIA Volume 3: SIA and ESIA Volume 4: ESMP, Framework ESMS and Assessment Against WBG Standards. Table 1.1 below provides an overview of the Technical Appendices provided in this Volume and indicates which Volume (one to four) they predominantly are associated with. It should be noted that Appendices may be associated with other Volumes and this will be noted within the respective Volume text.

**Table 1.1 : ESIA Technical Appendices**

| ESIA Volume | Technical Appendix | Document Title |
|---|---|---|
| ESIA Volume 1: Introduction | Appendix A | WB Performance Standards |
| | Appendix B | Technical Report – Detailed Process Description |
| | Appendix C | ESIA Terms of Reference |
| | Appendix D | Biodiversity Survey Terms of Reference |
| ESIA Volume 2: EIA | Appendix E | Technical Report – Air Quality Impact Assessment |
| | Appendix F | Technical Report – Noise Impact Assessment |
| | Appendix G | Technical Report – Morne Trois Pitons National Park Impact Assessment |
| | Appendix H | Technical Report – Terrestrial Ecology Impact Assessment |
| | Appendix I | Occupational Health and Safety & Working Conditions |
| ESIA Volume 3: SIA | Appendix J | Stakeholder Engagement – Meeting Minutes |
| | Appendix K | Stakeholder Engagement Plan including Community Grievance Mechanism |
| N/A – Applies to all ESIA Volumes | Appendix L | *Caraïbes Environnement Développement & Coll 2015 – Final Summary Report |

*Due to file size only the Final Summary Report has been provided. If required the full report can be disclosed separately.

# Appendix A. WB Performance Standards

| Performance Standard | Objectives |
|---|---|
| 1 Assessment and Management of Environmental and Social Risks and Impacts | • To identify and evaluate environmental and social risks and impacts of the project.<br>• To adopt a mitigation hierarchy to anticipate and avoid, or where avoidance is not possible, minimize, and where residual impacts remain, compensate/ offset for risks and impacts to workers, Affected Communities, and the environment.<br>• To promote improved environmental and social performance of clients through the effective use of management systems.<br>• To ensure that grievances from Affected Communities and external communications from other stakeholders are responded to and managed appropriately.<br>• To promote and provide means for adequate engagement with Affected Communities throughout the project cycle on issues that could potentially affect them and to ensure that relevant environmental and social information is disclosed and disseminated. |
| 2 Labour and Working Conditions | • To promote the fair treatment, non-discrimination, and equal opportunity of workers.<br>• To establish, maintain, and improve the worker-management relationship.<br>• To promote compliance with national employment and labour laws.<br>• To protect workers, including vulnerable categories of workers such as children, migrant workers, workers engaged by third parties, and workers in the client's supply chain.<br>• To promote safe and healthy working conditions, and the health of workers.<br>• To avoid the use of forced labour. |
| 3 Resource Efficiency and Pollution Abatement | • To avoid or minimize adverse impacts on human health and the environment by avoiding or minimizing pollution from project activities.<br>• To promote more sustainable use of resources, including energy and water.<br>• To reduce project-related GHG emissions. |
| 4 Community Health, Safety and Security | • To anticipate and avoid adverse impacts on the health and safety of the Affected Community during the project life from both routine and non-routine circumstances.<br>• To ensure that the safeguarding of personnel and property is carried out in accordance with relevant human rights principles and in a manner that avoids or minimizes risks to the Affected Communities. |
| 5 Land Acquisition and Involuntary Resettlement | • To avoid, and when avoidance is not possible, minimize displacement by exploring alternative project designs.<br>• To avoid forced eviction.<br>• To anticipate and avoid, or where avoidance is not possible, minimize adverse social and economic impacts from land acquisition or restrictions on land use by (i) providing compensation for loss of assets at replacement cost4 and (ii) ensuring that resettlement activities are implemented with appropriate disclosure of information, consultation, and the informed participation of those affected.<br>• To improve, or restore, the livelihoods and standards of living of displaced persons.<br>• To improve living conditions among physically displaced persons through the provision of adequate housing with security of tenure at resettlement sites |
| 6 Biodiversity Conservation and Sustainable Management of Living Natural Resources | • To protect and conserve biodiversity.<br>• To maintain the benefits from ecosystem services.<br>• To promote the sustainable management of living natural resources through the adoption of practices that integrates conservation needs and development priorities |

| Performance Standard | Objectives |
|---|---|
| 7 Indigenous Peoples | • To ensure that the development process fosters full respect for the human rights, dignity, aspirations, culture, and natural resource-based livelihoods of Indigenous Peoples.<br>• To anticipate and avoid adverse impacts of projects on communities of Indigenous Peoples, or when avoidance is not possible, to minimize and/or compensate for such impacts.<br>• To promote sustainable development benefits and opportunities for Indigenous Peoples in a culturally appropriate manner.<br>• To establish and maintain an ongoing relationship based on Informed Consultation and Participation (ICP) with the Indigenous Peoples affected by a project throughout the project's life-cycle.<br>• To ensure the Free, Prior, and Informed Consent (FPIC) of the Affected Communities of Indigenous Peoples when the circumstances described in this Performance Standard are present.<br>• To respect and preserve the culture, knowledge, and practices of Indigenous Peoples. |
| 8 Cultural Heritage | • To protect cultural heritage from the adverse impacts of project activities and support its preservation.<br>• To promote the equitable sharing of benefits from the use of cultural heritage. |

# Appendix B. Technical Report – Detailed Process Description

Dominica Geothermal Development Company Limited
*Powering a New Generation...*

JACOBS

# Dominica Geothermal Power Project – Environmental and Social Impact Assessment

NZ Ministry of Foreign Affairs & Trade

## Process Description

RZ020300-0009-KH-RPT-0001 | V2

July 2018

# Dominica Geothermal Development – Environmental and Social Impact Assessment

| | |
|---|---|
| Project No: | RZ020300.09 |
| Document Title: | Process Description |
| Document No.: | RZ020300-0009-KH-RPT-0001 |
| Revision: | V2 |
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| Client Name: | NZ Ministry of Foreign Affairs & Trade |
| Project Manager: | Alastair Brookes |
| Author: | Peter Apperley / Chris Kiely |
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| | | | | | |

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## Important note about your report

The sole purpose of this report and the associated services performed by Jacobs New Zealand Limited ("Jacobs") is to describe the Environmental and Social Impact Assessment (ESIA) for the Dominica Geothermal Power Project in accordance with the scope of services set out in the contract between Jacobs and the New Zealand Ministry of Foreign Affairs and Trade (the Client). That scope of services, as described in this report, was developed with the Client, the Government of the Commonwealth of Dominica (GoCD) and the Developer (Dominica Geothermal Development Company (DGDC) established and owned by the GoCD).

Jacobs has been contracted by the Client to undertake the conceptual design and overall project definition through their engineering team. In preparing this ESIA report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided. Except as otherwise stated in the ESIA report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

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# Glossary

| Term | Description |
|---|---|
| Baseload power plant | Electricity-generating units that are operated to meet the minimum load on the electricity supply system. |
| Binary-cycle plant | A geothermal electricity generating plant employing a closed-loop heat exchange system in which the heat of the geothermal fluid (the "primary fluid") is transferred to a lower-boiling-point fluid (the "secondary" or "working" fluid), which is thereby vaporised and used to drive a turbine/generator set. |
| Brine | A geothermal solution containing appreciable amounts of sodium chloride and/or other salts. |
| Commercial Operation Date (COD) | The date after which all testing and commissioning has been completed and the developer can start producing electricity for sale. |
| Condensate | Liquid water formed by condensation of steam. |
| Condenser | Equipment that condenses turbine exhaust steam into condensate. |
| Cooling tower | A structure in which heat is removed from hot condensate through heat exchange with air. |
| Drilling | Boring into the Earth to access geothermal resources, usually with oil and gas drilling equipment that has been modified to meet geothermal requirements. |
| Dry steam | Superheated steam without a water phase. |
| Efficiency | The ratio of the useful energy output of a machine or other energy-converting plant to the energy input. Technology with a higher efficiency will require less energy to do the same amount of work. |
| Emission | The release or discharge of a substance into the environment; generally refers to the release of gases or particulates into the air. |
| Enthalpy | A measurement of energy in a thermodynamic system. It is the thermodynamic quantity equivalent to the total heat content of a system. It is equal to the internal energy of the system plus the product of pressure and volume. |
| Fault | A fracture or fracture zone in the Earth's crust along which slippage of adjacent rocks has occurred. |
| Flash plant | Pressure vessels designed to effectively separate flash steam from the liquid phase. |
| Flash steam / Flashing | Steam produced when the pressure on a geothermal liquid is reduced. Also called flashing. |
| Geothermal energy | The Earth's interior heat made available by extraction of geothermal fluids. |
| Geothermal power plant | A facility which uses geothermal steam or heat to drive turbine-generators to produce electricity. Three different types make use of the various temperature ranges of geothermal resources: dry steam, flash and binary. |
| Geothermal reserves | Energy from a geothermal resource that is commercially recoverable now |
| Geothermal reservoir | A large volume of underground hot water and steam in porous and fractured hot rock. The hot water in geothermal reservoirs occupies only 2 to 5% of the volume of rock, but if the reservoir is large enough and hot enough, it can be a powerful source of energy. Geothermal reservoirs are sometimes overlain by a layer of impermeable rock. While geothermal reservoirs usually have surface manifestations such as hot springs or fumaroles, some do not. |
| Geothermal resources | A resource of geothermal nature which requires further work to be classified as a geothermal reserve. |
| Geothermal well | Geothermal production and injection wells are constructed of pipes layered inside one another and cemented into the earth and to each other. This protects any shallow drinking water aquifers from mixing with deeper geothermal water. |

| Term | Description |
|---|---|
| Injection | The process of returning spent geothermal fluids to the subsurface; also referred to as reinjection. |
| Injection well | A well through which geothermal water is returned to an underground reservoir after use. |
| Kilowatt (kW) | One thousand watts of electricity (power). |
| Kilowatt hour (kWh) | One thousand watthours (energy). |
| Megawatt (MW) | A unit of power, equal to a thousand kilowatts (kW) or one million watts(W). The watt is a unit of power (energy/time), the rate energy is consumed or converted to electricity. Assessment of the energy in geothermal systems is commonly in terms of equivalent electrical power or MWe, which takes into account the efficiency of conversion. |
| Megawatts under wellhead | A technical measure of the supply of geothermal fluids available at the well head valve, presented in megawatts of electrical energy as proven through testing. |
| Morne Trois Pitons National Park (MTPNP) World Heritage Site | A World Heritage Site is a natural or man-made site or structure recognised as being of outstanding international importance by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) and therefore designated as a site deserving of protection under international treaties. |
| Operations and maintenance (O&M) cost | Operating expenses are associated with operating a facility (e.g. engineering costs). Maintenance expenses are that portion of expenses consisting of labour, materials, and other direct and indirect expenses incurred for preserving the operating efficiency or physical condition of utility plants that are used for power production, transmission, and distribution of energy. |
| Permeability | The capacity of a substance (such as rock) to transmit a fluid. The degree of permeability depends on the number, size, and shape of the pores and/or fractures in the rock and their interconnections. It is measured by the time it takes a fluid of standard viscosity to move a given distance. |
| Production well | A well through which geothermal water is extracted from an underground reservoir to use in the generation of electricity. |
| Proven geothermal reserves | Defined as the electricity that can be generated and sold with reasonable certainty over the project life. Commonly used units are Mega Watt-hour. |
| Separator | A pressure vessel used to separate water and steam, normally by centrifugal action. |
| Slim hole | A geothermal exploration well which is drilled at a smaller diameter than a standard production well |
| Steam | The vapour form of water that develops when water boils. |
| Subsidence | A sinking of an area of the Earth's crust due to fluid withdrawal and pressure decline. |
| Surface Exploration | Scientific activities to investigate the geothermal reservoir using non-invasive techniques. Typically surface exploration will include geology, geochemistry, geophysics and aerial surveys. |
| Transmission line | Structures and conductors that carry bulk supplies of electrical energy from power-generating units. |
| Turbine | A machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction, or a mixture of the two. |
| Well logging | Assessing the geologic, engineering, and physical properties and characteristics of geothermal reservoirs with instruments placed in the wellbore. |
| Wellhead pressure | A measure of the pressure of geothermal fluids being produced by the geothermal reservoir as measured at the valve opening from the wellhead. |

# 1. Introduction

## 1.1 Document Purpose

The purpose of this document is to describe the process of constructing, operating and decommissioning a 7 $MW_e$ Geothermal Power Plant on the island of Dominica (the Project) in order to inform the environmental and social impact assessment (ESIA) to be undertaken prior to construction of the Project. This is required in accordance with local legislation and international lending institution safeguards.

## 1.2 Structure

The structure of this document is set out as follows:

- **Project Background** – a brief overview of the project history
- **Reservoir information** – the known conditions of the geothermal reservoir
- **Project Overview** – description of the proposed Dominica geothermal development, covering:
    - Power plant technology – an overview of the Organic Rankine Cycle and Steam Flash power plant technology options for converting the energy in the geothermal steam and/or brine to electrical energy.
    - Geothermal steamfield equipment – the layout and equipment of the preferred steamfield design.
    - Supporting infrastructure – water, roads and other infrastructure necessary to facilitate the Project development.
    - Electrical equipment and interconnection – overview of the indoor switch room and associated equipment, and the proposed interconnection to the DOMLEC grid.
    - Hazardous substances – overview of hazardous substances found on a typical geothermal plant and the method and location of disposal.
- **Construction** – activities required for the engineering design, procurement, and construction of facilities to support the geothermal project. The project will use the wells which have already been drilled and tested. As such this document assumes no drilling of new wells in advance of operation.
- **Operation** – activities required to operate and maintain the facility with the goals of maximising plant availability and providing reliable supply to DOMLEC. Monitoring and management of the geothermal reservoir is a component of this phase, and environmental emissions mostly occur as a result of plant operation.
- **Decommissioning** - activities required to decommission the above ground facilities and remediate the site to an agreed level. This may include plugging and abandoning geothermal wells.
- **Potential Environmental Issues from Activities** – review of issues as a result of construction, operation and decommissioning.

# 2. Project Background

The Commonwealth of Dominica is a small island developing state in the Caribbean Sea with a population of approximately 72,000 people and a land area of approximately 750 km$^2$. About 60% of the land is classified as a World Heritage site by UNESCO, due to its rich biodiversity. It is located near the centre of a string of islands known as the Lesser Antilles, between the neighbouring French territories of Martinique and Guadeloupe. The capital Roseau is located to the south-west of the island and has a population of around 15,000 people.




**Figure 2-1 : Map of Dominica and Caribbean islands**[1]

As with many other island nations, Dominica's primary source of electricity production is from diesel generation, which exposes the country's economy to uncertainty in regard to the cost and supply of diesel imports. Changing the power generation mix and reducing the cost and volatility of electricity prices have become development priorities for Dominica. Being a relatively young volcanic island, Dominica has significant geothermal resource potential. Therefore, since 2006 the Government of the Commonwealth of Dominica (GoCD) has pursued an exploration programme to evaluate the viability of geothermal resource in the Roseau Valley (Figure 2-2).

Geothermal power projects typically connect production wells through a steamfield facility to a power plant which, in turn, is connected to an electricity grid. Geothermal energy extracted from below the ground may take the form of steam, hot water (brine) or a combination of both, and often a quantity of non-condensable gases (mostly carbon dioxide, but also some hydrogen sulphide). Used geothermal fluids produced by the project are returned to the geothermal reservoir via injection wells, which may be located some distance away (i.e. over 1 km) from the production wells.

[1] http://www.locationcaribbean.com/caribbean-map

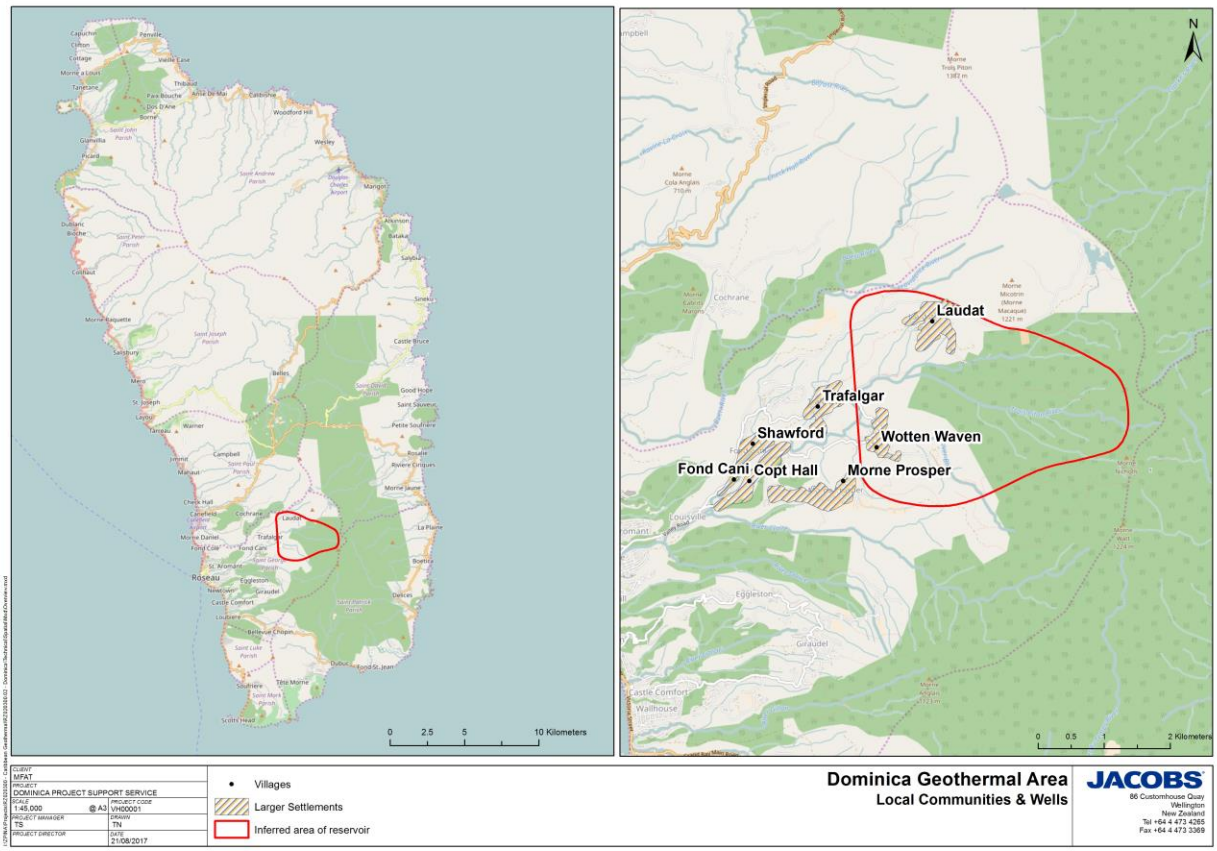


**Figure 2-2 : Location of Roseau Valley (Site of proposed Geothermal Power Plant in Laudat)**

The Dominica geothermal resource was extensively investigated by the GoCD between 2008 and 2013, with the support of the European Development Fund and the French Development Agency. Three exploratory wells were drilled from December 2011 to June 2012, characterising the reservoir as follows:

- A shallow depth with the top expected to occur at an approximate elevation of 0 m above sea level.
- Medium to high permeability and measured temperatures in the liquid dominated section in the range of 220 – 246°C.
- The lateral extent was conservatively estimated at a minimum surface area of about 9 km2 and thickness assumed to be around 1,000m.

The resource estimate undertaken by ELC[2] in 2013 indicated a 50% probability of a gross plant capacity of 91 $MW_e$, with a 90% probability of at least 57 $MW_e$ for the inferred area of the reservoir. This gave confidence that the field could be developed to serve the electrical power needs of the island, and potentially electricity could be exported to neighbouring islands via sub-sea cables. Two further wells were drilled in 2013 – 14 and provided evidence of an exploitable geothermal resource at the wellhead.

Having successfully carried out exploration, the Government now wishes to complete the Project through the recently established Dominica Geothermal Development Company Ltd, who will develop a 7 $MW_e$ geothermal power plant and sell electricity to DOMLEC. The project company is 100%-owned by GoCD, being established as a private company under the laws of the Commonwealth of Dominica. Electricity will be sold to DOMLEC, under the regulatory framework established through the Electricity Supply Act 2006. The project will be financed using grant monies from international agencies and bilateral partners, the World Bank and with the Government's own resources.

[2] Electroconsult S.p.A. "Wotten Waven Geothermal Field – Commonwealth of Dominica, West Indies – Feasibility Study Small Geothermal Power Plant", Final Draft, September 2013.

# 3. Reservoir Information

## 3.1 Wotten Waven Geothermal System

The Wotten Waven geothermal system is described in the ELC Preliminary Resource Assessment (ELC, 2012) and the Feasibility Study – Small Geothermal Report (ELC, 2013), together with gap analysis and commentary by World Bank experts (World Bank, 2013).

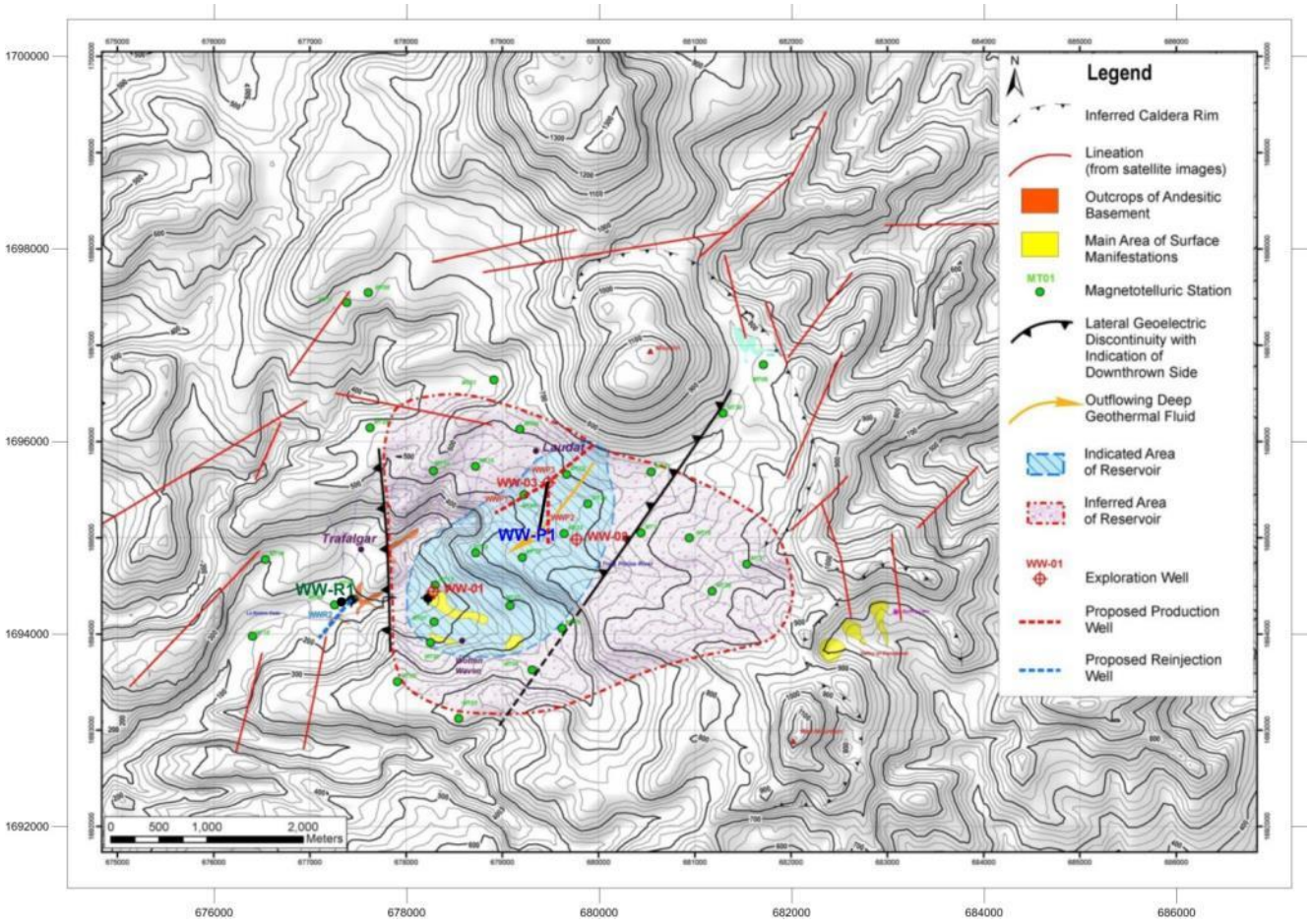


**Figure 3-1: Wotten Waven geothermal field, with locations of recent wells WW-P1 and WW-R1 (ELC, 2013)**

The conceptual model of the field presented by ELC assumes the main resource upflow is to the north under Mount Micotrin, with a flow to the south-west shown by the orange arrow in Figure 3-1. An alternative possibility is that the main upflow is indicated by fumaroles and thermal activity associated with the Acid Lake and Valley of Desolation. This was suggested by the World Bank and Jacobs considers this location more likely.

The well temperature, pressure and chemistry data and the existing MT data are not sufficient to clarify the location of the upflow. The World Bank has raised a concern that the eastern extension of the field may contain acidic fluids, but Jacobs does not consider this is likely to affect future operation of the existing wells. It should be investigated if a larger development is considered in future.

The reservoir temperatures and pressures measured in the existing in-field wells (excluding WW-R1) are nearly uniform and the deep permeability in these wells is generally good. As a result, the indicated (measured) reservoir area shown in Figure 3-1 corresponding to an area of 3 $km^2$ is considered to be sufficiently proven to be used as a basis for a small development using existing wells.

As shown in Table 3-1, ELC estimated that there is a 90% probability that the indicated resource is at least 25 $MW_e$, and a 50% probability of supporting 41 $MW_e$. These estimates provide sufficient confidence for a small scale development using existing wells to be sustainable for 30 years, although there is a low risk that recharge by low temperature or acidic fluids could prematurely reduce the output of the wells.

**Table 3-1: Inferred Geothermal Resource at Wotten Waven (ELC, 2013)**

| Wotten Waven Geothermal, Dominica | | | |
|---|---|---|---|
| | Electrical Energy Potential ($MW_e$) for 30 Years | | |
| | P90 | P50 (Median) | P10 |
| Inferred + Indicated Area | 57.0 | 91.5 | 123.0 |
| Indicated Area | 25.5 | 41.0 | 60.5 |
| Input Estimates and Assumptions | | | |
| | Lower Limit | Most Likely | Upper Limit |
| Inferred + Indicated Reservoir Area ($km^2$) | 9.0 | 10.0 | 13.0 |
| Indicated Area Reservoir Area ($km^2$) | 3.0 | 4.0 | 5.0 |
| Reservoir Temperature (°C) | 235 | 240 | 255 |
| Reservoir Thickness (m) | 800 | 1,000 | 1,200 |

## 3.2 Geothermal Wells

Five wells have been drilled to date, 3 slimhole exploration / production wells, one standard diameter production well and one standard diameter injection well, with details shown in Table 3-2.

**Table 3-2: Well physical parameters**

| Parameter | WW-01 | WW-02 | WW-03 | WW-P1 | WW-R1 |
|---|---|---|---|---|---|
| Wellhead, Easting (m) | 678,302 | 679,822 | n/a | 679,461 | 677,321 |
| Wellhead, Northing (m) | 1,694,864 | 1,695,029 | n/a | 1,695,567 | 1,694,334 |
| Wellhead elevation (masl) | 235 | 580 | 543 | 552 | 187 |
| Total depth (mRKB) | 1200 | 1469 | 1613 | 1505 | 1914 |
| Azimuth (°) | - | - | - | 190 | - |
| Throw (m) | - | - | - | 465 | - |
| Casing size (in) | 7 | 7 | 7 | 9-5/8 | 9-5/8 |
| Casing shoe depth (m) | 303 | 427.5 | 590.6 | 726 | 607 |
| Liner size (in) | 4-1/2 | 4-1/2 | 4-1/2 | 7 | Open hole |
| Liner depth (m) | 269-1200 | 281-1337 | 569-1612 | 700-1505 | 1914 |

### 3.2.1 Production Well Tests

Flow tests were undertaken on well WW-P1 by Geothermal Resource Group (GRG) for 5.4 days from 10 June 2014. During the tests, total mass flow ranged from 20 kg/s to a maximum of about 80 kg/s (288 ton/hr) at an enthalpy of between 1150 and 1190 kJ/kg and flowing wellhead pressure of 13.5 bara. Maximum flow rates could only be sustained for a few hours, on several occasions, due to limited sump capacity and injection equipment limitations.

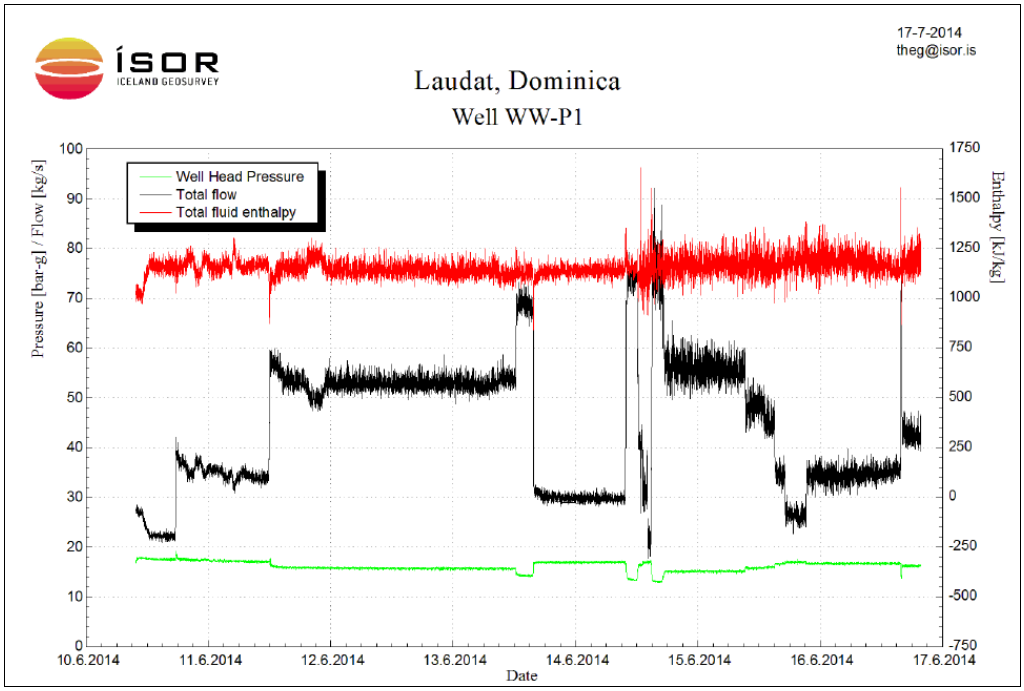


**Figure 3-2: Wellhead pressure and calculated total flow and total enthalpy during production test of Well WW-P1 (Jun 2014)**

As shown in Figure 3-3 below, the calculated steam flow at 7 bara separation pressure varied between 5.0 kg/s and 17.0 kg/s depending on the throttling of the well. During a stable flow period from June 12th and 13th at WHP of ~16 bar, ÍSOR calculated the steam flow at 7 bara separation pressure of 11.1 kg/s and liquid flow 41.8 kg/s – giving a steam fraction of 21%, corresponding to an enthalpy of 1130 kJ/kg. (ÍSOR, 2014)

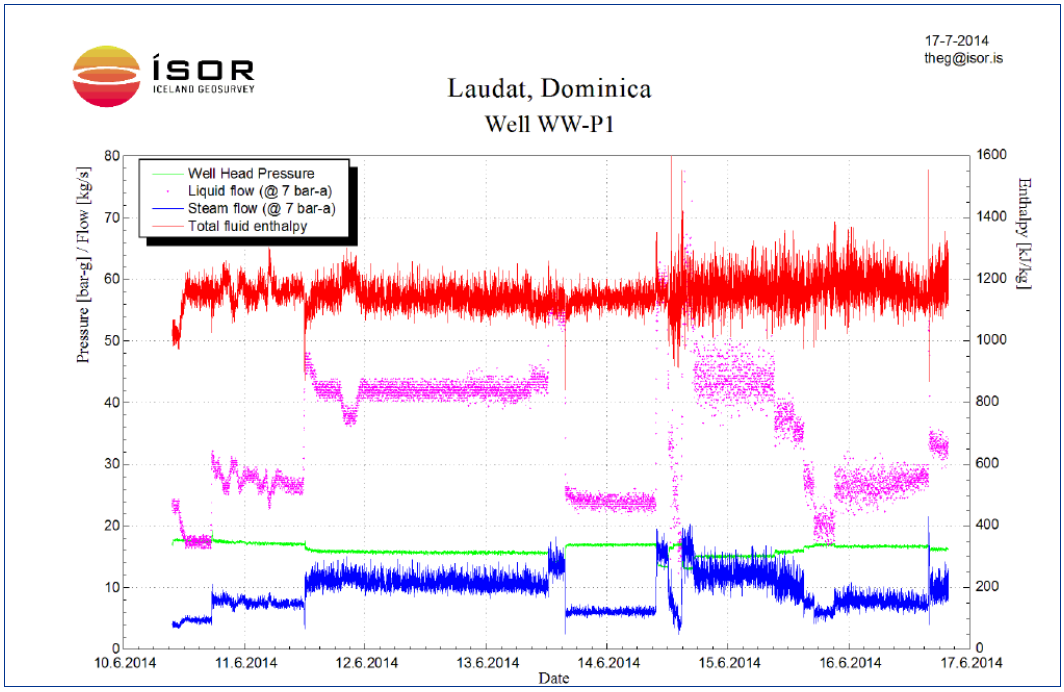


**Figure 3-3: Calculated liquid and steam flow at 7 bara separation pressure, together with well head pressure and the total fluid enthalpy for well WW-P1 (Jun 2014)**

Based on the results of step tests and previous observations, ÍSOR calculated the discharge at a Well Head Pressure of between 13.0 and 17.0 bara, as shown in Table 3-3 below. At atmospheric separation pressure and

a WHP of 13.0 bara the estimated steam flow is 22 kg/s. At 7 bara separation pressure the steam flow is calculated to be ~14-18 kg/s. Depending on the type of power plant to be installed at the site, the expected power output of WW-P1 at a separation pressure of 7 bara is between 7 and 9 $MW_e$ assuming a usage of ~2 kg/s of steam for each $MW_e$. (ÍSOR, 2014)

**Table 3-3: Liquid flow, steam flow, total flow and calculated discharge enthalpy at atmospheric separation pressure for different WHP**

| WHP (barg) | Total flow (kg/s) | Liquid flow (kg/s) | Steam flow (kg/s) | Enthalpy (kJ/kg) |
|---|---|---|---|---|
| **13.0** | 75.1 | 53.0 | 22.1 | 1140 |
| **15.1** | 54.7 | 37.0 | 17.7 | 1160 |
| **15.7** | 48.3 | 31.2 | 17.1 | 1170 |
| **16.0** | 44.5 | 28.9 | 15.6 | 1160 |
| **16.4** | 34.5 | 22.5 | 12.0 | 1170 |
| **16.9** | 26.0 | 16.1 | 9.9 | 1180 |

## 3.3 Geothermal Fluid Chemistry

During the flow tests on WW-P1 undertaken by GRG in June 2014, samples of the two-phase fluid were collected. Six complete samples of vapour and liquid were collected during the test and three additional samples of steam were also collected during a step test on 15 June for gas / steam ratio measurements. Liquid samples were also collected regularly from the weir box throughout the test for conductivity and pH measurements.

### 3.3.1 Chemical Analyses of Vapour Phase

The vapour phase samples were collected to evacuated double-port gas bottles containing a 10 M NaOH solution. The gases in the head-space of the bottles (Ar, $H_2$, $N_2$, $CH_4$ and $O_2$) were analysed using a gas chromatograph and $CO_2$ and $H_2S$ levels were determined by titration of the caustic solution. The liquid phase samples were collected in several sampling containers and subjected to various ion chromatography (IC), colorimetry, gravimetry, and mass spectrometry (MS) chemical tests (ÍSOR, 2014). The results are shown in Table 3-4 below.

**Table 3-4: Results from chemical analyses of the liquid and vapour phases of samples collected during the well test (ÍSOR)**

| Sample | | 20140816 | 20140808 | 20140809 | 20140810 | 20140811 | 20140812 |
|---|---|---|---|---|---|---|---|
| **Date** | | 10.6.2014 | 11.6.2014 | 12.6.2014 | 13.6.2014 | 14.6.2014 | 15.6.2014 |
| **Temperature** | (°C) | 205.4 | 205.2 | 203.4 | 198.3 | 203.5 | 201.9 |
| **Pressure** | (barg) | 16.8-17.1 | 16.4-16.8 | 14.9-15.1 | 13.5 | 15.8-16.0 | 15.0-15.9 |
| **Liquid phase** | | | | | | | |
| **pH/°C** | | 6.03/24.0°C | 6.19/25.4°C | 6.37/25.5°C | 6.44/26.0°C | 6.39/26.2°C | 6.23/26.2°C |
| **Conductivity** | (µS/cm/°C) | 7300/25.0°C | 7730/25°C | 7870/25°C | 8000/25°C | 7920/25°C | 7940/25°C |
| **$CO_2$** | (mg/L) | 154.6 | 133.7 | 113.4 | 106 | 108.6 | 116.2 |
| **$H_2S$** | (mg/L) | 19.65 | 11.05 | 7.21 | 7.2 | 5.25 | 8.56 |
| **$SiO_2$** | (mg/L) | 489.6 | 497.2 | 507.2 | 506 | 514.2 | 501.6 |
| **Cl** | (mg/L) | 2660 | 2830 | 2900 | 2950 | 2910 | 2940 |
| **B** | (mg/L) | 33.3 | 37.7 | 38.9 | 38.1 | 37.6 | 37.2 |

| Sample | | 20140816 | 20140808 | 20140809 | 20140810 | 20140811 | 20140812 |
|---|---|---|---|---|---|---|---|
| Br | (mg/L) | 11.3 | 12.1 | 12.4 | 12.5 | 12.4 | 12.6 |
| F | (mg/L) | 1.36 | 1.36 | 1.2 | 1.23 | 1.25 | 1.3 |
| Ca | (mg/L) | 56.5 | 55.7 | 55.6 | 56.7 | 55.2 | 56.4 |
| Na | (mg/L) | 1520 | 1620 | 1660 | 1670 | 1670 | 1680 |
| K | (mg/L) | 234 | 246 | 249 | 250 | 252 | 252 |
| Mg | (mg/L) | 0.22 | 0.2 | 0.25 | 0.29 | 0.26 | 0.28 |
| $NH_3$ | (mg/L) | 0.55 | 0.59 | 0.62 | 0.62 | 0.65 | 0.67 |
| $SO_4$ | (mg/L) | 22.4 | 21.5 | 21.8 | 21.1 | 21.1 | 20.4 |
| Fe | (mg/L) | 1.03 | 0.217 | 0.0511 | 0.147 | 0.0606 | 0.0338 |
| Al | (µg/L) | 195 | 189 | 178 | 196 | 190 | 181 |
| As | (µg/L) | 42.3 | 144 | 118 | 48.4 | 87.2 | 71.3 |
| Ba | (µg/L) | 448 | 481 | 479 | 498 | 509 | 506 |
| Cd | (µg/L) | 0.00922 | 0.0242 | 0.0148 | 0.01 | 0.00991 | 0.011 |
| Co | (µg/L) | 0.0858 | 0.00985 | <0.005 | 0.00937 | 0.00559 | <0.005 |
| Cr | (µg/L) | 22 | 9.38 | 2.22 | 6.6 | 3.03 | 1.28 |
| Cu | (µg/L) | 0.205 | 0.143 | 0.19 | 0.254 | 0.149 | 0.156 |
| Hg | (µg/L) | 0.00438 | 0.00865 | 0.00417 | 0.00945 | 0.0055 | <0.002 |
| Li | (µg/L) | 3650 | 3950 | 4040 | 4010 | 4050 | 4100 |
| Mn | (µg/L) | 274 | 151 | 127 | 184 | 171 | 176 |
| Mo | (µg/L) | 5.61 | 8.54 | 14.9 | 2.94 | 10.4 | 7.16 |
| Ni | (µg/L) | 13.6 | 2 | 1.33 | 3.05 | 1.84 | 1.52 |
| P | (µg/L) | 4.22 | 1.66 | 2.3 | <1 | 1.38 | 1.45 |
| Pb | (µg/L) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Sr | (µg/L) | 880 | 935 | 948 | 956 | 971 | 969 |
| V | (µg/L) | 0.115 | 0.128 | 0.223 | 0.141 | 0.152 | 0.137 |
| Zn | (µg/L) | 2.23 | 0.989 | 0.578 | 0.581 | 0.394 | 0.41 |
| TDS | (mg/L) | 4936 | 5076 | 5112 | 5228 | 5200 | 5200 |
| **Vapour phase** | | | | | | | |
| $CO_2$ | (mg/kg)* | 63200 | 39200 | 31600 | 26600 | 29900 | 28140 |
| $H_2S$ | (mg/kg)* | 2580 | 1770 | 1420 | 1220 | 1430 | 1300 |
| Ar | (mg/kg)* | 7.8 | 4.7 | 3.3 | 2.7 | 3.2 | 3.4 |
| $N_2$ | (mg/kg)* | 586 | 302 | 224 | 194 | 201 | 208 |
| $CH_4$ | (mg/kg)* | 7.8 | 5.6 | 4.3 | 3.8 | 3.9 | 3.8 |
| $O_2$ | (mg/kg)* | <0.01 | <0.01 | <0.01 | 1.4 | <0.01 | <0.01 |
| $H_2$ | (mg/kg)* | 9.9 | 6.1 | 4.6 | 4.3 | 3.8 | 3.3 |
| B | (mg/kg)* | 0.88 | 0.89 | 0.83 | 0.73 | 0.67 | 0.82 |
| $NH_3$ | (mg/kg)* | 3.11 | 1.5 | 3.01 | 2.68 | 3.48 | 3.2 |
| Na | (mg/kg)* | 0.86 | 3.15 | 0.37 | 0.4 | 0.42 | 0.33 |

*** mg/kg condensate**

### 3.3.2 Chemical Composition of Reservoir

Based on the above results, a chemical speciation programme WATCH was used to calculate the composition of the reservoir fluid. These are shown in Table 3-5 below, based on sample 20140810 and assuming a reservoir temperature of 246°C.

**Table 3-5: Calculated composition of reservoir liquid assuming reservoir temperature of 246°C (ÍSOR, 2014)**

| Sample | | 20140816 | 20140810 | 20140812 |
|---|---|---|---|---|
| **pH** | | 5.32 | 5.62 | 5.59 |
| **$CO_2$** | (mg/L) | 6042 | 3195 | 3080 |
| **$H_2S$** | (mg/L) | 258 | 149 | 145 |
| **$SiO_2$** | (mg/L) | 443 | 447 | 449 |
| **Cl** | (mg/L) | 2412 | 2606 | 2629 |
| **F** | (mg/L) | 1.2 | 1.1 | 1.2 |
| **Ca** | (mg/L) | 51 | 50 | 50 |
| **Na** | (mg/L) | 1378 | 1475 | 1502 |
| **K** | (mg/L) | 212 | 220 | 225 |
| **Mg** | (mg/L) | 0.2 | 0.26 | 0.25 |
| **$NH_3$** | (mg/L) | | 0.55 | |
| **$N_2$** | (mg/L) | 55.6 | 22.6 | 21.3 |
| **$SO_4$** | (mg/L) | 20.3 | 18.6 | 18.2 |

### 3.3.3 Conductivity and pH

Samples for pH and conductivity measurements were also collected from the weir box throughout the test. The conductivity and the pH increased rapidly during the first few hours of the test (Figure 3-4). The conductivity levelled off within the first 24 hours of the test, but continued to rise slightly throughout the remainder of the test.

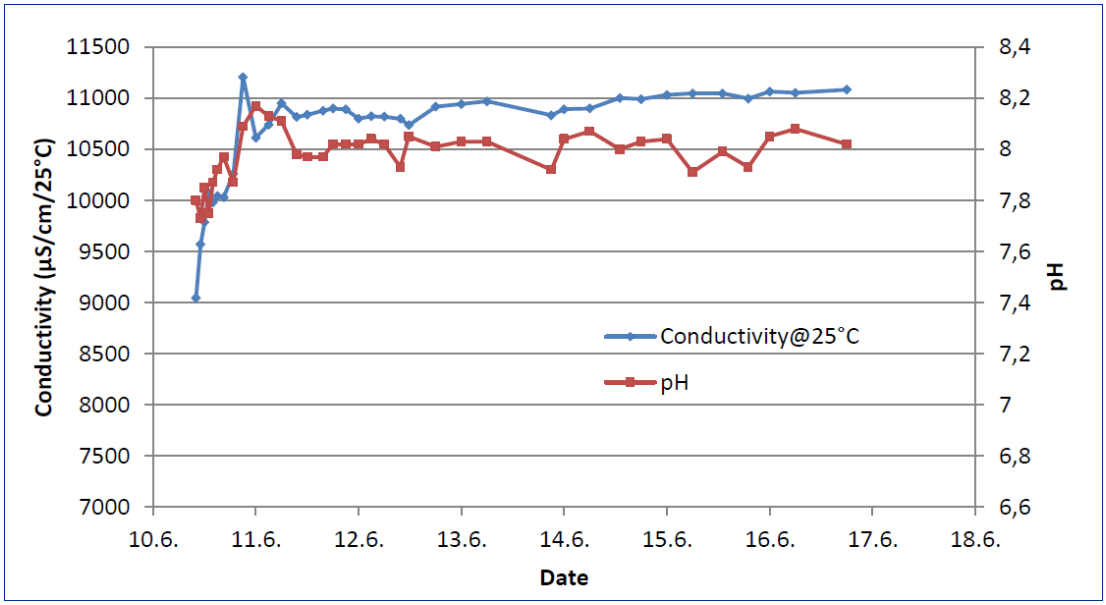


**Figure 3-4: Conductivity at 25°C and pH in samples collected from the weir box during the flow test (ÍSOR)**

### 3.3.4 Non Condensable Gas Content

ÍSOR also measured the non-condensable gas content of the discharge utilising three methods (with Giggenbach bottles, a gas flow meter and an inflatable plastic tube). These gave average gas/steam ratios of 16.5 L gas/kg condensate at a separation pressure of 15.5 bara (calculated at standard temperature and pressure (STP) conditions). As shown in Figure 3-5 below the gas concentration in the vapour phase decreases with increasing flow rate (which is inversely proportional to the well head pressure which controls the boiling and steam fraction).

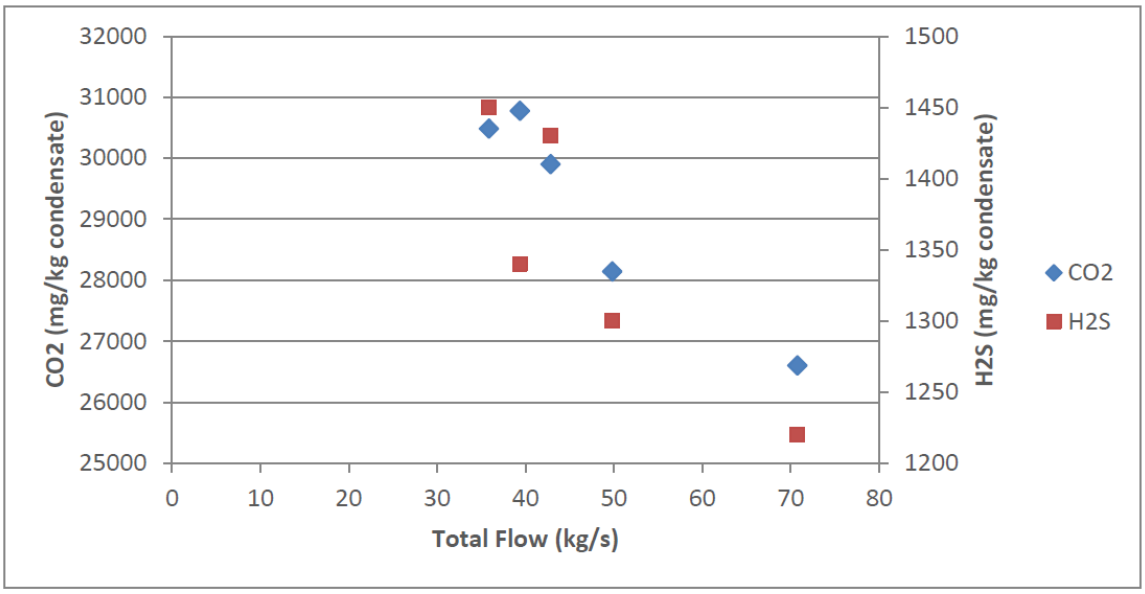


**Figure 3-5: Vapour phase concentration of $CO_2$ and $H_2S$ versus total flow from the well (ÍSOR) [assumed 15.5bara]**

### 3.3.5 Conclusions

Based on the chemical tests ÍSOR concluded that:

- Due to limited changes in the conductivity of the liquid phase throughout the test, the similar chemical composition of the samples collected during the test and the good agreement between geothermometers and logged reservoir temperature indicates that the discharge is representative for the reservoir fluid.
- The deep liquid (reservoir liquid) is relatively dilute with Cl and Na concentrations close to 2600 mg/L and 1500 mg/L respectively.
- Boiling due to depressurisation within the well is expected to cause calcite scaling at or slightly above the boiling level.
- The overall gas content of the steam at 150°C (4.8 bara) based on calculations from samples 20140810 and 20140812 was 1.6 wt% (at 4.8 bara) or approximately 8 L gas/kg condensate.

# 4. Project Overview

The Project comprises the development of a two-unit geothermal power plant with a gross capacity of 7 $MW_e$ in the Roseau Valley, Dominica. This covers the following stages: construction, completion, testing, commissioning, ownership, operation and decommissioning, including the steamfield, required electrical connections and integration with associated infrastructure. The preliminary design for the Project is ongoing, with detailed design to be completed following a formal tender process for an Engineer, Procure and Construct contractor(s) in 2018.

The Project will be developed by the Dominica Geothermal Development Company (DGDC), which was established mid-2017. The DGDC will operate under guidance from commercial, financial and technical advisors. The company will appoint an EPC contractor for the development and a separate Operations & Maintenance contractor.

The key components of the proposed 7 $MW_e$ power plant include:

- Power plant comprising 2 x 3.5 $MW_e$ units (either single flash steam condensing cycle or organic Rankine cycle units (binary turbine), which will be adjacent to wells WW-P1 and WW-03. The binary power plants may use wet cooling or dry cooling;
- Production well WW-P1 – The existing geothermal production well at Laudat is indicated to have potential to generate 6 to 9 $MW_e$ and will be the sole production well for the project;
- Reinjection wells WW-R1 (located in Trafalgar) and WW-01 (located in Wotten Waven) – The used geothermal fluid (brine and possibly some steam condensate) produced from production well WW-P1 would be disposed of into reinjection wells WW-R1 and WW-01;
- Cross-country brine reinjection piping – The 250 to 300 mm diameter reinjection pipeline will be carrying used geothermal fluid from Laudat to Trafalgar with approximate piping length of 3.5 km;
- Steamfield infrastructure including two phase piping, steam piping, steam separator, atmospheric flash tank, brine collection and disposal system, condensate collection and disposal system, pressure relief system, storage sump and rock muffler;
- Supporting infrastructure including existing well pads, turbine building, primary and ancillary equipment, cooling system, and water supply; and
- 3 x 11 kV underground cable interconnection to the DOMLEC electricity grid at the power plant site.

The Government has ownership of the existing well pads (WW-01, WW-02 and WW-03), whose locations are presented in Figure 4-1, along with the preferred injection line route. This route alignment will be finalised in close co-ordination with process engineering, mechanical, geotechnical and civil engineering design disciplines, along with the Government, Land and Survey Division and environmental and social scientists.

The conceptual power plant layout is displayed in Figure 4-2 and land will have to be acquired to site the power plant and other associated infrastructure.  Land requirements are discussed in detail in Section 4.5.

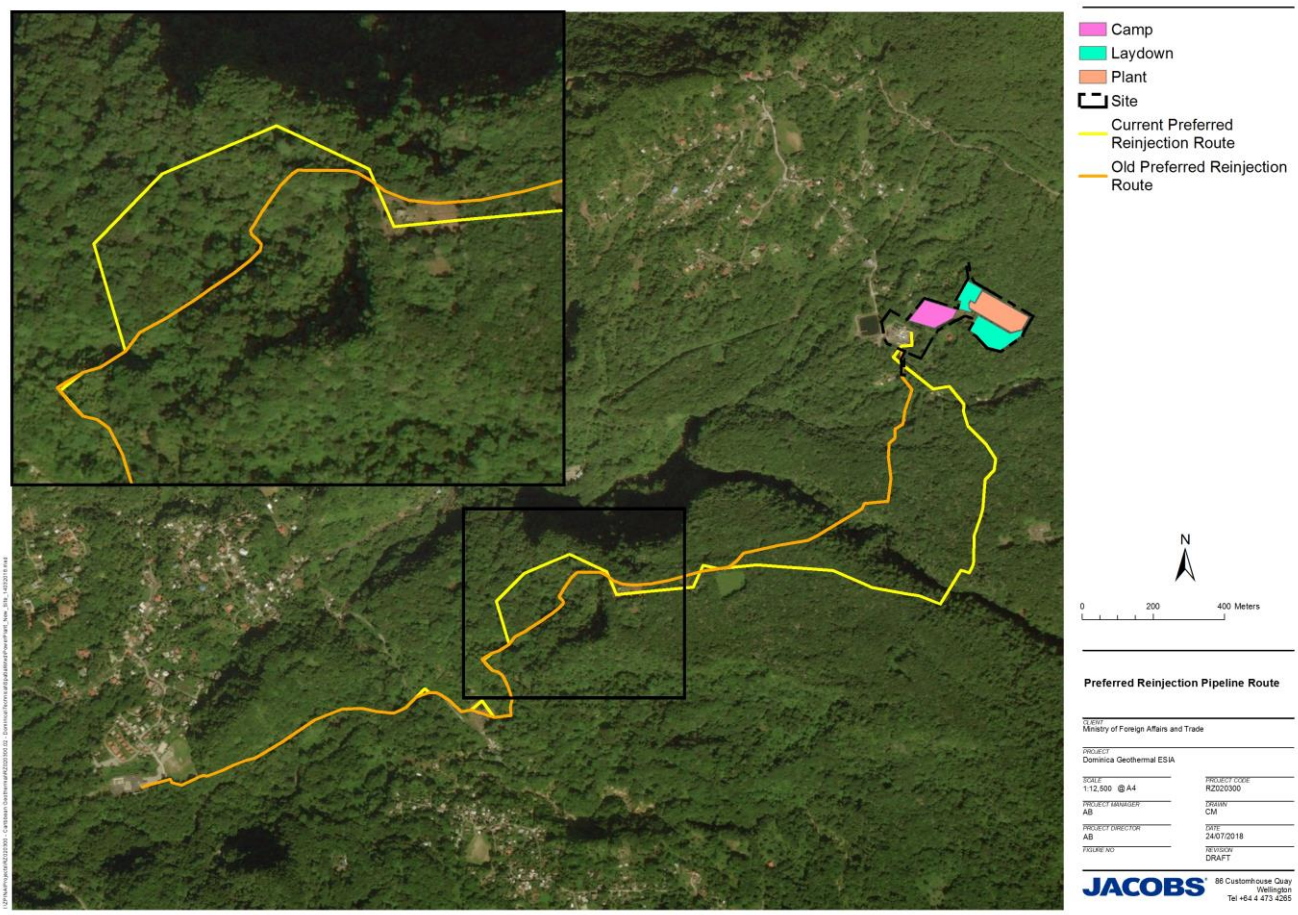


**Figure 4-1: Preferred injection pipeline route from WW-P1 to WW-01 and WW-R1**

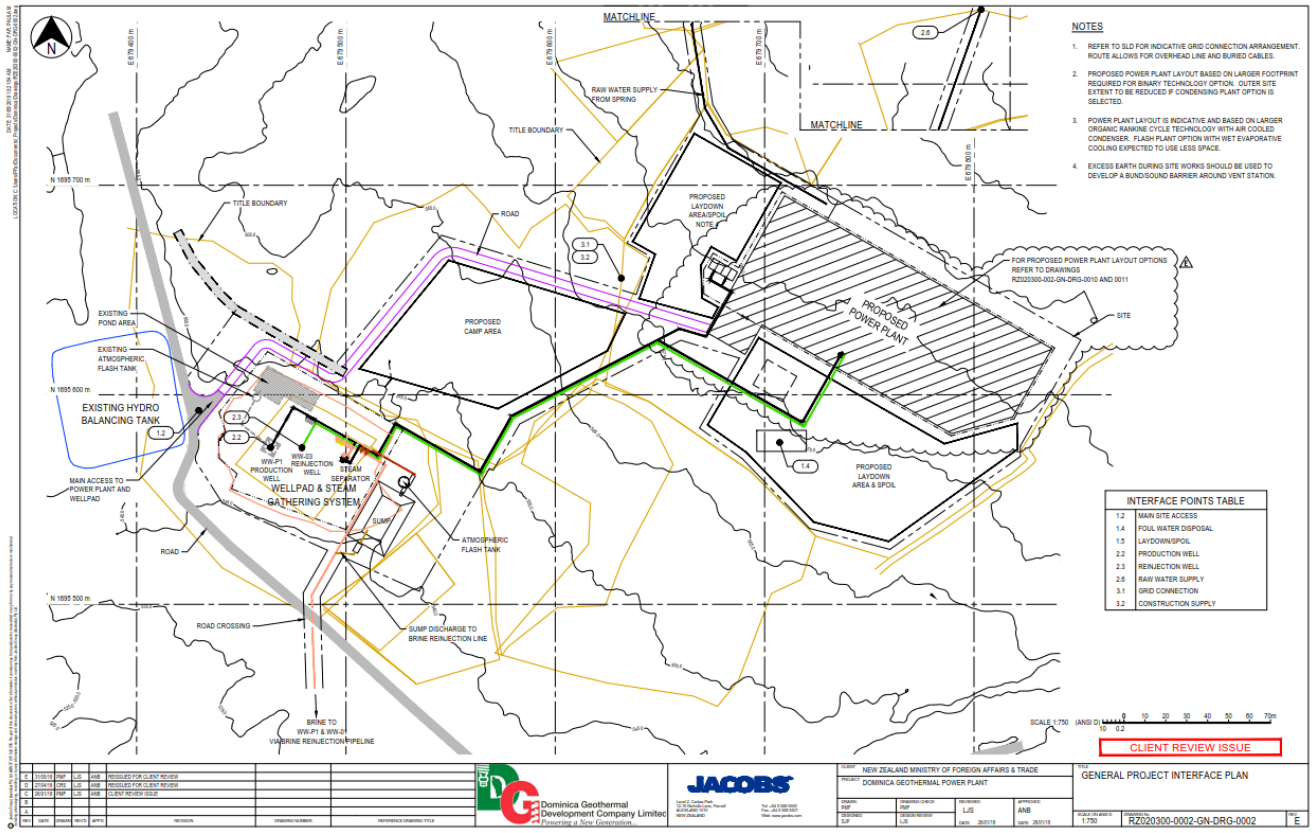


**Figure 4-2: Proposed Power Plant Site and Production Steamfield Layout**

## 4.1 Power Plant Technology Options

Various methods of electricity generation from geothermal wells are available, the selection of which is primarily driven by the nature of the geothermal resource. Energy is typically extracted from steam, or a mixture of brine and steam. There is much more energy in steam than in hot water and even though the ratio of brine to steam produced by WW-P1 is about 5:1, most energy still lies in the steam phase. As such it is proposed that steam will be used as the primary driver.

During project feasibility analysis various options were discounted including backpressure unit, dual flash cycle, geothermal combined cycle, triple flash cycle and Kalina cycle. As such there are two appropriate main power plant technology options:

i. Single flash steam condensing cycle; and

ii. Organic Rankine cycle (ORC)

It is proposed that suppliers will be invited to offer power plants based on a clear set of technical specifications for the project. This section discusses the likely options for electricity generation to allow various impacts for each of the two suitable technologies to be established and assessed in the ESIA.

### 4.1.1 Single flash steam condensing cycle

Geothermal steam from the separator is used directly in a steam turbine connected to a generator. After the steam passes through the steam turbine it is condensed for injection. Figure 4-3 presents the single flash plant process. The key features of this plant design are:

- Single steam admission pressure;

- Direct contact condenser and mechanical induced draft wet cooling tower;
- Hybrid non-condensable gas (NCG) removal system.

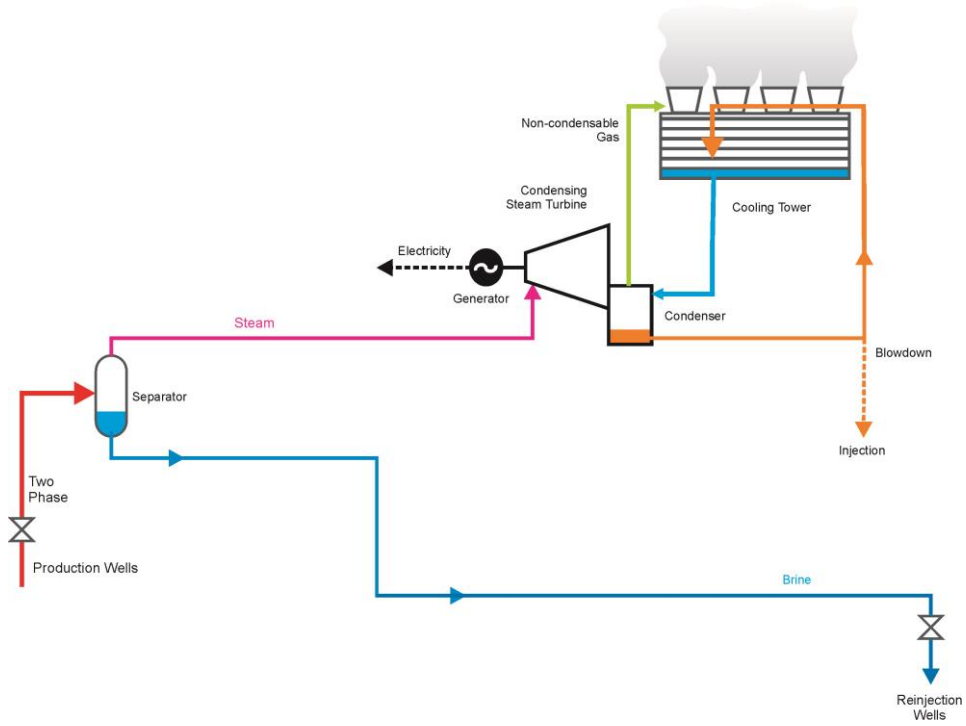


**Figure 4-3: Typical geothermal single flash steam condensing cycle[3]**

#### 4.1.1.1 Condensing Steam Turbine

Steam enters the turbine from the steamfield and the flow rate is modulated by a control valve called a governor valve. Excess steam is vented through an upstream steam vent system consisting of a pressure control valve and rock muffler (which is part of the “steamfield”). Immediately upstream of the governor valve is a main stop valve that shuts if the turbine trips.

The geothermal steam is passed through the turbine providing motive force to rotate the turbine and generator. The steam then exhausts into a condenser at a pressure of about 0.1 bara (i.e. under high vacuum). Figure 4-4 provides an indication of the size of plant envisaged for the Dominica project.

[3] http://theearthproject.com/everything-geothermal-energy/



**Figure 4-4: Condensing Steam Turbine (Source: GDA - http://www.gdareno.com)**

#### 4.1.1.2 Condenser

The purpose of the condenser is to condense the steam, creating a vacuum and thereby generate more power due to the higher pressure differential and higher heat drop across the turbine. Normally “direct contact condensers” are used in the geothermal industry. They rely on cool water (which comes from previously condensed steam that has passed through the turbine) being directly sprayed into the steam to condense it.

#### 4.1.1.3 Gas Extraction Equipment

In order to maintain the vacuum in the condenser, the non-condensable gases (NCGs) must be continuously removed. This is accomplished by use of a gas extraction system, steam-driven ejector or steam ejector / ring pump (hybrid). The type of system is determined during the bidding for the plant, and can be influenced by the value attached to steam used in the ejectors.

Whatever the approach, the NCGs extracted from the condenser are piped to the cooling tower where they are discharged to the atmosphere in the warm plume of moist air and dispersed to the environment.

#### 4.1.1.4 Oil System

A lubricating oil system is required for the turbine generator units. The system includes:

- Oil pumps;
- Oil coolers;
- Oil Tank.
- Filters and Purifiers

As mitigation for leakage or spills, oil containment bunds / trays are normally specified around or under all lube oil equipment to contain at least 110% of the total oil system capacity.

### 4.1.2 Organic Rankine Cycle

This technology requires geothermal fluids pass heat to an organic working fluid which boils and the organic vapour then drives a turbine connected to a generator. These are often also called ‘Binary Cycle’ plants because they use two fluids (the original steam and the organic secondary fluid).

Figure 4-5 shows a typical binary plant which separates the steam and brine. There are different combinations for using geothermal fluids in a binary cycle plant, the simplest being to use the geothermal fluid directly without any separation of the steam and brine phases.

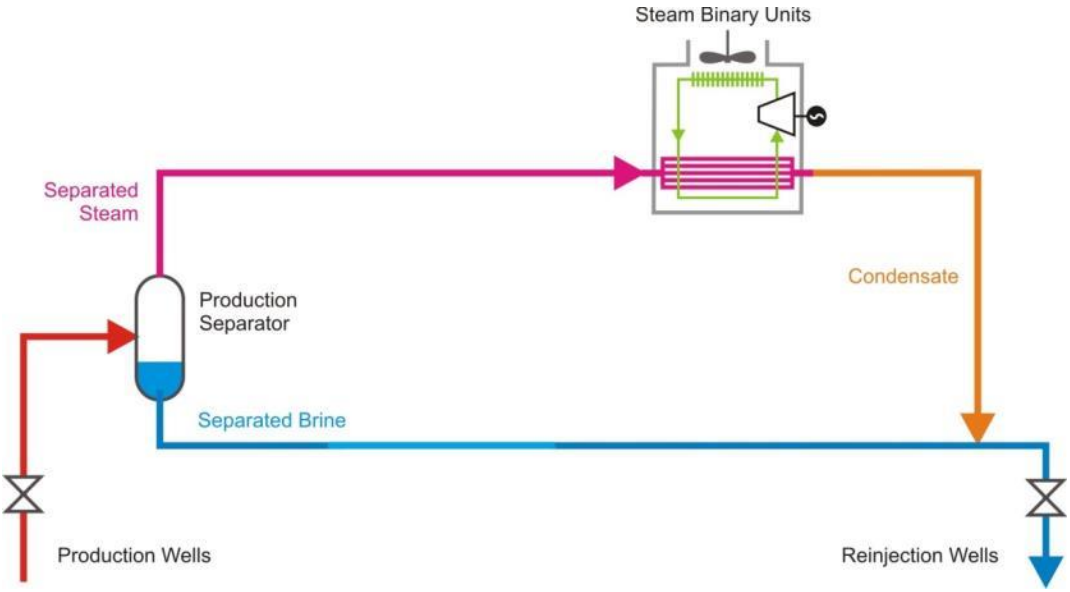


**Figure 4-5: Typical geothermal Organic Rankine cycle**

#### 4.1.2.1 Working Fluid and Heat Exchangers

Most working fluids employed for power generation with binary processes are flammable. Isopentane, N-Pentane and Isobutane are typical working fluids. N-pentane is recommended based on boiling point, use in New Zealand and safety. Being flammable necessitates requirements for safe design, construction, operation and maintenance. The working fluid must be topped-up on an ongoing basis which means that the fluid must be imported and stored safely over the life of the project.

The heat exchangers in a binary plant transfer the energy of the geothermal fluids to the working fluid. They are usually shell and tube type. In a typical plant a pre-heater and a vaporiser will be utilised. Typically, the brine will pass through the pre-heater and heat the working fluid to its boiling point. The steam condensing in the vaporiser will then vaporise the working fluid after which it is delivered to the turbine or expander. The number of heat exchangers will be at the discretion of the EPC contractor. A recuperator, upstream of the preheater, may also be used to transfer waste heat in the turbine exhaust to the working fluid.



**Figure 4-6: Binary plant heat exchangers (large plant example)**

#### 4.1.2.2 Working Fluid Pumps

The working fluid is circulated in a closed system at elevated pressures in order to extract the maximum amount of power for a given resource condition. Pumps are used to circulate the working fluid around the cycle. The pumps will be supplied by the power plant contractor.

### 4.1.3 Power Plant Cooling Options

A cooling system is required to reject heat which cannot be converted to electric power. In the case of the condensing steam turbine plant this is always an evaporative water cooling system because cooled water for subsequent heat rejection by evaporation is freely available from the steam which is previously condensed in the process.

In the case of the binary plant the cooling system is almost always air cooling. This is because the binary fluid leaves the binary turbine as a vapour which must then be condensed without direct contact with another fluid because it is reused again in the process. The condensation can be achieved either by air (dry) cooling or water (evaporative) cooling. The cooling process will be confirmed by the EPC contractor during bidding.

The main differences between the evaporative (wet) cooling option and the air (dry) cooling options are: the land area required for the cooling towers; the visual impact of the equipment; overall efficiency; visual emissions or plumes, the injection load and the total installed cost. The trade-off between different options is best evaluated against specific offers.

- Wet cooling towers are typically used with condensing steam Rankine cycle plants. Water cooling towers have a visible plume of water vapour when the relative humidity of the atmosphere is high and are particularly visible on cool mornings – this is because the air flow leaving the tower is 100% humid. Towers can be configured so that there is some sensible heating of the air flow leaving the tower which reduces the humidity below 100% and alleviates the visible plume as it leaves the tower. As a large part of the steam condensate is evaporated, the total amount of liquid to be reinjected is less than for air cooling.
- Air coolers have a larger land footprint than water coolers. Air coolers do not have a visible plume of water vapour, but may exhibit a heat haze.

It is proposed that both wet and dry cooling options are considered in the competitive bidding process unless the visual impact or land requirements preclude one or the other options determined through the ESIA. The

cooling system will typically be closely integrated with the power plant and supplied as part of the overall EPC power plant package.



**Figure 4-7: Air cooling for 9MW$_e$ binary plant (left). Evaporative cooling tower for 5MW$_e$ plant (right)**

### 4.1.4 Building for Main Power Plant Equipment

As the dominant power source for the island, bidding documents will specify that the main components of the power plant that are sensitive to a wet, tropical, corrosive geothermal environment be housed in appropriate enclosures designed to withstand heavy rainfall and hurricane conditions as per relevant building standards adjusted for a geothermal environment. The power plant will be constructed on a number of concrete foundations designed to withstand the weight and movement of large pieces of mechanical equipment and the associated building / structures. It is proposed that the power plant manufacturer / EPC contractor will take responsibility for preparing the foundations.

In the case of a single flash steam power plant it is typical to house the steam turbine generator and its associated equipment in a turbine hall or shelter in order to protect the machinery from both the tropical elements and the corrosive geothermal environment and provide for easier maintenance and operation. Some elements of the balance of plant equipment, including circulating water cooling systems and gas extraction systems are likely to be located outside this building but with adequate protection from the elements.

In the case of a binary power plant this equipment is usually housed outdoors, but with a substantial shelter over the equipment.

The control room and electrical control and monitoring equipment for both plant options will need to be housed in environmentally-controlled spaces, which may be connected to or separate from the turbine-generator building.

### 4.1.5 Fire Detection and Protection

Both plant options will require substantial fire detection and protection to prevent damage to components and buildings such as the cooling towers and oil containing equipment including the turbine-generators.

For both options, this would likely comprise a fire ring main and spray system that covers the physical plant, and an inert gas ($CO_2$, “inergen”, or similar) discharge system for the control room and building annex. A fire-fighting water tank will be required and sized in accordance with NFPA 850 (Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations). Monitoring systems associated with the fire protection system will be spaced around the site as required by the relevant fire service standards. The single flash option would also include monitors (spray cannons) covering the cooling tower.

Due to the flammable nature of the likely working fluid for the organic Rankine system, this plant option will require a full firefighting system comprising water storage tank in accordance with NFPA 850, fire water pump and jockey pump, fire-water mains, and hydrant/monitors. There will also need to be a fire detection system, plus hydrocarbon gas detectors that would identify any potential leakage.

### 4.1.6 Comparisons

**Table 4-1 : Main differences between Single Flash and Organic Rankine Cycle**

| Items / main difference | Single Flash | Organic Ranking Cycle |
|---|---|---|
| Typical Size | ~ 60 x 90 m inc. laydown | ~60 x 175 inc. laydown |
| Cooling system | Typically evaporative cooling: Possible visible water vapour plume during certain ambient conditions | Typically air cooled condenser<br>No visible water vapour plume |
| Motive fluid | Geothermal steam driven turbine | Hydrocarbon used as motive fluid to drive turbine, heat absorbed into motive fluid from geothermal steam via heat exchangers |
| Steamfield | Same components and operation | |

## 4.2 Geothermal Steamfield Equipment

The steamfield will be designed, procured and constructed for the entire capacity of the 7 $MW_e$ power plant. The two-phase fluid will be sent to a separator where it is divided into steam and brine phases. Steam will be directed to the power plant, and brine to the injection pipeline. The steamfield plays several important roles in the safe and reliable operation of a geothermal plant, being:

1) Handling variable multi-phase steam, brine and non-condensable gas flows while ensuring that neither production wells nor injection wells are adversely affected by its operation;
2) Matching the supply of steam to the power plant as it changes in response to fluctuations in electricity demand;
3) Provide clean steam to the steam turbine or the organic Rankine cycle heat exchangers;
4) Disposing of spent fluids into injection wells.

The steamfield will be identical for either option of power plant technology selected.

### 4.2.1 Steamfield Arrangement

The steamfield comprises the Steam Gathering System (SGS) and brine injection pipeline, made of the following systems:

- Two phase collection and separation;
- Steam gathering;
- Brine collection and disposal (including brine pumping if required);
- Condensate collection and disposal (if required);
- Pressure relief;
- Atmospheric Flash Tanks;
- Steam venting and pressure control;
- Storage sumps;
- Access tracks for construction and maintenance.

The preferred steamfield arrangement for the Project is shown in Figure 4-1 and Figure 4-2 of Section 4. The individual systems and infrastructure are described in the following sections.

### 4.2.2 Two Phase Collection and Separation System

This system consists of:

- The production well WW-P1;
- Two phase piping from production well to separator;
- Steam separator;
- Atmospheric flash tank (AFT).

The proposed total power plant capacity of 7 $MW_e$ is dictated by the well output and allows a reserve factor to accommodate some decline in well flow without reducing power generation. The flowrate from the well is controlled by a manual wellhead control valve. The piping system at Dominica will only have one production well and this will feed two-phase fluid directly to the separator, the preferred design of which is a vertically oriented Weber type. If another well is drilled in the future, the two wells will feed a common collection header, which in turn will feed the separator.

Low point drains (LPDs) will be located at the local low points on the two-phase line and be used on start-up and shutdown to drain down the condensate that forms from condensing steam. These will usually discharge to ground but can be piped to a storage sump for disposal. High point vents (HPVs) are located at high points to vent air and non-condensable gases (NCGs) on start-up and shutdown.

The separator is a key piece of equipment and should be designed to operate at variable flows and pressures aligned with power plant turn down ratios and rapid response to load changes imposed by the electrical grid system operator. For the Project, the separator will be installed on the WW-P1 well pad or potentially nearby at the adjacent power plant site.

A typical large vertical cyclone separator is shown in Figure 4-8.



**Figure 4-8: Typical geothermal separator**

For Dominica, this vessel will be between 7.5-10m high and approximately 1.8m in diameter. This will likely be a prominent visual impact depending on surrounding terrain and foliage.

Other key pieces of equipment to be housed on this pad will depend on the final technology selected, but will include an atmospheric flash tank (AFT) (which will also double as a two-phase or brine receiving vessel during well testing and during start-up of the brine line), steam venting and pressure control system, brine pumping units (if required) and a storage sump.

The AFT will be between 1m and 3m in diameter and it is also used to receive any discharges due to operational upsets. Should the level of brine in the separator brine drum rise beyond a high level, emergency dump valves (EDVs) will open and discharge brine to an AFT. The brine will flash inside the vessel and the steam component will discharge to atmosphere. The brine is sent to the local sump where it can then be pumped away to an injection well for disposal. An AFT is shown in Figure 4-9**.**



**Figure 4-9: Atmospheric Flash Tank (AFT / Silencer)**

### 4.2.3 Steam System

On exit from the separator the steam is gathered in a steam header and transported to the power plant. Condensate drain pots (CDPs) are located at low points in the system to collect condensate that has generated in the pipelines. Vents are located at the high points to vent air and non-condensable gases on start-up and shut down of the system. The piping is typically wrapped in calcium silicate and / or fibre-glass insulation material and an aluminium cladding.

Upstream of the power plant, a steam scrubber is utilised as a final condensate removal stage to ensure that the moisture content of steam is as low as possible prior to admission to the turbine. The geothermal condensate removed from the steam will be sent to a storage sump and pumped away for injection.

#### 4.2.3.1 Steam Pressure Relief System

Pressure relief is required on the steam gathering system on exit from the separator. The piping network will typically not be designed to withstand the pressure generated by a well that is shut in (i.e. not flowing). The difference between operating pressure and shut in pressure can be up to 40 bar or higher. Usually just the individual well branch line will be rated for full shut in pressure. It is therefore necessary to protect the rest of the system from over pressure.

Typical events that will cause an over pressure in the system include turbine trips which will cause the main turbine control valve (or governor valve) to close and lock in the system. Bursting discs will be used on the Project to release pressure in the event of an emergency build-up of pressure in the system. This equipment will

either discharge to atmosphere or pipe to the AFT. The preferred method will be confirmed by the contractor. This event is not part of normal operation of the plant.

#### 4.2.3.2 Steam Venting and Pressure Control System

The steam venting and pressure control system is used for the following purposes:

- "Trim" system pressure by venting steam to maintain the desired interface pressure on entry to the turbine;
- Vent steam in the event of system upsets (i.e. turbine trips).

A series of vent valves upstream of the power plant will vent steam as necessary. Steam is vented to a rock muffler which controls the release of pressurised steam and attenuates noise associated with this. The rock muffler consists of a pipe with numerous small holes (known as a sparger) buried in rocks with noise attenuating properties, typically scoria.

During normal operation there will be a small flowrate of steam through the vent system to maintain steam pressure on entry to the turbine. Upon turbine trip, the full steam load can be vented so as not to over-pressurise the system. Venting steam in this manner allows the rest of the system to operate as normal i.e. separators will continue to separate steam and brine at the desired pressure until the power plant can be brought back online. This avoids having to shut down the entire system. A typical vent system, vent valves and rock muffler from a large steamfield is shown in Figure 4-10.



**Figure 4-10: Vent system**

#### 4.2.3.3 Storage Sumps

For this project, storage sumps will be required at the production and brine injection well pads. This will store brine or condensate that is discharged due to operational upsets. A typical sump is shown in Figure 4-11 (sized to approximately 20m x 40m and 3m deep). The preferred option for emptying the sump at the production well pad WW-P1 is via gravity to the brine injection wells WW-R1 and WW-01.



**Figure 4-11: Storage sump**

### 4.2.4 Condensate Collection and Disposal System

Condensate is produced in two locations in a typical geothermal power project:

- As a result of temperature difference across the walls of the steam pipes and the surrounding atmosphere, despite the use of insulation;
- Discharge of excess condensate from the cooling tower basin (on condensing cycle options only, see explanation below).

Condensate produced in steam pipelines is generally collected via a condensate collection drain pot (CDP), found at local low points on the route and then disposed to ground via a steam trap. A typical CDP is shown in Figure 4-12.



**Figure 4-12: Condensate collection drain pot (CDP)**

This condensate will be discharged to a piped network and disposed of at downhill storage sumps. The condensate can then be pumped to an injection well for disposal.

If a steam condensing turbine option is selected, condensate will also be produced as a result of steam exhaust from the turbines, condensing inside the condenser (or heat exchanger). While some of this condensate is re-used inside the cooling tower to make up for losses due to evaporation and drift, the balance must be disposed of via an injection well. The volume of condensate produced is low compared with brine produced and it is envisaged that condensate be injected into well WW-03, located on pad WW-P1. It is not expected that the small flow of condensate will affect the performance of WW-P1. If it does, this condensate may be disposed of in WW-02. Disposal pumps may also be required but these are much smaller than those required for brine disposal and constitute a small amount of the over-all parasitic load for the plant.

Condensate disposal is normally done via a dedicated pipeline to a different well than that used for brine injection because condensate has different chemistry to the separated brine. However, this is not necessarily the case and in some instances (particularly binary options) there can be advantages in combining the flows to prevent silica deposition, depending on chemistry. Bidders will be asked to present their preferred approach, with the requirement to inject condensate to a dedicated well being optional.

### 4.2.5 Brine Collection and Injection System

The brine from the separators passes through a brine collection drum into a network of pipes that will feed the brine injection wells. The current preferred disposal option is via gravity. The injectivity index of wells WW-01 and WW-R1 indicate that both are required to dispose of the expected volume of brine produced from WW-P1 at full output. However, there is a degree of uncertainty around the injection capacities of the two wells and the volume of brine produced. In the unlikely event that the injection capacity does not meet the requirement or if significant wellhead pressures are required to force the brine into the reservoir, two possible solutions can be implemented.

Firstly, a pump station could be installed at WW-R1 prior to operation in order to increase the brine pressure into WW-R1 and increase the combined injection capacity of WW-R1. The quantity of pumps required is a decision made later in the project design, but is likely to be 2 x 100% (i.e. a duty and a standby, if pumps are required). The second option is stimulation of well WW-R1 by pumping cold water from the Roseau River to increase well injection capacity. This would require 51,840 $m^3$ of water to be pumped into WW-R1 at a rate of 20 kg/s over a 1-month period.

Connection to both wells would be undertaken during construction and installation of the brine injection pipeline. The injection pipeline will be insulated to reduce heat loss, which is necessary to avoid deposition of silica and to protect people and wildlife from burns. It will be clad in aluminium or other appropriate material and may be coloured or camouflaged to reduce visual impacts. The injection pipeline must operate at high temperature and pressure and needs to be carefully designed with suitable supports and guides which safely allow for thermal expansion of the pipe between its hot and cold states. This will require vertical or horizontal u-bends every ~100m.

The pipeline will also have drains at any low points for draining down the line on shutdown in order to prevent silica polymerising in the lines due to stagnant conditions. These drain points will be connected to the sumps at the injection well pads for subsequent disposal into the injection wells.

## 4.3 Supporting Infrastructure

### 4.3.1 Well Pads

Three well pads will be used for the development: WW-P1, WW-01 and WW-R1. All sites require remedial works to bring them up to standard.

- Site WW-P1: Site improvement, slope stabilization, drainage works, fencing, security lighting.
- Site WW-01: Site fencing, slope stabilization.
- Site WW-R1: Site fencing, security lighting, disposal of material/ general cleanup.

### 4.3.2 Water

The main requirements for water are:

- Potable;
- Supply for fire fighting;
- Maintenance and plant cleaning.

#### 4.3.2.1 Potable Water Supply

A potable water supply will be required for the geothermal development for drinking water, showers, toilets and kitchen facilities. The quantities of water required will be small as only a small work force (2 or 3 staff) would be required. Options for water sources include taking water from local streams or rivers, rain water or deliveries of bottled water. Water taken from local streams will require filtration and biological treatment. The most likely solution is:

- Drinking water delivered;
- Rainwater collection for showers (if permitted) and cleaning;

#### 4.3.2.2 Sewage treatment

Sewage treatment requirements are specified in the bidding documents to comply with the requirements for maximum levels of residual contaminants as defined in the IFC Performance Standards and EHS Guidelines and the Environmental and Social Management Plan shall be complied with for all fluids discharged from the Plant.

#### 4.3.2.3 Supply for fire water

As discussed in Section 4.1.5, water for fire-fighting will require a tank located at the site which will be sized in accordance with NFPA 850 (Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations). Water requirements for fire protection will be aligned with the power plant technology choice and specified in bidding documentation.

#### 4.3.2.4 Maintenance and cleaning

Unit maintenance would be undertaken to meet manufacturers, inspection agency and unit specific requirements.

Major steamfield maintenance and inspections will be undertaken during power plant unit shutdowns to take advantage of the reduced steam demand. Sections of the steamfield will be taken out of service during which the separators, scrubbers and flash tanks will be inspected, cleaned and Non-Destructive Testing (NDT) would be carried out. Brine pumps and motors, valves and actuators will be inspected, overhauled and tested.

Other major maintenance work is associated with the steam production and injection wells, which require periodic workovers to remove any scale deposition. Portable water sources are thought to be the most pragmatic solution to facilities beyond WW-P1 and out of reach of available tank water.

#### 4.3.2.5 Stormwater Management

Stormwater management will be required throughout construction and operation of the project infrastructure, taking account of well pads, steamfield equipment and power plant location. A stormwater management plan will be required before the construction phase and will include stormwater management during operation. The typical objectives of which are as follows:

- to minimise any potential adverse environmental effects on water quality and aquatic ecosystems from the proposed stormwater discharge from the operation of the development;

- to protect and enhance the natural character and amenity of watercourses from the proposed stormwater discharge from the operation of the steamfield and plant;
- to minimise any potential adverse environmental effects from flooding or erosion (inclusive of land or watercourses) from the stormwater discharge from the operation of the steamfield and plant.

Stormwater run-off from buildings and yards will be collected and discharged to local watercourse. Contaminated stormwater (e.g. oily water, hazardous substances) will go to a 3 stage interceptor before discharge to watercourse. It is not considered feasible to use the injection line for any contaminated stormwater.

### 4.3.3 Road Network

The road and track network for the Project existed prior to the geothermal drilling campaigns, although works were required to allow passage of the drilling rig. Road access to the well pads and power plant site has previously been established by the Government. Some remedial works will be required for the existing road network, but no new roads are needed. Some access tracks may be required around the preferred injection route.

## 4.4 Electrical Equipment and Interconnection

For each technology option, the layout and design of the electrical equipment will be similar but subject to constraints imposed by the technology chosen. This section discusses the electrical equipment involved in generating electricity and interconnecting to the DOMLEC electricity grid.

### 4.4.1 Connection to DOMLEC Grid

The new geothermal power plant will evacuate power at 11 kV through new three underground cables that will connect to the existing 11 kV switchgear at Laudat Hydro Station. These three new underground cables will run through land to be acquired for the power plant and through land owned by DOMLEC. They will be run under or directly alongside the proposed access road into the Project site. The length of this route is approximately 440 m. The proposed connection arrangement is provided in Figure 4-13.

For installation, trenches will be dug in which the cables will be laid and the trench backfilled. There is the potential to create sediment containing run-off when the trenches are open. This run-off will be handled as part of the mitigation measures proposed for civil construction works in general. Once installed, there will be no visual impact, nor impact on the use of the roads or amenities as they are underground. Therefore, no mitigation specific measures are required.

In addition to the 11 kV underground cable connection to the Laudat Hydro Station, DOMLEC are to also carry out ancillary works on the network. This includes the rebuild of the existing transmission line from Trafalgar Hydro Station to Fond Cole Power Station, which was destroyed by Hurricane Maria. As it represents an opportunity to build back better, DOMLEC have opted to upgrade the line to be capable of operating at 33 kV as part of this rebuild. That entails fitting slightly longer insulators which suspend the transmission wires from the poles. Also, they will extend the line from Trafalgar Hydro Station to Laudat Hydro Station to provide a 2nd circuit using the existing poles. These measures are to improve DOMLEC's network capacity, capability and flexibility and will be carried out even if the geothermal power plant is not developed and as such are not considered to be an associated facility as defined under Performance Standard 1. The construction method to be used for the rebuild will be determined by DOMLEC.




**Figure 4-13 : Proposed connection with DOMLEC Grid**

### 4.4.2 Generator

The energy contained within geothermal steam is converted to electrical energy using a turbine that is mechanically coupled to a generator. Figure 4-14 illustrates a typical generator (painted grey colour). The size of the generator required is dependent on the amount of power to be converted.

The electrical power from the generator will be transmitted from the power plant using insulated cables, at 11kV, allowing connection to the existing DOMLEC 11kV network without adding a step-up transformer.



**Figure 4-14: 5.8 $MW_e$ generator (Ngawha Power Station, New Zealand)**

### 4.4.3 Switchroom

In order to safely operate and transmit electrical power from one location to another an indoor switchroom will be built. This facility will house equipment required to de-energise and protect incoming / outgoing lines / cables etc. Typical switchroom equipment includes circuit breakers, surge arrestors, current transformers and voltage transformers.

## 4.5 Land Requirements

### 4.5.1 Power Plant

The land required for the power plant, and hence civil works required to prepare the site, will depend on the power plant technology selected and design by the EPC contractor. Figure 4-15 provides nominal land area requirements for 2 x 3.5 $MW_e$ power plants, with binary plant requiring an area of approximately 115m x 60m (~60 m x 175 m including laydown area) and steam condensing plant requiring approximately 50 m x 60 m (60 m x 90 m including laydown area). This gives estimated minimum land requirements (including laydown) of:

- Steam Condensing Plant: 5,400$m^2$
- Binary Plant: 10,500$m^2$

However, taking into consideration local site factors and specific plant requirements (terrain characteristics, operations facilities, maintenance facilities etc.), the proposed plant layout as presented in Figure 4-2 has a land requirement estimate of 20,000 $m^2$, for the largest case binary plant option – including laydown / spoil areas. Approximately 10% of the power plant site will be concreted and the rest covered with gravel.

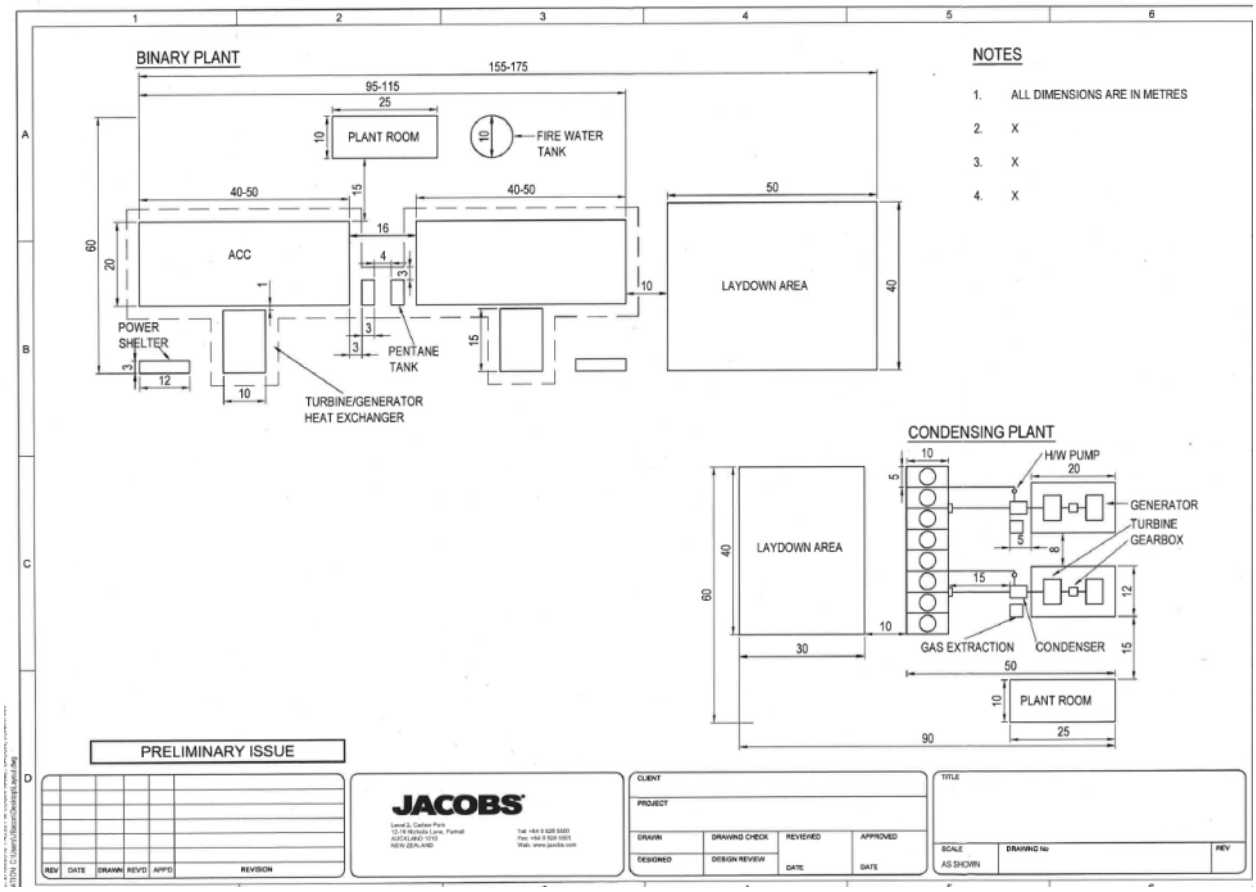


**Figure 4-15: Nominal land area required for 2 x 3.5 $MW_e$ binary and steam condensing technologies**

### 4.5.2 Steamfield

The felling of trees and other shrubs will be necessary in constructing an injection pipe corridor. Given the relatively small size of the project the brine transmission pipes will likely be limited to a diameter of DN 250-300mm (12” inches). A corridor of 3-5 metres wide will be required to enable access during construction. Expansion loops are required every ~100 m to account for expansion of the steel on contact with the hot brine. A number of trees will need to be felled to allow for space and construction access. A typical expansion loop is shown in Figure 4-16.



**Figure 4-16: Typical pipe expansion loop (large steam line, under construction)**

The estimated land requirements for the steamfield and associated equipment, such as the sumps, separator and atmospheric flash tanks, and wellpads are:

- Preferred 3.25km Injection Line: 13,000m$^2$
- Steamfield Equipment (includes pipes at PP): 1,700m$^2$
- Sump at Power Plant: 600m$^2$
- Wellpad WW-R1 & associated equipment: 2,000m$^2$
- Wellpad WW-01 & associated equipment: 2,000m$^2$

### 4.5.3 Switchroom & Transmission Line

The Project includes an indoor switchroom that will be located at the power plant site. This will connect to the transmission line that will connect to Laudat hydro power station to the north. The estimated land requirements are:

- Switchroom: 250 m$^2$
- 300m Transmission Line: 300 m$^2$

## 4.6 Hazardous Substances and Disposal

### 4.6.1 Geothermal Fluids

Uncontrolled discharges of geothermal fluids (brine and condensate) can be harmful to the environment. Brine can contain dangerous metals (such as arsenic) as well as other harmful substances (such as boron). These substances can leach into soils and accumulate if not remediated. Brine is also hot and could damage or kill flora and fauna in the vicinity of any discharge.

While geothermal condensate will contain far fewer quantities of hazardous materials, it can be rich in boron which will tend to accumulate in the cooling tower sludge. As noted in Section 3.3.3, the pH of this fluid is between 6.0 and 8.5.

All geothermal fluid should be captured and sent to injection wells. This is standard practice at most geothermal developments.

### 4.6.2 Working Fluid Storage

In a power plant utilising an ORC cycle the working fluid will require storage. The storage tank may require pressurisation depending on the volatility of the fluid selected.

Leakage of hydrocarbon working fluids and ancillary plant fluids such as oil presents a fire risk and a fire fighting system is normally integrated into the design.



**Figure 4-17: Working Fluid Storage Tank with bunding and fire protection system (red piping)**

### 4.6.3 Acid Storage

Depending on the nature of the geothermal fluids produced, acid dosing may be required as a pH modification step. This is required to adjust the pH of brine to ensure that Silica Saturation Index (SSI) limits are maintained within appropriate levels. The acid selected is normally concentrated sulphuric acid, though it may also be possible to use acetic acid. Based on the data obtained for WW-P1, it is not expected that there will be an issue with SSI for the envisaged steam separation pressures.

### 4.6.4 Antiscalant

Antiscalant dosing for prevention of calcite formation in the production well is likely to be required. This will be a poly-acrylate or poly maleic acid (PMA). Solutions will need to be securely contained and stored appropriately on site, with volumes and any controlled mixing undertaken dependent on scale accumulation in well and piping infrastructure.

### 4.6.5 Caustic Soda Storage

Caustic dosing from a skid mounted unit may be required to ensure the pH of the cooling water circuit is kept within appropriate limits. A system using pre-mixed sodium hydroxide is typical, although this may not be available in Dominica and it may be necessary to pre-mix the solution on site using bagged caustic soda.

### 4.6.6 Biocide Storage

For wet cooling towers biocide dosing is required to prevent build-up of biologic growth such as algae. Sodium Hypochlorite (NaOCl) is typical but must be shock dosed as otherwise the algae may become resistant to it. In this case other chemicals can be employed.

The biocide is stored in a tank to prevent degradation of biocide material (poly ethylene (HDPE) is common).

### 4.6.7 Dispersant

Cooling tower water dispersant(s) are chemicals that inhibit or prevent scale formation in the tower. As with caustic soda and biocide a bunded storage area is typical for all chemical storage tanks or containers. Bunding is usually specified to contain at least 110% of the volume of the largest tank and piping inside the bunded area.

Sumps would be provided to allow removal of hazardous chemicals with permanently located submersible pump(s) discharging into the cooling tower basin.

### 4.6.8 Turbine Lube Oil

Lubricating oil can cause adverse environmental impacts if leakage occurs. Plant areas will need to be bunded and have oily water separators to ensure any leaked or spilled fluids do not contaminate the site.

### 4.6.9 Disposal

These hazardous substances will be in use during the life of the plant and stored as described above. Disposal of the substances during the plants operation would only be required in the event of a spillage. In the event of a spillage, the bunding will contain most substances and it can then be collected to either be reused within the plant or injected into the injection well if appropriate. For other cases, specialist waste disposal contractors are employed. For the binary plant option, a spillage of the working fluid is a fire risk. In this case, the plant should be cleared and made safe and specialist waste disposal contractors brought in to collect and absorb the spillage.

# 5. Construction Activities

This section describes the construction activities typical for a condensing flash plant development. A binary plant development would not be significantly different.

## 5.1 Construction Overview

The construction activity will be concentrated on the main power plant, switchyard and separator station sites, but other work is required at the individual well-sites and in the piping corridors linking the wells to the power plant. Construction lay-down areas will be required for storage of equipment required for construction.

The plant for the construction works will include small drilling rigs, excavators, trucks, rollers, compactors, cranes, portable welders and generators and other items that are normal for such construction activities. It is not envisaged that a concrete batching plant will be required as concrete will be supplied by local plants. This requirement will be at the discretion of the EPC contractor.

The construction of the project is anticipated to last 18 months to two years, following the indicative schedule below.

| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
|---|---|---|---|---|---|---|---|---|
| Off-site preparatory work | ■ | | | | | | | |
| Site preparation | | ■ | ■ | | | | | |
| Foundations for equipment and pipelines | | | ■ | ■ | | | | |
| Powerhouse & permanent buildings | | | | ■ | ■ | | | |
| Major equipment installation | | | | | ■ | ■ | | |
| Interconnecting piping, wiring and instrumentation | | | | | | ■ | ■ | |
| Switchyard and transmission line | | | | | | | | ■ |

### 5.1.1 Separation Plant, Power Plant and Switchyard Construction

In the early stages most activity would occur off-site, including detailed engineering design, placing of construction contracts, and factory manufacturing and testing. Initial on-site work will be limited to final surveying and geotechnical investigations.

Once engineering is sufficiently advanced, site preparation would commence. This work involves bulk earthworks, roading, and preparation of the construction site including establishing temporary construction facilities, security fencing, drainage controls and access control. Construction facilities include lay-down space for storage of equipment and materials awaiting installation, amenities (washrooms, lunchrooms, car-parking) for construction workforce, and construction management offices. Prior to the commencement of construction, sediment and erosion control measures will be constructed in accordance with the sediment and erosion control plan and any local regulatory requirements. The objective of these measures is to:

- Avoid, or minimise, any potential adverse environmental effects on water quality and aquatic ecosystems from soil disturbance activities required during the construction;
- Avoid, or minimise, any potential adverse environmental effects on water quality and aquatic ecosystems from any watercourse crossings required during the construction;
- Avoid, or minimise, any potential adverse effects on land instability both within the site and on neighbouring properties during the soil disturbance activities required during the construction.

Thereafter, site construction work progressively involves:

- construction of foundations for major structures, equipment and pipelines;
- construction of the powerhouse and permanent ancillary and amenity buildings;

- erection of major and ancillary equipment such as steam-turbine generators, cooling towers, pumps;
- interconnecting piping, electrical wiring and instrument installation;
- switchyard and transmission line construction and connection to the grid.

Concrete foundations for the separator station will be constructed, followed by the set up and welding of steel pipes to transport steam and fluids such as brine, condensate, two-phase fluid to and from the power plant. Separator station plant and equipment will also be installed. At the separator station the excavation of a holding pond (lined) for geothermal fluid discharges will be required.

Specific disposal areas for washing out empty concrete trucks would be set up, with a hose and bunded area for discharge of washwater. The contractor will regularly remove accumulated concrete washings and these will be disposed of to landfill, while the water will percolate through the base of the bunded area to the ground.

During the site construction phase the site work-force reaches its maximum, in this instance some 10's of persons. Co-ordination on the timing of electrical interconnection works, responsibilities for completion and mutual agreement on the technical aspects must be fulfilled with DOMLEC.

As the power plant installation nears completion, commissioning commences, testing initially without, and then with, geothermal fluid. An important facet of commissioning involves cleaning of steam piping by steam blowing. Once the entire plant has been brought into operation a range of performance and reliability tests are undertaken. Having completed and passed performance and reliability tests the plant is handed over for commercial operation.

### 5.1.2 Injection Pipeline Construction

The construction contractor will form walking tracks within the injection pipe corridor and install infrastructure services between the track and pipeline route. Concrete foundations for the pipeline will be constructed, followed by the set up and welding of steel pipes to transport the separated brine. The volume of water required for these foundations is minimal and will be sourced from local watercourses. Pipe bridges will need to be constructed over the intermittent watercourses within the site as appropriate, and dependent on final steamfield configuration.

Local ponds (lined) to drain accumulated geothermal fluid during the shutdown of the injection pipeline will be excavated at low points in the pipeline.

The plant required for the injection pipeline construction works will include small drilling rigs for creating foundations, mobile cranes, trucks to transport materials and equipment, generators for pipe welding as well as excavators and trucks for foundation excavations. The preferred option includes the construction of a 160 m suspension pipe bridge over Breakfast River gorge. This will require manual cartage or potentially use of a helicopter to transport materials into some of the more remote areas, to be decided by the contractor.

## 5.2 Port to Site Access

All equipment will be required to be transported by sea to the island. Dominica's main port is at Woodbridge Bay, about 2km north of Roseau. The berth at Woodbridge Bay is used by both cargo and cruise vessels. The port has two shore cranes with capacities of 27 tons and 46 tons respectively. The port is capable of handling breakbulk, containers, bagged cargo and pallets[4].

[4] http://vertraco.nl/dominica/



**Figure 5-1: Woodbridge Bay Port**

A preliminary transportation and logistics assessment indicates cargo handling capabilities at the port are sufficient. The existing road network is currently undergoing repair after the recent storms in 2015 and 2016. Following the completion of these works, the road will be suitable for the transport of equipment to the project site. The photos below show the road network when it was used to transport the drilling rig and equipment and traffic baseline monitoring has been undertaken on this route.




**Figure 5-2: Access road to injection site (WW-R1) and football pitch (Caraïbes Environnement Developpement 2013)**



**Figure 5-3: Production site (WW-P1 right) from the southern access road (Caraïbes Environnement Developpement 2013)**




**Figure 5-4: Access road west of the site – 2011 photo (Caraïbes Environnement Developpement 2013)**

## 5.3 Local Site Access

The Laudat platform (containing WW-P1 and WW-03) is located close to the DOMLEC hydro balancing tank and is an open space cleared of vegetation, closed off with a gate (albeit in need of repair). The plots of land adjacent to the project are either open pasture, regenerating forest or planted with various types of fruit trees,

similar to the project site's original state. The area is not exclusively agricultural, with houses and a bar / restaurant situated close by to the north of the site. A paved road runs along the project site and enables access to the forest from the village of Laudat, as well as being the access road for two tourist sites (Titou Gorge and walking track to the Boiling Lake).[5]



**Figure 5-5: Panoramic view from east of the Laudat (WW-P1) Platform Site (Caraïbes Environnement Developpement 2013)**

The injection site (WW-01) near Wotten Waven is located directly next to the road and in close proximity to several vendors and tourism attractions (hot pools). To the north is forested area with a few people undertaking small scale farming. Injection site WW-R1 is near the village of Trafalgar and is located in a wetland area characterised by low vegetation. It lies in a small valley that is closed off to the north and south by tree-covered foothills and peaks. The vegetation is natural and wooded on the hillsides, with little human activity due to the difficult access. As shown in Figure 5-6 below, the injection well site is in an inhabited and developed zone with natural and somewhat inaccessible surroundings on all sides.



**Figure 5-6: Site WW-01 (left). View over Trafalgar (WW-R1) injection site (Caraïbes Environnement Developpement 2013)**

It is possible that construction activities relating to the power plant and steamfield may interfere with farming and subsistence activities on site. In addition to the local access roads there are existing tracks and routes for both private and public use near the Laudat site and on proposed injection line routes. Farm access will need to be maintained as far as practical during construction. The construction contractor and project owner will need to liaise with land owners to ensure construction works are co-ordinated with farming operations. This will be addressed further during the ESIA.

[5] Caraïbes Environnement Développement, 2013

## 5.4 Temporary Facilities

### 5.4.1 Construction Laydown Areas

One main construction laydown area is required adjacent to the power plant and separation plant site for the storage of power plant construction materials. The final location of this area is still being discussed. Other laydown areas may be required depending on contractor preferences, such as alongside the main pipe corridor for storage of injection pipeline construction materials.

Each laydown area will be fenced with security and access control. The power plant laydown area will be a base location and include site construction offices, worker amenities, lighting, stores & warehouse containers and similar facilities. The other laydown areas will be used predominantly for the storage of piping and equipment for the injection pipeline.

### 5.4.2 Staff Amenities

Amenities and ablutions for the construction workforce will include:

- potable water supply from either a tanker-supplied storage tank, or a dedicated treatment plant;
- lunchroom with hot water facilities;
- ablutions as required for the workforce with either on-site (packaged septic treatment plant) or off-site disposal (i.e. portable latrines);
- showers (as required) and an effluent soakage system.

### 5.4.3 Utility Services

Temporary telecommunications and electric power will be required during construction. A connection to the existing telecom network will be required.

A dedicated construction power supply will also be required at the power plant site. It was noted in the Caraïbes 2013 EIA report that Roseau Valley is covered by drinking water and wastewater systems, electric power grids and a telephone network and that both WW-P1 and WW-R1 sites were close to electricity networks. The adequacy of these connections will need to be determined in conjunction with DOMLEC, and they may need to be supplemented by portable diesel generators during construction.

### 5.4.4 Water and Wastewater Systems

Raw water will be required during construction and ongoing operation and maintenance of the plant. Water abstraction for the Project will require an authorisation application to the “Minister for Housing Lands Settlement and Water Resource Management” (Caraïbes Environnement Développement 2013).

Raw water for construction and permanent works shall be drawn from a naturally occurring spring located at higher elevation above the site.

The Employer shall be responsible for obtaining the permit to use the water for construction and permanent works. The Contractor shall be responsible for the design, execution and completion of the raw water intake structure and piping required to transfer to Site.

**Table 5-1: Proposed raw water supply information**

| Item | Natural Spring | Unit |
|---|---|---|
| 1. **Raw Water Source Location** | | |
| 1.1 Latitude | 15°19'58.20" | N |
| 1.2 Easting | 61°19'34.22" | W |
| 1.3 Elevation | 623 | mASL |
| 2. **Water take limits** | | |
| 2.1 Daily | 10,000 | Litres |
| 2.2 Monthly | 200,000 | Litres |
| 2.4 Maximum instant | 5 | Litres/s |

Domestic wastewater from amenities at the power plant site will need be collected and treated in packaged plant to meet discharge requirements. The contractor will also have to have plant in place for the worker's camp.

The construction contractor may elect to construct and service a suitably sized on-site sewage treatment system to meet the requirements of construction staff at the site. If so, the contractor will need to maintain the treatment plant and associated effluent disposal system to meet any required discharge criteria and to prevent odour or other nuisance to the community during the period of construction. The contractor will typically be responsible for decommissioning and removing the unit at the end of the construction period.

## 5.5 Commissioning Activities

### 5.5.1 Steamfield Commissioning

#### 5.5.1.1 Production Wellhead

The production well will be commissioned first before being put on-line with the two phase pipes. On start-up, it is possible for the wells to discharge debris such as stones and drilling residues as well as two phase fluid. The start-up method would be decided by the characteristics of the wells and the geothermal resource. It would be prudent to have an initial clearing discharge to the local silencer (rock muffler). The well will then be discharged to the local flash tank and brine will be captured in the wellpad sump.

#### 5.5.1.2 Two Phase Pipeline from WW-P1 to Separator

The production well WW-P1 will be brought on-line and used to flush the two phase lines up to the separator.

During commissioning, brine disposal is initially to the wellpad sump, therefore, the duration of steam blowing or other tests may be limited by the available sump capacity. If necessary, activity may need to be suspended to allow the sump to be emptied, typically pumped to an injection well. Noise levels at locations where steam is discharged to atmosphere is expected to be similar to well testing noise levels but short lived.

#### 5.5.1.3 Description of Steam Blow

Steam turbines are precision machines vulnerable to damage from any solid particles entrained in the steam. The manufacture and fabrication of piping results in solid matter being present inside the piping, and it is important to remove such contamination before finally connecting the pipework to the steam turbine. Removal of these solid particles from the pipe interior is accomplished by steam blowing wherein hot steam is passed through the piping at high velocity for a sustained period. Repeated exposure to the combination of thermal expansion / contraction and high fluid velocity is able to dislodge and remove the solid contaminants from the bore of the pipework. The source of steam for pipeline cleaning is the geothermal field itself, meaning that steam blowing occurs in the early stages of commissioning. The rock muffler may be used to discharge the

steam blowing vent to reduce noise emission. As the steam line is quite short it may also be possible to manually clean the line before commissioning.

An auxiliary steam blow will take place to clean power plant piping associated with systems such as steam ejectors. This will be done as per the procedure for the main steam line and may be carried out simultaneously. The remaining steam piping in the power plant from the governor valves to the turbine is then manually cleaned after the steam blows.

Pressure control valves (PCVs) provide steam pressure control. The PCVs will be removed and replaced by temporary spool pieces to allow steam blowing of the steam piping through to just upstream of the rock muffler. A temporary spool piece will also be installed on the end of the line to vent the steam above and away from ground level. Steam blow of the PCV lines can be done in conjunction with the main steam line.

#### 5.5.1.4 Injection Pipeline

The cross-country injection pipeline will be flushed after construction and as part of a hydro-test. Location of a suitable discharge point will depend on the site piping layout and geometry, but is expected to be into one of the sumps at the injection wellpads.

### 5.5.2 Power Plant

#### 5.5.2.1 General

Commissioning of the power plant involves a variety of activities. This is the first time that most of the equipment within the power plant will be tested. Listed below are some of the major aspects of the power plant commissioning phase.

#### 5.5.2.2 Turbine Oil Systems

The turbine oil systems will be circulated and flushed through temporary filters in the lines. The only waste generated will be the temporary filters used during the process.

#### 5.5.2.3 Cooling Water Pipes

Cooling water pipes will be flushed and the water will be circulated. Water used during the cleaning will be obtained from the site raw water supply and is usually discharged to the stormwater system. This water is then typically discharged to ground, pending environmental approval. No chemicals will be added during this process. Strainers will collect the minimal (handfuls) amount of debris expected to be generated and the debris will be taken to landfill.

#### 5.5.2.4 Wet Cooling Towers (if provided)

The cooling towers will have their first basin fill during commissioning. This will come from the site raw water supply. It is expected the fill would be completed over a 24 hour period.

#### 5.5.2.5 Biocide and Caustic Systems (if provided, for wet cooling tower chemical control)

These systems will receive first fill during commissioning. They will be located in separate areas that will be bunded so any potential spillage would be a localised, rare event, and would be cleaned up by an approved disposal contractor.

#### 5.5.2.6 Electrical Systems

The power plant and switchroom electrical systems will be energised under defined and controlled conditions according to contractor and grid operator guidelines.

# 6. Operation Activities

## 6.1 Typical Steamfield and Power Plant Operation Activities

The operation of the steamfield and power plant covers three phases:

- start-up;
- operation, and;
- shut-down.

### 6.1.1 Start-up

The start-up operation involves the start-up of the production well and the introduction of steam into the piping systems. Process drain valves are generally left open to remove condensate from the pipes and vessels, draining to storage sumps. Brine from the separator and AFT are discharged to the storage sumps at the power plant and separator station locations. Steam is vented to atmosphere through the steam vent valves located at high point vents as well as at the rock muffler located at the power plant.

### 6.1.2 Operation

During normal operation minimal steam venting occurs, the production steam is sent to the power plant and brine is sent to the power plant or directly to injection wells depending on the power plant technology. When all power plant systems are in operation, the power plant generates electricity which is exported to the grid.

### 6.1.3 Shut-down

Shut-down may be planned or due to unscheduled maintenance / outage or in some instances may involve a major transmission line outage. During shut-down the unit(s) stops generating electricity for export. The power plant vent valves will emit steam until the production wells are trimmed back to match the required remaining station demand. For a complete station shut the steamfield will be closed down and the steamfield piping systems will be drained to sumps at the wellpads as well as to the power plant sump. The production well will be either shut in or placed on bleed.

### 6.1.4 Emergency Shut down

If conditions arise that requires the power plant to immediately shut down, the plant systems will trip the power plant and steam will be directed away to the vent station. If during the emergency shutdown, the pressure continues to rise in the steamfield due to major equipment failure, the bursting discs may activate to release steam vertically to atmosphere. Under this situation the steam venting from the bursting disc will create a significant noise until the wells are shut in and geothermal fluids stop flowing.

This event is considered an emergency and is unlikely.

### 6.1.5 Maintenance

Unit maintenance would be undertaken to meet manufacturers, inspection agency and unit specific requirements. An inspection twelve months after commissioning is an anticipated requirement. Unit specific maintenance cycles will then be developed on the basis of the needs of the turbine generator sets. These are anticipated to be on a two to five yearly cycle, with early years of operation requiring more frequent maintenance. Given the expected power output of the plant and the quantity of electricity it will produce relative to the current grid demand, it is likely that outages would be scheduled during periods of low demand.

It is envisaged that a unit maintenance shut-down will occur annually. These annual shut-downs would be of about seven days in duration. Some specialised equipment (e.g. cranes) would be brought onto site for this work. The four yearly interval unit works takes about two to four weeks to perform (for a typical flash plant) and

an increased work force would be required. Additional labour resources would be engaged from local contractors and specialist providers.

Major steamfield maintenance and inspections will be undertaken during power plant unit shutdowns. The steamfield will be taken out of service during which time the separators, scrubbers and flash tanks will be inspected, cleaned and Non-Destructive Testing (NDT) would be carried out. Brine pumps and motors, valves and actuators will be inspected, overhauled and tested.

Other major maintenance work is associated with the steam production and injection wells, which require periodic workovers to remove any scale deposition.

## 6.2 Drilling Related Activities during Operation

The wells proposed for this project have been drilled and tested previously. Drilling activities related to new wells are not anticipated at the start of this project but at some point in the future it is likely that make up wells will be required to maintain operational requirements. An assessment of the impact of drilling new wells is considered outside the scope of this document and relevant ESIA, due to the uncertainty around all aspects of make-up wells required. A separate ESIA will be undertaken when make-up well requirements are well defined, at some point during the operation of the plant. Activities related to the maintenance of the already drilled wells, such as workovers, will occur during normal operation of the plant.

### 6.2.1 Cleanouts

In the course of the productive life of the wells, operational problems such as deposition of scale, silica, or calcite may develop in the wells affecting their operation. When this occurs, cleanouts using a drilling rig are sometimes required to restore the well's productivity or injectivity. Workover operations are of a relatively short duration (3 days to 15 days) and much of the ancillary equipment required to drill a new well is not required. A basic rig, substructure, BOP, pump and tank are generally sufficient. Water is used as the drilling fluid to avoid damaging permeable formations with drilling mud

### 6.2.2 Workover

A drilling workover generally entails some form of well repair which may require removing scale in the wellbore, removing the production liner, repairing the casing, deepening or side tracking the original bore, or plugging and abandoning all or part of the well.

The scale of a drilling workover operation falls somewhere between a new well and a clean out. Most of the ancillary equipment, i.e. cementing and mud handling equipment, and drilling consumables are often required.

Rather than scheduling periodic workovers or cleanouts, downhole antiscalant equipment may be fitted to wells. This will require regular site visits, both by operations staff and inhibitor delivering trucks. They will also require a garden shed sized hut on the wellpad to store the antiscalant.

### 6.2.3 Master Valve Change

Master valve changes can generally be undertaken without a drilling rig. The well is quenched by injecting cold water down the well in a controlled manner to prevent thermal stressing of the casing. Once the well is off-pressure the valve can be changed using a small crane. An alternative method used to change the master valve is installing a retrievable packer in the casing to isolate the well bore and so enabling the valve to be removed. The latter method requires a small drilling rig or other specialist packer installation equipment.

### 6.2.4 Make-up Wells

During the life of the station, declining output from the well supplying the plant will mean that it will be necessary to drill additional make-up wells to maintain the output from the plant.

The drilling operation required to drill new wells will depend on the total depth of the well, the types and sizes of casing to be used and the geological objectives / targets of the well. It can take between 30 and 60 days to drill a new well. New drilling pads may be required to accommodate the drilling rig, ancillary equipment and drilling waste disposal system. As well as the basic rig, up to four 30 $m^3$ mud storage tanks, mud pumps, mud cooling towers, solids handling equipment, cementing equipment, air drilling equipment and various storage and accommodation huts are located on or nearby the wellpad. Quantities of consumables, casing, cement and drilling mud additives are used during the drilling of a new well.

Multiple wells may be drilled from a single wellpad and it is envisaged WW-P1 pad would be utilised in the first instance for any additional make-up well.

# 7. Decommissioning Activities

For the Dominica geothermal development, it is assumed that design practices will allow for the full decommissioning of the power plant and steamfield, should that be required at the end of the plants design life or before if unforeseen conditions make the development uneconomic.

## 7.1 Overview

Following decommissioning, the site would be restored or reclaimed to its approximate original condition or to some standard that results in stable environmental conditions. Typical activities during the decommissioning / reclamation phase include:

- closure of all facilities and wells;
- removal of aboveground components and gravel from well pads;
- access roads (if not maintained for other uses);
- other ancillary facility sites;
- re-contouring the surface, and;
- re-vegetation.

The site activities associated with decommissioning are similar to those required for construction. Impacts would be similar to those addressed for the construction phase; however, many of these impacts would be reduced by implementing good industry practices. Restoration during this phase would also ensure that impacts beyond the life of the geothermal development are avoided or minimized.

It is likely that for plant decommissioning on this scale, a specialist contractor would be engaged to oversee the entire plant and steamfield decommissioning for a lump sum. Disposal of waste products such as concrete may be an issue. Disposal at local landfills may overwhelm the existing facilities on Dominica and landfill waste may need to be transported offsite to some other facility.

## 7.2 Infrastructure Components

### 7.2.1 Wells

Wells that are no longer required for production can be plugged and abandoned. This will require a drilling rig and associated equipment. The well is first quenched to eliminate its productivity. The quantity of water required and time to quench the well is dependent on porosity of the structure below the well but will be similar on a day to day basis as drilling (up to 8,000 $m^3$ / day). Cement is then pumped into the well bore to fully seal off the well. The cellar and the casing can then be removed if required but it is not good practice to locate permanent structures over abandoned wells. The steel components of the cellar can be sold for scrap but the concrete will have to be disposed at a landfill.

### 7.2.2 Steamfield Piping and Vessels

Equipment that is likely to be salvageable within the steamfield includes:

- Pipelines;
- Vessels;
- Valves (for steel);
- Pumps (depending on condition);
- Electrical components (for copper).

Pipeline supports are either

- pile type (i.e. buried in the ground to a given depth, surrounded by a concrete support) or;
- pad type (i.e. a large concrete pad to keep the support in place).

Pile type supports can either be removed from the ground completely or the support can be cut to a certain depth and the remaining steel and concrete buried over with topsoil. The support structure will be removed with a jackhammer and be disposed of to landfill.

The pad type support will be primarily all concrete except for the join between the pipe and the pad, which will contain metal. The pad will need to be removed and disposed of to landfill.

The pipe itself, provided it is good condition with minimal corrosion and minimal scaling on the pipe internals, can be recycled with an appropriate smelter if it is economic to do so. With the remote location of Dominica, removing the second hand pipe to an appropriate location may not be economically feasible.

The vessels, such as separation vessels, could be sold as second hand items or be sold to an appropriate recycling smelter. The foundations would need to be removed, as described previously.

Pumps and valves can either be sold as second hand equipment, depending on their condition, or sold as scrap items to be recycled or disposed of as required.

The copper in the electrical components, such as cables, will have recycling value and can be sold to an appropriate recycler. Other items which can't be salvaged will be sent to landfill.

### 7.2.3 Power Plant Equipment

If equipment items within the power plant are still in good working order, they can generally be sold second hand. Typical items would include:

- Flash Power Plants;
  - Turbine
  - Gas extraction equipment (steam ejectors, liquid ring vacuum pumps)
  - Condenser
  - Pumps (depending on condition)
- Binary Power Plants;
  - Turbine
  - Heat exchangers
  - Pumps (depending on condition).

Other items such as storage tanks can be sold for scrap so long as they are in a reasonable condition and if the cost of removal is equal or greater than the salvage value. Electrical equipment can be salvaged for its copper and other materials and sold to appropriate recycling entities.

The support structures for this equipment (foundations, support columns etc) will be disposed of to landfill. The structures will be required to be broken down to smaller components, likely by jackhammering, to allow for more manageable transport offsite to landfill.

### 7.2.4 Electrical Equipment

The electrical equipment, particularly the generator, will contain large quantities of copper which can be salvaged and sold.

The foundations will have to be removed as described previously.

### 7.2.5 Buildings

Modern building design and construction methods consider the whole life cycle of a building. These methods allow for the building to be removed after it has reached the end of its life without the need for total demolition and landfilling of all the components.

The building structure will typically be designed to be taken apart and if the structural members are in good condition they can be sold to an appropriate recycling smelter. The internals of the building will also be composed of large quantities of steel, access platforms for example, and can be disposed of with the structural members.

The structural concrete will need to be broken down into smaller, more manageable components and disposed of in the manner described in previous sections.

Electrical equipment within the building is likely to be too small scale to salvage (e.g. computers, lighting fixtures) and if they cannot be reused or recycled will likely be sent to landfill.

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# Appendix C. ESIA Terms of Reference

# Dominica Geothermal Development – Environmental and Social Impact Assessment

Ministry of Foreign Affairs and Trade

## Terms of Reference (ToR)

RZ020300-0000-NP-RPT-0001 | Version 7

July 2018

# Dominica Geothermal Development – Environmental and Social Impact Assessment

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## Document history and status

| Revision | Date | Description | By | Review | Approved |
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| 1 | 7 Oct 2016 | Draft for Submission to World Bank and GoCD | T Strange | B Clarke | A Brookes |
| 2 | 23 Nov 2016 | Changes following requests by World Bank | P Gabriel / Dorney Burgdorf | B Clarke | A Brookes |
| 3 | 10 January 2017 | Changes following further clarifications by World Bank | P Gabriel / Dorney Burgdorf | B Clarke | A Brookes |
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## Important note about your report

The sole purpose of this report and the associated services performed by Jacobs New Zealand Limited (Jacobs) is to provide a Terms of Reference for the Dominica Geothermal Power Plant Environmental and Social Impact Assessment in accordance with the scope of services set out in the contract between Jacobs and the Client (New Zealand Ministry of Foreign Affairs and Trade). That scope of services, as described in this report, was developed with the Client.

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The report is based on information supplied by Jacobs' Client and from information held by Jacobs for the Environmental and Social Impact Assessment project.

The report is based on information supplied by Jacobs' Client and from information held by Jacobs for the ESIA. This report has been prepared on behalf of, and for the exclusive use of, Jacobs' Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

## Glossary

| | |
|---|---|
| ASL | Above Sea Level |
| DOMLEC | Dominica Electricity Services Limited |
| DOWASCO | Dominica Water and Sewerage Company Limited |
| EIA | Environmental Impact Assessment |
| EHS | Environmental Health and Safety |
| EP | Equator Principles III (2013) |
| EPC | Engineer, Procure and Construct |
| GoCD | Government of the Commonwealth of Dominica |
| ESMS | Environmental and Social Management System |
| EPFI | Equator Principle Financial Institutions |
| ESMP | Environmental and Social Management Plan |
| ESIA | Environmental and Social Impact Assessment |
| IFC | International Finance Corporation |
| IUCN | International Union for Conservation of Nature |
| kV | Kilovolt |
| kW | Kilowatt |
| MW | Mega Watt |
| MWe | Mega Watt Electric |
| $NO_x$ | Oxides of Nitrogen |
| $NO_2$ | Nitrogen Dioxide |
| ORC | Organic Rankine Cycle |
| OUV | Outstanding Universal Value |
| $O_3$ | Ozone |
| $PM_{2.5}$ | Ultra-fine Particulate Matter |
| $PM_{10}$ | Fine Particulate Matter |
| PS | Performance Standard |
| SEP | Stakeholder Engagement Plan |
| $SO_2$ | Sulphur Dioxide |
| ToR | Terms of Reference |

# 1. Introduction

## 1.1 Background

The Commonwealth of Dominica is a small island developing state in the Caribbean Sea with a population of approximately 72,000 people and a land area of approximately 750 km$^2$. About 60% of the land is classified as a World Heritage site by UNESCO, due to its rich biodiversity. It is located near the centre of a string of islands known as the Lesser Antilles, between the neighbouring French territories of Martinique and Guadeloupe. The capital Roseau is located to the south-west of the island and has a population of around 15,000 people.

Dominica's power system relies heavily on diesel imports to generate electricity. Changing the power generation mix and reducing the cost and volatility of electricity prices have become development priorities for Dominica. To this end the Government of the Commonwealth of Dominica (GoCD) has pursued an exploration programme to evaluate the viability of geothermal resource in the Roseau Valley (Figure 1-1).

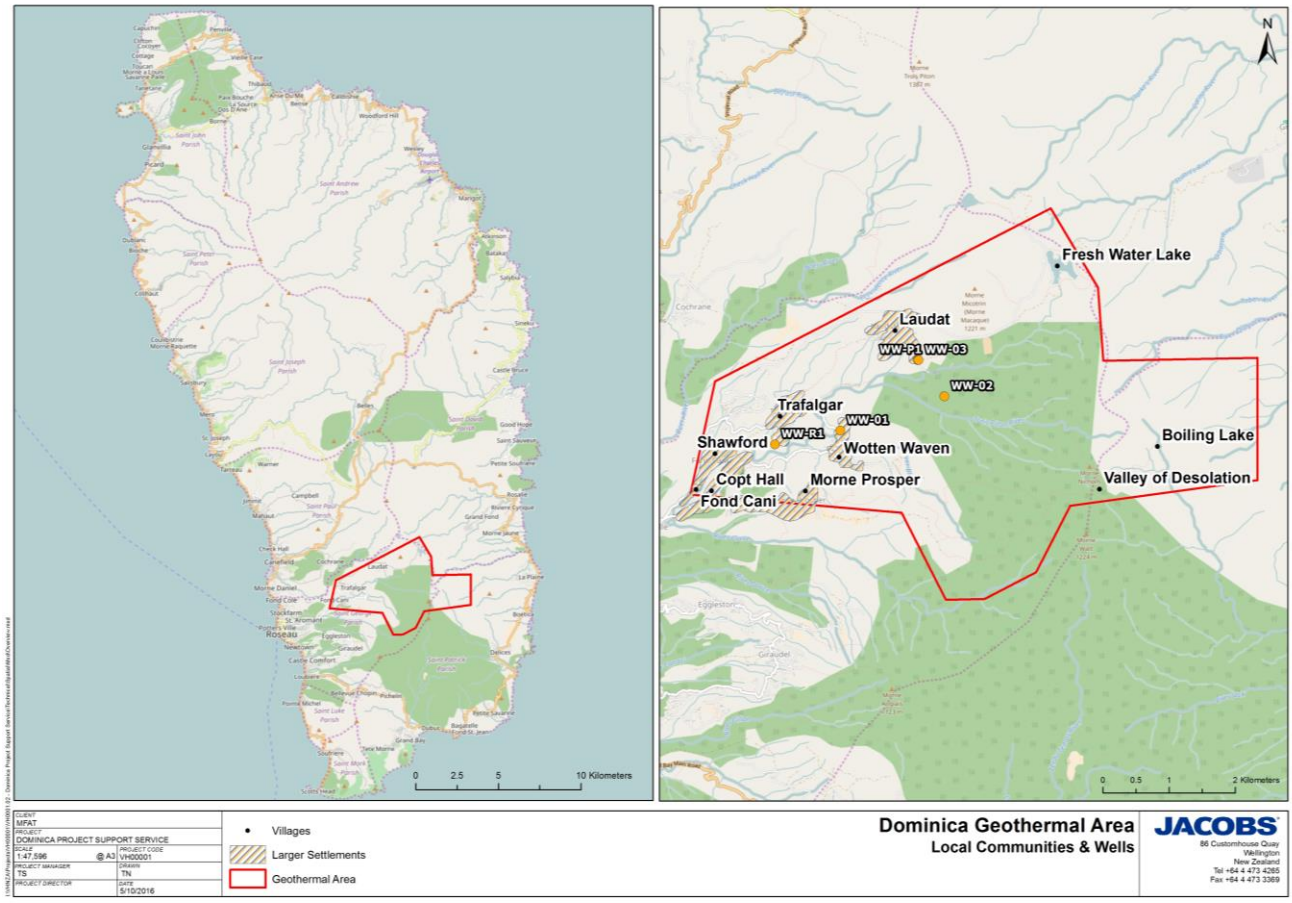



**Figure 1-1: Location of Roseau Valley (Site of proposed Geothermal Power Plant)**

The exploration programme has been conducted in a phased manner over the course of approximately 10 years:

| No. | Phase Name | Activities |
|---|---|---|
| 1 | Preparation | Project establishment, geoscientific investigations |
| 2 | Exploration | Exploration drilling of 3 slim hole wells and resource assessment |
| 3 | Production | Production drilling of one full size well and one reinjection well |
| 4 | Construction | Present phase comprising power plant construction and start-up |

The GoCD has previously taken the leadership to complete the successful drilling of exploration, production and injection wells in order to enable a geothermal power project in Dominica. The exploration campaign, which has been focussed in the Laudat-Wotten Waven-Trafalgar geothermal field, has proven the existence of a geothermal resource suitable for power generation.

The Government now wishes to complete the project by establishing the Dominica Geothermal Development Company Ltd (DGDC) to develop a 7 MW geothermal power plant and sell electricity to DOMLEC. The project company will be 100%-owned by GoCD, being established as a private company under the laws of the Commonwealth of Dominica. Electricity will be sold to DOMLEC, under the regulatory framework established through the Electricity Supply Act 2006. The project will be financed using grant monies from international agencies and bilateral partners, the World Bank and with the Government's own resources.

Prior to the construction and commissioning of the Geothermal Power Plant an assessment of the potential environmental and social impacts of construction and operation of the power plant and associated infrastructure is required in accordance with local legislation and international lending institution safeguards.

## 1.2 Purpose of the Terms of Reference

The Terms of Reference (ToR) describe the scope of the Environmental and Social Impact Assessment (ESIA) that will be carried out to evaluate the potential positive and negative impacts of construction and operation of the project in accordance with the requirements identified in Section 2. In addition it describes the process of identifying and implementing appropriate controls to avoid, mitigate and/or offset potential environmental and social impacts.

## 1.3 Structure of Terms of Reference

The structure of the ToR is set out as follows:

- Section 1 – Introduction
- Section 2 – Legislative Requirements
- Section 3 – Project Description
- Section 4 – ESIA Scope of Works

# 2. Legislative Requirements

It is important that a geothermal development meets internationally accepted environmental and social safeguard standards in order to ensure that benefits to project affected people are maximised and that potential adverse environmental and social impacts are minimised.

## 2.1 Local Legislation

With sole responsibility for physical development of land in Dominica, the GoCD manages physical development through the Commonwealth of Dominica Physical Planning Act 2002. In accordance with this Act, development permission is required before the construction of the project may commence. Clause 17 of the Act states:

*'No person shall carry out any development of land except under and in accordance with the terms of a development permission granted in that behalf prior to the commencement of such development…'*

Applications for development permission must be submitted to the Physical Planning Department within the Ministry of Agriculture and Environmental Protection along with an Environmental Impact Assessment (Clause 20(1)(b)). As defined in the Act an Environmental Impact Assessment (EIA) means:

- *'The environmental appraisal which will identify positive and negative impacts on the site, the immediate communities as well as on the wider regional context.*
- *The environmental assessment includes the direct impact of each project component as well as on the physical, socio-economic and socio-cultural features of the site, the immediate communities as well as the wider regional context.'*

Before carrying out an EIA a Terms of Reference should be submitted to the Ministry for review in order to confirm the scope of the EIA.

In accordance with Clause 22(1) the Chief Physical Planner may require the applicant to:

*a) Publish details of his application at such times, in such places and in such manner as may be specified in the notice;*

*b) Give details of his application to such persons or authorities as may be specified in the notice.*

Further, as specified in Clause 22(3), where an EIA is required, the Authority shall:

*a) publish a notice in at least one daily newspaper and affix a notice on the land to which the application relates that an application to develop land has been received and will be determined on a date specified in the notice; and*

b) *invite comments and representations either in writing or orally on such application.*

The Chief Physical Planner may also *'consult in writing any public officer or other person who appears to him to be able to provide information relevant to an application for development permission to enable the Chief Physical Planner to advise the Minister or the Authority , as appropriate, with regard to the application'* (Clause 24 (1)).

The ESIA will be approved by the Physical Planning Department of the GoCD in consultation with relevant Departments (i.e. the Environmental Coordinating Unit, Lands and Surveys Department, Environmental Heath and Safety Department). Monitoring of the implementation of Environmental and Social Management Systems will be conducted by the Environmental Health and Safety Department.

## 2.2 International Standards

As the World Bank has indicated its intention to provide funding to the development, the project is also required to demonstrate compliance with the World Bank Performance Standards for Private Sector Activities, OP 4.03,

(WBG, 2013) and the WBG Environmental, Health, and Safety Guidelines (hereafter referred to as the 'EHS Guidelines').

### 2.2.1 Categorising the Project

In accordance with the World Bank's Operational Policy, the World Bank undertakes environmental screening of each proposed project to determine the appropriate extent and type of Environmental Assessment (EA) needed. The Bank classifies the proposed project into one of three key categories, depending on the type, location, sensitivity, and scale of the project, as well as the nature and magnitude of its potential environmental impacts.

- **Category A:** A Category A project is likely to have significant adverse environmental impacts that are sensitive, diverse, or unprecedented. These impacts may affect an area broader than the sites or facilities subject to physical works. The EA for a Category A project examines the project's potential negative and positive environmental impacts, compares them with those of feasible alternatives (including the "without project" scenario), and recommends any measures needed to prevent, minimise, mitigate, or compensate for adverse impacts and improve environmental performance. For a Category A project, the borrower is responsible for preparing a report, normally an Environmental Impact Assessment (or a suitably comprehensive regional or sectoral EA).
- **Category B:** A Category B project has potential adverse environmental impacts on human populations or environmentally important areas - including wetlands, forests, grasslands, and other natural habitats - which are less adverse than those of Category A projects. These impacts are site-specific; few if any of them are irreversible; and in most cases mitigatory measures can be designed more readily than for Category A projects. The scope of EA for a Category B project may vary from project to project, but it is narrower than that of Category A assessment. Like Category A, a Category B environmental assessment examines the project's potential negative and positive environmental impacts and recommends any measures needed to prevent, minimize, mitigate, or compensate for adverse impacts and improve environmental performance. The findings and results of EA for Category B projects are described in the project documentation (Project Appraisal Document and Project Information Document).
- **Category C:** A Category C project is likely to have minimal or no adverse environmental impacts. Beyond screening, no further EA action is required.

All Category A and Category B Projects require an assessment process to address the relevant environmental and social risks and impacts of the proposed project in accordance with the applicable standards (i.e. WBG IFC Performance Standards and/or the WBG Environmental and Social Framework and the WBG EHS Guidelines). The assessment documentation should propose measures to minimise, mitigate, and offset adverse impacts in a manner relevant and appropriate to the nature and scale of the proposed project. For Category A, and as appropriate, Category B Projects, the assessment documentation includes an Environmental and Social Impact Assessment (ESIA), Environmental and Social Management Plan (ESMP) and Environmental and Social Management System (ESMS).

The assessment process should, in the first instance, address compliance with relevant host country (Dominica) laws, regulations and permits that pertain to environmental and social issues and with the IFC Performance Standards and EHS Guidelines.

Based on a description of the project (Section 3), a review of previous studies, summarised in Section 4.2 and a preliminary risk assessment (Section 4.4) carried out by Jacobs New Zealand Limited (Jacobs) it is considered the project should be given a preliminary classification of **Category A**. This is for the following reasons:

- Based on the initial preliminary risk assessment, most of the potential social and environmental impacts have been determined to be of low risk (i.e. to be managed by routine procedures) and would therefore not require any additional design mitigation.
- The route injection line Option C (Figure 3-4) passes close to the residential area of Laudat and therefore there may be adverse impacts due to:
    - Potential physical relocation or infringement of land use for residents of Laudat. Such displacement is undesirable and also not expected to occur, but cannot be completely ruled out at this stage.

- Potential disturbance of habitat (i.e. through vegetation removal) that has been classified as 'high' sensitivity by Caraibes Environment Development (2015a/b). High sensitivity areas were classified as those that contained the following:
    - A high number of protected species inside (IUCN, French and Dominican legislation);
    - An area with very few anthropic influences; or
    - A high number of endemic species (Dominican and Caribbean).
- Three of the potential power plant sites (Option 1A, 1 and 3 – see Figure 3-3)) fall within habitat that has been classified as 'high' sensitivity by Caraibes Environment Development (2015a/b).

It should be noted that the habitat classification carried out by Caraibes Environment Development in 2015 was done at a high level when the potential reinjection line routes and power plant sites were not known. Assigning the project as Category A is a precautionary approach at this stage based on the current level of uncertainty with site locations of reinjection lines and the power plant. This categorisation will be confirmed following site visits in December 2016 and by further studies through the ESIA process.

### 2.2.2 World Bank Performance Standards for Private Sector Activities May 2013

As the project is considered a private sector led economic development project, the following World Bank Performance Standards would apply to the project (note that these standards are equivalent to the IFC Performance Standards – Appendix A (IFC, 2012):

- Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts;
- Performance Standard 2: Labor and Working Conditions;
- Performance Standard 3: Resource Efficiency and Pollution Prevention;
- Performance Standard 4: Community Health, Safety, and Security
- Performance Standard 5: Land Acquisition and Involuntary Resettlement;
- Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources;
- Performance Standard 7: Indigenous Peoples; and
- Performance Standard 8: Cultural Heritage.

### 2.2.3 General and Industry Specific EHS Guidelines

In addition to the performance standards, the WBG has developed Environmental, Health and Safety (EHS) Guidelines covering both general and industry specific issues. The EHS Guidelines contain the performance levels and measures that are normally acceptable to WBG and are generally considered to be achievable in new facilities at reasonable costs by existing technology. The environmental assessment process may recommend alternative (higher or lower) levels or measures, which, if acceptable to the financiers, become project or site-specific requirements.

In general, when host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures are appropriate in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

The General EHS Guidelines became available for use in April 2007 and will be used in the preparation of the ESIA Report and supporting technical analysis. The industry specific guidelines are as follows:

- Geothermal Power Generation, and
- Electric Power Transmission and Distribution.

#### 2.2.3.1 Environmental, Health and Safety General Guidelines (April, 2007)

The EHS Guidelines cover the following key areas:

**Environmental**

The general environmental guidelines are:

- Air Emissions and Ambient Air Quality
- Energy Conservation
- Wastewater and Ambient Water Quality
- Water Conservation
- Hazardous Materials Management
- Waste Management
- Noise

**Occupational Health and Safety Guidelines**

The general occupational health and safety guidelines are:

- General Facility and Design and Operation
- Communication and Training
- Physical Hazards
- Chemical Hazards
- Biological Hazards
- Radiological Hazards
- Personal Protective Equipment
- Special Hazard Environments
- Monitoring

**Community Health and Safety Guidelines**

The general community health and safety guidelines are:

- Water Quality and Availability
- Structural Safety of Project Infrastructure
- Life and Fire Safety
- Traffic Safety
- Transport of Hazardous Materials
- Disease Prevention
- Emergency Preparedness and Response

**Construction and Demolition Guidelines**

The general construction and demolition guidelines are:

- Environment
- Occupational Health and Safety
- Community Health and Safety

#### 2.2.3.2 Environmental, Health and Safety Guidelines for Geothermal Power Plants (April, 2007)

These guidelines provide a summary of EHS issues associated with geothermal power generation and recommendations for their management. These include:

**Environmental**

Environmental issues that may occur during geothermal power generation projects, include the following:

- Effluents
- Air emissions
- Solid waste
- Well blowouts and pipeline failures
- Water consumption and extraction

**Occupational Health and Safety**

Occupational health and safety issues during the construction and decommissioning of geothermal power generation projects are common to those of other industrial facilities and their prevention and control are discussed in the General EHS Guidelines. Specific health and safety issues in geothermal power projects include the potential for exposure to:

- Geothermal gases
- Confined spaces
- Heat
- Noise

**Community Health and Safety**

Community health and safety issues during the construction and decommissioning of geothermal power generation plants are common to those of most large industrial facilities, and are discussed in the General EHS Guidelines. Community health and safety issues during the operation of geothermal power generation plants include:

- Exposure to hydrogen sulphide gas
- Infrastructure safety
- Impacts on water resources

Performance indicators and monitoring for each of the issues listed above follows the advice provided in the General EHS Guidelines.

#### 2.2.3.3 Environmental, Health, and Safety Guidelines for Electric Power Transmission and Distribution

The EHS Guidelines for Electric Power Transmission and Distribution sets out relevant information that needs to be considered in the environmental and social impact assessment of transmission lines between a generation facility and a substation located within an electricity grid. Key issues covered include:

- construction and maintenance of Right of Way and impacts on terrestrial habitats;
- electric and magnetic fields (EMF);
- hazardous materials; and
- occupational health and safety.

### 2.2.4 Other Relevant Treaties and Legislation

International treaties that Dominica is signatory to and any local Dominican legislation will be listed and a summary of key requirements will be included in the Policy, Legal and Administrative Framework section of the ESIA.

The project is located approximately 400 m from the Morne Trois Piton National Park UNESCO World Heritage Site and as such the assessment of potential impacts will be completed in line with International Union for the Conservation of Nature (IUCN) World Heritage Advice Note on Environmental Assessment.

# 3. Project Description

## 3.1 Overview

The project comprises the construction, completion, testing, commissioning, ownership and operation of geothermal wells, steam gathering and reinjection system, power plant with nameplate capacity of 7MW and connection to electrical grid and associated infrastructure in the Roseau Valley, Dominica.

The preliminary design for the project is ongoing with detailed design to be completed following a formal tender process for an Engineer, Procure and Construct contractor(s). Therefore some of the descriptions provided in this Section are high level and typical of a geothermal development in this setting.

Geothermal projects connect production wells through a steamfield facility to a power plant which is connected to an electricity grid. Geothermal fluids consist of steam, hot water (brine) and a small quantity of non-condensable gases (mostly carbon dioxide, but also some hydrogen sulphide). Used geothermal fluids produced by the project (separated brine and steam condensate) are returned to the geothermal reservoir via reinjection wells, which may be located some distance away (i.e. over 1 km) from the production wells to avoid short-circuiting or premature cooling of the production wells.

The key components of the proposed 7 MW power plant include:

- Power plant comprising 2 x 3.5 MW units or a single 7 MW unit (either Steam Rankine Cycle or Organic Rankine Cycle units).
- Production well at WW-P1 - The existing geothermal production well, WW-P1 at Laudat, is indicated to have potential to generate 6 to 9 MWe of geothermal electricity and will be the sole production well for the project. In the event that there is a decline in production well output to a level that will no longer sustain the full operation of the power plant, a workover of WW-P1 may be required or it might be necessary to drill an additional make-up well which would also be located on pad WW-P1
- Reinjection to wells WW-R1 and WW-01 - The used geothermal fluid (brine and possibly some steam condensate) produced from production well WW-P1 would be disposed of into reinjection wells WW-R1 and WW-01 in Trafalgar and Wotten Waven respectively via a 30 cm diameter pipeline of up to 4 km in length. WW-R1 will require injection of cold water for a period of up to three months to improve reinjection capacity prior to commissioning.
- Steamfield infrastructure including two phase piping, steam separators, atmospheric flash tank, steam gathering system, brine collection and disposal system, condensate collection and disposal system, pressure relief system and storage sump.
- Supporting Infrastructure including well pads, turbine building, primary and ancillary equipment, cooling system, road network and water/waste water supply.
- Substation and interconnection to the DOMLEC electricity grid via a transmission line to Laudat Power Plant.

Further description of the proposed technology and land requirements is provided below.

## 3.2 Power Conversion Technologies

Energy can be extracted from both brine and steam, or a mixture thereof, and turned into electric power. There is much more energy in steam than in hot water and even though the ratio of brine to steam produced by WW-P1 is about 5:1, most energy still lies in the steam phase. There are two main power plant technology options, steam Rankine cycle or organic Rankine cycle, either of which is suitable:

1) Steam Rankine Cycle

Geothermal steam is used directly in a steam turbine connected to a generator. After the steam passes through the steam turbine it can either be condensed or discharged directly to atmosphere. The atmospheric discharge option (sometimes called a back pressure turbine) is not recommended for the initial project development as

this can create a significant visual plume, it would only achieve ~3.5 MW output and there would be substantial work required to retrofit and convert the turbine to a condensing option.

2) Organic Rankine Cycle (ORC)

The geothermal fluids pass heat to an organic working fluid which boils and the organic vapour then drives a turbine connected to a generator. These are often also called 'Binary Cycle' plants because they use two fluids (the original steam and the organic secondary fluid). Organic Rankine Cycle plants may use brine, steam or two-phase fluids produced from the wells, with any of the options potentially providing a suitable solution.

## 3.3 Cooling System

A cooling system is required to reject heat which cannot be converted to electric power. This can either be air (dry) cooling or water (evaporative) cooling. The main differences between the two are: the land area required for the cooling towers; the visual impact of the equipment; overall efficiency; visual emissions, the reinjection load and the total installed cost.

- Organic Rankine Cycle plants are usually configured with air coolers, but they can be specified to use water cooling. Air coolers do not have a visible plume of water vapour, but may exhibit a heat haze and typically have a larger land footprint than water coolers.
- Wet cooling towers are typically used with condensing Steam Rankine Cycle plants. They have the advantage that part of the steam condensate is evaporated, so the total amount of liquid to be injected is less than for air cooling. However, water cooling towers may have a visible plume of water vapour when the relative humidity of the atmosphere is high.

A hybrid cooling option (which includes a small amount of dry cooling) can provide an alternative which removes the visual plumes of water vapour from water cooling towers, but comes at a slightly increased cost. The cooling system will typically be closely integrated with the power plant and supplied as part of the overall power plant package.



**Figure 3-1: Turbine Hall and Evaporative Cooling Tower (left). Air cooling for 20MW plant (right)**

## 3.4 Steamfield

The steamfield will comprise of the following:

1) A single production well on WW-P1 located in Laudat. Separation of steam and brine will take place on the production pad, with steam being transferred via a pipeline to the power plant, which would be located adjacent to the production well pad. River water was utilised for drilling and it is expected that existing infrastructure may be used for the provision of water for the power plant.

2) Approximately 3 km of cross-country pipelines to take hot brine for reinjection into two wells, WW-R1 and WW-01. The specific route for the brine line has not yet been confirmed (refer Section 3.7.2).

3) Well WW-03 located adjacent to WWP1 or WW-02 may be used for condensate injection, although this requirement will depend on the technology selected.

The steamfield equipment plays several important roles in the safe and reliable operation of a geothermal plant:

- Handling variable multi-phase steam, brine and non-condensable gas flows while ensuring that neither production wells nor reinjection wells are adversely affected by its operation.
- Matching the supply of steam to the power plant with the demand for steam from power plant as it changes in response to fluctuations in electricity demand.
- Providing clean steam (or brine) to the steam turbine or the Organic Rankine Cycle heat exchangers.
- Disposing of spent fluids into reinjection wells.

The steamfield will take production of two-phase fluid from WW-P1. Although in the current project only one production well is envisaged, the addition of future wells will be considered in the layout and design of pad WW-P1. The two-phase fluid will be sent to a separator where it will be divided into steam and brine phases, before flowing to the power plant (depending on technology) or reinjection pipeline. It may be necessary to install two separators if a two-phase development approach is chosen.

Separators may be vertical or horizontal, with major differences being the space required, tolerance to changes in geothermal fluids and overall efficiency. The separator is best located close to the production well and so is likely to be installed on the WW-P1 well pad. Other key pieces of equipment to be housed on this pad will depend on the final technology selected, but may include an atmospheric flash tank, steam venting and pressure control system, and storage sumps.

If a steam condensing turbine option is selected there is a requirement to inject the condensate produced. This is normally done via a dedicated pipeline to a different well than that used for brine injection because condensate has different chemistry to that of the separated brine. However, this is not necessarily the case and in some instances there can be advantages in combining the flows to prevent silica deposition, depending on the chemistry. This will be addressed during the detailed design process. The volume of condensate produced is low compared with brine produced and, if required, it is recommended that condensate be injected into well WW-03, located on pad WW-P1 or to WW-02. Organic Rankine Cycle technology enables condensate to be recombined and reinjected with the brine.

The steamfield takes the used geothermal fluids to reinjection wells WW-R1 and WW-01. The steamfield pipeline will be insulated to reduce heat loss, which is necessary to avoid deposition of silica. It will be clad in aluminium or other appropriate material and may be coloured or camouflaged to reduce visual impacts. The reinjection pipeline must operate at high temperature and pressure and needs to be carefully designed with suitable supports and guides which safely allow for thermal expansion of the pipe between its hot and cold states. This will require vertical or horizontal u-bends.

## 3.5 Civil Works

Three existing well pads will be used for the development WW-P1, WW-01 and WW-R1. All sites will require remedial works to bring them up to standard, with an initial indication of the work required as follows:

- Site WW-P1: Site improvement, slope stabilization, drainage works, fencing, security lighting.
- Site WW-01: Site fencing, slope stabilization, improve road access.
- Site WW-R1: Site fencing, security lighting, disposal of material/ general clean-up.

WW-P1 will contain the majority of fluid production and separation equipment, with power generation equipment to be located on a newly created pad adjacent to WW-P1. The Government currently owns the well pads. However, additional land will be required for the power plant site and for the injection line piping system. The land required for the power plant, and hence civil works required to prepare the site, will depend on the power plant technology selected. Figure 3-2 provides nominal land area required for 2 x 3.5 MW power plants, with binary plant requiring an area of approximately 115 m x 60 m (plus laydown area) and steam condensing plant

requiring approximately 50 m x 40 m (plus laydown area). A larger scale version of this Figure is provided in Appendix B.

Land requirements are discussed in more detail in Section 3.7.

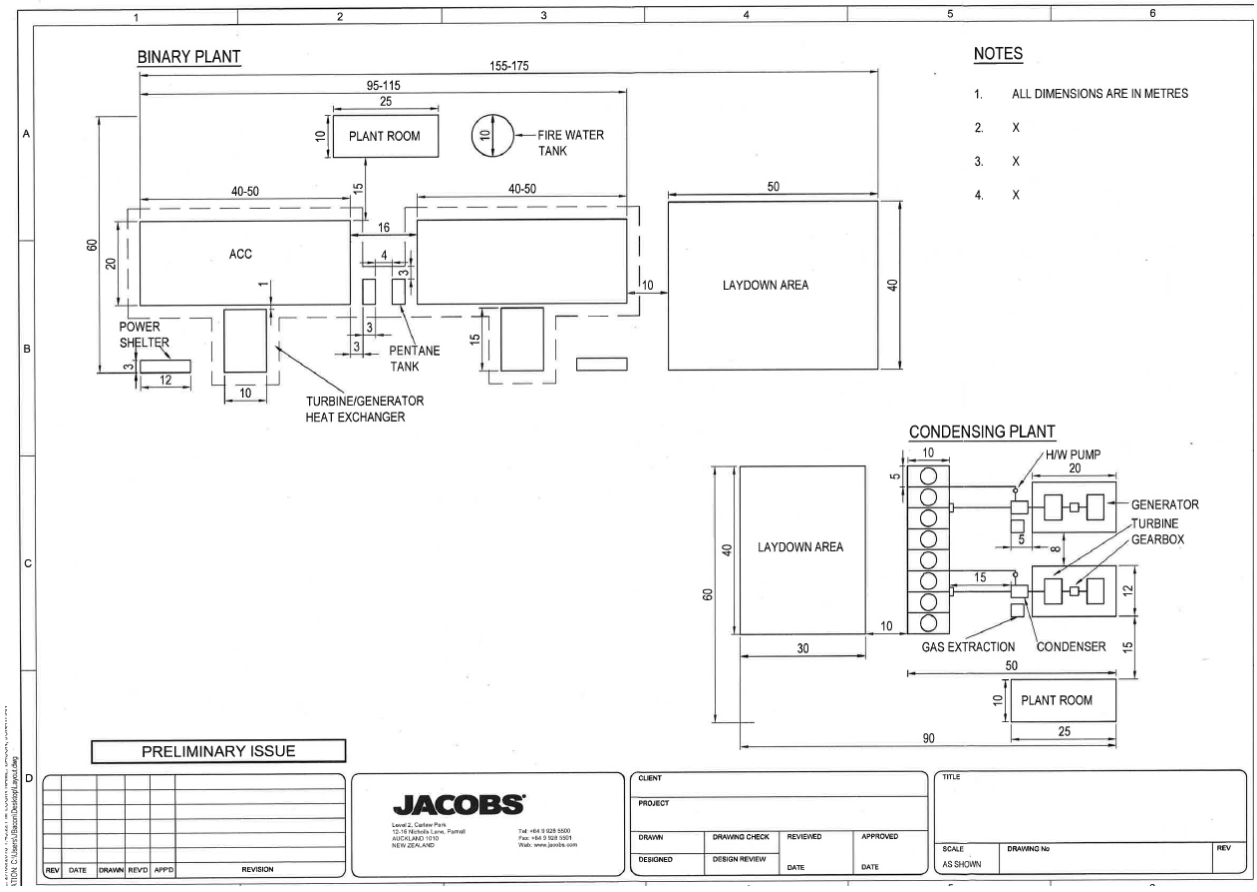



**Figure 3-2: Nominal land area required for 2 x 3.5 MW binary and steam condensing technologies**

The power plant will be constructed on a concrete pad designed to withstand the weight and movement of large pieces of mechanical equipment.

As the dominant power source for the island, it is recommended that the main components of the power plant be housed in a fully enclosed building designed to withstand heavy rainfall and hurricane conditions. This should be constructed to accommodate 2 x 3.5 MW turbines. Some elements of the balance of plant equipment, including circulating water cooling systems and gas extraction systems may be outside but under appropriate cover.

Access to the well pads is the responsibility of the Government and an evaluation of the roads and public infrastructure is required to ensure that the power plant can be safely delivered.

## 3.6 Land Requirements

In line with International Standards, the project will seek to avoid involuntary resettlement, economic displacement and minimise compulsory land acquisition. The Roseau Valley is relatively sparsely populated and the Government has already carried out numerous consultations and outreach with local landowners. As part of the ESIA process any additional land acquisition, including potential resettlement or economic displacement, will be completed in accordance with WB Performance Standard 5. The process will consist of the following steps:

1) An Audit of the land acquisition completed to date (known as Completion Audit) to ensure compliance with World Bank PS 5 and the IFC Guidance Note on PS 5, Annex B, 'Completion Audit -Table of Contents'.

2) For known new sites required for the project, where land acquisition will result in physical or economic displacement, a Resettlement Action Plan (RAP) and/or Livelihood Restoration Plan (LRP) will be completed prior to project construction. The contents of the Resettlement and/or Livelihood Framework, and/or any Resettlement Action Plans and Livelihood Plans will follow the principles and requirements as outlined in the World Bank PS 5, and further elaborated in the IFC Guidance Note on PS 5 with special attention to Annex A, Outline of a Resettlement Action Plan.

3) For any additional sites not known prior to appraisal but which might be required during project implementation that could result in physical or economic displacement, a Resettlement and/or Livelihood Restoration Framework will be prepared.

### 3.6.1 Land Acquisition

The Government has acquired the land for the existing well pads. Of the three sites which were purchased (WW-P1, WW-01, WW-R1), two were purchased through negotiated agreement and WW-P1 was purchased by Compulsory Acquisition under the Land Acquisition Act 1946, as the owner of the land is deceased. An audit of the land acquisition completed to date will be carried out and measures taken to mitigate any identified gaps.

Construction and operation of the plant may require the acquisition of up to three or more adjacent properties currently in private ownership, which may total approximately 6.5 acres. The final reinjection route is still being determined and will require a land corridor approximately 15 - 30 foot wide. An estimated 4 acres of lands will be required to establish the right of way for the reinjection pipeline and associated infrastructure. Future land acquisition will be completed in accordance with the requirements of WB Performance Standard 5 including the completion of compensation payments, along with involuntary resettlement and economic displacement requirements described below.

### 3.6.2 Involuntary Resettlement

As the Roseau Valley is relatively sparsely populated, it is considered unlikely that involuntary resettlement will be required. However, until the final requirements and locations have been finalised it cannot be ruled out. The Government has carried out numerous consultations and outreach with local landowners over the past six years as is documented in the previous two EIAs (2009 and 2011), a Gap Analysis (2013) and the ESIA Baseline Study (2015). For the areas where project related civil works will be undertaken and people are physically displaced, a Resettlement Action Plan will be prepared and implemented prior to project construction.

### 3.6.3 Economic Displacement and Livelihood Impacts

There are a number of farmers and potential small businesses that could be displaced by development of the project. For the areas where project related civil works will be undertaken in locations where economic displacement could result, a Livelihood Restoration Plan will be prepared and implemented prior to project construction.

### 3.6.4 Power Plant

Sites around WW-P1 were examined for suitability for expansion of the geothermal project and power plant siting. It is proposed that the new separation plant be located on the western end of the existing wellpad. The remaining space on the wellpad should be conserved for future production drilling. Three sites have been identified which are suitable for the development, with relatively modest slope and located in close proximity to existing wellpad.

1) Option 1 immediately North of WW-P1 is large enough to accommodate a condensing plant, with provision to include the Option 1A site for ancillary requirements such as offices and maintenance facilities. Much of this site is in the ownership of the government as a 3.8 acre parcel of land was acquired for WW-P1.

2) Option 2 is to the east of WW-P1 and on approximately the same elevation. Ready access could be formed from WW-P1. The site would be suitable for a condensing plant, but also has a potential use as an

extended wellpad for future drilling programs (i.e. export plant). A local preference was expressed by the Community Liaison Officer that this area be used for future drilling.

3) Option 3 is a larger site suitable for a binary plant. It is located some 100m north-east of WW-P1 and has a 12° slope to the north which could be readily levelled to form a platform. It is currently used for small scale agriculture.

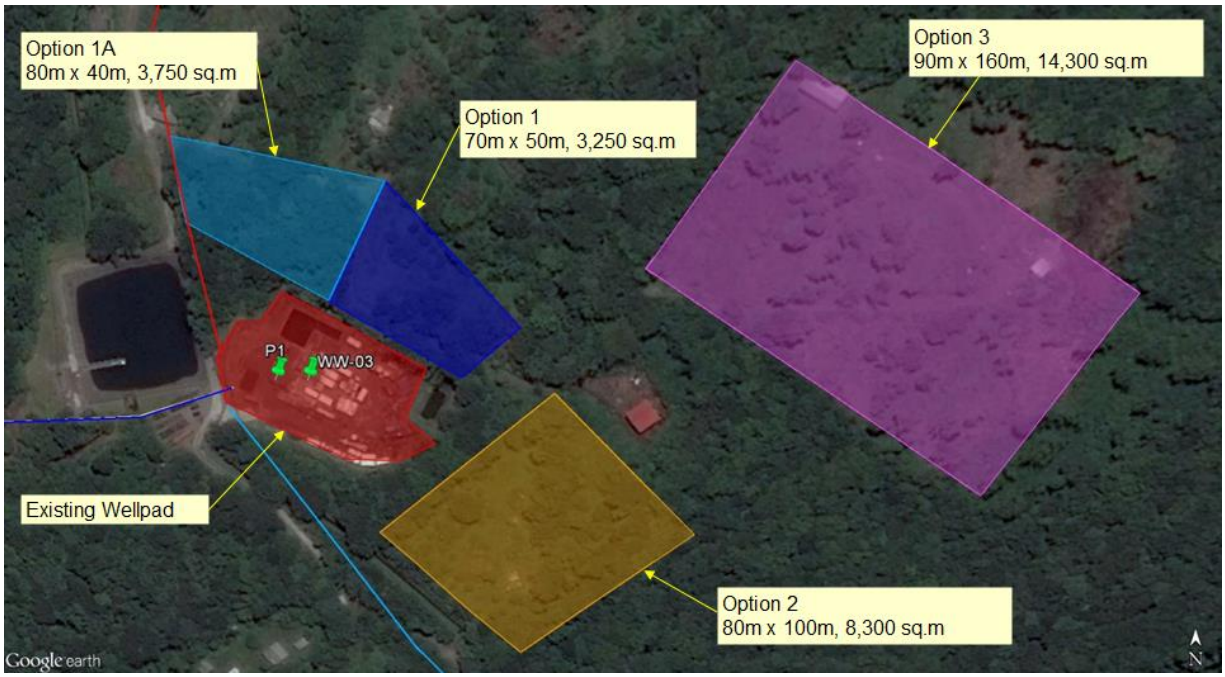



**Figure 3-3: Power plant site options**

Option 1 and 1A are the preferred sites as they are largely in the ownership of the Government. They are best suited to a steam Rankine condensing plant. If a binary plant is selected Option 3 is the preferred site, although it may be possible to place a binary plant with wet cooling onto Option 1 and 1A. Option 2 should be retained for future drilling and production expansion.

### 3.6.5 Steamfield

Options for steam/brine separation, steam pressure control, steam scrubbing, and start-up, normal and emergency shutdown operations need to be considered and the land required to achieve these operations needs to be determined through a preliminary steamfield design exercise. These will be practically the same for all power plant technology options.

The land requirements for the steamfield piping system are dominated by the brine reinjection pipeline, which will run from WW-P1 to WW-01 and/or WW-R1. The diameter of the pipeline would be approximately DN 250 to 300 mm (10 to 12 inches).

Site visits by mechanical and geotechnical disciplines identified eight possible pipeline routes. The routes were evaluated on the basis of the constructability, topography, geohazard exposure (i.e. landslides, rock falls, etc), estimated capital costs, operational considerations and social and environmental constraints. The following route options are preferred and shown in Figure 3-4:

- Option A, D and F
- Option C, D and F
- Option H and F

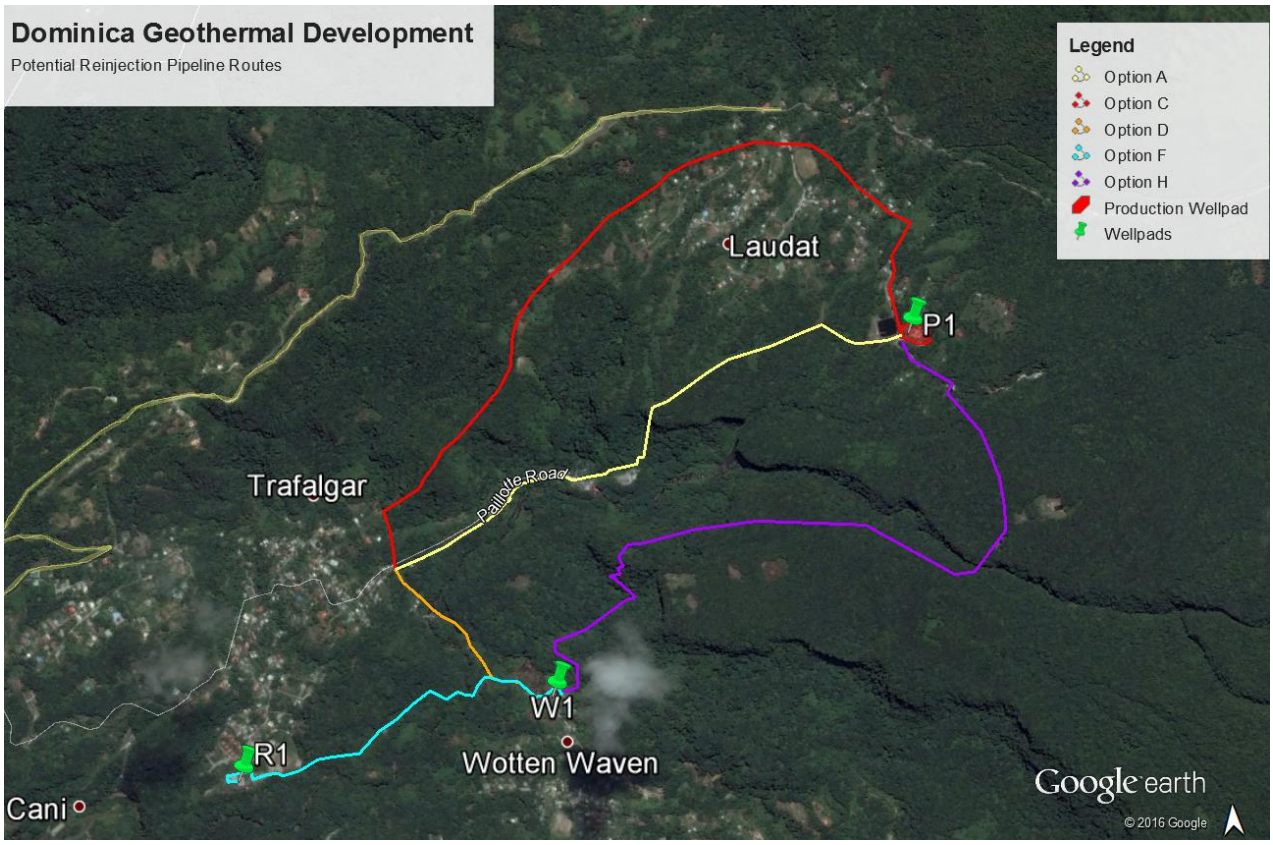



**Figure 3-4: Proposed reinjection pipeline routes from WW-P1 to WW-R1 and WW-01**

Final route selection will be carried out in close co-ordination between the process engineering, mechanical, geotechnical and civil engineering design disciplines, along with the Government, Land and Survey Division and environmental and social scientists.

Option A - Follows DOMLEC's hydropower pipelines across easily navigated topography and would need to utilise DOMLECs existing bridge which currently carries the penstock. Construction would be simpler in this section and there is adequate space for expansion loops. The pipeline would then need to descend the 60 – 80m vertical cliff, alongside the existing hydro pipeline (Figure 3-5). Once the cliff has been descended, the route runs alongside the river and road.

Option C – This is the longest route and would require pumping of brine (~80kW – 100kW load) from WW-P1 at 554m asl to 615m asl. The route would follow the existing penstock route, before traversing to the north and west of Laudat to avoid the village itself and associated road/accessway crossings. The pipeline would descend down a steep and narrow ridge line on which the Waitukubuli National Trail presently runs.

Option D – From the point where the Trail meets the road, the pipeline would cross the river, supported on the new bailey bridge, before following the road to Wotten Waven and pad WW-01.

Option F – This section of pipeline would go from WW-01 to WW-R1. The pipeline would follow the river, crossing the gorge with a pipe bridge near the river junction. The last 200m before the football field would follow a narrow track with minimal space for expansion loops. The track has steep slopes and would require rockfall protection. Space for construction in this part of the trail is limited.

Option H - This route would traverse cross country from WW-P1 to near the old aerial tram station. From there the pipe would cross the Breakfast River Gorge using a suspension bridge of 50 – 70 m. The pipeline would then cross relatively flat terrain before descending down a short section of narrow pathway, which broadens and eventually comes out by WW-01.

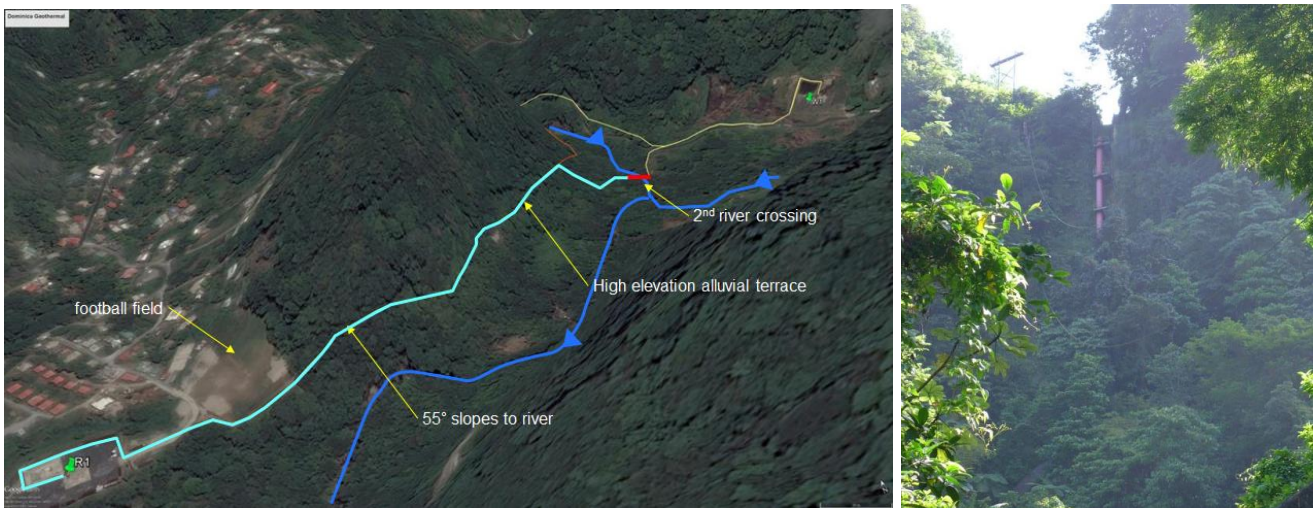



**Figure 3-5: Recommended reinjection pipeline route from WW-01 to WW-R1**

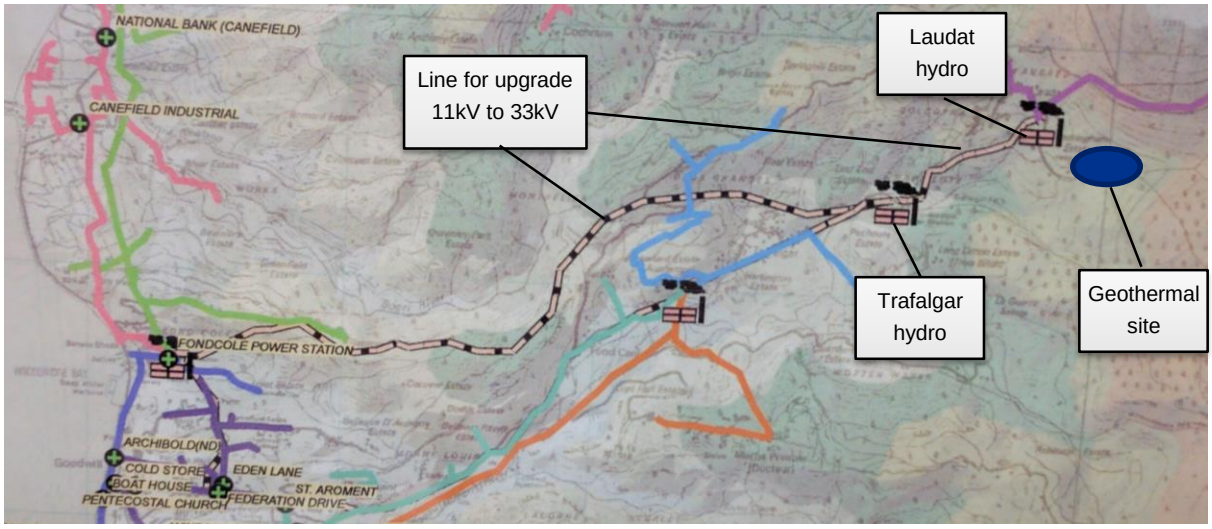
## 3.7 Electricity Transmission Infrastructure

There is still some discussion on the optimum transmission infrastructure to support grid interconnection of the power plant, which is presently the subject of a power systems analysis. The following interconnection approach is therefore subject to refinement based on the outputs of technical work. As associated infrastructure, these works will be considered in the ESIA as they are directly related to the project.

The geothermal plant will (likely) connect to the DOMLEC grid at the project site and have a direct 33 kV connection to Fond Cole. The geothermal plant would have a step-up 11kV:33 kV transformer located at the power plant site. A new 11 kV line would be constructed from Laudat hydro power station to the 11kV busbar at the geothermal power plant. The poles would also carry the 33 kV line from the geothermal power plant, which would not connect Laudat hydro station to the 33 kV system, before interconnecting with the existing line between Laudat and Trafalgar.

The power lines from Laudat to Fond Cole will be upgraded from 11 kV to 33 kV by reinsulating the existing lines. The existing route and wires will remain unchanged. Minor works will be required to disconnect the existing dedicated 11 kV line from the Trafalgar power station such that a direct line for the geothermal plant is provided.

**Figure 3.1 : Location of existing power lines in relation to geothermal project site**



# 4. Scope of Work

## 4.1 Objective of the Study

The goal of the ESIA is to evaluate the temporary and permanent impacts of the construction, commissioning, operation and decommissioning of the power plant, steamfield and transmission infrastructure, on the natural and human environment. The study will make recommendations to mitigate or minimize the foreseeable negative impacts, which will be captured in the Environmental and Social Management Plan (ESMP). An Environmental and Social Management System (ESMS) will also need to be established to ensure implementation of relevant environmental and social controls.

The ESIA will build upon the existing safeguards work carried out for exploration and production drilling, baseline survey work carried out through the INTERREG IIIB Programme and recommendations provided in the 'Situational analysis for the preparation of the Wotten Waven-Trafalgar-Laudat field in the Roseau Valley'.

Any drilling of further wells at existing well pads will be covered in the ESIA, but any future delineation wells for a new development (which maybe 10 years way or more) will not be included.

## 4.2 Baseline Environmental and Social Data

The Roseau Valley lies inland from the coast, bordering the capital city of Roseau. The valley is heavily wooded with rich vegetation and various communities exist in the area (Trafalgar, Laudat, Fond Cani and Wotten Waven). There also exist some very popular tourist attractions, such as the hot springs at Wotten Waven, Trafalgar Falls, the Boiling Lake, Titou Gorge, Valley of Desolation, and the Freshwater Lake.

Existing physical, biological and socio-economic conditions will be described in the ESIA to form the basis for an assessment of potential impacts from the construction and operation of the Project. This will include:

- Air quality, climate, meteorological and acoustic data
- Water quality and hydrology
- Land use, land cover and visual amenity
- Terrestrial and aquatic ecology, with an emphasis on rare, endangered and endemic species, critical habitats and ecosystems services
- Natural hazards, such as hurricanes, landslips and flooding
- Socioeconomic environment, including public health, settlements (demographic profile, gender profile and land ownership), social infrastructure, economic profile (i.e. level of employment) and economic activities (reference should be made to Section 4.2.2.8 for more details)
- Culture and heritage
- Transport infrastructure and traffic movements.

These will be established through the review of literature and findings of earlier studies and completion of supplementary baseline data collection activities to address any perceived gaps in information.

### 4.2.1 Studies Completed to Date

To date the following environmental and social studies have been completed:

- Caraibes Environment Development (2009) Regulatory Impact Assessment on the Initial Environment - Environmental Feasibility Study.
- Caraibes Environment Development (2011). Stage 1: Exploration Drilling Process – Environmental Impact Assessment.
- Caraibes Environment Development (2013) Stage 2: Preliminary Environmental Impact Assessment of Geothermal Production and Re-Injection Drilling Wells in Dominica – Environmental Impact Assessment.

- To support the preparation of an ESIA for the Project, baseline surveys of the social, physical and biological environment within the Roseau Valley were completed between October 2013 and April 2015. These were summarised in the following reports (collectively referred to as the 'Baseline Study'):
  - Caraibes Environment Development (2015a). Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production. Final report, May 2015. Section 3 Biodiversity / Terrestrial Flora and Fauna.
  - Caraibes Environment Development (2015b). Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production. Final summary report.

### 4.2.2 Gap Analysis

A review of these studies has been carried out. The findings of this review are presented below along with any further baseline data collection proposed. In addition a review of the situational analysis prepared by the World Bank has been carried out, with relevant findings incorporated into the scope of work described below.

#### 4.2.2.1 Air Quality

Caraibes Environment Development conducted baseline survey of air quality in 30 locations in 2014 (Caraibes Environment Development, 2015a/b). The survey monitored concentrations of sulphur dioxide ($SO_2$); hydrogen sulphide ($H_2S$); oxides of nitrogen (NOx) – nitrogen dioxide ($NO_2$); fine particulate ($PM_{10}$) and ultra-fine particulate ($PM_{2.5}$); and ozone ($O_3$) on two occasions, once during the dry season (23 April to 6 May 2014) and once in the wet season (20 November to 11 December 2014). The study also selected the location for the installation of a reference weather station, which enabled measurement of the principal weather features over the course of a year. This data will be used to establish the air quality baseline in the ESIA.

#### 4.2.2.2 Noise

During baseline sampling, noise measurements were taken in the principal residential zones, the main tourist sites and valley hotels (Caraibes Environment Development, 2015a/b). Two noise measurement campaigns were carried out in the tourist high season (December 2013) and low season (April 2014). Five residential zones studied: Laudat, Fond Cani North / Fond Cani West & South, Trafalgar, Wotten Waven, Morne Prosper with 54 acoustic measurement points analysed over a 24 hour period. The results attributed ambient noise levels to local fauna, human activity, vegetation and running water (rivers and waterfalls, etc.). Ambient noise levels were generally higher at night and there were higher ambient noise levels closer to tourist sites and hotels. This data will be used to establish the baseline in the ESIA.

The data recorded as part of the baseline study has been deemed sufficient to use in the ESIA to satisfy the requirements of the local and international legislation and guidelines.

#### 4.2.2.3 Hydrology and Hydrogeology

No information on hydrology (flows) or hydrogeology is presented in previous EIAs for drilling or the baseline report prepared by Caraibes Environment. However, gauging of surface water flows has been carried out at the following locations by DOWASCO:

| Location | Coordinates | |
|---|---|---|
| River Claire | - N15d17'51.89" | W61d19'44.32" |
| River Douce | - N15d18'11.82" | W61d22'06.21" |
| Titou Gorge | - N15d19'44.66" | W61d19'30.11" |
| Trafalgar River | - N15d19'24.98" | W61d20'33.46" |
| River Blanc | - N15d18'41.39" | W61d19'29.96" |
| Tributary | - N15d18'37.83" | W61d19'21.78" |

In addition, it is understood that DOMLEC carries out continuous monitoring of flows entering the hydroelectric power plant at Laudat. Therefore it is proposed to request information from DOMLEC regarding abstraction of water from Titou Gorge, which is the most likely source of water abstraction for development of the geothermal power plant, due to its proximity to the site. This will supplement the information already obtained by DOWASCO.

Detailed information on hydrogeology is not considered necessary for the ESIA as there is not proposed to be abstraction of groundwater for construction or operation of the project.

#### 4.2.2.4 Aquatic Ecology and Water Quality

The baseline studies in 2015 recorded the current condition of the aquatic habitats, water quality and biological values of the waterways in the study area (Caraibes Environment Development, 2015a/b). The baseline data is considered comprehensive in the documentation of current water quality and the condition of the biota present, including all relevant biological groups (diatoms, macroinvertebrates, microcrustaceans and fish). It is noted that systems for classifying the health of aquatic communities in the study region were limited, however, appropriate attempts were made to develop relevant biological indices that can be used as the basis for assessment of potential impacts associated with the proposed development. Species vulnerability to disturbance was assessed using the International Union for Conservation of Nature (IUCN) Red Lists.

There were three sampling trips undertaken to establish baseline conditions, and this information will be sufficient for preparation of the ESIA. However, it is recommended that further sampling be undertaken prior to construction of the project in order to establish the magnitude of any natural variability in the system. This will provide a robust basis for comparison with ongoing monitoring during the construction and operations stages.

#### 4.2.2.5 Landscape, Visual and Heritage

The baseline study for visual amenity captured the location of view points over the valley from high points as well as the view up the valley from Roseau, providing descriptions of landscape and architectural characteristics of the territory. The baseline data also included discussions with historians, botanists and residents from Laudat and documentary research. Landscape types were established, as well as key infrastructure and buildings in the locality. This data will be used to establish the baseline in the ESIA.

Further information may be collected on site visits by Jacobs and through ongoing consultation with the local communities, related to the temporary visual impact of vertical steam discharges.

#### 4.2.2.6 Terrestrial Flora and Fauna

An initial baseline survey for flora and fauna and subsequent analysis was carried out in 2008 with the aim to provide an introduction to the biodiversity of the Roseau Valley, and also the legal context related to forest clearing and protected natural spaces. Three areas were initially selected in 2011 for detailed flora and fauna assessment and then a fourth added in 2015 (Caraibes Environment Development, 2015a/b). At each area the dominant habitat and flora and fauna species were described and matched to vegetation type descriptions. The general description of the biodiversity and flora and fauna in the Roseau Valley was informative and based on expert knowledge of the island biodiversity (using the International Union for Conservation of Nature (IUCN) Red Lists). There was also a high level classification of the sensitivity of the habitat carried out, which the geothermal resource areas into the following:

1) High sensitivity areas containing:
    - A high number of protected species inside (IUCN, French and Dominican legislation);
    - An area with very few anthropic influences;
    - A high number of endemic species (Dominican and Caribbean); or
    - The presence of species poorly represented elsewhere.
2) Medium sensitivity areas containing:
    - Lower number of protected species than high sensitivity areas;

- Higher level of anthropogenic disturbance than high sensitivity areas; and
- Less endemic species (Dominican and Caribbean)

3) Low sensitivity areas containing:
   - Higher level of anthropogenic disturbance than medium sensitivity areas; and
   - Fewer endemic and protected species than medium sensitivity areas.

The description of fauna species and habitats was based on opportunistic observations during the vegetation / flora survey and the methods and results of targeted surveys were not discussed. To address this limitation, the authors noted that up to 176 bird species were reported in the literature for the island, including three species of threatened status listed under the IUCN and two species protected in Dominica.

The bird species of the island of Dominica were listed and described in the baseline studies. However, these species were not identified in the reports or potential habitats mapped within the Project area. Similarly, it is not possible to determine from the reports whether threatened vertebrate species are present within the Project area. Therefore, further ground-based surveys will be required as part of the terrestrial ecological assessment in the footprint of the proposed power plant site and reinjection line route.

#### 4.2.2.7 Natural Hazards (including Flood Risk)

Bibliographical data was collected in the Roseau Valley during baseline sampling activities (Caraibes Environment Development, 2015a/b). For flooding, the measurement and monitoring of water flow rates in the valley was recorded and for earthquakes and land movements, historical document describing previous seismic activities were assessed as well as analysis of precise geological maps of the valley. This desk-based survey was complemented by field data that allowed the determination of:

- The hydrological characteristics of the valley (water tables, flooding zones, population survey).
- Natural phenomenon index (lithology, slope, geomorphology).
- Correlation with hazards observed on neighbouring islands.

Analysis of this data allowed for flood modelling and hazard mapping for the valley, identifying areas along the potential reinjection routes which may be prone to landslips.

The data recorded as part of the baseline study has been deemed sufficient to use in the ESIA to satisfy the requirements of the local and international legislation and guidelines. This data will be used to establish the baseline in the ESIA.

#### 4.2.2.8 Socio-economic

The project's socioeconomic baseline has benefited from previous EIAs (2009 and 2011); a Gap Analysis carried out by the World Bank in early 2013; and a subsequent ESIA social, physical and biological baseline survey (ESIA Baseline Study) carried out between 2013 and 2015. Current baseline information collected by Caraibes Environment Development in 2015 is based upon desktop study and data collection including 25-30 interviews conducted with local stakeholders. In addition, the report indicates that three public meetings were held on 11, 12 and 13 December 2013 in Laudat, Trafalgar and Wotten-Waven respectively. Additional meetings were also noted in November of 2013 and January of 2014 per memos from the Ministry of Public Works and Ports Geothermal Project Management Unit. Further details of the meetings completed to date will be provided to the extent feasible in the ESIA and Stakeholder Engagement Plan (SEP). A Stakeholder Engagement Plan (SEP), including a grievance mechanism, is to be prepared. The project socio-economic area of influence is not specifically defined but consultation is focused around the three communities of Laudat, Trafalgar and Wotten-Waven.

About 1,800 people live in the Roseau Valley, of which nearly 1000 in Trafalgar and Shawford, and the remaining in the hamlets of Wotten Waven/Casseau, Copthall, and Laudat. Many livelihoods in the Valley depend on tourism, as this is one of the main tourist sites in the country, primarily for hot springs and nature

activities; on small-scale agriculture; as well as jobs in the capital. The 2013 consultations documented community concerns for the potential risks associated with a geothermal plant; potential impacts (which can be both positive and negative) on ecotourism; and potential for job creation, among others.

The baseline includes demographic information on the Roseau Valley from Dominica's Central Statistical Office supplemented by information from field surveys and the Caribbean Development Bank on quality of life, education, housing, infrastructure governance and the economy. There is very little information on community health and safety.

The ESIA to be conducted for the proposed project will build upon previous studies and complete any remaining gaps, primarily concerning community engagement; community health risks; land acquisition and potential involuntary resettlement; livelihood issues; and cultural heritage. An Environmental and Social Management Plan (ESMP) will be prepared and include action plans as needed, and the ESMS developed. Further work is required in the following areas:

- Community engagement - Further engagement including approximately 10 town hall meetings, approximately 4-6 focus groups meetings in each affected community, and 2-4 community workshops will be carried out to broaden community understanding of the project and understand the communities concerns in greater detail. Informal meetings with local schools and members of the affected community will also be conducted on a quarterly basis. Additional details of the planned community engagement process during the ESIA preparation phase and during project implementation are outlined in the SEP being developed for the project.
- Community health - As part of the consultation conducted to date, health has been identified as a significant community concern. Therefore, it is important to establish baseline conditions for health in the Roseau Valley prior to construction of the project to understand any changes in local health following development of the project. Further data should include basic health statistics on disease, life expectancy, and illness.
- Livelihood –Socio-economic census data should be collected for the households and farmers that will be directly affected by the project to determine if a livelihood restoration process is required. 4-6 focus groups will also be conducted to better understand eco-tourism impacts and impacts on farmers.

There are no indigenous communities located in the immediate vicinity of the project geothermal area, with the nearest community being an estimated 15 km north-east (the Carib Territory). Therefore, impacts upon indigenous communities are not considered relevant and have been screened out of the ESIA.

It is possible that the project will provide community development opportunities through the provision of new jobs for local residents, indirect economic development impacts, collaboration and public involvement opportunities such as trips to other power facilities, and potential opportunities for education and industry diversification. As part of the Assessment, community development initiatives and benefit sharing options will be explored and considered. A community development program which sets out these initiatives may also be developed as appropriate.

### 4.2.3 Cultural Heritage

Current baseline information collected by Caraibes Environment Development in 2015 identified several cultural heritage elements in the Roseau Valley, including those related to agricultural heritage and architectural heritage. The complex and ancient history of human occupation of the island has led to numerous influences on current and past architecture in the Roseau Valley. One example from Wotten Waven includes a water mill dating from the 18$^{th}$ century.

The ESIA will have a cultural baseline to assess whether any of the project activities are located in areas with cultural or architectural significance (tangible features). It will also include a consultation process with local people so that the potential impact on unique natural features or intangible forms of culture are identified and understood. The ESMP includes a chance finds procedure, and depending on the findings of the baseline assessment, more project specific mitigation measures in impacted areas may be necessary. UNESCO will be consulted to ensure that there is no potential impact to the designation of the nearby World Heritage Site (the

Mornes Trois Pitons National Park), nor inconsistency with any existing or planned management plans for the core area and surroundings.

### 4.2.4 Traffic

No baseline traffic data has been identified for the Roseau Valley. Although it is believed that traffic levels are not high, there is potential for existing road users to be affected by construction traffic. Therefore it is proposed to conduct traffic counts within the potentially affected communities of Laudat, Trafalgar and Wotten Waven to establish baseline conditions, and consider the influence of cruise ships. In addition, a site visit will be conducted to review the existing road infrastructure and take photographs to document its current condition.

## 4.3 Stakeholder Engagement

Building on stakeholder engagement that has already been completed, a process of identifying relevant stakeholders that may be directly or indirectly affected by the project will be completed. A Stakeholder Engagement Plan (SEP) is being prepared for the project which will guide engagement activities which are to be conducted in order to address the information gaps identified in Section 4.2.1.8. The objectives of this SEP are to:

- Identify the local legal framework of consultation activities and disclosure requirements, particularly in respect of those public consultation activities that are directly required under the local permitting process;
- Identify potential stakeholders in the area of influence, as well as relevant interested parties such as government agencies and other key stakeholders;
- Record all consultation activities, including those prior to the commencement of the environmental and social impact assessment (ESIA) process;
- Describe how concerns or grievances will be handled;
- Provide an action plan for further consultation including at least 2 meetings bi-annually in each affected community during preparation, construction and operational phases of the project, including details on appropriate formats for effective and culturally meaningful interaction with the community and relevant stakeholders; and
- Provide a disclosure plan, including the identification of any locations where relevant project documentation will be available locally and elsewhere as well as languages to be used.

The SEP will be revised and updated periodically including upon completion of the ESIA to assist with ongoing engagement throughout the Geothermal Programme.

## 4.4 Impact Assessment

The assessment of all environmental and social impacts will encompass both potential impacts and uncertain risks. The level of investigation of potential impacts or particular risks will be proportionate to the severity of potential consequences and likelihood of such an event occurring.

To guide the ESIA and ensure sufficient focus on key issues/risks a preliminary risk assessment has been conducted by Jacobs. The key issues/risks identified through this process are highlighted in Table 4-1 below:

**Table 4-1: Key Issues/Risks to be addressed in ESIA**

| Aspect | Potential Impact |
|---|---|
| Air Quality | • Emission of gases such as hydrogen sulphide (the primary indicator gas for odour) from the power plant during operation.<br>• Generation of dust and combustion gas emission through earth moving and construction activities.<br>• Odour from hydrogen sulphide emissions. |

| Aspect | Potential Impact |
|---|---|
| Greenhouse Gas | • Greenhouse gas emissions from construction machinery and the power plant during operation. |
| Natural Hazards | • Risks related from natural hazards, such as seismic activity, landslides, hurricanes, volcanic activity and flood inundation. |
| Geothermal Features | • Potential impact on surface geothermal features as a result of abstraction of steam and reinjection of brine/condensate |
| Community Health | • Potential impacts on community health, such as potential for seismic activity, emissions of hydrogen sulphide and generation of dust, noise, subsidence and from major accident hazards if organic Rankine plant is installed. Fire risk is also a consideration in particular with binary plant.<br>• During the commissioning stage of the project, when various parts of the power plant are first started-up, discharges of non-condensable gases (NCGs) may occur outside of the normal disposal points. |
| Cultural Heritage | • Potential impacts on cultural heritage features (architecturally significant buildings and agricultural areas). |
| Social (including land acquisition) | • Positive impacts upon the local community through the generation of employment opportunities.<br>• Any economic displacement of members of the community as a result of land acquisition for the development of the power plant and steamfield.<br>• There is also the potential for temporary effects upon communities and tourism if works (including construction traffic) inhibit access to schools, communities and tourist attractions.<br>• Appropriate consideration will be given to livelihood restoration for any parties that are economically displaced by the project. Further engagement including town hall meetings, focus groups meetings in each affected community, and community workshops will be carried out to broaden community understanding of the project and understand the communities concerns in greater detail.<br>• Informal meetings with local schools and members of the affected community will also be conducted on a quarterly basis.<br>• It is important to establish baseline conditions for health in the Roseau Valley prior to construction of the project to understand any changes in local health following development of the project. Further data should include basic health statistics on disease, life expectancy, and illness.<br>• Socio-economic census data should be collected for the households and farmers that will be directly affected by the project to determine if a livelihood restoration process is required. Focus groups will also be conducted to better understand eco-tourism impacts and impacts on farmers. |
| Working Conditions | • The ESIA will provide a more detailed description of the proposed civil works, the operation of power plant and of the steamfield, as well as the related labour requirements and working conditions. The potential for labour influx has been reviewed, will be further examined, but is not expected to be an issue for the project.<br>• There will be consideration of the working conditions of employees/contractors engaged in construction and operation.<br>• Human Resources (HR) Policies and Procedures. DGDC will need to draft and implement human resources regulations following Dominica's Labour legislation and the requirements of PS2, specifically articulating the workers' rights to form and join workers' organizations, and procedures for workers to express their grievances and protect their rights without retaliation or discrimination.<br>• Occupational Health and Safety. A comprehensive set of plans, standards, procedures and work instructions should be prepared and adopted by DGDC to cover all aspects of occupational health and safety. Risks to the occupational health and welfare of personnel involved in the project implementation should be assessed and mitigated following a risk management process in accordance with DGDC's adopted requirements. Contractors will be required to comply with the occupational health and safety procedures.<br>• A Security Management Plan will be developed to safeguard project, workers and property and to ensure that safeguarding activities are carried out in a legitimate manner that avoids or minimizes risks to the community's safety and security, as per PS2 and PS4. |
| Noise | • Construction and operation of the power plant will generate noise (i.e. from steam discharges) which |

| Aspect | Potential Impact |
|---|---|
| | may impact upon the surrounding communities and wildlife. |
| Pest Species | • Importation of machinery/equipment for use in construction and operation can lead to introduction of pest species. |
| Soil and Groundwater | • Spillage of hazardous substances stored/used in construction and operation of the power plant.<br>• Generation and disposal of construction and domestic waste.<br>• Creation of solid wastes, sludge and slurries.<br>• Contamination of shallow aquifers. |
| Terrestrial Flora and Fauna | • Removal of vegetation and earthworks to enable construction of the re-injection pipeline, which could result in impacts on biodiversity with particular reference to critical habitat for endangered species, associated with the nearby Morne Trois National Park World Heritage Site. Special reference will be made to any rare or threatened species as well as endemic species of both animals and plants. Impacts on the Outstanding Universal Value (OUV) of the Morne Trois National Park World Heritage Site in relation to biodiversity will be considered.<br>• Noise and air quality impacts on the Morne Trois National Park World Heritage Site and the OUV of the site. |
| Visual Amenity | • Construction of new infrastructure will alter the visual landscape.<br>• Vertical steam discharges could create temporary visual impacts.<br>• Impacts on the OUV of the Morne Trois National Park World Heritage Site in relation to visual impacts. |
| Water Quality and Freshwater Ecology | • Reinjection of brine and condensate.<br>• Sedimentation of water courses during construction as result of run-off from earthworks.<br>• Spillage of hazardous substances used during construction and operation of the power plant.<br>• Discharge of stormwater containing contaminants from the power plant to local water courses. . |
| Water Resources | • Abstraction of water for domestic purposes and fire suppression system within power plant. |

An assessment of these issues/risks and all other potential environmental and social impacts of the proposed works described in Section 3 will be carried out, including any potential cumulative impacts. The ESIA will state the criteria adopted in assessing the proposed project and its impacts, such as compliance with relevant legislation, policies, standards, community acceptance and maximisation of environmental and social benefits and minimisation of risks.

To support the impact assessment, air dispersion modelling and acoustic modelling will be carried out to estimate potential impacts on the local population and wildlife.

### 4.4.1 Air Quality Modelling

For the air dispersion modelling assessment it is proposed to use the CALPUFF dispersion model to assess the effects of hydrogen sulphide releases from releases of geothermal fluids during the well testing and operational phases of the project. Meteorological data for the model will be developed using the diagnostic meteorological model WRF, and formatted for use with CALPUFF using the CALMET meteorological model. Locally collected meteorological data will be assessed to determine its quality, and if practicable will be integrated into the meteorological dataset for use with the dispersion model.

The modelling will be dependent upon assumptions made in regard to $H_2S$ discharge rates and the nature of the discharges themselves. These will be informed by analysis of the geothermal fluid made previously, and by process descriptions which should provide details of the well locations, geothermal fluid discharge rates, and parameterisation of the discharges in terms of heights, velocities, and temperatures.

The resulting ground level concentrations of $H_2S$ in the surrounding area will be compared to IFC Performance Standards 2012 and World Bank Environmental Health and Safety General Guidelines 2007 (listed above in Section 2) to assess the environmental impact and identify areas where potentially adverse health or nuisance

effects may result. Locations of potentially sensitive receptors will also be identified using aerial imagery, and by information gathered during site visits.

ALOHA consequence modelling of major credible accident scenarios pertaining to use and storage of iso-pentane should the organic Rankine cycle plant option be selected to determine extent of an accident event such as vapour cloud release, vapour cloud explosion.

### 4.4.2 Acoustic Modelling

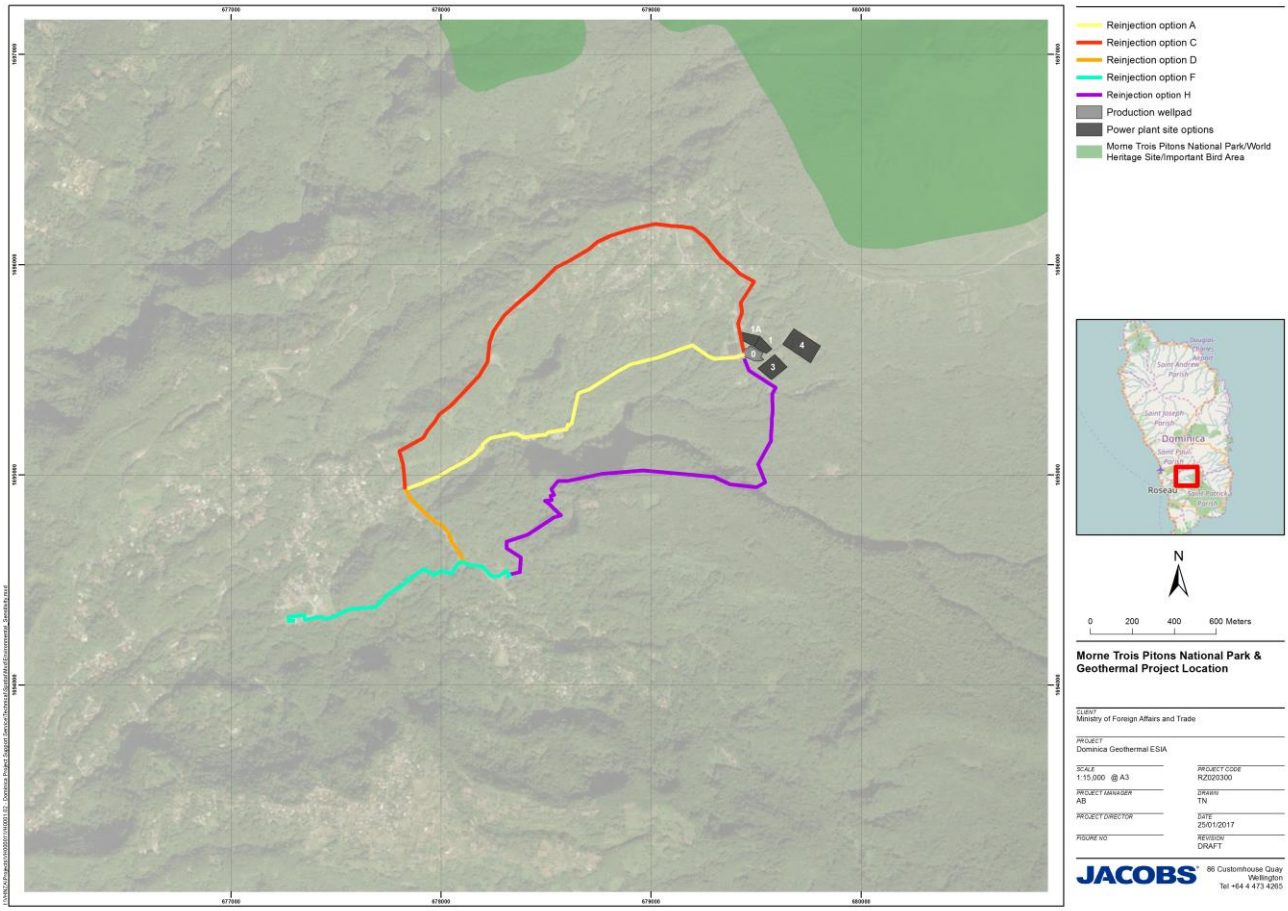
Monitored background noise levels will determine noise criteria in accordance with IFC Performance Standards 2012 and World Bank Environmental Health and Safety General Guidelines 2007 (refer to Section 2). Local guidelines will also be reviewed to determine if any are relevant to noise. Aerial imagery will be reviewed alongside the Caraibes Environment Development (2015a/b) baseline study report to determine nearby potentially affected receivers.

Based on the provided inputs and design, an equipment inventory will be prepared for the operational noise model. Noise levels will be modelled using the ISO9613-1 standard within SoundPlan 7.4 modelling software. Broad management measures for operational noise mitigation will be provided and re-modelled if required. Potential construction noise impacts will also be modelled using ISO9613. Basic construction noise management measures will be provided.

### 4.4.3 Morne Trois National Park World Heritage Site

The project is estimated to fall around 400m from the boundary of the Morne Trois National Park UNESCO World Heritage Site at its nearest point. Therefore, the ESIA will provide an assessment of potential impacts of the project on the Outstanding Universal Value (OUV) of the Morne Trois National Park World Heritage Site, in line with IUCN's World Heritage Advice Note on Environmental Assessment. For reference, the location of the project in relation to Morne Trois National Park World Heritage Site is shown on Figure 4.1 below.

**Figure 4.1 : Location of the Morne Trois National Park World Heritage Site**




## 4.5 Management and Monitoring

The ESIA will propose measures for the mitigation, avoidance and/or offsetting of potential adverse impacts to ensure adverse impacts are as low as reasonable possible. In addition it will include monitoring (including the performance measures that will be used) to be conducted to ensure control measures are effective and impacts are minimised.

## 4.6 Reporting

### 4.6.1 Environmental and Social Impact Assessment

The ESIA will provide stakeholders with sufficient information to understand the type and nature of the project, the potential environmental and social impacts, and the measures proposed to mitigate all adverse impacts. All phases of the project will be described including pre-construction, construction and operation. Direct, indirect and cumulative impacts will be identified and assessed with respect to environmental and social values and potential extent of impacts.

The ESIA report will include the following:

- A Non-Technical Summary of the potential environmental and social impacts of the project.
- A description of the project's objectives and rationale, as well as its relationships to strategic policies and plans.
- Description of the proposed construction works and operation of the power plant and steamfield.

- A description of feasible alternatives capable of substantially meeting the proposal's objectives.
- An outline of the relevant legislation and approvals required for the project to proceed.
- Descriptions of the existing environment, particularly where this is relevant to the assessment of impacts.
- An assessment of the risks of adverse and beneficial environmental and social impacts arising from the project.
- Measures for avoiding, minimising, managing and monitoring adverse impacts.
- A description of stakeholder consultation undertaken.
- Responses to issues raised during public and stakeholder consultation.

The ESIA will be supported by appendices containing relevant data, technical reports and any other sources of the ESIA analysis.

### 4.6.2 Environmental and Social Management Plan

An Environmental and Social Management Plan will be prepared, which identifies the potential environmental and social impacts, the proposed means of mitigation/avoidance and monitoring (including the performance measures that will be used) to be conducted to ensure control measures are effective and adverse impacts are minimised. The plans should also set out reporting requirements and corrective actions.

### 4.6.3 Environmental and Social Management System

An Environmental and Social Management System (ESMS) will be established to enable implementation of environmental and social controls for the project. The ESMS documentation will describe:

- **Policy** – overarching policy defining environmental and social objectives and principles guiding the project
- **Identification of risks and impacts** – Process for identifying environmental and social risks and impacts of the project
- **Management programs** – a suite of programs, including management plans and procedures that describe mitigation and performance improvement measures that address potential environmental and social risks and impacts associated with the project
- **Organisation capacity and competency** - identification of roles, responsibilities and authority for implementation of the ESMS
- **Emergency preparedness and response** – establish and maintain a system in collaboration with appropriate third parties to ensure preparedness for response to accidental and emergency situations associated with the project
- **Monitoring and review** – procedures for monitoring and measuring effectiveness of the management programmes, including compliance with legal/contractual and regulatory requirements
- **Stakeholder engagement** – process and mechanisms for ongoing engagement with stakeholders
- **External communications and grievance mechanisms** – procedures for addressing communications from external stakeholders, including recording receipt, screening of enquiries, evaluation of issues raised and response. Furthermore a grievance mechanism should be established to facilitate resolution of concerns raised by members of the effected communities
- **Ongoing reporting to affected communities** – periodic reporting i.e. of progress, to affected communities.

### 4.6.4 Stakeholder Engagement Plan

A comprehensive and inclusive program of consultation with stakeholders throughout the geothermal programme is required. To facilitate this, a Stakeholder Engagement Plan (SEP) will be prepared, which describes:

- The purpose, aims, objectives and protocols for community and stakeholder consultation.
- Issues or risks for community and stakeholder consultation (i.e. what will cause the consultation to succeed/ fail).
- Proposed consultation approach.
- Stakeholders to be consulted.
- Consultation activities to be undertaken for the ESIA.
- Undertaking stakeholder analysis and mapping, including identification of development stakeholders, residents of local communities, government agencies, etc.) and their likely areas of interest, assessment of potential stakeholder risks and establishment of a stakeholder register for the ESIA.
- Development of an implementation plan, including timeline/ key dates for key stakeholder consultation activities.
- Development of community and stakeholder consultation protocols, in consultation with the project team.
- Development of a grievance mechanism, which outlines a process for handling and responding to complaints and grievances raised by the community in respect of the proposed development.

In addition it is expected that a Livelihood Restoration Plan will be required addressing engagement with members of the community that will be economically displaced as a result of the project. If required a Resettlement Policy Framework and Resettlement Action Plan will be developed as described in Section 3.6, The Completion Audit will be consistent with World Bank PS 5 and the IFC Guidance Note on PS 5, Annex B, Completion Audit -Table of Contents.

## 4.7 Project Team

The team will comprise of personnel with expertise in the following fields:

- Project Management of ESIA to meet requirements of World Bank Group Standards
- Terrestrial Ecology
- Water quality and aquatic ecology
- Air quality and air dispersion modelling
- Acoustic modelling
- Stakeholder engagement and social impact assessment
- Economics
- Hydrology
- Hydrogeology
- Geographical Information Services
- Greenhouse Gas
- Visual impact
- Natural hazards (geology, geotechnical , geothermal features)
- Risk assessment of major credible accidents
- Waste, hazardous substances and occupational health and safety
- Management systems.

## 4.8 Schedule

The ESIA is proposed to be completed by September 2017.

# 5. References

Caraibes Environment Development (2009). Regulatory Impact Assessment on the Initial Environment - Environmental Feasibility Study.

Caraibes Environment Development (2011). Stage 1: Exploration Drilling Process – Environmental Impact Assessment.

Caraibes Environment Development (2013). Stage 2: Preliminary Environmental Impact Assessment of Geothermal Production and Re-Injection Drilling Wells in Dominica – Environmental Impact Assessment.

Caraibes Environment Development (2015a). Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production. Final report, May 2015. Section 3 Biodiversity / Terrestrial Flora and Fauna.

Caraibes Environment Development (2015b). Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production. Final summary report.

IUCN (2013). World Heritage Advice Note Environmental Assessment & World Heritage.

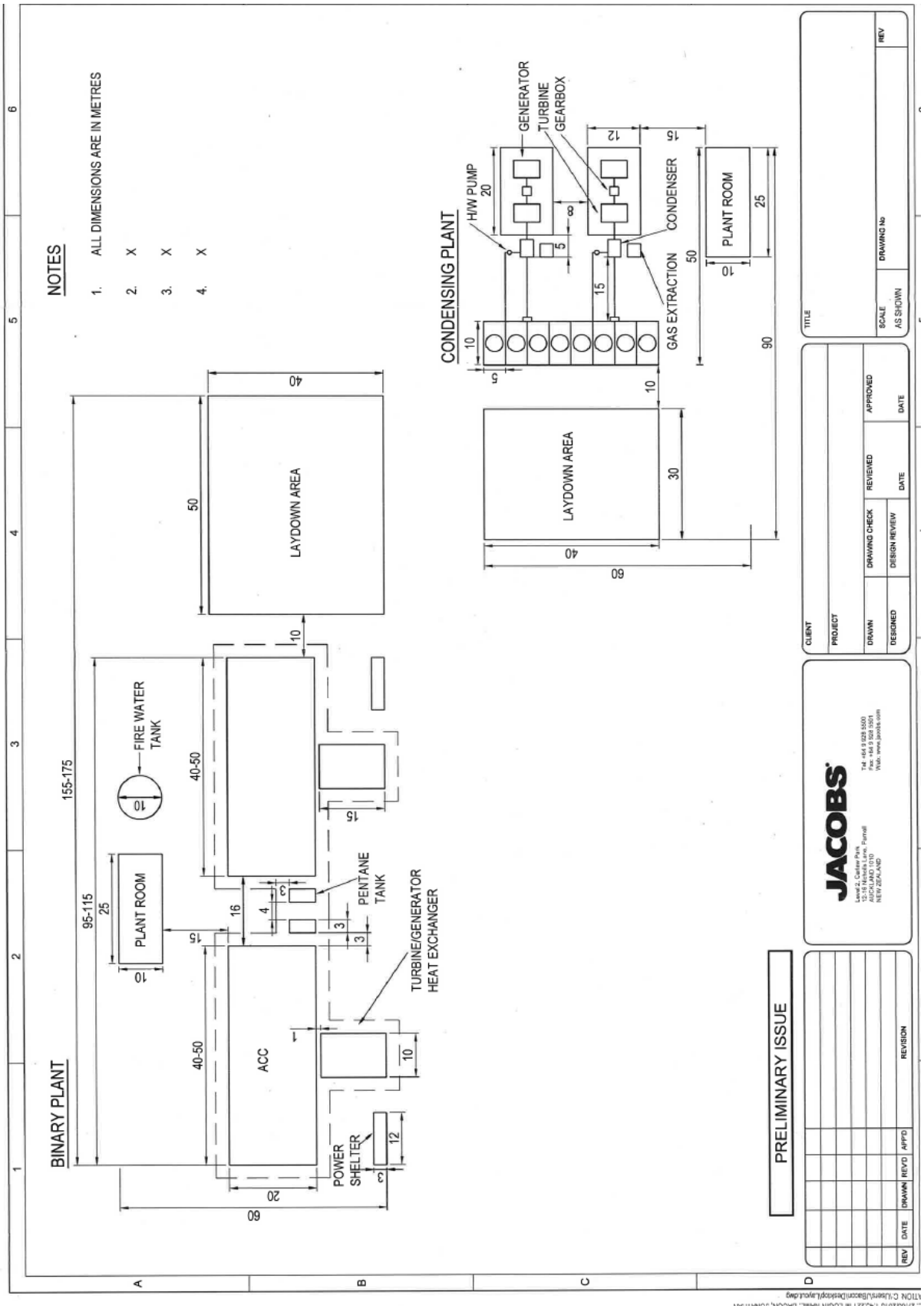
World Bank. Power Development in Dominica – A Situational Analysis for the Preparation of the Wotten Waven-Trafalgar-Laudat field in the Roseau Valley.

# Appendix A. WBG IFC Performance Standards

| Performance Standard | Objectives |
|---|---|
| Social and Environmental Assessment and Management Systems | • To identify and evaluate environmental and social risks and impacts of the project.<br>• To adopt a mitigation hierarchy to anticipate and avoid, or where avoidance is not possible, minimize, and where residual impacts remain, compensate/ offset for risks and impacts to workers, Affected Communities, and the environment.<br>• To promote improved environmental and social performance of clients through the effective use of management systems.<br>• To ensure that grievances from Affected Communities and external communications from other stakeholders are responded to and managed appropriately.<br>• To promote and provide means for adequate engagement with Affected Communities throughout the project cycle on issues that could potentially affect them and to ensure that relevant environmental and social information is disclosed and disseminated. |
| Labour and Working Conditions | • To promote the fair treatment, non-discrimination, and equal opportunity of workers.<br>• To establish, maintain, and improve the worker-management relationship.<br>• To promote compliance with national employment and labour laws.<br>• To protect workers, including vulnerable categories of workers such as children, migrant workers, workers engaged by third parties, and workers in the client's supply chain.<br>• To promote safe and healthy working conditions, and the health of workers.<br>• To avoid the use of forced labour. |
| Pollution Prevention and Abatement | • To avoid or minimize adverse impacts on human health and the environment by avoiding or minimizing pollution from project activities.<br>• To promote more sustainable use of resources, including energy and water.<br>• To reduce project-related GHG emissions. |
| Community Health, Safety and Security | • To anticipate and avoid adverse impacts on the health and safety of the Affected Community during the project life from both routine and non-routine circumstances.<br>• To ensure that the safeguarding of personnel and property is carried out in accordance with relevant human rights principles and in a manner that avoids or minimizes risks to the Affected Communities. |
| Land Acquisition and Involuntary Resettlement | • To avoid, and when avoidance is not possible, minimize displacement by exploring alternative project designs.<br>• To avoid forced eviction.<br>• To anticipate and avoid, or where avoidance is not possible, minimize adverse social and economic impacts from land |

| Performance Standard | Objectives |
|---|---|
| | acquisition or restrictions on land use by (i) providing compensation for loss of assets at replacement cost and (ii) ensuring that resettlement activities are implemented with appropriate disclosure of information, consultation, and the informed participation of those affected.<br>• To improve, or restore, the livelihoods and standards of living of displaced persons.<br>• To improve living conditions among physically displaced persons through the provision of adequate housing with security of tenure at resettlement sites. |
| Biological Conservation and Sustainable Natural Resource Management | • To protect and conserve biodiversity.<br>• To maintain the benefits from ecosystem services.<br>• To promote the sustainable management of living natural resources through the adoption of practices that integrate conservation needs and development priorities. |
| Indigenous Peoples | • To ensure that the development process fosters full respect for the human rights, dignity, aspirations, culture, and natural resource-based livelihoods of Indigenous Peoples.<br>• To anticipate and avoid adverse impacts of projects on communities of Indigenous Peoples, or when avoidance is not possible, to minimize and/or compensate for such impacts.<br>• To promote sustainable development benefits and opportunities for Indigenous Peoples in a culturally appropriate manner.<br>• To establish and maintain an ongoing relationship based on Informed Consultation and Participation (ICP) with the Indigenous Peoples affected by a project throughout the project's life-cycle.<br>• To ensure the Free, Prior, and Informed Consent (FPIC) of the Affected Communities of Indigenous Peoples when the circumstances described in this Performance Standard are present<br>• To respect and preserve the culture, knowledge, and practices of Indigenous Peoples. |
| Cultural Heritage | • To protect cultural heritage from the adverse impacts of project activities and support its preservation.<br>• To promote the equitable sharing of benefits from the use of cultural heritage. |

# Appendix B. Nominal land area for 2 x 3.5MW binary and steam condensing technologies



# Appendix C. Project Schedule

A high level summary of the project schedule is presented below:

| Task Name | Duration | Start | Finish |
|---|---|---|---|
| **Dominica Geothermal Project Establishment** | **280 days** | **Thu 19/05/16** | **Wed 14/06/17** |
| **Technical** | **484 days?** | **Thu 19/05/16** | **Tue 27/03/18** |
| **Geothermal Plant & Steamfield** | **338 days** | **Mon 20/06/16** | **Wed 4/10/17** |
| **Grid connection & power system** | **330 days** | **Thu 19/05/16** | **Wed 23/08/17** |
| **DOMLEC transmission work** | **181 days?** | **Tue 18/07/17** | **Tue 27/03/18** |
| **Public infrastructure & civil works** | **473 days** | **Mon 30/05/16** | **Wed 21/03/18** |
| **Procurement** | **387 days** | **Tue 1/11/16** | **Wed 25/04/18** |
| **Commercial** | **296 days** | **Mon 2/01/17** | **Mon 19/02/18** |
| **Environmental & Social** | **445 days** | **Thu 19/05/16** | **Wed 31/01/18** |
| **Undertake ESIA** | **360 days** | **Thu 19/05/16** | **Wed 4/10/17** |
| Project kick-off and RFI | 1 wk | Sat 20/08/16 | Thu 25/08/16 |
| Gap Analysis of baseline studies | 2.2 wks | Wed 24/08/16 | Wed 7/09/16 |
| Process Description | 20 wks | Thu 19/05/16 | Wed 5/10/16 |
| Preparation of Baseline ToRs | 6 wks | Mon 12/09/16 | Fri 21/10/16 |
| Submission of draft ESIA TOR | 6 wks | Thu 20/10/16 | Wed 30/11/16 |
| Final ESIA TOR approved by GoCD | 4 wks | Thu 15/12/16 | Wed 11/01/17 |
| Preparation for site visit | 2 wks | Thu 1/12/16 | Wed 14/12/16 |
| Scoping/Baseline site visit | 2 wks | Thu 15/12/16 | Wed 28/12/16 |
| Stakeholder engagement | 30 wks | Thu 15/12/16 | Wed 12/07/17 |
| Biodiversity Assessment | 12 wks | Thu 25/05/17 | Thu 10/08/17 |
| Modelling | 10 wks | Thu 18/05/17 | Wed 26/07/17 |
| Preparation of Technical Reports | 4 wks | Thu 27/07/17 | Wed 23/08/17 |
| Preparation of ESIA, ESMP, ESMS | 4 wks | Thu 24/08/17 | Wed 20/09/17 |
| Submission of draft ESIA to MFAT and DGDC | | Fri 8/09/17 | Fri 8/09/17 |
| ***Project on hold following Hurricane Maria*** | ***24 wks*** | ***Tue 18/09/17*** | ***Fri 2/03/17*** |
| Conduct Land Acquisition Census Survey | 3 wks | Mon 20/03/18 | Fri 6/04/18 |
| Preparation of Revised ESIA and ESMP | 8 wks | Mon 12/03/18 | Wed 9/05/18 |
| Preparation of ARAP | 4 wks | Mon 9/04/18 | Wed 9/05/18 |
| Submission of Draft ESIA and ESMP to WB | | Wed 9/05/18 | Wed 9/05/18 |
| WB Review | 3 wks | Wed 9/05/18 | Wed 30/05/18 |
| Revise ESIA based on WB Comments | 2.5 wks | Wed 30/05/18 | Fri 15/06/18 |
| Submission of Final Draft ESIA and ESMP to WB | | Fri 15/06/18 | Fri 15/06/18 |
| WB SGS Review | 2 wks | Mon 18/06/18 | Mon 3/07/18 |
| Disclosure of ESIA NTS to communities | 1 wk | Mon 2/02/18 | Fri 6/07/18 |
| Preparation of Final ESIA and ESMP to WB for Disclosure | 2 wks | Mon 3/07/18 | Fri 13/07/18 |
| Submit Final ESIA and ESMP to WB for Disclosure | | Fri 13/07/18 | Fri 13/07/18 |
| Submit ESIA & ESMP to GoCD | 1 wk | Fri 13/07/18 | Fri 20/07/18 |
| WB ESIA disclosure period | 17 wks | Mon 16/07/18 | Wed 9/11/18 |

| | | | |
|---|---|---|---|
| **Government Activities & Decision Making** | **154 days** | **Fri 20/07/2018** | **Mon 20/12/18** |
| **WB Financial Approval** | | **Wed 1/02/17** | **Mon 20/12/18** |

# Appendix D. Biodiversity Survey Terms of Reference

# Dominica Geothermal Development – Environmental and Social Impact Assessment

Ministry of Foreign Affairs and Trade

## Biodiversity Assessment Terms of Reference

RZ020300-0000-NP-RPT-0002 | V1

June 2017

# Dominica Geothermal Development - Environmental & Social Impact Assessment

| | |
|---|---|
| Project No: | RZ020300 |
| Document Title: | Biodiversity Assessment Terms of Reference |
| Document No.: | RZ020300-0000-NP-RPT-0002 |
| Revision: | V2 |
| Date: | May 2017 |
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| Project Manager: | Alastair Brookes |
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| File Name: | |

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## Document history and status

| Revision | Date | Description | By | Review | Approved |
|---|---|---|---|---|---|
| V0 | April 2017 | First Draft | C Thomson | P Gabriel | A Brookes |
| V1 | May 2017 | World Bank comments added. | C Thomson | P Gabriel | A Brookes |
| V2 | 5 June 2017 | Reviewed following World Bank Regional Safeguard Advisor (RSA) | C Thomson | P Gabriel | A Brookes |
| | | | | | |
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# 1. Terms of Reference for Biodiversity Assessment

## 1.1 Purpose of the Terms of Reference

This Biodiversity Terms of Reference (ToR) describes the scope of the field surveys for the biodiversity assessment for the Environmental and Social Impact Assessment (ESIA) that will be carried out to evaluate the potential positive and negative impacts of construction and operation of the project in accordance with laws of the Commonwealth of Dominica (GoCD) and international standards (World Bank Performance Standards for Private Sector Activities., May 2013). This relates specifically to Performance Standard 6 (PS6) Biodiversity Conservation and Sustainable Management of Living Natural Resources (IFC 2012). This document should be read in conjunction with the ToR for the ESIA (issued to the GoCD in January 2017).

The biodiversity assessment will aim to assess potential impacts on biodiversity throughout all phases of the Project. The data collected by the sub-consultant will be used to address the following objectives:

- Describe the characteristics and ecological condition of the vegetation communities and habitats within the study area. Characterise the key ecosystems within the Project area and adjacent habitats including ecosystems that could be specifically linked to geothermal resources (thermal pools and vents).
- To obtain an understanding of the main biodiversity values of the Project area and its surrounding area, including, but not limited to, the biodiversity values as described in para. 16 of PS6.
- To evaluate whether the Project is located within Critical Habitat (CH) as defined by the IFC's PS6.
- To assess the potential impacts on biodiversity in the Project area as a result of the proposal including direct and indirect impacts of the Project on biodiversity values.
- To develop management and mitigation measures in line with the mitigation hierarchy described in PS6 that specifically focus on avoiding and minimising impacts to those values during Project activities.

## 1.2 Background

### 1.2.1 Provision of Background Information

The biodiversity assessment will need to provide detail on the predicted impacts of the Project on biodiversity through all phases of the Project. This would include a literature review of the potential impacts of geothermal projects on biodiversity by members of the ESIA team. The literature review would serve to provide the reader with some context to relevance of the information presented in the biodiversity assessment and the potential impacts on the project on biodiversity. The ESIA will provide a review of relevant literature that includes current knowledge and background on other similar geothermal projects, to synthesis what the typical and potential impacts of the proposed action on terrestrial biodiversity may be and this should include potential direct and indirect impacts.

### 1.2.2 Previous Biodiversity Assessments

An initial flora and fauna analysis was carried out in 2008 by an ecologist and field assistant which appear to be experienced with the local flora and fauna. The goal of this work was to provide an introduction to the biodiversity of the Roseau Valley, and also the legal context related to forest clearing and protected natural spaces. Three areas were initially selected in 2011 and then a forth added in 2015 for more detailed flora and fauna assessment. At each area the dominant habitat and flora and fauna species is described and matched to vegetation type descriptions.

### 1.2.3 Need for Further Field Study

A more targeted approach is now required in the ESIA that address the extent and distribution of vegetation and habitat types along the preferred re-injection line route and other sites selected for the plant infrastructure. This could be targeted within the area of potential impact only to limit survey effort and based on stratified sampling effort where feasible. The proposed locations for further survey are outlined in Figure 1-1.

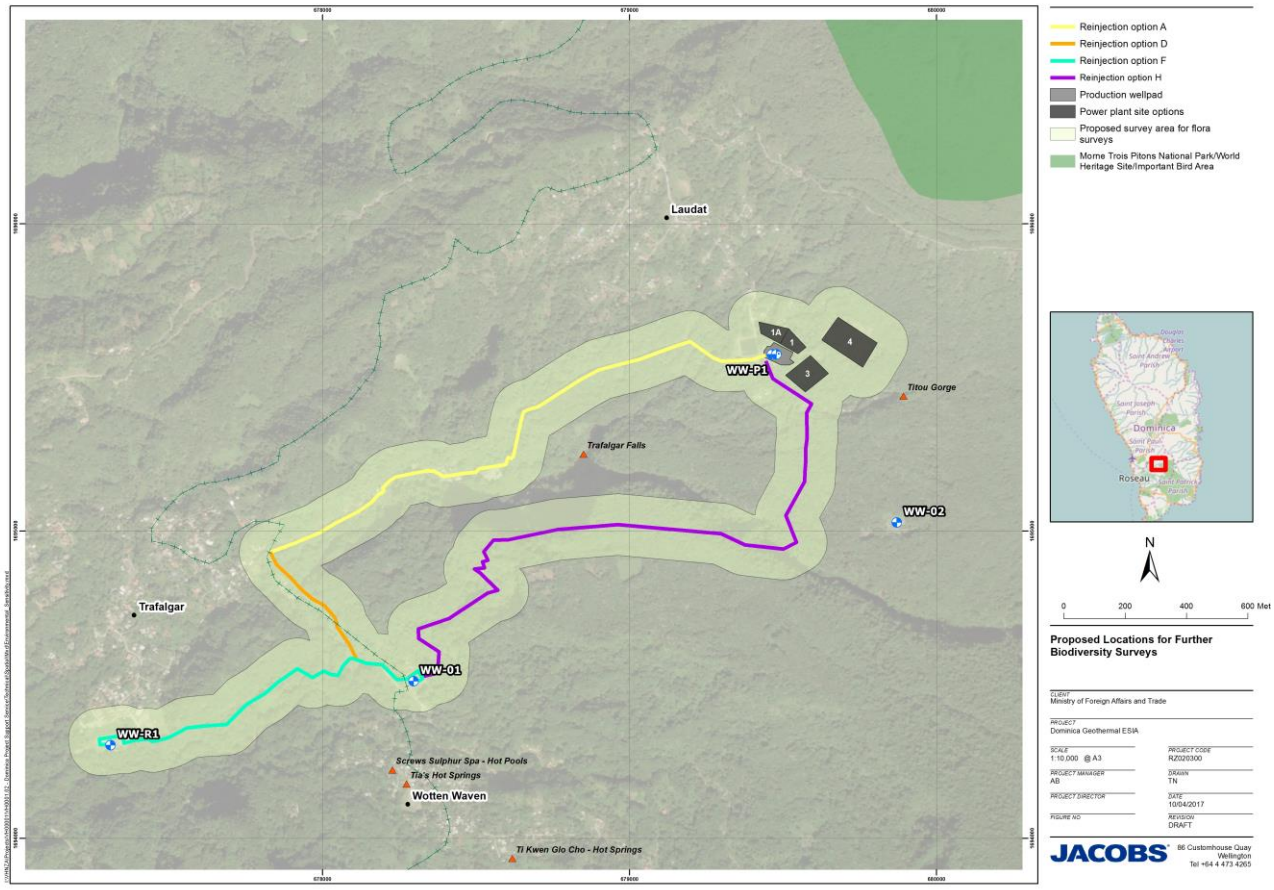


**Figure 1-1: Proposed Locations for Further Biodiversity Surveys**

The ESIA Team will undertake a preliminary land-use/habitat classification of the study area shall be prepared in GIS by interpretation of satellite imaginary and/or aerial photography. This information shall be used to stratify the vegetation and habitat types for further detailed field survey. Stratification is necessary to ensure that the full range of potential habitats and vegetation types are systematically sampled. Stratification shall consider land-use and elevation. Ecologists will then need to ground-truth vegetation types using a rapid assessment approach.

## 1.3 Key Issues

Significant biodiversity issues of concern include the following:

- The options proposed for the reinjection lines traverse potential habitat for three globally threatened bird species- two endemic species of the Amazona parrots, *Amazona arausiaca* (vulnerable), and *Amazona imperialis* (endangered) and the Forest thrush, *Cichlherminia herminieri* (vulnerable) all on the IUCN red list.
- The project would traverse land that contains the middle reaches of a number of major streams and rivers that provide potable water.
- Fumarolic vegetation- One of the rarest formations on Dominica. The occurrence of and potential impact to rare or endemic species of fumaroles associated vegetation should be considered when evaluating geothermal infrastructure.
- A UNESCO-designated World Heritage Site (Morn Trios Pitons National Park) adjoins the study area to the north and east, upstream of the site.

## 1.4 Scope of Work – Field Surveys

### 1.4.1 Introduction

A targeted survey of the terrestrial ecology shall be conducted to provide a baseline assessment of the existing terrestrial ecosystems and species on the Project site, in a manner that allows an assessment, by others, of the future actual and potential impacts on the ecosystems and species from the development of the Project. This includes the route of the preferred injection pipeline and any sites for future plant infrastructure

The purpose of the survey is to identify the ecological values that may be affected by the Project in terms of:

- Flora and fauna diversity, including habitats of rare and threatened species,
- Threatened, rare, vulnerable, and endangered species.

The surveys carried out will focus on the following groups / species:

- Vegetation / Flora;
- Bird / Avifauna, in particular the three globally threatened species mentioned above ;
- Herpetofauna (Amphibians and Reptiles);
- Mammals; and

Survey methodologies must be replicable and scientifically robust. Sampling techniques shall be adequate to provide a detailed list of species and habitats using primarily visual and aural methods. Trapping and handling of species is not expected as part of this study.

### 1.4.2 Vegetation, Terrestrial Habitat and Flora Survey

A rapid plot based assessment is to be used to identify the vegetation communities and their boundaries. Data can be input into GIS for mapping vegetation types across the study area.

A combination of transects and plot-based surveys shall be used to provide information on vegetation boundaries, floristic diversity and the possible presence of rare and threatened plants. The transect data shall be used to develop a digital map of vegetation types and their approximate boundaries with a focus on the areas subject to disturbance from the Project. This would include up to 100 metres from the reinjection line and along any proposed access roads and ancillary sites required for machinery, stockpiling of pipes and workers facilities.

Plot-based surveys shall be carried out using 20 x 20 m (400 $m^2$) plots established at each stratification unit at the priority sites identified.

The plot based survey shall aim to record all plant species in the plot and their relative cover (abundance) within the plot using an appropriate scale. Particular attention shall be paid to the dominant, rare, endemic, threatened, protected, invasive species, and the species that are of importance to local communities. Locations of rare or threatened plant species shall be identified using a GPS and data on the size and distribution of the population shall be recorded.

The following general data shall be recorded at each floristic plot:

- Unique identifier (Plot number);
- Location using exact GPS coordinate;
- Photographs showing habitat structure and any notable plant species;
- Altitude and slope characteristic; and
- Habitat types and structure.

Additional habitat condition data shall be recorded at each plot, including the level of modification or disturbance of habitat found within the plot and this shall be assessed according to the following grading:

- Relatively stable or undisturbed communities (e.g. old growth, unlogged forest);
- Late successional or lightly disturbed communities (e.g. old growth forest that was selectively logged in recent years);
- Mid-successional or moderately to heavily disturbed communities (e.g. young to mature secondary forest); and
- Early successional or severely disturbed communities.

### 1.4.3 Birds / Avifauna

The survey shall focus on sampling bird species' richness and abundance located within the range of different habitat strata present. The impenetrable density of the forest habitats are likely to preclude the use of line transects surveys and therefore point count methods are proposed. Surveys shall be conducted over wet and dry seasons and the survey date and weather conditions shall be recorded. A full-season bird survey campaign will be conducted, whose timeline will span beyond the preparation/completion of the ESIA. This will consider wet and dry seasons as well as migratory species of avifauna that might be present in the temperate winter months. When planning the bird survey campaign, the potential for identification of migratory species will be considered.

Point count surveys involve a 20 minute time-based survey and each point to record all birds seen or heard within a 50m radius of the census point. Bird surveys shall be conducted within 4 hours of sunrise to sample peak activity time and surveys shall avoid adverse weather (e.g. high wind or rain). Geographic coordinates shall be recorded at each survey point.

Observations on birds shall be done primarily through visual observation and call identification. Nests and important food source/trees for any protected and rare species described previously shall be recorded and captured with GPS positions noted.

### 1.4.4 Amphibians

Surveys shall involve a combination of diurnal and nocturnal census and will have the greatest chance of detecting most species if undertaken at night, in wet weather.

Systematic daytime searches for adult frogs shall be conducted with a survey effort of at least one hour within the relevant habitat of each stratification unit (this refers to off-stream wetlands and minor tributaries and the fringes of the major stream habitat). Nocturnal surveys shall involve a combination of listening for frog calls, spotlighting, searching within habitat and call recording. All aspects of the watercourse and adjacent areas must be searched, including under logs and rocks, under bark and in litter.

Surveys along the stream channels that are crossed by the pipeline shall involve a nocturnal fixed time search involving two person hours of searching per 200m section of the stream. Sites shall be selected to sample different terrestrial habitat types present along the river or stream.

### 1.4.5 Reptiles

Timed, diurnal active searches shall be undertaken, which involve a 30 minute search effort per stratification unit up to 100 hectares in size.

Particular attention shall be paid to rocky landscapes, where the reptiles can typically gather. Searches shall focus on rocky outcrops, logs, and leaf litter. The thirty minute active search per stratification unit shall be repeated at night to survey for nocturnal reptiles.

The type and number of species shall be recorded during the survey. Areas of high concentration shall be captured with GPS. Study area and observations of significance shall be photographed.

### 1.4.6 Mammals

Surveys shall aim to sample all stratification units in the Project area and aim to survey from vantage points above the canopy or walking inside the forest along available trails.

Line-transect sampling shall be used, as this is the most established technique for many mammals. Survey methodology shall include recording signs (faecal pellets, tracks, feeding signs, breeding sites or nests) and mammal sounds by walking inside the forest along available trails. The length of transect shall aim to be a minimum 1000m, but this may vary where access is not possible or very difficult. Surveys shall be repeated during the day and at night. The survey shall be completed between 6am to 10am and repeated between 6pm and 10pm using spotlight method to record both diurnal and nocturnal species. All individuals detected on and to each side of the transect line shall be recorded. The location and length of each transect shall be recorded and mapped.

The identification of the species shall include their scientific name. In case scientific name determination is impossible or uncertain, at least the genus shall be clearly indicated followed by the term sp.

For cryptic mammal species motion-detection camera traps shall be used at a density of 1 trap / 20 hectares. Camera traps shall be set along the search transects and shall be set (unbaited) and at approximately 40cm – 50cm above the ground to accommodate the height of the target species. Mammal species can be active day or night, and therefore camera traps shall be programmed to take pictures 24 hours per day. In locations with low traffic, camera traps shall be typically checked only once every 14– 30 days, whereas they shall be checked every 5-10 days at sites with high traffic, in order to avoid running out battery and filling up memory cards. Cameras shall be placed on existing tracks where mammal signs are observed.

The likely occurrence of mammals' species of conservation importance shall be also recorded based on the availability of suitable habitat. Local people shall be interviewed regarding the mammals species, number, breeding and hunting in the study area. A list with protected and threatened animal species along with photographs shall be prepared before the survey. A number of local markets shall be visited to collect similar information.

### 1.4.7 Locations

Each site/plot/transect shall be captured with GPS so that exact locations can be repeated as part of monitoring exercises as necessary.

### 1.4.8 Timing

Terrestrial ecology surveys shall be conducted at a suitable time of year if possible, with any limitations in seasonality noted in the results.

## 1.5 Survey Reporting

Reporting on the terrestrial ecology surveys shall include clear information on the location of survey sites (maps and GPS coordinates), methods used, survey dates, and any other important information. The data shall be presented in summary tables, with the protected, threatened, vulnerable, rare, or endemic species tabulated and mapped.

A description of each vegetation type is required, including the vegetation classification, and name of dominant plants species in each strata. The information should be sufficient to allow development of a detailed vegetation type map over the study area showing the distribution and type of each vegetation community and important habitat for rare or threatened species.

The report should include a list of species recorded and the following information to allow readers to assess whether the scope and methods of the studies were adequate to provide baseline data for the Project and to detect species of conservation interest within the Project area:

- Specific dates of surveys at each sampling site for each taxon;
- Specific locations of surveys and sampling points;
- Number of sampling points;
- Length of sampling (# days, hours, etc.);
- Detailed field methods - how were samples or records taken, what equipment was used, etc. (e.g. # and length of transects, etc.);
- Names of field workers carrying out the surveys and their qualifications;
- Names of people who identified the species;
- Description of biodiversity values for the Project area with respect to para. 16 of Performance Standard 6. Provide comment on any other biodiversity values of importance in the project area, such as Critically Endangered or Endangered species, CITES species, endemic species, etc.;
- Identification of any data gaps; and
- Recommendations for follow-up studies and/or surveys.

## 1.6 Use of the Biodiversity Survey Data by the ESIA Team

Using the data provided by the biodiversity surveyors, the proximity of the Project to any environmentally sensitive areas shall be shown on a map of suitable scale. Areas shall be regarded as sensitive if identified as important habitat for protected, threatened, vulnerable or rare species of flora and fauna.

Results from the surveys shall be analysed and interpreted with respect to literature from the study area. The indication of the species shall include scientific name. In any case where the exact scientific name cannot be determined the genus shall be clearly indicated followed by the term sp.

### 1.6.1 Impact Assessment

The ESIA team will use the sub-consultants survey data to assess the impacts of the Project on the biodiversity values identified by the survey and to determine appropriate mitigation measures. Potential impacts on biodiversity should be assessed in regards to all aspects of the Project including:

- Overlay of the Project area with established or proposed protected areas, Key Biodiversity Areas (KBAs), Important Bird Areas (IBAs), Alliance for Zero Extinction (AZEs) Sites or Habitat of Endangered, Vulnerable or Near Threatened species.
- Comment on broad habitat types with respect to the modified and natural habitat definition as defined in Performance Standard 6, including comment on the type and extent of anthropogenic activities.
- Critical Habitat Assessment (as per PS6).
- Loss of habitat through land occupied for construction and operation of the Project and its facilities.
- Possible barrier effect of roads and associated vegetation clearance, and consequent impacts on landscape and animal population connectivity.
- Hydrological impacts.
- Air pollutants and dust.
- Noise and vibration.
- Light and other disturbance, including disturbance from the presence of humans.
- Mortality and injury to animals from vehicle collisions and from machinery.
- Habitat fragmentation and edge effects.
- Induced access and in-migration (and resulting pressures on biodiversity and natural resources).
- Hunting, bushmeat and wildlife trade.

- Invasive species and pathogens.
- Calculate how much forest will be cleared for the Project and evaluate the indirect impacts that the Project may bring (including from roads, construction, transport, etc).
- Evaluate significance of the impacts on each biodiversity value including the biodiversity values recognised in the nearby World Heritage Area.

### 1.6.2 Mitigation and offsets

The ESIA team will use the sub-consultants survey data and the assessment of impacts of the Project on the biodiversity values to determine appropriate mitigation measures. Mitigation options would consider:

- Application of the mitigation hierarchy as described in PS6 to avoid, minimise or remedy the impacts from Project activities on the key biodiversity values identified and sensitive biodiversity areas, focusing on avoidance as a first step (location of access roads, proposed infrastructure, etc). If avoidance is not possible then minimising and mitigating any impacts on-site (restoration, changing operations to have less impact, etc.).
- Develop a set of mitigation measures that can be incorporated into the Project Standard Operating Procedures (SOPs).
- After mitigation is taken into account, determine the residual impact and its significance. Identify impacts that cannot be avoided or mitigated and thus will need to be offset.

### 1.6.3 Consultation

The ESIA team will use the data collected by the sub-consultant to consult with relevant specialists as necessary to understand the importance of the biodiversity values identified from the field surveys. Internationally-based scientists, specialists, or NGOs may be consulted regarding habitats or species relevant to the assessment.

## 1.7 Summary

Further survey effort is required to identify flora and fauna, in particular rare and conservation significant species, and link these to vegetation / habitat map(s) to determine the extent of potential impacts on important species. Data should be presented and delivered in a clear and manageable format for analysis by ecologists, allowing them to complete the ESIA.

# Appendix E. Technical Report – Air Quality Impact Assessment

Dominica Geothermal Development Company Limited
*Powering a New Generation...*

JACOBS

# Dominica Geothermal Power Plant – Environmental and Social Impact Assessment

NZ Ministry of Foreign Affairs and Trade

## Technical Report – Air Quality Impact Assessment

RZ020300-0002-NP-RPT-0010 | V2

July 2018

# Dominica Geothermal Development

| | |
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## Document history and status

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## Important note about your report

The sole purpose of this report and the associated services performed by Jacobs New Zealand Limited ("Jacobs") is to describe the Environmental and Social Impact Assessment (ESIA) for the Dominica Geothermal Power Project in accordance with the scope of services set out in the contract between Jacobs and the New Zealand Ministry of Foreign Affairs and Trade (the Client). That scope of services, as described in this report, was developed with the Client, the Government of the Commonwealth of Dominica (GoCD) and the Developer (Dominica Geothermal Development Company (DGDC) established and owned by the GoCD).

Jacobs has been contracted by the Client to undertake the conceptual design and overall project definition through their engineering team. In preparing this ESIA report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided. Except as otherwise stated in the ESIA report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

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# 1. Introduction

## 1.1 Overview

This Technical Report is part of an Environmental and Social Impact Assessment (ESIA) for the construction and operation of the Dominica Geothermal Power Project (hereafter referred to as 'the Project'). The Project comprises the construction, completion, testing, commissioning, and operation of geothermal wells, steam gathering and reinjection system, power plant with a capacity of 7 MW and connection to electrical grid and associated infrastructure in the Roseau Valley, Dominica. The design for the Project is ongoing, with detailed design to be completed following a formal tender process for an Engineer, Procure and Construct (EPC) Contractor(s) in 2017.

## 1.2 Project Description

The key components of the proposed 7 MW power plant include:

- Power plant comprising 2 x 3.5 MW units (either single flash steam condensing cycle or organic Rankine cycle units (binary turbine), which will be adjacent to wells WW-P1 and WW-03. The binary power plants may use wet cooling or dry cooling;
- Production well WW-P1 – The existing geothermal production well at Laudat is indicated to have potential to generate 6 to 9 MW and will be the sole production well for the project;
- Reinjection wells WW-R1 (located in Trafalgar) and WW-01 (located in Wotten Waven) – The used geothermal fluid (brine and possibly some steam condensate) produced from production well WW-P1 would be disposed of into reinjection wells WW-R1 and WW-01 via a 250 to 300 mm diameter reinjection pipeline of up to 3.25 km in length;
- Steamfield infrastructure including two phase piping, steam separator, atmospheric flash tank, brine collection and disposal system, condensate collection and disposal system, pressure relief system, storage sump and rock muffler;
- Supporting infrastructure including existing well pads, turbine building, primary and ancillary equipment, cooling system, and water supply; and
- 11 kV interconnection to the DOMLEC electricity grid at the power plant site.

Figure 1.1 provides the locations of the well pads (WW-P1, WW-03, WW-R1 and WW-01) and reinjection lines.

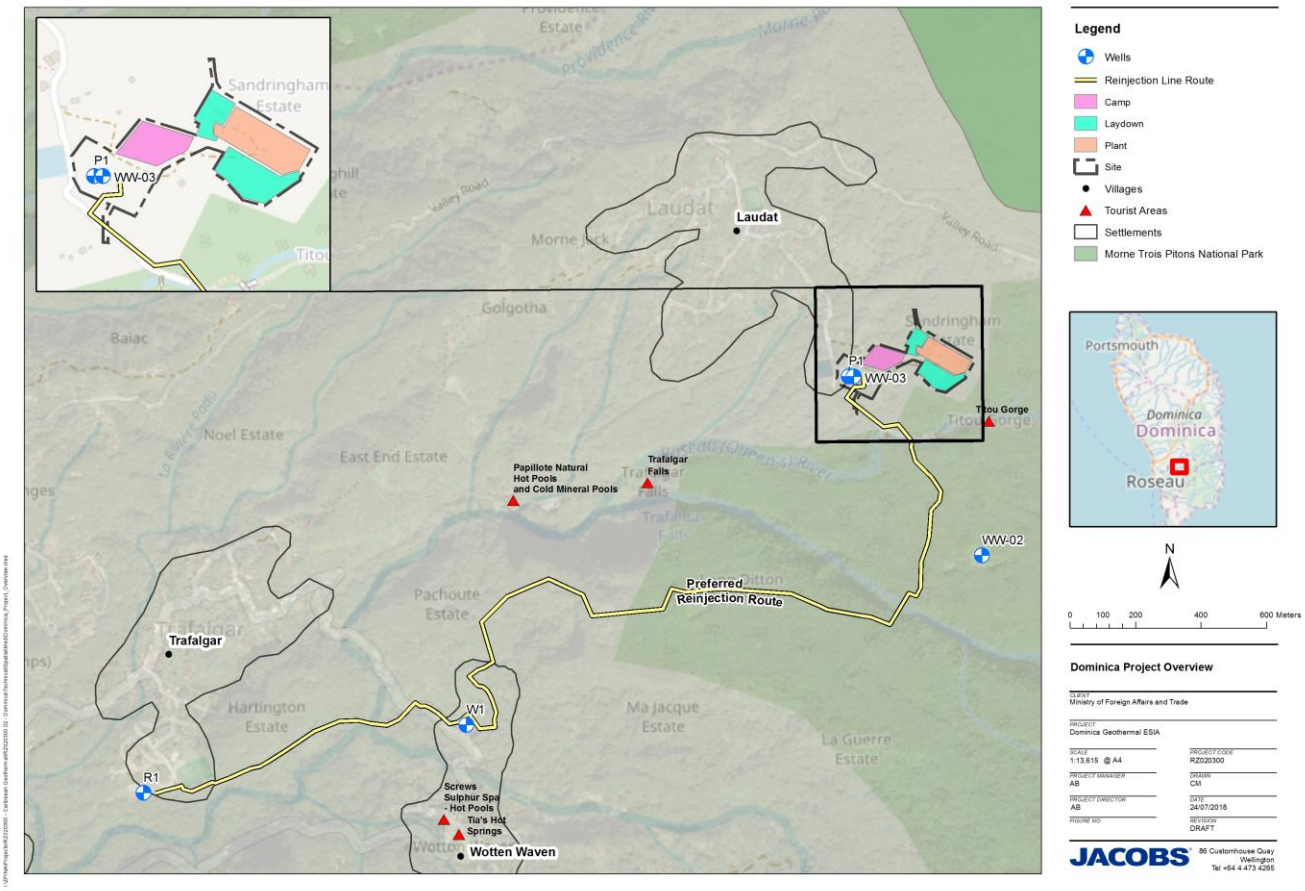


**Figure 1.1 : Project Overview Purpose**

This report assesses the potential impacts associated with the construction and operations of the Project on air quality, and provides an assessment of potential air quality impacts at nearby residential locations, including:

- Release of non-condensable gases (NCGs), specifically hydrogen sulphide gas ($H_2S$); and
- Nuisance dust.

The report is one of several technical reports prepared as a supporting documentation for an Environmental and Social Impacts Assessment (ESIA). It is based on a feasibility study preliminary design and the information given in this document is expected to be updated as the design progresses.

## 1.3 Limitations and assumptions

Limitations to the modelling and prediction of contaminant concentrations in ambient air are heavily dependent on the accuracy of the emissions and meteorological data used in the model. During the initial stages of the Project, specific configuration of the power plant and related air discharges are not available. Consequently, air discharges from similar existing geothermal power plants have been adapted for the purpose of this assessment. The emissions data assumed for the dispersion modelling assessment has been taken from Jacobs' assumptions of plant layout and early characterisation of the chemical composition of the geothermal resource. The emissions of NCGs and dust from the power plant and overall site may vary from those predicted in this report depending on the final type and layout of the power plant and on the composition of the geothermal fluids.

# 2. Site Description

The Commonwealth of Dominica is a small island developing state in the Caribbean Sea with a population of approximately 72,000 people and a land area of approximately 750 km$^2$. About 60% of the land is classified as a World Heritage site by UNESCO, due to its rich biodiversity. It is located near the centre of a string of islands known as the Lesser Antilles, between the neighbouring French territories of Martinique and Guadeloupe. The capital Roseau is located to the south-west of the island and has a population of around 15,000 people.




**Figure 2.1 : Map of Dominica and Caribbean islands**

### 2.1.1 Terrain and Land Use

Dominica consists of steep terrain which is largely covered by tropical rain forest. The island is the most mountainous of the Lesser Antilles group of islands, with the highest peak being Morne Diablotins at an elevation of 1447 metres above sea level.

### 2.1.2 Climate and Meteorology

Dominica has a tropical climate moderated by northeast trade winds and heavy rainfall. Average daytime temperatures vary from 26°C to 32°C, with diurnal variations of usually no greater than 3°C. The island receives approximately 2,600 mm of precipitation per year on average.

### 2.1.3 Existing Air Quality

The existing air quality is expected to be generally good, given the relatively low population, absence of heavy industry, and the relatively small size of the island. Anthropogenic emissions are primarily limited to diesel-fired power generators, traffic, and solid fuel combustion for cooking, etc.

As Dominica is a volcanic island there are natural sources of atmospheric emissions, including steam, carbon dioxide, and hydrogen sulphide, from natural geothermal features such as vents and fumaroles and in some areas the smell of hydrogen sulphide is noticeable[1].

Baseline monitoring has been undertaken previously to determine the existing levels of air contaminants, including $H_2S$ but also $NO_2$, $SO_2$, ozone, and particulate matter as $PM_{10}$ and $PM_{2.5}$. The monitoring was undertaken at 30 locations for two 15-day periods (one during the wet season and one during the dry season). Monitoring of gaseous contaminants (i.e. $H_2S$, $NO_2$, $SO_2$, and ozone) was done using passive samplers, which provide an integrated concentration for the course of the monitoring period. $PM_{10}$ and $PM_{2.5}$ were continuously measured during the monitoring period using continuous (active) particulate monitors. A summary of the results are provided in Table 2.1 below.

The monitoring sites used to conduct the baseline ambient air monitoring represent a variety of environments across the island of Dominica, including the capital (Roseau), villages in the vicinity of the Project (Laudat, Trafalgar, Fond Cani, Wotten Waven), and the Project area itself (near Laudat).

Key conclusions resulting from the baseline monitoring campaign include:

- Minor differences were observed between the wet and dry season measurements.
- $NO_2$ levels were low, and not significantly affected by anthropogenic emissions.
- Ozone concentrations were similarly low and did not appear to be significantly affected by anthropogenic emissions.
- $SO_2$ concentrations were variable, with some locations, particularly in the Wotten Waven and Morne Prosper sites having the highest measurements. Given the absence of $SO_2$ discharges in the area however, it is likely that these readings are a result of the analysis method used for $SO_2$ for the passive samples where $H_2S$ was also presented resulting in false positives levels.
- $H_2S$ concentrations were above the odour threshold limit of 0.3 µg/m$^3$ at all sites, and at many sites in the Project area exceeded the nuisance threshold value of 7 µg/m$^3$. The highest concentration of $H_2S$ measured was 19.1 µg/m$^3$ as a 15-day average. Using a conversion factor to estimate concentrations from longer averaging periods to 1-hour averages, this equates to around 62 µg/m$^3$ as a 1-hour average for comparison with the odour threshold of 7 µg/m$^3$. However, the measured concentrations are not considered unusual for active geothermal areas.
- Particulate matter (as $PM_{10}$ and $PM_{2.5}$) monitoring results indicated some influence from anthropogenic emissions, principally from burning activities.

[1] Recorded in field notes from Jacobs site visit

**Table 2.1 : Baseline Ambient Monitoring Results (average of wet and dry season monitoring results)**

| Site ID | Site Location | Average Contaminant Concentrations, µg/m$^3$ | | | |
|---|---|---|---|---|---|
| | | $NO_2$ | $SO_2$ | $H_2S$ | Ozone |
| LD1 | Fresh lake | 0.2 | 0.2 | 0.7 | 71.5 |
| LD2 | Laudat | 2.3 | 1.5 | 1.0 | 51.9 |
| LD3 | Laudat | 5.7 | 6.3 | 1.4 | - |
| LD4 | Laudat | 2.6 | 7.0 | 6.1 | 48.1 |
| LD5 | Laudat | 0.6 | 0.8 | 6.8 | 36.8 |
| LD6 | Laudat | 0.5 | 8.1 | 1.6 | 54.1 |
| TR7 | Trafalgar | 1.5 | 5.3 | 2.7 | 25.6 |
| TR8 | Trafalgar | 1.8 | 5.6 | 2.5 | 29.9 |
| TR9 | Trafalgar | 3.1 | 15.2 | 5.8 | - |
| TR10 | Trafalgar | 0.9 | 16.7 | 9.7 | 22.7 |
| TR11 | Trafalgar | 5.0 | 6.3 | 2.3 | - |
| TR12 | Trafalgar | 4.4 | 13.3 | 3.9 | - |
| WW19 | Wotten Waven | 0.9 | 18.5 | 11.5 | 35.4 |
| WW20 | Wotten Waven | 0.9 | 28.1 | 18.6 | 42.3 |
| WW21 | Wotten Waven | 6.1 | 39.6 | 11.4 | 34.8 |
| WW22 | Wotten Waven | 0.9 | 34.0 | 19.1 | 43.0 |
| WW23 | Wotten Waven | 0.4 | 58.4 | 18.4 | - |
| WW24 | Wotten Waven | 0.8 | 3.7 | 5.1 | 22.1 |
| WW25 | Wotten Waven | 3.1 | 21.8 | 11.9 | - |
| WW26 | Wotten Waven | 2.4 | 11.5 | 6.2 | - |
| MP27 | Morne Prosper | 5.8 | 41.4 | 9.4 | 46.5 |
| MP28 | Morne Prosper | 0.7 | 23.5 | 4.7 | - |
| MP29 | Morne Prosper | 2.6 | 17.1 | 5.6 | - |
| FC13 | Fond Cani | 2.7 | 7.7 | 3.5 | - |
| FC14 | Fond Cani | 1.5 | 16.7 | 5.9 | 17.9 |
| FC15 | Fond Cani | 6.7 | 7.8 | 9.3 | 30.4 |
| FC16 | Fond Cani | 10.7 | 9.0 | 5.8 | - |
| FC17 | Fond Cani | 5.5 | 29.1 | 6.9 | - |
| FC18 | Fond Cani | 4.4 | 9.6 | 7.4 | - |
| CT30 | Roseau | 13.9 | 11.8 | 6.2 | - |
| ***Maximum*** | | ***13.9*** | ***58.4*** | ***19.1*** | ***71.5*** |

### 2.1.4 Sensitive Receptors to Power Plant Emissions

Sensitive receptors in regard to air quality impacts from the Project include private residences, schools, hospitals, or other areas where people may be potentially exposed to discharges from the site. For the purpose of this assessment representative locations at nearby villages have been selected to predict the level of potential impacts of the discharges. These receptor locations are provided in Table 2.2 below, and on the map in Figure 2.2.

**Table 2.2 : Sensitive Receptor Locations**

| Receptor ID | Description | UTM X (m) | UTM Y (m) |
|---|---|---|---|
| 1 | Boiling Lake | 683085 | 1694272 |
| 2 | Copt Hall | 676788 | 1694159 |
| 3 | Fond Cani (north) | 677187 | 1695410 |
| 4 | Fond Cani (south) | 676115 | 1693622 |
| 5 | Fresh Water Lake | 681576 | 1696995 |
| 6 | Laudat North | 679049 | 1696166 |
| 7 | Laudat South | 679297 | 1695814 |
| 8 | Laudat West | 678639 | 1695967 |
| 9 | Morne Prosper | 677876 | 1693710 |
| 10 | Shawford | 676403 | 1694163 |
| 11 | Trafalgar East | 677774 | 1694913 |
| 12 | Trafalgar South | 677406 | 1694405 |
| 13 | Trafalgar West | 677173 | 1694965 |
| 14 | Valley of Desolation | 682213 | 1693626 |
| 15 | Wotten Waven | 678308 | 1694252 |

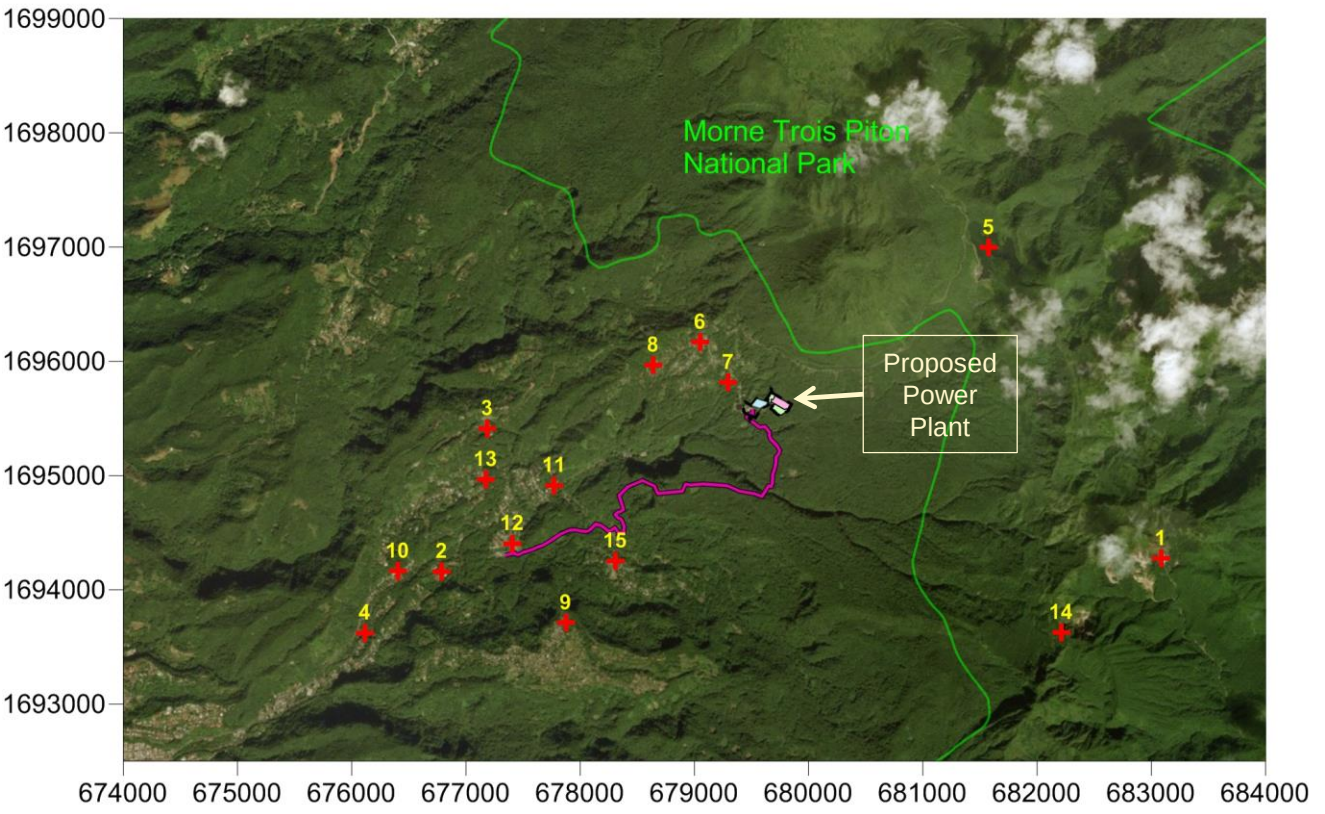


**Figure 2.2 : Sensitive Receptor Locations**

# 3. Air Emissions

## 3.1 Nature of Emissions

### 3.1.1 Non-Condensable Gases

Emission of NCGs is likely to be around four per cent of the total combined steam. The NCGs released will include hydrogen sulphide ($H_2S$) carbon dioxide ($CO_2$), and minor pollutants such as mercury (Hg), arsenic (As), ammonia ($NH_3$), fluoride (F-). The IFC EHS Guidelines for Geothermal Power Generation (2007b) state: "*Hydrogen sulfide and mercury are the main potential air pollutants* [from geothermal power plants]. *The presence and concentration of potential air pollutants may vary depending on the characteristics of the geothermal resource"*. For this assessment only $H_2S$ and mercury have been considered, as the other pollutants are expected to be present in very minor concentrations and have limited potential to cause adverse impacts.

The IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation (2011) notes that; *"$H_2S$ is toxic, but rarely of sufficient concentration* [from geothermal power plants] *to be harmful after venting to the atmosphere and dispersal"*.

### 3.1.2 Dust and Combustion Gas Emissions

Combustion gas emissions from the exhausts of transport vehicles, construction machinery, and electricity generators using diesel fuel will be associated with construction activities, and to a lesser extent operation and maintenance of the Project. Potential pollutants from diesel combustion include nitrogen oxides ($NO_X$), which comprises of nitrogen dioxide ($NO_2$) and nitrogen oxide (NO)), sulphur dioxide ($SO_2$), carbon monoxide (CO), and carbon dioxide ($CO_2$), and particulate matter smaller than 10 and 2.5 microns ($PM_{10}$ and $PM_{2.5}$, respectively).

There will be minor discharges of particulate matter associated with wet cooling towers. Because wet cooling towers provide direct contact between the cooling water and the air passing through the tower, some of the liquid water may be entrained in the air stream and be carried out of the tower as drift droplets.

Construction activities also have the potential to result in fugitive dust discharges that could have nuisance effects on the surrounding environment.

## 3.2 Potential Discharges during Project Phases

### 3.2.1 Air Discharges during Construction

The construction activities with potential to create nuisance dust include:

- Minor reshaping works of the production and reinjection well pad, earthworks for the formation of power plant, and switchyard site and site access roads;
- Excavations for foundations and construction of power plant and steamlines infrastructure; and,
- Clearance and earthworks of the condensate reinjection pipeline route approximately 4 m wide and 4 km long.

Following commissioning of the well, the two phase pipelines and steam lines will be commissioned via a "steam blow" where hot steam (from the geothermal resource) will be passed through the piping at high velocity for a sustained period. This will remove any solid particles present in the piping interior which may damage the steam turbines. As with production well testing steam and NCGs will be discharged to atmosphere, although for a much shorter time.

Although very unlikely, there is also the potential for a well blowout to occur during drilling, which will result in the unplanned release of geothermal fluids including NCGs.

During construction activities there will also be a number of sources of combustion gas emissions from the exhausts of drilling rig, transport vehicles, construction machinery, and electricity generators using diesel fuel. Potential pollutants from diesel combustion include nitrogen oxides ($NO_X$), sulphur dioxide ($SO_2$), carbon monoxide (CO), carbon dioxide ($CO_2$), and particulate matter smaller than 10 and 2.5 microns ($PM_{10}$ and $PM_{2.5}$, respectively).

### 3.2.2 Air Discharges during Operation

The Process Description for the ESIA describes two types of technologies (Rankine steam condensing and organic Rankine binary) for generating electrical energy from this geothermal resource. At this stage it is too early to confirm which technology option would be used for the Project. Regardless of the option selected, emissions from the Project will include the release of NCGs from sources such as steam vents and from a point source situated in the cooling tower arrangement. Although these can be considered 'natural' in the sense that they are already emitted from numerous existing fumaroles and vents on Dominica, the power plant will emit these in larger quantities than might be experienced naturally. Hydrogen sulphide is the primary NCGs of concern with potential to have adverse impacts on the surrounding environment, with nuisance odour impacts occurring at relatively low concentrations.

Additionally, unplanned or intermittent releases of steam and NCGs could result from:

- Pipeline failures due to damage or corrosion;
- Power plant shutdowns in which steam from the steam separator is vented to air via a rock muffler; and,
- Overpressure release of steam through flash tanks.

If the Project uses wet cooling towers there will be minor amounts of particulate matter discharged from the cooling towers as water droplets. These droplets may contain trace amounts of dissolved solids that would remain airborne as the droplets evaporate. These discharges are typically mitigated by drift eliminators, and are not expected to have a significant impact on the surrounding environment.

Combustion gas emissions during operation will be limited to emergency generators, firewater pumps, and service vehicles required for transporting maintenance equipment and materials.

### 3.2.3 Drilling for Additional Production Wells

As discussed in Section 1 the exploration phase of the Project has been completed, and the preferred production well site has been drilled and tested to confirm adequate conditions for power generation. Additional wells may need to be drilled at a later date to supplement the decline of wells over time.

If additional production wells are required, once the drilling is completed, the wells will be discharged for a period (up to 14 days) to determine well productivity, and estimate likely well run-down over time. A short initial discharge will be made to clear the well of debris, and then the well will be discharged into a portable well test silencer that will enable measurements of flow and enthalpy. This test is run until stable conditions are obtained and could release between 10 and 50 tonnes per hour of geothermal fluid (including brine, steam and non-condensable gases (NCGs)). Once the well has stabilized, samples of the discharge brine and any separated steam will be collected for chemical analysis.

Emission of NCGs is likely to be around four to five per cent of the total combined steam and NCGs released, and will include hydrogen sulphide ($H_2S$) carbon dioxide ($CO_2$), and minor pollutants; mercury (Hg), arsenic (As), ammonia ($NH_3$), fluoride (F-). The IFC EHS Guidelines for Geothermal Power Generation (2007b) state: "*Hydrogen sulfide and mercury are the main potential air pollutants* [from geothermal power plants]. *The presence and concentration of potential air pollutants may vary depending on the characteristics of the geothermal resource"*. The discharges will be similar to what are emitted during the operational phase of the Project, which have been assessed in this report.

Although very unlikely, there is also the potential for a well blowout to occur during drilling, which would result in the unplanned release of geothermal fluids including NCGs.

During additional drilling activities there will also be a number of sources of combustion gas emissions from the exhausts of drilling rig, transport vehicles, construction machinery, and electricity generators using diesel fuel. Potential pollutants from diesel combustion include nitrogen oxides ($NO_X$), which comprises of nitrogen dioxide ($NO_2$) and nitrogen oxide (NO)), sulphur dioxide ($SO_2$), carbon monoxide (CO), and carbon dioxide ($CO_2$), and particulate matter smaller than 10 and 2.5 microns ($PM_{10}$ and $PM_{2.5}$, respectively).

### 3.2.4 Air Discharges during Decommissioning

Decommissioning whole geothermal developments is a rare operation as generally, if the resource conditions are still favourable, equipment can be refurbished or replaced. Power plants can undergo refurbishment at the end of their design life to upgrade and repair equipment to enable operation and generation to continue.

For the Dominica geothermal power project, it is assumed that design practices will allow for the full decommissioning of the power plant and steam field should that be required at the end of the plants design life, or before if unforeseen conditions make the development uneconomic.

Emissions generated by activities during the decommissioning and reclamation phase will include dust emissions from land clearing, structure removal, backfilling, dumping, and reclamation of disturbed areas (grading, seeding, planting).

# 4. Guidelines and Standards

## 4.1 Introduction

The Commonwealth of Dominica has no regulations or standards with specific regard to ambient air quality. For this assessment recommendations from the World Health Organisation (WHO) and the New Zealand Ambient Air Quality Guidelines 2002 (AAQG) (MfE, 2002) have been considered.

Regarding the general requirement for assessing the impacts to air quality, this report has been prepared to meet the requirements of the WB Performance Standards, which provide guidance for managing environmental and social risk in project financing.

## 4.2 International Standards

As the World Bank has indicated its intention to provide funding to the development, the project is also required to demonstrate compliance with the World Bank Performance Standards for Private Sector Activities, OP 4.03, (WBG, 2013) and the WBG Environmental, Health, and Safety Guidelines (hereafter referred to as the 'EHS Guidelines').

## 4.3 Performance Standards

The WB Performance Standards, which are equivalent to the IFC Performance Standards on Social and Environmental Sustainability (IFC, 2012), are made up of eight performance standards which establish the standards the project should meet over the life of the investment.

Performance Standard 3 on Resource Efficiency and Pollution Prevention outlines the requirements for clients regarding GHG emissions. The objectives of Performance Standard 3 are:

- *'To avoid or minimize adverse impacts on human health and the environment by avoiding or minimizing pollution from project activities;*
- *To promote more sustainable use of resources, including energy and water; and*
- *To reduce project-related GHG emissions.'*

The General Requirements of Performance Standard 3 require that projects apply resource efficiency and pollution prevention principles and techniques which are technically and financially feasible and meet with good international industry practice (GIIP), regardless of the project's location.

Requirement 10 of Performance Standard 3 deals with pollution prevention including emissions to air:

*'The client will avoid the release of pollutants or, when avoidance is not feasible, minimize and/or control the intensity and mass flow of their release. This applies to the release of pollutants to air, water, and land due to routine, non-routine, and accidental circumstances with the potential for local, regional, and transboundary impacts. Where historical pollution such as land or ground water contamination exists, the client will seek to determine whether it is responsible for mitigation measures. If it is determined that the client is legally responsible, then these liabilities will be resolved in accordance with national law, or where this is silent, with GIIP [Good International Industry Practice].'*

## 4.4 Environmental, Health and Safety Guidelines

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP). When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as required by their respective policies and standards. The General EHS Guidelines are designed to be used together with the relevant Industry Sector EHS Guidelines which provide guidance to users on EHS issues in specific industry sectors.

The applicable EHS Guidelines comprise:

- Environmental, Health and Safety (EHS) General Guidelines (IFC, 2007a); and
- EHS Guidelines for Geothermal Power Generation (IFC, 2007b).

If the Project is seeking funding from the World Bank and it will be necessary to demonstrate use of these guidelines.

The EHS General Guidelines require that projects are assessed against the national ambient air quality guidelines or standards for the country in which they will operate, or in their absence, the WHO Ambient Air Quality Guidelines. It also provides general guidance on assessment, mitigation, and monitoring of specific air pollutants.

Specific to air quality the EHS Guidelines for Geothermal Power Generation provide recommendations for management of air quality emissions. These include:

- Considering technological options that include total or partial re-injection of gases with geothermal fluids within the context of potential environmental impacts from alternative generating technologies together with other primary factors, such as the fit of the technology to the geologic resource and economic considerations (e.g. capital and operation / maintenance costs);
- When total re-injection is not feasible, venting of hydrogen sulphide and non-condensable volatile mercury if, based on an assessment of potential impact to ambient concentrations, pollutant levels will not exceed applicable safety and health standards; and
- If necessary, use of abatement systems to remove hydrogen sulphide and mercury emissions from non-condensable gases. Examples of hydrogen sulphide controls can include wet or dry scrubber systems or a liquid phase reduction / oxidation system, while mercury emissions controls may include gas stream condensation with further separation or adsorption methods.

## 4.5 Air Quality Criteria Used in this Assessment

The primary pollutants of concern for the Project will be dust generated during construction activities, and emissions of NCGs from well testing and power plant operation. Of most relevance is likely to be hydrogen sulphide ($H_2S$) as other contaminants are usually present in very minor concentrations. Discharges of other contaminants (e.g. fugitive dust and products of diesel combustion) will be for a limited period during the construction phase. The assessment criteria used for these potential sources, across all phases, are presented in the following sections.

### 4.5.1 General

The final assessment of the significance of the impact, taking into account the impact specific assessment criteria, and mitigation measures, has been categorised using the definitions presented in Table 4.1.

**Table 4.1 : Significance of Impacts**

| Significance | Impacts |
|---|---|
| **Positive** | An enhancement of some ecosystems or population parameter |
| **Negligible** | Incidental on-site effect. No ecological consequences. |
| **Minor** | Minor release immediately contained. Reduction in abundance / biomass of flora fauna in affected area. No changes to biodiversity. Minor environmental nuisance. |
| **Moderate** | Off-site release contained with outside assistance. Reduction in biomass in local area without significant loss of pre-impact ecological functioning. Significant sustained environmental nuisance. |
| **Major** | Off-site release with significant impact to biodiversity and ecological functioning with eventual recovery (maybe not to pre impact conditions). |
| **Severe** | Toxic release with off-site detrimental effect. Irreversible changes to abundance of biomass in affected environment. Loss of ecological functioning with little prospect of full recovery. |

### 4.5.2 Hydrogen Sulphide

As discussed in Section 4.1, there are no national ambient air quality guidelines or standards for Dominica. In the absence of national guidelines and standards the IFC EHS General Guidelines recommend using the WHO Ambient Air Quality Guidelines (WHO AAQG) (2005). The WHO AAQG recommends a guideline value which is based on the lowest-observed-adverse-effect level (LOAEL) of 15,000 µg/m$^3$, the level at which eye irritation is caused. A safety factor of 100 is applied to the LOAEL in order to obtain the WHO AAQG for $H_2S$ of 150 µg/m$^3$ as a 24-hour average.

The New Zealand Ministry for the Environment (MfE) Ambient Air Quality Guidelines (NZ AAQG) (2002), provides a guideline value of 7 µg·m-$^3$ (1-hour average) for $H_2S$, which is based on odour threshold rather than health effects, and in addition, notes that it may be unsuitable for use in geothermal areas due to decreased sensitivity through continuous exposure.

A summary of the potential health effects of $H_2S$, summarised from the NZ AAQG, is presented in Table 4.2.

**Table 4.2 : Health effects of $H_2S$**

| Concentration (µg/m$^3$) | Effect |
|---|---|
| 0.2-2.0 | Odour threshold - detectable by 50% of people. Considered to have a smell of “rotten eggs” at 3 to 4 times this concentration. |
| 7.0 | Nuisance odour level (not considered applicable to geothermal areas) |
| 15,000* | Eye irritation (LOEAL) |
| 70,000 | Permanent eye damage |
| 225,000 | Paralysis of olfactory perception (odour can no longer be detected) |
| 400,000 | Risk of pulmonary oedema |
| 750,000 | Over-stimulates the central nervous system, causing rapid breathing, cessation of breathing, convulsions, and unconsciousness. |
| 1,400,000 | Lethal |

* The WHO Concise Chemical Assessment Document notes this concentration as the lowest observed adverse effect level (LOAEL) (WHO, 2003)

As shown in Table 4.2, the level at which health effects of $H_2S$ become a concern are well above the level at which it is considered to be a nuisance odour. In general, emissions from most geothermal power plants are at a level which could produce nuisance odour effects, but are well below levels for adverse health effects.

The NZ MfE Good Practice Guide for Assessing and Managing Odour in New Zealand suggests the use of "FIDOL" for assessing the impact of odours. This method was developed for assessing actual odour events, however can be applied to predicted impacts if reasonable assumptions on the FIDOL parameters can be determined. FIDOL incorporates an assessment of:

- Frequency - how often an individual is exposed to odour;
- Intensity - the strength of the odour;
- Duration - the length of a particular odour event;
- Offensiveness - the 'hedonic tone' of the odour; and
- Location - the type of land use and nature of human activities in the vicinity of an odour source.

### 4.5.3 Mercury (Hg)

The effects of chronic exposure to elemental mercury include central nervous system effects (such as erethism, irritability, insomnia), severe salivation, gingivitis and tremor, kidney effects (including proteinuria) and acrodynia in children. The WHO ambient air guideline for inorganic mercury is 1 µg/m$^3$ as an annual average, and is based on protecting against potential health impacts on the central nervous system. This limit is proposed for the Project.

### 4.5.4 Nuisance Dust

The production of dust from construction works such as the formation of roads and preparation of lay-down and drill zones will be inevitable. Modelling for dust is generally not considered appropriate for assessing construction impacts, as emission rates vary depending on a combination of the construction activity and meteorological conditions, which cannot be reliably predicted. For this assessment *Guidance on the Assessment of Dust from Demolition and Construction, Version 1.1* developed by the Institute of Air Quality Management (IAQM) (2014) has been used.

Activities on Site have been divided into four types to reflect their different potential effects. These are:

- Demolition;
- Earthworks;
- Construction; and
- Trackout.

Of these four types of activities, only earthworks and construction are relevant to the Project as no demolition and minimal materials transport is required.

The IAQM method uses a five step process for assessing dust impacts from construction activities:

**Step 1.** Screening based on distance to nearest receptor. No further assessment is required if there are no receptors within a certain distance of the works;

**Step 2.** Assess risk of dust effects from activities by:

- the scale and nature of the works, which determines the risk of dust arising; and
- the sensitivity of the area.

**Step 3.** Determine site specific mitigation for remaining activities with greater than negligible effects.

**Step 4.** Assess significance of remaining activities after mitigation has been considered.

**Step 5.** Reporting.

The Step 1 screening criteria provided by the IAQM guidance suggests screening out assessment of impacts from activities where sensitive 'human receptors' will be more than 350 m from the boundary of the site, 50metres of the route used by construction vehicles, or up to 500 metres from the Site entrance. Sensitive 'ecological receptors' can be screened out if they are greater than 50 metres from the boundary of the site, 50 metres of the route used by construction vehicles, or 500 metres from the site entrance.

The Step 2 assessment determines the Dust Emission Magnitude for each of four dust generating activities; demolition, earthworks, construction, and track out. The classes are; Large, Medium, or Small, with suggested definitions for each category. The lists of suggested definitions for earthworks and construction activities are presented in Appendix A.

The class of activity is then considered in relation to the distance of the nearest receptor and a risk category determined through an assessment matrix for each of three categories:

- Sensitivity to dust soiling effects;
- Sensitivity of people to health effects from $PM_{10}$; and,
- Sensitivity of Ecological effects.

A copy of each matrix for earthworks and construction is presented in Appendix A.

# 5. Emissions Estimation

## 5.1 Non-Condensable Gases (NCGs)

Emissions of NCGs from the plant's operation have been estimated based on assumptions of plant design for both options of geothermal plant (i.e. steam condensing and binary/ORC). The composition of NCGs in the geothermal fluid is based on tests undertaken during the exploration phase of the project. These assumptions are described below:

- Approximately 2.3 kg/s of steam flow per MW of power generation (16.1 kg/s total for a 7 MW power development).
- Steam from the well will consist of around 1.6% NCGs by weight for a total of 0.26 kg/s.
- NCGs consist of 4.3% $H_2S$ by weight for a discharge rate of 11.08 g/s $H_2S$.
- Mercury is present in varying concentrations in geothermal resources, with typical concentrations being around 20 ppb in the steam, but may be up to 500 ppb (Arnorsson, 2004). We have assumed the upper limit for a mass discharge rate of 0.0081 g/s.
- NCGs will be discharged into the cooling tower plumes in order to enhance dispersion of the gases via thermal buoyancy and mechanical draft provided by the cooling towers.

## 5.2 Discharge Parameters

Two types of power plant are currently being considered for the Project, a standard steam condensing plant, and an Organic Rankine Cycle (ORC) plant. For the purpose of assessing NCGs dispersion, the nature of the discharges will be similar, with the main differences being the configuration of the cooling fans/towers. Table 5.1 provides the emission parameters for two options for the Project, the steam condensing option and the ORC option. The discharge parameters have been based on preliminary site design drawings and referenced to similar projects. Both options have been assessed as buoyant line sources, under the assumption that the discharges will be vented through the cooling towers in order to enhance buoyancy. The most important parameter is the contaminant discharge rate for $H_2S$ of 11.08 g/s, whereas the other parameters would be expected to have less of an influence on the model predictions.

**Table 5.1 : Estimated Discharge Parameters and Emission Rates for Operation of Power Plant**

| Parameter | Steam Condensing Option | ORC Option |
|---|---|---|
| Line source length (m) | 40 | 100 |
| Line source height(m) | 18 | 7 |
| Building Height | 18 | 7 |
| Building Width (m) | 20 | 20 |
| Temperature (C) | 35 | 35 |
| Buoyancy Parameter ($m^4/s^3$) | 419 | 1900 |
| $H_2S$ (g/s) | 11.08 | 11.08 |
| Hg (g/s) | 0.0081 | 0.0081 |

# 6. Dispersion Modelling Assessment

## 6.1 Modelling Methodology

Emissions of non-condensable gases from the Project have been modelled using the CALPUFF modelling system, which consists principally of a meteorological model CALMET, and a transport and dispersion model CALPUFF.

The CALMET meteorological model is used to provide meteorological data over the study area which is necessary as an input into the CALPUFF dispersion model. The CALMET model is initialised with terrain and land use data describing the region of interest as well as meteorological data from various sources. In the absence of high quality meteorological data in this area, the WRF meteorological model was used to generate a 50 x 50 kilometre wind field. CALMET used this data to generate a dataset for input into CALPUFF.

CALPUFF is a non-steady-state Gaussian puff dispersion model capable of simulating the effects of time and space-varying meteorological conditions on pollutant transport, transformation, and removal (Scire et al. 2000a). This model requires time-variant two and three-dimensional meteorological data output from a model such as CALMET, as well as information regarding the relative location and nature of the sources to be modelled for the application. Output from the CALPUFF model includes ground-level concentrations of the species considered, as well as dry and wet depositional fluxes.

### 6.1.1 CALMET Settings

The CALMET diagnostic meteorological model was used to develop three-dimensional wind fields, temperature, and atmospheric stability or use with the CALPUFF dispersion model. The settings include:

- A 50 by 50 grid of 0.2 km intervals over the region, with 10 vertical levels;
- Local terrain data was obtained from NASA Shuttle Radar data for the island of Dominica;
- Land use categories were obtained from information provided by the United States Geographical Survey (USGS);
- CALMET default geophysical parameters were used based on local land use categories contained in the topographical maps; and
- Surface and upper air wind and temperature profiles and estimates of the surface humidity and pressure were commissioned from Lakes Environmental Software, who used the Weather Research Forecast (WRF) model, to develop the dataset.

The CALMET modelling domain area adopted for this assessment extends over a 20 x 20 km area, and encompasses the entire island of Dominica. A horizontal grid spacing of 200 metres was selected for the CALMET simulation. With this grid spacing, it was possible to maximize run time and file size efficiencies while still capturing large-scale terrain feature influences on wind flow patterns. To properly simulate pollution transport and dispersion, it is also important to simulate the typical vertical profiles of wind direction, wind speed, temperature, and turbulence intensity within the atmospheric boundary layer (i.e., the layer within about 2000 metres above the Earth's surface). To capture this vertical structure, ten vertical layers were selected for the extent of the modelling domain area. CALMET defines a vertical layer as the midpoint between two faces (i.e., 12 faces corresponds to 11 layers, with the lowest layer always being ground level or 10 m). The vertical faces used in this study are: 0, 20, 40, 80, 160, 320, 640, 1000, 1500, 2000, 2500 and 3000 metres.

The resultant meteorological file from CALMET covered the period 1/1/2015 to 1/1/2016 consisted of 365 days. A windrose of meteorological data extracted at a location near the Project area is provided as Figure 6.1, and shows the majority of winds are from the east, with average wind speeds of 5.4 m/s and calm winds (winds less than 0.5 m/s) occurring 0.1% of the time.

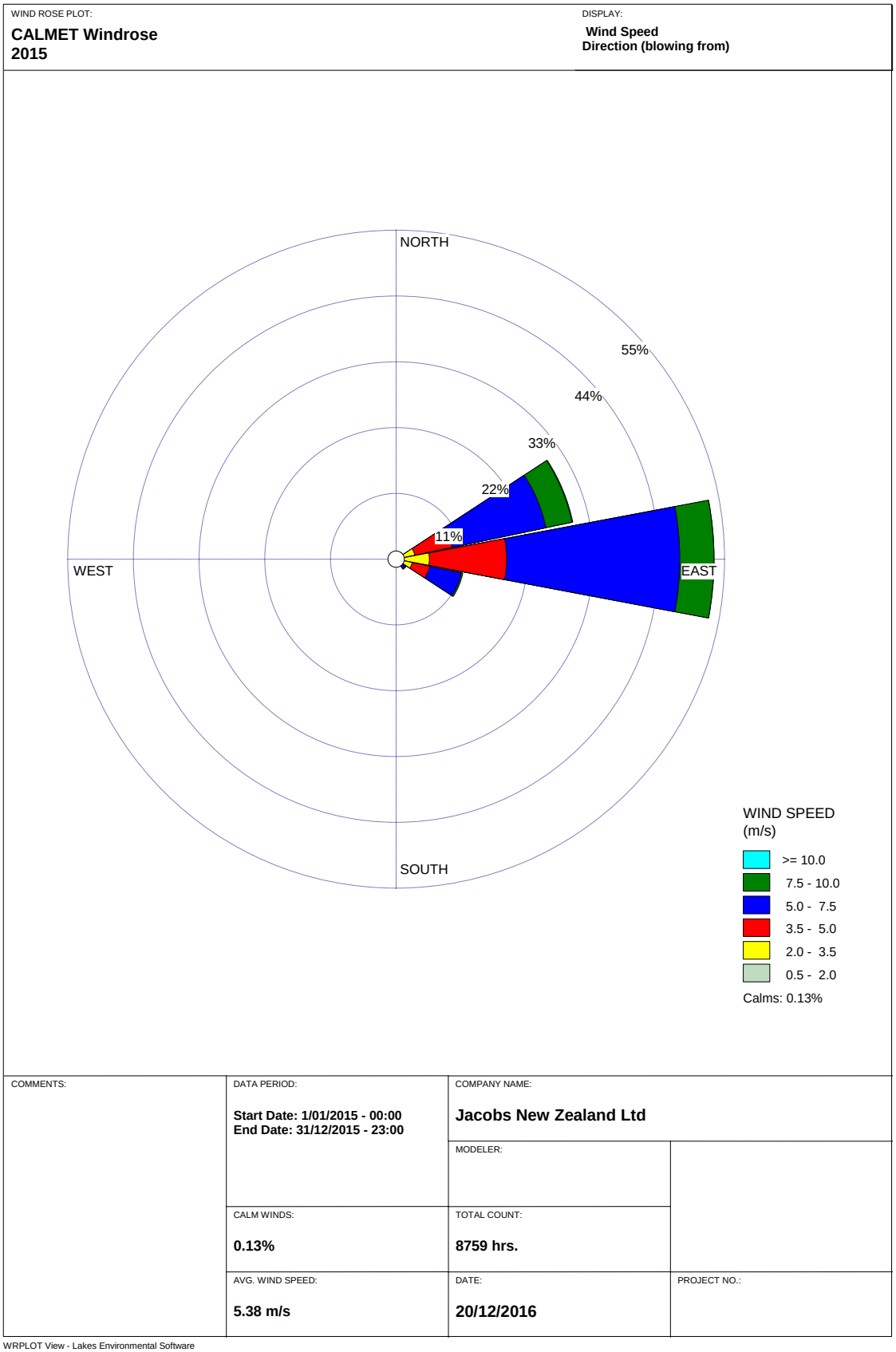


**Figure 6.1 : CALMET Windrose for Project Location**

### 6.1.2 CALPUFF Settings

The CALPUFF dispersion model (Version 7.2.1) was used for this assessment. The model contains the PRIME algorithms, which are considered more reliable than earlier algorithms for assessing building wake effects caused by winds blowing over and around those buildings located near the stacks. However, downwash potential in the lee of structures was not included for modelling of stack discharges, given that the dimensions of the buildings relative to the stack height are not sufficiently high or wide to result in downwash effects in the model.

CALPUFF was set up as follows:

- The discharges were modelled as buoyant line sources;
- Dispersion estimated using the micro-meteorological dispersion algorithms. These are recommended by Scire (2003) as being theoretically more sound than using dispersion curves;
- Dispersion rates were calculated using turbulence computed from micrometeorology;
- Transitional plume rise was switched on;
- No chemical transformation was included;
- The model was run to predict one-hour, 24-hour, and annual averages; and
- The default model settings for CALPUFF were used except as otherwise specified.

A copy of the CALPUFF model input file is provided as Appendix B.

## 6.2 Modelling Results

The highest ground level concentrations (GLCs) as 99.9$^{th}$ percentile 1-hour average for $H_2S$ predicted by the modelling at the sensitive receptors are presented in Table 6.1 below. Isopleth diagrams of the model prediction are presented as Figure 6.2 (for condensing plant option) and Figure 6.3 (for ORC option) below. The isopleth diagrams indicate the main area of impacts from the discharges is predicted to be the west and northwest of the Project site, downwind due to the predominant easterlies. South-easterly winds, while not frequently observed, appear to result in elevated concentrations to the northwest of the Project. These winds are likely to be relatively light, resulting in poorer dispersion of the plume.

The highest predicted GLC of $H_2S$ as a 99.9$^{th}$ percentile 1-hour average was 1,100 µg/m$^3$ for the steam condensing option and 8,210 µg/m$^3$ for the ORC option, and occurs adjacent to the cooling towers, to the north-west of the laydown area. The difference between the two scenarios is due to the nature of the sources, with the ORC source having a lower discharge height as well as a lower buoyancy which results in higher concentrations near the point of discharge compared to the steam-condensing option. Both scenarios are predicted to result in concentrations that are well below the WHO lowest observable adverse effect level (LOAEL) for $H_2S$ of 15,000 µg/m$^3$, although they are significantly above the NZ Ministry for the Environment Odour-based guideline of 7 µg/m$^3$ (It should be noted that this odour guideline should not be applied to areas with active natural geothermal features such as the Project area).

However, the maximum predicted concentrations decrease rapidly with distance from the power plant, and in the main residential areas are below the nuisance odour threshold of 7 µg/m$^3$. The model predictions for the ORC option are significantly lower than for the steam condenser option at the sensitive receptors, despite the ORC predictions being higher near the power plant itself. This is presumably due to differences in release height and estimated buoyancy of the discharges which result in higher concentrations near the power plant, but greater dispersion at further distances.

Predicted 1-hour concentrations of $H_2S$ within the Morne Trois Piton National Park are highest directly north northwest of the power plant, with highest concentrations being around 85 µg/m$^3$ for the steam condensing option and 28 µg/m$^3$ for the ORC option. The highest concentrations are well below the LOAEL for $H_2S$, and are not likely to result in adverse ecosystem impacts.

It is possible that the operation of the power plant could result in a discernible increase in odour from $H_2S$ discharges at residences nearest to the Project area. However, given the active geothermal nature of the area and the existing baseline levels of $H_2S$ in this area, it is unlikely that these would reach nuisance levels.

**Table 6.1 : Predicted 99.9$^{th}$ Percentile GLCs of 1-hour average $H_2S$ (µg/m$^3$) from 7 MW Geothermal Plant Operation**

| Receptor ID | Description | Predicted 1-hour average (99.9$^{th}$ percentile) $H_2S$ Concentrations (µm$^3$) | |
|---|---|---|---|
| | | Steam Condensing Option | Binary/ORC Option |
| 1 | Boiling Lake | 0.0003 | 0.006 |
| 2 | Copt Hall | 1. 5 | 0.3 |
| 3 | Fond Cani (north) | 8.0 | 2.3 |
| 4 | Fond Cani (south) | 0.9 | 0.3 |
| 5 | Fresh Water Lake | 0.008 | 0.003 |
| 6 | Laudat_North | 8.8 | 1.1 |
| 7 | Laudat South | 5.6 | 5.1 |
| 8 | Laudat West | 14.9 | 2.9 |
| 9 | Morne Prosper | 1.2 | 0.1 |
| 10 | Shawford | 1.7 | 0.5 |
| 11 | Trafalgar East | 2.7 | 0.5 |
| 12 | Trafalgar South | 1.2 | 0.2 |
| 13 | Trafalgar West | 3.5 | 0.9 |
| 14 | Valley of Desolation | 0.008 | 0.007 |
| 15 | Wotten Waven | 0.3 | 0.02 |
| Highest at Morne Trois National Park | | 85 | 28 |
| Highest within modelling domain | | 1110 | 8210 |

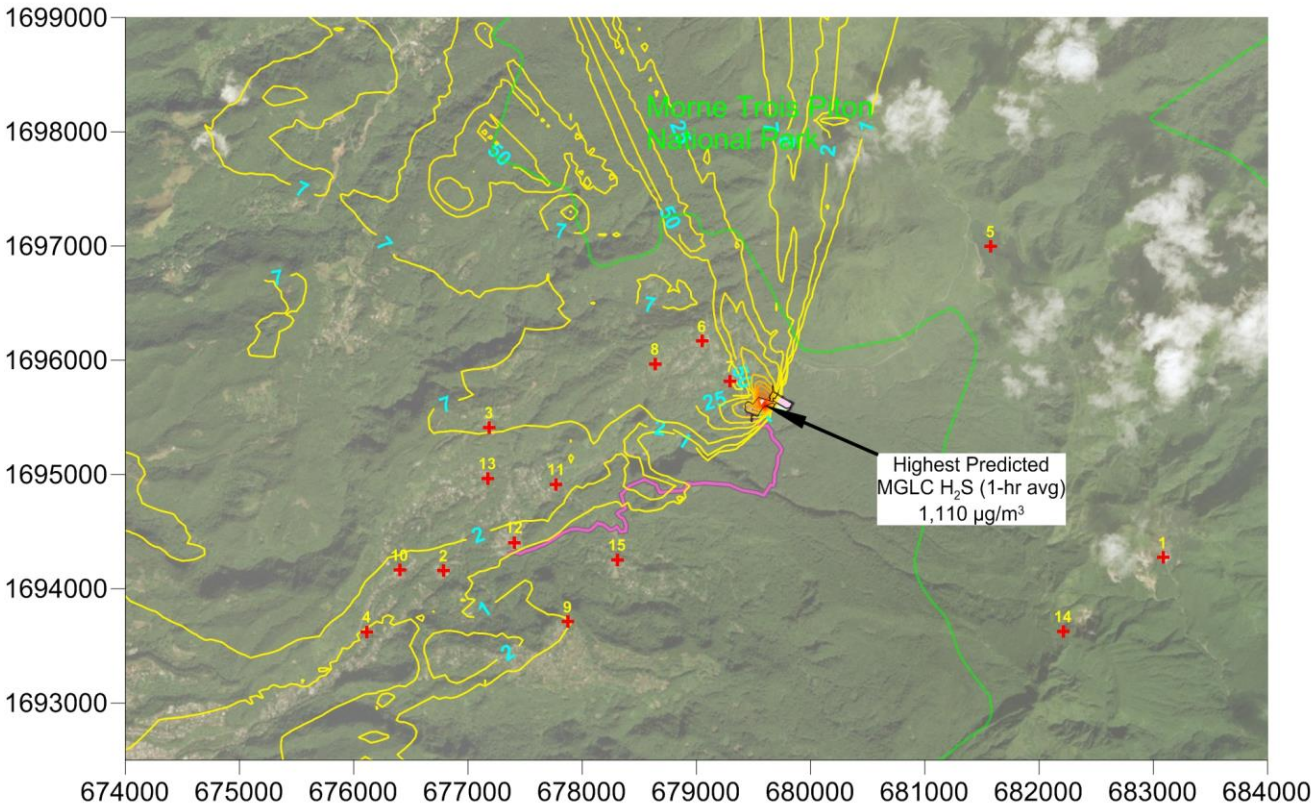


**Figure 6.2 : Predicted GLCs as a 99.9th %ile 1-hour average of $H_2S$ (µg/m³) from 7 MW Geothermal Plant Operation (Steam Condensing Option)**

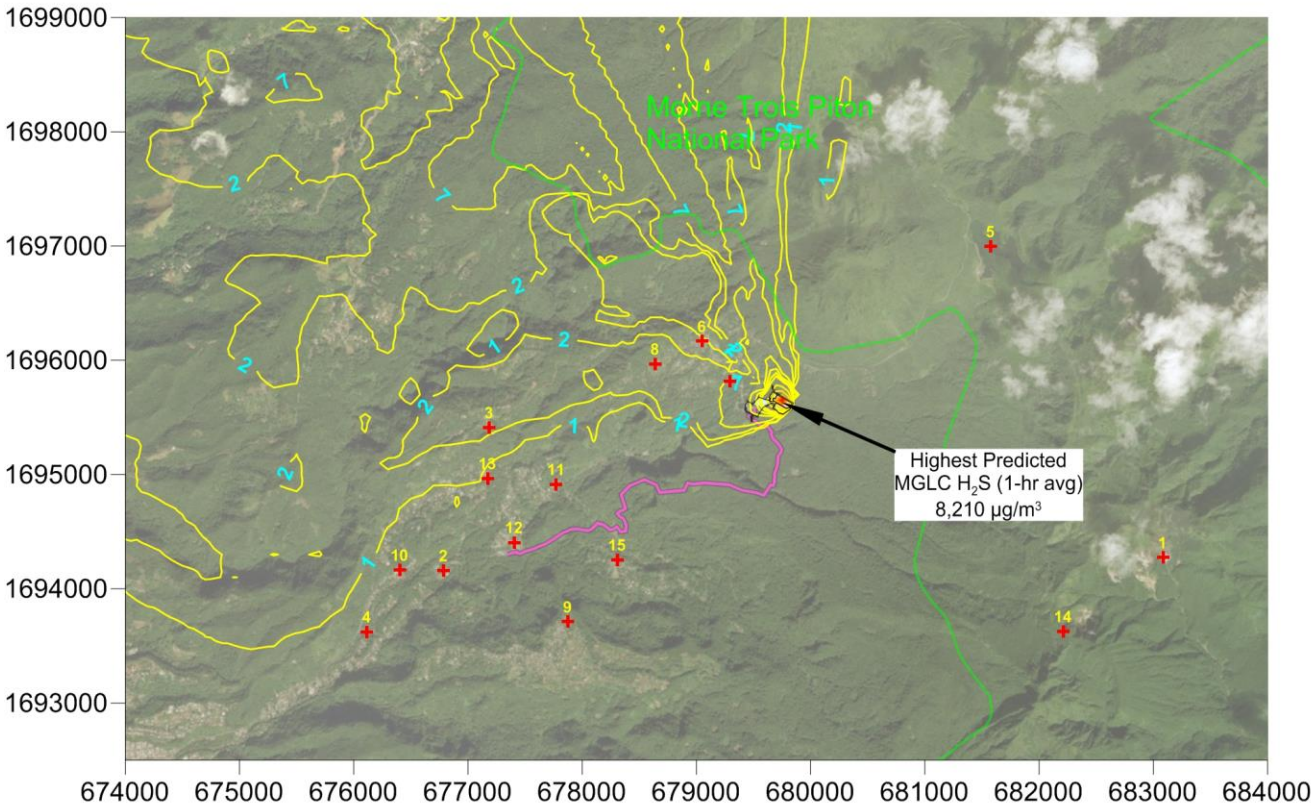


**Figure 6.3 : Predicted GLCs as a 99.9th %ile 1-hour average of $H_2S$ (µg/m³) from 7 MW Geothermal Plant Operation (ORC Option)**

Predictions of $H_2S$ as 24-hour averages are provided in Table 6.2 below, and similarly indicate concentrations of $H_2S$ are below the WHO guideline for $H_2S$ of 150 µg/m³ at all sensitive receptors. Concentrations near the power plant are predicted to exceed this guideline value, with the 150 µg/m³ limit exceeded just beyond the boundary in a very limited area, but not where there are residences.

Highest predicted 24-hour average concentrations of $H_2S$ at the Morne Trois National Park occur at the boundary to the north northwest of the power plant, with the maximum concentrations being 7 µg/m³ for the ORC option and 23 µg/m³ for the steam condensing option. This indicates the likelihood of some minor odour impacts at this location from the plant, but health and ecosystem impacts will be low.

**Table 6.2 : Predicted MGLCs of 24-hour average $H_2S$ (µg/m³) from 7 MW Geothermal Plant Operation**

| Receptor ID | Description | Predicted 24-hour average $H_2S$ Concentrations (µm³) | |
|---|---|---|---|
| | | Steam Condensing Option | Binary/ORC Option |
| 1 | Boiling Lake | 0.03 | 0.14 |
| 2 | Copt Hall | 0.21 | 0.04 |
| 3 | Fond Cani (north) | 2.48 | 0.34 |
| 4 | Fond Cani (south) | 0.18 | 0.03 |
| 5 | Fresh Water Lake | 0.05 | 0.05 |
| 6 | Laudat_North | 3.62 | 0.30 |
| 7 | Laudat South | 0.98 | 1.01 |

| Receptor ID | Description | Predicted 24-hour average $H_2S$ Concentrations ($\mu m^3$) | |
|---|---|---|---|
| | | Steam Condensing Option | Binary/ORC Option |
| 8 | Laudat West | 2.72 | 0.50 |
| 9 | Morne Prosper | 0.55 | 0.15 |
| 10 | Shawford | 0.49 | 0.07 |
| 11 | Trafalgar East | 0.84 | 0.07 |
| 12 | Trafalgar South | 0.19 | 0.04 |
| 13 | Trafalgar West | 1.46 | 0.15 |
| 14 | Valley of Desolation | 0.02 | 0.04 |
| 15 | Wotten Waven | 0.18 | 0.03 |
| Highest at Morne Trois National Park | | 23 | 7 |
| Highest within modelling domain | | 720 | 4110 |

The highest measured background concentration of $H_2S$ measured as part of the baseline assessment (provided in Table ) is 19 µg/$m^3$, which if added to the model predictions results in concentrations that remain well below the LOAEL of 15,000 µg/$m^3$ and the 24-hour average guideline of 150 µg/$m^3$ at all receptors. The highest maximum ground level concentration (MGLC) as a 24-hour average occurring at nearby receptors is 3.62 µg/$m^3$ which occurs at Laudat North with 23 µg/$m^3$ predicted to occur at the boundary of the Morne Trois Piton National Park for the steam condensing option.

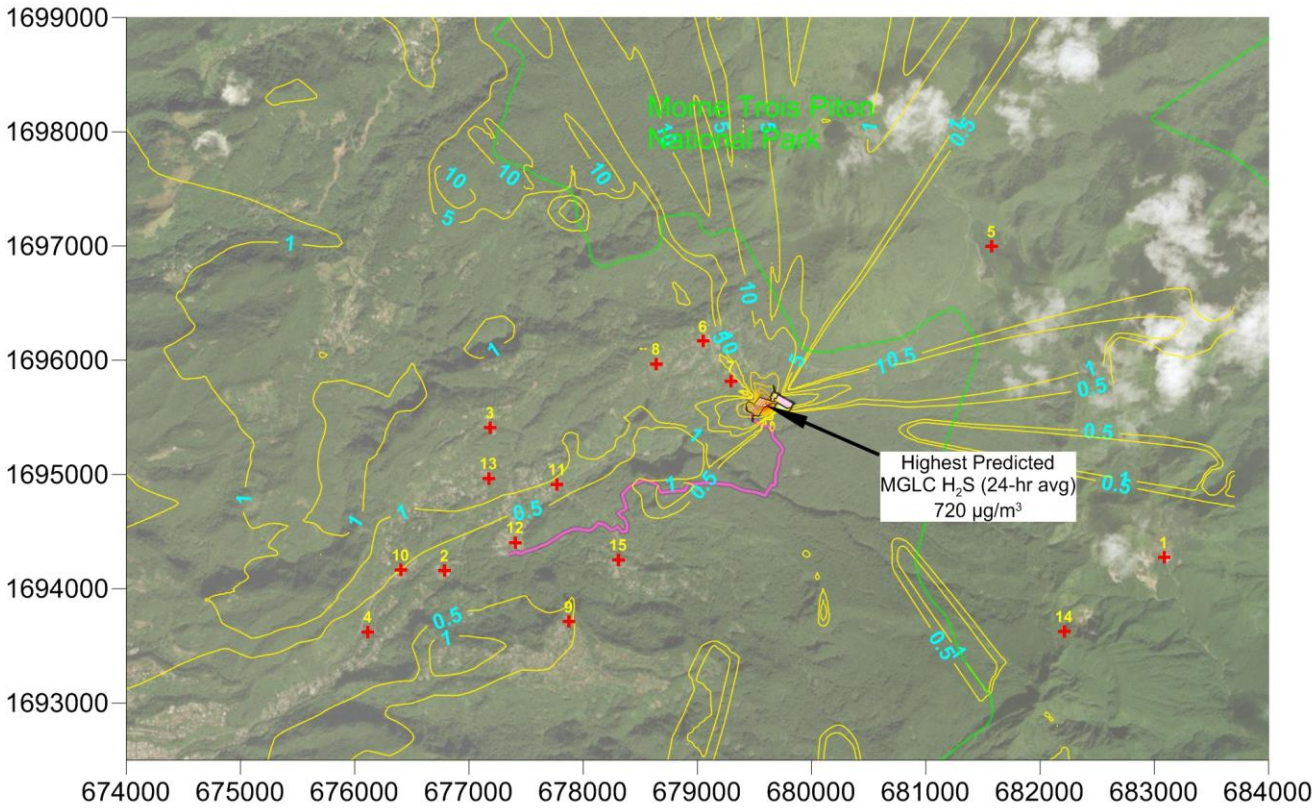


**Figure 6.4 : Predicted MGLCs of 24-hour average $H_2S$ (µg/m³) from 7 MW Geothermal Plant Operation (Steam Condensing Option)**

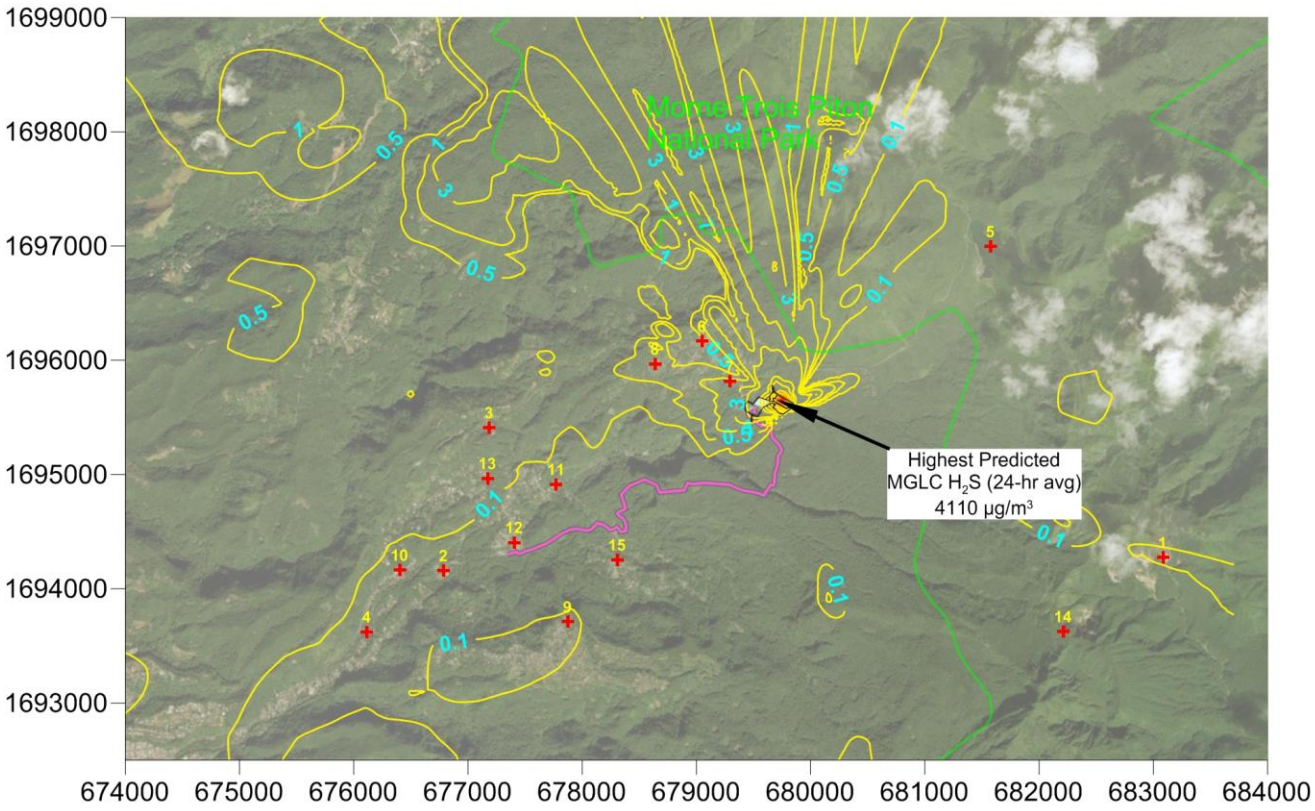


**Figure 6.5 : Predicted MGLCs of 24-hour average $H_2S$ (µg/m³) from 7 MW Geothermal Plant Operation (ORC Option)**

The annual average mercury concentrations predicted by the modelling at the sensitive receptors during operation of the power plant are provided in Table 6.3 below. The highest annual average ground level concentration of mercury was predicted to be 0.53 µg/m³, and occurs near the Project boundary. This is below the WHO ambient air guideline for inorganic mercury of 1 µg/m³. Concentrations are much lower at the sensitive receptors, and beyond the park boundary, with the highest predicted concentration at sensitive receptors being 0.003 µg/m³. Given the low concentrations of mercury predicted, which are likely to be significantly lower as the mercury concentrations in the steam is expected to be well below the upper range found in geothermal resources, mercury discharges from the Project have a minor level of impact on the surrounding environment.

**Table 6.3 : Predicted MGLCs of Annual Average Mercury (µg/m³) from 7 MW Geothermal Plant Operation**

| Receptor ID | Description | Predicted Annual Average Mercury Concentration (µm³) | |
|---|---|---|---|
| | | Steam Condensing Option | Binary/ORC Option |
| 1 | Boiling Lake | 9.7E-08 | 2.4E-05 |
| 2 | Copt Hall | 4.5E-06 | 1.5E-04 |
| 3 | Fond Cani (north) | 4.5E-04 | 1.8E-03 |
| 4 | Fond Cani (south) | 2.9E-06 | 1.3E-04 |
| 5 | Fresh Water Lake | 1.3E-07 | 3.5E-05 |
| 6 | Laudat North | 3.0E-05 | 2.6E-03 |
| 7 | Laudat South | 2.2E-05 | 7.2E-04 |
| 8 | Laudat West | 1.6E-04 | 2.0E-03 |

| Receptor ID | Description | Predicted Annual Average Mercury Concentration (µm$^3$) | |
|---|---|---|---|
| | | Steam Condensing Option | Binary/ORC Option |
| 9 | Morne Prosper | 3.1E-06 | 4.1E-04 |
| 10 | Shawford | 9.2E-06 | 3.6E-04 |
| 11 | Trafalgar East | 2.3E-05 | 6.1E-04 |
| 12 | Trafalgar South | 3.8E-06 | 1.4E-04 |
| 13 | Trafalgar West | 6.6E-05 | 1.1E-03 |
| 14 | Valley of Desolation | 7.7E-08 | 1.5E-05 |
| 15 | Wotten Waven | 7.6E-07 | 1.3E-04 |
| Highest at Morne Trois National Park (at park boundary) | | 1.9E-04 | 4.4E-05 |
| Highest within modelling domain | | 3.4E-01 | 5.3E-01 |

# 7. Air Quality Impact Assessment

## 7.1 Construction

### 7.1.1 Health

Health impacts from $H_2S$ during construction activities will be short term during the well commissioning, and unlikely to reach levels which would result in an adverse impact on health.

Safety monitoring systems with warning alarms for high emissions of potentially hazardous gases will be incorporated as part of the drilling set-up.

### 7.1.2 Odour

The FIDOL assessment for odour impacts during exploration undertaken above, will equally apply to the construction phase, as there are likely to be $H_2S$ levels above the nuisance odour limit identified in the NZ AAQG, but that the emissions will be for short duration during well testing and will be less noticeable as a result of desensitisation from continuous exposure to elevated background concentrations from natural sources.

### 7.1.3 Dust

Most construction activities can be screened out due to the distance from receptors, which appear from aerial imagery to be generally greater than 350 metres from the Project, although there are some residences (<20) within 200-350 metres of the Project. Additional works on tracks and the laydown area would be no greater than the exploration activities already undertaken. It is possible that sections of the reinjection line will be located nearer to receptors.

A general assessment of the dust emission magnitude of earthworks activities which may be associated with the Project would class them as “small” following the IAQM assessment definition in Appendix A:

*‘Total site area <2,500 $m^2$, soil type with large grain size (e.g. sand), <5 heavy earth moving vehicles active at any one time, formation of bunds <4 m in height, total material moved <10,000 tonne, earthworks during wetter months.’*

Similarly, an assessment of the dust emission magnitude of construction activities associated with the Project would class them as “small” following the IAQM assessment definition:

*‘Total building volume <25,000 $m^3$, construction material with low potential for dust release (e.g. metal cladding or timber).’*

**Table 7.1 : Dust Emission Magnitude**

| Activity | Dust Emission Magnitude |
|---|---|
| Earthworks | Small |
| Construction | Small |

The majority of the construction activities associated with the Project will not closer than 100 m of the nearest residences, giving the Project a ‘Low’ sensitivity classification in regard to dust soiling effects.

Similarly, human health impacts are classified as ‘Low’ given the absence of residences within 200 metres of the Project, and with few residences (estimated at well below 100 residential properties from examining aerial imagery) within 100 metres of the Project.

Ecological effects are classified as “Negligible”, as the Project area is more than 50 metres of a sensitive ecological area (e.g. the Morne Trois Pitons National Park).

These sensitivity classifications are summarised in Table 7.2 below.

**Table 7.2 : Outcome of Defining the Sensitivity of the Area to Dust Effects**

| Potential Impact | Earthworks | Construction |
|---|---|---|
| Dust Soiling | Low | Low |
| Human Health | Low | Low |
| Ecological | Negligible | Negligible |

The dust emission magnitude for the earthworks and construction activities in **Table 7.1** should be combined with the sensitivity of the area as described in **Table 7.2** to determine the risk of impacts with no mitigation applied. The risk matrices in Appendix A are then applied to assign a level of risk for each activity. The resulting dust risk for earthworks and construction activities are shown in **Table 7.3** below. As the dust emission magnitude for all activities is classified as 'Small', and the sensitivity of the area is classified as 'Low' for all activities, the resulting risk is therefore classified as 'Negligible' for dust soiling, human health and ecological effects. For those cases where the risk category is 'Negligible', no mitigation measures beyond those required by legislation will be required, although good practice dust management methods are recommended in any case.

**Table 7.3 : Dust Risk Table to Define Site-Specific Mitigation**

| Source | Dust Soiling | Human Health | Ecology |
|---|---|---|---|
| Earthworks | Negligible | Negligible | Negligible |
| Construction | Negligible | Negligible | Negligible |

When taken in combination with the relatively short duration of the construction, it is considered that there will be no significant impact from generated dust emissions at these sites.

### 7.1.4 Combustion Gases

Ambient air monitoring undertaken during the baseline monitoring described in Section 2.1.3 indicate that overall air quality is good with respect to combustion gases, although there is the potential for cumulative impacts of $SO_2$ and particulate matter. However, combustion emissions associated with construction activities will be more than 350 metres from the main residential areas and emissions from the main source will occur over a relatively short duration. As such, it is considered that the potential impact on people living and working in the surrounding area combustion gas emissions will be **Negligible**.

## 7.2 Operation

The results of the CALPUFF modelling are presented as a plot of $H_2S$ concentration versus downwind distance in Figure 6.2. The predicted highest one-hour maximum ground level $H_2S$ concentration as a 99.9 %ile was 8,210 $\mu g \cdot m^{-3}$ and this occurs within 50 metres downwind from the source. This value is well below the WHO lowest observable adverse effect level (LOAEL), of 15,000 $\mu g \cdot m^{-3}$.

The results of the CALPUFF modelling suggest it is possible that there will be $H_2S$ odour concentrations downwind from the Project that will be smelt by local residents and has the potential under certain meteorological conditions to be regarded as a nuisance (offensive or objectionable). However, the NZ AAQG note that continuous exposure to $H_2S$ will reduce a receptor's sensitivity to it, this is likely to be the case in Dominica where there are already natural levels of $H_2S$ present as a result of the natural geothermal activity on the Island.

A FIDOL assessment of the nuisance odour impact is considered below, based on the results of the CALPUFF modelling:

**Frequency**

- The discharges of odour will be more or less continuous from operation of the Project, although meteorological conditions resulting in the highest concentrations are likely to be intermittent.

**Intensity**

- The odour intensity is considered to be high as $H_2S$ has a very low odour threshold and a very recognisable odour, although Dominican residents may have a reduced sensitivity to it as a result of continuous exposure from natural emission sources.

**Duration**

- The duration of the discharges will be more or less continuous. However, for individual receptors, the odour would only be apparent when downwind of the Project.

**Offensiveness**

- $H_2S$ is described as having the odour of “rotten eggs”, although, as with intensity, Dominican residents may have a reduced sensitivity to it as a result of continuous exposure from natural emission sources.

**Location**

- On the basis of the modelling it is possible that nuisance odour will be detectable within the local villages to the west of the Project location (downwind of the predominant easterlies) and could potentially impact residences in their day to day activities.

Overall, it is considered that there would be a minor impact on receptors with regard to odour, due to the relatively concentrations predicted at the main residential areas and a likely desensitised local population.

There will be no nuisance dust impacts during the operation of the power plant.

Combustion emissions from the operation of the Project will be restricted to occasional use equipment such as emergency generators, firewater pumps, and maintenance vehicles. As such, it is considered that the potential impact on people living and working in the surrounding area from combustion emissions will be **Negligible**.

# 8. Mitigation and Monitoring

## 8.1 Mitigation

Although the unmitigated impacts of nuisance dust are not considered to be significant in the wider context of the Project, there could be individual residences within closer proximity to construction sites, as well as local use of near-by walking tracks and farming areas. The Project will apply good working practices to minimise potential impacts through mitigation techniques such as water suppression, covering or enclosed storage of aggregates (including topsoil and sand) where practical, and limiting dust generation activities in high winds or specific wind directions, if required.

Routine maintenance checks will be undertaken on wellheads and blowout prevention equipment to check it is in operable condition.

If a wet cooling tower system is to be used for the Project, drift eliminators will be incorporated into the final design to minimise particulate emissions.

Impacts from the operational station will be dependent on the geothermal fluid chemistry and the plant design. Given the predicted level of effects is predicted to be at an acceptable level, additional measures such as total or partial re-injection of gases with geothermal fluids; and abatement systems to remove hydrogen sulphide emissions from NCGs (e.g. wet/dry scrubbers), are not required.

## 8.2 Monitoring

Safety monitoring systems with warning alarms for high emissions of potentially hazardous gases, including $H_2S$, incorporated at the well sites, the power plant and reinjection sites, as well as providing direct safety measures in the event of a blowout, will highlight potential $H_2S$ emissions issues which could arise during well commissioning and operation. All personnel and local residents will be made aware of the procedure should an alarm be activated.

As part of good working practice the construction manager will complete routine checks on dust generation from construction activities, and confirm that dust suppression and appropriate storage is being used where required. In addition, a mechanism for complaints regarding dust will be available to locals, and due regard given to any issues raised.

Ambient monitoring for $H_2S$ can be easily undertaken at sensitive locations (e.g. nearby residential areas) using low-level ambient $H_2S$ monitors such as Odalog [2], which can be deployed at multiple locations for up to two months at a time.

For the Organic Rankine Cycle option, there will be infrared heat detectors and pentane vapour monitors installed at the power plant site around the working fluid condenser/equipment and cooling tower, for early detection of any leaks of pentane or heat sources.

[2] http://www.odalog.com/data-logging-products/low-range/

# 9. Conclusion

There are a number of potential pathways for effects on air quality to occur during the various phases of the Dominica geothermal development.

Emissions associated with the combustion of diesel fuel for; drilling rig, transport vehicles, construction machinery, and electricity generators during exploration and construction, and; emergency generators, firewater pumps, and service vehicles during operation have been considered to represent a **Negligible** impact on air quality due to their relatively short duration and distance from receptors.

The potential impacts which have been identified as having minor impacts are:

- Dust generation from construction activities related to the preparation of tracks, drill sites, and laydown areas during the construction stage and the additional preparation for the well pads, power plant, steam lines, and transmission equipment associated with the power plant operation. The impacts of these activities will be reduced by using good working practices to minimise the generation of dust.
- Release of NCGs from well testing activities, with $H_2S$ being the most relevant. Only nuisance impacts associated with increased ambient concentration of $H_2S$ are anticipated to be of concern, as health impacts only occur with exposure to very high concentrations, which are not expected to occur as a result of this project.
- The potential for $H_2S$ health impacts and nuisance odour during the operation of the plant. Dispersion modelling of potential discharges from plant operation indicates that the health impacts will be **Negligible** at all areas, including at nearby sensitive receptors. Nuisance odour impacts will likely be observable in the immediate vicinity of the plant, though at the nearest sensitive receptors these will be typical of active geothermal regions and would likely be indistinguishable from existing background levels.

With appropriate mitigation and monitoring in place it is considered that the potential impacts on air quality of the surrounding area will be acceptable.

# 10. References

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Institute of Air Quality Management (IAQM) (2014). IAQM Guidance on the assessment of dust from demolition and construction, Institute of Air Quality Management, London. [Accessed at www.iaqm.co.uk/text/guidance/construction-dust-2014.pdf in September 2017].

# Appendix A. Dust Assessment Criteria

The assessment criteria below have been summarised from the *Guidance on the Assessment of Dust from Demolition and Construction* developed by the Institute of Air Quality Management (IAQM) (2014).

## A.1 Dust Emission Magnitude

**Earthworks**

Earthworks will primarily involve excavating material, haulage, tipping and stockpiling. This may also involve levelling the site and landscaping. Every site is different in terms of timing (seasonality), geology, topography and duration and therefore professional judgement must be applied when classifying the earthworks' activities.

The following are examples of the potential dust emission classes (note that not all the criteria need to be met for a particular class); other criteria may be used if justified in the assessment:

- Large: Total site area >10,000 $m^2$, potentially dusty soil type (e.g. clay, which will be prone to suspension when dry to due small particle size), >10 heavy earth moving vehicles active at any one time, formation of bunds >8m in height, total material moved >100,000 tonne;
- Medium: Total site area 2,500$m^2$ – 10,000 $m^2$, moderately dusty soil type (e.g. silt), 5-10 heavy earth moving vehicles active at any one time, formation of bunds 4 m – 8 m in height, total material moved 20,000 tonne – 100,000 tonne; and
- Small: Total site area <2,500 $m^2$, soil type with large grain size (e.g. sand), <5 heavy earth moving vehicles active at any one time, formation of bunds <4 m in height, total material moved <10,000 tonne, earthworks during wetter months.

**Construction**

The key issues when determining the potential dust emission class during the construction phase include the size of the building(s)/infrastructure, method of construction, construction materials, and duration of build. Every site is different in terms of timing (seasonality), building type, duration, scale (volume and height) and therefore professional judgement must be applied when classifying the construction activities into one of the 3 magnitude classes.

The following are examples of the potential dust emission classes (note that not all the criteria need to be met for a particular class); other criteria may be used if justified in the assessment:

Large: Total building volume >100,000$m^3$, piling, on site concrete batching; sandblasting

Medium: Total building volume 25,000$m^3$ – 100,000$m^3$, potentially dusty construction material (e.g. concrete), piling, on site concrete batching; and

Small: Total building volume <25,000$m^3$, construction material with low potential for dust release (e.g. metal cladding or timber).

## A.2 Area Sensitivity

The dust emission magnitudes for both earthworks and construction activities should then be used in the matrix in Table A1 to determine the earthworks risk category for dust soiling effects with no mitigation applied. Similarly, the dust emission classes should be used in the matrix provided in Table A2 to assess risk to human health, and Table A3 for assessing ecological risk.

**Table A1 Sensitivity of the area to Dust Soiling Effects on People and Property**

| Receptor Sensitivity | Number of Receptors | Distance from Source (m) | | | |
|---|---|---|---|---|---|
| | | <20 | <50 | <100 | <350 |
| High | >100 | High | High | Medium | Low |
| | 10-100 | High | Medium | Low | Low |
| | 1-10 | Medium | Low | Low | Low |
| Medium | >1 | Low | Low | Low | Low |
| Low | >1 | Low | Low | Low | Low |

**Table A2 : Sensitivity of the area to Human Health Impacts**

| Receptor Sensitivity | Annual Mean $PM_{10}$ Concentration | Number of Receptors | Distance from Source (m) | | | | |
|---|---|---|---|---|---|---|---|
| | | | <20 | <50 | <100 | <200 | <350 |
| High | >32 µg/m$^3$ | >100 | High | High | High | Medium | Low |
| | | 10-100 | High | High | Medium | Low | Low |
| | | 1-10 | High | Medium | Low | Low | Low |
| | 28-32 µg/m$^3$ | >100 | High | High | Low | Low | Low |
| | | 10-100 | High | Medium | Low | Low | Low |
| | | 1-10 | High | Medium | Low | Low | Low |
| | 24-28 µg/m$^3$ | >100 | High | Medium | Low | Low | Low |
| | | 10-100 | High | Medium | Low | Low | Low |
| | | 1-10 | Medium | Low | Low | Low | Low |
| | <24µg/m$^3$ | >100 | Medium | Low | Low | Low | Low |
| | | 10-100 | Low | Low | Low | Low | Low |
| | | 1-10 | Low | Low | Low | Low | Low |
| Medium | >32 µg/m$^3$ | >100 | High | Medium | Low | Low | Low |
| | | 10-100 | Medium | Low | Low | Low | Low |
| | | 1-10 | Medium | Low | Low | Low | Low |
| | 28-32 µg/m$^3$ | >100 | Low | Low | Low | Low | Low |
| | | 10-100 | Low | Low | Low | Low | Low |
| | | 1-10 | Low | Low | Low | Low | Low |
| | 24-28 µg/m$^3$ | >100 | Low | Low | Low | Low | Low |
| | | 10-100 | Low | Low | Low | Low | Low |
| | | 1-10 | Low | Low | Low | Low | Low |
| | <24µg/m$^3$ | >100 | Low | Low | Low | Low | Low |
| | | 10-100 | Low | Low | Low | Low | Low |
| | | 1-10 | Low | Low | Low | Low | Low |
| Low | - | >1 | Low | Low | Low | Low | Low |

**Table A3 : Sensitivity of the area to Ecological Impacts**

| Receptor Sensitivity | Number of Receptors | Distance from Source (m) | |
|---|---|---|---|
| | | <20 | <50 |
| High | >100 | High | Medium |
| | 10-100 | Medium | Low |
| | 1-10 | Low | Low |
| Medium | >1 | Low | Low |
| Low | >1 | Low | Low |

## A.3 Risk of Dust Impacts

The dust emission magnitude determined for construction and earthworks activities (i.e. small, medium or large) should be combined with the sensitivity of the area determined by the matrices in Tables A1, A2 and A3) to determine the risk of impacts with no mitigation applied. The matrix in Table A4 provides a method of assigning the level of risk for each activity. This should be used to determining the level of mitigation that must be applied. For those cases where the risk category is 'Negligible', no mitigation measures beyond those required by legislation will be required.

**Table A4 : Risk of Dust Impacts**

| Sensitivity of Area | Dust Emission Magnitude | | |
|---|---|---|---|
| | Large | Medium | Small |
| High | High Risk | Medium Risk | Low Risk |
| Medium | Medium Risk | Medium Risk | Low Risk |
| Low | Low Risk | Low Risk | Negligible |

# Appendix B. CALPUFF Model Input File

```
CALPUFF.INP     2.0          File version record

---------- Run title (3 lines) ------------------------------------------
           CALPUFF MODEL CONTROL FILE
           -------------------------
--------------------------------------------------------------------------------

INPUT GROUP: 0 -- Input and Output File Names

--------------
Default Name  Type          File Name
------------  ----          ---------
CALMET.DAT    input    ! METDAT = F:\Modeling\Dominica\CALMET\calmet_2015.dat !
   or
ISCMET.DAT    input    * ISCDAT =           *
   or
PLMMET.DAT    input    * PLMDAT =           *
   or
PROFILE.DAT   input    * PRFDAT =           *
SURFACE.DAT   input    * SFCDAT =           *
RESTARTB.DAT  input    * RSTARTB=           *
--------------------------------------------------------------------------------
CALPUFF.LST   output   ! PUFLST = CALPUFF3b.lst !
CONC.DAT      output   ! CONDAT = CALPUFF3b.con !
DFLX.DAT      output   ! DFDAT = CALPUFF3b.dry !
WFLX.DAT      output   ! WFDAT = CALPUFF3b.wet !

VISB.DAT      output   ! VISDAT = CALPUFF3b.vis !
TK2D.DAT      output   * T2DDAT = *
RHO2D.DAT     output   * RHODAT = *
RESTARTE.DAT  output   * RSTARTE=           *
--------------------------------------------------------------------------------
Emission Files
--------------
PTEMARB.DAT   input    * PTDAT  =           *
VOLEMARB.DAT  input    * VOLDAT =           *
BAEMARB.DAT   input    * ARDAT  =           *
LNEMARB.DAT   input    * LNDAT  =           *
--------------------------------------------------------------------------------
Other Files
-----------
OZONE.DAT     input    * OZDAT  =           *
VD.DAT        input    * VDDAT  =           *
CHEM.DAT      input    * CHEMDAT=           *
AUX           input    * AUXEXT =           *
(Extension added to METDAT filename(s) for files
 with auxiliary 2D and 3D data)
H2O2.DAT      input    * H2O2DAT=           *
NH3Z.DAT      input    * NH3ZDAT=           *
HILL.DAT      input    * HILDAT=            *
HILLRCT.DAT   input    * RCTDAT=            *
COASTLN.DAT   input    * CSTDAT=            *
FLUXBDY.DAT   input    * BDYDAT=            *
BCON.DAT      input    * BCNDAT=            *
```

```
DEBUG.DAT     output   * DEBUG =            *
MASSFLX.DAT   output   * FLXDAT=           *
MASSBAL.DAT   output   * BALDAT=           *
FOG.DAT       output   * FOGDAT=           *
RISE.DAT      output   * RISDAT=           *
------------------------------------------------------------------------------
All file names will be converted to lower case if LCFILES = T
Otherwise, if LCFILES = F, file names will be converted to UPPER CASE
       T = lower case      ! LCFILES = T !
       F = UPPER CASE
NOTE: (1) file/path names can be up to 132 characters in length


Provision for multiple input files
----------------------------------

    Number of Modeling Domains (NMETDOM)
                          Default: 1      ! NMETDOM =   1   !

    Number of CALMET.DAT files for run (NMETDAT)
                          Default: 1      ! NMETDAT = 1 !

    Number of PTEMARB.DAT files for run (NPTDAT)
                          Default: 0      ! NPTDAT =   0   !

    Number of BAEMARB.DAT files for run (NARDAT)
                          Default: 0      ! NARDAT =   0   !

    Number of VOLEMARB.DAT files for run (NVOLDAT)
                          Default: 0      ! NVOLDAT =   0   !

!END!

-------------
Subgroup (0a)
-------------

  Provide a name for each CALMET domain if NMETDOM > 1
  Enter NMETDOM lines.
                           a,b
Default Name           Domain Name
------------           ------------
 none                * DOMAIN=     *   *END*


  The following CALMET.DAT filenames are processed in sequence
  if NMETDAT > 1

  Enter NMETDAT lines, 1 line for each file name.

                           a,c,d
Default Name  Type          File Name
------------  ----          ---------
 none         input    * METDAT=  *    *END*
-------------
   a
```

The name for each CALMET domain and each CALMET.DAT file is treated
as a separate input subgroup and therefore must end with an input
group(terminator.

b

Use DOMAIN1= to assign the name for the outermost CALMET domain.
Use DOMAIN2= to assign the name for the next inner CALMET domain.
Use DOMAIN3= to assign the name for the next inner CALMET domain, etc.

| When inner domains with equal resolution (grid-cell size) |
| overlap, the data from the FIRST such domain in the list will |
| be used if all other criteria for choosing the controlling |
| grid domain are inconclusive. |

c

Use METDAT1= to assign the file names for the outermost CALMET domain.
Use METDAT2= to assign the file names for the next inner CALMET domain.
Use METDAT3= to assign the file names for the next inner CALMET domain, etc.

d

The filenames for each domain must be provided in sequential order

---
Subgroup (0b)
---

The following PTEMARB.DAT filenames are processed if NPTDAT>0
(Each file contains a subset of the sources, for the entire simulation)

| Default Name | Type | File Name |
|---|---|---|
| none | input | * PTDAT= * *END* |

---
Subgroup (0c)
---

The following BAEMARB.DAT filenames are processed if NARDAT>0
(Each file contains a subset of the sources, for the entire simulation)

| Default Name | Type | File Name |
|---|---|---|
| none | input | * ARDAT= * *END* |

---
Subgroup (0d)
---

The following VOLEMARB.DAT filenames are processed if NVOLDAT>0
(Each file contains a subset of the sources, for the entire simulation)

| Default Name | Type | File Name |
|---|---|---|
| none | input | * VOLDAT= * *END* |

```
--------------------------------------------------------------------------------

INPUT GROUP: 1 -- General run control parameters
--------------

   Option to run all periods found
   in the met. file     (METRUN)   Default: 0       ! METRUN = 1 !

      METRUN = 0 - Run period explicitly defined below
      METRUN = 1 - Run all periods in met. file

   Starting date:    Year   (IBYR)  --    No default   ! IBYR = 2011 !
                     Month  (IBMO)  --    No default   ! IBMO = 1 !
                     Day    (IBDY)  --    No default   ! IBDY = 1 !
   Starting time:    Hour   (IBHR)  --    No default   ! IBHR = 0 !
                     Minute (IBMIN) --    No default   ! IBMIN = 0 !
                     Second (IBSEC) --    No default   ! IBSEC = 0 !

   Ending date:      Year   (IEYR)  --    No default   ! IEYR = 2012 !
                     Month  (IEMO)  --    No default   ! IEMO = 1 !
                     Day    (IEDY)  --    No default   ! IEDY = 1 !
   Ending time:      Hour   (IEHR)  --    No default   ! IEHR = 0 !
                     Minute (IEMIN) --    No default   ! IEMIN = 0 !
                     Second (IESEC) --    No default   ! IESEC = 0 !

   (These are only used if METRUN = 0)

   Base time zone:          (ABTZ)  --    No default   ! ABTZ = UTC-0400 !
    (character*8)
   The modeling domain may span multiple time zones.  ABTZ defines the
   base time zone used for the entire simulation.  This must match the
   base time zone of the meteorological data.
   Examples:
      Los Angeles, USA          = UTC-0800
      New York, USA             = UTC-0500
      Santiago, Chile           = UTC-0400
      Greenwich Mean Time (GMT) = UTC+0000
      Rome, Italy               = UTC+0100
      Cape Town, S.Africa       = UTC+0200
      Sydney, Australia         = UTC+1000

   Length of modeling time-step (seconds)
   Equal to update period in the primary
   meteorological data files, or an
   integer fraction of it (1/2, 1/3 ...)
   Must be no larger than 1 hour
   (NSECDT)                     Default:3600     ! NSECDT =  3600  !
                           Units: seconds

   Number of chemical species (NSPEC)
                           Default: 5       ! NSPEC = 1 !

   Number of chemical species
   to be emitted  (NSE)           Default: 3       ! NSE = 1 !

   Flag to stop run after
```

```
SETUP phase (ITEST)            Default: 2      ! ITEST =  2   !
(Used to allow checking
of the model inputs, files, etc.)
     ITEST = 1 - STOPS program after SETUP phase
     ITEST = 2 - Continues with execution of program
                 after SETUP

Restart Configuration:

  Control flag (MRESTART)      Default: 0      ! MRESTART =  0   !

     0 = Do not read or write a restart file
     1 = Read a restart file at the beginning of
        the run
     2 = Write a restart file during run
     3 = Read a restart file at beginning of run
        and write a restart file during run

  Number of periods in Restart
  output cycle (NRESPD)        Default: 0      ! NRESPD =  0   !

     0 = File written only at last period
    >0 = File updated every NRESPD periods

Meteorological Data Format (METFM)
                          Default: 1      ! METFM =  1   !

     METFM = 1 - CALMET binary file (CALMET.MET)
     METFM = 2 - ISC ASCII file (ISCMET.MET)
     METFM = 3 - AUSPLUME ASCII file (PLMMET.MET)
     METFM = 4 - CTDM plus tower file (PROFILE.DAT) and
                 surface parameters file (SURFACE.DAT)
     METFM = 5 - AERMET tower file (PROFILE.DAT) and
                 surface parameters file (SURFACE.DAT)

Meteorological Profile Data Format (MPRFFM)
      (used only for METFM = 1, 2, 3)
                          Default: 1      ! MPRFFM =  1   !

     MPRFFM = 1 - CTDM plus tower file (PROFILE.DAT)
     MPRFFM = 2 - AERMET tower file (PROFILE.DAT)

PG sigma-y is adjusted by the factor (AVET/PGTIME)**0.2
Averaging Time (minutes) (AVET)
                          Default: 60.0   ! AVET = 60. !
PG Averaging Time (minutes) (PGTIME)
                          Default: 60.0   ! PGTIME = 60. !


Output units for binary concentration and flux files
written in Dataset v2.2 or later formats
(IOUTU)                       Default: 1      ! IOUTU =  1   !
   1 = mass      -  g/m3 (conc) or g/m2/s (dep)
   2 = odour     -  odour_units (conc)
   3 = radiation -  Bq/m3 (conc) or Bq/m2/s (dep)
```

```
    Output Dataset format for binary concentration
    and flux files (e.g., CONC.DAT)
    (IOVERS)                  Default: 2      ! IOVERS =  2   !
      1 = Dataset Version 2.1
      2 = Dataset Version 2.2


!END!


--------------------------------------------------------------------------------

INPUT GROUP: 2 -- Technical options
--------------


    Vertical distribution used in the
    near field (MGAUSS)               Default: 1     ! MGAUSS =  1   !
      0 = uniform
      1 = Gaussian

    Terrain adjustment method
    (MCTADJ)                      Default: 3     ! MCTADJ =  3   !
      0 = no adjustment
      1 = ISC-type of terrain adjustment
      2 = simple, CALPUFF-type of terrain
          adjustment
      3 = partial plume path adjustment

    Subgrid-scale complex terrain
    flag (MCTSG)                  Default: 0     ! MCTSG =  0   !
      0 = not modeled
      1 = modeled

    Near-field puffs modeled as
    elongated slugs? (MSLUG)          Default: 0     ! MSLUG =  0   !
      0 = no
      1 = yes (slug model used)

    Transitional plume rise modeled?
    (MTRANS)                      Default: 1     ! MTRANS =  1   !
      0 = no  (i.e., final rise only)
      1 = yes (i.e., transitional rise computed)

    Stack tip downwash? (MTIP)        Default: 1     ! MTIP =  1  !
      0 = no  (i.e., no stack tip downwash)
      1 = yes (i.e., use stack tip downwash)

    Method used to compute plume rise for
    point sources not subject to building
    downwash? (MRISE)             Default: 1     ! MRISE =  1  !
      1 = Briggs plume rise
      2 = Numerical plume rise

    Method used to simulate building
```

downwash? (MBDW) Default: 1 ! MBDW = 1 !
1 = ISC method
2 = PRIME method

Vertical wind shear modeled above
stack top (modified Briggs plume rise)?
(MSHEAR) Default: 0 ! MSHEAR = 0 !
0 = no (i.e., vertical wind shear not modeled)
1 = yes (i.e., vertical wind shear modeled)

Puff splitting allowed? (MSPLIT) Default: 0 ! MSPLIT = 0 !
0 = no (i.e., puffs not split)
1 = yes (i.e., puffs are split)

Chemical mechanism flag (MCHEM) Default: 1 ! MCHEM = 0 !
0 = chemical transformation not
modeled
1 = transformation rates computed
internally (MESOPUFF II scheme)
2 = user-specified transformation
rates used
3 = transformation rates computed
internally (RIVAD/ARM3 scheme)
4 = secondary organic aerosol formation
computed (MESOPUFF II scheme for OH)
5 = user-specified half-life with or
without transfer to child species
6 = transformation rates computed
internally (Updated RIVAD scheme with
ISORROPIA equilibrium)
7 = transformation rates computed
internally (Updated RIVAD scheme with
ISORROPIA equilibrium and CalTech SOA)

Aqueous phase transformation flag (MAQCHEM)
(Used only if MCHEM = 6, or 7) Default: 0 ! MAQCHEM = 0 !
0 = aqueous phase transformation
not modeled
1 = transformation rates and wet
scavenging coefficients adjusted
for in-cloud aqueous phase reactions
(adapted from RADM cloud model
implementation in CMAQ/SCICHEM)

Liquid Water Content flag (MLWC)
(Used only if MAQCHEM = 1) Default: 1 ! MLWC = 1 !
0 = water content estimated from cloud cover
and presence of precipitation
1 = gridded cloud water data read from CALMET
water content output files (filenames are
the CALMET.DAT names PLUS the extension
AUXEXT provided in Input Group 0)

Wet removal modeled ? (MWT) Default: 1 ! MWT = 1 !
0 = no
1 = yes

Dry deposition modeled ? (MDRY) Default: 1 ! MDRY = 1 !
0 = no
1 = yes
(dry deposition method specified
for each species in Input Group 3)

Gravitational settling (plume tilt)
modeled ? (MTILT) Default: 0 ! MTILT = 0 !
0 = no
1 = yes
(puff center falls at the gravitational
settling velocity for 1 particle species)

Restrictions:
- MDRY = 1
- NSPEC = 1 (must be particle species as well)
- sg = 0 GEOMETRIC STANDARD DEVIATION in Group 8 is
set to zero for a single particle diameter

Method used to compute dispersion
coefficients (MDISP) Default: 3 ! MDISP = 3 !

1 = dispersion coefficients computed from measured values
of turbulence, sigma v, sigma w
2 = dispersion coefficients from internally calculated
sigma v, sigma w using micrometeorological variables
(u*, w*, L, etc.)
3 = PG dispersion coefficients for RURAL areas (computed using
the ISCST multi-segment approximation) and MP coefficients in
urban areas
4 = same as 3 except PG coefficients computed using
the MESOPUFF II eqns.
5 = CTDM sigmas used for stable and neutral conditions.
For unstable conditions, sigmas are computed as in
MDISP = 3, described above. MDISP = 5 assumes that
measured values are read

Sigma-v/sigma-theta, sigma-w measurements used? (MTURBVW)
(Used only if MDISP = 1 or 5) Default: 3 ! MTURBVW = 3 !
1 = use sigma-v or sigma-theta measurements
from PROFILE.DAT to compute sigma-y
(valid for METFM = 1, 2, 3, 4, 5)
2 = use sigma-w measurements
from PROFILE.DAT to compute sigma-z
(valid for METFM = 1, 2, 3, 4, 5)
3 = use both sigma-(v/theta) and sigma-w
from PROFILE.DAT to compute sigma-y and sigma-z
(valid for METFM = 1, 2, 3, 4, 5)
4 = use sigma-theta measurements
from PLMMET.DAT to compute sigma-y
(valid only if METFM = 3)

Back-up method used to compute dispersion
when measured turbulence data are

missing (MDISP2) Default: 3 ! MDISP2 = 3 !
(used only if MDISP = 1 or 5)
2 = dispersion coefficients from internally calculated
sigma v, sigma w using micrometeorological variables
(u*, w*, L, etc.)
3 = PG dispersion coefficients for RURAL areas (computed using
the ISCST multi-segment approximation) and MP coefficients in
urban areas
4 = same as 3 except PG coefficients computed using
the MESOPUFF II eqns.

[DIAGNOSTIC FEATURE]
Method used for Lagrangian timescale for Sigma-y
(used only if MDISP=1,2 or MDISP2=1,2)
(MTAULY) Default: 0 ! MTAULY = 0 !
0 = Draxler default 617.284 (s)
1 = Computed as Lag. Length / (.75 q) -- after SCIPUFF
10 < Direct user input (s) -- e.g., 306.9

[DIAGNOSTIC FEATURE]
Method used for Advective-Decay timescale for Turbulence
(used only if MDISP=2 or MDISP2=2)
(MTAUADV) Default: 0 ! MTAUADV = 0 !
0 = No turbulence advection
1 = Computed (OPTION NOT IMPLEMENTED)
10 < Direct user input (s) -- e.g., 800

Method used to compute turbulence sigma-v &
sigma-w using micrometeorological variables
(Used only if MDISP = 2 or MDISP2 = 2)
(MCTURB) Default: 1 ! MCTURB = 1 !
1 = Standard CALPUFF subroutines
2 = AERMOD subroutines

PG sigma-y,z adj. for roughness? Default: 0 ! MROUGH = 0 !
(MROUGH)
0 = no
1 = yes

Partial plume penetration of Default: 1 ! MPARTL = 1 !
elevated inversion modeled for
point sources?
(MPARTL)
0 = no
1 = yes

Partial plume penetration of Default: 1 ! MPARTLBA = 1 !
elevated inversion modeled for
buoyant area sources?
(MPARTLBA)
0 = no
1 = yes

Strength of temperature inversion Default: 0 ! MTINV = 0 !

provided in PROFILE.DAT extended records?
(MTINV)
  0 = no (computed from measured/default gradients)
  1 = yes

PDF used for dispersion under convective conditions?
                    Default: 0    ! MPDF =  0  !
(MPDF)
  0 = no
  1 = yes

Sub-Grid TIBL module used for shore line?
                    Default: 0    ! MSGTIBL = 0  !
(MSGTIBL)
  0 = no
  1 = yes

Boundary conditions (concentration) modeled?
                    Default: 0    ! MBCON = 0  !
(MBCON)
  0 = no
  1 = yes, using formatted BCON.DAT file
  2 = yes, using unformatted CONC.DAT file

Note:  MBCON > 0 requires that the last species modeled
     be 'BCON'.  Mass is placed in species BCON when
     generating boundary condition puffs so that clean
     air entering the modeling domain can be simulated
     in the same way as polluted air.  Specify zero
     emission of species BCON for all regular sources.

Individual source contributions saved?
                    Default: 0    ! MSOURCE = 0  !
(MSOURCE)
  0 = no
  1 = yes

Analyses of fogging and icing impacts due to emissions from
arrays of mechanically-forced cooling towers can be performed
using CALPUFF in conjunction with a cooling tower emissions
processor (CTEMISS) and its associated postprocessors.  Hourly
emissions of water vapor and temperature from each cooling tower
cell are computed for the current cell configuration and ambient
conditions by CTEMISS. CALPUFF models the dispersion of these
emissions and provides cloud information in a specialized format
for further analysis. Output to FOG.DAT is provided in either
'plume mode' or 'receptor mode' format.

Configure for FOG Model output?
                    Default: 0    ! MFOG =  0   !
(MFOG)
  0 = no
  1 = yes  - report results in PLUME Mode format
  2 = yes  - report results in RECEPTOR Mode format

```
    Test options specified to see if
    they conform to regulatory
    values? (MREG)                    Default: 1     ! MREG =  0   !

      0 = NO checks are made
      1 = Technical options must conform to USEPA
         Long Range Transport (LRT) guidance
                  METFM    1 or 2
                  AVET     60. (min)
                  PGTIME   60. (min)
                  MGAUSS   1
                  MCTADJ   3
                  MTRANS   1
                  MTIP     1
                  MRISE    1
                  MCHEM    1 or 3 (if modeling SOx, NOx)
                  MWT      1
                  MDRY     1
                  MDISP    2 or 3
                  MPDF     0 if MDISP=3
                         1 if MDISP=2
                  MROUGH   0
                  MPARTL   1
                  MPARTLBA 0
                  SYTDEP   550. (m)
                  MHFTSZ   0
                  SVMIN    0.5 (m/s)


!END!


-------------------------------------------------------------------------------

INPUT GROUP: 3a, 3b -- Species list
-------------------

------------
Subgroup (3a)
------------

  The following species are modeled:
! CSPEC = H2S !        !END!

                                        Dry              OUTPUT GROUP
    SPECIES         MODELED          EMITTED      DEPOSITED              NUMBER
     NAME        (0=NO, 1=YES)    (0=NO, 1=YES)    (0=NO,              (0=NONE,
   (Limit: 12                          1=COMPUTED-GAS       1=1st CGRUP,
    Characters                           2=COMPUTED-PARTICLE   2=2nd CGRUP,
    in length)                          3=USER-SPECIFIED)     3= etc.)
!        H2S=       1,             1,          1,                0   !

!END!

  Note:  The last species in (3a) must be 'BCON' when using the
```

boundary condition option (MBCON > 0). Species BCON should typically be modeled as inert (no chem transformation or removal).

---
Subgroup (3b)
---
The following names are used for Species-Groups in which results for certain species are combined (added) prior to output. The CGRUP name will be used as the species name in output files. Use this feature to model specific particle-size distributions by treating each size-range as a separate species. Order must be consistent with 3(a) above.

---

INPUT GROUP: 4 -- Map Projection and Grid control parameters
---

Projection for all (X,Y):
---

Map projection
(PMAP) Default: UTM ! PMAP = UTM !

UTM : Universal Transverse Mercator
TTM : Tangential Transverse Mercator
LCC : Lambert Conformal Conic
PS : Polar Stereographic
EM : Equatorial Mercator
LAZA : Lambert Azimuthal Equal Area

False Easting and Northing (km) at the projection origin
(Used only if PMAP= TTM, LCC, or LAZA)
(FEAST) Default=0.0 ! FEAST = 0.000 !
(FNORTH) Default=0.0 ! FNORTH = 0.000 !

UTM zone (1 to 60)
(Used only if PMAP=UTM)
(IUTMZN) No Default ! IUTMZN = 20 !

Hemisphere for UTM projection?
(Used only if PMAP=UTM)
(UTMHEM) Default: N ! UTMHEM = N !
N : Northern hemisphere projection
S : Southern hemisphere projection

Latitude and Longitude (decimal degrees) of projection origin
(Used only if PMAP= TTM, LCC, PS, EM, or LAZA)
(RLAT0) No Default ! RLAT0 = 0N !
(RLON0) No Default ! RLON0 = 0E !

TTM : RLON0 identifies central (true N/S) meridian of projection
RLAT0 selected for convenience
LCC : RLON0 identifies central (true N/S) meridian of projection
RLAT0 selected for convenience
PS : RLON0 identifies central (grid N/S) meridian of projection
RLAT0 selected for convenience
EM : RLON0 identifies central meridian of projection
RLAT0 is REPLACED by 0.0N (Equator)
LAZA: RLON0 identifies longitude of tangent-point of mapping plane
RLAT0 identifies latitude of tangent-point of mapping plane

Matching parallel(s) of latitude (decimal degrees) for projection
(Used only if PMAP= LCC or PS)
(XLAT1) No Default ! XLAT1 = 0N !
(XLAT2) No Default ! XLAT2 = 0N !

LCC : Projection cone slices through Earth's surface at XLAT1 and XLAT2
PS : Projection plane slices through Earth at XLAT1
(XLAT2 is not used)

---
Note: Latitudes and longitudes should be positive, and include a
letter N,S,E, or W indicating north or south latitude, and
east or west longitude. For example,
35.9 N Latitude = 35.9N
118.7 E Longitude = 118.7E

Datum-region
---

The Datum-Region for the coordinates is identified by a character
string. Many mapping products currently available use the model of the
Earth known as the World Geodetic System 1984 (WGS-84). Other local
models may be in use, and their selection in CALMET will make its output
consistent with local mapping products. The list of Datum-Regions with
official transformation parameters is provided by the National Imagery and
Mapping Agency (NIMA).

NIMA Datum - Regions(Examples)
---
WGS-84 WGS-84 Reference Ellipsoid and Geoid, Global coverage (WGS84)
NAS-C NORTH AMERICAN 1927 Clarke 1866 Spheroid, MEAN FOR CONUS (NAD27)
NAR-C NORTH AMERICAN 1983 GRS 80 Spheroid, MEAN FOR CONUS (NAD83)
NWS-84 NWS 6370KM Radius, Sphere
ESR-S ESRI REFERENCE 6371KM Radius, Sphere

Datum-region for output coordinates
(DATUM) Default: WGS-84 ! DATUM = WGS-84 !

METEOROLOGICAL Grid:

Rectangular grid defined for projection PMAP,
with X the Easting and Y the Northing coordinate

```
      No. X grid cells (NX)      No default     ! NX = 100 !
      No. Y grid cells (NY)      No default     ! NY = 100 !
    No. vertical layers (NZ)      No default     ! NZ = 11 !

     Grid spacing (DGRIDKM)      No default     ! DGRIDKM = .2 !
                    Units: km

        Cell face heights
          (ZFACE(nz+1))      No defaults
                    Units: m
! ZFACE = 0,20,40,80,160,320,640,1000,1500,2000,2500,3000 !

     Reference Coordinates
    of SOUTHWEST corner of
       grid cell(1, 1):

     X coordinate (XORIGKM)     No default     ! XORIGKM = 671.8 !
     Y coordinate (YORIGKM)     No default     ! YORIGKM = 1685 !
                    Units: km
```

COMPUTATIONAL Grid:

The computational grid is identical to or a subset of the MET. grid.
The lower left (LL) corner of the computational grid is at grid point (IBCOMP, JBCOMP) of the MET. grid. The upper right (UR) corner of the computational grid is at grid point (IECOMP, JECOMP) of the MET. grid.
The grid spacing of the computational grid is the same as the MET. grid.

```
  X index of LL corner (IBCOMP)      No default     ! IBCOMP = 1 !
        (1 <= IBCOMP <= NX)

  Y index of LL corner (JBCOMP)      No default     ! JBCOMP = 1 !
        (1 <= JBCOMP <= NY)


  X index of UR corner (IECOMP)      No default     ! IECOMP = 100 !
        (1 <= IECOMP <= NX)

  Y index of UR corner (JECOMP)      No default     ! JECOMP = 100 !
        (1 <= JECOMP <= NY)
```

SAMPLING Grid (GRIDDED RECEPTORS):

The lower left (LL) corner of the sampling grid is at grid point (IBSAMP, JBSAMP) of the MET. grid. The upper right (UR) corner of the sampling grid is at grid point (IESAMP, JESAMP) of the MET. grid.
The sampling grid must be identical to or a subset of the computational grid. It may be a nested grid inside the computational grid.
The grid spacing of the sampling grid is DGRIDKM/MESHDN.

```
  Logical flag indicating if gridded
  receptors are used (LSAMP)        Default: T     ! LSAMP = T !
  (T=yes, F=no)
```

```
      X index of LL corner (IBSAMP)      No default     ! IBSAMP = 10 !
       (IBCOMP <= IBSAMP <= IECOMP)

      Y index of LL corner (JBSAMP)      No default     ! JBSAMP = 25 !
       (JBCOMP <= JBSAMP <= JECOMP)


      X index of UR corner (IESAMP)      No default     ! IESAMP = 60 !
       (IBCOMP <= IESAMP <= IECOMP)

      Y index of UR corner (JESAMP)      No default     ! JESAMP = 75 !
       (JBCOMP <= JESAMP <= JECOMP)


     Nesting factor of the sampling
      grid (MESHDN)                    Default: 1     ! MESHDN = 4 !
      (MESHDN is an integer >= 1)

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 5 -- Output Options
--------------
                                  *                    *
    FILE                   DEFAULT VALUE           VALUE THIS RUN
    ----                   -------------           --------------

  Concentrations (ICON)            1                  ! ICON = 1 !
  Dry Fluxes (IDRY)               1                  ! IDRY = 1 !
  Wet Fluxes (IWET)                1                  ! IWET = 1 !
  2D Temperature (IT2D)            0                  ! IT2D = 0 !
  2D Density (IRHO)               0                  ! IRHO = 0 !
  Relative Humidity (IVIS)         1                  ! IVIS = 1 !
   (relative humidity file is
    required for visibility
    analysis)
  Use data compression option in output file?
  (LCOMPRS)                        Default: T         ! LCOMPRS = T !

  *
   0 = Do not create file, 1 = create file


   QA PLOT FILE OUTPUT OPTION:

     Create a standard series of output files (e.g.
     locations of sources, receptors, grids ...)
     suitable for plotting?
     (IQAPLOT)                    Default: 1         ! IQAPLOT = 1 !
       0 = no
       1 = yes
```

DIAGNOSTIC PUFF-TRACKING OUTPUT OPTION:

Puff locations and properties reported to
PFTRAK.DAT file for postprocessing?
(IPFTRAK) Default: 0 ! IPFTRAK = 0 !
0 = no
1 = yes, update puff output at end of each timestep
2 = yes, update puff output at end of each sampling step

DIAGNOSTIC MASS FLUX OUTPUT OPTIONS:

Mass flux across specified boundaries
for selected species reported?
(IMFLX) Default: 0 ! IMFLX = 0 !
0 = no
1 = yes (FLUXBDY.DAT and MASSFLX.DAT filenames
are specified in Input Group 0)

Mass balance for each species
reported?
(IMBAL) Default: 0 ! IMBAL = 0 !
0 = no
1 = yes (MASSBAL.DAT filename is
specified in Input Group 0)

NUMERICAL RISE OUTPUT OPTION:

Create a file with plume properties for each rise
increment, for each model timestep?
This applies to sources modeled with numerical rise
and is limited to ONE source in the run.
(INRISE) Default: 0 ! INRISE = 0 !
0 = no
1 = yes (RISE.DAT filename is
specified in Input Group 0)

LINE PRINTER OUTPUT OPTIONS:

Print concentrations (ICPRT) Default: 0 ! ICPRT = 1 !
Print dry fluxes (IDPRT) Default: 0 ! IDPRT = 0 !
Print wet fluxes (IWPRT) Default: 0 ! IWPRT = 0 !
(0 = Do not print, 1 = Print)

Concentration print interval
(ICFRQ) in timesteps Default: 1 ! ICFRQ = 1 !
Dry flux print interval
(IDFRQ) in timesteps Default: 1 ! IDFRQ = 1 !
Wet flux print interval
(IWFRQ) in timesteps Default: 1 ! IWFRQ = 1 !

Units for Line Printer Output
(IPRTU) Default: 1 ! IPRTU = 3 !
for for
Concentration Deposition

```
          1 =      g/m**3        g/m**2/s
          2 =     mg/m**3        mg/m**2/s
          3 =     ug/m**3        ug/m**2/s
          4 =     ng/m**3        ng/m**2/s
          5 =    Odour Units

      Messages tracking progress of run
      written to the screen ?
      (IMESG)                    Default: 2        ! IMESG =  2   !
        0 = no
        1 = yes (advection step, puff ID)
        2 = yes (YYYYJJJHH, # old puffs, # emitted puffs)


    SPECIES (or GROUP for combined species) LIST FOR OUTPUT OPTIONS

              ---- CONCENTRATIONS ----   ------ DRY FLUXES ------   ------ WET FLUXES ------   -- MASS FLUX --
   SPECIES
   /GROUP       PRINTED?  SAVED ON DISK?   PRINTED?  SAVED ON DISK?   PRINTED?  SAVED ON
DISK?   SAVED ON DISK?
   -------      ------------------------   ------------------------   ------------------------   ---------------
!         H2S=   0,          1,          0,          1,          0,          1,          0   !
  Note:  Species BCON (for MBCON > 0) does not need to be saved on disk.


    OPTIONS FOR PRINTING "DEBUG" QUANTITIES (much output)

      Logical for debug output
      (LDEBUG)                    Default: F     ! LDEBUG = F !

      First puff to track
      (IPFDEB)                   Default: 1     ! IPFDEB =  1  !

      Number of puffs to track
      (NPFDEB)                    Default: 1     ! NPFDEB =  1  !

      Met. period to start output
      (NN1)                      Default: 1     ! NN1 =  1   !

      Met. period to end output
      (NN2)                      Default: 10    ! NN2 =  10  !

!END!


--------------------------------------------------------------------------------


INPUT GROUP: 6a, 6b, & 6c -- Subgrid scale complex terrain inputs
-------------------------

---------------
Subgroup (6a)
---------------
      Number of terrain features (NHILL)       Default: 0     ! NHILL =  0   !
```

```
      Number of special complex terrain
      receptors  (NCTREC)                  Default: 0     ! NCTREC =  0   !

      Terrain and CTSG Receptor data for
      CTSG hills input in CTDM format ?
      (MHILL)                          No Default     ! MHILL =  2   !
      1 = Hill and Receptor data created
         by CTDM processors & read from
         HILL.DAT and HILLRCT.DAT files
      2 = Hill data created by OPTHILL &
         input below in Subgroup (6b);
         Receptor data in Subgroup (6c)

      Factor to convert horizontal dimensions  Default: 1.0   ! XHILL2M = 1.0 !
      to meters (MHILL=1)

      Factor to convert vertical dimensions    Default: 1.0   ! ZHILL2M = 1.0 !
      to meters (MHILL=1)

      X-origin of CTDM system relative to      No Default     ! XCTDMKM = 0 !
      CALPUFF coordinate system, in Kilometers (MHILL=1)

      Y-origin of CTDM system relative to      No Default     ! YCTDMKM = 0 !
      CALPUFF coordinate system, in Kilometers (MHILL=1)

! END !

---------------
Subgroup (6b)
---------------

                  1 **
    HILL information


HILL         XC       YC       THETAH  ZGRID  RELIEF    EXPO 1    EXPO 2   SCALE 1    SCALE 2    AMAX1
AMAX2
 NO.        (km)     (km)     (deg.)  (m)    (m)       (m)       (m)      (m)        (m)        (m)
----        ----     ----     ------  -----  ------    ------    ------   -------    -------    -----     -----

---------------
Subgroup (6c)
---------------

   COMPLEX TERRAIN RECEPTOR INFORMATION

                  XRCT        YRCT        ZRCT         XHH
                  (km)        (km)        (m)
                 ------      -----      ------        ----


-------------------
1
    Description of Complex Terrain Variables:
        XC, YC  = Coordinates of center of hill
        THETAH  = Orientation of major axis of hill (clockwise from
```

North)
ZGRID = Height of the 0 of the grid above mean sea level
RELIEF = Height of the crest of the hill above the grid elevation
EXPO 1 = Hill-shape exponent for the major axis
EXPO 2 = Hill-shape exponent for the major axis
SCALE 1 = Horizontal length scale along the major axis
SCALE 2 = Horizontal length scale along the minor axis
AMAX = Maximum allowed axis length for the major axis
BMAX = Maximum allowed axis length for the major axis

XRCT, YRCT = Coordinates of the complex terrain receptors
ZRCT = Height of the ground (MSL) at the complex terrain Receptor
XHH = Hill number associated with each complex terrain receptor (NOTE: MUST BE ENTERED AS A REAL NUMBER)

**
NOTE: DATA for each hill and CTSG receptor are treated as a separate input subgroup and therefore must end with an input group terminator.

---

INPUT GROUP: 7 -- Chemical parameters for dry deposition of gases
---

| SPECIES NAME | DIFFUSIVITY (cm**2/s) | ALPHA STAR | REACTIVITY (s/cm) | MESOPHYLL RESISTANCE | HENRY'S LAW COEFFICIENT (dimensionless) |
|---|---|---|---|---|---|
| ! H2S = | 0.1656, | 1, | 8, | 5, | 3.5 ! |

!END!

---

INPUT GROUP: 8 -- Size parameters for dry deposition of particles
---

For SINGLE SPECIES, the mean and standard deviation are used to compute a deposition velocity for NINT (see group 9) size-ranges, and these are then averaged to obtain a mean deposition velocity.

For GROUPED SPECIES, the size distribution should be explicitly specified (by the 'species' in the group), and the standard deviation for each should be entered as 0. The model will then use the deposition velocity for the stated mean diameter.

| SPECIES NAME | GEOMETRIC MASS MEAN DIAMETER (microns) | GEOMETRIC STANDARD DEVIATION (microns) |
|---|---|---|

```
      -------      -------------------        ------------------

!END!

------------------------------------------------------------------------------

INPUT GROUP: 9 -- Miscellaneous dry deposition parameters
--------------

    Reference cuticle resistance (s/cm)
    (RCUTR)                    Default: 30    !  RCUTR = 30.0 !
    Reference ground resistance  (s/cm)
    (RGR)                      Default: 10    !    RGR = 10.0 !
    Reference pollutant reactivity
    (REACTR)                    Default: 8     ! REACTR = 8.0 !

    Number of particle-size intervals used to
    evaluate effective particle deposition velocity
    (NINT)                     Default: 9     !   NINT =  9  !

    Vegetation state in unirrigated areas
    (IVEG)                     Default: 1     !   IVEG =  1   !
      IVEG=1 for active and unstressed vegetation
      IVEG=2 for active and stressed vegetation
      IVEG=3 for inactive vegetation

!END!

------------------------------------------------------------------------------

INPUT GROUP: 10 -- Wet Deposition Parameters
---------------

                  Scavenging Coefficient -- Units: (sec)**(-1)

      Pollutant      Liquid Precip.       Frozen Precip.
      ---------      --------------       --------------

!        H2S =            0,           0 !

!END!

------------------------------------------------------------------------------

INPUT GROUP: 11a, 11b -- Chemistry Parameters
---------------------

---------------
```

Subgroup (11a)
---

Several parameters are needed for one or more of the chemical transformation mechanisms. Those used for each mechanism are:

```
                    M           B
                    A  B  R  R  R    C  B      N
                 B    V  C  N  N  N  M  K  C  O    D
                 C  M  G  K  I  I  I  H  H  K  F  V  E
               M  K  N  N  N  T  T  T  2  2  P  R  C  C
               O  O  H  H  H  E  E  E  O  O  M  A  N  A
Mechanism (MCHEM)      Z  3  3  3  3  1  2  3  2  2  F  C  X  Y
--------------------   --------------------------------------------
0 None                 . . . . . . . . . . . . . .
1 MESOPUFF II            X  X  .  .  X  X  X  X  .  .  .  .  .  .
2 User Rates             .  .  .  .  .  .  .  .  .  .  .  .  .  .
3 RIVAD                 X  X  .  .  X  .  .  .  .  .  .  .  .  .
4 SOA                  X  X  .  .  .  .  .  .  .  .  X  X  X  .
5 Radioactive Decay     .  .  .  .  .  .  .  .  .  .  .  .  .  X
6 RIVAD/ISORRPIA        X  X  X  X  X  X  .  .  X  X  .  .  .  .
7 RIVAD/ISORRPIA/SOA    X  X  X  X  X  X  .  .  X  X  X  X  .  .
```

Ozone data input option (MOZ)  Default: 1  ! MOZ = 1 !
(Used only if MCHEM = 1, 3, 4, 6, or 7)
0 = use a monthly background ozone value
1 = read hourly ozone concentrations from
the OZONE.DAT data file

Monthly ozone concentrations in ppb (BCKO3)
(Used only if MCHEM = 1,3,4,6, or 7 and either
MOZ = 0, or
MOZ = 1 and all hourly O3 data missing)
Default: 12*80.
! BCKO3 = 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00 !

Ammonia data option (MNH3)  Default: 0  ! MNH3 = 0 !
(Used only if MCHEM = 6 or 7)
0 = use monthly background ammonia values (BCKNH3) - no vertical variation
1 = read monthly background ammonia values for each layer from
the NH3Z.DAT data file

Ammonia vertical averaging option (MAVGNH3)
(Used only if MCHEM = 6 or 7, and MNH3 = 1)
0 = use NH3 at puff center height (no averaging is done)
1 = average NH3 values over vertical extent of puff
Default: 1  ! MAVGNH3 = 1 !

Monthly ammonia concentrations in ppb (BCKNH3)
(Used only if MCHEM = 1 or 3, or
if MCHEM = 6 or 7, and MNH3 = 0)
Default: 12*10.
! BCKNH3 = 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00 !

Nighttime SO2 loss rate in %/hour (RNITE1)
(Used only if MCHEM = 1, 6 or 7)

```
   This rate is used only at night for MCHEM=1
   and is added to the computed rate both day
   and night for MCHEM=6,7 (heterogeneous reactions)
                          Default: 0.2         ! RNITE1 = .2 !

   Nighttime NOx loss rate in %/hour (RNITE2)
   (Used only if MCHEM = 1)
                          Default: 2.0         ! RNITE2 = 2.0 !

   Nighttime HNO3 formation rate in %/hour (RNITE3)
   (Used only if MCHEM = 1)
                          Default: 2.0         ! RNITE3 = 2.0 !

   H2O2 data input option (MH2O2)    Default: 1          ! MH2O2 =  1   !
   (Used only if MCHEM = 6 or 7, and MAQCHEM = 1)
     0 = use a monthly background H2O2 value
     1 = read hourly H2O2 concentrations from
         the H2O2.DAT data file

   Monthly H2O2 concentrations in ppb (BCKH2O2)
   (Used only if MQACHEM = 1 and either
     MH2O2 = 0 or
     MH2O2 = 1 and all hourly H2O2 data missing)
                          Default: 12*1.
   !  BCKH2O2 = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00 !


--- Data for SECONDARY ORGANIC AEROSOL (SOA) Options
   (used only if MCHEM = 4 or 7)

   The MCHEM = 4 SOA module uses monthly values of:
        Fine particulate concentration in ug/m^3 (BCKPMF)
        Organic fraction of fine particulate     (OFRAC)
        VOC / NOX ratio (after reaction)         (VCNX)

   The MCHEM = 7 SOA module uses monthly values of:
        Fine particulate concentration in ug/m^3 (BCKPMF)
        Organic fraction of fine particulate     (OFRAC)

   These characterize the air mass when computing
   the formation of SOA from VOC emissions.
   Typical values for several distinct air mass types are:

     Month    1    2    3    4    5    6    7    8    9   10   11   12
           Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec

   Clean Continental
     BCKPMF   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
     OFRAC  .15  .15  .20  .20  .20  .20  .20  .20  .20  .20  .20  .15
     VCNX    50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.

   Clean Marine (surface)
     BCKPMF  .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
     OFRAC  .25  .25  .30  .30  .30  .30  .30  .30  .30  .30  .30  .25
     VCNX    50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
```

```
    Urban - low biogenic (controls present)
      BCKPMF  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.
      OFRAC  .20  .20  .25  .25  .25  .25  .25  .25  .20  .20  .20  .20
      VCNX    4.   4.   4.   4.   4.   4.   4.   4.   4.   4.   4.   4.

    Urban - high biogenic (controls present)
      BCKPMF  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.
      OFRAC  .25  .25  .30  .30  .30  .55  .55  .55  .35  .35  .35  .25
      VCNX   15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.

    Regional Plume
      BCKPMF  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
      OFRAC  .20  .20  .25  .35  .25  .40  .40  .40  .30  .30  .30  .20
      VCNX   15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.

    Urban - no controls present
      BCKPMF 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
      OFRAC  .30  .30  .35  .35  .35  .55  .55  .55  .35  .35  .35  .30
      VCNX    2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.

    Default: Clean Continental
    !  BCKPMF = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00 !
    !  OFRAC  = 0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15 !
    !  VCNX   = 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00 !

 --- End Data for SECONDARY ORGANIC AEROSOL (SOA) Option


    Number of half-life decay specification blocks provided in Subgroup 11b
    (Used only if MCHEM = 5)
    (NDECAY)                          Default: 0      ! NDECAY =  0   !

!END!


----------
Subgroup (11b)
----------

    Each species modeled may be assigned a decay half-life (sec), and the associated
    mass lost may be assigned to one or more other modeled species using a mass yield
    factor. This information is used only for MCHEM=5.

    Provide NDECAY blocks assigning the half-life for a parent species and mass yield
    factors for each child species (if any) produced by the decay.
    Set HALF_LIFE=0.0 for NO decay (infinite half-life).


                        a          b
      SPECIES      Half-Life   Mass Yield
       NAME         (sec)       Factor
      -------      ---------   ----------

    *   SPEC1   =    3600.,       -1.0   *    (Parent)
    *   SPEC2   =     -1.0,        0.0   *    (Child)
   *END*
```

```
--------
   a
    Specify a half life that is greater than or equal to zero for 1 parent species
    in each block, and set the yield factor for this species to -1
   b
    Specify a yield factor that is greater than or equal to zero for 1 or more child
    species in each block, and set the half-life for each of these species to -1

    NOTE: Assignments in each block are treated as a separate input
          subgroup and therefore must end with an input group terminator.
          If NDECAY=0, no assignments and input group terminators should appear.

-------------------------------------------------------------------------------


INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters
---------------

    Horizontal size of puff (m) beyond which
    time-dependent dispersion equations (Heffter)
    are used to determine sigma-y and
    sigma-z (SYTDEP)                    Default: 550.   ! SYTDEP = 5.5E02 !

    Switch for using Heffter equation for sigma z
    as above (0 = Not use Heffter; 1 = use Heffter
    (MHFTSZ)                            Default: 0      ! MHFTSZ =  0   !

    Stability class used to determine plume
    growth rates for puffs above the boundary
    layer (JSUP)                        Default: 5      ! JSUP =  5   !

    Vertical dispersion constant for stable
    conditions (k1 in Eqn. 2.7-3)  (CONK1)     Default: 0.01   ! CONK1 = .01 !

    Vertical dispersion constant for neutral/
    unstable conditions (k2 in Eqn. 2.7-4)
    (CONK2)                             Default: 0.1    ! CONK2 = .1 !

    Factor for determining Transition-point from
    Schulman-Scire to Huber-Snyder Building Downwash
    scheme (SS used for Hs < Hb + TBD * HL)
    (TBD)                               Default: 0.5    ! TBD = .5 !
      TBD < 0   ==> always use Huber-Snyder
      TBD = 1.5 ==> always use Schulman-Scire
      TBD = 0.5 ==> ISC Transition-point

    Range of land use categories for which
    urban dispersion is assumed
    (IURB1, IURB2)                        Default: 10     ! IURB1 =  10  !
                                        19     ! IURB2 =  19  !

    Site characterization parameters for single-point Met data files ---------
    (needed for METFM = 2,3,4,5)

      Land use category for modeling domain
```

(ILANDUIN) Default: 20 ! ILANDUIN = 20 !

Roughness length (m) for modeling domain
(Z0IN) Default: 0.25 ! Z0IN = .25 !

Leaf area index for modeling domain
(XLAIIN) Default: 3.0 ! XLAIIN = 3.0 !

Elevation above sea level (m)
(ELEVIN) Default: 0.0 ! ELEVIN = .0 !

Latitude (degrees) for met location
(XLATIN) Default: -999. ! XLATIN = -999. !

Longitude (degrees) for met location
(XLONIN) Default: -999. ! XLONIN = -999. !

Specialized information for interpreting single-point Met data files -----

Anemometer height (m) (Used only if METFM = 2,3)
(ANEMHT) Default: 10. ! ANEMHT = 10.0 !

Form of lateral turbulance data in PROFILE.DAT file
(Used only if METFM = 4,5 or MTURBVW = 1 or 3)
(ISIGMAV) Default: 1 ! ISIGMAV = 1 !
0 = read sigma-theta
1 = read sigma-v

Choice of mixing heights (Used only if METFM = 4)
(IMIXCTDM) Default: 0 ! IMIXCTDM = 0 !
0 = read PREDICTED mixing heights
1 = read OBSERVED mixing heights

Maximum length of a slug (met. grid units)
(XMXLEN) Default: 1.0 ! XMXLEN = 1.0 !

Maximum travel distance of a puff/slug (in
grid units) during one sampling step
(XSAMLEN) Default: 1.0 ! XSAMLEN = 1.0 !

Maximum Number of slugs/puffs release from
one source during one time step
(MXNEW) Default: 99 ! MXNEW = 99 !

Maximum Number of sampling steps for
one puff/slug during one time step
(MXSAM) Default: 99 ! MXSAM = 99 !

Number of iterations used when computing
the transport wind for a sampling step
that includes gradual rise (for CALMET
and PROFILE winds)
(NCOUNT) Default: 2 ! NCOUNT = 2 !

Minimum sigma y for a new puff/slug (m)
(SYMIN) Default: 1.0 ! SYMIN = 1.0 !

Minimum sigma z for a new puff/slug (m)
(SZMIN) Default: 1.0 ! SZMIN = 1.0 !

Maximum sigma z (m) allowed to avoid
numerical problem in calculating virtual
time or distance. Cap should be large
enough to have no influence on normal events.
Enter a negative cap to disable.
(SZCAP_M) Default: 5.0e06 ! SZCAP_M = 5.0E06 !

Default minimum turbulence velocities sigma-v and sigma-w
for each stability class over land and over water (m/s)
(SVMIN(12) and SWMIN(12))

| | LAND | | | | | | WATER | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stab Class : | A | B | C | D | E | F | A | B | C | D | E | F |
| Default SVMIN : | .50, | .50, | .50, | .50, | .50, | .50, | .37, | .37, | .37, | .37, | .37, | .37 |
| Default SWMIN : | .20, | .12, | .08, | .06, | .03, | .016, | .20, | .12, | .08, | .06, | .03, | .016 |

! SVMIN = 0.500, 0.500, 0.500, 0.500, 0.500, 0.500, 0.370, 0.370, 0.370, 0.370, 0.370, 0.370!
! SWMIN = 0.200, 0.120, 0.080, 0.060, 0.030, 0.016, 0.200, 0.120, 0.080, 0.060, 0.030, 0.016!

Divergence criterion for dw/dz across puff
used to initiate adjustment for horizontal
convergence (1/s)
Partial adjustment starts at CDIV(1), and
full adjustment is reached at CDIV(2)
(CDIV(2)) Default: 0.0,0.0 ! CDIV = .0, .0 !

Search radius (number of cells) for nearest
land and water cells used in the subgrid
TIBL module
(NLUTIBL) Default: 4 ! NLUTIBL = 4 !

Minimum wind speed (m/s) allowed for
non-calm conditions. Also used as minimum
speed returned when using power-law
extrapolation toward surface
(WSCALM) Default: 0.5 ! WSCALM = .5 !

Maximum mixing height (m)
(XMAXZI) Default: 3000. ! XMAXZI = 3000.0 !

Minimum mixing height (m)
(XMINZI) Default: 50. ! XMINZI = 20.0 !

Default wind speed classes --
5 upper bounds (m/s) are entered;
the 6th class has no upper limit
(WSCAT(5)) Default :
ISC RURAL : 1.54, 3.09, 5.14, 8.23, 10.8 (10.8+)

| Wind Speed Class : | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|

```
                    ! WSCAT = 1.54, 3.09, 5.14, 8.23, 10.80 !

Default wind speed profile power-law
exponents for stabilities 1-6
(PLX0(6))                Default   : ISC RURAL values
                      ISC RURAL : .07, .07, .10, .15, .35, .55
                      ISC URBAN : .15, .15, .20, .25, .30, .30

                  Stability Class :  A     B     C     D     E     F
                                    ---   ---   ---   ---   ---   ---
                     ! PLX0 = 0.07, 0.07, 0.10, 0.15, 0.35, 0.55 !

Default potential temperature gradient
for stable classes E, F (degK/m)
(PTG0(2))                Default: 0.020, 0.035
                      ! PTG0 = 0.020,   0.035 !

Default plume path coefficients for
each stability class (used when option
for partial plume height terrain adjustment
is selected -- MCTADJ=3)
(PPC(6))              Stability Class :  A     B     C     D     E     F
                    Default  PPC : .50,  .50,  .50,  .50,  .35,  .35
                                    ---   ---   ---   ---   ---   ---
                      !  PPC = 0.50, 0.50, 0.50, 0.50, 0.35, 0.35 !

Slug-to-puff transition criterion factor
equal to sigma-y/length of slug
(SL2PF)                  Default: 10.       ! SL2PF = 10.0 !

Puff-splitting control variables ------------------------

 VERTICAL SPLIT
 --------------

 Number of puffs that result every time a puff
 is split - nsplit=2 means that 1 puff splits
 into 2
 (NSPLIT)                Default:   3       ! NSPLIT =  3  !

 Time(s) of a day when split puffs are eligible to
 be split once again; this is typically set once
 per day, around sunset before nocturnal shear develops.
 24 values: 0 is midnight (00:00) and 23 is 11 PM (23:00)
 0=do not re-split    1=eligible for re-split
 (IRESPLIT(24))           Default:  Hour 17 = 1
 !  IRESPLIT = 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0 !

 Split is allowed only if last hour's mixing
 height (m) exceeds a minimum value
 (ZISPLIT)                Default: 100.      ! ZISPLIT = 100.0 !

 Split is allowed only if ratio of last hour's
 mixing ht to the maximum mixing ht experienced
 by the puff is less than a maximum value (this
 postpones a split until a nocturnal layer develops)
```

(ROLDMAX) Default: 0.25 ! ROLDMAX = 0.25 !

HORIZONTAL SPLIT
---

Number of puffs that result every time a puff
is split - nsplith=5 means that 1 puff splits
into 5
(NSPLITH) Default: 5 ! NSPLITH = 5 !

Minimum sigma-y (Grid Cells Units) of puff
before it may be split
(SYSPLITH) Default: 1.0 ! SYSPLITH = 1.0 !

Minimum puff elongation rate (SYSPLITH/hr) due to
wind shear, before it may be split
(SHSPLITH) Default: 2. ! SHSPLITH = 2.0 !

Minimum concentration (g/m^3) of each
species in puff before it may be split
Enter array of NSPEC values; if a single value is
entered, it will be used for ALL species
(CNSPLITH) Default: 1.0E-07 ! CNSPLITH = 1.0E-07 !

Integration control variables ----------

Fractional convergence criterion for numerical SLUG
sampling integration
(EPSSLUG) Default: 1.0e-04 ! EPSSLUG = 1.0E-04 !

Fractional convergence criterion for numerical AREA
source integration
(EPSAREA) Default: 1.0e-06 ! EPSAREA = 1.0E-06 !

Trajectory step-length (m) used for numerical rise
integration
(DSRISE) Default: 1.0 ! DSRISE = 1.0 !

Boundary Condition (BC) Puff control variables ----------

Minimum height (m) to which BC puffs are mixed as they are emitted
(MBCON=2 ONLY). Actual height is reset to the current mixing height
at the release point if greater than this minimum.
(HTMINBC) Default: 500. ! HTMINBC = 500.0 !

Search radius (km) about a receptor for sampling nearest BC puff.
BC puffs are typically emitted with a spacing of one grid cell
length, so the search radius should be greater than DGRIDKM.
(RSAMPBC) Default: 10. ! RSAMPBC = 10.0 !

Near-Surface depletion adjustment to concentration profile used when
sampling BC puffs?
(MDEPBC) Default: 1 ! MDEPBC = 1 !
0 = Concentration is NOT adjusted for depletion
1 = Adjust Concentration for depletion

!END!

---

INPUT GROUPS: 13a, 13b, 13c, 13d -- Point source parameters
---

---
Subgroup (13a)
---

Number of point sources with
parameters provided below (NPT1) No default ! NPT1 = 0 !

Units used for point source
emissions below (IPTU) Default: 1 ! IPTU = 1 !
1 = g/s
2 = kg/hr
3 = lb/hr
4 = tons/yr
5 = Odour Unit * m**3/s (vol. flux of odour compound)
6 = Odour Unit * m**3/min
7 = metric tons/yr
8 = Bq/s (Bq = becquerel = disintegrations/s)
9 = GBq/yr

Number of source-species
combinations with variable
emissions scaling factors
provided below in (13d) (NSPT1) Default: 0 ! NSPT1 = 0 !

Number of point sources with
variable emission parameters
provided in external file (NPT2) No default ! NPT2 = 0 !

(If NPT2 > 0, these point
source emissions are read from
the file: PTEMARB.DAT)

!END!

---
Subgroup (13b)
---

a
POINT SOURCE: CONSTANT DATA
---

| | | | | | | b | c | | |
|---|---|---|---|---|---|---|---|---|---|
| Source No. | X Coordinate (km) | Y Coordinate (km) | Stack Height (m) | Base Elevation (m) | Stack Diameter (m) | Exit Vel. (m/s) | Exit Temp. (deg. K) | Bldg. Dwash | Emission Rates |
| ------ | ---------- | ---------- | ------ | ------ | -------- | ----- | -------- | ----- | -------- |

---

a
Data for each source are treated as a separate input subgroup
and therefore must end with an input group terminator.

SRCNAM is a 12-character name for a source
(No default)
X is an array holding the source data listed by the column headings
(No default)
SIGYZI is an array holding the initial sigma-y and sigma-z (m)
(Default: 0.,0.)
FMFAC is a vertical momentum flux factor (0. or 1.0) used to represent
the effect of rain-caps or other physical configurations that
reduce momentum rise associated with the actual exit velocity.
(Default: 1.0 -- full momentum used)
ZPLTFM is the platform height (m) for sources influenced by an isolated
structure that has a significant open area between the surface
and the bulk of the structure, such as an offshore oil platform.
The Base Elevation is that of the surface (ground or ocean),
and the Stack Height is the release height above the Base (not
above the platform). Building heights entered in Subgroup 13c
must be those of the buildings on the platform, measured from
the platform deck. ZPLTFM is used only with MBDW=1 (ISC
downwash method) for sources with building downwash.
(Default: 0.0)

b
0. = No building downwash modeled
1. = Downwash modeled for buildings resting on the surface
2. = Downwash modeled for buildings raised above the surface (ZPLTFM > 0.)
NOTE: must be entered as a REAL number (i.e., with decimal point)

c
An emission rate must be entered for every pollutant modeled.
Enter emission rate of zero for secondary pollutants that are
modeled, but not emitted. Units are specified by IPTU
(e.g. 1 for g/s).

---
Subgroup (13c)
---
Subgroup (13c)
---

BUILDING DIMENSION DATA FOR SOURCES SUBJECT TO DOWNWASH
---
Source(a)
No. Effective building height, width, length and X/Y offset (in meters)
every 10 degrees. LENGTH, XBADJ, and YBADJ are only needed for
MBDW=2 (PRIME downwash option)
------ ---

---

a

Building height, width, length, and X/Y offset from the source are treated as a separate input subgroup for each source and therefore must end with an input group terminator. The X/Y offset is the position, relative to the stack, of the center of the upwind face of the projected building, with the x-axis pointing along the flow direction.

---
Subgroup (13d)
---

a
POINT SOURCE: VARIABLE EMISSIONS DATA
---

Use this subgroup to describe temporal variations in the emission rates given in 13b. Factors entered multiply the rates in 13b.
Skip sources here that have constant emissions. For more elaborate variation in source parameters, use PTEMARB.DAT and NPT2 > 0.

IVARY determines the type of variation, and is source-specific:
(IVARY) Default: 0

- 0 = Constant
- 1 = Diurnal cycle (24 scaling factors: hours 1-24)
- 2 = Monthly cycle (12 scaling factors: months 1-12)
- 3 = Hour & Season (4 groups of 24 hourly scaling factors, where first group is DEC-JAN-FEB)
- 4 = Speed & Stab. (6 groups of 6 scaling factors, where first group is Stability Class A, and the speed classes have upper bounds (m/s) defined in Group 12
- 5 = Temperature (12 scaling factors, where temperature classes have upper bounds (C) of: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 50+)

---
a
Data for each species are treated as a separate input subgroup and therefore must end with an input group terminator.

---

INPUT GROUPS: 14a, 14b, 14c, 14d -- Area source parameters
---

---
Subgroup (14a)
---

Number of polygon area sources with parameters specified below (NAR1) No default ! NAR1 = 0 !

Units used for area source

```
    emissions below          (IARU)       Default: 1  !  IARU =   1  !
         1 =       g/m**2/s
         2 =      kg/m**2/hr
         3 =      lb/m**2/hr
         4 =     tons/m**2/yr
         5 =     Odour Unit * m/s  (vol. flux/m**2 of odour compound)
         6 =     Odour Unit * m/min
         7 =     metric tons/m**2/yr
         8 =     Bq/m**2/s  (Bq = becquerel = disintegrations/s)
         9 =     GBq/m**2/yr

    Number of source-species
    combinations with variable
    emissions scaling factors
    provided below in (14d)       (NSAR1) Default: 0  !  NSAR1 =  0  !

    Number of buoyant polygon area sources
    with variable location and emission
    parameters (NAR2)                  No default  !  NAR2 =  0   !
    (If NAR2 > 0, ALL parameter data for
    these sources are read from the file: BAEMARB.DAT)

!END!

---------------
Subgroup (14b)
---------------
                              a
        AREA SOURCE: CONSTANT DATA
        ----------------------------
                                          b
Source          Effect.    Base      Initial    Emission
 No.            Height   Elevation   Sigma z     Rates
                 (m)       (m)         (m)
-------         ------    ------     --------   ---------

--------
   a
    Data for each source are treated as a separate input subgroup
    and therefore must end with an input group terminator.
   b
    An emission rate must be entered for every pollutant modeled.
    Enter emission rate of zero for secondary pollutants that are
    modeled, but not emitted.  Units are specified by IARU
    (e.g. 1 for g/m**2/s).

---------------
Subgroup (14c)
---------------

        COORDINATES (km) FOR EACH VERTEX(4) OF EACH POLYGON
        ---------------------------------------------------------
Source                                          a
 No.      Ordered list of X followed by list of Y, grouped by source
------    ------------------------------------------------------------
```

---
a
Data for each source are treated as a separate input subgroup
and therefore must end with an input group terminator.

---
Subgroup (14d)
---

a
AREA SOURCE: VARIABLE EMISSIONS DATA
---

Use this subgroup to describe temporal variations in the emission
rates given in 14b. Factors entered multiply the rates in 14b.
Skip sources here that have constant emissions. For more elaborate
variation in source parameters, use BAEMARB.DAT and NAR2 > 0.

IVARY determines the type of variation, and is source-specific:
(IVARY) Default: 0
0 = Constant
1 = Diurnal cycle (24 scaling factors: hours 1-24)
2 = Monthly cycle (12 scaling factors: months 1-12)
3 = Hour & Season (4 groups of 24 hourly scaling factors,
where first group is DEC-JAN-FEB)
4 = Speed & Stab. (6 groups of 6 scaling factors, where
first group is Stability Class A,
and the speed classes have upper
bounds (m/s) defined in Group 12
5 = Temperature (12 scaling factors, where temperature
classes have upper bounds (C) of:
0, 5, 10, 15, 20, 25, 30, 35, 40,
45, 50, 50+)

---
a
Data for each species are treated as a separate input subgroup
and therefore must end with an input group terminator.

---

INPUT GROUPS: 15a, 15b, 15c -- Line source parameters
---

---
Subgroup (15a)
---

Number of buoyant line sources
with variable location and emission
parameters (NLN2) No default ! NLN2 = 0 !

(If NLN2 > 0, ALL parameter data for

these sources are read from the file: LNEMARB.DAT)

Number of buoyant line sources (NLINES) No default ! NLINES = 1 !

Units used for line source
emissions below (ILNU) Default: 1 ! ILNU = 1 !
1 = g/s
2 = kg/hr
3 = lb/hr
4 = tons/yr
5 = Odour Unit * m**3/s (vol. flux of odour compound)
6 = Odour Unit * m**3/min
7 = metric tons/yr
8 = Bq/s (Bq = becquerel = disintegrations/s)
9 = GBq/yr

Number of source-species
combinations with variable
emissions scaling factors
provided below in (15c) (NSLN1) Default: 0 ! NSLN1 = 0 !

Maximum number of segments used to model
each line (MXNSEG) Default: 7 ! MXNSEG = 7 !

The following variables are required only if NLINES > 0. They are
used in the buoyant line source plume rise calculations.

Number of distances at which Default: 6 ! NLRISE = 6 !
transitional rise is computed

Average building length (XL) No default ! XL = 40 !
(in meters)

Average building height (HBL) No default ! HBL = 15 !
(in meters)

Average building width (WBL) No default ! WBL = 5 !
(in meters)

Average line source width (WML) No default ! WML = 5 !
(in meters)

Average separation between buildings (DXL) No default ! DXL = 10 !
(in meters)

Average buoyancy parameter (FPRIMEL) No default ! FPRIMEL = 419 !
(in m**4/s**3)

!END!

---
Subgroup (15b)
---

BUOYANT LINE SOURCE: CONSTANT DATA
---

```
                                                                    a
Source     Beg. X      Beg. Y      End. X    End. Y     Release    Base        Emission
 No.     Coordinate  Coordinate  Coordinate Coordinate  Height    Elevation      Rates
           (km)        (km)        (km)       (km)       (m)       (m)
------   ----------  ----------  ---------  ----------  -------   ---------    ---------
  1 ! SRCNAM = SRC 1 !
  1 ! X = 679.4625598, 1695.610582, 679.4926323, 1695.60813,     15.1,      566, 11.08 !


!END!


--------

   a
    Data for each source are treated as a separate input subgroup
    and therefore must end with an input group terminator.

   b
    An emission rate must be entered for every pollutant modeled.
    Enter emission rate of zero for secondary pollutants that are
    modeled, but not emitted.  Units are specified by ILNTU
    (e.g. 1 for g/s).

---------------
Subgroup (15c)
---------------
                                        a
        BUOYANT LINE SOURCE: VARIABLE EMISSIONS DATA
        ---------------------------------------------

    Use this subgroup to describe temporal variations in the emission
    rates given in 15b.  Factors entered multiply the rates in 15b.
    Skip sources here that have constant emissions.

    IVARY determines the type of variation, and is source-specific:
    (IVARY)                          Default: 0
         0 =      Constant
         1 =      Diurnal cycle (24 scaling factors: hours 1-24)
         2 =      Monthly cycle (12 scaling factors: months 1-12)
         3 =      Hour & Season (4 groups of 24 hourly scaling factors,
                            where first group is DEC-JAN-FEB)
         4 =      Speed & Stab. (6 groups of 6 scaling factors, where
                            first group is Stability Class A,
                            and the speed classes have upper
                            bounds (m/s) defined in Group 12
         5 =      Temperature   (12 scaling factors, where temperature
                            classes have upper bounds (C) of:
                            0, 5, 10, 15, 20, 25, 30, 35, 40,
                            45, 50, 50+)



--------
   a
    Data for each species are treated as a separate input subgroup
```

and therefore must end with an input group terminator.

---

INPUT GROUPS: 16a, 16b, 16c -- Volume source parameters
---

---
Subgroup (16a)
---

Number of volume sources with
parameters provided in 16b,c (NVL1) No default ! NVL1 = 0 !

Units used for volume source
emissions below in 16b (IVLU) Default: 1 ! IVLU = 1 !
1 = g/s
2 = kg/hr
3 = lb/hr
4 = tons/yr
5 = Odour Unit * m**3/s (vol. flux of odour compound)
6 = Odour Unit * m**3/min
7 = metric tons/yr
8 = Bq/s (Bq = becquerel = disintegrations/s)
9 = GBq/yr

Number of source-species
combinations with variable
emissions scaling factors
provided below in (16c) (NSVL1) Default: 0 ! NSVL1 = 0 !

Number of volume sources with
variable location and emission
parameters (NVL2) No default ! NVL2 = 0 !

(If NVL2 > 0, ALL parameter data for
these sources are read from the VOLEMARB.DAT file(s) )

!END!

---
Subgroup (16b)
---

a
VOLUME SOURCE: CONSTANT DATA
---

b

| X Coordinate (km) | Y Coordinate (km) | Effect. Height (m) | Base Elevation (m) | Initial Sigma y (m) | Initial Sigma z (m) | Emission Rates |
|---|---|---|---|---|---|---|
| ---------- | ---------- | ------ | ------ | -------- | -------- | -------- |

---
a

Data for each source are treated as a separate input subgroup
and therefore must end with an input group terminator.

b
An emission rate must be entered for every pollutant modeled.
Enter emission rate of zero for secondary pollutants that are
modeled, but not emitted. Units are specified by IVLU
(e.g. 1 for g/s).

---
Subgroup (16c)
---

a
VOLUME SOURCE: VARIABLE EMISSIONS DATA
---

Use this subgroup to describe temporal variations in the emission
rates given in 16b. Factors entered multiply the rates in 16b.
Skip sources here that have constant emissions. For more elaborate
variation in source parameters, use VOLEMARB.DAT and NVL2 > 0.

IVARY determines the type of variation, and is source-specific:
(IVARY) Default: 0
0 = Constant
1 = Diurnal cycle (24 scaling factors: hours 1-24)
2 = Monthly cycle (12 scaling factors: months 1-12)
3 = Hour & Season (4 groups of 24 hourly scaling factors,
where first group is DEC-JAN-FEB)
4 = Speed & Stab. (6 groups of 6 scaling factors, where
first group is Stability Class A,
and the speed classes have upper
bounds (m/s) defined in Group 12
5 = Temperature (12 scaling factors, where temperature
classes have upper bounds (C) of:
0, 5, 10, 15, 20, 25, 30, 35, 40,
45, 50, 50+)

---
a
Data for each species are treated as a separate input subgroup
and therefore must end with an input group terminator.

---

INPUT GROUPS: 17a & 17b -- Non-gridded (discrete) receptor information
---

---
Subgroup (17a)
---

Number of non-gridded receptors (NREC) No default ! NREC = 15 !

!END!

---
Subgroup (17b)
---

a
NON-GRIDDED (DISCRETE) RECEPTOR DATA
---

| Receptor No. | X Coordinate (km) | Y Coordinate (km) | Ground Elevation (m) | Height b Above Ground (m) | |
|---|---|---|---|---|---|
| 1 | ! X = | 683.08496 | 1694.27175 | 788 | 1.8! !END! |
| 2 | ! X = | 676.78769 | 1694.15906 | 128 | 1.8! !END! |
| 3 | ! X = | 677.18657 | 1695.40992 | 456 | 1.8! !END! |
| 4 | ! X = | 676.11493 | 1693.62233 | 96 | 1.8! !END! |
| 5 | ! X = | 681.57628 | 1696.99513 | 769 | 1.8! !END! |
| 6 | ! X = | 679.04888 | 1696.16631 | 605 | 1.8! !END! |
| 7 | ! X = | 679.29651 | 1695.81445 | 561 | 1.8! !END! |
| 8 | ! X = | 678.63944 | 1695.96685 | 572 | 1.8! !END! |
| 9 | ! X = | 677.87574 | 1693.71032 | 445 | 1.8! !END! |
| 10 | ! X = | 676.40317 | 1694.16261 | 132 | 1.8! !END! |
| 11 | ! X = | 677.77411 | 1694.91266 | 262 | 1.8! !END! |
| 12 | ! X = | 677.40579 | 1694.40462 | 192 | 1.8! !END! |
| 13 | ! X = | 677.17294 | 1694.96527 | 280 | 1.8! !END! |
| 14 | ! X = | 682.21249 | 1693.62586 | 904 | 1.8! !END! |
| 15 | ! X = | 678.30756 | 1694.25223 | 251 | 1.8! !END! |

---

a
Data for each receptor are treated as a separate input subgroup and therefore must end with an input group terminator.

b
Receptor height above ground is optional. If no value is entered, the receptor is placed on the ground.

# Appendix F. Technical Report – Noise Impact Assessment

Dominica Geothermal Development Company Limited
*Powering a New Generation...*

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# Dominica Geothermal Power Plant - Environmental and Social Impact Assessment

NZ Ministry of Foreign Affairs and Trade

## Dominica Geothermal Power Plant Technical Report - Noise Impact Assessment

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# Dominica Geothermal Power Plant - Environmental and Social Impact Assessment

| | |
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**Appendix B. Predicted noise contours (Neutral weather condition)**

**Appendix C. Predicted noise contours (Adverse weather condition)**

## Important note about your report

The sole purpose of this report and the associated services performed by Jacobs New Zealand Limited ("Jacobs") is to describe the Noise Assessment for the Dominica Geothermal Power Project Environmental and Social Impact Assessment (ESIA) Project in accordance with the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

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# 1. Introduction

## 1.1 Overview

This Technical Report is part of an Environmental and Social Impact Assessment (ESIA) for the construction and operation of the Dominica Geothermal Power Project (hereafter referred to as 'the Project'). The Project comprises the construction, completion, testing, commissioning and operation of geothermal wells, steam gathering and reinjection system, power plant with nameplate capacity of 7 MW and connection to electrical grid and associated infrastructure in the Roseau Valley, Dominica. The design for the Project is ongoing, with further detailed design to be completed following a formal tender process for an Engineer, Procure and Construct contractor(s) in 2017.

## 1.2 Project Description

The key components of the proposed 7 MW power plant include:

- Power plant comprising 2 x 3.5 MW units or single 1 MW unit (either single flash steam condensing cycle or organic Rankine cycle units)
- Production well WW-P1 - The existing geothermal production well at Laudat has the potential to generate 6 to 9 MWe of electricity and will be the sole production well for the project.
- Reinjection to existing wells WW-03, WW-R1 and WW-01. The used geothermal fluids (brine and some steam condensate) would be disposed of into reinjection wells WW-R1 and WW-01 via a pipeline of up to 4 km in length and condensate to WW-03 which is located near WW-P1.
- Steamfield infrastructure including two phase piping, steam separators, atmospheric flash tank, steam gathering system, brine collection and disposal system, condensate collection and disposal system, pressure relief system and storage sump.
- Supporting infrastructure including well pads, turbine building, primary and ancillary equipment, cooling system, road network and water/waste water supply
- Substation and interconnection to the DOMLEC electricity grid at Laudat Power Plant.

Figure 1.1 provides the locations of the well pads (WW-P1, WW-03, WW-R1 and WW-01) and reinjection lines. Figure 1.2 shows the layout of the power plant.

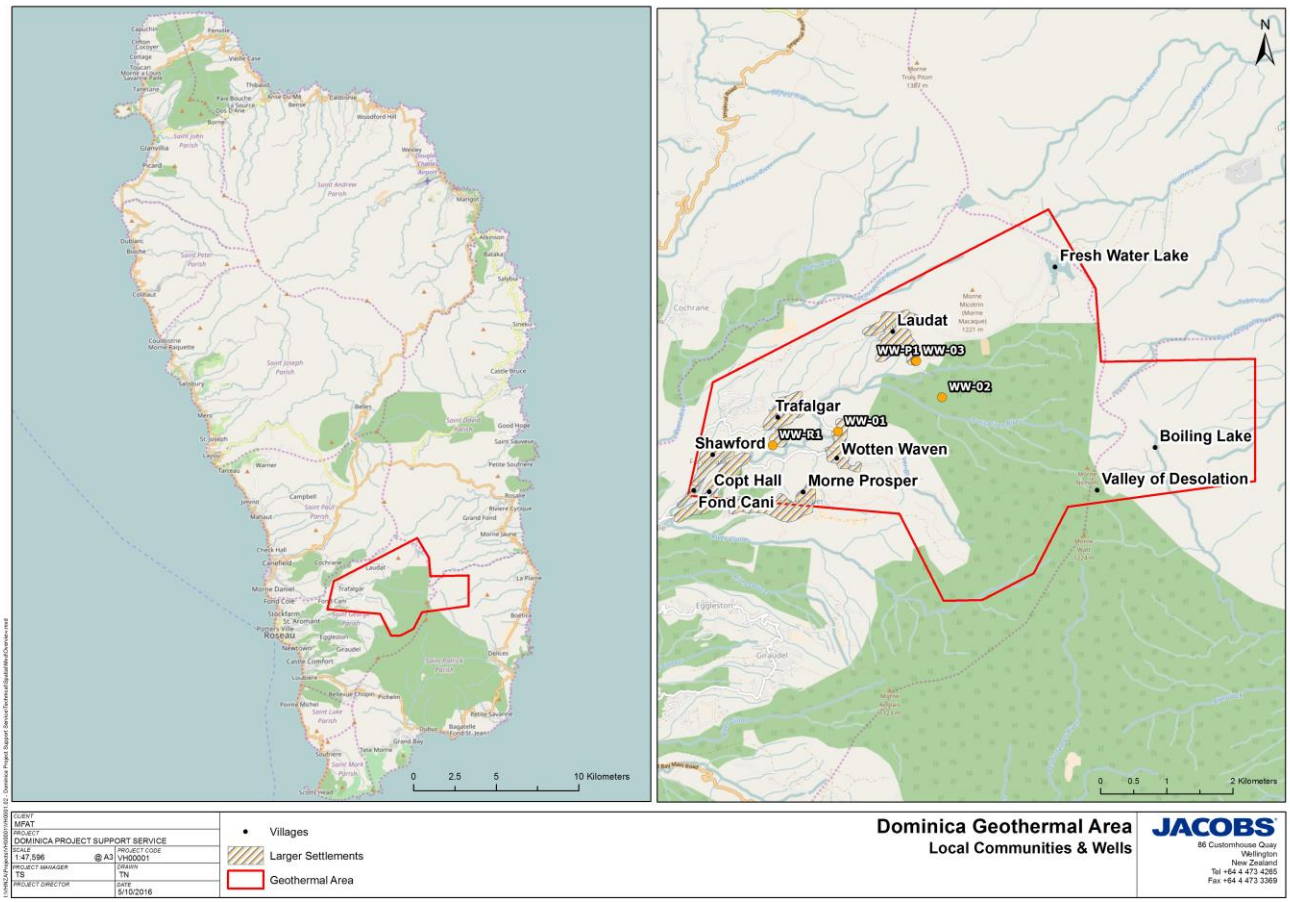



**Figure 1.1 : Site layout and nearby residential areas**

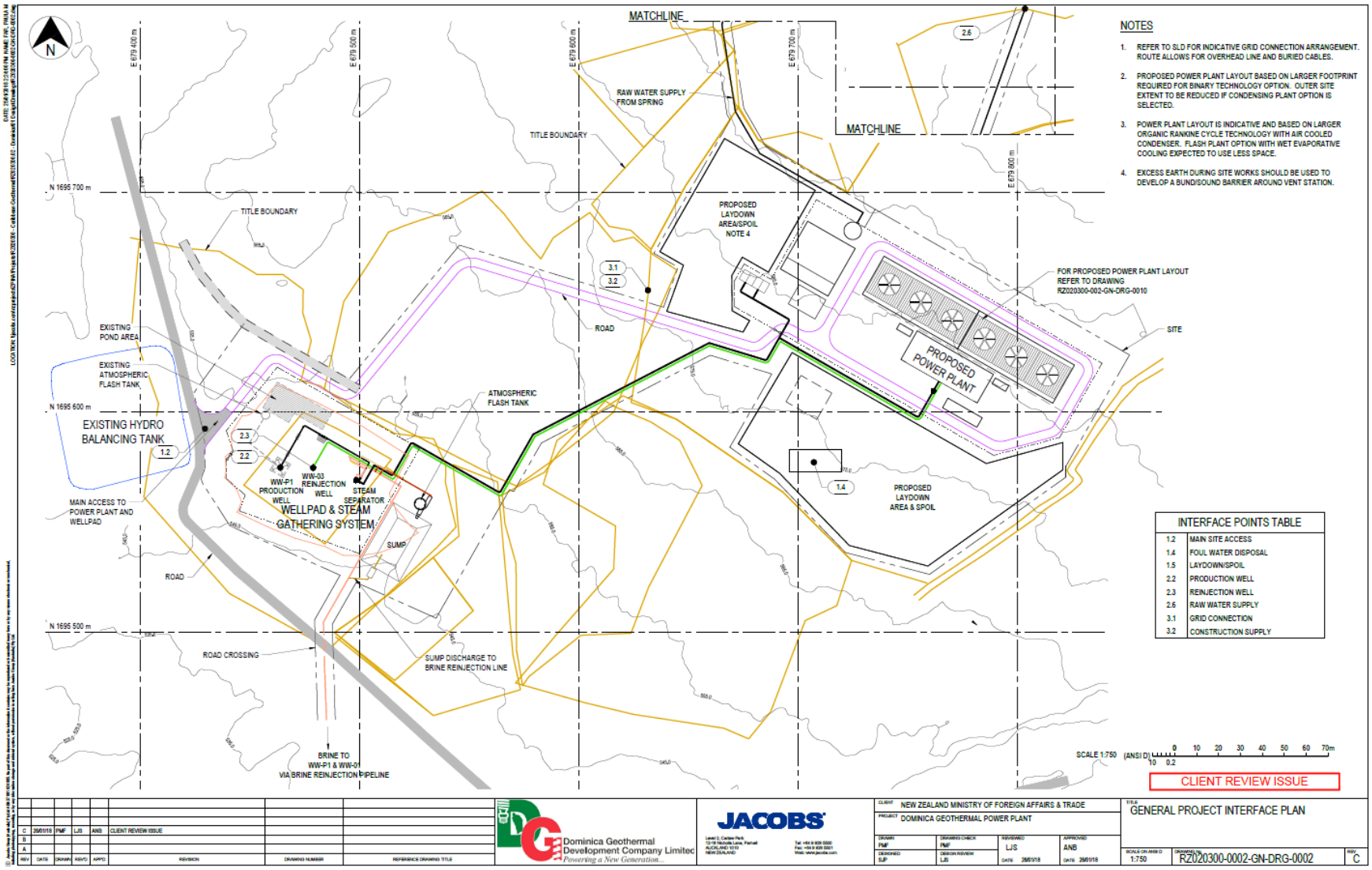



**Figure 1.2 : Power Plant Layout**

## 1.3 Purpose

This report identifies noise impacts associated with this type of facility and provides an assessment of potential noise impacts at nearby residential locations. The report is one of several technical reports prepared as a supporting documentation for an Environmental and Social Impacts Assessment (ESIA). It is based on a feasibility study preliminary design and the information given in this document is expected to be updated as the design progresses.

## 1.4 Limitations and Assumptions

Limitations to the modelling and prediction of environmental noise levels are heavily dependent on the accuracy of the noise data used in the model. During the initial stages of the Project, specific information of equipment manufacturers and models are not available and therefore the acoustic data for similar known equipment has been substituted to enable far field noise levels to be estimated. The acoustic data assumed for the model report has been taken from Jacobs' in house noise database and therefore is generic in nature. The noise emissions from the power plant and overall site may vary from those predicted in this report depending on the specific make and model of the equipment selected and the design of the structures that house it.

It is recommended that at the time of detailed design of the project equipment specification and procurement should be made with the assistance of an acoustic consultant. A full inventory of plant and equipment and associated noise emission data should be developed such that a noise model could be used to confirm the noise level predictions made in this report.

# 2. Description of the Existing Environment

## 2.1 Site Characteristics

The Project is located in the Roseau Valley, in central, southern Dominica and is near the villages of Laudat, Trafalgar, Shawford, Wotten Waven and Casseau. Landuse is predominately mature or secondary rainforest, or rural agricultural.

It is understood each of these villages contains a primary school, and three small health centres are located in the villages of Trafalgar, Wotten Waven and Laudat.

The project is located in a mountainous area, with the landform generally falling away to the southwest of the site.

## 2.2 Existing Noise Environment

The nearest and most representative affected properties in the surrounding villages have been considered in this assessment. These villages and the propose project site have been presented in Figure 1.1 which include:

- Laudat
- Trafalgar
- Copt Hall
- Shawford
- Fond Cani
- Morne Prosper
- Wotten Waven.

Additionally the following natural locations have been considered:

- Boiling Lake
- Valley of Desolation
- Fresh water Lake (2.5km north east of Laudat).

## 2.3 Noise Monitoring Results

The existing ambient noise environment in areas surrounding the proposed project site was measured during the peak tourist season of December 2013 and repeated during the off season in April 2014.

Noise monitoring was undertaken at representative locations in five villages surrounding the site:

- Laudat
- Fond Cani (north, west and south)
- Trafalgar
- Wotten Waven
- Morne Prosper.

Monitoring locations have been presented in Figure 2.1.

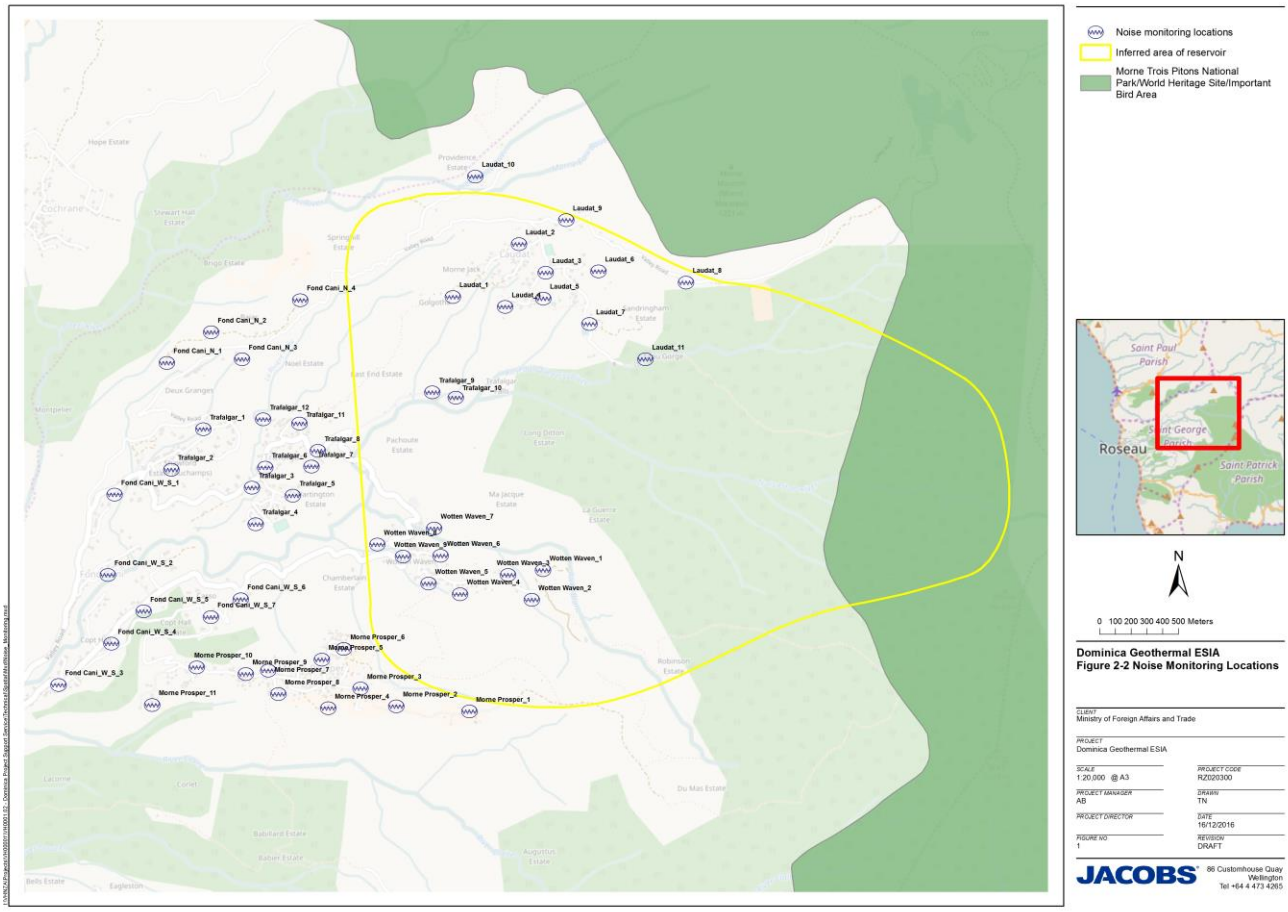



**Figure 2.1 : Noise monitoring locations**

When measuring noise levels, the use of statistical descriptors is necessary to understand and describe how variations in the noise environment occur over any given period. A list of common descriptors used in this noise assessment as well as their meaning is given below.

- $L_{Amax}$ maximum noise level measured at a given location over the 15 minute interval.
- $L_{A10}$ – the noise level exceeded for 10% of the 15 minute interval, this is commonly referred to as the average-maximum level.
- $L_{Aeq}$ – the noise level having the same energy as the time varying noise level over the 15 minute interval.
- $L_{A90}$ – the noise level exceeded for 90 percent of the 15 minute interval. This is commonly referred to as the background noise level and represents the quietest 90 seconds in a 15 minute period.

The results of the attend noise measurements have been summarised in Table 2.1 for each of the monitoring locations and detailed results are presented in Appendix A.

**Table 2.1 : Attended noise monitoring results**

| Location | Monitored noise level $L_{Aeq}$(period) dB(A) | | | |
|---|---|---|---|---|
| | Peak tourist season December 2013 | | Off tourist season April 2014 | |
| | Daytime (7am to 9pm) | Night time (9pm to 7am) | Daytime (7am to 9pm) | Night time (9pm to 7am) |
| Laudat | | | | |
| Average $L_{Aeq}$ | 44.3 | 47.1 | 44.4 | 46.7 |
| Maximum $L_{Aeq}$ | 53.0 | 53.5 | 51.0 | 52.0 |
| Minimum $L_{Aeq}$ | 35.5 | 40.0 | 38.0 | 42.0 |
| Fond Cani North | | | | |
| Average $L_{Aeq}$ | 44.0 | 48.0 | 39.9 | 44.1 |
| Maximum $L_{Aeq}$ | 49.0 | 49.0 | 43.5 | 49.0 |
| Minimum $L_{Aeq}$ | 38.0 | 46.5 | 36.0 | 37.5 |
| Fond Cani West and South | | | | |
| Average $L_{Aeq}$ | 53.2 | 53.3 | 52.6 | 50.4 |
| Maximum $L_{Aeq}$ | 59.5 | 60.0 | 57.5 | 57.5 |
| Minimum $L_{Aeq}$ | 43.0 | 46.5 | 42.0 | 41.0 |
| Morne Prosper | | | | |
| Average $L_{Aeq}$ | 45.6 | 48.4 | 41.3 | 43.6 |
| Maximum $L_{Aeq}$ | 49.5 | 52.0 | 46.0 | 47.0 |
| Minimum $L_{Aeq}$ | 38.0 | 43.5 | 36.0 | 35.0 |
| Wotten Waven | | | | |
| Average $L_{Aeq}$ | 46.0 | 52.8 | 47.1 | 49.6 |
| Maximum $L_{Aeq}$ | 49.0 | 57.5 | 49.5 | 51.0 |
| Minimum $L_{Aeq}$ | 39.5 | 45.0 | 41.0 | 48.0 |
| Trafalgar | | | | |
| Average $L_{Aeq}$ | 52.0 | 54.4 | 47.1 | 47.3 |
| Maximum $L_{Aeq}$ | 60.0 | 62.5 | 50.5 | 50.5 |
| Minimum $L_{Aeq}$ | 43.5 | 46.5 | 44.0 | 43.5 |

## 2.4 Discussion

The detailed noise monitoring data for each site is provided in Appendix A. Further details are contained within the Environmental Baseline Study "*Initial environmental status of the Rodeau Valley in Dominica, planned for development of geothermal electricity production*" (document: REPORT-E3B2-R0206/15/OF/HG-EN, dated May 2015).

The main sources of noise in the area surrounding the project are local fauna, residential noise, low traffic on local roads, wind and water courses. Ambient noise levels are generally louder during night time hours due to local fauna such as insects and nocturnal wildlife. In the vicinity of local traffic generating developments, such as schools, hotels and tourist attractions, noise levels were somewhat higher.

# 3. Noise Limits

The operations of the Project have the potential to impact on residential and other noise sensitive receiver amenity and therefore must be assessed to determine requirements for noise mitigation where necessary. The use of guidelines to define a level of noise emissions from an industrial facility provides the most affected receivers with noise impacts that are within an acceptable range for day to day wellbeing.

The Project specific noise criteria will be taken to be the most stringent of the noise goals of either the World Bank Group (WBG) Environmental Health and Safety (EHS) Guideline or the Dominican regulations.

## 3.1 Dominican Regulations – Environmental Standards for Protection against Noise (June 2003)

This document sets the maximum permissible noise levels for noise produced by fixed and mobile sources. This document presents the following maximum noise levels.

**Table 3.1 : Dominica Environmental Noise Standards**

| Receiver category | Maximum permissible external noise level $L_{Aeq}$(period) dB(A)* | |
|---|---|---|
| | Daytime (7am to 9pm) | Night time (9pm to 7am) |
| **Area 1 - Zones of tranquillity** | | |
| Hospitals, medical centres, place of worship | 55 | 50 |
| Offices, schools | 60 | 55 |
| Zoos, botanical gardens | 60 | 55 |
| Quiet areas for the preservation of habitat | 60 | 50 |
| **Area 2 – Residential Zones** | | |
| Residential areas | 60 | 50 |
| Residential areas within commercial and/or industrial areas | 65 | 55 |
| **Area 3 – Commercial Zones** | | |
| Industrial zones | 70 | 55 |
| Commercial zones | 70 | 55 |

** As no statistical parameter appears to be presented in this document, it is assumed that these levels are $L_{Aeq}$(period).*

## 3.2 WBG EHS Guidelines

The WBG recommends noise limits for residential locations in accordance with its EHS Guidelines. These guidelines have been adopted from Guidelines for Community Noise, World Health Organization, 1999 and are values for noise levels measured outside a dwelling. The noise level guidelines from the IFC have been reproduced in Table 3.2 :

**Table 3.2 : IFC noise guidelines for noise sensitive locations**

| Receptor | Day 07:00-22:00 | Night-time 22:00-07:00 |
|---|---|---|
| | $L_{Aeq1\ hr}$ | $L_{Aeq1\ hr}$ |
| Residential, Institutional Educational | 55 dB(A) | 45 dB(A) |

| Receptor | Day 07:00-22:00 | Night-time 22:00-07:00 |
|---|---|---|
| Industrial, Commercial | 70 dB(A) | 70 dB(A) |

The guidelines state:

*"Noise impacts should not exceed the levels presented in Table 3.2 or result in a maximum increase in background levels of 3 dB at the nearest receptor location – off site"*

The additional criteria of background plus 3 dB(A) is referred to as a maximum increase in noise levels and is only to be adopted where the guideline levels in the table are already exceeded. For the purposes of these calculations, the minimum monitored $L_{Aeq}$ during the tourist down season for each village will be used.

**Table 3.3 : World Bank noise guidelines for power stations**

| Location (Residential, Institutional Educational receptors) | Initial noise limits dB(A) | | Existing dB(A) | | Final noise limits dB(A) | |
|---|---|---|---|---|---|---|
| | Daytime 07:00-22:00 | Night-time 22:00-07:00 | Daytime 07:00-22:00 | Night-time 22:00-07:00 | Daytime 07:00-22:00 | Night-time 22:00-07:00 |
| | $L_{Aeq1\ hr}$ | $L_{Aeq1\ hr}$ | $L_{Aeq\ period}$ | $L_{Aeq\ period}$ | $L_{Aeq1\ hr}$ | $L_{Aeq1\ hr}$ |
| Laudat | 55 | 45 | 38.0 | 42.0 | 55 | 45 |
| Fond Cani North | | | 36.0 | 37.5 | 55 | 45 |
| Fond Cani West and South | | | 42.0 | 41.0 | 55 | 45 |
| Morne Prosper | | | 36.0 | 35.0 | 55 | 45 |
| Wotten Waven | | | 41.0 | 48.0 | 55 | 51 |
| Trafalgar | | | 44.0 | 43.5 | 55 | 45 |

It can be seen that the WBG EHS noise guidelines are generally applicable, however for locations in Wotten Waven, the night time noise level is greater than the guidelines and as such the alternative 'background plus 3 dB(A)' criteria may be applied during this period at this location.

## 3.3 Summary of operational noise criteria

Given the different criteria applicable to this project, the minimum criteria for each location will be used to assess operational noise associated with the project. These have been set out below in Table 3.4.

**Table 3.4 : Summary of operational noise criteria (LAeq 1 hour)**

| Location | World Bank Base Criteria dB(A) | | World Bank 'Plus 3' Criteria dB(A) | | Dominica Criteria dB(A) | | Final noise criteria dB(A) | |
|---|---|---|---|---|---|---|---|---|
| | Day | Night | Day | Night | Day | Night | Day | Night |
| Laudat | 55 | 45 | 55 | 45 | 60 | 55 | **55** | **45** |
| Fond Cani North | 55 | 45 | 55 | 45 | 60 | 55 | **55** | **45** |
| Fond Cani West and South | 55 | 45 | 55 | 45 | 60 | 55 | **55** | **45** |
| Morne Prosper | 55 | 45 | 55 | 45 | 60 | 55 | **55** | **45** |

| Location | World Bank Base Criteria dB(A) | | World Bank 'Plus 3' Criteria dB(A) | | Dominica Criteria dB(A) | | Final noise criteria dB(A) | |
|---|---|---|---|---|---|---|---|---|
| Wotten Waven | 55 | 45 | 55 | 51 | 60 | 55 | **55** | **51** |
| Trafalgar | 55 | 45 | 55 | 45 | 60 | 55 | **55** | **45** |
| Recreational areas | 55 | 45 | 55 | 45 | 60 | 50 | **55** | **45** |

It can be seen that where compliance is shown to meet the World Bank 'Background plus 3' noise criteria, local noise criteria will also be met.

## 3.4 Construction Noise Limits

The risk of adverse impact of construction noise within a community is determined by the extent of its emergence above the existing background noise level, the duration and scheduling of the event and the characteristics of the noise.

There is no specific construction noise impact criteria identified for the Project, however, an increase of 15 dB(A) above daytime background noise levels and 10 dB(A) above night time noise levels has been used as a guideline to determine if mitigation of construction noise is likely to be required. Again, the minimum monitored $L_{Aeq}$ during the tourist down season for each village has been referenced in these calculations.

**Table 3.5 : Construction noise guidelines**

| Location (Residential, Institutional Educational receptors) | Existing dB(A) | | Allowance dB(A) | | Construction noise limits dB(A) | |
|---|---|---|---|---|---|---|
| | Day 07:00-22:00 | Night-time 22:00-07:00 | Day 07:00-22:00 | Night-time 22:00-07:00 | Day 07:00-22:00 | Night-time 22:00-07:00 |
| | $L_{Aeq1\ hr}$ | $L_{Aeq1\ hr}$ | $L_{Aeq\ period}$ | $L_{Aeq\ period}$ | $L_{Aeq1\ hr}$ | $L_{Aeq1\ hr}$ |
| Laudat | 38.0 | 42.0 | 15 | 10 | **53.0** | **52.0** |
| Fond Cani North | 36.0 | 37.5 | | | **51.0** | **47.5** |
| Fond Cani West and South | 42.0 | 41.0 | | | **57.0** | **51.0** |
| Morne Prosper | 36.0 | 35.0 | | | **51.0** | **45.0** |
| Wotten Waven | 41.0 | 48.0 | | | **56.0** | **58.0** |
| Trafalgar | 44.0 | 43.5 | | | **59.0** | **53.5** |

# 4. Effects of Prevailing Weather Conditions

## 4.1 Wind

Wind has the potential to increase noise at a receiver when it is light and stable and blows from the direction of the noise source. As the strength of the wind increases the noise produced by the wind will obscure noise from most industrial and transport sources.

Wind effects need to be considered when wind is a feature of the area under consideration. Where the source to receiver wind component at speeds of up to 3 m/s occur for 30% or more of the time in any seasonal period (during the day, evening or night), then wind is considered to be a feature of the area and noise level predictions must be made under these conditions.

In order to determine the prevailing wind conditions for the project, 12 months of wind data collected in 2015 within the project area was development into annual and seasonal wind roses. These are displayed below in Figure 4.1.

Seasonal wind records indicate that prevailing winds are not a feature of the areas since the frequency of occurrence of winds up to 3 m/s is below the 30% threshold for all seasons. Hence, prevailing winds have not been considered as part of this noise assessment.

## 4.2 Temperature Inversions

Temperature inversions, when they occur, have the ability to increase noise levels by focusing sound waves. Temperature inversions occur predominantly at night during the winter months. For a temperature inversion to be a significant characteristic of the area it needs to occur for approximately 30% of the total night-time during winter, or about two nights per week.

Temperature inversions occur during E, F and G stability categories. These three categories are considered to represent weak, moderate and strong inversions respectively. For noise-assessment purposes, only moderate and strong inversions are considered significant enough to require assessment.

In dispersion modelling, stability class is used to categorise the rate at which a plume will disperse. In the Pasquill-Gifford stability class assignment scheme there are six stability classes, A through to F. Class A relates to unstable conditions, such as might be found on a sunny day with light winds. Class F relates to stable conditions, such as those that occur when the sky is clear, the winds are light and an inversion is present. The intermediate classes B, C, D and E relate to intermediate dispersion conditions. A seventh class, G, has also been defined to accommodate extremely stable conditions such as might be found in arid rural areas."

An analysis of the occurrence of each stability class has not been conducted. However, to provide for a conservative 'worst case' assessment, noise modelling of night-time operations allows for temperature inversion.

With regard to construction noise impacts, as all construction works will be undertaken during the day period (when the likelihood of temperature inversions is significantly reduced), construction noise due to the project has only been modelled under neutral condition.

## 4.3 Noise Modelling Parameters for Metrological Conditions

The resultant weather conditions used to predict the level of noise for the different modelling scenarios are shown below:

- Construction and operational noise – neutral weather condition, 2 m/s wind from source to receiver and Pasquil Stability Class C; and
- Operational noise – enhanced weather condition, 2 m/s wind from source to receiver and Pasquil Stability Class F.

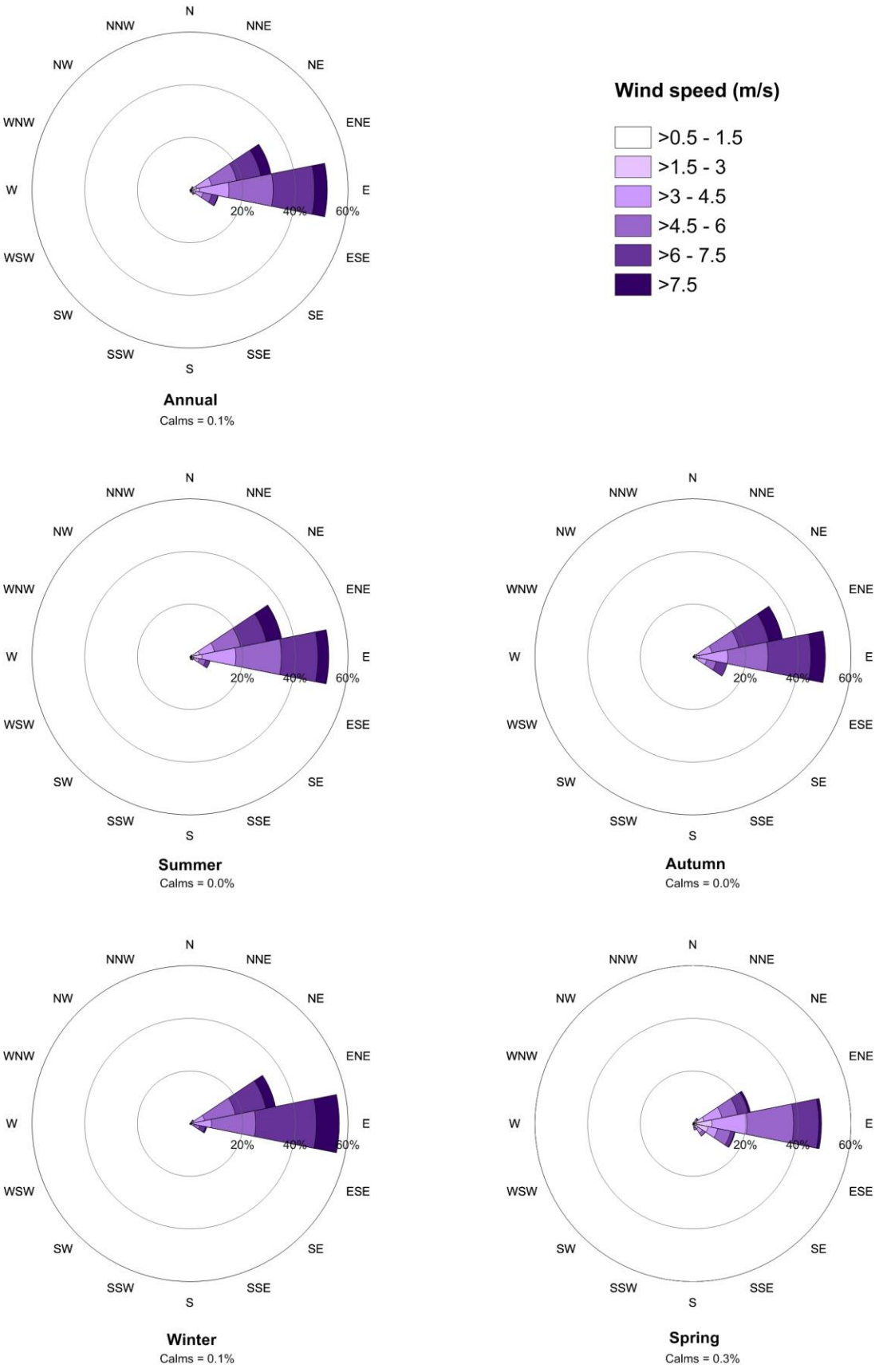



**Figure 4.1 : Wind roses for 2015**

# 5. Significance of Noise Impacts

The significance of construction and operational noise impacts can be characterised as the product of the degree of predicted impact (magnitude of impact) and the value of the receiver that is subjected to that impact (sensitivity of receiver). The criteria for the definition of magnitude and sensitivity are presented below.

## 5.1 Magnitude of Impacts

The definition of the magnitude ratings are explained in Table 5.1 below.

**Table 5.1 : Magnitude rating definition**

| Category | Description |
|---|---|
| Major | an impact that is significant and mitigation must be considered. |
| Moderate | an impact that is significant and mitigation should be considered. |
| Minor | an impact that is significant, but small enough that noise management practices would ensure noise levels are below significance criteria. |
| Negligible | no need to consider in decision making, no mitigation required. |

The magnitude of the noise impact is defined by a series of noise change categories with an associated semantic scale presented in Table 5.2 below.

**Table 5.2 : Magnitude of noise impact criteria**

| Magnitude of impact | Exceedance of operational noise criteria – dB(A) |
|---|---|
| Major | ≥ 5 |
| Moderate | 3.0 – 4.9 |
| Minor | 0.1 – 2.9 |
| Negligible | 0 |

## 5.2 Sensitivity of Receivers

The definition of the sensitivities of receivers to noise impacts during construction and operation are based on the maximum permissible daytime noise levels specified in Table 3.1. The sensitivity of receiver definition is presented in Table 5.3 below.

**Table 5.3 : Sensitivity of receiver definition**

| Category | Description |
|---|---|
| High | Hospitals, medical centres, place of worship |
| Medium | Offices, schools<br>Zoos, botanical gardens<br>Quiet areas for the preservation of habitat<br>Residential areas |
| Low | Residential areas within commercial and/or industrial areas |
| Negligible | Commercial and industrial premises |

## 5.3 Evaluating the Significance of Impacts

The significance of effect is a function of the value or sensitivity of the receptor and the magnitude of the impact. Table 5.4 presents the significance of effect, based on the magnitude of impact in Table 5.2 and the sensitivity of receptors in Table 5.3.

**Table 5.4 : Significance of noise impact**

| Sensitivity of receiver | | Magnitude of impact | | | |
|---|---|---|---|---|---|
| | | **Major** | **Moderate** | **Minor** | **Negligible** |
| | High | Major | Major | Moderate | Negligible |
| | Medium | Major | Moderate | Minor | Negligible |
| | Low | Moderate | Minor | Negligible | Negligible |
| | Negligible | Minor | Negligible | Negligible | Negligible |

# 6. Construction Noise Assessment

The construction of the project is expected to last for at least two years during which time the construction and commissioning of the geothermal plant will be completed. This report has considered potential construction impacts from the following project construction phases:

- Power plant
- Reinjection pipelines
- Suspension bridge
- Tramway Carpark.

It should be noted that for the development of the power plant no additional well drilling will be required, however at a later date well drilling for additional production wells and reinjection wells may be required due to well declines over time.

Noise levels typically decrease with increasing separation distance from the site, increasing screening from terrain or structures and are also affected to some extent by meteorological and ground surface conditions.

Potential construction noise impacts were modelled using the CONCAWE algorithm in the SoundPLAN noise modelling software package.

## 6.1 Construction Activities

The identified construction activities for the Project include several phases that have the potential to generate noise impacts in the far field. Although the equipment types and numbers would vary in practice, the likely activities and typical equipment during construction will include:

**Table 6.1 : Representative construction phases and equipment**

| Construction stage | Noisiest equipment | Sound Power Level dB(A) |
|---|---|---|
| **Power Plant** | | |
| Earthworks | D7 Dozer<br>30t Excavator<br>40t Road dump truck<br>20t Vibratory roller | 115 |
| Plant construction | 100T Mobile crane<br>Gas cutter x2<br>Ratchet gun x2 | 109 |
| Building construction | Concrete truck and pump<br>Concrete drill<br>Welder<br>Nail gun<br>Truck mounted crane | 110 |
| **Reinjection pipelines** | | |
| Earthworks | Bobcat<br><10t Vibratory roller | 111 |
| Footings | Concrete truck and pump | 109 |

| Construction stage | Noisiest equipment | Sound Power Level dB(A) |
|---|---|---|
| | Concrete drill | |
| Placement of pipe sections | 100T Mobile crane<br>Gas cutter<br>Ratchet gun | 107 |
| **Production / Reinjection well** | | |
| Earthworks | Bobcat<br><10t Vibratory roller | 111 |
| Finishing works | 100T Mobile crane<br>Gas cutter<br>Ratchet gun | 107 |
| **Suspension Bridge** | | |
| Earthworks | Bobcat<br><10t Vibratory roller | 111 |
| Footings | Concrete truck and pump<br>Concrete drill | 109 |
| Placement of cables and platform | 100T Mobile crane<br>Gas cutter<br>Ratchet gun | 107 |
| **Tramway carpark** | | |
| Earthworks | 15t Road grader<br>30t Excavator<br>40t Road dump truck<br>2 x 20t Vibratory roller | 116 |
| Asphalting | Asphalt paving machine<br>30T Road dump truck | 110 |

Due to uncertainties around haulage routes, material sites and detailed project design, potential impacts associated with traffic movements have not been considered. It should be noted that for the development of the power plant no additional well drilling will be required, however at a later date well drilling for additional production wells and reinjection wells may be required due to well declines over time.

## 6.2 Results of Construction Noise Calculations

Noise levels have been predicted for the closest residential properties to each work area. These sites have been shown below in Figure 6.1**.**

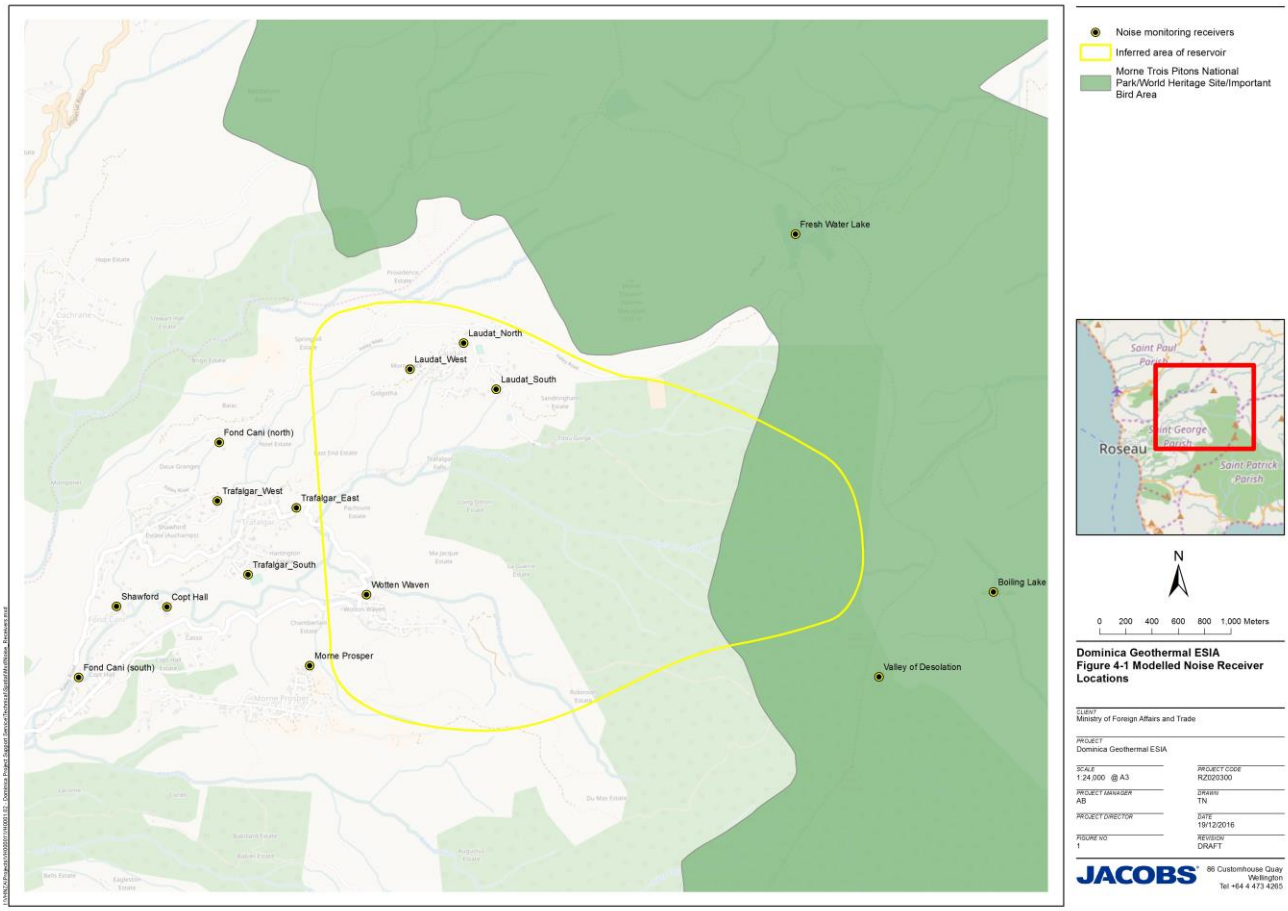



**Figure 6.1 : Noise prediction locations**

The noise level at the sensitive receiver locations during the construction phase of the plant and associated infrastructure will vary depending on the location of the work within the site, the type and number of equipment operating at any one time, the duration of the activity, and meteorological conditions at the time. In the absence of a complete methodology and to simplify the large number of variables for construction activities around the site, a “typical “construction scenario has been assessed for the Project. The scenario includes all equipment outlined in each phase of Table 6.1, operating for 50% of the time. This is not intended to be a worst case scenario for the construction activities but should serve to provide an indication of the expected levels on a day to day basis. Table 4-2 presents the predicted noise levels for a typical operation scenario noise impact.

The CONCAWE algorithm has been used to predict noise impacts from neutral weather conditions. Meteorological modelling and weather records have shown that temperature inversions are not a feature of the island and as such noise transmission under adverse weather conditions has not been considered.

Construction scenarios are defined using the following abbreviations:

- PPE - Power Plant Earthworks
- PPC - Power Plant Construction
- PPB - Power Plant Building Construction
- RPE - Reinjection Pipeline Earthworks
- RPF - Reinjection Pipeline Footings

- RPP - Reinjection Pipeline Pipe Installation
- WE - Production / Reinjection Well Earthworks
- WF - Production / Reinjection Well Finishing
- SBE - Suspension Bridge Earthworks
- SBF - Suspension Bridge Footings
- SBC - Suspension Bridge Placement of Cables
- TCE - Tramway Carpark Earthworks
- TCA - Tramway Carpark Asphalting

**Table 6-2: Predicted construction noise levels (Neutral meteorological conditions)**

| Receiver | Daytime Noise criteria dB(A) | Predicted maximum $L_{Aeq}$ during construction stage [dB(A)] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PPE | PPC | PPB | RPE | RPF | RPP | WE | WF | SBE | SBF | SBC | TCE | TCA |
| Laudat (north) | 53.0 | 26 | IA | IA | 25 | IA | IA | IA | IA | IA | IA | IA | 28 | IA |
| Laudat (south) | 53.0 | 53 | 47 | 48 | 37 | 35 | 33 | 43 | 39 | IA | IA | IA | 33 | 27 |
| Laudat (west) | 53.0 | 34 | 28 | 29 | 28 | 26 | IA | 29 | IA | IA | IA | IA | 28 | IA |
| Trafalgar (east) | 59.0 | 27 | IA | IA | 38 | 36 | 34 | 35 | 31 | IA | IA | IA | IA | IA |
| Trafalgar (south) | 59.0 | IA | IA | IA | 59 | 57 | 55 | 53 | 49 | IA | IA | IA | IA | IA |
| Trafalgar (west) | 59.0 | IA | IA | IA | 31 | 29 | 27 | 30 | 26 | IA | IA | IA | IA | IA |
| Copt Hall | 57.0 | IA | IA | IA | 25 | IA | IA | IA | IA | IA | IA | IA | IA | IA |
| Shawford | 57.0 | IA | IA | IA | 29 | 27 | 25 | 29 | IA | IA | IA | IA | IA | IA |
| Fond Cani (north) | 51.0 | IA | IA | IA | 26 | IA | IA | 26 | IA | IA | IA | IA | IA | IA |
| Fondi Cani (south) | 57.0 | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA |
| Morne Prosper | 51.0 | IA | IA | IA | 30 | 28 | 26 | 29 | 25 | IA | IA | IA | IA | IA |
| Wotten Waven | 56.0 | IA | IA | IA | 46 | 44 | 42 | 47 | 43 | IA | IA | IA | IA | IA |
| Boiling Lake* | 55.0 | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA |
| Valley of Desolation* | 55.0 | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA |
| Freshwater lake* | 55.0 | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA | IA |

***BOLD** indicates a potential exceedance of construction noise criteria / IA = Inaudible [less than 20dB(A)]*

*= Major Significance of Impact; = Moderate Significance of Impact; = Minor Significance of Impact; = Negligible Significance of Impact*

## 6.3 Discussion

### 6.3.1 Power plant works

Construction works associated with the power plant, i.e. PPE, PPC and PPB, are predicted to comply with the daytime noise limits at all surrounding residential receivers. The predicted maximum noise level of each power plant construction scenario is as follow:

- PPE works is 53 dB(A) at the Laudat (south) residential receiver;
- PPC works is 47 dB(A) at the Laudat (south) residential receiver; and
- PPB works is 48 dB(A) at the Laudat (south) residential receiver.

The power plant construction works have been predicted to be inaudible at most residential receivers, and is considered to have negligible significance noise impact.

### 6.3.2 Reinjection pipeline works

Works associated with the construction of the reinjection pipeline, i.e. RPE, RPF and RPP, are predicted to comply with the noise limits at all other surrounding residential receivers. The maximum noise level of the reinjection pipeline construction activities are predicted to be as follow:

- RPE works is 59 dB(A) at the Trafalgar (south) residential receiver;
- RPF works is 57 dB(A) at the Trafalgar (south) residential receiver; and
- RPP works is 55 dB(A) at the Trafalgar (south) residential receiver.

Reinjection pipeline works are considered to have negligible significance of impact at all surrounding receivers.

Noise mitigation measures have been recommended in Section 8 of this report to reduce the impacts of reinjection pipeline construction works on surrounding receivers.

### 6.3.3 Reinjection well works

Works associated with the construction of the reinjection wells, i.e. WE and WF, are predicted to comply with the noise limits at all surrounding residential receivers.

Reinjection well earthworks and finishing works are considered to have negligible significance of impact at all surrounding receivers.

Based on the noise predictions, receivers surrounded will comply with the noise limits where they are least 45 metres from any reinjection wells construction works.

### 6.3.4 Bridge and carpark works

Construction works associated with the suspension bridge and tramway carpark, i.e. SBE, SBF, SBC, TCE and PPB, are predicted to comply with the daytime noise limits at all surrounding residential receivers.

Bridge and carpark works are considered to have negligible significance of impact at all surrounding receivers.

# 7. Proposed Operational Activities Assessment

## 7.1 Assessment Methodology

The noise assessment considers the predicted noise impacts at the most affected receiver locations and compares these to the Project noise criteria. From Section 3 the WBG requirements were identified the limiting condition for noise impact assessment.

The prediction of noise impacts has been undertaken using SoundPLAN noise modelling software, which incorporates specific Project information to predict noise levels at sensitive receiver locations. The assessment of noise impacts from the project has compared the predicted levels at the receiver locations to the noise goals identified in Section **3** to confirm compliance with environmental objectives.

The noise model used the CONCAWE algorithm to predict the $L_{Aeq\ 1\ hour}$ noise level impacts at the nearby residences. Although in practice the noise level from the project may vary depending on demand, these noise impacts are considered to be constant for both daytime and night time periods. The CONCAWE algorithm has been used to predict noise impacts from both adverse and neutral weather conditions.

### 7.1.1 Modelling Methodology

The assessment of noise impacts at residential locations nearest to the power plant is based on the prediction of noise levels using a noise model. The noise model for this Project was developed from topographic data for the area and identification of receiver locations from available aerial photography. Precise equipment noise levels and site layouts were not determined at the time of the assessment and as such a combination of typical noise levels and project OHS design specifications have been used for modelled noisy equipment.

To predict the noise impact at the nearby receivers and approximation of the individual contribution from each major source is required. Where necessary, estimates of the contribution have been made based on measurements of similar sources from other sites. The major sources of noise emissions associated with each project component are presented below in Table 7.1. This table is not an exhaustive list of noise sources from the project however the main items of noisy plant have been identified for the noise model.

**Table 7.1 : Representative operational noise sources**

| Component | Equipment | Sound Power Level (SWL) dB(A) |
|---|---|---|
| Power plant – Flash steam condensing unit | Turbine (including exhaust ducting, inlet valves and pipes) | 93 |
| | Evaporative cooling towers | 81 |
| | Steam ejectors | 90 |
| | Pumps | 96 |
| | **TOTAL** | **99** |
| Power Plant – Organic Rankine Cycle unit | Turbine (including exhaust ducting, inlet valves and pipes) | 93 |
| | Air cooled condenser (ACC) fans | 88 |
| | Working fluid feed pumps | 97 |
| | Vapouriser / pre-heater / desuperheater | 76 |
| | **TOTAL** | **99** |
| Steam gathering system | Atmospheric flash tank | 118 |

| Component | Equipment | Sound Power Level (SWL) dB(A) |
|---|---|---|
| | Rock muffler | 80 |
| | Steam inlet pipes and valves inc. pressure control valves | 76 |
| | **TOTAL** | **118** |
| Reinjection wells | Reinjection pumps | 77 |
| Commissioning of both power plant and reinjection wells | Steam pressure releases | 118 |

** Noise levels for these units were unable to be obtained and as such an SWL of 93 has been used in this preliminary assessment, this being the OHS limit of 85dB(A) at a distance of 1m.*

The loudest noise events during operation are likely to be associated with either:

a) the emergency release of steam pressure as a result of a ruptured disk; or

b) steam vented from rock muffler when plant trips out or shuts down.

These events may be up to 140 dB(A), however will be very short term. Although noise levels from this event may be high, they will not exceed 1hr noise criteria due to their short duration.

The CONCAWE algorithm has been used to predict noise impacts from neutral weather conditions. Meteorological modelling and weather records have shown that temperature inversions are not a feature of the island and as such noise transmission under adverse weather conditions has not been considered.

Modelling of the plant site has assumed all equipment is operating at full capacity at the site boundary. No localised shielding on the project site (for example from buildings or other site equipment) has been included in the model. As such the following noise predictions represent an unlikely 'worst case' forecast of potential noise impacts.

### 7.1.2 Modelling Predictions

The noise levels were predicted for the nearest residential locations in each village as presented in Figure 6.1.

As emissions from the plant will remain steady, noise has been assessed against the more stringent night time criteria only. Table 7.2 and Table 7.3 present summaries of the noise predictions for the nearest locations against the night time noise goals.

The noise contours for the predicted noise levels for the two preferred power plant options have been overlaid onto the aerial photography and are presented in Appendix B.

Operational scenarios are defined using the following abbreviations:

- PS3 - Power Plant Steam Cycle – Site option 3
- PR3 - Power Plant Rankine cycle – Site Option 3
- SGS - Steam Gathering System
- RIW - Production / Reinjection Wells
- COM - Commissioning

**Table 7.2: Predicted operational noise levels (Neutral meteorological conditions)**

| Receiver | Operational noise criteria | Predicted maximum $L_{Aeq}$ during operation [dB(A)] | | | | |
|---|---|---|---|---|---|---|
| | Night | PS3 | PR3 | SGS | RIW | COM |
| Laudat (north) | 45 | IA | IA | 33 | IA | 33 |
| Laudat (south) | 45 | 40 | 38 | **53** | IA | **53** |
| Laudat (west) | 45 | 25 | 23 | 39 | IA | 39 |
| Trafalgar (east) | 45 | IA | IA | 45 | IA | 45 |
| Trafalgar (south) | 45 | IA | IA | **63** | 22 | **63** |
| Trafalgar (west) | 45 | IA | IA | 40 | IA | 40 |
| Copt Hall | 45 | IA | IA | 32 | IA | 32 |
| Shawford | 45 | IA | IA | 39 | IA | 39 |
| Fond Cani (north) | 45 | IA | IA | 36 | IA | 36 |
| Fondi Cani (south) | 45 | IA | IA | IA | IA | IA |
| Morne Prosper | 45 | IA | IA | 39 | IA | 39 |
| Wotten Waven | 51 | IA | IA | **57** | IA | **57** |
| Boiling Lake* | 45 | IA | IA | IA | IA | IA |
| Valley of Desolation* | 45 | IA | IA | IA | IA | 21 |
| Freshwater lake* | 45 | IA | IA | IA | IA | IA |

***BOLD*** *indicates a potential exceedance of construction noise criteria / IA = Inaudible [less than 20dB(A)]*

*= Major Significance of Impact; = Moderate Significance of Impact; = Minor Significance of Impact; = Negligible Significance of Impact*

**Table 7.3: Predicted operational noise levels (Enhanced meteorological conditions)**

| Receiver | Operational noise criteria | Predicted maximum $L_{Aeq}$ during operation [dB(A)] | | | | |
|---|---|---|---|---|---|---|
| | Night | PS3 | PR3 | SGS | RIW | COM |
| Laudat (north) | 45 | 22 | 20 | 40 | IA | 40 |
| Laudat (south) | 45 | 44 | 42 | **55** | IA | **55** |
| Laudat (west) | 45 | 29 | 27 | 45 | IA | 45 |
| Trafalgar (east) | 45 | 21 | IA | **50** | IA | **50** |
| Trafalgar (south) | 45 | IA | IA | **64** | 23 | **64** |
| Trafalgar (west) | 45 | IA | IA | 45 | IA | 45 |
| Copt Hall | 45 | IA | IA | 36 | IA | 36 |
| Shawford | 45 | IA | IA | 44 | IA | 44 |
| Fond Cani (north) | 45 | IA | IA | 42 | IA | 42 |
| Fondi Cani (south) | 45 | IA | IA | 25 | IA | 25 |

| Receiver | Operational noise criteria | Predicted maximum $L_{Aeq}$ during operation [dB(A)] | | | | |
|---|---|---|---|---|---|---|
| | Night | PS3 | PR3 | SGS | RIW | COM |
| Morne Prosper | 45 | IA | IA | 45 | IA | 45 |
| Wotten Waven | 51 | IA | IA | **60** | IA | **60** |
| Boiling Lake* | 45 | IA | IA | IA | IA | IA |
| Valley of Desolation* | 45 | IA | IA | IA | IA | 28 |
| Freshwater lake* | 45 | IA | IA | IA | IA | IA |

***BOLD*** *indicates a potential exceedance of construction noise criteria / IA = Inaudible [less than 20dB(A)]*

*= Major Significance of Impact; = Moderate Significance of Impact; = Minor Significance of Impact; = Negligible Significance of Impact*

## 7.2 Discussion

The predicted noise levels presented in Table 7.2 and Table 7.3 indicate that the operations of the Steam or Rankine power plant at the preferred site will most likely comply with the noise criteria at all surrounding residential receivers. The predicted noise levels show that operational noise from the Steam or Rankine power plant are inaudible at most surrounding receivers except at Laudat (south), Laudat (west) and Trafalgar (east). Operational noise levels of the Steam power plant are predicted to be up to 40 dB(A) during neutral weather condition and up to 44 dB(A) during enhanced weather condition. While operational noise levels of the Rankine power plant are predicted to be up to 38 dB(A) during neutral weather condition and up to 42 dB(A) during enhanced weather condition. Based on the predicted operational noise levels of the power plant, it can be seen that the Rankine power plant is the quieter option. Operational noise impacts of either Steam or Rankine power plant at the preferred site are considered to have negligible significance of impact at all surrounding receivers.

Operations of the production / reinjection wells are also predicted to comply with the noise criteria at all surrounding residential receivers. The noise modelling results show that production / reinjection wells are inaudible at most receivers except at Laudat (south), Trafalgar (east), Trafalgar (south), Trafalgar (west), Morne Prosper and Wotten Waven. The worst case operational noise impact of production / reinjection wells has been predicted to be 22 dB(A) during neutral weather condition and 23 dB(A) during enhanced weather condition. Both worst case operation noise impacts were predicted at Trafalgar (south). Production / reinjection wells are considered to have negligible significance of impact at all surrounding receivers.

Steam gathering system and commissioning noise impacts during neutral weather condition are predicted to exceed the noise criteria at Laudat (south), Trafalgar (south) and Wotten Waven, but are predicted to comply with the noise criteria at all other surrounding residential receivers. During enhanced weather condition, steam gathering system and commissioning noise impacts are predicted to exceed the noise criteria at Laudat (south), Trafalgar (east), Trafalgar (south) and Wotten Waven, but are predicted to comply with the noise criteria at all other surrounding residential receivers. The predicted noise impacts at Laudat (south), Trafalgar (east), Trafalgar (south) and Wotten Waven have been predicted to exceed the noise criteria by 10 dB(A), 5 dB(A), 19 dB(A) and 9 dB(A) respectively during enhanced weather condition. Steam gathering system and commissioning works will potentially have major significance of impact at Laudat (south), Trafalgar (east), Trafalgar (south) and Wotten Waven, but is considered to have negligible significance of impact at all other surrounding receivers. That said, it is understood that commissioning testing will only occur for a relatively short period and is therefore, not considered to be an adverse impact. The implementation of management measures, such as community consultation, notification, undertaking team gathering system operations and commissioning testing during daytime period only etc. would generally be sufficient in reducing receiver annoyance.

Recommended noise mitigation measures have been provided in Section 8 of this report to ensure that the power plant operates in a noise compliant manner.

# 8. Recommended Mitigation

## 8.1 Construction Noise

Worse case construction noise impacts are predicted to comply with the noise limits at all surrounding residential receivers. Notwithstanding this finding, it will be important for the contractor to undertake all reasonable and feasible measures to manage noise levels, minimise noise impacts and liaise with affected landowners and local communities.

During the planning and scheduling of construction works the predicted noise levels should be considered in establishing work site locations, construction techniques and on site practises. The following principles and proactive noise management measures should be considered for implementation:

- A Construction Noise Management Plan (CNMP) should be formulated to provide a framework for addressing construction noise levels. Noise control options including site mitigation and the investigation of low noise plant should be detailed and direction provided for the delivery of best practice noise management on site.
- Construction works should adopt Best Management Practice (BMP) and Best Available Technology Economically Achievable (BATEA) practices. BMP includes factors discussed within this report and encouragement of a project objective to reduce noise emissions. BATEA practices involve incorporating the most advanced and affordable technology to minimise noise emissions.
- Limit construction works to daytime hours where reasonable and feasible.
- Locating haul routes as far as possible from residential receivers
- Using equipment that has been well maintained so that noise emissions are minimised
- Provide localised noise screening where works are to be conducted within 200 metres (the compliance distance) of any sensitive receivers.
- Where possible, static construction plant such as generators should be located adjacent to on-site structures to impede noise propagation.
- Engines shall not be started and on-site activities shall not be undertaken outside of the daytime construction hours. Non noise generating works can be undertaken at staging areas where works are not adjacent to residential receivers.
- Construction activities should be undertaken in accordance with BS 5228, Code of Practice for Noise Control on Construction and Demolition Sites. All equipment used on site would be required to demonstrate compliance with the noise levels recommended within BS 5228.
- Appropriate use of all plant and equipment, with reasonable work practices applied, including no extended periods of ‘revving’, idling or ‘warming up’ in proximity to existing residential receivers. Any excessively loud activities should be scheduled during periods of the day when general ambient noise levels are greatest. This would reduce the potential for cumulative noise impacts (relating to worst-case elevated operations) and extended periods of off-site annoyance.
- Minimising reversing alarm noise emissions from mobile plant and transport truck operations should be considered, provided occupational health and safety requirements are satisfied. Where practicable, site entry and exit points should be managed to limit the need for reversing.
- Construction plant source noise levels should be confirmed prior to the commencement of works to verify construction noise impacts and noise management measures.
- Provide a summary of required construction noise management practices to all staff and contractors and be included during site inductions. The summary should include, as a minimum, the permitted hours of construction work, work site locations and site ingress/egress.
- Local residents and land owners are to be notified a minimum of 2 weeks prior to the commencement of construction works. The notification would detail proposed construction works, permitted hours of work and potential noise impacts.

## 8.2 Operational Noise

Based on the predicted noise levels as presented in Table 7.2, it is shown that the Rankine type power plant is the quieter compared to the Steam type power plant. Based on this assessment, it is recommended that the Rankine power plant be installed.

As the steam gathering system and commissioning phases of the power plant has the potential to adversely impact on surrounding residential receivers, it is recommended that the measures be implemented during these operations of the power plant:

- Steam gathering system operations and commissioning testing should be conducted during daytime periods only.
- Erect temporary localised screening during steam gathering system operations and commissioning testing. Potential noise impact reduction of up to 6 dB(A) is achievable where acoustic screens are located within 5 metres of the construction works, be at least 300 mm above the height of the noise source and provide a solid façade impeding line of sight to nearest receivers – any gaps negate noise reduction performance.
- Notify local residents and landowners prior to any steam gathering system operation and commissioning testing.

# 9. Conclusion

An assessment of construction and operational noise impacts on residential noise sensitive receivers has been undertaken for the proposed Project in the Roseau Valley, in central, southern Dominica. The assessment considered the operational noise impacts of the proposed Steam cycle and Rankine cycle options at the preferred site.

The construction noise assessment identified that these activities are expected to occur for at least two years. During this time, activities would incorporate a multitude of equipment combinations and locations within the site. The construction noise assessment has identified management levels at surrounding receivers for these impacts and undertaken typical construction scenarios to determine the likelihood of noise impacts at residential locations. The outcome of the construction noise assessment has identified that noise levels are not likely to cause adverse impacts at all surrounding receiver locations during all construction activities.

The operations of the power plant, steam gathering system, production / reinjection wells and commissioning were modelled using predictive noise modelling software. The result of these predictions indicates that power plant operations, production / reinjection wells operations are likely to comply with the noise criteria at all surrounding receivers. Steam gathering system and commissioning operations are likely to comply with the noise criteria at most receivers except at Laudat (south), Trafalgar (east), Trafalgar (south) and Wotten Waven.

To ensure that all construction activities are well within the noise management levels, mitigation measures such as formulating of construction noise management plan, adopting Best Management Practice and Best Available Technology Economically Achievable practices, limiting construction works to daytime hours, appropriate use of all plant and equipment etc. should be implemented.

To ensure steam gathering system and commissioning operational noise do not adversely impact on surrounding receivers, it is recommended that these two operations should be conducted during daytime periods only; temporary localised screening be installed during steam gathering system operation and commissioning testing, and local residents and landowners be notified prior to any of these operation.

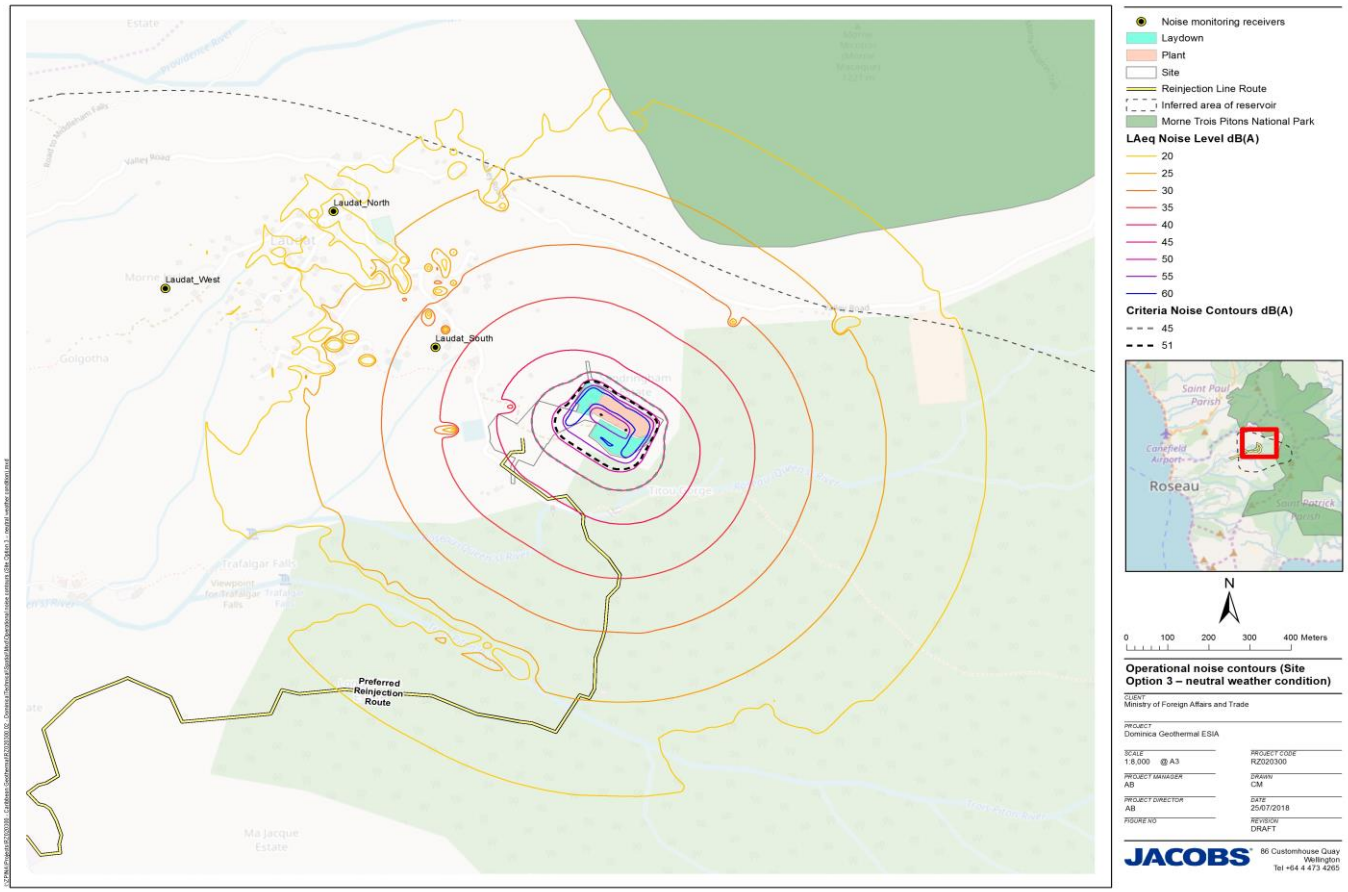
# Appendix A. Detailed monitoring results

| Location | Monitored noise level $L_{Aeq}$(period) dB(A) | | | |
|---|---|---|---|---|
| | Peak tourist season December 2013 | | Off tourist season April 2014 | |
| | Daytime (7am to 9pm) | Night time (9pm to 7am) | Daytime (7am to 9pm) | Night time (9pm to 7am) |
| Laudat | | | | |
| Location 1 | 39.5 | 44.5 | 42.0 | 47.0 |
| Location 2 | 39.5 | 42.0 | 42.0 | 44.0 |
| Location 3 | 39.5 | 42.5 | 43.5 | 43.5 |
| Location 4 | 39.0 | 40.0 | 42.5 | 45.0 |
| Location 5 | 40.0 | 41.5 | 43.5 | 44.5 |
| Location 6 | 44.5 | 45.0 | 43.5 | 45.5 |
| Location 7 | 36.5 | 40.5 | 42.0 | 45.0 |
| Location 8 | 35.5 | 40.5 | 38.0 | 42.0 |
| Location 9 | 36.5 | 49.0 | 41.5 | 43.5 |
| Location 10 | 39.0 | 51.0 | 44.0 | 49.5 |
| Location 11 | 53.0 | 53.5 | 51.0 | 52.0 |
| **Average** | **44.3** | **47.1** | **44.4** | **46.7** |
| **Maximum** | **53.0** | **53.5** | **51.0** | **52.0** |
| **Minimum** | **35.5** | **40.0** | **38.0** | **42.0** |
| Fond Cani North | | | | |
| Location 1 | 38.0 | 47.5 | 37.0 | 40.5 |
| Location 2 | 39.0 | 46.5 | 43.5 | 49.0 |
| Location 3 | 39.0 | 48.5 | 39.0 | 38.5 |
| Location 4 | 49.0 | 49.0 | 36.0 | 37.5 |
| **Average** | **44.0** | **48.0** | **39.9** | **44.1** |
| **Maximum** | **49.0** | **49.0** | **43.5** | **49.0** |
| **Minimum** | **38.0** | **46.5** | **36.0** | **37.5** |
| Fond Cani West and South | | | | |
| Location 1 | 49.5 | 46.5 | 48.5 | 48.5 |
| Location 2 | 59.5 | 60.0 | 57.5 | 57.5 |
| Location 3 | 55.0 | 49.5 | 57.0 | 43.0 |
| Location 4 | 47.0 | 47.0 | 46.5 | 44.0 |
| Location 5 | 43.0 | 50.0 | 46.0 | 45.0 |
| Location 6 | 46.0 | 50.0 | 46.5 | 46.5 |

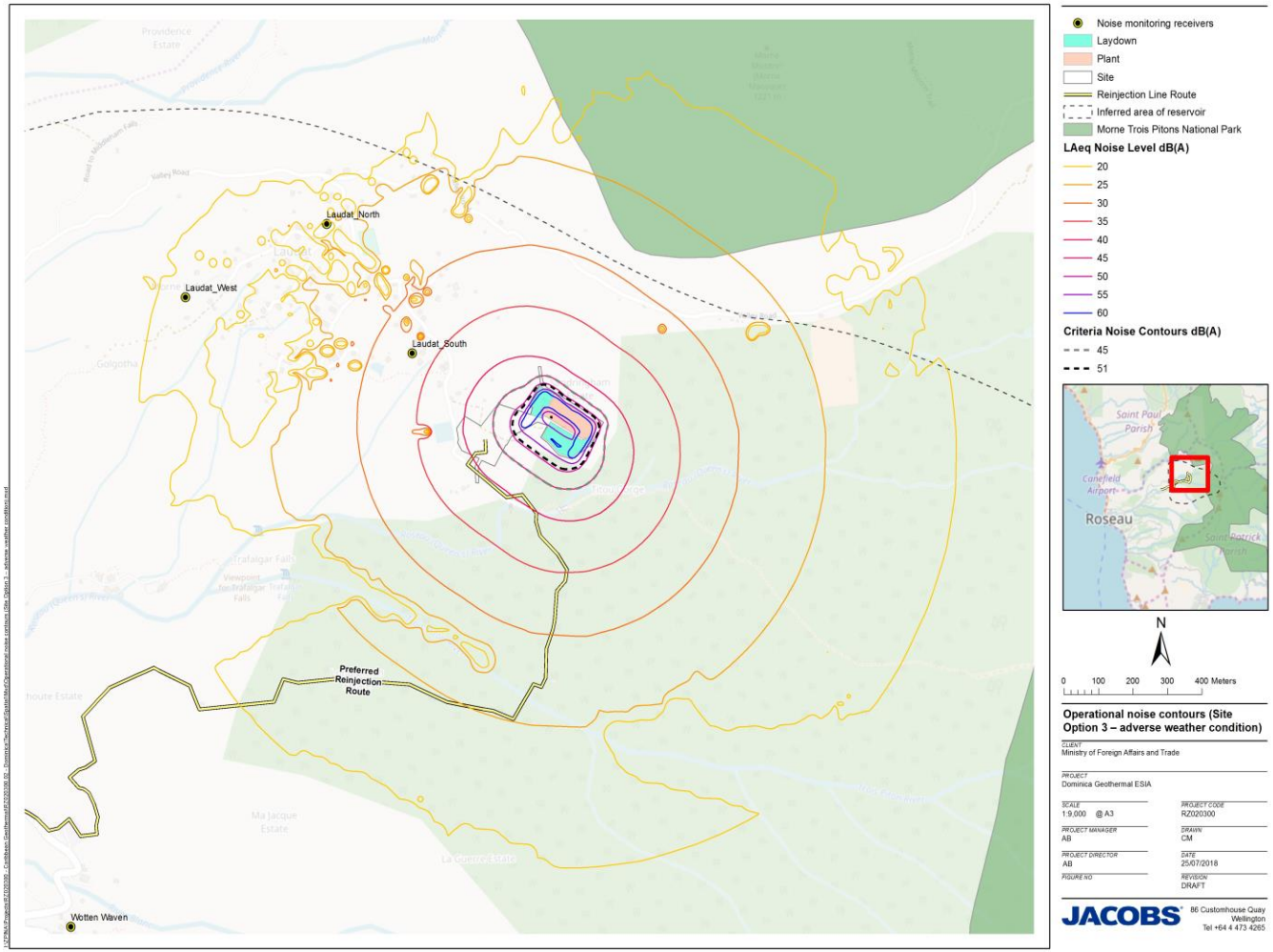
| Location | Monitored noise level $L_{Aeq}$(period) dB(A) | | | |
|---|---|---|---|---|
| | Peak tourist season December 2013 | | Off tourist season April 2014 | |
| | Daytime (7am to 9pm) | Night time (9pm to 7am) | Daytime (7am to 9pm) | Night time (9pm to 7am) |
| Location 7 | 46.0 | 50.0 | 42.0 | 41.0 |
| **Average** | **53.2** | **53.3** | **52.6** | **50.4** |
| **Maximum** | **59.5** | **60.0** | **57.5** | **57.5** |
| **Minimum** | **43.0** | **46.5** | **42.0** | **41.0** |
| Morne Prosper | | | | |
| Location 1 | 38.0 | 45.0 | 38.0 | 45.0 |
| Location 2 | 38.0 | 45.0 | 39.0 | 46.0 |
| Location 3 | 47.0 | 52.0 | - | - |
| Location 4 | 42.5 | 46.0 | 39.5 | 35.0 |
| Location 5 | 49.5 | 51.0 | 41.5 | 45.5 |
| Location 6 | 47.0 | 50.0 | 41.0 | 38.5 |
| Location 7 | 43.0 | 46.5 | 43.0 | 47.0 |
| Location 8 | 41.0 | 43.5 | 36.0 | 35.0 |
| Location 9 | 48.5 | 48.0 | 46.0 | 44.5 |
| **Average** | **45.6** | **48.4** | **41.3** | **43.6** |
| **Maximum** | **49.5** | **52.0** | **46.0** | **47.0** |
| **Minimum** | **38.0** | **43.5** | **36.0** | **35.0** |
| Wotten Waven | | | | |
| Location 1 | 40.0 | 53.0 | 45.5 | 49.0 |
| Location 2 | 41.0 | 45.0 | 47.0 | 51.0 |
| Location 3 | 39.5 | 45.0 | 41.0 | 48.0 |
| Location 4 | 43.0 | 49.0 | 46.0 | 48.0 |
| Location 5 | 45.5 | 46.5 | 49.5 | 51.0 |
| Location 6 | 46.0 | 52.0 | 45.5 | 48.0 |
| Location 7 | 49.0 | 50.5 | 49.0 | 50.0 |
| Location 8 | 48.5 | 57.0 | 46.0 | 50.5 |
| Location 9 | 49.0 | 57.5 | 49.0 | 49.5 |
| **Average** | **46.0** | **52.8** | **47.1** | **49.6** |
| **Maximum** | **49.0** | **57.5** | **49.5** | **51.0** |
| **Minimum** | **39.5** | **45.0** | **41.0** | **48.0** |
| Trafalgar | | | | |
| Location 1 | 44.0 | 47.0 | 44.0 | 44.5 |

| Location | Monitored noise level $L_{Aeq}$(period) dB(A) | | | |
|---|---|---|---|---|
| | Peak tourist season December 2013 | | Off tourist season April 2014 | |
| | Daytime (7am to 9pm) | Night time (9pm to 7am) | Daytime (7am to 9pm) | Night time (9pm to 7am) |
| Location 2 | 44.0 | 46.5 | 45.0 | 43.5 |
| Location 3 | 53.5 | 56.0 | 47.0 | 47.0 |
| Location 4 | 60.0 | 62.5 | 44.5 | 46.5 |
| Location 5 | 46.0 | 51.0 | 45.0 | 46.0 |
| Location 6 | 50.0 | 52.5 | 49.5 | 49.0 |
| Location 7 | 43.5 | 48.5 | 45.0 | 43.5 |
| Location 8 | 52.0 | 52.0 | - | - |
| Location 9 | 50.0 | 52.5 | 49.0 | 50.5 |
| Location 10 | 51.0 | 52.0 | 50.5 | 50.0 |
| Location 11 | 45.0 | 47.5 | 49.0 | 47.5 |
| Location 12 | 48.0 | 50.5 | 44.5 | 48.0 |
| **Average** | **52.0** | **54.4** | **47.1** | **47.3** |
| **Maximum** | **60.0** | **62.5** | **50.5** | **50.5** |
| **Minimum** | **43.5** | **46.5** | **44.0** | **43.5** |

# Appendix B. Predicted noise contours (Neutral weather condition)



# Appendix C. Predicted noise contours (Adverse weather condition)



# Appendix G. Technical Report – Morne Trois Pitons National Park Impact Assessment

Dominica Geothermal Development Company Limited
*Powering a New Generation...*

JACOBS

# Dominica Geothermal Development

# Environmental and Social Impact Assessment

Ministry of Foreign Affairs and Trade

## Morne Trois Pitons National Park Impact Assessment

RZ020300-0002-NP-RPT-0012 | V2

July 2018



# Dominica Geothermal Development – Environmental and Social Impact Assessment

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# Glossary

| | |
|---|---|
| ALOHA | Areal Locations of Hazardous Atmospheres |
| dB(A) | A-weighted decibels |
| DOMLEC | Dominica Electricity Services Limited |
| EIA | Environmental Impact Assessment |
| ESMP | Environmental and social management plan |
| ESIA | Environmental and social impact assessment |
| $H_2S$ | Hydrogen sulphide |
| IFC | International Finance Corporation |
| IUCN | International Union for the Conservation of Nature |
| MTPNP | Morne Trois Pitons National Park |
| MW | Megawatt |
| OUV | Outstanding Universal Value |
| PS | Performance Standard |
| UNDP | United Nations Development Programme |
| UNESCO | United Nations Educational, Scientific Cultural Organisation |
| WHC | World Heritage Centre |
| WHS | World Heritage Site |

# 1. Introduction

## 1.1 Overview

The Commonwealth of Dominica is a small island developing state in the Caribbean Sea. It has a population of approximately 72,000 people and a land area of approximately 750 km$^2$. Around 22% of the island is a protected area, of which approximately 9% is designated by the United Nations Educational, Scientific Cultural Organisation (UNESCO) as the Morne Trois Pitons National Park (MTPNP) World Heritage Site (WHS).

This report is one of several technical reports prepared as supporting documentation for an Environmental and Social Impact Assessment (ESIA) of the proposed 7 megawatts (MW) Dominica Geothermal Project (the Project), which is being developed by the Dominica Geothermal Development Company Ltd – a government owned Special Project Vehicle.

The proposed geothermal development is located approximately 460 m from the WHS boundary at the closest point. As such, an assessment of potential impacts on the WHS is required, consistent with the International Union for the Conservation of Nature (IUCN) World Heritage Advice Note on Environmental Assessment (IUCN, 2013).

The location of the Project in relation to the western boundary of Morne Trois Pitons National Park World Heritage Site is shown in Figure 1.1. The Project infrastructure is shown in more detail in Figure 1.1.

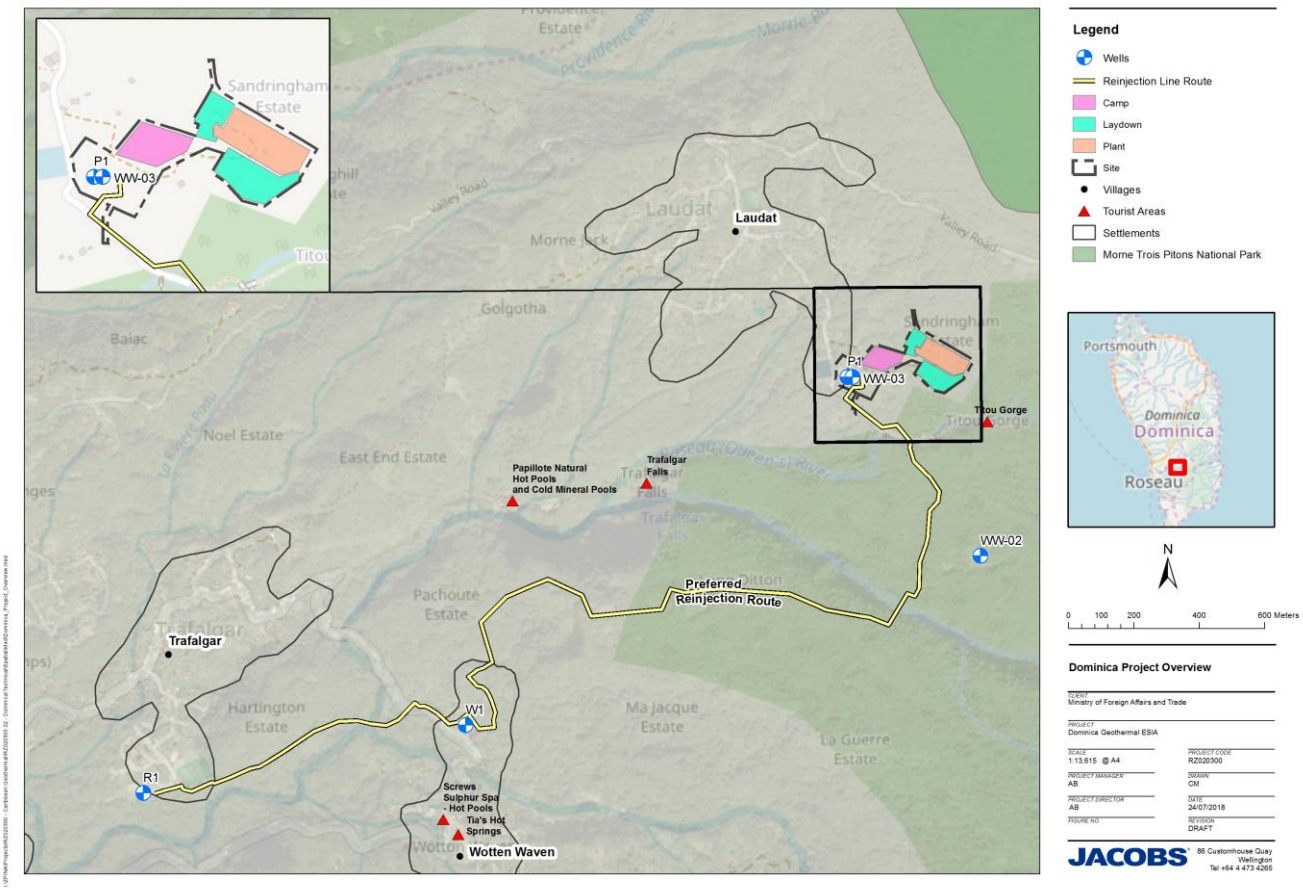


Figure 1.1: Location of power plant and reinjection pipeline (the Project) in the Roseau Valley

## 1.2 Proposed Development

The Project is proposed as a two-unit geothermal power plant with a gross capacity of 7 MW. Detailed descriptions of the Project infrastructure are provided in the Process Description, and summarised below.

- Power plant comprising 2 x 3.5 MW units (either single flash steam condensing cycle or organic Rankine cycle units (binary turbine), which will be adjacent to wells WW-P1 and WW-03. The binary power plants may use wet cooling or dry cooling;
- Production well WW-P1 – The existing geothermal production well at Laudat is indicated to have potential to generate 6 to 9 MW and will be the sole production well for the project;
- Reinjection wells WW-R1 (located in Trafalgar) and WW-01 (located in Wotten Waven) – The used geothermal fluid (brine and possibly some steam condensate) produced from production well WW-P1 would be disposed of into reinjection wells WW-R1 and WW-01 via a 250 to 300 mm diameter reinjection pipeline of up to 3.25 km in length;
- Steamfield infrastructure including two phase piping, steam separator, atmospheric flash tank, brine collection and disposal system, condensate collection and disposal system, pressure relief system, storage sump and rock muffler;
- Supporting infrastructure including existing well pads, turbine building, primary and ancillary equipment, cooling system, and water supply; and
- 11 kV interconnection to the DOMLEC electricity grid at the power plant site.

Further details of the specific Project elements are provided in ESIA Volume 1: Introduction and ESIA Volume 5: Technical Appendices, Technical Report – Detailed Process Description.

## 1.3 Activities Proposed

Since the commencement of exploratory drilling in 2011, five wells have been drilled (WW-P1, WW-R1, WW-01, WW-02 and WW-03). The Project will use the wells which have already been drilled and tested. As such this document assumes no drilling of new wells in advance of operation. If additional 'make-up' wells are required during the lifespan of the Project, a separate ESIA will be undertaken when the requirements are known. Maintenance of the existing wells is, however, considered within this ESIA. Project-related activities expected to be required are set out in Table 1.1. No part of the infrastructure lies within the boundaries of the WHS. Construction of the Project will take 18 months to two years.

**Table 1.1: Indicative activities required during each phase of the Project**

| Activity |
|---|
| **Construction** |
| • Vegetation clearance (outside boundaries of WHS) for the power plant site, laydown areas, reinjection route and creation/widening of access roads<br>• Earthworks (outside boundaries of WHS) for the power plant site, laydown areas, reinjection route and creation of access tracks for the reinjection line<br>• Operation of construction plant (outside boundaries of WHS)<br>• Increased presence of vehicles<br>• Increased human presence<br>• Release of run-off or sediments during construction<br>• Accidental spillage of chemical or hydrocarbon loads<br>• Use of water for equipment washdown, workers (potable and sanitary uses), and potentially a reserve for fire-fighting. Water could be abstracted from Titou Gorge Stream (c.150 m south of the plant, and downstream of the WHS). |
| **Operation** |
| • Monitoring and maintenance of the geothermal reservoir, including well workovers, as detailed in ESIA Volume 5: Technical Appendices, Technical Report – Detailed Process Description.<br>• Water use - for workers, supply for fire-fighting, and for maintenance and plant cleaning. This would be sourced from surface water |

| |
|---|
| sources and/or brought in from off-site<br>• Water abstraction – possible requirement to pump cold water from the Roseau River (from a location downstream of the WHS) to increase well injection capacity<br>• Increased human presence<br>• Emissions to air of non-condensable gases<br>• Air coolers, which do not have a visible plume of water vapour but may exhibit a heat haze OR water cooling towers, which have a visible plume of water vapour when the relative humidity of the atmosphere is high<br>• Other routine maintenance works<br>• If Organic Rankine Cycle (ORC) technology is selected, the flammable substance n-pentane will be required (c. 30 tonnes), to be stored in the condenser and process lines and in a bunded storage tank at the power plant site, in the condenser and process lines of the power plant. |
| **Decommissioning** |
| • Activities likely to be similar in nature to those during construction, above, but less extensive and intensive<br>• Plugging and abandoning geothermal wells |

## 1.4 Assessment Methodology

### 1.4.1 Introduction

World Heritage Sites are those places which have been determined by UNESCO to be of "Outstanding Universal Value"[1] (OUV), fulfilling at least 1 of 10 selection criteria, and meeting conditions relating to site integrity, and protection/management systems. Their designation indicates that they are deemed important to the collective interests of humanity.

In addition to the national legislation and financier's requirements regarding Environmental Assessments, as set out in the ESIA Volume 1: Introduction, Chapter 2, this assessment also reflects the requirements of the IUCN World Heritage Advice Note on Environmental Assessment (IUCN, 2013). The Advice Note provides guidance on integrating natural[2] World Heritage Sites, such as the MTPNP, within Environmental Assessments. The guidance is concerned specifically with impacts of the Project on the OUV of the site, rather than all potential impacts.

### 1.4.2 Outstanding Universal Value

OUV has three components:

- Values;
- Integrity; and
- Protection and management.

All development proposals that could affect the OUV of a WHS are required to be submitted by States Party to the World Heritage Committee before a decision on their funding, permitting or implementation is taken. As such, a copy of this ESIA will be provided to the World Heritage Committee for comment.

### 1.4.3 World Heritage Impact Assessment Principles

The World Heritage Advice Note sets out eight Impact Assessment Principles with which the assessment is required to comply. The principles are set out within Table 1.2, and references provided to their location for this development.

[1] Defined as *"…natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity."*

[2] World Heritage sites are designated by criteria which categorise them as natural, cultural or mixed.

**Table 1.2: World Heritage Impact Assessment Principles**

| No. | Requirement of Environmental Assessment for proposals affecting natural World Heritage Sites | Details / reference where addressed in report |
|---|---|---|
| 1 | Take place as early as possible in the decision-making process. | Consultation between the GoCD and the World Heritage Committee has been ongoing since the inception of the development proposals (as documented in UNESCO Mission Report (UNESCO, 2017b)). |
| 2 | Identify and evaluate reasonable alternatives to the proposal. | Section 3.2 |
| 3 | Assess the likely environmental and social effects of the development proposal(s) on the Outstanding Universal Value of the site. | Section 3 |
| 4 | Identify adequate mitigation measures for any residual negative impacts on Outstanding Universal Value that cannot be further reduced. | Section 4 |
| 5 | Include a separate chapter on World Heritage impacts in the Environmental Assessment report. | This document comprises the WHS assessment. |
| 6 | Be publicly disclosed and subject to thorough public consultation. | Details of consultation undertaken for the Project are detailed within Stakeholder Engagement Plan (located in ESIA Volume 5: Technical Appendices), and included consideration of the MTPNP. |
| 7 | Propose, implement and independently audit an environmental management plan. | Monitoring and management will be undertaken as detailed in Section 4. |
| 8 | Effectively integrate the conclusions of the assessment into the decision-making process. | The conclusions of this document and the ESIA as a whole will be taken into consideration by the deciding authorities, as required by national legislation and international standards. |

The guidance requires consideration of all likely effects of the proposal on the OUV of the WHS, including potential direct, indirect and cumulative effects. Potential social issues that could impact on the site's OUV should also be assessed, and a consideration provided of alternative options, including the 'no project' option.

### 1.4.4 Mitigation and Residual Impacts

Adequate mitigation measures are identified for potential minor residual negative impacts identified on OUV that cannot be avoided or further reduced. The assessment also notes how these measures will be implemented, who will implement them within what timeframe, and what resources are secured for their implementation.

The assessment presents conclusions on the proposal's potential negative impacts on all relevant aspects of OUV, including on values, integrity and protection and management.

Based on the findings of the assessment and any residual impacts, a preferred development proposal option/scenario is recommended.

# 2. Existing Environment

## 2.1 Background

The MTPNP World Heritage site was first proposed as a forest reserve in 1952. In 1975 it was designated a National Park under the National Parks and Protected Areas Act No.16. It was inscribed as a WHS in 1997 and falls within IUCN Management Category II: National Park.

## 2.2 Site Description

The MTPNP covers nearly 7000 hectares of the volcanic island, comprising a rugged mountain landscape and deep canyons. There are five live volcanic centres within the park, the highest of which reaches 1,342 metres. The landscape is scenically striking and features natural hot springs, bubbling mud ponds, lakes and magnificent waterfalls. Within the park are the sources of the major watercourses of the southern part of the island.

Amongst the park's most notable features are the Boiling Lake, a flooded fumarole which is consistently around 95°C, surrounded by impressive cliffs. The sounds, colours, heavy vapours and strong sulphurous smell make this a highly unusual sight. It is the largest feature of its type in the world and is a particular draw for tourists.

Fuelled by abundant seasonal rainfall (c.7 metres annually), lush vegetation covers much of the landscape of the MTPNP – an exception being the comparatively barren 'Valley of Desolation'. The extreme topography and varied mosaic of vegetation and habitats makes for a highly diverse ecological system supporting a wide variety of species.

The area of the inscribed site is 6,857 hectares. A number of changes to the boundaries have taken place since, and formal publication of the current boundary and buffer zone is understood to be expected in the near future.

### 2.2.1 Hurricane Maria

Hurricane Maria caused havoc and destruction on the night of Monday 18 September 2017. MTPNP would have been undoubtedly damaged, first hand observations mention forest defoliation of between 80 to 90% ultimately leading to tree deaths (DominicaVibes, 2017) with Dominica's wildlife having been severely hit. Conservation efforts associated with the island's rare bird species (Imperial Parrot and Red-necked parrot) ensured that a number kept in captivity were held safe (American Bird Conservancy, 2018). Populations in the wild have fared less well. Rainforest ecosystems such as those found on Dominica have been through previous hurricane events and vegetation cover and habitat integrity has returned rapidly (within 2 years; DominicaVibes, 2017) reaching semi-maturity or maturity.

The damage caused by the hurricane to MTPNP is not addressed further in this impact assessment. However, further actions have been proposed in the chapter covering Terrestrial Ecology Impact Assessment.

## 2.3 Designation

### 2.3.1 Values

In respect of the "Values" component of OUV, the site was inscribed under natural criteria (viii) and (x).

**Criterion (viii):** earth processes[3]. The application to this site is summarised as follows:

- The array and intact nature of geomorphologic features;

[3] *"Outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features"*

- The distinctive geology and landforms comprised of three major types of geological formations;
- The spectrum of volcanic activity in the form of streams of various colours, fumaroles, mud ponds and hot springs; and
- The ongoing geomorphological processes of reduction taking place in a largely undisturbed setting, which are of great scenic value and major scientific interest.

**Criterion (x):** threatened species and their habitats[4]. The application to this site is summarised as follows:

- The site is a very rare example of a largely intact forest areas remaining in the Insular Caribbean;
- Its high levels of endemism (birds, plants and herpetofauna), within a region recognised as a centre of endemism of global importance and with highly threatened biodiversity; and
- The variety of forest types, and associated diverse flora.

### 2.3.2 Integrity

Integrity is a measure of 'wholeness' and requires assessment of the extent to which the site:

1) Includes all elements necessary to express its OUV;
2) Is of adequate size to ensure the complete representation of features and processes which convey its significance; and
3) Suffers from negative effects of developments and/or neglect.

UNESCO (2017a) details the site's compliance with these criteria. It notes that the MTPNP supports a "microcosm of Dominica's biological diversity and species endemism, and provides intact and protected habitat for a wide diversity of flora and fauna, including a range of endemic species across several taxonomic groups".

### 2.3.3 Protection and Management

Responsibility for protection and management of the MTPNP falls under the remit of the Division of Forestry, Wildlife and National Parks, which is part of the Ministry of Agriculture and Fisheries. Day-to-day responsibility for the MTPNP lies with the National Parks Unit of the Division.

In March 2017, a joint World Heritage Centre (WHC) and IUCN 'reactive monitoring mission' to the MTPNP took place. The mission reported the site to be in a good state of conservation (UNESCO, 2017a/b). This is in part due to the natural protection afforded by the harsh terrain and the lack of road infrastructure through most of the site. Some agricultural encroachment has been noted in the south of the site. Neither report identified any immediate threat to the park's essential attributes and natural heritage values, provided legal requirements continue to be maintained and enforced. A summary of the mission findings and their implications for the Project is provided in Section 2.7.

## 2.4 Existing Site Conditions

### 2.4.1 Introduction

Based on the scale of the proposed development, the activities required, and its distance from the WHS, a high-level baseline is provided, focussed on threatened and protected features.

### 2.4.2 Flora / Habitats

Five forest types can be distinguished within the MTPNP, including rare elfin or cloud forest at the highest elevations, followed at progressively lower elevations by montane forest, rainforest, seasonal forest, dry scrub

[4] *"Contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation."*

woodland and littoral woodland. The microclimatic variations afforded by the terrain support a wealth of plant species, including endemic vascular plant species (recorded as 21 in 1997).

The site is the largest of the national parks in the Windward Islands and Leeward Islands, has the most varied volcanic features, and is the only one with major forest cover.

**Table 2.1: Sensitive feature of the MTPNP – flora/habitats**

| Component of OUV | Category of feature | Examples |
|---|---|---|
| Values | Threatened species and their habitats[5] | • elfin forest<br>• montane forest<br>• rainforest<br>• seasonal forest<br>• dry scrub woodland<br>• littoral woodland<br>• endemic vascular (recorded as 21 in 1997) and non-vascular plants |

### 2.4.3 Fauna

The rich and varied fauna includes endemic reptiles and amphibians, and 80% of the island's bird species, including the Vulnerable[6] and endemic red-necked parrot (*Amazona arausiaca*). This species lives in forested areas in just a handful of areas on Dominica. In total 17% of the island's population distribution occurs within the MTPNP. Adjacent areas of critical importance are not protected and one of the major threats to the species is habitat loss, mainly caused by clearance for agriculture (UNESCO, 2017b).

Other species recorded in 1997 were 12 species of bat, 12 species of herpetofauna and 30 decapod crustaceans. The park also provides habitat for the Imperial parrot or Sisserou (*Amazona imperialis*), the island's national bird and of symbolic importance due to its inclusion on the national flag.

**Table 2.2: Sensitive feature of the MTPNP – fauna**

| Component of OUV | Category of feature | Examples |
|---|---|---|
| Values | Threatened species and their habitats | Globally threatened species (IUCN Red List of Threatened Species):<br>• Critically Endangered giant ditch frog (*Leptodactylus fallax*)<br>• Endangered, endemic and restricted-range imperial parrot;<br>• Endangered and endemic tree frog (*Eleutherodactylus amplinympha*)<br>• Vulnerable, endemic and restricted-range red-necked parrot;<br>• Vulnerable and restricted-range forest thrush (*Turdus lherminieri)*<br>15 restricted-range bird species:<br>• Lesser Antillean swift (*Chaetura martinica*)<br>• Green-throated carib (*Eulampis holosericeus*)<br>• Purple-throated carib (*Eulampis jugularis*)<br>• Blue-headed hummingbird (*Cyanophaia bicolor*)<br>• Antillean crested hummingbird (*Orthorhyncus cristatus*)<br>• Lesser Antillean flycatcher (*Myiarchus oberi*)<br>• Lesser Antillean pewee (*Contopus latirostris*)<br>• Scaly-breasted thrasher (*Allenia fusca*)<br>• Pearly-eyed thrasher (*Margarops fuscatus*) |

[5] Under the definitions of the International Finance Corporation (IFC) Performance Standard 6 (PS6), habitats of significant importance to Critically Endangered, Endangered, endemic or restricted-range species, are considered Critical.
[6] IUCN Red List http://www.iucnredlist.org/details/22686395/0

| Component of OUV | Category of feature | Examples |
|---|---|---|
| | | • Brown trembler (*Cinclocerthia ruficauda*)<br>• Rufous-throated solitaire (*Myadestes genibarbis*)<br>• Antillean euphonia (*Euphonia musica*)<br>• Plumbeous warbler (*Setophaga plumbea*)<br>• Lesser Antillean bullfinch (*Loxigilla noctis*)<br>• Lesser Antillean saltator (*Saltator albicollis*) |

## 2.5 Social Context

28 villages lie within a mile of the MTPNP boundaries, although there are no settlements or major roads within the park itself. There is a small quarry in the northeast of the park, and very limited areas of other activities, but it is otherwise a largely undisturbed environment. Tourism activities are present but limited in extent due to the poor infrastructure. In 1997, 10,000 -15,000 visitors were thought to hike to the Emerald Pool, and 1,500-2,000 to the Boiling Lake; it is possible that these figures have increased in the intervening years. An 'aerial tram' was developed, which took visitors into the park itself, however operation ceased some years ago due to financial reasons. Water and power rights are granted to DOMLEC through the park and have not resulted in any major issues to date.

## 2.6 Evaluation

The impact assessment in Section 3 considers potential impacts of the development on the three elements of OUV of the WHS. The occurrence of a likely significant effect requires both an impact on a sensitive feature, and an effects pathway. As per the site's inscription, the sensitive features of the MTPNP can be categorised as shown in Table 2.3. The presence or absence of an effects pathway from the proposed development on each of the features is therefore also shown.

**Table 2.3: Elements of the OUV of MTPNP**

| Component of OUV | Category of feature (where applicable) and examples | Effects pathway possible |
|---|---|---|
| Values | Earth processes:<br>• array of geomorphologic features<br>• the distinctive geology and landforms<br>• the spectrum of volcanic activity including streams, fumaroles, mud ponds and hot springs<br>• the ongoing geomorphological processes | No |
| | Threatened species and their habitats:<br>• see Table 3<br>• see Table 4 | Yes |
| Integrity | • intact nature of geomorphologic features<br>• largely undisturbed setting<br>• natural attributes considered to be whole and intact<br>• site includes all elements necessary to express its outstanding universal value<br>• site is of adequate size to express its outstanding universal value | Yes |
| Protection and management | • adequate systems of protection and management in place to safeguard the future of the site | No |

As shown in Table 2.3, earth processes and geological/geomorphological features are unlikely to be affected by the proposed scheme as no effects pathways have been identified. The assessments of geology, soils and groundwater, and of geothermal resources within the ESIA Volume 2: EIA concluded no significant impacts on geothermal features inside the park. It should be noted that natural variation is observed in the characteristics

of some features of the MTPNP. The Boiling Lake, for example, has been known to vary in water level, and even to disappear periodically; this last occurred in early 2017 and before that, about 12 years ago.

Similarly, to the geomorphology of the MTPNP site, no changes to the protection and management of the site are part of the proposals, and there is considered to be no pathway for impacts on this element of the OUV. Thus no adverse impacts are anticipated on the above, and these features are therefore not discussed further.

## 2.7 UNESCO Visit

The objectives and corresponding findings of the 2017 WHC/IUCN mission to the MTPNP are summarised below. The resulting recommendations of the report are provided in Section 4, and will sit alongside the mitigation detailed by this assessment.

i. Consider the impacts of existing and potential future geothermal infrastructure in the Roseau Valley.

It was reiterated to the mission team that no development of geothermal infrastructure would ever be allowed within the MTPNP and proposed buffer zone. No actual or potential threats to the site were identified in relation to the four existing but non-operational wells, however two (at Laudat village and Trafalgar) were considered to require specific and enhanced monitoring to safeguard this.

ii. Assess progress towards the development of this ESIA.

Draft Terms of Reference for this ESIA were submitted to the World Heritage Centre for review by IUCN shortly after the mission. These incorporated the need to integrate in the study a specific assessment of potential impacts on the site's OUV.

iii. Identify any other potential threats to the OUV of the site.

Climate change was identified as a primary potential threat in the future, as well as hydropower development and tourism pressure.

iv. Assess current arrangements in respect of integrity, and of protection and management.

Resources were described as "stretched yet effective", and the legislation was reported to define clearly the site as a no-take area with strictly regulated access. An enhanced management plan in respect of all the protected areas on the island and supported by the United Nations Development Programme (UNDP) is in development. Ongoing studies in relation to a buffer zone and zoning strategy, funded by the World Bank were also reported to be in progress.

# 3. Assessment of Impacts

## 3.1 Assessment of Proposed Project Design

The significance of an impact can be considered a product of the magnitude of the impact and the sensitivity of the feature. The term 'magnitude' encompasses: duration and spatial extent of the impact; reversibility; likelihood; and compliance with legal standards and established professional criteria. 'Sensitivity' is a measure of the feature's capacity to absorb proposed changes and/or the opportunities for mitigation. For further details of impact assessments methodology, reference should be made ESIA Volume 2: EIA.

Significance is classified in accordance with the impact evaluation matrix in Table 3.1, which considers the magnitude and sensitivity of the impact.

For those sensitive features of the OUV for which there exists an effect pathway, likely effects from direct, indirect and cumulative impacts of the proposal are assessed in Table 3.2. Of the activities set out within Section 1.3, only those activities which have potential to have an impact on the WHS are included. The magnitude, sensitivity and resulting significance are also detailed in Table 3.1.

**Table 3.1: Impact evaluation matrix**

| | | Magnitude | | | |
|---|---|---|---|---|---|
| | | **Major** | **Moderate** | **Minor** | **Negligible** |
| **Sensitivity** | **High** | Major | Major | Moderate | Negligible |
| | **Medium** | Major | Moderate | Minor | Negligible |
| | **Low** | Moderate | Minor | Negligible | Negligible |
| | **Negligible** | Minor | Negligible | Negligible | Negligible |

**Table 3.2: Assessment of significance of impact on WHS in the absence of mitigation**

| Activity | Potential impact | Effect | Magnitude | Sensitivity | Significance |
|---|---|---|---|---|---|
| **Construction** | | | | | |
| Vegetation clearance | • loss of habitat (outside the WHS)<br>• reduction of ecological connectivity | Habitat loss and resulting fragmentation outside the WHS has a low likelihood of indirectly and/or cumulatively contributing to similar effects within the WHS, including Critical habitat. This is because of the scale of the Project infrastructure and high degree of regeneration post-disturbance.<br>Removal of nests or nesting habitat outside the WHS which would otherwise act as fringe habitat and extend the range of a species, including species which are threatened and/or protected.<br>Reduction of foraging habitat for species which may move in and out of the site. | Minor | Medium | Minor |
| Construction activities including earthworks, excavations, creation/widening of access roads, and the operation of construction plant | • noise | Construction noise levels have been modelled for three points within the MTPNP: Boiling Lake, Valley of Desolation and Freshwater Lake. Noise levels are predicted to be inaudible (less than 20dB(A)) under all 13 construction scenarios. | Negligible | Medium | Negligible |
| | • harmful air emissions<br>• dust<br>• night-time illumination of platforms | If of sufficient magnitude, air emissions and dust could result in disturbance to animals within the WHS, and associated stress and reduction in fecundity.<br>Air emissions and dust during construction have been modelled for three points within the MTPNP: Boiling Lake, Valley of Desolation and Freshwater Lake.<br>Maximum predicted concentrations of hydrogen sulphide ($H_2S$) decrease rapidly with distance from the power plant and adverse impacts are not | Negligible | Low | Negligible |

| Activity | Potential impact | Effect | Magnitude | Sensitivity | Significance |
|---|---|---|---|---|---|
| | | expected.<br>Dust emissions from 'small'[7] earthworks are considered negligible at distances >200m.<br>Works on tracks and the laydown area would be no greater than the exploration activities already undertaken.<br>There is a small potential for cumulative impacts of $SO_2$ and particulate matter, however the effect at the MTPNP would be negligible.<br>Lighting of platforms is unlikely to be sufficiently disturbing at 600m to result in stress, behavioural changes or reduced breeding success. | | | |
| | • introduction/spread of invasive plant species | Spread of invasive species into the WHS, which may outcompete native species. However, no air-dispersed plant species are known to be of concern in this area. Construction plant and vehicles will not drive onto the WHS so no impacts will occur. | Minor | Medium | Minor |
| | • release of hazardous substances from accidental spillage or major accident | Uncontrolled discharges of geothermal fluids (brine and condensate) can be harmful to the environment, containing substances such as arsenic and boron. Brine is also very hot.<br>Unless occurring on a major scale, however, release of contaminants is unlikely to result in significant impacts, as the WHS is upstream of the Project site.<br>Uncontrolled discharges of geothermal fluids (brine and condensate | Minor | Medium | Minor |
| | • run-off or sedimentation | Unless occurring on a major scale, contamination of watercourses is unlikely to result in significant impacts, as the WHS is upstream of the Project site. | Minor | Medium | Minor |

[7] As defined in the Institute of Air Quality Management (IAQM) (2011). For details see the ESIA Volume 3: EIA, Chapter 4 - Air Quality.

| Activity | Potential impact | Effect | Magnitude | Sensitivity | Significance |
|---|---|---|---|---|---|
| Increased presence of vehicles | • noise and vibration<br>• dust<br>• emissions to the air<br>• collision with animals | Effects would be as above, but not on a scale that would be noticeable at the MTPNP.<br>Vehicles would not be present on the MTPNP, and encounters with animals outside the park boundaries are considered unlikely. | Minor | Low | Negligible |
| Increased human presence | • encroachment<br>• increased access to WHS through improved infrastructure | An influx of workers in search of employment, and associated businesses and services, may result in settlements growing. This may place increased pressure on resources such as land, water, waste disposal procedures. Given the Project site is on a small island this is unlikely to occur on scale that would impact the WHS. | Minor | Low | Negligible |
| **Operation** | | | | | |
| Operation of power plant (including turbines, fans, pumps etc.), reinjection wells, and steam pressure releases during commissioning of both power plant and reinjection wells | • noise | Operational noise levels have been modelled for three points within the MTPNP: Boiling Lake, Valley of Desolation and Freshwater Lake. Noise levels are predicted to be inaudible (less than 20dB(A)) under all 10 operational scenarios, with one exception, which is 21dB(A) at the Valley of Desolation, during steam pressure releases. Noise level changes of 3dB(A) are imperceptible to human receptors and a change of 1dB(A) is therefore negligible, even for sensitive animals. | Negligible | Medium | Negligible |
| | • harmful air emissions | If of sufficient magnitude, air emissions and dust could result in disturbance to animals within the WHS, and associated stress and reduction in fecundity.<br>Air emissions and dust during construction have been modelled for three points within the MTPNP: Boiling Lake, Valley of Desolation and Freshwater Lake.<br>Maximum predicted concentrations of hydrogen sulphide ($H_2S$) were found to decrease rapidly with | Negligible | Low | Negligible |

| Activity | Potential impact | Effect | Magnitude | Sensitivity | Significance |
|---|---|---|---|---|---|
| | | distance from the power plant and adverse impacts are not expected. | | | |
| Maintenance activities including well workovers and cleanouts, which could include small-scale drilling | • release of toxic gas e.g. hydrogen sulphide<br>• noise<br>• vibration | In high concentrations hydrogen sulphide can result in necrosis and mortality.<br>Vibration, noise and lighting may affect fauna, resulting in stress, behavioural changes, reduced breeding success.<br>The above are not expected to be experienced within the WHS boundaries at a magnitude that would be above negligible. | Minor | Low | Negligible |
| Increased human presence | • encroachment<br>• increased access to WHS through improved infrastructure | A workforce of only two or three workers is expected during operation; therefore, no impacts are expected. | Minor | Low | Negligible |
| If ORC technology is selected, storage and use of the flammable substance n-pentane | • leak or rupture of n-pentane storage tank at the power plant | Based on the Areal Locations of Hazardous Atmospheres (ALOHA) modelling detailed within ESIA Volume 2: EIA, Chapter 15, the spatial extent and level of consequence of a leak or rupture of an n-pentane storage tank at the power plant was estimated for three scenarios.<br>The effects at the WHS boundary under this scenario were negligible. | Minor | Low | Negligible |
| | • leak or rupture of n-pentane storage tank at the power plant resulting in a pool fire in the bund | Under the modelled scenario, the effects at the WHS boundary were negligible. | Minor | Low | Negligible |
| | • boiling liquid expanding vapour explosion (BLEVE)[8] | Under the modelled scenario the thermal radiation from this event sufficient to cause pain (to humans) within 60 seconds extends to 462m from the incident location, which is approximately 140m from the WHS | Moderate | Low | Minor |

[8] A BLEVE is an explosion caused by the rupture of a vessel containing a pressurised liquid above its boiling point. This is a rare event that can occur only if safety measures fail completely or in other very unusual circumstances.

| Activity | Potential impact | Effect | Magnitude | Sensitivity | Significance |
|---|---|---|---|---|---|
| | | boundary. Effects at this distance could be sufficient to cause disturbance and damage to plants and animals. | | | |
| **Decommissioning** | | | | | |
| Activities likely to be undertaken will be similar in nature to those during construction but will likely be less extensive and intensive. These activities may include plugging and abandoning geothermal wells. | An indicative operational lifetime for the Project is 30 years. After this point, a programme of activities will be required to decommission the above-ground facilities and remediate the site to an agreed level.<br>Because of the long timescale until this phase of the Project occurs, it is recommended that a separate assessment of impacts is undertaken at that time, including all mitigation and monitoring required to avoid significant adverse impacts on OUV. | | | | |

## 3.2 Alternatives

The preferred power plant site and reinjection pipeline route were selected through a multi-criteria assessment process covering a range of technical, socio-economic and environmental issues. The presence of the WHS was one of the environmental considerations.

### 3.2.1 Reinjection Route

In July 2016, eight possible routes for the reinjection pipeline were identified. Three were shortlisted on the basis of constructability, topography, and proximity to local villages. Following public consultation and the completion of a LIDAR survey, a preferred option was selected. The Preferred Route comprises sections along the general alignment of 'H' and 'F' (see Figure 3.1); this route passes furthest from the WHS of the eight, and also had advantages in respect of safety during construction, disturbance to the local community, potential for interference with existing infrastructure, possible impacts on tourism, and long-term resilience to flooding events.

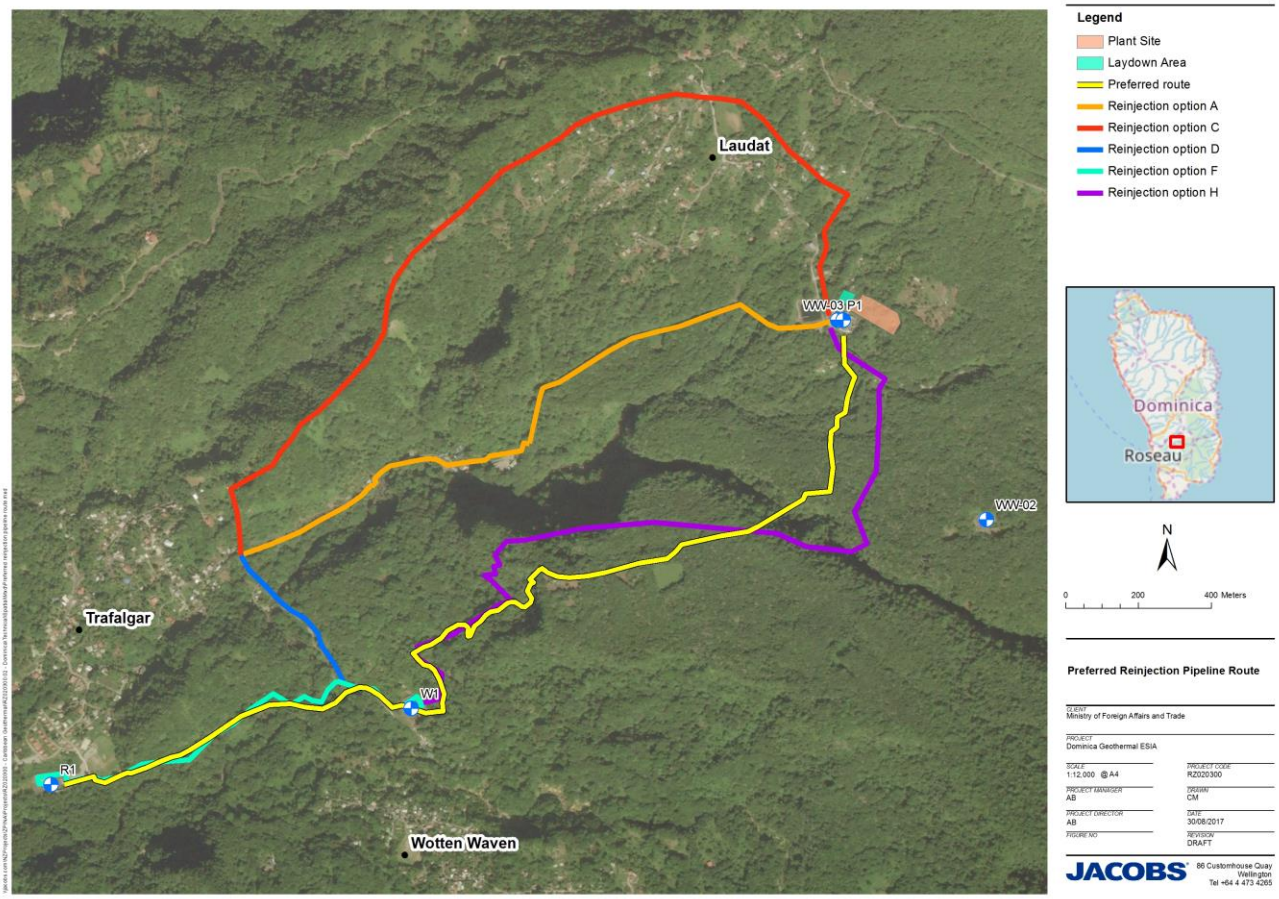


**Figure 3.1: Reinjection line route options considered, including the Preferred Route**

### 3.2.2 Project Site Alternatives

Three sites were considered for the power plant (1/1A, 2 and 3), each situated around WW-P1. ESIA Volume 1: Introduction, Section 4 provides a detailed assessment of alternatives and justification for the proposed option. Because the options are situated close together, there were no considerations between the three in relation to the WHS. The preferred option was selected on other grounds.

### 3.2.3 'No Project' Option

The 'do-nothing' option for the Project would result in the continued 'status-quo' for energy generation and reliance on diesel power within Dominica. The proposed Project represents a step change for Dominica in moving towards renewable sources of energy generation, increasing competitiveness, and providing improved energy security. The 'do-nothing' option is therefore not considered viable as it does not meet the Government's policy objectives, as detailed in the ESIA Volume 1: Introduction, Section 4**.**

Renewable energy is considered of particular relevance to Dominica in light of its island status and therefore its susceptibility to climate change-related increases in sea-level, and increased incidence and magnitude of tropical storms and hurricanes. Reliance on fossil fuels for energy, and the associated air emissions, is known to be a major contributor to climate change.

# 4. Mitigation and Monitoring

## 4.1 Mitigation for Minor Impacts

No significant (greater than minor) negative impacts have been identified through the assessment process. Although non-significant, the IUCN guidance requires that “adequate” mitigation is also identified for minor impacts on OUV. Mitigation for minor effects identified in Table 4.1 is detailed in Table 4.2.

## 4.2 Generic Good Practice Mitigation

The following generic good practice mitigation is considered adequate to further minimise adverse impacts, including negligible impacts:

- Implement dust-suppression measures such as covering vehicles transporting materials, ensuring vehicles use wheel wash facilities at site, and use of water spray dust suppression systems.
- Highly noisy activities should be undertaken during daylight hours where possible.
- Inductions/tool-box talks for staff should include reference to measures required to protect biodiversity.
- Proposals for the MTPNP buffer zone should be progressed, and this area maintained as a development-free zone. Activities that would facilitate access to the MTPNP should not be encouraged.
- Standard safe storage for n-pentane includes storage under a nitrogen blanket; incorporation of a Pressure Relief Valve; appropriate bunding; and a deluge fire extinguishment system. Heat and pentane sensors are also fitted around the storage tank and the plant to detect any leaks and heat changes.

## 4.3 Implementation of Mitigation

Implementation of mitigation will be prior to the phase in which the corresponding impact is expected to occur. Responsibility for the implementation of mitigation set out in the ESIA will become the responsibility of the appointed Engineering, Procurement, and Construction Contractor, overseen by the Dominica Geothermal Development Company Ltd.

**Table 4.1: Mitigation for minor impacts, and resulting residual effects**

| Activity | Potential impact | Potential Impact | Significance | Mitigation | Residual |
|---|---|---|---|---|---|
| Vegetation clearance | • Loss of habitat outside the WHS<br>• Reduction of ecological connectivity | Habitat loss and resulting fragmentation outside the WHS has a low likelihood of indirectly and/or cumulatively contributing to similar effects within the WHS, including Critical habitat.<br>This is because of the scale of the Project infrastructure and high degree of regeneration post- disturbance.<br>Removal of nests or nesting habitat outside the WHS which would otherwise act as fringe habitat and extend the range of a species, including species which are threatened and/or protected.<br>Reduction of foraging habitat for species which may move in and out of the site. | Minor | • Vegetation clearance activities should commence outside the breeding season for five key threatened species identified, to minimise impacts on breeding animals. The breeding seasons of the three bird species are overlapping, between January and August[9]. The amphibian species are thought to breed year-round, but primarily between May and July[10].<br>• Habitat cleared should be the minimum possible, with any way-leave area required of the minimum width necessary.<br>• Use temporary fencing to prevent inadvertent damage outside designated construction areas.<br>• Avoid piling of clear-felled vegetation on standing live vegetation which would hinder movement of wildlife. | Negligible |
| Construction activities including earthworks, excavations, creation/widening of access roads, and the operation of construction plant | • Introduction/spread of invasive plant species | Spread of invasive species into the WHS, which may outcompete native species. However, no air-dispersed plant species are known to be of concern in this area. Construction plant and vehicles will not drive onto the WHS so no impacts will occur. | Minor | • Any replanting / landscaping should use native or endemic species to prevent the incursion of opportunistic invasive species.<br>• Machinery and vehicles should be cleaned upon entry/exit, and any soil brought on or off site screened for invasive species or plant pathogens. | Negligible |
| | • Release of hazardous substances from accidental spillage or major accident | Uncontrolled discharges of geothermal fluids (brine and condensate) can be harmful to the environment, containing substances such as arsenic and boron. Brine is also very hot.<br>Unless occurring on a major scale, however, release of contaminants is unlikely to result in significant impacts, as the WHS is upstream of the Project site.<br>Uncontrolled discharges of geothermal fluids | Minor | • Minimise potential for sedimentation impacts by ensuring good construction site practices are implemented.<br>• Appropriate disposal of solid and liquid wastes, in line with recommendations in international and national standards, and using designated facilities as required.<br>• Any effluent discharged to surface watercourses must meet the more stringent of international water quality discharge standards prior to release to remove pollutants. | Negligible |

[9] http://www.iucnredlist.org/ (Accessed September 2017)
[10] http://www.amphibianark.org/pdf/Husbandry/Leptodactylus%20fallax%20-%20Management%20Guidelines.pdf (Accessed September 2017)

| Activity | Potential impact | Potential Impact | Significance | Mitigation | Residual |
|---|---|---|---|---|---|
| | | (brine and condensate | | | |
| | • Run-off or sedimentation | Unless occurring on a major scale, contamination of watercourses is unlikely to result in significant impacts, as the WHS is upstream of the Project site. | Minor | • Minimise potential for pollutants and surface water run-off to migrate off-site by ensuring standard good construction site practices are implemented. | Negligible |
| Storage and use of the flammable substance n-pentane | • Boiling liquid expanding vapour explosion (BLEVE)[11] | Under the modelled scenario the thermal radiation from this event sufficient to cause pain (to humans) within 60 seconds extends to 462m from the incident location, which is approximately 140m from the WHS boundary. Effects at this distance could be sufficient to cause disturbance and damage to plants and animals. | Minor | • Detailed measures to minimise the likelihood and magnitude of a BLEVE occurring is provided in ESIA Volume 2: EIA, Chapter 15, including:<br>- Induction and training;<br>- Standard Operating Procedures;<br>- Routine inspections;<br>- Good record keeping; and<br>- Suitable firefighting equipment. | Negligible |

[11] A BLEVE is an explosion caused by the rupture of a vessel containing a pressurised liquid above its boiling point. This is a rare event that can occur only if safety measures fail completely or in other very unusual circumstances.

DRAFT

## 4.4 Monitoring

The MTPNP supports at least five species considered Threatened by IUCN: giant ditch frog, imperial parrot, red-necked parrot, forest thrush, and a species of tree frog (*Eleutherodactylus amplinympha*). The UNESCO Mission Report (UNESCO, 2017b) considered that habitat loss required for the construction of the power plant and installation of the pipeline could negatively impact the red-necked parrot – and potentially other Threatened species. Measures identified in Sections 4.2 and 4.3 will minimise habitat loss in the vicinity of the Project infrastructure and no habitat loss will take place within the WHS.

In addition, and in line with the UNESCO Mission Report (UNESCO, 2017b) it is recommended that a programme of monitoring be implemented. This should comprise firstly a programme of monitoring for the five key species identified, recommended to be at every six months from pre-construction until the completion of one year of construction, and annually thereafter for a minimum of five years of operation. The programme should also include the ongoing monitoring in the Laudat and Trafalgar area for any other potential impacts on the OUV of the WHS.

Monitoring will be detailed in an Environmental and Social Management Plan (ESMP), to be developed following detailed design of the Project. The Plan will be agreed with input from the MTPNP managing authorities (National Parks Unit of the Division of Forestry, Wildlife and National Parks), and implemented prior to construction where appropriate. The monitoring programme outlined will enhance understanding of the ecology of the MTPNP and surrounding areas, and ensure that if any adverse effects on OUV were to occur, these would be detected in a timely manner and properly mitigated.

Independent third-party auditing of the implementation of the ESMP will be undertaken at regular intervals. The budget for this auditing and its frequency will be specified in the ESMP and verified by the relevant regulators.

## 4.5 Residual Impacts

Following the implementation of mitigation measures set out within this document and within the ESIA Volume 4: ESMP, Framework ESMS and Assessment Against WBG Standards, no significant adverse effects on OUV of the MTPNP are predicted. Because of the sensitivity and importance of the WHS it is also recommended that the monitoring is undertaken.

## 4.6 WHC/IUCN recommendations

A number of recommendations were made following the WHC/IUCN mission (2017b). A number are addressed in the execution of this assessment, whilst others are beyond the scope of this ESIA, however they complement and are complemented by the mitigation and monitoring recommended within this document. The full text of the recommendations is provided in Appendix A.

- **Recommendation 1 -** Ensure that no hydropower or geothermal projects are allowed within the boundaries of the WHS, and foresee an EIA for each of the future hydropower or geothermal projects in its vicinity, assessing potential impacts on the OUV in line with the IUCN guidance.
- **Recommendation 2 -** Continue monitoring in the area of Laudat and Trafalgar for any potential impacts on the OUV from the exploration phase of the geothermal project.
- **Recommendation 3 -** Undertake an assessment of potential impacts of the geothermal project on the OUV.
- **Recommendation 4 -** Establish an effective buffer zone of the Morne Trois Pitons.
- **Recommendation 5 -** Finalize the preparation of an updated management plan for the WHS in the framework of the project financed to this end by UNDP.
- **Recommendation 6 -** Further consolidate the governance of all protected areas of Dominica.
- **Recommendation 7 -** Develop and implement a long-term monitoring programme of climate change impacts on biodiversity values, with special attention given to the most sensitive species and habitats.

# 5. Summary

MTPNP is a site of global importance and one of the world's Key Biodiversity Areas. It contains Critical habitat and supports at least five species considered Threatened by IUCN: two amphibians, two parrots and one passerine bird.

Impacts associated with the proposed geothermal Project will be experienced downstream of and outside the boundaries of the WHS and its proposed buffer zone. No construction or other Project activities will take place within the site, there will be no clearing of vegetation or habitat within the site, and no significant cumulative impacts have been identified.

Provided that the appropriate generic good practice and specific mitigation set out in this document and the Project ESMP is properly implemented, none of the activities to be undertaken has been identified as likely to result in significant adverse impacts on the Outstanding Universal Value of the site, either now or in future, via direct or indirect means. The recommendations set out by the 2017 mission report (2017b) sit alongside the mitigation and monitoring, and are congruent with it.

On this basis the development proposal is considered acceptable in respect of impacts on the WHS.

# 6. References

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# Appendix A. WHC / IUCN Recommendations

**Recommendation 1**

Ensure that no hydropower or geothermal projects are allowed within the boundaries of the property as they are incompatible with its World Heritage status, and foresee an EIA for each of the future hydropower or geothermal projects in the vicinity of the property, assessing potential impacts on the Outstanding Universal Value (OUV) in line with the IUCN World Heritage Advice Note on Environmental Assessment, before making any decisions that are difficult to reverse, in accordance with paragraph 172 of the Operational Guidelines.

**Recommendation 2**

Continue monitoring in the area of Laudat and Trafalgar for any potential impacts on the OUV of the property from the exploration phase of the geothermal project and to ensure that any impacts from the operational phase can be detected in a timely manner and properly mitigated.

**Recommendation 3**

Undertake, as foreseen in the terms of reference of the Environmental and Social Impact Assessment (ESIA), an assessment of potential impacts of the geothermal project on the OUV of the property, in line with IUCN's World Heritage advice note on environmental assessment) considering any necessary mitigation measures, and submit a copy of the ESIA to the World Heritage Centre for review by IUCN, prior to any decision to approve the operational phase of the project.

**Recommendation 4**

Establish an effective buffer zone of the Morne Trois Pitons, in the framework of the project financed to this end by the GEF, ensuring that threats to OUV, including conditions of integrity, are clearly considered in this process and, once the buffer zone of the National Park has been established, to develop a minor boundary modification proposal to officially establish a buffer zone of the property.

**Recommendation 5**

Finalize the preparation of an updated management plan for the property in the framework of the project financed to this end by UNDP.

**Recommendation 6**

Further consolidate the governance of all protected areas of Dominica, taking into consideration the institution of a national park service, based on the conclusions of the study funded by the Caribbean Development Bank and in conformity with the original provisions of the National Parks and Protected Areas Act (1975).

**Recommendation 7**

Develop and implement a long-term monitoring programme of climate change impacts on biodiversity values, with special attention given to the most sensitive species and habitats.

# Appendix H. Technical Report – Terrestrial Ecology Impact Assessment

# Dominica Geothermal Development – Environmental and Social Impact Assessment

Ministry of Foreign Affairs and Trade

## Terrestrial Ecology Impact Assessment

RZ020300-0002-NP-RPT-0013 | V2

August 2018

# Dominica Geothermal Development – Environmental and Social Impact Assessment

| | |
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| Document Title: | Terrestrial Ecology Impact Assessment |
| Document No.: | RZ020300-0002-NP-RPT-0013 |
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| A | 13/09/17 | First draft | H Greene | P Rogers | P Rogers |
| B | 08/03/18 | Second draft – post-Hurricane Maria situation and actions | P Rogers | I Pearson | I Pearson |
| C | 2/5/18 | Minor edits to finalise report | H Greene | P Rogers | B Clarke |
| V1 | 15/6/18 | FINAL for ISSUE | H Greene | P Rogers | B Clarke |
| V2 | 01/08/18 | Critical habitat assessment and minor updates following WBRSS review | H Greene | P Rogers | B Clarke |
| | | | | | |

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## Glossary

| | |
|---|---|
| DOMLEC | Dominica Electricity Services Limited |
| EIA | Environmental Impact Assessment |
| EHS | Environmental Health and Safety |
| GoCD | Government of the Commonwealth of Dominica |
| ESIA | Environmental and social impact assessment |
| IFC | International Finance Corporation |
| IUCN | International Union for the Conservation of Nature |
| MTPNP | Morne Trois Pitons National Park |
| MW | Megawatt |
| PS | Performance Standard |
| ToR | Terms of Reference |
| UNESCO | United Nations Educational, Scientific Cultural Organisation |
| WHS | World Heritage Site |

# 1. Introduction

## 1.1 Overview

The Commonwealth of Dominica is a small island developing state in the Caribbean Sea. It has a population of approximately 72,000 people and a land area of approximately 750 km$^2$. Around 22% of the island is a protected area, of which approximately 9% is designated by the United Nations Educational, Scientific Cultural Organisation (UNESCO) as the Morne Trois Pitons National Park (MTPNP) World Heritage Site (WHS).

This report is one of several technical reports prepared as supporting documentation for an Environmental and Social Impact Assessment (ESIA) of the proposed 7 megawatts (MW) Dominica Geothermal Project (the Project), which is being developed by the Dominica Geothermal Development Company Ltd – a government owned Special Project Vehicle.

The location of the Project is shown in Figure 1.1. The Project infrastructure is shown in more detail in Figure 1.2. As shown in Figure 1.1, the proposed development is located approximately 450 m from the WHS boundary at the closest point. As such, an assessment of potential impacts on the WHS has been prepared as a separate document, which should be read in conjunction with this assessment.

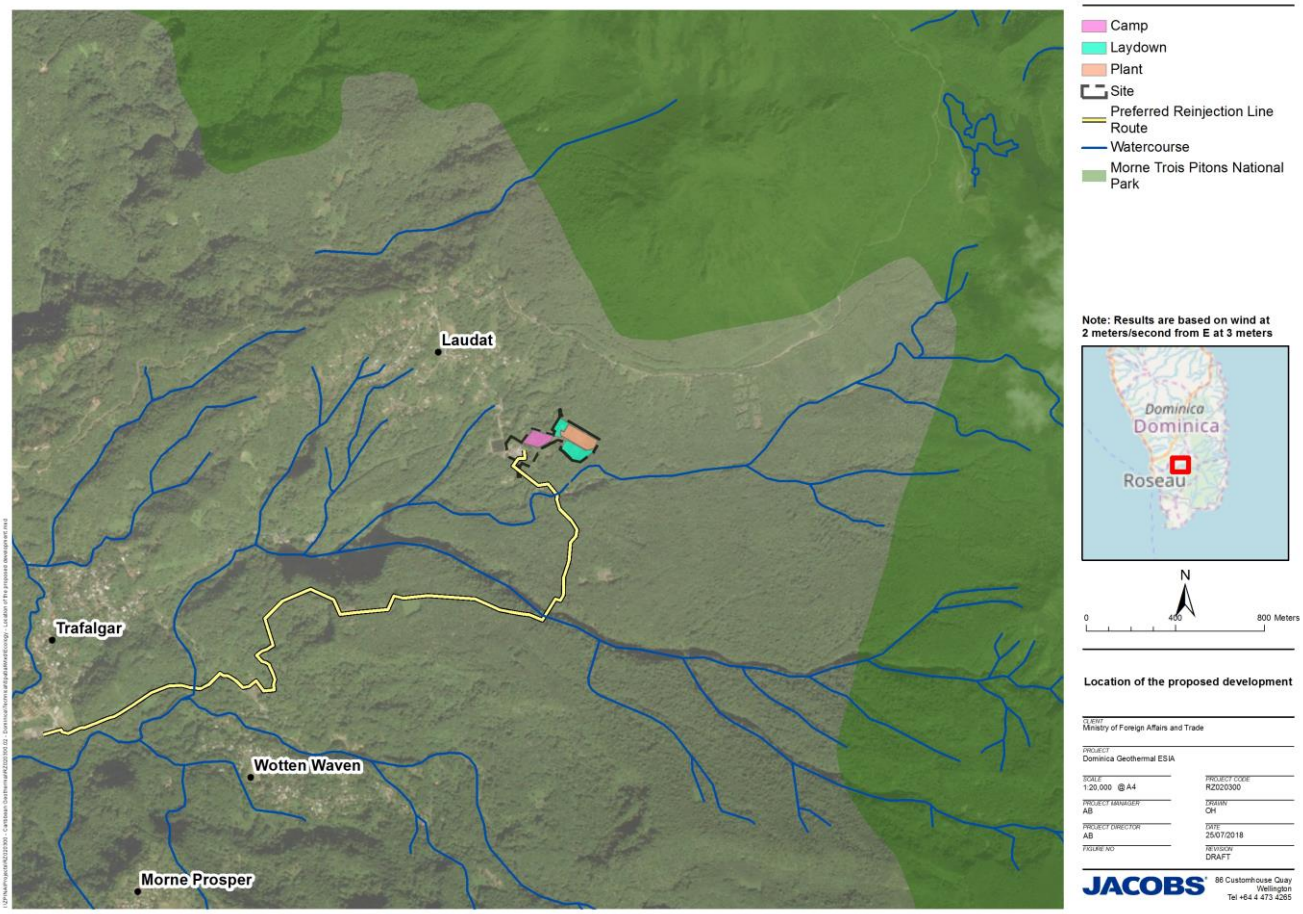


**Figure 1.1: Location of the proposed development**

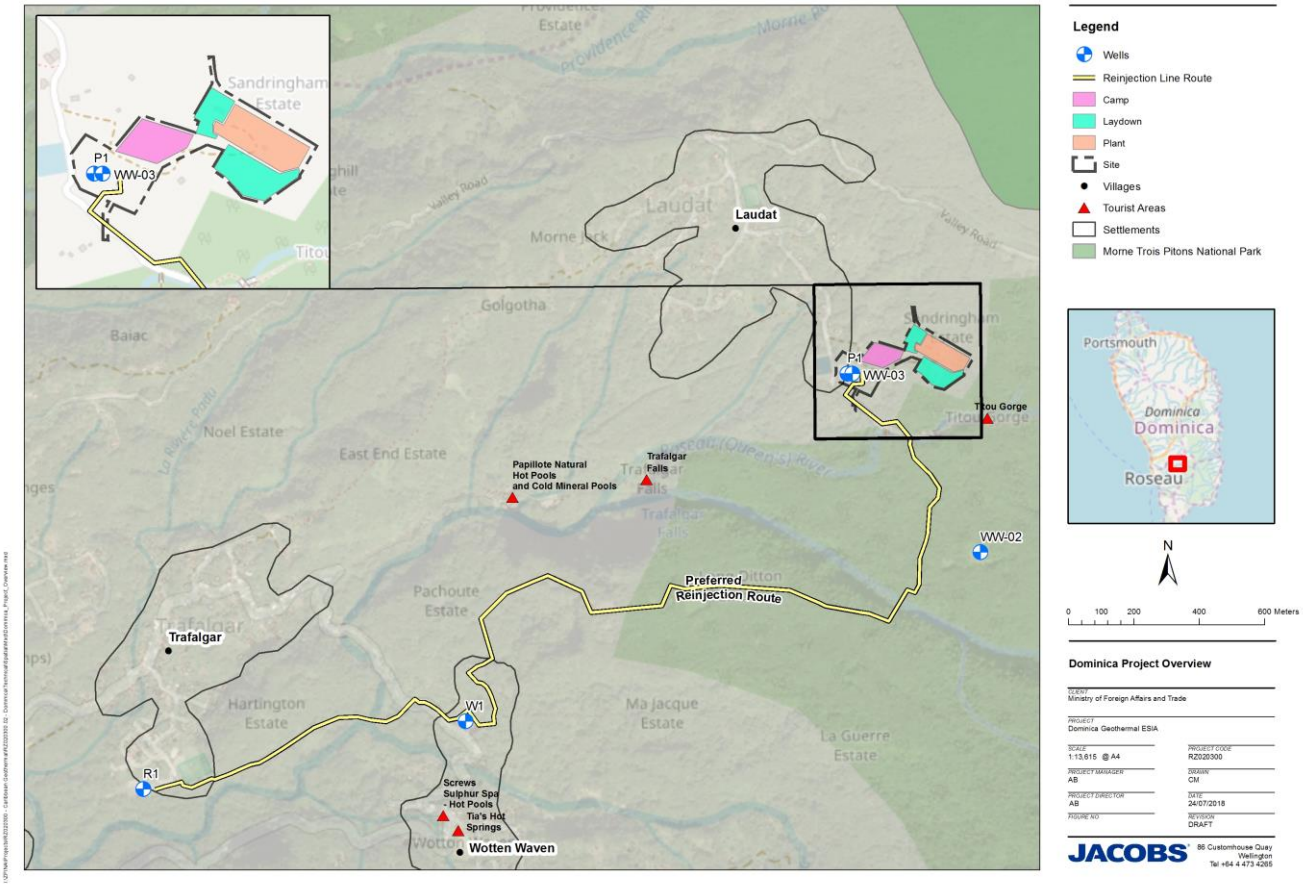


**Figure 1.2: Location of power plant and reinjection pipeline (the Project) in the Roseau Valley**

## 1.2 Proposed Development

The Project is proposed as a two-unit geothermal power plant with a gross capacity of 7 MW. Detailed descriptions of the Project infrastructure are provided in the Process Description, and summarised below.

- Power plant comprising 2 x 3.5 MW units (binary or steam condensing), located adjacent to wells WW-P1 and WW-03;
- Production well WW-P1 – an existing geothermal production well at Laudat will be the sole production well for the Project;
- Injection of used geothermal fluids (brine) to wells WW-R1 and WW-01 via a pipeline of 3.25km in length;
- Steamfield infrastructure adjacent to WW-P1 including injection of steam condensate to well WW-03;
- Supporting infrastructure including existing well pads, turbine building, primary and ancillary equipment, cooling system, and water supply;
- Access road; and
- 11kV interconnection to the Dominica Electric Utility Company (DOMLEC) electricity grid at the power plant site. Three new cables will be run under or directly alongside the proposed access road into the Project site. The length of this route is approximately 440m.

No part of the infrastructure lies within the boundaries of the WHS. Further details of the specific Project elements are provided in ESIA Volume 1: Introduction and ESIA Volume 5: Technical Appendices, Technical Report – Detailed Process Description.

## 1.3 Activities Proposed

Since the commencement of exploratory drilling in 2011, five wells have been drilled (WW-P1, WW-R1, WW-01, WW-02 and WW-03). The Project will use the wells which have already been drilled and tested. As such this document assumes no drilling of new wells in advance of operation. If additional 'make-up' wells are required during the lifespan of the Project, a separate ESIA will be undertaken when the requirements are known. Maintenance of the existing wells is, however, considered within this ESIA. Project-related activities expected to be required are set out in Table 1.1. Construction of the Project will take 18 months to two years.

**Table 1.1: Indicative activities required during each phase of the Project**

| Activity |
|---|
| **Construction** |
| • Vegetation clearance for the power plant site, laydown areas, reinjection route and creation/widening of access roads<br>• Earthworks for the power plant site, laydown areas, reinjection route and creation of access tracks for the reinjection line<br>• Digging of trenches for the 11 kV interconnection<br>• Operation of construction plant<br>• Increased presence of vehicles<br>• Increased human presence<br>• Release of run-off or sediments during construction<br>• Accidental spillage of chemical or hydrocarbon loads<br>• Use of water for equipment washdown, workers (potable and sanitary uses), and potentially a reserve for fire-fighting. Water could be abstracted from Titou Gorge Stream (c.150 m south of the plant). |
| **Operation** |
| • Monitoring and maintenance of the geothermal reservoir, including well workovers, as detailed in ESIA Volume 5: Technical Appendices, Technical Report – Detailed Process Description.<br>• Water use - for workers, supply for fire-fighting, and for maintenance and plant cleaning. This would be sourced from surface water sources and/or brought in from off-site<br>• Water abstraction – possible requirement to pump cold water from the Roseau River to increase well injection capacity<br>• Increased human presence<br>• Emissions to air of non-condensable gases<br>• Air coolers, which do not have a visible plume of water vapour but may exhibit a heat haze OR water cooling towers, which have a visible plume of water vapour when the relative humidity of the atmosphere is high<br>• Other routine maintenance works<br>• If Organic Rankine Cycle (ORC) technology is selected, the flammable substance n-pentane will be required (c. 30 tonnes), to be stored in a bunded storage tank in the power plant site, and in the condenser and process lines of the power plant. |
| **Decommissioning** |
| • Activities likely to be similar in nature to those during construction, above, but less extensive and intensive<br>• Plugging and abandoning geothermal wells |

## 1.4 Assessment Methodology

This impact assessment describes and assesses the potential impacts from the proposed Project on the important terrestrial ecology features of the Project site and surroundings, during each phase of the Project. Impacts on features of the aquatic ecological environment are considered in Chapter 8.

As set out in ESIA Volume 1: Introduction, Chapter 2, national legislation of particular relevance to the assessment is:

- Forestry and Wildlife Act, 1976 (amended, 1982 and 1990);
- Forest Act (1959), Chapter 60:01;
- National Parks and Protected Areas Act (1975); and

- Physical Planning Act (2002).

The International Finance Corporation (IFC) Performance Standard (PS) 6: *Biodiversity Conservation and Sustainable Management of Living Natural Resources*, is also applicable.

In order to ensure that data collected during biodiversity field surveys would be adequate to produce a report in accordance with laws of the Commonwealth of Dominica (GoCD) and international standards, a set of Biodiversity Terms of Reference (ToR) were developed. This scope was reviewed by a World Bank Regional Safeguard Advisor, and was provided to the field survey team for their reference. The Biodiversity ToR can be found in ESIA Volume 5: Technical Appendices, Appendix D. The focus for survey data and assessment was floral and faunal diversity, including rare and/or threatened species and habitats which support those species. Threatened species are those classified as Critically Endangered (CE), Endangered (EN) or Vulnerable (VU) by the International Union for the Conservation of Nature (IUCN) Red List (IUCN, 2017).

Survey data was collected in 2017 by Dominica-based consultancy Eclipse Inc. Note that the surveys were undertaken prior to Hurricane Maria (see Section 1.5 below). The impact assessment also takes supplementary information from desk-based sources.

The impact assessment has been conducted in accordance with the assessment methodology outlined in ESIA Volume 1: Introduction, Chapter 2. Mitigation has been identified where necessary to reduce the scale and nature of potential impacts. Proposed monitoring is also detailed, and any residual effects are summarised.

## 1.5 Hurricane Maria

On the evening of Monday 18 September 2017 the eye of a devastating Category 5 hurricane (Hurricane Maria) reached the shores of Dominica. With winds of 165+ mph travelling over the island at 9 mph, Hurricane Maria left a trail of devastation to infrastructure and nature alike. First hand observations mention forest defoliation of between 80 to 90% ultimately leading to tree deaths (DominicaVibes, 2017) with Dominica's wildlife having been severely hit. Conservation efforts associated with the island's rare bird species (Imperial Parrot and Red-necked parrot) ensured that a number kept in captivity were held safe (American Bird Conservancy, 2018) and there have been sightings of further birds flying in the wild.

The baseline surveys and impact assessment were undertaken prior to Hurricane Maria, and as such this document presents the baseline at that time in Section 2. Following Hurricane Maria, the report has been revised to provide high-level updates to baseline conditions (Section 2.9), and to the proposed ecological mitigation and monitoring (Section 4.2).

# 2. Existing Environment

## 2.1 Data Collection Prior to 2017

An initial flora and fauna analysis was carried out in 2008 to gain a preliminary understanding of the biodiversity of the Roseau Valley. Three areas were selected in 2011 for detailed flora and fauna assessment, and a fourth was added in 2015. At each of these four areas the dominant habitat and flora and fauna species was described and matched to vegetation type descriptions.

## 2.2 Data Collection in 2017

### 2.2.1 Survey Methods

A more targeted approach was required for the ESIA, focussed on habitats in the area of potential impact, i.e. along the preferred re-injection line route and other sites selected for the plant infrastructure.

A preliminary land-use/habitat classification of the study area was prepared in GIS by interpreting satellite imagery and aerial photography. This information was used to stratify the vegetation to ensure that the full range of habitats was systematically sampled. Field ecologists were then able to ground-truth vegetation types using a rapid assessment approach.

Surveys for birds, herpetofauna and mammals was also undertaken. Survey methodologies were replicable and scientifically robust, and used primarily visual and aural methods. Limited nocturnal survey for animal species was also undertaken at accessible locations.

### 2.2.2 Survey Locations

A combination of transects and plot-based surveys was used. The route of the proposed reinjection line was the basis for establishing a transect spanning thre following locations: Trafalgar, Trois Bitons, Wotten Waven and Laudat:

- Trafalgar – 7 quadrats and Wotten Waven – 1 quadrat;
- Trois Bitons – 15 quadrats; and
- Laudat – 6 quadrats.

In addition, in order to enable the evaluation of potential impacts of the proposed infrastructure the biodiversity of the Wotten Waven reinjection site and the proposed construction location in Laudat were surveyed separately. Data collection locations are shown on Figure 2.1.

Particular attention was paid to dominant, rare, endemic, threatened, protected, invasive species, and to those species that are of importance to local communities.

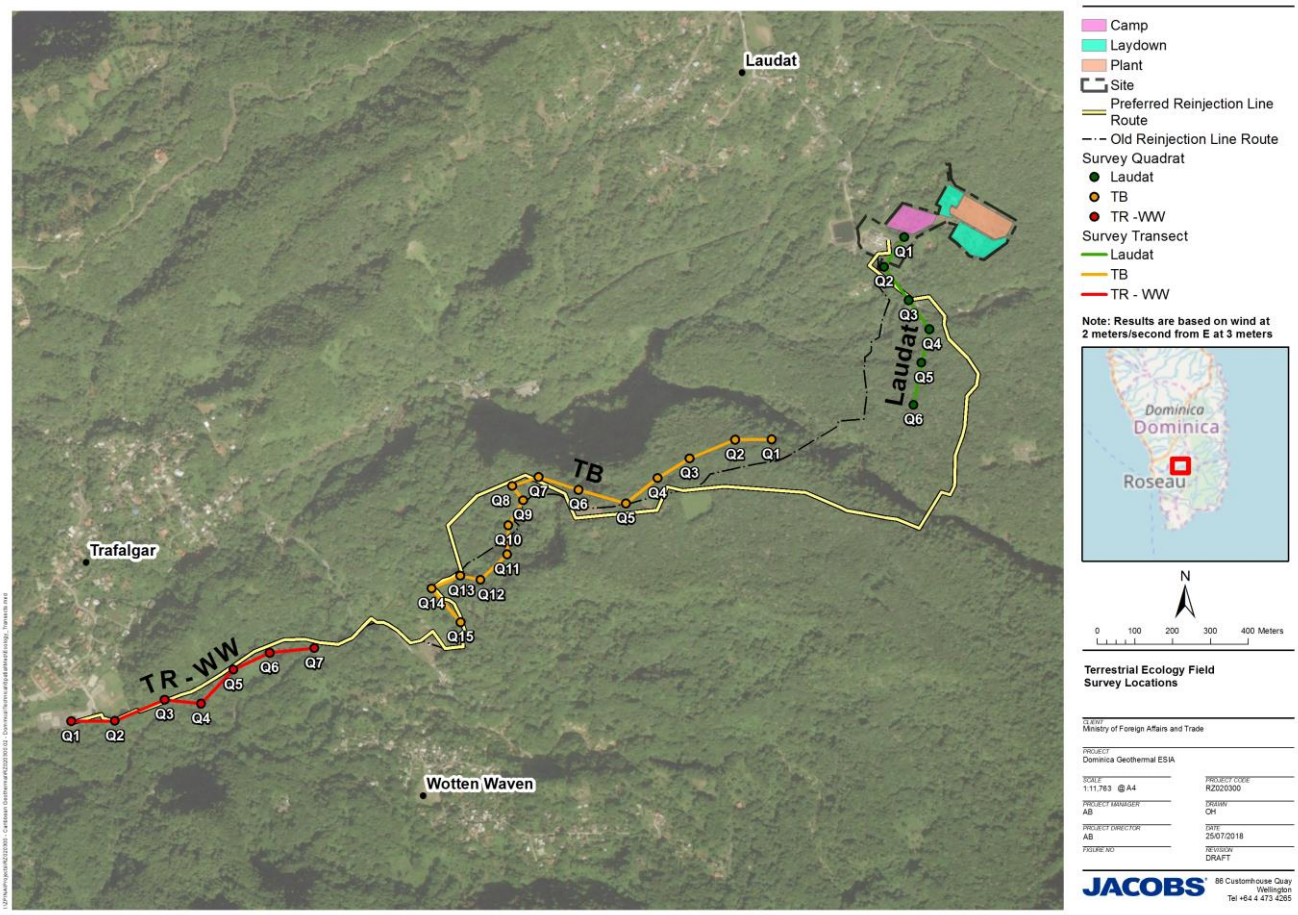


**Figure 2.1. Field survey locations**

## 2.3 Limitations and Assumptions

The following limitations and assumptions apply to this assessment:

- Biodiversity data for the Roseau Valley collected in 2008 was not available for review, and thus the more recent data from 2017 has been used in this assessment.
- Some parts of the survey transects were not surveyed due to accessibility and health and safety concerns. Where possible these locations were surveyed from a distance and descriptions provided.
- Where conflicting information within the raw data was provided, professional judgement has been used to make an appropriate and precautionary assessment.

## 2.4 Protected Areas

The protected area of principal relevance to the project is Morne Trois Pitons National Park, a World Heritage Site which lies approximately 600m northwest, and upstream, of the proposed Project infrastructure. Impacts on the ecology of the site have been considered separately and are not discussed further here, other than in the context of the wider diversity of the area.

The MTPNP, along with three other sites on the island, is also designated by BirdLife International as an Important Bird Area (IBA). Two small coastal/island IBAs are located on the south and southeast coasts, and the Morne Diablotin National Park in the north of the island, is the other. The designation also renders all four sites Key Biodiversity Areas (KBA). In addition, an Endemic Bird Area (EBA) extends across the whole of the

Lesser Antilles, and supports seven endemic bird genera. Dominica has three endemic bird species of its own[1], and also supports 18 restricted-range bird species.

Nationally, Dominica recognises 10 protected areas, covering 22% of the terrestrial habitat, and 0.01% of the marine area. No other established or proposed protected areas have been identified.

## 2.5 Habitats

The major vegetation type in all areas surveyed is secondary rain forest at varying stages of succession. Some agricultural habitats were also present, both those currently under cultivation and those apparently abandoned.

No rare or threatened plant species were identified in any of the transects or plot-based surveys.

### 2.5.1 Trafalgar - Transect

This transect runs along the southern side of the Trafalgar playing field in a south-easterly direction, through privately-owned land with active and abandoned agriculture. The line ends at the Trafalgar River gorge.

The Trafalgar area is typically secondary rainforest as a result of disturbance, primarily from housing and agricultural development and the impact of Hurricane David. In some areas, vestiges of old stands remain, surrounded by smaller re-growth.

Quadrat 1 (Q1) is adjacent to an access road which leads to the geothermal reinjection line. It supports savannah-like species, with some secondary rainforest vegetation, including some areas which have been cleared. Invasive *Mimosa* spp. were noted to be dominant here. Q2 features a steep slope down to the Roseau River, rendering it inaccessible but it was visually assessed to have a dense secondary forest emerging, with full canopy cover. Q3 is similarly partly inaccessible, being located in an elevated forested area, with evidence of landslides historically. Q4 to Q6 feature flatter terrain and with a greater proportion of active agriculture. Q7 is located towards the edge of a cliff overlooking the river, and has no evidence of active agriculture.

### 2.5.2 Trois Bitons - Transect

This is an estate on an elevated plateau north of the village of Wotten Waven. The site is flanked by a steep escarpment on its southern and western sides, and with the deep gorge of the Trois Pitons River on the north and north-eastern sides. This natural barrier limits access into the area.

The predominant vegetation type is secondary rainforest, with some areas which have been subjected to logging and agriculture. The second half of the route was not safely accessible, and so visual observations were made from the trail that traverses the area. Much of this part of the route was apparently abandoned agricultural land. Q14 and Q15 showed more signs of human activity, in the form of small farming activities, tourism and street vendors, and the main road from Trafalgar to Wotten Waven.

### 2.5.3 Laudat - Transect

The transect was located southeast of the village of Laudat and comprised largely secondary rainforest. The primary forest has been extensively impacted by road construction, establishment of electricity infrastructure, shifting agriculture, tourism development and the impact of extreme weather events, especially Hurricane David in 1979. The DOMLEC pipeline passes near to Q2/Q3.

Some remnants of rainforest were identified, surrounded by natural regeneration, however generally there are few typical rainforest trees present.

[1] Jamaican petrel *Pterodroma caribbaea* (CR), red-necked Amazon *Amazona arausiaca* (VU), Imperial Amazon *Amazona imperialis* (EN).

### 2.5.4 Laudat - Infrastructure Location

A plot-based survey was undertaken at the proposed location for the power plant site and laydown area. This area includes an abandoned dwelling, and agricultural land with low-growing ground cover and some trees. The primary remaining crop was citrus fruits.

### 2.5.5 Wotten Waven – Infrastructure Location

This site is adjacent to the Wotten Waven to Trafalgar main road, approximately 140 m from the Wotten Waven Sulphur Springs tourist site. The site was originally selected for exploratory drilling and is one of the proposed reinjection wells.

The area is characterized by a high water table, and there is a wetland/marsh area, with patches of fumarolic vegetation and hot water pools. To the southwest and the north lies secondary rainforest and agricultural land, where crops such as banana, coconut, mango and breadfruit are cultivated.

## 2.6 Birds

95% of Dominica's 206 resident and visiting bird species are categorised as Least Concern by IUCN, whilst 2% are Near Threatened, and 3% (equating to 6 species) are Globally Threatened, which comprise the categories: Vulnerable (3); Endangered (2); and Critically Endangered (1)[2]. None of these species were recorded during field surveys.

Along the Trafalgar transect, 325 individual birds of 26 species were identified during the survey, all of Least Concern. In addition, the barn owl (*Tyto alba nigrescens*) was recorded during a night-time survey. A further three species are thought to frequent the area, one of which is the Vulnerable red-necked parrot (*Amazona arausiaca*), reported to be a frequent visitor earlier in the year, foraging on citrus tree fruits.

At the Wooten Waven proposed infrastructure site, 14 species were recorded and a further 12 were not encountered but have been verified as present by residents and a local guide. At the Laudat proposed infrastructure site, 17 species were recorded and a further 9 are considered to be present.

At all three locations, the same five species endemic to the Lesser Antilles, five endemic to the Caribbean and two native to a small number of Lesser Antillean islands were present. These Dominican endemics/near endemics are the blue-headed hummingbird (*Cyanophaia bicolor*) and plumbeous warbler (*Dendroica plumbea*). Both have small ranges and declining population, but are within the limits of the category Least Concern. All remaining species are considered common or abundant resident breeders and are also of Least Concern. Across all sites a total of 31 species were identified or verified to be present generally in the area.

## 2.7 Mammals

Mammalian diversity was very low at all surveyed locations. Along the Trafalgar transect and at the Wooten Waven and Laudat proposed infrastructure sites, unidentified insectivorous and frugivorous bat species was recorded. At all locations, field signs of agouti (*Dasyprocta antillensis*) were noted, and common opossum (*Didelphys marsupialis*) and rats (*Rattus rattus*) are reported.

## 2.8 Herpetofauna

Along the Trafalgar transect and at the Wooten Waven and Laudat infrastructure locations, one amphibian was recorded, the Near Threatened tink frog *Eleutherodactylus martinicensis*. This was in greatest abundance at Trafalgar, with 140 individuals recorded, and only two at Wooten Waven.

[2] Leach's storm-petrel *Hydrobates leucorhous* (VU), black-capped petrel *Pterodroma hasitata* (EN), Jamaican petrel *Pterodroma caribbaea* (CR), red-necked Amazon (VU), Imperial Amazon (EN), forest thrush *Turdus lherminieri* (VU)

The Puerto Rican crested anole (*Anolis cristatellus*) is an introduced species identified at Trafalgar and the Wooten Waven and Laudat infrastructure sites. It is considered invasive due to its competition with the native anole (*Anolis oculatus*). The latter is thought to be present at Laudat, but was not recorded, and despite the impact of the non-native species, the native species is considered of Least Concern. Another endemic, Dominican ground lizard (*Ameiva fuscata*) was recorded at Trafalgar and has not been assessed for its conservation status.

The Dominican boa (*Boa constrictor nebulosi*), black-and-white checkered snake (*Liophis juliae juliae*), house gecko (*Hemidactylus mabouia)*, dwarf gecko (*Sphaerodactylus vincentii*), and golden skink (*Mabouya mabouya*) were not observed during surveys but are considered present in the Trafalgar area. Previous survey data indicated their presence at Laudat also.

## 2.9 Evaluation

No species which are Threatened or rare have been recorded in the study area during surveys. One Threatened species which is verifiably understood to be present, is:

- red-necked parrot: Vulnerable

A Critical Habitat screening assessment has been undertaken based on the presence of this species, provided in Appendix 1, including an analysis of Modified, Natural and Critical habitats within the Project area.

In addition to the red-necked parrot, the following endemic or near-endemic species are of unknown or less than Threatened conservation status, but are considered to be of relevance to the assessment:

- tink frog, Near Threatened
- Dominican ground lizard, Not Assessed;
- Dominica anole; Least Concern;
- blue-headed hummingbird, Least Concern; and
- plumbeous warbler, Least Concern.

## 2.10 Post-Hurricane Maria

The Project footprint as described in Section 1 of this report has been revisited since the hurricane. Dominica Geothermal Development Company Ltd (DGDC) conducted an assessment of their existing assets, the condition of the proposed Project sites and their continued viability (DGDC, 2017). The DGDC report does not provide any specific detail on the condition of the environment or surrounding habitats, however, photographic records have been taken which do provide some level of detail as to the environmental state.

Observations include the following with references to corresponding figures (photographs) within DGDC (2017):

- Higher exposed areas such as hill-tops have been stripped of tree cover, medium to small trees remain on lower slopes only, but it is clear that some if not all of these have been defoliated to some extent. Ground cover plants and habitats remain intact (see DGDC report; Figure 1 and 2);
- Lower more sheltered areas appear to show good vegetation cover that has not been so badly damaged (DGDC, Figure 3);
- Landslides and hill slips have occurred especially along access tracks destabilising vegetation and exposing bare rock and soil to the elements (DGDC, Figure 4, 6, 7);
- Grassed areas on flat surfaces e.g. those around wellheads (see DGDC, Figure 8, 9, 12) appear intact and have not incurred storm damage;
- Some trees located around the proposed power plant site appear to have been defoliated (See DGDC, Figure 13). Text in 3.2.1 notes large quantities of fallen trees and minor edge collapses into river gorges. Large amount of debris in river courses carried downstream;

- Fallen or semi-fallen trees remain a risk along access tracks and may need to be felled to ensure safe passage (see DGDC, Figure 14 and Section 3.2.1);
- Steeper hillside vegetation has been badly damaged which could lead to further erosion and slips (see DGDC, Figure 16). Major landslides evident which could destabilise further in time should another storm event occur;
- River courses have become choked with new debris, rocks, fallen tree materials and other detritus (see DGDC, Figure 18); and
- Defoliated trees around existing infrastructure are likely to die possibly leading to greater exposure until vegetation cover is restored (see DGDC, Figure 19).

Rainforest ecosystems such as those found on Dominica have been through previous hurricane events and vegetation cover and habitat integrity has returned rapidly (within 2 years as reported by DominicaVibes, 2017). Indeed, such events provide many species with new opportunities e.g. similar to when a mature tree is felled in a rainforest, opening up the canopy, and providing dormant seeds the chance to grow. It is clear that the environment has dramatically changed as a result of Hurricane Maria, and natural habitat regrowth will be different from what was there before. However, studies completed to date since the hurricane have indicated the presence of a mature habitat representative of the island. It is therefore proposed that no further ecological studies are undertaken as this would not provide any new information on the underlying habitats present. Instead, the situation post-Maria does provide new opportunities for the Project to work with nature through proposed mitigation actions e.g. tree planting to stabilise slopes and stop further erosion and restoring river courses. These actions are described further in Section 6.

# 3. Assessment of Impacts

The significance of an impact can be considered a product of the magnitude of the impact and the sensitivity of the feature. The term 'magnitude' encompasses: duration and spatial extent of the impact; reversibility; likelihood; and compliance with legal standards and established professional criteria. 'Sensitivity' is a measure of the feature's capacity to absorb proposed changes and/or the opportunities for mitigation.

Significance is classified in accordance with the impact evaluation matrix in Table 3.1, which considers the magnitude and sensitivity of the impact.

For the species and habitats evaluated in Section 2.8 as important to this assessment, the activities detailed in Section 1.3 which may impact the feature directly, indirectly and/or cumulatively, are detailed in Table 3.2. Where an impact is initiated in construction but also occurs throughout operation (e.g. permanent habitat removal), it is discussed only within operational impacts.

**Table 3.1: Impact evaluation matrix**

| | | Magnitude | | | |
|---|---|---|---|---|---|
| | | **Major** | **Moderate** | **Minor** | **Negligible** |
| **Sensitivity** | **High** | Major | Major | Moderate | Negligible |
| | **Medium** | Major | Moderate | Minor | Negligible |
| | **Low** | Moderate | Minor | Negligible | Negligible |
| | **Negligible** | Minor | Negligible | Negligible | Negligible |

**Table 3.2: Assessment of significance of impacts in the absence of mitigation**

| Activity | Potential impact | Effect | Significance |
|---|---|---|---|
| **Construction** | | | |
| Construction activities including earthworks, excavations, creation/widening of access roads, and the operation of construction plant | • noise | Construction noise levels have been modelled for receptor locations around the Project area. Noise levels during construction are predicted to be inaudible or of negligible significance under all 13 construction scenarios. | Negligible |
| | • harmful air emissions<br>• dust<br>• night-time illumination of platforms | Air emissions and dust during construction have been modelled for receptor locations at and around the source points.<br>Dust emissions from 'small'[3] earthworks are considered negligible at distances >200 m. As the sensitivity of the area is classified as 'Low', the resulting risk is classified as 'Negligible' for ecological impacts.<br>There is a small potential for cumulative impacts of $SO_2$ and particulate matter, however the effect would be highly localised.<br>Lighting of platforms could cause minor disturbance to animals in the immediate vicinity of the construction area. | Negligible |

[3] As defined in the Institute of Air Quality Management (IAQM) (2011). For details see the ESIA Volume 3: EIA, Chapter 4 - Air Quality.

| Activity | Potential impact | Effect | Significance |
|---|---|---|---|
| | • introduction/spread of invasive plant species | The transport of significant quantities of soil on or off site is not expected. Spread of invasive species which may outcompete native species is possible, although based on the scale of the construction area, is unlikely to be significant. | Negligible |
| | • release of hazardous substances from accidental spillage or major accident | Uncontrolled discharges of geothermal fluids (brine and condensate) can be harmful to the environment, containing substances such as arsenic and boron. Brine is also very hot.<br>Impacts could occur downstream, including damage to plant tissue, necrosis and animal sickness or mortality. Release on a scale which would have a significant effect would be unlikely. | Minor |
| | • run-off or sedimentation | If not treated, run-off and sedimentation will reduce water quality and increase deposition downstream, potentially contaminating drinking water used by animals, and inhibiting plant growth. Release on a scale which would have a significant effect would be unlikely. | Minor |
| Increased presence of vehicles | • noise and vibration<br>• dust<br>• emissions to the air<br>• collision with animals | Effects from noise, vibration and dust would be as above, but not on a scale greater than negligible.<br>Direct mortality of individuals from collisions or entrapment in uncovered holes, pipes or machinery is unlikely to occur in sufficient numbers to affect the wider population. | Negligible |
| Increased human presence | • encroachment | An influx of workers in search of employment, and associated businesses and services, may result in settlements growing. This may place increased pressure on resources such as land, water, waste disposal procedures. The Project size and location is unlikely to attract large numbers of job-seekers. Localised inappropriate waste disposal may however occur. | Negligible |
| Temporary removal of terrestrial habitats to accommodate the construction corridor for the reinjection line. During construction, the corridor will be 10 m wide (of which 3-4 m will be permanent loss, see below). | • loss of habitat<br>• reduction of ecological connectivity | Temporary reduction in extent of secondary rainforest and agricultural land, and associated impacts on animal communities associated which rely on these habitats for food, shelter and breeding.<br>Parts of the habitats to be lost could support threatened species but are not considered to be core habitat. The extent of the habitat loss is relatively small, and the vegetation along the reinjection line is expected to regenerate rapidly. | Negligible |
| **Operation** | | | |
| Permanent removal of terrestrial habitats to accommodate footprint of construction. The land required for the power plant site is expected to be between 0.32 ha and 1.42 ha, all of which is Modified.<br>In addition, the 3.25 km pipeline will have a permanent wayleave of 3-4m, | • loss of habitat<br>• reduction of ecological connectivity | Permanent reduction in extent of secondary rainforest and agricultural land, and associated impacts on animal communities associated which rely on these habitats for food, shelter and breeding.<br>Parts of the habitats to be lost could support threatened species but are not considered to be core habitat. The extent of the habitat loss is | Minor |

| Activity | Potential impact | Effect | Significance |
|---|---|---|---|
| with an associated loss of 1.4 ha Modified Habitat and 1.7 ha Natural Habitat. | | relatively small; however, some severance of habitats will result. | |
| Operation of power plant (including turbines, fans, pumps etc.), reinjection wells, and steam pressure releases during commissioning of both power plant and reinjection wells | • noise | Operational noise levels have been modelled for 13 locations. Noise levels are predicted to be inaudible or of negligible significance in all scenarios, except one. Under the commissioning scenario, there are exceedances at three locations: Trafalgar, Laudat and Wotten Waven, however it is understood that commissioning testing will only occur for a relatively short period. | Minor |
| | • harmful air emissions | If of sufficient magnitude, air emissions and dust could result in disturbance to animals, and associated stress and reduction in fecundity.<br>Air emissions such as $H_2S$, $SO_2$ and mercury have been modelled throughout the project area. Small exceedances may occur close to the emission sources, however concentrations will decrease rapidly with distance and adverse impacts are not expected. | Negligible |
| Maintenance activities including well workovers and cleanouts, which could include small-scale drilling | • Release of toxic gas e.g. hydrogen sulphide<br>• Noise<br>• vibration | In high concentrations hydrogen sulphide can result in necrosis and mortality.<br>Vibration, noise and lighting may affect fauna, resulting in stress, behavioural changes, reduced breeding success. These activities would be relatively infrequent and short-term and thus not expected to be significant. | Negligible |
| Increased human presence | • encroachment | A workforce of only two or three workers is expected during operation, therefore no impacts are expected. | Negligible |
| If ORC technology is selected, storage and use of the flammable substance n-pentane | • leak or rupture of n-pentane storage tank at the power plant | Based on the Areal Locations of Hazardous Atmospheres (ALOHA) modelling detailed within ESIA Volume 2: EIA, Chapter 15, the spatial extent and level of consequence of a three scenarios at the power plant was estimated.<br>The level of impact under this scenario was found to be contained within the power plant, and the level of impact on surrounding areas of Negligible significance. | Negligible |
| | • leak or rupture of n-pentane storage tank at the power plant resulting in a pool fire in the bund | A burning pool fire which could affect animals and habitats outside the power plant is possible but highly unlikely. The level of impact on the areas surrounding the power plant were assessed as of Negligible significance. | Negligible |
| | • boiling liquid expanding vapour explosion (BLEVE)[4] | Under the modelled scenario the thermal radiation from this event sufficient to cause pain (to humans) within 60 seconds extends to 462 m from the incident location. Lethal effects may extend to 209 m, with an intermediate category of | Minor |

[4] A BLEVE is an explosion caused by the rupture of a vessel containing a pressurised liquid above its boiling point. This is a rare event that can occur only if safety measures fail completely or in other very unusual circumstances.

| Activity | Potential impact | Effect | Significance |
|---|---|---|---|
| | | 2nd degree burns (to humans) extending to 296 m. Such an incident could have substantial and wide-ranging consequences for animals and habitats, but is a very unlikely occurrence. | |
| **Decommissioning** | | | |
| Activities likely to be undertaken will be similar in nature to those during construction but will likely be less extensive and intensive. These activities may include plugging and abandoning geothermal wells. | An indicative operational lifetime for the Project is 30 years. After this point, a programme of activities will be required to decommission the above-ground facilities and remediate the site to an agreed level.<br>Because of the long timescale until this phase of the Project occurs, it is recommended that a separate assessment of impacts is undertaken at that time, including all mitigation and monitoring required to avoid significant adverse impacts. | | |

# 4. Mitigation and Monitoring

The important species and habitats identified in the assessment were red-necked parrot, tink frog, Dominican ground lizard, Dominica anole, blue-headed hummingbird, and plumbeous warbler, and their habitats. No likely significant (greater than minor) negative impacts have been identified through the assessment process, and thus no specific mitigation is required for these species.

Part of the reinjection line corridor is currently Natural Habitat (see Appendix 1). In line with Performance Standard 6, in areas of Natural Habitat, mitigation has been designed to achieve No Net Loss of biodiversity, where feasible. This has included / will include the following activities:

- A number of options for the reinjection in route were considered, with consideration for ecological impacts, to avoid sensitive habitats.
- Habitat cleared will be minimum possible, with any way-leave area required of the minimum width necessary. This will contribute to minimising habitat fragmentation.
- The 6-7m of the construction corridor of the reinjection line that is not required permanently will be replanted with native species as soon as possible after construction.
- A biodiversity offset will be created to a minimum extent of 1.7 ha (equivalent to the Natural Habitat lost under the Project Area). A Habitat Management Plan (HMP) will be developed to establish the biodiversity offset required to achieve No Net Loss of Natural Habitats, with input from local specialists and stakeholders as appropriate. The biodiversity offset will also incorporate the measures identified in Section 6: Post-Hurricane Maria Actions, where appropriate.

A minor impact was identified as a result of fragmentation of habitats by the reinjection line. In order to minimise severance effects, the pipeline will have under/overpasses installed at intervals along its length. The exact nature and positioning of these will be developed during detailed design. In addition, because the pipeline is located above-ground, smaller animals are expected to be able to pass under it.

Furthermore, standard good practice measures such as the following will however help to further minimise adverse impacts:

- Implement dust-suppression measures such as covering vehicles transporting materials, ensuring vehicles use wheel wash facilities at site, and use of water spray dust suppression systems.
- Highly noisy activities should be undertaken during daylight hours where possible.
- Inductions/tool-box talks for staff should include reference to measures required to protect biodiversity.
- Appropriate provision should for be made for waste disposal.
- Vegetation clearance activities should commence outside the breeding season for red-necked parrot (breeding is between February and June). Where possible it should avoid the primary amphibian breeding season between May and August also.
- Use temporary fencing to prevent inadvertent damage outside designated construction areas.
- Avoid piling of clear-felled vegetation on standing live vegetation which would hinder movement of wildlife.
- Any replanting / landscaping should use native or endemic species to prevent the incursion of opportunistic invasive species.
- Machinery and vehicles should be cleaned upon entry/exit, and any soil brought on or off site screened for invasive species or plant pathogens.
- Minimise potential for sedimentation impacts by ensuring good construction site practices are implemented.
- Appropriate disposal of solid and liquid wastes, in line with recommendations in international and national standards, and using designated facilities as required.
- Any effluent discharged to surface watercourses must meet the more stringent of international water quality discharge standards prior to release to remove pollutants.

- Minimise potential for pollutants and surface water run-off to migrate off-site by ensuring standard good construction site practices are implemented.
- Ensure all standard safe storage measures for n-pentane are implemented, as detailed in ESIA Volume 2: EIA, Chapter 15.

These measures will be included within the Environmental and Social Management Plan (ESMP), to be developed following detailed design of the Project. The Plan will be agreed with input from relevant authorities and implemented prior to construction where appropriate. It will also include mitigation/monitoring measures identified as required in the MTPNP assessment. As detailed above, an HMP will be developed to establish the biodiversity offset required to achieve No Net Loss of Natural Habitats. It should be noted that the additional mitigation and monitoring set out within the MTPNP assessment are of relevance to ecological receptors generally, and should be considered alongside this assessment.

Provided the mitigation described is implemented effectively, no specific monitoring plan is considered to be required.

# 5. Residual Impacts / Summary

The field surveys and desk study information indicate a relatively low diversity and abundance of important ecological features, with the majority of important habitats and species being instead concentrated within the MTPNP. Whilst the surrounding areas provide important functions in terms of connectivity and supplementary habitat, there is no identified Critical Habitat and the only Threatened species thought to use the area finds its core habitat within the MTPNP. No culturally or socially important plant species were identified.

Impacts identified were notably loss of secondary rainforest and agricultural habitats, and the small likelihood but potentially substantial consequences of a major leak, fire or explosion. None of the impacts identified would be greater than minor significance and thus no specific mitigation was required. A biodiversity offset is proposed to ensure the Project achieves No Net Loss of Natural Habitats, and as close to No Net Loss of all habitats as possible. In addition, a range of standard good practice measures are recommended to minimise adverse impacts further. These measures are consistent with the recommendations of the assessment of impacts on the MTPNP, and will assist in maintaining the values, integrity and protection of that site too.

# 6. Post-Hurricane Maria Actions

Despite the damage that Hurricane Maria has caused to surrounding ecosystems and habitats, it does present the Project with a number of opportunities which would serve to support the project, but could also improve and contribute towards a better natural environment. The following are actions that will be undertaken by DGDC under a Habitat Management Plan, and which will be complementary to the biodiversity offset identified in Section 4:

- **Stabilising bare slopes or improve resilience on slopes where trees have fallen** – promote tree and shrub planting to stabilise lose soil and rock, prevent further erosion and slips. This could also include supporting local nurseries to grow more trees which in turn could be used by local communities;
- **Areas of fallen trees surrounding well pads and other infrastructure** – plant native tree species to stabilise ground conditions, improve ecological resilience and reduce rainwater run-off which in turn could pollute water courses and cause soil erosion;
- **Restore river courses** – remove bulky items where possible such as fallen trees, logs and other detritus and large rocks which could block river flow and cause flooding; destabilise slopes or cause soil erosion to surrounding terrestrial areas;
- **Removal of habitat cover** – provide hibernacula of log piles, stone/rock piles for amphibians and other animals which might have been lost along with tree canopy cover;
- **Exposed ground** - plant native grass seed with fertilizer where exposed ground is still visible or where slopes are too steep or where soil has been washed away; and
- **Baseline monitoring** – although detrimental in general terms, the recent decimation of local habitats and ecosystems at least provides a clear baseline to develop a monitoring programme especially for forest recovery and the key animal groups that use it along with monitoring improvements of aquatic species in water courses.

# 7. References

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# Appendix A. Critical Habitat Screening

## A.1 Introduction

Under IFC Performance Standard 6 (PS6), habitats can be defined as Modified, Natural or Critical. Definitions of these habitats can be variable according to setting but are broadly defined as follows.

- **Modified Habitat:** Modified habitats are areas that may contain a large proportion of plant and/or animal species of non-native origin, and/or where human activity has substantially modified an area's primary ecological function and species composition. Modified habitats may include areas managed for agriculture, forest plantations, reclaimed coastal zones, and reclaimed wetlands.
- **Natural Habitat:** Natural habitats are areas composed of viable assemblages of plant and/or animal species of largely native origin, and/or where human activity has not essentially modified an area's primary ecological functions and species composition,
- **Critical Habitat:** Critical habitats are areas with high biodiversity value, including:

  (i) habitat of significant importance to Critically Endangered and/or Endangered species;

  (ii) habitat of significant importance to endemic and/or restricted-range species;

  (iii) habitat supporting globally significant concentrations of migratory species and/or congregatory species;

  (iv) highly threatened and/or unique ecosystems; and/or

  (v) areas associated with key evolutionary processes.

A Critical Habitat Assessment determines whether or not Critical Habitat is present in the Project area and wider habitats, and thus what, if any, additional requirements are triggered as a result. Because of their greater importance for biodiversity and conservation, PS6 typically places additional constraints on the development that can take place, and the mitigation required, within areas of Critical habitat.

This Critical Habitat assessment considers species identified during desktop review and through baseline surveys as being IUCN Red List Threatened (that is, Vulnerable, Endangered or Critically Endangered) and potentially present in the Project area.

Available baseline information indicates that the Project area may support the Vulnerable red-necked parrot. A Critical Habitat screening process has therefore been undertaken, in line with the principles laid out in PS6 and the associated Guidance Note 6 (GN6).

## A.2 Habitats within the Project Area

Based on the terrestrial ecology surveys and desk-based assessment undertaken to date and discussed in Section 2, the Project area comprises predominantly secondary rainforest and agricultural habitats.

Figure A1 below provides an overview of Modified and Natural habitats along the reinjection line, based on survey information and recent (2018) high-resolution orthophotography. The construction corridor along the reinjection line is 10 m wide (reduced to 3-4 m during operation), giving a total area of 4.0 ha. Of this, 2.3 ha (58%) is considered to be Modified Habitat and the remaining 1.7 ha (42%) is considered to be Natural Habitat. In addition, the entirety of the main power plant site is also Modified habitat (1.4 ha).

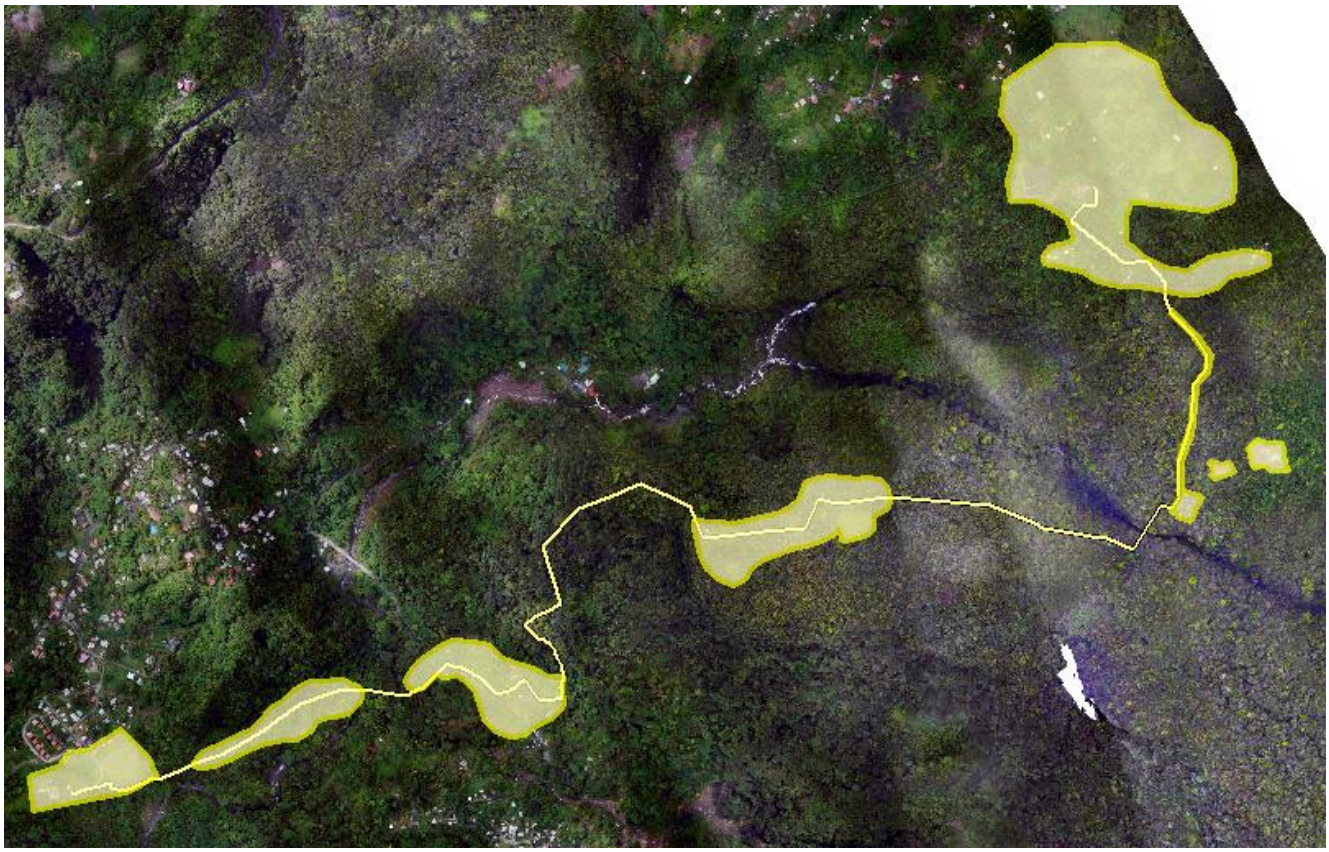

**Figure A1 : Modified and Natural Habitat within the Project Area. Yellow shaded areas are Modified Habitats. Note that Modified Habitats have been captured more widely than the reinjection corridor. This is shown for context but not included in the calculations of habitat loss.**

In line with PS6 Paragraph 15, in areas of Natural Habitat, mitigation is required to achieve no let loss of biodiversity where feasible, following the mitigation hierarchy. Mitigation for the loss of Natural Habitat is included within Section 4 in accordance with this requirement.

## A.3 Criteria for Critical Habitat

Critical Habitat criteria are defined in IFC Guidance Note 6, paragraphs GN69 to GN97. Table A1 below summarises the Critical Habitat Criteria 1 to 5.

**Table A1 : Critical Habitat Criteria**

| Criteria | Tier 1 | Tier 2 |
|---|---|---|
| Criterion 1: Critically Endangered (CR) / Endangered (EN) Species | (a) Habitat required to sustain ≥ 10 percent of the global population of a CR or EN species/subspecies where there are known, regular occurrences of the species and where that habitat could be considered a discrete management unit for that species.<br><br>(b) Habitat with known, regular occurrences of CR or EN species where that habitat is one of 10 or fewer discrete management sites globally for that species. | (c) Habitat that supports the regular occurrence of a single individual of a CR species and/or habitat containing regionally- important concentrations of a Red-listed EN species where that habitat could be considered a discrete management unit for that species/subspecies.<br><br>(d) Habitat of significant importance to CR or EN species that are wide ranging and/or whose population distribution is not well understood and where the loss of such a habitat could potentially impact the long-term survivability of the species. |

| Criteria | Tier 1 | Tier 2 |
|---|---|---|
| | | (e) As appropriate, habitat containing nationally/regionally important concentrations of an EN, CR or equivalent national/regional listing. |
| Criterion 2: Habitat of Significant Importance to Endemic and / or Restricted-Range Species | (a) Habitat known to sustain ≥ 95 percent of the global population of an endemic or restricted-range species where that habitat could be considered a discrete management unit for that species (e.g., a single-site endemic). | (b) Habitat known to sustain ≥ 1 percent but < 95 percent of the global population of an endemic or restricted-range species where that habitat could be considered a discrete management unit for that species, where data are available and/or based on expert judgment. |
| Criterion 3: Habitat Supporting Globally Significant Concentration of Migratory Species and / or Congregatory Species | (a) Habitat known to sustain, on a cyclical or otherwise regular basis, ≥ 95 percent of the global population of a migratory or congregatory species at any point of the species' lifecycle where that habitat could be considered a discrete management unit for that species. | (b) Habitat known to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent but < 95 percent of the global population of a migratory or congregatory species at any point of the species' lifecycle and where that habitat could be considered a discrete management unit for that species, where adequate data are available and/or based on expert judgment.<br><br>(c) For birds, habitat that meets BirdLife International's Criterion A4 for congregations and/or Ramsar Criteria 5 or 6 for Identifying Wetlands of International Importance.<br><br>(d) For species with large but clumped distributions, a provisional threshold is set at ≥5 percent of the global population for both terrestrial and marine species.<br><br>(e) Source sites that contribute ≥ 1 percent of the global population of recruits. |
| Criterion 4: Highly Threatened and / or Unique Ecosystems | Criterion 4 has no tiered system although recent publication (Keith et al, 2013) may introduce this. This criterion must include one of the following<br>a) the ecosystem is at risk of significantly decreasing in area or quality;<br>b) has a small spatial extent; and /or<br>c) Contains unique assemblages of species including assemblages or concentrations of biome-restricted species. Highly threatened or unique ecosystems are defined by a combination of factors which may include long-term trend, rarity, ecological condition, and threat. | |
| Criterion 5: Areas Associated with Key Evolutionary Processes | The criterion is defined by:<br>a) the physical features of a landscape that might be associated with particular evolutionary processes; and/or<br>b) Sub-populations of species that are phylogenetically or morphogenetically distinct and may be of special conservation concern given their distinct evolutionary history. The latter includes evolutionarily significant units and evolutionarily distinct and globally endangered species. | |
| Notes:<br>• No Tier system is in place for Criterion 4 and 5. | | |

## A.4 Discrete Management Unit

As part of the process of determining whether Critical Habitat is present, the IFC Performance Standard 6 Criteria 1-3 requires a project to determine the Discrete Management Unit (DMU), which is the area of habitat to be considered for the Critical Habitat assessment. The DMU should have a sensible and definable ecological or political boundary *'within which the biological communities and/or management issues have more in common with each other than they do with those in adjacent areas'*.

DMUs do not imply management control or responsibility by the Project, and often include areas outside of their control. The DMU also does not indicate Project footprint or impacted area, and in most cases is larger than either of these. This ensures impacts on biodiversity values in the larger landscape are adequately considered.

The delineation of the management unit depends on the species of concern. Available baseline information indicates that the Project area may support the IUCN Vulnerable red-necked parrot. The DMU is therefore defined for this species.

The red-necked parrot occurs primarily in rainforest canopies, but is known to visit coastal areas to search for food. It is increasingly observed on agricultural land, feeding on citrus, passion fruit and mango plantations. Breeding is between February and June, with nests usually situated in the cavities of large forest trees.

The IUCN reports the red-necked parrot's range as primarily the Morne Diablotin Massif (north central Dominica) with birds also occupying habitats in the far north, east, south-east and centre of the island, and including the MTPNP. It should be noted that information on the ecology of the bird dates prior to Hurricane Maria but these broad locations are likely to have remained unchanged.

The DMU has been defined as encompassing the MTPNP, the Project Area, and the adjoining areas of habitat. Figure A2 shows the MTPNP, the Project Area, and the range of the red-necked parrot within the southern part of Dominica, as identified by IUCN[5]. It should be noted that IUCN reports the area outwith the orange shaded area as "possibly extinct" for this species although the bird is understood to be extant in the Project area and its surroundings.

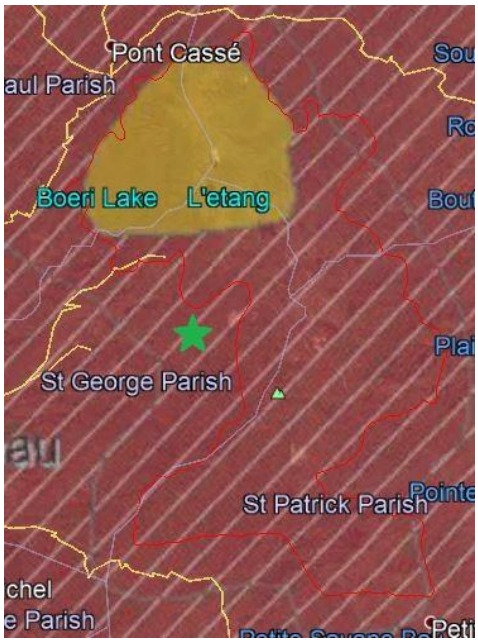


**Figure A2: Relative locations of the MTPNP, the Project Area, and range of the red-necked parrot**

*Key: green star = project location; red outline = MTPNP; orange shading = red-necked parrot extant (resident); red/white shading = red-necked parrot possibly extinct based on IUCN mapping*

### Critical Habitat Candidate Species

Further information on the species has been sought through a desktop review of available literature. It should be noted that the available literature on the red-necked parrot is limited, and that information almost exclusively dates from prior to Hurricane Maria. Table A2 outlines the Critical Habitat triggers for Criterion 1 to 3 with respect to this species.

[5] http://maps.iucnredlist.org/map.html?id=22686395

**Table A2 : Critical Habitat triggers for Criteria 1 to 3: red-necked parrot**

| Species | Common Name | IUCN Listing | Criterion 1 | Criterion 2 | Criterion 3 | Observation Type and Locations | Species Information | Criterion Rationale |
|---|---|---|---|---|---|---|---|---|
| *Amazona arausiaca* | red-necked parrot | V | N | N | N | Secondary evidence through baseline surveys. | This species is endemic to Dominica. It has distinctive bright green plumage, and takes its name from the bright red feathers around its throat.<br>Its numbers declined during the 20th century due historically to hunting and illegal trade, and more recently to clearance for agriculture, although when planted, the species may benefit from the fruit crops. Conservation action has helped this species recover from an all-time population low in 1980, with abundance increasing eight-fold, from c.150 to c.1200 (IUCN, 2017). Its numbers are however still low, and its range restricted to a single island.<br>It occurs primarily in rainforest canopies up to 800 m and occasionally to 1200 m, but is also known to visit coastal areas to search for food. It is increasingly observed on agricultural land, feeding on citrus, passion fruit and mango plantations. Breeding is between February and June, with nests usually situated in the cavities of large forest trees.<br>The IUCN reports the red-necked parrot's range as primarily the Morne Diablotin Massif (north central Dominica), with birds also occupying habitats in the far north, east, south-east and centre of the island, and including the MTPNP.<br>During Hurricane Maria a number of birds were kept in captivity were held safe and wild birds have been sighted since the hurricane (American Bird Conservancy, 2018). | Criterion 1 requires the species to be CR or EN, which this species is not. It is possible that the species conservation status may have changed since Hurricane Maria, however early reports indicate that the species has survived relatively well.<br>Criterion 2 relates to Habitat of Significant Importance to Endemic and / or Restricted-Range Species. The species has a restricted range on the basis of its number of locations and total population size. No sightings or other evidence of the species was made during surveys however the species is reported as known from the area and considered locally to be present in/around the project area. Desk study sources indicate its presence in the MTPNP. Given the greater quality and extent of habitat within the MTPNP it is likely that birds use the national park as primary habitat but may also pass through or feed within the Project area. The Project area is therefore not considered to sustain ≥95% or ≥1% but <95% of the global population, and as such is not deemed to trigger Criteria 2.<br>Criteria 3 requires the species to be migratory or congregatory, which this species is not. |

**Critical Habitat Criterion 1 – 3**

The results of the Critical Habitat Screening assessment as outlined in Table A2 above identified that no species trigger either Tier of Criteria 1 to 3.

**Critical Habitat Criterion 4**

PS6 describes this Criterion to be highly threatened or unique ecosystems including those:

- that are at risk of significantly decreasing in area or quality;
- with a small spatial extent; and
- containing unique assemblages of species including assemblages or concentrations of biome-restricted species.

Highly threatened or unique ecosystems are defined by a combination of factors which may include long-term trend, rarity, ecological condition, and threat. The habitats within the Project area and DMU do not fall within these criteria. The habitats such as secondary forest and agricultural land are common within the wider area and are not under threat. The assemblage of species is relatively poor in diversity and abundance within the Project are and DMU.

**Critical Habitat Criterion 5**

PS6 describes this Criterion as relating to:

- physical features of a landscape that might be associated with particular evolutionary processes; and/or
- subpopulations of species that are phylogenetically or morphogenetically distinct and may be of special conservation concern given their distinct evolutionary history.

There are no physical features within the Project area and DMUs that are known to be associated with evolutionary processes. The baseline surveys did not identify any species subpopulations known to be phylogenetically or morphogenetically distinct. As a result, it is determined that the Project area and DMUs is not important in the conservation of Key Evolutionary Processes.

## A.5 Other Recognised High Biodiversity Values

Determination of Critical Habitat is not necessarily limited to the five criteria above. Other recognised high biodiversity values can also support a Critical Habitat designation, and should be considered on a case-by-case basis. A number of example high biodiversity values are set out in Table A3, together with a summary of whether these values are triggered by the Project. Shaded cells indicate that the value is, or may be, met.

**Table A3 : IFC High Biodiversity Values**

| IFC High Biodiversity Values | Assessment |
|---|---|
| Areas required for the reintroduction of CR and EN species and refuge sites for these species (habitat used during periods of stress (e.g. flood, drought or fire)). | The Project area is mainly secondary rainforest and agricultural land. Whilst these may provide limited habitat of use to CR and EN species they are far poorer in extent and quality than the nearby MTPNP and not specifically required for reintroductions. **Not met.** |
| Ecosystems of known special significance to CR and EN species for climate adaptation purposes | The Project area is dominated by secondary rainforest and agricultural land and is not therefore considered of low value of significance for CR and EN species in respect of climate adaptation. **Not met.** |
| Concentrations of Vulnerable (VU) species in cases where there is uncertainty regarding the listing, and the actual status of the species may be EN or CR. | A single Vulnerable species, the red-necked parrot may be present in the Project area but is not thought to find core habitat there.<br>Following Hurricane Maria, it is likely that the actual conservation status of the species is uncertain, although early evidence indicates the species is doing relatively well. |

| IFC High Biodiversity Values | Assessment |
|---|---|
| | It is considered that this does not constitute a concentration of Vulnerable species. **Not met.** |
| Areas of primary / old growth / pristine forests and/or other areas with especially high levels of species diversity. | The Project area contains remnants of old growth forest, though these are typically isolated and small. They do not however have especially high levels of species diversity. **Not met.** |
| Landscape and ecological processes (e.g. water catchments, area critical erosion control, disturbance regimes (e.g. fire, flood) required for maintaining critical habitat. | The Project area has a varied topography but does not support landscape and ecological processes stated. No Critical Habitat has been identified. **Not met.** |
| Habitat necessary for the survival of keystone species. | The Project area is mainly secondary rainforest and agricultural land and does not comprise habitat necessary for the survival of keystone species. **Not met.** |
| Areas of high scientific value such as those containing concentrations of species new and/or little known to science. | The Project area is mainly secondary rainforest and agricultural land and does not comprise an area of high scientific value. **Not met.** |
| Areas that meet the criteria of the IUCN's Protected Area Management Categories Ia, Ib and II, although areas that meet criteria for Management Categories III-VI may also qualify depending on the biodiversity values inherent to those sites. | The Project area is not within a IUCN Protected Area. **Not met.** |
| UNESCO Natural World Heritage Sites that are recognised for their Global Outstanding Value. | The site lies approximately 600 m from the UNESCO World Heritage Site, MTPNP. **Not met.** |
| The majority of Key Biodiversity Area (KBAs) which encompass *inter alia* Ramsar Sites, Important Bird Area (IBA), Important Plant Areas (IPA) and Alliance for Zero Extinction Sites (AZE). | The nearest KBA is the MTPNP World Heritage Site, approximately 600 m from the Project area. **Not met.** |
| Areas determined to be irreplaceable or of high priority / significance based on systematic conservation planning techniques carried out at the landscape and/or regional scale by governmental bodies, recognised academic institutions and/or other relevant qualified organisations (including internationally recognised NGOs) | The Project area has not been identified as irreplaceable or of high priority / significance for conservation. There are however moves to create a buffer zone around the MTPNP, located 600 m from the Project area. The extent of the proposed zone is unknown, though it is possible the buffer could potentially extend to this distance. **Possibly met.** |
| Areas identified by the client as High Conservation Value (HCV) using internationally recognised standards, where criteria used to designate such areas is consistent with the high biodiversity values listed in paragraph 16 of IFC Performance Standard 6. | Project area is predominantly secondary rainforest and agricultural land and is not identified by the client as a HCV area due to it not containing areas of outstanding or critical importance for biodiversity. **Not met.** |

One High Biodiversity Value could possibly be met but is not considered sufficient to render the relevant habitats as being Critical.

## A.6 Conclusion

The Critical Habitat Screening Assessment found that none of the Criteria for Critical Habitat are triggered for the red-necked parrot, and the High Biodiversity Values are insufficiently met to trigger Critical Habitat status.

The assessment identifies that 1.7 ha of Natural Habitat would be lost under the Project footprint, specifically the reinjection line corridor. A mitigation measure for a biodiversity offset is included within Section 4, in line with the PS6 requirement for No Net Loss within Natural Habitats.

# Appendix I. Working Conditions, Occupational Health and Safety

Dominica Geothermal Development Company Limited
*Powering a New Generation...*

JACOBS

# Dominica Geothermal Development – Environmental and Social Impact Assessment

Ministry of Foreign Affairs and Trade

## Occupational Health and Safety and Working Conditions

RZ020300-0000-NP-RPT-0003-0015 | V2

July 2018

# Dominica Geothermal Development – Environmental and Social Impact Assessment

| | |
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**Appendix A. Grievance Form**

# 1. Introduction

This Technical Report provides a high-level overview of the proposed labour and working conditions, and sets out a framework as to occupational health and safety systems and practices which will be implemented in the construction, operation and maintenance of the Project. It is anticipated that detailed labour, health and safety documents will be prepared by the EPC Contractor prior to commencement of project construction works and by Dominica Geothermal Development Company (DGDC) prior to commissioning the plant. These would cover hazard identification, safe work practices, emergency response plans, incident/accident management, auditing and review etc.

## 1.1 Structure of the Report

This Technical Report is structured as follows:

- Section 2 describes the relevant international and Dominica legislation and guidelines;
- Section 3 describes how the Project will comply legislation relating to labour and working conditions;
- Section 4 describes the worker's grievance mechanism;
- Section 5 gives an overview of the construction / operation Occupational, Health and Safety (OHS) Plans;
- Section 6 describes the site safety management and awareness measures; and
- Section 7 outlines the relevant reporting, reviewing and auditing procedures to be implemented on site.

# 2. Legislation and Guidelines

The following national and international legislation and guidelines are relevant to this report. Reference should also be made to the Volume 1 – Section 2: Policy, Legal and Administrative Framework.

## 2.1 World Bank Performance Standards for Private Sector Activities May 2013

The following national and international legislation and guidelines are relevant to this report. Reference should also be made to the Technical Report – Policy, Legal and Administrative Framework.

The World Bank Performance Standards (PSs) relevant to this report are as follows:

**PS1: Assessment and Management of Environmental and Social Risks and Impacts:**

- To identify and evaluate environmental and social risks and impacts of the project.
- To adopt a mitigation hierarchy to anticipate and avoid, or where avoidance is not possible, minimize, and, where residual impacts remain, compensate/offset for risks and impacts to workers, Affected Communities, and the environment.
- To promote improved environmental and social performance of clients through the effective use of management systems.
- To ensure that grievances from Affected Communities and external communications from other stakeholders are responded to and managed appropriately.
- To promote and provide means for adequate engagement with Affected Communities throughout the project cycle on issues that could potentially affect them and to ensure that relevant environmental and social information is disclosed and disseminated.

**PS2: Labour and Working Conditions of the Equator Principles require the Project's proponent:**

- To promote the fair treatment, non-discrimination, and equal opportunity of workers.
- To establish, maintain, and improve the worker-management relationship.
- To promote compliance with national employment and labour laws.
- To protect workers, including vulnerable categories of workers such as children, migrant workers, workers engaged by third parties, and workers in the client's supply chain.
- To promote safe and healthy working conditions, and the health of workers.
- To avoid the use of forced labour.

**PS4: Community Health, Safety and Security:**

- To avoid or minimise risks to and impacts on the health and safety of the local community during the Project life cycle.
- To ensure that the safeguarding of personnel and property avoids or minimises risks to the community's safety and security.

## 2.2 World Bank Environmental, Health and Safety (EHS) Guidelines

Occupational safety and health systems for the development will also need to be compliant with the requirements set out in the World Bank General Environmental, Health and Safety (EHS) Guidelines. The EHS Guidelines contain international performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. They are designed and should be used together with the relevant industry sector guidelines. The most applicable EHS guidelines to this Project are:

- EHS General Environment, Health and Safety (EHS) General Guidelines (April 2007).
- EHS Guidelines Geothermal Power Generation (2007); and

- EHS Guidelines for Electric Power Transmission and Distribution (2007).

## 2.3 Dominica

Dominica legislation pertaining to Labour is made up of a number of Acts (Database of Labour Legislation, 2017). Acts relevant to occupational health and safety, working conditions and contracts of employment include the following:

- Accidents and Occupational Diseases (Notification) Act;
- Employment and Training Act;
- Employment Safety Act;
- Labour Standards Act and Labour Standards (Amendment) Act, 1991;
- Protection of Employment Act;
- Protection of Wages Act;
- Recruitment of Workers Act; and
- Trade Unions Act.

All activities conducted in relation to the Project shall comply with the laws and regulations of Dominica.

# 3. Labour and Working Conditions

## 3.1 Compliance with the Labour Code and WBG EHS Guidelines

The Project shall be constructed and operated in accordance with the laws and regulations pertaining to employment, human rights and worker rights in Dominica. As discussed in Section 2 above, it shall also abide by the policies of the WBG EHS Guidelines.

A Human Resources Policy to demonstrate compliance with Dominica Labour Legislation and WBG EHS Guidelines will be developed prior to commencement of any work by employees of either DGDC or the EPC Contractor on the Project. This policy shall be regularly reviewed as the Project progresses.

## 3.2 Contracts of Employment

All employees working on the Project shall have a mutually agreed Contract of Employment with their employer. This contract will include:

- Type of employment;
- Period of employment - working hours, working days and length of employment;
- Holidays – annual leave and public holidays;
- Duties and job title;
- Payment including overtime;
- Insurance;
- Procedures to deal with personal grievances; and
- Termination of employment.

In addition, the following with be a requirement of the EPC Contractor or DGDC in regards to labour and working conditions:

- Provision of information throughout the recruitment process on the employer's labour, health and safety policies;
- Assignment of tasks to employees that are consistent with their physical capacities and job skills ;
- Operation of programmes for employees' health management, including regular health checks; and
- Ongoing safety education and training as required to perform, supervise, and manage assigned tasks without mishap.

## 3.3 Health Checks

Regular health assessments of all staff at the site shall be carried out during the Project. Costs for these assessments shall be borne by the employer. An example of the type and frequency of health checks is provided in Table 3-1.

**Table 3-1: Example Health Assessment Schedule**

| Type of Health Inspection | Personnel | Frequency | Comments |
|---|---|---|---|
| Pre-employment health check | Potential employees | Before signing of employment contracts | |
| Routine health inspection | All workers (including subcontractors) | Once a year | |

| Type of Health Inspection | Personnel | Frequency | Comments |
|---|---|---|---|
| Special health inspections | Workers who handle heavy metals and organic solvents | If requested | |
| | Workers exposed to noise/vibration, dust or harmful rays | If requested | Special tests where appropriate including lung function, sight and hearing, etc |

As well as regular worker health assessments, occupational health monitoring will be conducted at the site. This includes:

- noise monitoring;
- electric and magnetic field monitoring; and
- occupational hygiene air quality monitoring.

## 3.4 Training

Training will be an important component of health and safety for both the construction and operation / maintenance of the power plant. All staff will receive appropriate health and safety training so they can undertake their work tasks in a safe manner. The level of health and safety training provided will depend on the health and safety hazards of each individual's work.

### 3.4.1 Induction Training

Health and safety induction training will be provided for all new Project employees prior to the commencement of their duties. The training will cover health and safety, familiarisation with the site and site-specific hazards. All new employees will be required to attend the safety induction course prior to receiving entry badges for authorisation to enter the project site.

Induction training will be conducted by the OHS Manager. It will be the responsibility of the DGDC and EPC Contractor to ensure all staff receives induction training.

The induction programme will cover the following:

- Site safety policy;
- Project safety objectives and behavioural based health and safety;
- Site safety rules;
- Work permit and security systems;
- Job safety analysis / risk assessment;
- Communicate HSSE roles and responsibilities of respective positions (e.g. managers, supervisors, HSSE personnel and workers);
- The site hazard labelling / signage system;
- Personal protective equipment (PPE);
- Hazards and accident reporting; and
- Emergency procedures.

Visitors to the site shall also attend a visitor orientation and control programme to ensure they do not enter hazardous areas unescorted.

### 3.4.2 Ongoing Health and Safety Training

As well as a site induction for new workers, ongoing health and safety training shall be provided by the DGDC or EPC Contractor. This will be sufficient to ensure that staff have the appropriate technical skills and safety awareness to perform their assigned jobs properly and safely. Staff involved in potentially hazardous tasks, e.g. working in hazardous areas, working at heights, working in confined spaces etc., where additional skills are needed, will be given specialised training as per the job requirement.

A proportion of employees will be required to attend additional training courses, such as basic industrial first aid or firefighting.

An example of the type and frequency of safety training is provided in Table 3-2. The DGDC or EPC Contractor may also provide further training as part of their internal requirements.

**Table 3-2: Example Safety Training Requirements**

| Type of Training | Personnel | Frequency | Comments |
|---|---|---|---|
| Regular training | Site staff | 2 hours/ month | Including subcontractors |
| Training by OHS Manger | Staff higher than foreman position | 16 hours / year | Including subcontractors |
| Adaptation training | Staff whose work activity has changed | Dependent on activity | |
| Special training | Staff engaged in hazardous activities | Dependent on activity | |
| Basic fire fighting | All staff or not less than 40% of all people on site | Once a year | By a third party |
| Emergency drill | All staff or not less than 80% of all people on site | Once a year | |

The level and type of safety training provided shall be documented in a Safety Training Register.

## 3.5 Discipline

Discipline of employees is addressed in Protection of Employment Act. Both the EPC Contractor and DGDC will be required to have discipline measures and procedures included within their Human Resource Policy.

## 3.6 Dispute Resolution

The Trade Unions Act provides details for the resolution of labour disputes. The Human Resource Policy will include procedures for dispute resolution, including details of external mediators.

# 4. Worker's Grievance Mechanism

## 4.1 Overview

A worker's grievance mechanism will be established as part of the Environmental and Social Management System (ESMS). This grievance mechanism will be designed to receive and facilitate resolution of concerns and grievances about the Project's working conditions and safety performance. It will be scaled to the risks and impacts of the Project and have workers as its primary user. It will seek to resolve concerns promptly, using an understandable and transparent consultative process that is culturally appropriate, readily accessible, at no cost, and without retribution to the party that originated the issue or concern. The mechanism should not impede access to judicial or administrative remedies. The Project Sponsors will inform the workers about the mechanism in the course of the workers engagement and induction process.

## 4.2 Proposed Grievance Mechanism

Site preparation, construction activities and the use of temporary worker accommodation pose potential risks to the health, safety, and security and therefore well-being of construction workers if not managed appropriately. Community health and safety risks associated with the use of temporary accommodation sites include those relating to sanitation, disease, cultural alienation and fire. Similarly, there are potentially negative occupational health and safety impacts related to personal accident or injury on any construction site. There are also potential adverse impacts on workers related to their terms of engagement and relationship with their employer.

The Project will establish a grievance mechanism for workers, which will include any concerns related to health and safety. Each affected person will be free to register a grievance, in accordance with procedures specified below. This mechanism covers any type of complaint, and includes three main steps:

- The registration of the complaint or dispute;
- The amicable resolution of the complaint; and
- Use of mediation if necessary.

Most of these issues can often be resolved by a good faith discussion with the complainant and may be resolved by additional communication (e.g. providing detailed information about the rights of the workers on the Project). However, some issues may only be able to be resolved through a formal legal process. Figure 4-1 shows the proposed complaints handling mechanism.

## 4.3 Recording of Complaints

The Project will use the following means to register complaint from workers:

- Provision of a dedicated phone number to provide information on the Project, and register complaints; and
- Provision of a comment box / complaints register in DGDC or the EPC Contractor's site offices once the construction has started. Workers will be able to lodge complaints using a Grievance Form (Appendix A). Any oral complaint given to the Health and Safety Office of DGDC or the EPC Contractor or will also be registered.

The existence of this register and access conditions will be widely disseminated to workers during induction activities.

Workers complaints relating to employment and health and safety issues of the Project will be recorded and kept in a communications / complaints log book and in a database. A quarterly report monitoring the complaints recorded will be generated for the attention of the management of DGDC or the EPC Contractor.

When a complaint is received, it must be recorded in the Grievance Mechanism and Complaints Form in Appendix B. The complaint should be recorded by the Health and Safety (HS) Manager and the Human Resources (HR) Manager, or other members of the Project Team receiving the complaint before being passed onto the HS Manager and the HR Manager to action. The HS Manager and the HR Manager will then follow up with the complainant directly to discuss options for a resolution.

All communications or complaints must be acknowledged by the HS Manager and the HR Manager within 5 business days and a response must be made to the complainant within 30 business days.

If the complaint is resolved internally, details of the complaint and resolution should be provided in the complaints form and filed. If the complaint cannot be resolved, the HS Manager and the HR Manager shall organise a mediation session with the local authority.

## 4.4 Mediation by Local Authorities

If the solution proposed by DGDC or the EPC Contractor is rejected by the complainant, and no amicable solution can be found, the issue will be transmitted to the Provincial People's Committees / Provincial Departments. All evidence and documentation will be transmitted, in order to allow the authorities to understand the issue at stake. The Provincial People's Committees / Provincial Departments will then hold a mediation session with the affected parties and relevant members of the Project Team in order to develop a solution. If the complainant is not satisfied with the solution, the matter must then be referred to the Judicial Courts.

## 4.5 Complaint Processing Time

All communications or complaints will be acknowledged within five business days and a response within 30 business days.

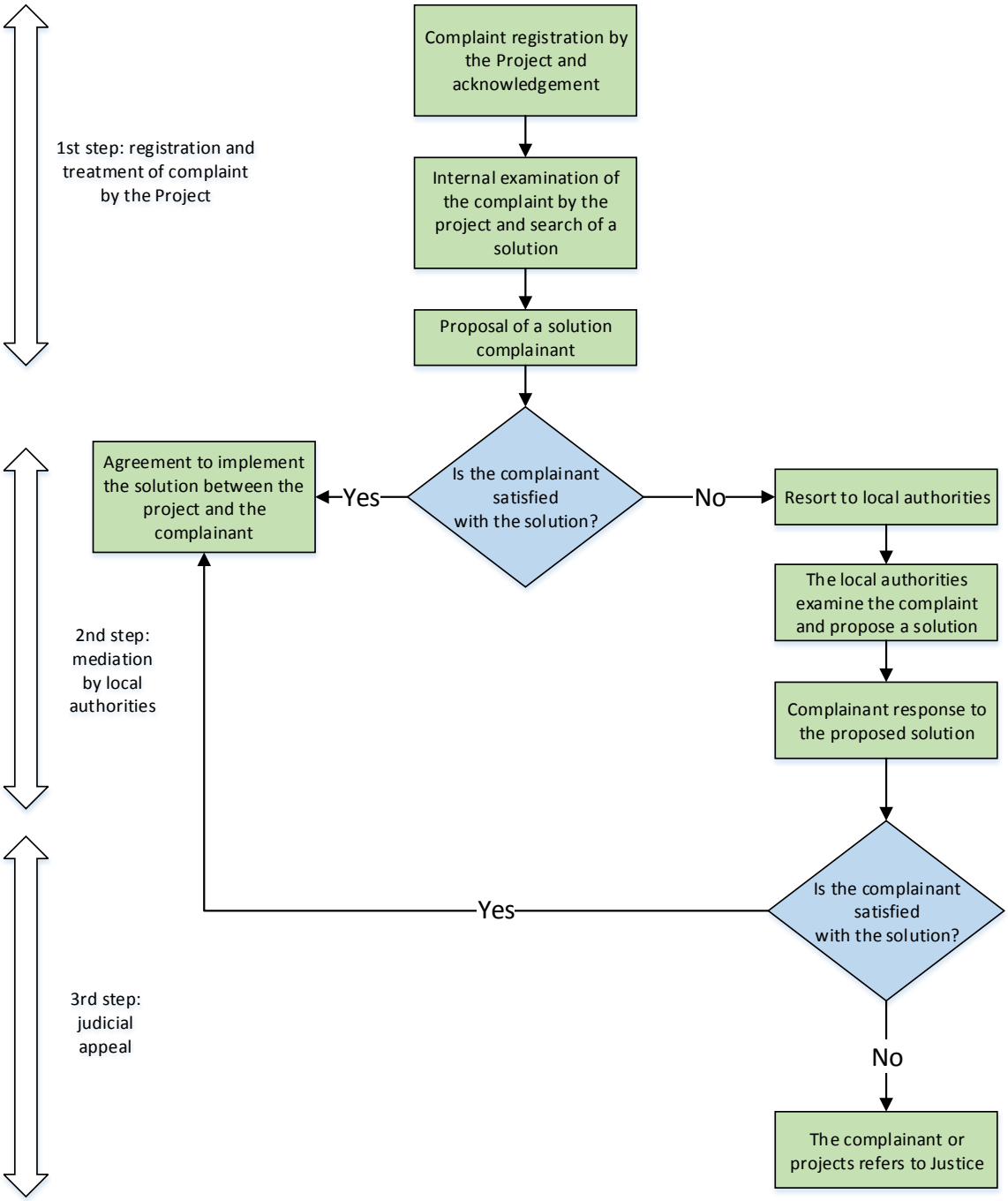


**Figure 4-1: Grievance/ Complaints Handling Process**

# 5. Overview of the Construction / Operation OHS Plans

The Employment Safety Act is the principal form of legislation pertaining to Occupational Health and Safety although specific Occupational Diseases are covered within the Accidents and Occupational Diseases (Notification) Act.

DGDC and the EPC Contractor will be required to develop OSH Plans for the construction and operation activities at the Project, which will apply to all personnel involved in the Project, including sub-contractors and part-time workers.

The primary health and safety objectives will be to ensure effective measures and management of occupational health and safety to minimise workplace accidents and injuries.

The health and safety procedures within the OHS Plans will be developed to form a comprehensive Health and Safety Management System. They will also meet the requirements specified in the WBG EHS Guidelines pertaining to occupational safety and health.

Set out in the following sections are the key elements of the site health and safety procedure to be included within the OHS Plans. This report provides a high level overview of health and safety considerations only, with further detail being provided in the final OHS Plans prepared by DGDC and EPC Contractor prior to commencement of onsite work.

## 5.1 Plan Requirements

The OHS Plans will outline the procedures essential for the protection of personnel during construction and operation. They will be designed to assist all those who deal with OHS as a functional responsibility within the context of their job.

Occupational health and safety performance should be evaluated against internationally published exposure guidelines, of which examples include:

- Threshold Limit Value (TLV) occupational exposure guidelines and Biological Exposure Indices (BEIs) published by American Conference of Governmental Industrial Hygienists (ACGIH) (various dates);
- Pocket Guide to Chemical Hazards published by the United States National Institute for Occupational Health and Safety (NIOSH) (2007);
- Permissible Exposure Limits (PELs) published by the Occupational Safety and Health Administration of the United States (OSHA) (various dates);
- Indicative Occupational Exposure Limit Values published by European Union member states (2017);
- or other similar sources.

In particular, they will include:

- Demonstration of compliance with Dominica Labour Legislation and World Bank EHS Construction related Occupational Health and Safety Guidelines (Section 1.2 of the WBG EHS Industry Guidelines – Geothermal Power Plants (2007) and Section 1.2 of the WBG EHS Guidelines – Electric Power Transmission and Distribution (2007)), including consideration of the following risk that are directly related to geothermal developments:
  - Geothermal gas exposure;
  - Confined Spaces;
  - Heat; and
  - Noise.
- OHS responsibility / reporting structure;

- Details of site inductions and ongoing training;
- Hazard identification and risk assessment;
- Mitigation measures including mandatory personal protection equipment (PPE);
- Safe working procedures and safety rules (includes permit-to-work procedures, working at height, etc)
- Response to health and safety incidents, including investigation and reporting;
- Emergency response plans;
- Reporting, auditing and record keeping systems;
- Scheduled OSH meetings; and
- Inspection and auditing procedures.

The key goal of the plans will be to instil a safety culture within the site employees through education, good communication, a motivated workforce, recognition of individual/team effort and safety incentive programmes.

The OSH Plans will be living documents that will be regularly updated throughout the life of the Project to ensure compliance with changes in regulation and industry practice.

## 5.2 Health and Safety Responsibilities

It is the responsibility of all individuals working within the Project to be aware of health and safety hazards. Health and safety should be encouraged by example, knowledge, skills, overall attitude, and involvement in the OHS Plans.

DGDC and the EPC Contractor will establish a hierarchy of responsibility with regards for the provision of health and safety. The precise titles and roles of each member will be determined by the DGDC and the EPC Contractor prior to work on the site; however, the following is an indicative list of personnel with specific OHS responsibilities:

- Construction / Operation Site Manager;
- OHS Manager;
- OHS Supervisors / Safety Officers;
- Work Supervisors;
- All Staff; and
- Visitors.

The OHS Plans will define the responsibilities of these personnel. These will include those who will enforce the OHS plans, the reporting lines for OHS management, discipline procedures for safety violations, etc. An example is given in Table 5-1.

**Table 5-1: Example of Health and Safety Responsibility Hierarchy**

| Position | Responsibility |
|---|---|
| Construction / Operation Site Manager | Establishment of the OHS programme, ensuring that it meets the Owner's contractual requirements |
| OHS Manager | Head of emergency response<br>Inspecting safety equipment, PPE and firefighting equipment, and taking action as required when equipment does not meet the required standard<br>Choosing suitable products when purchasing protective equipment, hazardous machines, instruments and facilities<br>Organising safety training |

| Position | Responsibility |
|---|---|
| | Instructing the site security team on their role<br>Investigating the causes of accidents and ensuring the appropriate follow-up measures are undertaken<br>Discipline of personnel who violate safety rules<br>Maintaining OHS records and reporting to the Health and Safety Committee on a monthly basis and to the appropriate authorities when required<br>Managing the medical care of patients who are injured in a workplace accident |
| OHS Supervisors / Safety Officers | Routine checking of equipment, facilities and instruments to identify hazards and ensure safe operation<br>Training and instruction in the use of protective equipment<br>Accident reporting on any incidents within their area of responsibility |
| Work Supervisors | Ensuring machinery / equipment is used by appropriately trained personnel in a safe manner<br>Ensuring personnel working with / in hazardous substances or locations have the appropriate level of protection before work commences<br>Ensuring appropriate permits-to-work have been obtained |
| All Staff and Visitors | Duty of care<br>Identification and communication of hazards<br>Compliance with instructions and the OHS Plans |

In addition, any subcontractors appointed by the DGDC or the EPC Contractor will be required to submit their own OHS Plan, with an appropriate responsibility hierarchy, for approval prior to appointment.

A Health and Safety Committee will be formed, comprising members of senior management and any subcontractor's representatives. This committee will meet on a monthly basis to discuss labour, health and safety concerns.

# 6. Site Safety Management and Awareness

The following outlines the general safety measures to be applied during the construction, operation and maintenance of the Project.

## 6.1 Site Management Systems

As well as the main OSH Plans, specific procedures which will be contained in the Health and Safety Management Systems (HSMS) shall be developed for each element of the Project (construction and operation), including the following:

- Safety management organisation / reporting chain;
- Design safety and constructability program;
- Construction methodology;
- Hazard / risk assessment and proposed mitigation measures; and
- Safety checklists.

### 6.1.1 Hazard / Risk Assessment

The aim of the hazard and risk assessment is to limit the risks to life, prevent injury and property loss by identifying and mitigating the potential hazards posed during the various activities undertaken in the construction, operation and maintenance of the Project.

Each Safety Management System will have a procedure for identifying all hazards associated with the activity in question. A hazard in this context is defined as any aspect of the Project activities which could result in harm to onsite personnel. These may include some of the following:

- Non-ionizing radiation;
- Heat;
- Noise;
- Confined spaces;
- Electrical hazards;
- Fire and explosion hazards;
- Chemical hazards; and
- Dust.

Each hazard will then be assigned a risk level based on the likelihood and severity of the consequence of exposure using a matrix system, such as that provided in Table 2.1.1 of the WBG EHS General Guidelines: Occupational Health and Safety. Depending on the assigned level of risk appropriate mitigation measures will be proposed to eliminate, control or minimise the risks associated with each hazard. It shall be DGDC and the EPC Contractor's responsibility to ensure these measures are undertaken. The output from this hazard identification and risk assessment process will be a Hazard Register and a series of corrective actions required to implement the mitigation proposed to reduce the level of risk of a hazard to an acceptable level. The Hazards Register will be regularly reviewed and updated.

## 6.2 Personal Protective Equipment

All workers shall at a minimum wear safety shoes, safety helmets and safety glasses. Some personnel will require additional specialist PPE if exposed to specific hazards. An example of PPE requirements for specific tasks is set out in Table 6-1. Other tasks that are not included within this table may have further PPE requirements.

**Table 6-1: Example of PPE Requirements**

| Work | Minimum Items to be Supplied |
|---|---|
| All workers | Safety helmet, safety shoes and safety glasses |
| Work at heights | Safety harness and rope |
| Work where oxygen deficiency is expected | Portable or supplied air (fixed lines)<br>On-site rescue equipment |
| Work producing harmful gas | Facemasks with appropriate filters for air purification (chemicals, mists, vapours and gases)<br>Single or multi-gas personal monitors |
| Electrical work | Live wire alarm<br>Safety gloves |
| Work producing dust | Facemasks with appropriate filters for dust removal and air purification |
| Welding and grinding work | Face shield / welder goggles and earmuffs<br>Protective clothing |
| Work producing noise greater than 85 dB over an 8 hour day or an instantaneous noise of greater than 140 dB | Earplugs / earmuffs |
| Work handling poison and toxic substances | Gloves, apron, splash suits, face shield or goggles |
| Harmful radiation such as X-rays | Protective glasses with side-shields<br>Radioactive meter |

## 6.3 Safe Work Rules and Procedures

The safe construction and operation of the site will be reliant on staff comprehending and obeying safety rules and restrictions. Because of this, the dissemination of safe work rules and procedures will be crucial.

Generic rules shall be provided within employment contracts and task specific procedures will be communicated during tool box talks and displayed on machinery or within hazardous work areas. An example of some basic safety rules include:

- All site safety signage shall be obeyed;
- No unauthorised staff shall enter restricted areas;
- No work shall be undertaken without prior instruction;
- No staff shall undertake work for which they have not received adequate training;
- No running or horseplay within the site;
- All staff shall use designated safe walkways and site entrances and exits;
- All staff shall wear provided personal protective equipment, which at a minimum shall include safety shoes, safety glasses and fastened safety helmets;
- Operating machinery shall not be left unattended; and
- Zero tolerance policy on alcohol or drugs in the work place.

In addition to rules, safe work procedures will be developed for operating equipment and work around machinery. These are likely to include the following (not a comprehensive list):

- Fire prevention;
- Jjob site safety inspection;
- Transportation;
- Excavations, trenching and shoring;

- Asbestos and other fibres;
- Welding, cutting and brazing;
- Piling operations;
- Work place ladders and scaffolding;
- Hand tools and power tools;
- Paints and coatings;
- Concrete forms and shorings;
- Crane and lifting equipment;
- Slings and lifting gear (rigging);
- Mechanical equipment;
- Material handling;
- Electricity;
- Ionizing radiation;
- Liquefied petroleum gases; and
- Chemicals.

A comprehensive catalogue of safe work procedures shall be developed as part of the OHS Plans and Safety Management Systems.

Compliance with safe work rules and procedures will be an important facet of the employment contracts between Project employers and employees and failure to comply will result in disciplinary action.

## 6.4 Permits to Work

All hazardous work shall be completed in accordance with a Permit-to Work System which will require the completion of a permit-to-work form and approval by the OHS Manager prior to commencement. Hazardous work is likely to include the following (not a comprehensive list):

- Work with or near hazardous substances;
- Welding and cutting of containers and pipes where explosives or inflammables may remain;
- Work in confined spaces where toxic gases may be present;
- Work at heights;
- Installing and repairing hazardous equipment;
- Work with live electrical systems; and
- Radioactive work.

## 6.5 Site Safety Facilities

The facilities provided at the site shall be to a level that allows health and safety standards to be maintained. These shall include:

- Provision of first-aid equipment and stations;
- An onsite medical facility including trained medical staff;
- Clean eating areas;
- Sanitary facilities;
- Safe access to work and communal areas;

- Sufficient air supply in indoors work areas;
- Emergency response equipment; and
- Appropriate labelling / signage of equipment and hazards.

## 6.6 Meetings

It is imperative that health and safety messages are communicated so that all staff are aware of their responsibilities.

### 6.6.1 Daily Tool Box Talks

Daily 5-10 minute meetings shall be conducted by Site Supervisors before commencing work to publicize and emphasize safety and health procedures relevant to the nature and location of work taking place on that day. Where work permits are required, the Site Supervisor will use this time to ensure that personnel involved are fully aware of all limitations and restrictions, safety requirements, and job execution details. This will ensure that all personnel working at the site are aware of hazards and controls required at the start of each day's work.

### 6.6.2 Weekly OHS Meetings

Weekly OHS meetings shall be conducted by the OHS Manager. The purpose of these meetings will be to:

- Provide a regular update of safety alerts;
- Review all incident reports and make recommendations;
- Review tool box meeting minutes/topics;
- Review weekly inspections/audits; and
- Provide an opportunity for staff to raise health and safety concerns.

### 6.6.3 Safety and Health Management Committee

The Construction Site Manager and the Operation Site Manager shall appoint a Health and Safely Management Committee, which will include members of subcontractor organisations. The Committee shall meet every month to undertake a joint safety check. The Committee shall review the following:

- Summary of current health and safety issues;
- Evaluation of the state of health and safety controls at the site;
- Evaluation of the communication of health and safety messages to staff;
- Assessment of any health and safety incidents (especially lost time incidents);
- Recommended changes to equipment, policy and / or procedure as a result of injury, damage or failure;
- Recognition of health and safety success and failures; and
- Any other matters raised as necessary for the management of health and safety.

These meetings will provide an on-going forum for managing health and safety at the site and reacting to changing conditions and work activities. The outputs from these meetings will be a monthly report, which will be provided to the local labour authority.

## 6.7 Monitoring and Inspections

The OHS Plans and Health and Safety Management Systems will include a schedule of regular safety inspections and monitoring of exposure to hazards. This will include the state of the site as well as the maintenance of equipment and a comparison to internationally published exposure guidelines. Table 6-2 sets out an example schedule for conducting safety checks and inspections.

**Table 6-2: Example of Inspections and Monitoring Schedule**

| Description | Site Area | Frequency | Inspector | Focus |
|---|---|---|---|---|
| Safety patrol | All the areas in the construction site | Every day | Work Supervisors | Filling out the safety check form |
| Weekly check | Work place hazards and construction equipment / machinery | Weekly | OSH Safety Manager | Hazards / defects in equipment |
| Maintenance checks | Hazardous machines, facilities and tools | More than once in every quarter or as given in supplier's specifications | Specialist | Safety of machinery / tools |
| Noise levels | Where exposure to noise is likely to occur | upon commencement then twice a year if there is not a problem or at a frequency as determined by the hazard assessment. | Specialist | Compliance with threshold values** |
| Electric and magnetic field monitoring | Where exposure to electric and magnetic fields is likely to occur | upon commencement then twice a year if there is not a problem or at a frequency as determined by the hazard assessment | Specialist | Compliance with threshold values* |
| Occupational air quality monitoring | Where exposure to hazardous air emissions is likely to occur | upon commencement then twice a year if there is not a problem or at a frequency as determined by the hazard assessment | Specialist | Compliance with threshold values** |

*As given in the WBG's Environmental, Health, and Safety Guidelines: Thermal Power Plants

**As given in the WBG's General Environmental, Health, and Safety Guidelines: Occupational Health and Safety

The Site Manager shall instigate measures to correct non-conformance in safety performance found during safety checks and inspections. A record of the safety checks and inspections, and resulting actions, shall be provided to the Health and Safety Management Committee every month.

## 6.8 Security Procedures

A security procedure shall be included within the OHS Plan and HSMS. The document shall cover the following issues:

- Areas of security control;
- Working hours;
- Prohibited articles / activities on the site;
- Duties of security staff;
- Entry and exit from the site; and
- Application, issue and display of security passes (including vehicle passes).

The security procedures will be communicated to all site personnel as part of their induction training. It will outline the duties, tasks and responsibilities of employees working on the Project. It will also provide actions in the event of an identified security breach.

## 6.9 Emergency Response Procedures

Emergency Response Procedures will form an integral part of the OHS Plans and HSMS. As part of these, an Emergency Response Plan shall be prepared to address emergencies of all scales, such as:

- Small incidents such as minor spillages or individual incidents resulting in minor harm;

- Large incidents major spillages or failure of control equipment that could result in offsite impacts or severe injuries or even fatalities;
- Natural disasters such as tsunami or an earthquake;
- Fires or explosions; or
- Release of toxic gases or substances.

This plan will include responsible personnel in the event of an accident / incident or emergency, procedures to be followed, a site evacuation plan and contact details of emergency response facilities.

DGDC and the EPC Contractor shall also co-ordinate and provide training for a disaster action team.

The site shall at all times have adequate and functioning firefighting facilities. The Safety Manager shall conduct regular training for workers on how to use firefighting equipment safely.

Accident / incident and disaster reporting requirements will also be detailed in the Emergency Response Plan.

## 6.10 Accident /Incident Reporting and Investigation

All employees, contractors and visitors will be required to report any incidents that occur, including fire, explosion, natural disaster, equipment failure, plant, vehicle or other accident, other incidents or near misses during the construction and operation of the power plant. Procedures will be developed by the construction contractor and the plant operator for the reporting, investigating of all accidents and incidents that as a minimum result in first aid treatment or are deemed to be a near miss which for other reason could have resulted in an accident that caused significant injury or even a fatality.

The procedures will cover:

- Responsibilities for employees, site supervisors, and managers for notifying the incident/accident, investigating and reporting on the incident/accident and for implementing any recommended corrective actions as a result of the incident/accident investigation.
- All incidents, including near misses to personnel, plant and equipment damage must be reported to the person's immediate supervisor or foreperson.
- How the incident (lost time accident (LTA), no lost time accident (NLTA) or near miss) is recorded in the site's Accident Register and who is required to complete the initial sections of the Incident Investigation Report Form.
- Who should undertake the incident investigation and the information that shall be recorded on the Incident Investigation Report Form including all recommendations including improvements, work practice changes, disciplinary actions, etc.
- Procedures for notifying incidents/accidents to government and provincial agencies, including the time period allowed for reporting such incidents.
- How corrective actions as a result of the incident/accident investigation are implemented and the Hazards Register is amended.

# 7. Reporting, Reviews and Audits

## 7.1 Reporting to the Local Labour Authority

DGDC and the EPC Contractor shall establish contact with the local labour authority to determine the appropriate reporting channels. Once construction has commenced the following shall be communicated:

### 7.1.1 Bi-annual Reports

The output of the Health and Safely Management Committee's meeting will be a bi-annual report provided to the local labour authority. This will summarise the actions undertaken as the result of onsite meetings, any current health and safety issues and an evaluation of the current state of health and safety at the site.

### 7.1.2 Labour Disputes and Dismissals

If any issues are raised by either employers or employees relating to labour or working conditions, such as contravention of site rules or contractual disputes, these shall in the first instance be dealt with as outlined in the site Human Resource Policy. Where a disciplinary action result in a dismissal or contractual mediation is required this shall be reported immediately to the local labour authority.

### 7.1.3 Notification of Accidents/Incidents

All accidents and incidents which result in first aid treatment during the construction and operation of the power plant shall be reported via the appropriate channels to the Health and Safety Management Committee. Minor incidents along with the incident/accident investigation report shall be supplied to the local labour authority along with the monthly report. Serious accidents that result in serious harm or a fatality should be reported immediately to the local labour authority.

## 7.2 Management Review

This report outlines the requirement for a number of site documents and procedures, including a Human Resource Policy, OHS Plan, Health and Safety Management System, Hazard Register and Emergency Action Plan. As discussed previously these should be all be 'living' documents and procedures in that they should be regularly reviewed and updated when required.

Together, they comprise the site labour, occupational safety and health system. This should be overhauled on at least an annual basis to ensure it is inclusive of new guidelines and legislation and that the existing systems are working as required. The Construction / Operation Site Manager shall be responsible for ensuring this is undertaken.

## 7.3 External Auditing of Health and Safety Systems

Independent audits of the Construction and Operation OHS Plans shall be undertaken by an appropriately qualified person to ensure compliance with Dominica Labour Legislation and World Bank EHS Guidelines. In addition, onsite audits shall be conducted on a timeframe specified within the plans to ensure the health and safety practices are compliant.

If unsafe practices are identified during the audits, immediate cessation of the work shall ensue until the situation has been remedied to an acceptable level. Corrective actions will be documented and provided to the Health and Safety Management Committee.

The accident and fatality rates of the Project shall be benchmarked against the performance of other facilities in this sector in developing countries through consultation with published sources.

# 8. Conclusions

The report demonstrates that the development will meet the requirements of the World Bank EHS Construction related Occupational Health and Safety Guidelines and that the proposed occupational health and safety systems for each stage will meet good international industry practice. The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs.

# Appendix A. Grievance Form

| GRIEVANCE REGISTRATION | | |
|---|---|---|
| Date: | Filled by: | |
| Plaintiff's name : | Plaintiff's gender: M / F | Plaintiff occupation: |
| Plaintiff's contact (address, tel. number): | | |
| □ The plaintiff is filling an individual complain | | |
| □ The plaintiff is representing an individual or group of workers<br>- Name of the individual or group of worker:<br>- Nature of the individual or group of workers:<br>- Location/address: | | |
| Description of the grievance: | | |

| GRIEVANCE TREATMENT | |
|---|---|
| Date of the response: | Filled by: |
| Proposed action(s) to remedy to the grievance: | |
| Plaintiff's acceptance of the proposed action: | |

| GRIEVANCE CLOSURE | |
|---|---|
| Date of grievance closure: | Filled by: |
| **Ending of the grievance treatment:** | |

# Appendix J. Stakeholder Engagement – Meeting Minutes

COMMONWEALTH OF DOMINICA

# MINISTRY OF PUBLIC WORKS, ENERGY AND PORTS
# GEOTHERMAL PROJECT MANAGEMENT UNIT

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3rd Floor, Government Headquarters
Kennedy Avenue
Roseau
Commonwealth of Dominica

**FROM:** Project Officer / Geothermal Project Management Unit

**TO:** Permanent Secretary/ Ministry of Public Works, Energy & Ports

**DATE:** January 25, 2014

**SUBJECT: Community Meeting – Project Update - Laudat**

A community meeting was held on Thursday January 23, 2014 at the Laudat Primary School to inform residents of the Roseau Valley and more specifically those of Laudat of the on-going drilling activities.

In attendance were:

Hon. Dr. John Collin McIntyre: Parliamentary Representative for the Roseau Valley
Alexis George: GPMU
Clarence Reems/ Verrette Sampson: Drilling Supervisors, GRG.
Annette Mortensen: Geologist, ISOR
Mandela Christian: Office of Disaster Management
Aaron Rolle: Community Liason Officer
Members of the Laudat Improvement Committee
Residents of Laudat and neighbouring communities (approximately 60)
Quick Links Productions: Provided video coverage

The GPMU representative gave welcome remarks and acknowledged the presence of the Parliamentary Representative and the team from GRG and ISOR.

Mr. George delivered a brief power point presentation of the status of drilling activities. The floor was then opened for question and answer session.

Questions and comments included the following:

- In case of emergency what has been put in place for the residents? There should be information placed on notice boards, leaflets, brochures, to indicate what is to be done in the event of an emergency.
- What are the direct benefits of the project to the communities of the Roseau Valley and to the country?
- Why haven't the land owners been compensated for use of their land from the exploratory phase to date? That confirms the level of disrespect shown to land owners.
- Has the EIA's been made available to the public? Is so where can it be accessed?
- What about the health risk/ hazards? Will the residents be provided with masks?
- What about the persons who don't attend the meetings, how are they informed and kept up to date as to what's going on? There is need to improve on the public relations and dissemination of information.

- Concerns related to the environment: who performed the EIA's? Who were the persons surveyed in the Roseau Valley that is mentioned in the EIA? We believe the drilling activity is negatively affecting the tourist/ visitor experience due to the noise etc. and the whole idea of being in the natural environment.
- Is GoCD concerned about the state of the Rain Forest Aerial Tram?
- Will the land owners be compensated fairly and in a timely manner if their land is acquired?
- In 1949 CDC purchased land in Laudat for the Hydro Project and land owners received payment before any work was undertaken on the ground; can we expect the same for the Geothermal Project?
- If directional drilling is targeted towards the Valley of desolation or Boiling Lake, Will these areas be monitored during the Well Testing Activities?
- Will the GoCD consider that residents receive some compensation for every KW of electricity generated or get special concessions or reductions on their electricity bills?
- Where do we go from here? We need adequate responses to our questions/ concerns at the next community meeting.

- The EIA is very technical; we need a better understanding of it.
- The Permanent Secretary and Minister for PWEP as well as the Prime Minister should attend the meetings.
- Signage should be placed along the route to the site highlighting that there is drilling activity on-going. Residents living in close proximity to the site should be made more aware and there is need to perform a simulation exercise in the event of an emergency situation.
- The Health Centre is not adequately supplied.
- The Village Improvement Committee is not providing adequate representation to the community of Laudat.
- GoCD needs to look at an alternate exit route for Laudat.
- In the event that there is an emergency on site there should be a system put in place that will automatically inform the Police, Fire and Ambulance Service and for the residents, text messages (through LIME/ DIGICEL) could be sent to alert them.
- Banks will not guarantee loans to persons whose property is in close proximity to existing drill sites or within the geothermal project area. *Flagged*
- In respect to the cost to land owners in terms of not being able to fully develop their properties in one way or another because of the uncertainty that exists whether their property will be acquired or not; can a fund be set up for the affected land owners for that purpose.
- Two residents (Mary Ralph and Mr. Magloire) complained of irritation to the nose and throat since drilling commenced.
- Residents would like a meeting to be held with the Policy makers but would like to receive a written proposal of the developmental plans of the project and the effect on land owners/ residents before said meeting.

Submitted for your information.

Alexis V. George
Project Officer, GPMU

COMMONWEALTH OF DOMINICA

# MINISTRY OF PUBLIC WORKS, ENERGY AND PORTS
# GEOTHERMAL PROJECT MANAGEMENT UNIT

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Commonwealth of Dominica

**FROM:** Project Officer / Geothermal Project Management Unit

**TO:** Permanent Secretary/ Ministry of Public Works, Energy & Ports

**DATE:** January 8, 2013

**SUBJECT: Summary of Meetings held by the PMU in the Roseau Valley**

Below is a summary of Meetings held by the Geothermal Project Management Unit in the Roseau Valley.

| **Wotten Waven** | **Trafalgar** | **Laudat** |
|---|---|---|
| January 16, 2011 5:30 pm | January 12, 2011 7:00pm | January 20, 2011 6:30 pm |
| November 10, 2011 6:00pm | November 8, 2011 6pm | November 11, 2011 7:00pm |
| June 13, 2012 5:30 pm | March 28, 2012 6pm | February 15, 2012 7:00pm |
| | | April 13, 2012 7:00 pm |
| | | April 16, 2012 7:00 pm |

**Drilling Environmental Impact Assessment (EIA)**

- Contractor: Caraibes Environnement (Guadeloupe)
- Funding Agency: ADEME
- Work commenced on island: March 2011 (Hydrobiology and Landscape studies)
- First draft submitted: July 28, 2011
- Second Draft submitted: December 2011
- Final version submitted: January 22, 2012 (endorsed by ADEME)

**Visit to Schools in Roseau Valley** (presentation of project and distribution of promotional items to students and staff)

- Wotten Waven Primary School: February 8, 2012
- Trafalgar Primary School: February 16, 2012
- Morne Prosper Primary School: February 8, 2012
- Laudat Primary School: March 8, 2012

**Site Visit – Laudat Primary School**
The Laudat Primary School visited Site WW-3 during drilling operations on March 7, 2012. The students and staff got a tour of the site and were to

……..
Geothermal PMU





DRAFT

# Report on Community Consultations

**Report on Community Consultation**

Laudat Community at Laudat Primary School 29 June 2017 – 7pm

**Introduction**

This report is to inform on the community consultation as recommended in the Stakeholder Engagement Plan for the Dominica Geothermal Project. One of the main objectives of the consultation is to have open comprehensive engagement activities to build trust, encourage participation and facilitate community understanding of the project. During the consultation, an update was given as to the current state of the project and any planned activities

The objective of this report is to provide information three areas.

1. Attendance
2. Concerns about the project
3. Expectations




Dr Vince Henderson addressing members of the Laudat community

Attendance

MP Dr John Collin McIntyre

MP Ian Douglas

Ambassador Dr Vince Henderson

Members of the Board of DGDC

Project Manager – Mark Tomkins

Employees of DGDC

World Bank team

Jacobs team

IRC – Francis Paul, Glenn Khan

Members of the community of Laudat

**Concerns**

Will the re-injection pipeline pass through the village?

Noise level and effect on the community

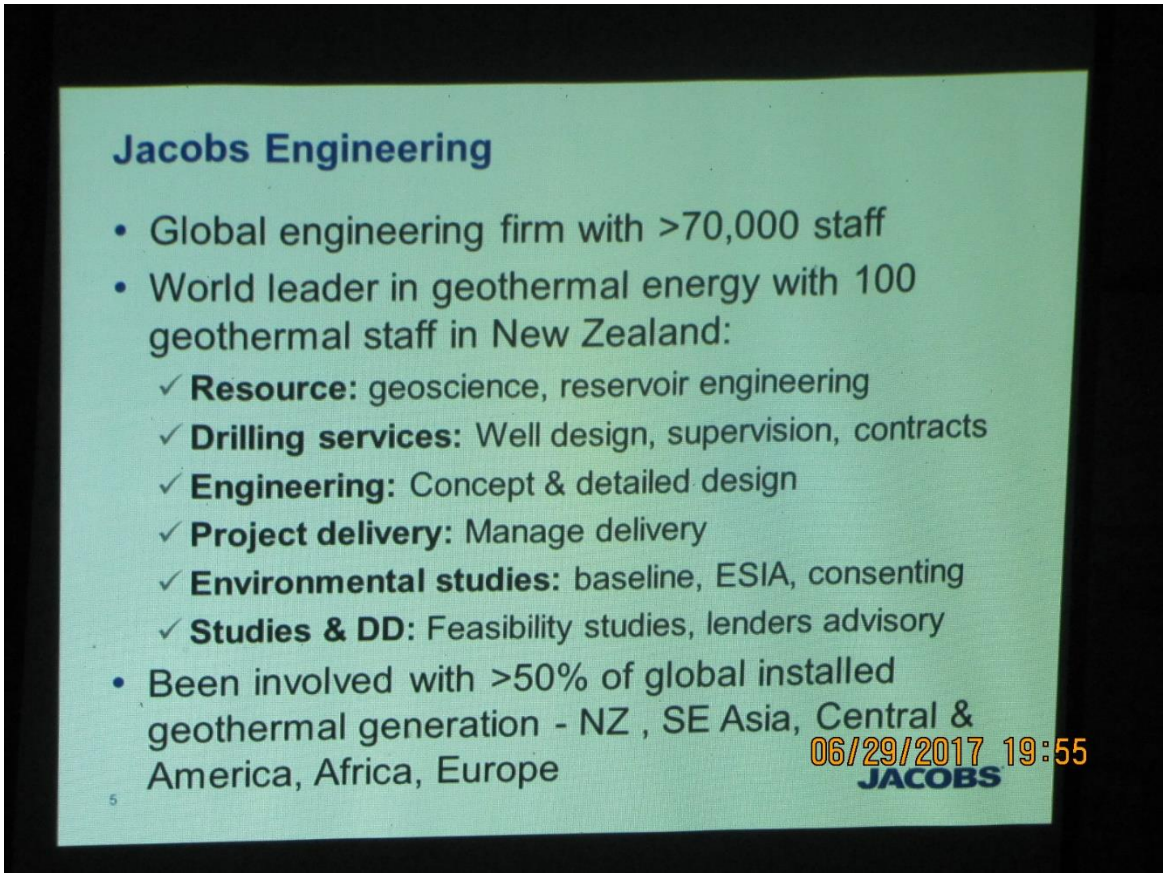
When and how will Payment for property be made if acquired?

What is meant by market value for land?

During Hydro expansion lands were acquired no payment to date.

How is the community going to benefit, medical, education, sports?

Will shares be available for purchase?







Dorney addressing Laudat community

**Geothermal Power Plant Development Project**
**Presentation to Community leaders of The Roseau Valley**
**Wednesday December 14 2016**
**Time: 5:30 PM**

**Attendance List**

| No | Name | Organisation | Contact Info |
|---|---|---|---|
| 1 | Jeffery Charles | | jeffery1269@gmail.com/2857347 |
| 2 | Glenn Khan | IRC- Executive Director | |
| 3 | Garry Shillingford | Community Liaison Officer - MTEE | |
| 4 | Alfred Rolle | | |
| 5 | Hon.Dr Collin Intyre | Parlimentary Representative | |
| 6 | Dr. Vince Henderson | Ambassador to United States & OAS | |
| 7 | Alaistair Brookes | Jacobs | |
| 8 | Peter Gabriel | Jacobs | |
| 9 | David Wenstrup | Clean Infra Partners | |
| 10 | Edward Lambert | Special Advisor | |
| 11 | Joan & Algenon Ducreay | Petit Paradise | lpetitparadise20@hotmail.com ; 2762761/4404352 |
| 12 | Janet Taylor | | 440 3118 |
| 13 | Lilian Xavier | Trafalgar Vendors Association | sexylily71@hotmail.com; 617 3996 |
| 14 | Government Information Service | | |
| 15 | Electrical Division | | |
| 16 | Michael Fadelle | Renewable Energy Coordinator - MTEE | |
| 17 | Ernest Fontaine | Da-Scape | 616 6800 |
| 18 | Francis Paul | IRC Commissioner | |
| 19 | Alexis George | Ministry of Public Works | |
| 20 | Daniel Fadelle | | |
| 21 | Esther Lambert | | |
| 22 | Bernadette Lambert | IRC - Chairperson | 2959590 |
| 23 | Marilyn Cuffy-Morris | | 276 2689 |
| 24 | Nahgie Laflout | | nahjielaflout@hotmail.com; 245 4328 |
| 25 | Atherton Martin | | athiemartin@gmail.com; 2761878 |
| 26 | Bernicia Allan | Trafalgar Village Council | berniciakallan@gmail.com; 2767029/6174768 |

| | | | |
|---|---|---|---|
| 27 | Anne Jno Baptiste | Papillote Wilderness Retreat | |
| 28 | Patricia Rolle | | |
| 29 | Bertillia McKenzie | DOMLEC - GM | |
| 30 | Ellise Darwton | DOMLEC | |
| 31 | Dave Stamp | DOMLEC | |
| 32 | Fitzroy Jones | DOMLEC/ Land Owner | |
| 33 | Charles McClean | DOMLEC | 2658640 |
| 34 | Claudette Rolle | Community Leader – Fresh water Lake facility | |
| 35 | Kelvin Rolle | Chief Physical Planner | |
| 36 | Rudolph George | Wotten Waven Improvement Committee | |
| 37 | Sylvanie Burton | Permanent Secretary - MTEE | |
| 38 | Justinn Kase | IRC | |
| 39 | Elizabeth Hill | IRC-Commissioner | |
| 40 | Eisenhower Douglas | IRC-Commissioner | |
| 41 | Gregor Nassief | DHTA | |
| 42 | Helene Rolle | Tourism Stakeholder | |

Meeting was called to order by Mr. Edward Lambert at 5:53 pm with a prayer.

Members of the head table:

Ambassador Henderson, Hon Dr. McIntyre, Mr. Lambert, David Wenstrup, Alastair Brookes, Peter Gabriel.

Ambassador Henderson moderated the meeting.

Questions to panel after presentations:

1. What are the plans for resettlement & compensation?
2. Is Jacobs going to be a shareholder in the Company?
3. What size plant did Kenya start with?
4. How many people work in Geothermal Unit?
5. What is the cost of administration for the Geothermal Unit?
6. The wells in the Roseau Valley have been capped for how long?
7. How much has been spent to maintain them?
8. Why isn't the government interested in transmission instead of generating and selling to DOMLEC?
9. The people of Laudat have been unfairly treated in the past and had crimes worse than slavery committed against them. There are delicate property issues in Laudat. Are there any plans to take care of them?

10. Geographic Area covered by the EIA – a French group has done a baseline assessment where the Roseau Valley has been redefined to include the City- is the city to be included in the scope of works for this ESIA?
11. An ESIA could reveal information which says that the project should not go forward YET project seems to be a fait accompli. The RE policy in existence for Dominica speaks to simultaneous effort at developing at least two or three RE projects, not just geothermal. TS Erika has taught us that an entire geographical area can be compromised. Is there a plan B? What is the plan B.? Note that all other areas spoken of in the presentations are huge countries and it is a matter of scale.
12. Will electricity bills decrease as a result of this initiative?





**Geothermal Power Plant Development Project Presentation to Community Leaders**

**Wotten Waven Community Centre**

**December 14, 2016, from 5.30 p.m.**

**Draft Agenda**

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***Chair:*** *Ambassador Edward Lambert*

5.30 p.m. **Welcome and Opening Remarks** - Hon. Dr. John Collin McIntyre, Parliamentary Representative

**5.45 p.m.** **Summary of Government Policy, and Purpose of the meeting** – Hon Douglas, Minister for Energy

**6.00 p.m.** **Overview of project roles and different parties** - Mrs. Sylvanie Burton, Permanent Secretary, Ministry of Trade, Energy and Employment

**6.15 p.m.** **Overview of project development to date, timelines, interaction of commercial/financial, technical considerations** – Mr. Alastair Brookes, Caribbean Geothermal Advisor, Contracted by New Zealand Aid

**6.45 p.m.** **Overview of the Environmental and Social Impact Assessment process** – Mr. Pete Gabriel, Environmental Consultant, Jacobs New Zealand Ltd.

**7.30 p.m.** **Questions and answer**

**Vote of Thanks** - community member (Wotten Waven??)

**Refreshments**

# Report on Community Consultations

**Focus Group Accommodation**

Papillote Wilderness Retreat 30 June 2017 – 6:30 pm

**Attendance**

DGDC Staff

Lyn Fontenelle

Justen Kasey

Allan Toussaint

**Jacobs**

Dorney Burgdorf

**Accommodation**

Chez Ophelia – Mark Marie

Rocky Mountain Lodge – Emmanuel Rock

Papillote Wilderness Retreat – Ann Jno Baptiste

**Concerns**

What will be the total Cost of the project?

What will be the effect of Geothermal Plant, if shut down, on National grid?

Was consideration given for a bank of batteries to store excess energy?

Is there a plan for worst case scenario?

When will shares be available for purchase?

Why not solar? – Less intrusive

Why was this type of Consultation not done before decision was made to drill?

Why did trees close to balancing tank turn brown?

What will be noise level?

What will be the visual impact?

Will there be a social development fund for education and health?

Considering that risks and exposure will be borne by residents, should they have special benefits?

Examples of benefits – Low or no electricity bills, State of the art recording studio

What metal will be used for plant? - concerns of corrosive atmosphere

One member of the group is totally against the project because of negative effects

Very concerned on negative impact on Tourism any activity in the Roseau valley will affect Tourism

**Expectations**

Hope to see at least 50% reduction in Electricity bills

More consultation in the future

Increased use of their services during the project

**Focus Group Watton Waven Vendors**

**Wotton Waven Community Centre 12 July 2017 – 6:30pm**

**Attendance**

Firstly, Members of the DGDC in attendance at that consultation were,

Justinn Kase
Lyn John Fontenelle

Garry Shillingford

Allan Toussaint

Vendors from the Wotton Waven community were also in attendance

Edrice George

Minovia Joseph

Flavia Damier

Pamela Sampson

Julian George

Nastia George

Gloria Damier

Helen Sergeant

Catherine Joseph

Mr. Justin Kasen and Lyn Fontenelle gave a short overview and current state of the project. The involvement of stakeholders like Jacobs and the world bank was shared and the reasons and importance of the meeting was expressed.

**Concerns**

Secondly, the vendors were allowed to freely state their concerns with the project. Most of their concerns were in the form of questions as listed below:

What happen if the reinjection pipe has a leak and dangerous fluids are flowing on the surface?

What impact will the project have on our vending business in terms of the volume of traffic, time of transporting (Tourist season)?

How long will the project take to complete?

Will the area where vendors are located be acquired for reinjection pipeline?

Will there be fumes, dust and noise affecting our business?

If you have to transfer vendors where will be the new location?

Will we be allowed to vend during construction of Reinjection pipeline?

What size pipes will be transported to the community?

When is the project due to start in our community?

Concern from Melo (rastaman)

I believe if we are impacted we will not be compensated, we have not been regarded. I am in favour of the project but afraid of the impact as far as impact on Tourism is concerned. We will get less Tourist or no Tourist.

**Expectations**

Finally, the vendors were asked about expectations of the project. Generally, the most common expectation of the project was lower electricity bills. Most see the production of power for local consumption using the geothermal resource should mean using a lot less diesel for power production. As a result, it is expected that the fuel surcharge component on their electricity bill will be drastically reduced or even disappear. Additionally, they expect jobs to be made available to residents during the construction and production phase.

**Conclusion**

**All members of the DGDC were involved in assisting vendors in completing the questionnaires**

The consultation was positive and informative. However, consideration must be given to producing an animation of how the production of electricity using geothermal really works. This will help our stakeholders better understand the process. A second animation depicting the power station site and the reinjection site with a view of what is happening below the surface of the earth will answer a lot of questions, particularly how geothermal is renewable. It is apparent from constant interaction with community members that they find it difficult to imagine how the reinjected fluid will find its way back to the production well.

**Trafalgar Vendors**

Trafalgar Tourism Facility – July 2, 2017 – 3pm




Dorney explaining the process to the vendors

Dorney Burgdorf from Jacobs made a short presentation on the current state of the project. An overview of the project was given including Jacobs past and future involvement in the project.

Attendance

Project Manager – Mark Tomkins

Jacobs team

Employees DGDC

Trafalgar Vendors

**Concerns**

Q - Will the project affect the waterfall

Q -Will the project affect the business environment

Dorney – During drilling was there any effect on your businesses

Dorney – How would you want the project to contribute to your community, education, health, sports.

**Focus Group**

Wotton Waven Spa operators

This group was met one on one after they did not attend a planned meeting. Generally, they had the same concerns and fears about the project.

The group includes:

Ti Kwen Glo Cho – Henry George

Screws – Edison Joseph

Bongo Baths – Helen Rolle

Tia Bamboo Cottages – Tia Joseph

**Concerns**

What effect will production and re-injection have on our hot water supply?

If negative will we be compensated?

Would the geothermal company be willing to give us a supply from their pipeline if our supply is affected?

Toxic fumes and noise

Traffic of large trucks

How will the community benefit from the project?

What is in it for the people?

**Expectations**

Employment generation

Cheaper power

More business during construction

COMMONWEALTH OF DOMINICA

# MINISTRY OF PUBLIC WORKS, ENERGY AND PORTS
# GEOTHERMAL PROJECT MANAGEMENT UNIT

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Fax: (767) 448 0182
E-mail: geothermal@dominica.gov.dm

3rd Floor, Government Headquarters
Kennedy Avenue
Roseau
Commonwealth of Dominica

**FROM:** Project Officer / Geothermal Project Management Unit

**TO:** Permanent Secretary/ Ministry of Public Works, Energy & Ports

**DATE:** November 13, 2013

**SUBJECT:** **Community Meeting – Trafalgar**

A community meeting was held on Tuesday November 12, 2013 at the Trafalgar Community Centre to inform residents of the Roseau Valley and more specifically those of Lily Valley of the on-going drilling activities, likely impacts to the community and also to present the Environmental Impact Assessment Study (EIA).

In attendance were:
Dr. Colin McIntyre: Parl. Representative for Roseau Valley
Lucien Blackmoore: Permanent Secretary, MPWEP
Alexis George/ Lyn Fontenelle: GPMU
Kelvin Rolle: Chief Physical Planner (Ag)
Mandela Christian: Office of Disaster Management
Olivier Felicite: Team Leader, Caraïbe Environnement
Gaelle Herbert: Caraïbe Environnement
Paul Bonnetblanc: Teranov
Frederic Gerard: Teranov
Aaron Rolle: Community Liason Officer
Members of the Trafalgar Village Council
Residents of Trafalgar and neighbouring communities (approximately 30)
Members of the Media (Marpin 2k4)

The GPMU gave an update on the project and informed the meeting of the likely impacts to include:

- Visual/ landscape
- Noise/ lights at night (24 hour operation)
- Traffic/ road conditions (movement of heavy equipment to site)
- Potential hazards ($H_2S$ gas, hot water / steam release, fire)

Residents were informed of the main results of the EIA and some of the mitigation measure that would be adopted.

Upon completion of the power point presentations by the Project Officer and the EIA team, there was a lengthy interaction between the panel and the audience which was well received.

The overarching concern was with the safety of the drilling operation and more importantly that of the residents in the event of an incident. Other points raised included the following:

- Possibility of training opportunities for residents of the Roseau Valley as well as providing financial assistance to persons who are currently studying in geothermal related fields
- Having weekly or biweekly updates on the project aired on radio or published online
- Persons indicated that the use of websites or social media such as facebook to disseminate information would be welcome
- Persons who own land in close proximity to the well pad asked whether it was safe to build their house since they already had planning permission and whether they would be compensated in the event there was an incident that would prevent them from building or continue residing in the houses
- Sponsorship of community activities; whether the project would assist with the infrastructural and social development of the community
- Why the existing site was selected as the location for the reinjection well. Why wasn't another location in a less populated area selected
- Where will the pipeline for reinjection run and will it be safe, how will it be monitored
- When will the power plant come online
- Will the one production well be sufficient to supply the 15 – 20 MW plant
- Will the drilling mud cause any pollution…are the chemicals that will be used toxic
- What role will DOMLEC play in the development, will there be power purchase agreements
- Will there be training for interested persons within the community to be first responders for geothermal hazards
- Why is the noise level form the drill site high at some times and low at other times

Submitted for your information.

Alexis V. George
Project Officer, GPMU

# GEOTHERMAL RISK DEVELOPMENT PROJECT – DOMINICA

## WOMEN FOCUS GROUP MEETING – WOTTEN WAVEN

A Focus Group Meeting with the Women of Wotten Waven was held for the Geothermal Risk Development Project – Dominica on Saturday March 24th, 2018 at the Wotten Waven Resource Centre. --- women attended.

The Meeting was coordinated by Marie-Jose Edwards of Eclipse Inc. In attendance were Mrs. Lyn Fontanelle and Mr. Allan Toussaint of the Geothermal Development Company Ltd and Mr. Lennox St. Aimee, a member of the Eclipse Inc team.

The Administrative and Safeguards Officer and provided answers to questions and queries brought up by attendees throughout the sessions, she outlined the grievance mechanisms in place for the Project and indicated that grievance forms will be available at strategic locations and informed the group that future meetings will be held to update them on the status of the project and to provide additional data and information on the project. The liaison Officer re-introduced himself and provided his contact to all attendees, encouraging them to contact him for additional information / queries.

The meeting started at 3.55 PM, with about 10 women present. The Meeting ended at 5:00 PM, with seventeen (17) women in attendance.

## OUTCOME OF FOCUS GROUP MEETING

**In response to the question, "What impact did Hurricane Maria have on you, as an individual, and the community?"**

- 90 % or respondents indicated that they have lost the roofs of their homes while 95% have lost their livelihood.

- Other responses were as follows:
    - One woman said that the hurricane has affected customers to her business. She noted that "right now it is the peak season, but the visitors are very few" and that it has been a big blow for her. She also mentioned that she lost part of her roof, as well as her fridge getting 'messed up', and complained about the condition of the road/bridge to the community. She noted as her priority:

- Getting her business back on track;
- Needing money;
- Repairs to her roof; and
- Fixing of the damaged bridge & road.

- A second participant related that her house was uncovered and that she had to live in a church with her three children for a while. She noted that she was a single parent and supported her children as a small roadside vendor of primarily ice pops & plantain chips. Her fridge, she mentioned, also got 'messed up'. This small vendor was "not in favor of how the authorities were going about assisting the vendors". She noted that the government was requesting that only registered small businesses would obtain assistance. That her business was not registered and at this juncture, she did not have the $80.00 to register a small business;

- Most participants thought that a few persons in the community were still traumatized although some counselling was provided

**When asked about priority needs post Maria the responses were as follows:**

- The covering of their roofs;
- Restoring basic livelihood;
- That there has been counselling but more is required.
- Vendors indicated that they have not been updated on assistance to them from the small business assistance fund since it was discussed in January and that they would like the GDC to raise this issue with the relevant government authorities on their behalf. One participant suggested that, as an alternative to the way the assistance is being given by the authorities, the payment for the registration of the small business be deducted from the amount given.

**The vendors were then asked, "What do you think about the Geothermal Project?". Vendors views on the project were as follows:**

- Of the 12 persons present at the start of the meeting three (3) persons indicated support for the project, five (5) were against, four (4) remained neutral.

- A participant noted that several meetings were being held and the same questions were being asked. She stated "I am not for the project…. lights are not going to be cheaper. We are surrounded by many volcanoes and they are all connected";
- One woman felt that the project was going to affect their livelihood. She noted "I do not really like the idea; we are in a volcanic basin".
- Another participant pointed out that she "Believed good things will come out of it", referring to the project;

**When asked why so many persons were against the project some of the responses were as follows:**

- A woman noted 'not enough education' and there was general agreement by members on this.
- Another stated that she does not think that electricity bill will be lower as a result
- Another woman noted that she had no problem with geothermal and pointed out that "People are generally afraid of change" and noting that there will be more jobs.

**Women's views on the Impact of the Geothermal project on the community were as follows:**

When asked whether the community would be better off without the project, there was an emphatic "YES" from 80% of the participants

One participant stated that "We do not know".

In terms of benefits to the community the overall general responses were as follows:

- Paying less money for electricity;
- Generating jobs; and
- The village will be developed;
- A participant pointed out that "When big companies come to a community they usually give something to the community" and went on to ask "What is in it for the community? Can we get a road or a community Centre?"

**When asked if the women had questions to pose to the DGDC the following were posed as well as comments:**

- What would be the impact of the project on the rainforest.
- Another participant noted that the well was in a tender area and wanted to know how often the well would be maintained.
- A question was also asked about the company's plan to educate the children and youth of the community.
- A participant pointed out that "the project will be good for business when it comes on board, but I can do without it";
- The last comment from the Group was a woman saying, "I am afraid" and indicating the possibility of an explosion

**Social impact of the project on the community**

The group (95%) indicated that there is no evidence of domestic violence in the Wotten Waven Community

95% of the women felt that an influx of workers in the community would have no effect on persons in the community

**Additional Information Requested by the Community**

When asked what additional information was required, 70% indicated that they will need additional information on the operations of the project despite having attended several meetings. The following constitute some of the information needs as outlined by the women:

- Will there be a plant in Wotten Waven;
- Where the pipes will be running;
- What effect is the project going to have on the spas.

Other questions asked were as follows:

- Will we be inhaling the fumes;
- What will be its effects on vegetation and backyard gardens;

- What effect will the smell have on the people; and
- She also suggested the need for an exit if evacuation is needed, further suggesting a road from Wotten Waven to Morne Prosper.

**APPENDICES**

**AGENDA - WOMEN FOCUS GROUP MEETING**

**Venue – Wotten Waven**

**Date & Time: March 24th, 2018 / 3:00 PM**

- Opening Prayers
- Introduction
- Introduction of participants
- Open Discussion
- Any other questions
- Closing remarks

**QUESTIONS**

**What impact did Hurricane Maria have on you and your family?**

What is your priority for recovering from H Maria? Outline at least 3 priority areas

What are the needs of your community post Maria

Do people still suffer from trauma and do you think there is a need for counselling?

**What do you think about the Geothermal Project?**

What information do you have on the Project?

What additional information would you like to have on the project

**What impacts will do you think the project will have on and your family?**

(Will the project have any impact on your livelihood)

What improvements or disadvantages will this project have on your livelihood

What does your family think about the project?

In what ways do you think you will be better off without this project?

**What are the benefits of the project on your community?**

Will households in the community benefit from such a project?

What contribution will the project make to the community?

Will the community be better off without having such a project?

**What changes do you think the project will have on your community and on your lives?**

What effects will it have on the current lifestyle of the community

How do you intend to manage any changes that occur?

**What worries you most about the project**

What should be done to make you less worried about the project

**What is the History of domestic violence in your community?**

**There might be an influx of male workers in your community during project construction, how do you think it will affect your community?**

- Will it spur on teenage pregnancy, drugs etc.
- Is there any semblance of sex trade in your community?

**GEOTHERMAL RISK DEVELOPMENT PROJECT – DOMINICA**

## WOMEN FOCUS GROUP MEETING – LAUDAT

A Focus Group Meeting with the women of the Laudat community was held for the Geothermal Risk Development Project – Dominica on Saturday March 17th, 2018 at the Laudat School Building.

The meeting was coordinated by Ms. Marie-Jose Edwards of Eclipse Inc. In attendance were Mrs. Lyn Fontenelle, Administrative and Safeguards Officer. Mr. Allan Toussaint, Community Liaison Officer and Mr. Shillingford of Dominica Geothermal Development Company Ltd and Mr. Lennox St. Aimee, a member of the Eclipse Inc. team.

The Administrative and Safeguards Officer and provided answers to questions and queries brought up by attendees throughout the sessions, she outlined the grievance mechanisms inn place for the Project and indicated that grievance forms will be available at strategic location and informed the group that future meetings will be held to update them on the status of the project and to provide additional data and information on the project. The liaison Officer re-introduced himself and provided his contact to all attendees, encouraging them to contact him for additional information / queries.

The meeting started at 3.55 PM with eleven (11) women and ended at 5:00 PM, with seventeen (17) women.

**OUTCOME OF FOCUS GROUP MEETING:**

**In response to a question "What impact did Hurricane Maria on you and your family?"**

Responses were along these lines:

- 90% of the women present stated that Hurricane Maria went away with their small businesses which were associated with the tourism sector. 75% of the women lost their houses or roofs and over 50% reported that they had either lost their poultry farms and/or vegetable gardens. About 50% of the women indicted that they were no longer able to bring an income to the household. About 75% of the women noted that they had received some form of assistance as small farmers but stated that they would like to see their place of employment, Fresh water lake facility, restored.

In terms of the community, the major concerns were as follows:

The priority needs in terms of post Maria recovery were said to be:

- Recovering of roofs and repairs of houses;
- Restoration of chicken farms & vegetable gardens;
- Counselling for people who are still traumatized;
- To return to stable jobs with good pay;

**The group was then asked, "What do you think about the Geothermal Project?**". The women responded to the question as follows:

- About 50% of the women were not in favor of the project while 25% indicating that they were in favor. The remaining 25% remained neutral. The reasons cited against and for the project were, as follows:
  - the fragility of the soil;
  - concerns about safety;
  - electricity will not be cheaper;
  - the project is being promoted as clean energy;
  - electricity will be cheaper; and
  - even not in my time, my children or grandchildren will benefit.

**In response to a question, "What impact will the project have on women and your family?". The women responded as follows:**

- 40% of the women felt that it could become a tourism attraction;
- 90% felt that it could also bring more employment to the women of the community.
- About 50% felt that the community would be better off without the project.

1. The Group was then asked, "**What changes do you think the project will have on your community and on your lives?**",

The response indicated the following:

- 98% of the women indicating that they were in favor of the project, with one woman against;
- Safety concerns were cited by the woman who indicated that she was against the project;
- A concern was also raised in relation to rumors of a possible leak on the site. Mrs. Fontenelle cleared the air on this rumor;
- Paying less for electricity, (as being promoted);
- A question as to whether there are other such projects in the Caribbean and are there related health issues;
- A need for more education/information was suggested;
- A question asked of the effect of the gas on farming people and the environment;
- A woman asked, "What are the byproducts of this project and how can it be used?";
- Someone wanted to know the areas of study for jobs that might be available;
- A question was asked as to when the project would be on stream.
- A member of the group wanted to know if there would be monitoring of the effect of the project on the community; and
- A question as to whether water sources would be affected ended this section.

**Social impact of the project on the community**

95% of the women indicated that there were no open cases of domestic violence known to the community.

1. The Group was informed that "**When there is an influx of male workers in any community there tend to be social disruption**" and then asked, "What are your thoughts on this in respect to your community?"

   The general conscientious was that this had not happened in the past with other project and the hope was that it would not happen with this project. The incident of teenage pregnancy was not a problem in the community. Generally, the group felt that there was a low level of crime in the community.

2. The Group was then asked if they had any question for the facilitators and/or the project personnel.

The following questions were asked:

- What benefits would accrue to the community.

- Were there would be safeguards in the project's design?
- Will the project affect the volcanoes, "as we are living on a volcanic island"?

The facilitator asked the group what they think there are benefits that they think could come to the community through this project: The following benefits were suggested:

- More jobs could be created;
- Cheaper electricity for consumers;
- Electricity at half price or free;
- Having an individual from the community on the Board of the Company;
- The establishment of a skills development fund for the community;

3. In her final comments, Mrs. Fontenelle addressed most of the concerns raised by the group. She went on to explain the grievance mechanism that was in place for the project. She noted the presence of Mr. Allan Toussaint, the project's community liaison officer, who she advised would be the first point of contact for complaints. She also mentioned that complaint forms would be placed at accessible locations in the community. She promised that the company will be back for a community meeting in early April, when a power point presentation on the project will be shown.

**AGENDA -VENDORS / WOTTEN WAVEN**

**Venue – Wotten Waven**

**Date & Time: March 24th, 2018 / 5:00 PM**

- Opening Prayers

- Introduction
- Introduction of participants
- Open Discussion
- Any other questions
- Closing remarks

**QUESTIONS**

**What impact did Hurricane Maria have on you and your family?**

What is your priority for recovering from H Maria? Outline at least 3 priority areas

What are the needs of your community post Maria

Do people still suffer from trauma and do you think there is a need for counselling?

**What do you think about the Geothermal Project?**

What information do you have on the Project?

What additional information would you like to have on the project

**What impacts will do you think the project will have on and your family?**

(Will the project have any impact on your livelihood)

What improvements or disadvantages will this project have on your livelihood

What does your family think about the project?

In what ways do you think you will be better off without this project?

**What are the benefits of the project on your community?**

Will households in the community benefit from such a project?

What contribution will the project make to the community?

Will the community be better off without having such a project?

**What changes do you think the project will have on your community and on your lives?**

What effects will it have on the current lifestyle of the community

How do you intend to manage any changes that occur?

**What worries you most about the project?**

What should be done to make you less worried about the project

**What is the History of domestic violence in your community?**

**There might be an influx of male workers in your community during project construction, how do you think it will affect your community?**

- Will it spur on teenage pregnancy, drugs etc.
- Is there any semblance of sex trade in your community?

# GEOTHERMAL RISK DEVELOPMENT PROJECT – DOMINICA
# VENDORS FOCUS GROUP MEETING – TRAFALGAR

A Focus Group Meeting with the Vendors of Trafalgar was held for the Geothermal Risk Development Project – Dominica on Sunday March 25th, 2018 at the Trafalgar Tourism Facility. The Meeting coordinated by Ms. Marie-Jose' Edwards of Eclipse Inc. The Meeting started at 3:40 p.m. with ten (10) vendors present.

The Meeting was coordinated by Marie-Jose Edwards of Eclipse Inc. In attendance were Mrs. Lyn Fontanelle and Mr. Allan Toussaint of the Geothermal Development Company Ltd and Mr. Lennox St. Aimee, a member of the Eclipse Inc team.

The Administrative and Safeguards Officer and provided answers to questions and queries brought up by attendees throughout the sessions, she outlined the grievance mechanisms in place for the Project and indicated that grievance forms will be available at strategic locations and informed the group that future meetings will be held to update them on the status of the project and to provide additional data and information on the project. The liaison Officer re-introduced himself and provided his contact to all attendees, encouraging them to contact him for additional information / queries.

The Meeting ended at 4:35 PM, with about fifteen (16) vendors in attendance.

## OUTCOME OF FOCUS GROUP MEETING:

**In response to the question, "What impact did Hurricane Maria had on you, as an individual, and on the community?"**

- 90% of the vendors indicated that they had no job and no money. One vendor pointed out that "everybody was in the same boat";
- 95% of the vendors said that they needed finance to get back on their feet. They also noted that the authorities need to speed up the process of helping vendors;
- 80% of the vendors reported that their roofs or houses were destroyed. One vendor reporting that she has since recovered her house;
- The vendors reported that their supplies were usually left at the Tourism facility and that Hurricane Maria blew away 100% of these supplies;

**In terms of impact on the community, the major concerns were:**

- The recovering of their roofs;
- Restoring basic livelihood;
- Better roads;
- Being still traumatized; and
- The need for counselling which they noted should have been done already.

**When asked about the priority needs post Maria, the responses were as follows:**

- Better roads;
- Repairs to houses and roofs

**Vendors were then asked, "What do you think of the Geothermal Project?". The responses from the vendors were as follows:**

- 50% of the vendors saw it was a good idea, if it was going to benefit them, such as lowering electricity rates;
- 90% of the vendors also noted that the community needed more information about the project;
- 95% of the vendors indicated that they had previously attended meetings of the project;

**The Group was then asked, "What worries you most about the project?". The responses were as follows:**

- The quality of the air will be affected;
- An increase of Sulphur in the air;
- The possibility of tremors;
- Contamination of water supply;
- It will affect the waterfall; and
- Possible health issues

**The meeting was then asked, "Do you think that the project will affect you, as vendors?". The vendors responded as follows:**

- About 50% felt that if it does not come to their area, then they had no problem;
- About 95% of the vendors indicated that if it does not affect the waterfalls, then no problem either;
- 90% felt it would have a positive effect on livelihood, such as lower electricity bills;

**The Group was then asked the question "What is the History of domestic violence in your community?"**

There was a response from one member stating that "It is not a problem here". 90% of the vendors agreed that it was not a problem but felt that it was not 100% free of domestic violence.

**The vendors were also asked "Is there any semblance of sex trade in your community?". All the responses from the vendors indicated that there was none:**

- It is not a problem;
- I have not heard of any such cases;
- No history of such.

**The facilitator then asked the vendors whether they had any questions of their own. The following questions were asked by the group:**

- Will there be any fumes or leaks;
- What if DOMLEC changes the price at which power is sold to them;
- In case the waterfall changes its course, will the geothermal authority come to our assistance;
- Will it affect the volcanoes;
- Are the route of the reinjection pipes prone to landslide;
- Will the plant be noisy;
- A question was also asked concerning the Visitors' Centre at Laudat.

In response to a question from the facilitator, the group indicated that the main occupation of the community was farming & vending. They also noted that the community had a youthful population. They also stated that there were twenty (20) vendors at the facility and about another ten (10) in the village.

**APPENDICES**

**AGENDA – Vendors / Wotten Waven**

**Venue – Wotten Waven**

**Date & Time: March 24th, 2018 / 5:00 PM**

- Opening Prayers
- Introduction
- Introduction of participants
- Open Discussion
- Any other questions
- Closing remarks

**QUESTIONS**

**What impact did Hurricane Maria have on you and your family?**

What is your priority for recovering from H Maria? Outline at least 3 priority areas

What are the needs of your community post Maria

Do people still suffer from trauma and do you think there is a need for counselling?

**What do you think about the Geothermal Project?**

What information do you have on the Project?

What additional information would you like to have on the project

**What impacts will do you think the project will have on and your family?**

(Will the project have any impact on your livelihood)

What improvements or disadvantages will this project have on your livelihood

What does your family think about the project?

In what ways do you think you will be better off without this project?

**What are the benefits of the project on your community?**

Will households in the community benefit from such a project?

What contribution will the project make to the community?

Will the community be better off without having such a project?

**What changes do you think the project will have on your community and on your lives?**

What effects will it have on the current lifestyle of the community

How do you intend to manage any changes that occur?

**What worries you most about the project?**

What should be done to make you less worried about the project

**What is the History of domestic violence in your community?**

**There might be an influx of male workers in your community during project construction, how do you think it will affect your community?**

- Will it spur on teenage pregnancy, drugs etc.
- Is there any semblance of sex trade in your community?

# GEOTHERMAL RISK DEVELOPMENT PROJECT – DOMINICA

## VENDORS FOCUS GROUP MEETING – WOTTEN WAVEN

A Focus Group Meeting with the Vendors of Wotten Waven was held on Saturday March 24th, 2018 at the Wotten Waven Resource Centre. There are between 17 – 21 registered vendors in the area

The meeting was coordinated by Ms. Marie-Jose Edwards of Eclipse Inc. In attendance were Mrs. Lyn Fontenelle, Administrative and Safeguards Officer, Mr. Allan Toussaint, Community Liaison Officer and Mr. Shillingford of Dominica Geothermal Development Company Ltd and Mr. Lennox St. Aimee, a member of the Eclipse Inc. team.

The Administrative and Safeguards Officer provided answers to questions and queries brought up by attendees throughout the sessions, she outlined the grievance mechanisms in place for the Project and indicated that grievance forms will be available at strategic locations and informed the group that future meetings will be held to update them on the status of the project and to provide additional data and information on the project. The liaison Officer re-introduced himself and provided his contact to all attendees, encouraging them to contact him for additional information / queries.

The meeting started at 5.20 PM, immediately following the Women Focus Group Meeting, with 9 vendors present at the start. The meeting ended at 6:15 PM.

### OUTCOME OF FOCUS GROUP MEETING

**In response to the question, "What impact did Hurricane Maria have on you, as an individual, and the community?"**

- 90 % or respondents indicated that they have lost the roofs of their homes while 95% have lost their livelihood. In terms of livelihood they specifically referred to the destruction of their vending stalls and goods for sale as well as the loss of most cruise ships and the revenue which could accrue to them from sales of goods and services. They commented on the fortnightly visit of one of the cruise lines and the minimum revenue that this ship generates when compared to post Maria calls and sales

In terms of impact on the community the major concerns were as follows:

- Destruction of the main roads
- Destruction of access bridge. One person indicated that he had lost access to his property and home as a result
- Absence of tourists and loss of revenue
- A small percentage of persons indicated that some persons suffered trauma as a result

When asked about priority needs post Maria the responses were as follows:

- Repair of houses and roofs; and
- Repair or replacement of vending stalls by government
- Return of tourist to the community
- Return of tourist to the community
- There was a mixed response to counselling for community member but, generally, it was felt needed;

**The vendors were then asked, "What do you think about the Geothermal Project?". Vendors views on the project were as follows:**

- 60 % of vendors did not support the project. The reasons cited were as follows:
- Impact on the health of the community. Fear for our health" as stated. Some of the vendors felt that they should be relocated since their vending stalls were too close to the reinjection site. Participants enquired as to whether they were going to be relocated. In fact, the vendors indicated that one government official informed them that they would be relocated within the Shangri La area once transactions with the company was finalized.
- Most vendors felt that relocation would put them at a disadvantage given the existing route undertaken by cruise visitors.
- Impact on the vulcanism of the island and the danger of volcanic eruption and earthquakes. One vendor stated that "It was a poor chance to have such a project among the people, the boiling lake can erupt at any time"

**Vendors views on the Impact of the Geothermal project on the community**

- 90% of vendors were not sure that the community would benefit from the geothermal project.

Other indicated the following:

- "maybe jobs"
- Lower electricity bill
- The greatest fear of the project as indicated by vendors is the impact on their health. Most vendors feel that the project will have a negative impact on their health.

**In response to a question as to whether the project would bring changes to the community, the group responded, as follows:**

- One vendor noted noise, especially at nights. Others felt that people would get accustomed to the noise;
- Another vendor stated that "It will change things for the better, not for worst".

- A vendor also suggested the need for additional educational open sessions in the community by project personnel.

**In terms of priority needs of the community with respect to the operations of the geothermal project the vendors cited the following:**

- Proper roads;
- Bridge to be in good condition;
- Exit points in the event of an evacuation; and
- Safe guard measures for the community in case of any emergencies resulting from the project

**Social Impact of the Project on the Community**

The group (95%) indicated that there is no evidence of domestic violence in the Wotten Waven Community

1. The Group was informed that “There might be an influx of male workers in your community during the project’s construction, how do you think it will affect your community?”.

- 95% of the vendors felt that, generally, there would not be a problem; they indicated that there has been no history of this type of behavior in the community

## APPENDICES

### AGENDA – VENDORS / WOTTEN WAVEN

**Venue – Wotten Waven**

**Date & Time: March 24th, 2018 / 5:00 PM**

- Opening Prayers
- Introduction
- Introduction of participants
- Open Discussion
- Any other questions
- Closing remarks

### QUESTIONS

**What impact did Hurricane Maria have on you and your family?**

What is your priority for recovering from H Maria? Outline at least 3 priority areas

What are the needs of your community post Maria

Do people still suffer from trauma and do you think there is a need for counselling?

**What do you think about the Geothermal Project?**

What information do you have on the Project?

What additional information would you like to have on the project

**What impacts will do you think the project will have on and your family?**

(Will the project have any impact on your livelihood)

What improvements or disadvantages will this project have on your livelihood

What does your family think about the project?

In what ways do you think you will be better off without this project?

**What are the benefits of the project on your community?**

Will households in the community benefit from such a project?

What contribution will the project make to the community?

Will the community be better off without having such a project?

**What changes do you think the project will have on your community and on your lives?**

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What should be done to make you less worried about the project

**What is the History of domestic violence in your community?**

**There might be an influx of male workers in your community during project construction, how do you think it will affect your community?**

- Will it spur on teenage pregnancy, drugs etc.
- Is there any semblance of sex trade in your community?

# GEOTHERMAL RISK DEVELOPMENT PROJECT – DOMINICA

## WOMEN FOCUS GROUP MEETING – TRAFALGAR

### Introduction

A Focus Group Meeting with the women of the Trafalgar community was held for the Geothermal Risk Development Project – Dominica on Sunday March 18th, 2018 at the Trafalgar School Building.

The meeting was coordinated by Ms. Marie-Jose Edwards of Eclipse Inc. In attendance were Mrs. Lyn Fontenelle, Administrative and Safeguards Officer, Mr. Allan Toussaint, Community Liaison Officer and Mr. Shillingford of Dominica Geothermal Development Company Ltd and Mr. Lennox St. Aimee, a member of the Eclipse Inc. team.

The Administrative and Safeguards Officer and provided answers to questions and queries brought up by attendees throughout the sessions, she outlined the grievance mechanisms in place for the Project and indicated that grievance forms will be available at strategic locations and informed the group that future meetings will be held to update them on the status of the project and to provide additional data and information on the project. The liaison Officer re-introduced himself and provided his contact to all attendees, encouraging them to contact him for additional information / queries.

The meeting started at 3.35 p.m. with four (4) women present. The meeting ended at 5:00 p.m. with seventeen (17) women in attendance.

### OUTCOME OF FOCUS GROUP MEETING

**In response to the question, "What impact did Hurricane Maria have on you, as an individual, and the community?"**

- 90 % or respondents indicated that they have lost the roofs of their homes while 95% have lost their livelihood.

Other responses were as follows:

- Some women stated that Hurricane Maria affected their farms but most noted that they are back on track;
- Damages to houses & roofs were recorded at five (5) of those present;
- One women lost her work but has since found another job while two (2) other women indicated that their livelihood have been affected;
- Two women reported that they are still suffering from the shock of the hurricane;

**When asked about priority needs post Maria the responses were as follows:**

- The covering of their roofs and rehabilitation of their houses
- Restoring basic livelihood
- Recovering of roofs and rehabilitation of houses;
- Counselling for people who are still traumatized;

**The vendors were then asked, "What do you think about the Geothermal Project?". Vendors views on the project were as follows:**

80 % of persons were generally in favour of the project but express the following concerns

- One participant felt that "It would be good for us in Trafalgar". However, she was not in favor of the country sending energy overseas;
- Another participant wanted to know what the plant would be like and sought an explanation on the health risk to the community
- Another wanted to know how the energy will be generated. She was skeptical about tampering with nature and inquired why is not wind and solar energy attempted first.
- A woman noted that there was a promise of cheaper electricity with the hydro project, but it was not so; she hoped that this would not be the same with geothermal;
- A concern also surfaced of the leaves of trees turning to different colors when it rains.

**When asked the following question** "**What Impact do you think that the project will have on you, as an individual, your family and the community**?"

- 85% of the participants had a positive view of the project with some areas of concerns as expressed in the following responses:
- The Group felt that the project could do the following:
  - Bring money back in one's pocket;
  - Create extra employment for certain person;
  - Provide educational opportunities for new skills; and
  - May have positive or negative social impact on the community.

In response to what the group saw as its biggest fears for themselves and the community, 40 % expressed fears. Some of the responses were as follows:

- The plant refusing to work, or something goes terrible wrong;
- What can happen is unknown, therefore, one does not know what to expect;
- What if a volcano explodes;
- A negative effect on the tourism industry; and
- It is rumored that it can generate cancer

**Women's views on whether the community would be better off without this project were as follows:**

- 80 % of the women felt that the community would benefit from the project.
- There was an anticipation from a participant that it would be better off;
- Another participant suggested the need for a disaster plan; and
- The participants agreed that more information is needed by the community.

**Social impact of the project on the community**

**When asked about the history of domestic violence in their community?"**

**The women generally agreed that there was moderate to very little domestic violence in the community. Their responses were as follows:**

- The group agreed to a response from a member that "It has cool out a little but there was in the community";
- However, they would not speculate as to the current level of domestic violence in the community;
- In response to a query from the facilitator, the group felt that domestic violence could be managed by:
    - Speaking to the individuals involved; and
    - The need to follow up by the authorities when complaints are made to them.

**In response to a possibility of an influx of male workers in the community during the project's construction, and any potential impact on the community, the response was as follows:**

- A participant noted the need to ensure that such workers are properly screened;
- Another participant saw the possibility of an increase of drugs and alcoholism;
- A participant noted the possibility of community impacting its culture on the foreign workers;
- A woman indicated the need for education starting at the home, as to what to expect; and
- There was also a suggestion for targeted sessions to various sections of the community;

## APPENDICES

### AGENDA- MEETING WITH THE VENDORS / TRAFALGAR

**Venue – Trafalgar Primary School Building**

**Date & Time: Sunday March 18th, 2018 / 3:00 PM**

- Opening Prayers
- Introduction
- Introduction of participants
- Open Discussion
- Any other questions
- Closing remarks

### QUESTIONS

**What impact did Hurricane Maria have on you and your family?**

What is your priority for recovering from H Maria? Outline at least 3 priority areas

What are the needs of your community post Maria

Do people still suffer from trauma and do you think there is a need for counselling?

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**There might be an influx of male workers in your community during project construction, how do you think it will affect your community?**

- Will it spur on teenage pregnancy, drugs etc.
- Is there any semblance of sex trade in your community?




# Dominica Geothermal Power Plant

## Environmental and Social Impact Assessment

July 2018

Dominica Geothermal Development Company Ltd

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# Agenda

1. Project Overview
2. Technology Overview
3. Construction and Operational Phase Outline
4. ESIA Process
5. ESIA Studies
6. Environmental Impacts, Mitigation and Monitoring
7. Community and Social Impacts
8. Conclusions
9. Project Consultation
10. Grievance Mechanism

# Project Components Overview

- Geothermal Power Plant (7 MW) at Laudat
- Production well (called WW-P1) which provides steam and brine to drive the power plant at Laudat
- Reinjection wells called WW-R1 (Trafalgar) and WW-01 (Wotten Waven) for the return of brine to the below ground geothermal reservoir
- Brine reinjection line running from Laudat to Trafalgar, a12 inch line with a 10 metre maximum corridor
- 11 kV underground power line connecting power plant Laudat Hydropower Station

# Project Area of Influence




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# Power Plant Layout



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# Power Plant Technology Options

Typical Organic Rankine Cycle



- Larger footprint (size)
- Potentially less visual vapour
- Least efficient / most expensive

Typical single flash stream condensing cycle



- Smaller footprint (size)
- Potential visual vapour (depending on weather)
- Most efficient / least expensive

# Example of a Reinjection Pipeline





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## Pre-Construction Phase

- Land valuations
- Negotiations on land
- Land acquisition and compensation paid
- Process to be completed according to World Bank requirements, prior to construction commencement

## Construction Phase

- Anticipated to begin late 2018 or early 2019 and last 18 months
- For 2 months - site clearing and earth movement, establishment of temporary construction facilities and roadways
- For 7-9 months major civil and structural works
- For last 3 months, testing and commissioning

## Operational Phase

- **Start-up** - Mid 2020
- **Maintenance -** Envisaged that a unit maintenance shut-down will occur annually. Lasting roughly seven days

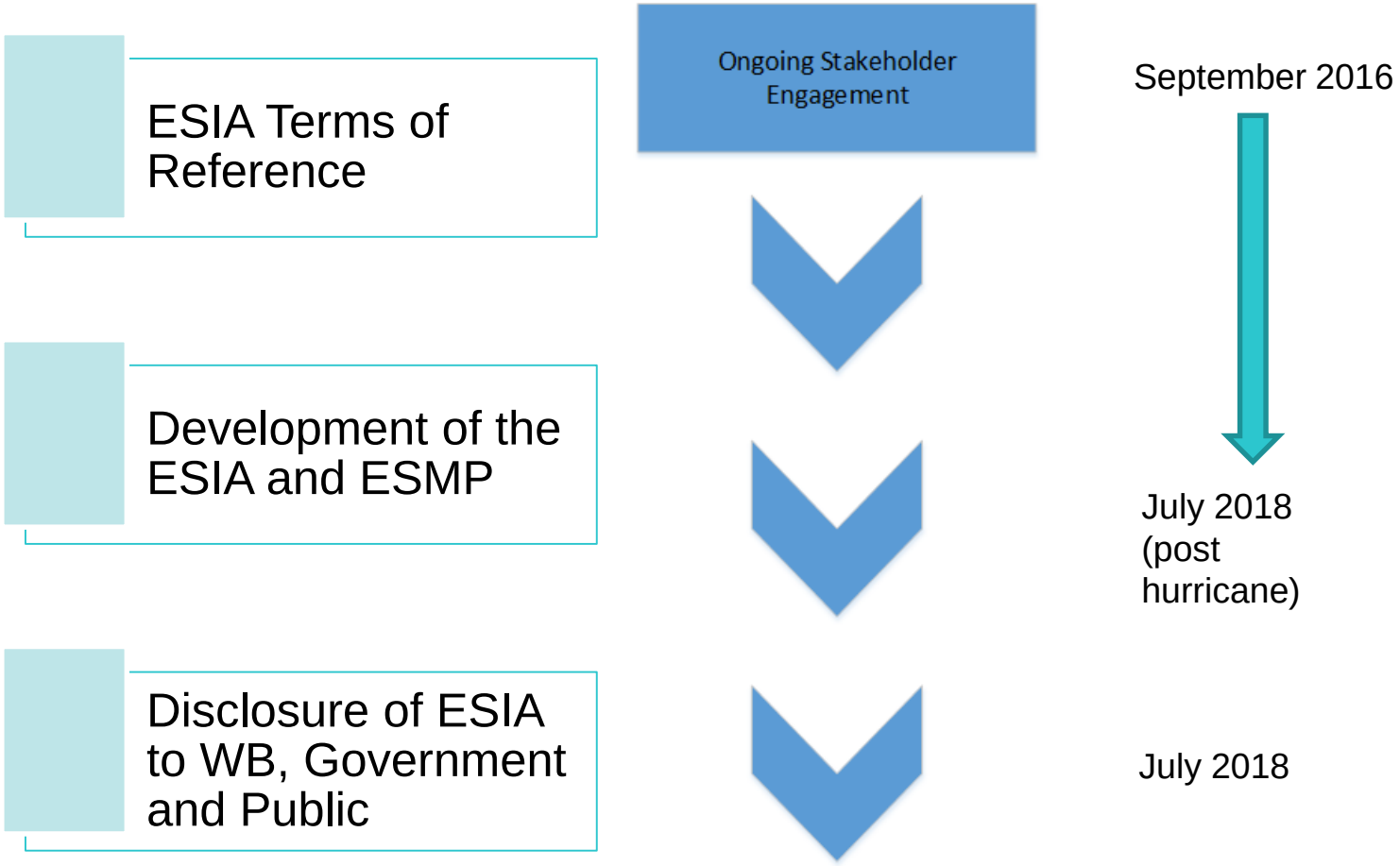
# What is an ESIA?

## ESIA = Environmental and Social Impact Assessment

- The goal of the ESIA for the Project is to evaluate the temporary and permanent impacts of the construction, operation and decommissioning of the Project on the natural and human environment.

- Based upon this evaluation, mitigation measures are developed to reduce all impacts to acceptable levels.

# ESIA Process





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# Impact Level Determination

- An impact is essentially any change to a resource or receptor brought about by the presence of the proposed project component, project discharge or by the execution of a proposed project related activity.

- Level of impact can range from ‘major’, ‘moderate’, ‘minor’ or ‘negligible’ based on consideration of parameters such as:
  - Duration of the impact – ranging from ‘well into operation’ to ‘temporary with no detectable impact’.
  - Spatial extent of the impact – for instance, within the site boundary, within district, regionally, nationally, and internationally.
- Mitigation measures are proposed for any impacts that are minor significance or above.



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# What are the present environmental conditions in the Project area?

- Air Quality
- Water Quality
- Ecology and Natural Resources
- Natural hazards
- Noise
- Landscape and Visual



# What are the findings of the ESIA?

## Air Quality and Public Health

Impacts:

- Minor temporary impacts from dust during construction
- Hydrogen sulphide releases - no anticipated health effects during operations are predicted levels to be well below World Health Organisation (WHO) thresholds of observed adverse effect levels, however, potential for increased odour near the Power Plant

Mitigation and Monitoring:

- Dust prevention measures during construction as outlines in Air Quality Management Plan
- Dust and air quality  monitoring during construction against WHO ambient air guidelines
- Monitoring at residences near the Power Plant and in Roseau for hydrogen sulphide

# Noise

Impacts:

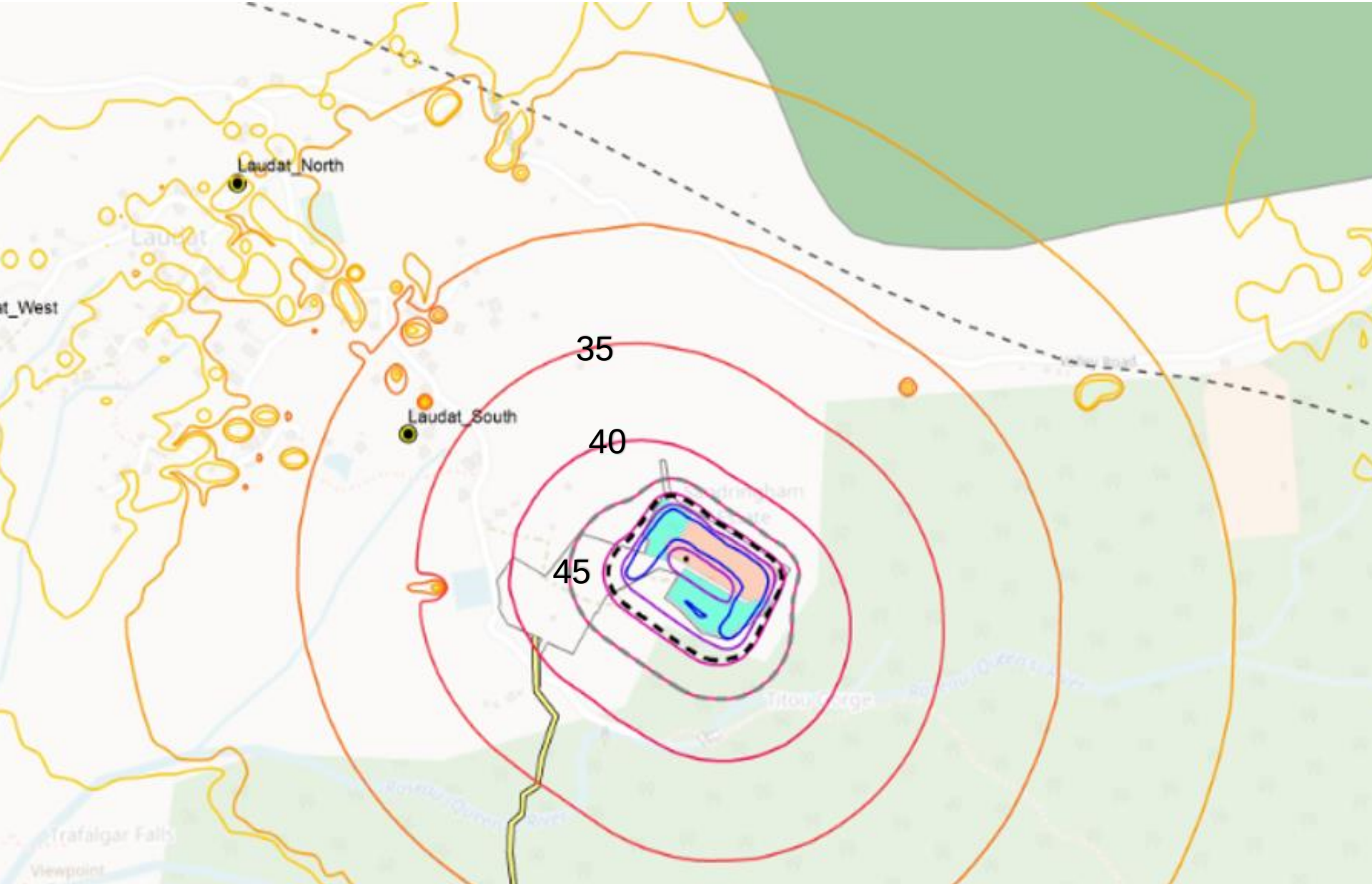
- Minor temporary noise increases impacting residents during construction
- Noise impacts during steam blowing (1 week), commissioning works will be intermittent over a three month period and is dependent on the activities being undertaken and testing periodically (hour or two).
- Operational noise levels at the Power Plant are predicted to comply with WHO noise standards (55 db(A) during day and 45 dB(A) at night) at all surrounding residences

Mitigation and Monitoring:

- Restrict noisy activities during commissioning to daytime
- Temporary localised screening during construction
- Monitoring to ensure noise levels are within limits

# Noise Levels Predicted During Operation





# Water Quality

Impacts:

- When vegetation is cleared for Power Plant, potential for increased soil erosion and run-off during construction which could affect Roseau river water quality.
- Also potential for soil erosion at stream crossings for reinjection pipelines

Mitigation and Mitigation:

- Development of erosion and sediment control procedures and stormwater management and site drainage design.
- Interceptors, silt fences and sumps to reduce sediment run off into the water course and clean water diversions at stream crossings
- A monitoring program will be put in place for monitoring discharges from sediment control devices

# Ecology

Impacts:

- Overall ecology effects expected to be minor
- When vegetation is cleared from Power Plant or r-injection area, this could cause changes in fish habitat
- Changes in river sediment characteristics and amount during construction
- No habitat loss and negligible impact on MTPNP

Mitigation and Monitoring:

- Erosion and sediment control procedures
- Landscaping and replanting
- Monitoring of  5 key species at a frequency of every six months during construction and annually thereafter in Project area

# Landscape and Visual

Impacts:

- Short term changes during clearance while vegetation regrows
- Views from properties surrounding the Power Plant may be degraded in the short term
- Due to the size of the pipeline corridor (10 m) and the pipeline itself (30 cm), it is unlikely that during operation the pipeline will not drastically change the view

Mitigation and Monitoring:

- Planting regimes are expected to reduce visual impacts over time and restore them to acceptable levels

# Natural Hazards and Geothermal Features



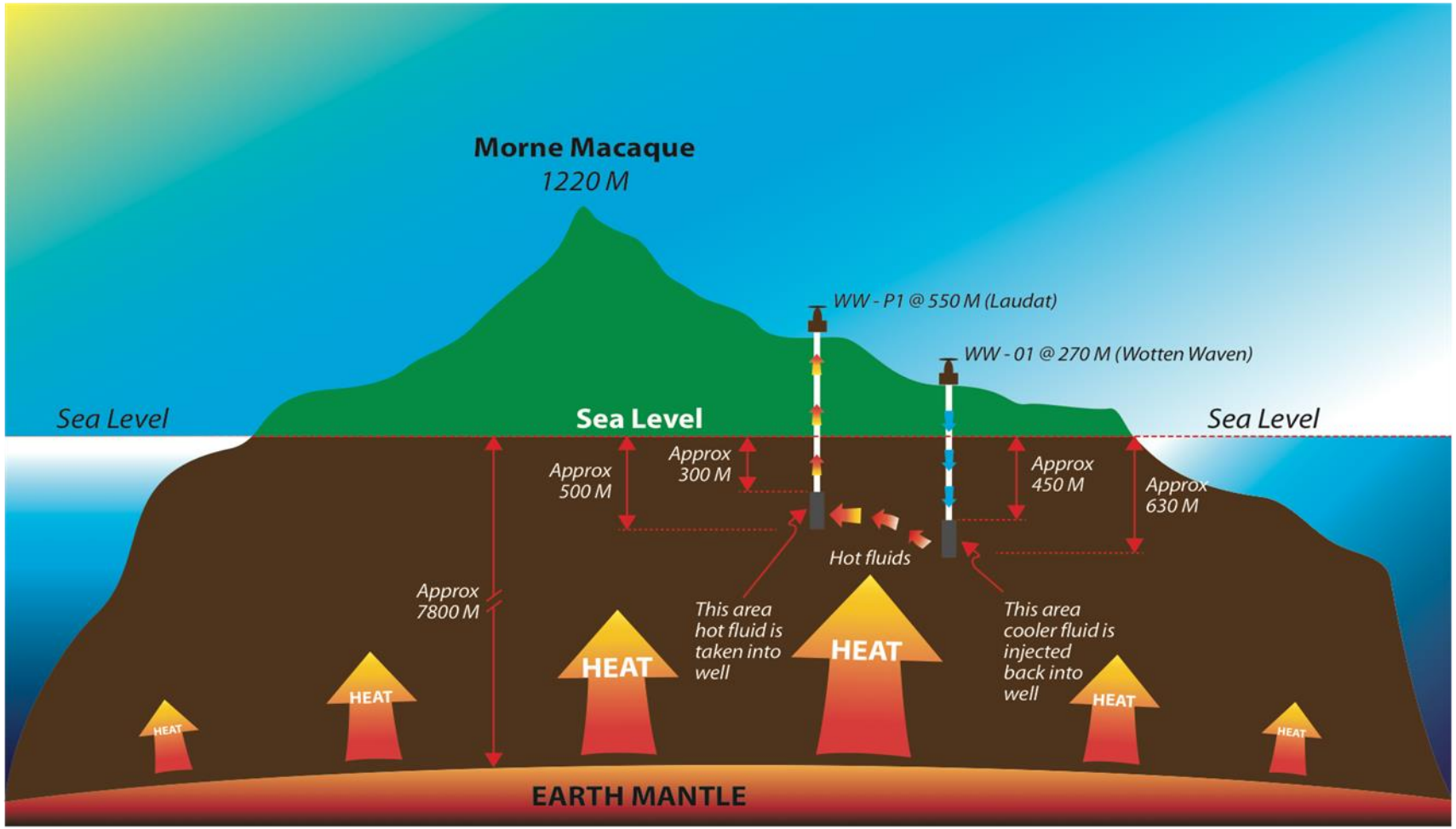
Impacts:

- Potential for landslides and natural hazards.
- The reinjection pipeline will be at some risk from flooding as occurred during the Hurricane Maria
- Geothermal features – not anticipated to be impacted as the project will be 1000 metres down and pools are surface features

Mitigation and Monitoring:

- Flooding on the reinjection pipeline will be minimised by careful route construction and design of river crossing structures.
- Landslide Management Procedure
- A monitoring program will be put in place for the hot pools to monitor any changes

# Overview of Wells



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# Traffic

Impacts:

- Increased levels of traffic during construction, with potential temporary diversions and minor delays particularly for pedestrians and cyclists

Mitigation:

- Development of a Traffic Management Plan
- Workers Camp to minimise daily traffic during construction

# Community and Social Impacts

- The Project will have a beneficial impact on employment during construction in the Roseau Valley. Additional jobs created indirectly (through retail, hospitality, transportations, etc.) would also bring minor beneficial impacts for employment in the local area.
- The unskilled and semi-skilled workforce is anticipated to generally come from the local area but will not be large in number.
- GoCD has indicated that funding for some community development initiatives along with development of the power plant will be provided.
- Construction of Visitors Center adjacent to the Power Plant which could generate positive impacts on tourism

# Community and Social Impacts (cont.)



- Approximately 12 properties or portions of properties would need to be acquired. For proposed land acquisitions and resettlement associated with the Project, an Abbreviated Resettlement Action Plan (ARAP) has been prepared.
- General community health impacts of the Project are considered to be minor. Community safety impacts from increased traffic and associated safety risks would create moderate impacts. However, impacts would likely be short-term and localised and risks would be highest during the peak construction period.

# Monitoring

- Wastewater effluent quality
- Stormwater quality
- Biodiversity
- Slope stability
- Geothermal features
- Air quality
- Noise
- Social surveys






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# Conclusions

- The ESIA summarises a large amount of technical work undertaken to assess the impacts of the proposed Project.
- Main impacts include: noise, land acquisition, traffic, natural hazards, erosion, and temporary changes associated with construction.
- Mitigation and monitoring actions have been set out in the Environmental and Social Management Plan that address the key environmental and social impacts identified in the analysis.
- Implementation of the mitigation, management and monitoring measures in the ESMP for each phase of the Project will ensure that the environmental and social impacts of the Project overall will be acceptable.

# Project Consultation Going Forward

- **Community Liaison Officer – Alan Toussant**

  allan.toussaint@geodominica.com

  (767) 448-6178 / 79

  (767) 275-7392 (cell)

- **Grievance Mechanism:**

  Concerns and complaints during construction and operations to be recorded and addressed – form online

- **Ongoing Land Acquisition Process**



# Grievance Mechanism

- This is a process which allows the communities impacted by the development to lodge their concerns with DGDC in regards to potential issues with the development that may arise during the construction and operation of the geothermal development
- DGDC will receive the grievance, evaluate it and act upon.
- The party submitting the grievance will be advised of the actions undertaken to resolve the issue

# Questions?

# Thank you for listening

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**Dominica Geothermal Development Company**
**ESIA – Non-Technical Summary Community Consultations**
**July 2018**

Meetings were held in the communities as follows:

Laudat – Tuesday 4th July 2018 6:00 PM

Trafalgar – Wednesday 5th July 2018 6:00 PM

Wotten Waven – Thursday 6th July 2018 6:00 PM

All meetings started at 6:30 PM. Community Liaison Officer – Allan Toussaint Chaired all the meetings.

DGDC was represented at the meetings by: Mark Tomkins, Lyn John-Fontenelle, Rawlins Bruney, Dalton Eloi, Allan Toussaint, Garry Shillingford. Fidel Grant attended the meeting in Laudat.

Jacobs was represented by Dorney Burgdorf.

The meetings were generally well attended (see attendance lists in Appendix 1) and very interactive. The NTS was disclosed on the DGDC's and Gov't of Dominica's website from June 25th 2018 (www.geodominica.com & www.dominica.gov.dm), hardcopies were available at the DGDC offices and at public spaces in the Roseau Valley ( Resource Centre in Wotten Waven, Health Centres in Trafalgar & Laudat). Notices were placed on local radio (DBS Radio) and online newspaper (Dominicanewsonline.com) inviting the public to the consultations and directing them to the NTS document.

The Agenda followed for all meetings was:

## AGENDA

**Allan Toussaint/Community Liaison Officer, DGDC**
**Opening Prayer**

**Apologies for absence of Minister/Parliamentary Representative (off-island)**

**Welcome & Introductory Remarks**
**Chairperson**

**Overview of the Geothermal Project**
**Mark Tomkins, Project Manager**

**Overview re ESIA**
**Dorney Burgdorf/ESIA Specialist**

**Question and Answers**

**Thank you and Closing Remarks**

# APPENDIX 1

Attendance list Laudat

| NO. | NAME | ADDRESS | OCCUPATION | EMAIL ADDRESS | TELEPHONE NO. |
|---|---|---|---|---|---|
| 1 | Joel Lambert | Laudat | | | |
| 2 | Alfred Rolle | Laudat | | | |
| 3 | Henry | Copt Hall | | | |
| 4 | Kleen Burnette | Laudat | | | |
| 5 | Aaron Rolle | Laudat | | | |
| 6 | Berani Rolle | Laudat | | | |
| 7 | Claudette Rolle | Laudat | | | |
| 8 | Earl Jno Lewis | Laudat | | | |
| 9 | Charles McClean | Laudat | | | |
| 10 | Ralph Magloire | Laudat | | | 6128853 |
| 11 | Kyle Sylvester | Shawford | Sales Clerk | Sylvesterkyle@hotmail.com | 3179974 |
| 12 | Donna Sylvester | Shawford | Sales Clerk | Moartess2008@hotmail.com | 6142689 |
| 13 | Dr. Patrick Cloos | Laudat | Medical Professional | Patrick.cloos@umontreal.com | |
| 14 | Augustus Junkere | Laudat | Mechanic | | 2658445 |
| 15 | Christiana Abraham | Laudat | Researcher | Christianabraham@hotmail.com | 2255056 |
| 16 | George Daway | Laudat | | | |
| 17 | Fabiana Moses | Laudat | | | 2779323 |
| 18 | Cyril Daway | Laudat | | | |
| 19 | James Daway | Laudat | | | |

Attendance List Trafalgar

| NO | NAME | ADDRESS | OCCUPATION | EMAIL ADDRESS | TELEPHONE NO. |
|---|---|---|---|---|---|
| 1 | Barbara Barrie | Trafalgar | NEP Worker | Conniebarrieroberts@gmail.com | 2776400 |
| 2 | Vernanda Raymond | Shawford | Chief Librarian | Vernandara@gmail.com | 2457966 |
| 3 | Kyle Toussaint | Shawford | Mechanic | Kyle.Toussaint94@gmail.com | 6130560 |
| 4 | Khern Toussaint | Shawford | Student | | |
| 5 | Ashton Rolle | Trafalgar | Trademan | | |
| 6 | Laura Denis | Trafalgar | Vendor | | 2250815 |
| 7 | Miranda Baptiste | Shawford | | | 3165039 |
| 8 | Sandra St Jean | Trafalgar | NEP Worker | | |
| 9 | Alexandrine Rolle | Trafalgar | | | |
| 10 | Arthurton Bellot | Trafalgar | GIS Intern (NEP) | Brettson92@gmail.com | |
| 11 | Michael Ross | Trafalgar | Administrative Assistant | Treasure18@gmail.com | 2455699 |
| 12 | Joanne Bellot | Trafalgar | Assistant Manager | Bellot70@yahoo.com | 2253459 |
| 13 | Annalisa Jensen | Trafalgar | Artist/Teacher | | 2654000 |
| 14 | Mitch Francis | Trafalgar | Carpenter | Mitchfrancis1988@gmail.com | 6130380 |
| 15 | Dabria Toussaint | Shawford | Student | | |
| 16 | Jannelle Raymond | Shawford | Student | | |
| 17 | Corrie Phillip | Shawford | Student | | |
| 18 | Allianne Toussaint | Shawford | Student | | |
| 19 | Evette Daniel | | | | |
| 20 | Vera Daniel | Trafalgar | | | |

Attendance list Wotten Waven

| NO | NAME | ADDRESS | OCCUPATION | EMAIL ADDRESS | TELEPHONE NO. |
|---|---|---|---|---|---|
| 1 | Dayne o. George | Wotton Waven | Self Employed | Raw_stylez@yahoo.com | 2257222 |
| 2 | Dale Joseph | Wotton Waven | - | Lyfestarle@gmail.com | 2258218 |
| 3 | Rudolph George | Wotton Waven | | wottonwaven@gmail.com | 2356074 |
| 4 | Julian Joseph | Wotton Waven | - | | |
| 5 | Edward Green | Canefield | - | | |
| 6 | Joanalie Ducreay | Wotton Waven | | yducreay@gmail.com | 3167732 |
| 7 | Hezron Ducreay | Wotton Waven | Teacher | elducreay@hotmail.com | 2857425/3173463 |
| 8 | McCarthy Marie | Copt Hall | Economist | mccarthymar@gmail.com | 6168000 |
| 9 | Virginia Bedneau | Wotton Waven | Vendor | | 3163515 |
| 10 | Sherwin | Wotton Waven | Host at Guest house | | 6120403 |
| 11 | Dorienn Joseph | Wotton Waven | Contractor | Guroo27@hotmail.com | 2251641 |
| 12 | Jamon Francis | Wotton Waven | | | |
| 13 | Mary Abraham | Wotton Waven | | | |
| 14 | Alina Morancie | Wotton Waven | Farmer | | |
| 15 | Celsa Joseph | Wotton Waven | | | |
| 16 | George | Wotton Waven | | | |
| 17 | Kendell Ducreay | Wotton Waven | | | |
| 18 | Jose Allan | Wotton Waven | | | |
| 19 | Brenda Joseph | Wotton Waven | | | |

Questions /Suggestions/Comments:

**Laudat:**

1. Will the WB review the assessment?
2. Was it necessary to dig the wells at different locations?
3. What is being put in place for pipes being passed over water sources? Why over Titou Gorge?
4. How many lands is the government going to acquire for the project?
5. The NTS does not answer what is actually going to happen on the ground or long-term health issues
6. What are the concrete measures to address concerns raised?
7. Has a public health assessment been done?
8. (linking the relation between geothermal activities and volcanic eruptions) Can you exclude that this type of activity will exclude a major earthquake? Re: geothermal plant in Basel Switzerland?
9. Are there two ESIAs? Does not see any content dealing with social issues in the NTS. Asks for policy makers and cabinet of Ministers to meet with the community – What if the company (DGDC) is sold afterwards?
10. Is there a policy in place for people not to become poorer? What is there for the community?
11. Not because it is funded by the WB its ok
12. An insurance fund should be established with $5M for the community
13. How is the community as a whole going to benefit directly from the project?
14. The stakes are high for the people of Laudat – what is the value of the properties? Whose land is going to be taken for the project
15. Did the ESIA take into consideration future expansion?

**Trafalgar:**

1.Why the great distance between the production plant and reinjection wells?
2.On the natural hazards slide- there is mention of natural and other hazards…..what are the other hazards?
3. Is an emergency response plan included in the ESIA?
4. Is it standard for a production plant to be built so close to where people live?

**Wotten Waven:**

**1.**What is the difference in the way the different plants work?
**2.**How many people will be needed to run the plant? Comment: So, it is not going to generate any employment
**3.** What measures are on place if something goes wrong? E.g. release of poisonous steam
**4.** Counselling should be arranged for the people of Laudat to allay their fears with respect to this project and the dangers
**5.** Could there be a process for people of the Valley to have free hot water?
**6.** How will the plant be affected if there is an earthquake given that Dominica is due for one?
**7.**Will there be any effect on the Spas?
**8.** Will the plant contribute to global warming?
**9.** Would an earthquake have any effect on the wells?
**10.** How many gallons (of water) does 3 hours translate to?

**11.**What is the estimated lifespan of a production well?
**12.**How long have the wells in New Zealand lasted?
**13.** In terms of wells not producing – would it be due to the metal deteriorating?
**14.** Suggestion – that the project gives weekly updates to the communities
**15.** Is DGDC selling a product? How sure are we that electricity will be cheaper since DOMLEC has a monopoly?
**16.** Is there geothermal power in Hawaii?
**17.** Is Dominica due for a volcanic eruption?
**18.** Suggestion: People of the Valley should be compensated for the increased risk by having no electricity bills
**19.** How much power/electricity will we get out of the plant?
**20.** How much (electricity) is DOMLEC putting out?
**21.** What are the minor health impacts spoken about (in presentation)?
**22.** What happens to the waste from the plant?
**23.** What effects would a leak (of the reinjection line) have on the environment?
**24.** Will the pipeline interfere with the national trail?
**25.** What happens when the trail is shut down for maintenance?
**26.** How are private landowners being compensated?
**27.** What percentage of energy is from geothermal in NZ?
**28.** How soon will there be a reduction in electricity bills?
**29.** Suggestion – that guest houses in the Roseau Valley be used as accommodation for workers on plant
**30.** Where are the 12 properties to be acquired?
**31.** 4.4.2 of NTS can you clarify the comment on thermal spas.

# Appendix K. Stakeholder Engagement Plan including Community Grievance Mechanism

Dominica Geothermal Development Company Limited
*Powering a New Generation...*

JACOBS

# Dominica Geothermal Development – Environmental and Social Impact Assessment

Ministry of Foreign Affairs and Trade

## Stakeholder Engagement Plan

RZ020300-0002-NP-RPT-0003 | V2

July 2018



# Dominica Geothermal Development – Environmental and Social Impact Assessment

Project No: RZ020300
Document Title: Dominica ESIA Stakeholder Engagement Plan
Document No.: RZ020300-0002-NP-RPT-0003
Revision: V2
Date: July 2018
Client Name: Ministry of Foreign Affairs and Trade
Project Manager: Alastair Brookes
Author: Dorney Burgdorf
Project No: RZ020300
Document Title: Dominica ESIA Stakeholder Engagement Plan

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## Document history and status

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|---|---|---|---|---|---|
| A | 5 Oct 2016 | Draft for Issue to Client | D Burgdorf | T Strange | A Brookes |
| B | 17 Oct 2016 | Revision including Potentially Affected Parties | T Strange | | |
| C | 11 September 2017 | Minor revisions following recent stakeholder consultation activities. | P Gabriel | D Burgdorf | |
| D | March 2018 | Minor updates following World Bank comments | L. Turk | D Burgdorf | |
| E | April 2018 | Updates following community surveys post Hurricane Maria | K Ashdown | L.Turk | |
| V1 | June 2018 | FINAL for ISSUE WITH ESIA | K Ashdown | L.Turk | A Brookes |
| V2 | July 2018 | ESIA Updated incorporating WB Comments | D. Burgdorf | B. Clarke | A. Brookes |

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## Important Note About Your Report

The sole purpose of this report and the associated services performed by Jacobs New Zealand Limited ("Jacobs") is to describe the Stakeholder Engagement Plan (SEP) for the Dominica Geothermal Power Project in accordance with the scope of services set out in the contract between Jacobs and the New Zealand Ministry of Foreign Affairs and Trade (the Client). That scope of services, as described in this report, was developed with the Client, the Government of the Commonwealth of Dominica (GoCD) and the Developer (Dominica Geothermal Development Company (DGDC) established and owned by the GoCD).

Jacobs has been contracted by the Client to undertake the conceptual design and overall project definition through their engineering team. In preparing this ESIA report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided. Except as otherwise stated in the ESIA report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

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## Glossary

| Acronym | Meaning |
|---|---|
| ADEME | French Environment and Energy Management Agency |
| AFD | Agence Francaise de Developpement |
| CLO | Community Liaison Officer |
| DGDC | Dominica Geothermal Development Company Ltd |
| DHTA | Dominica Hotel and Tourism Association |
| DOMLEC | Dominica Electricity Services Limited |
| DOWASCO | Dominica Water and Sewerage Company Limited |
| EIA | Environmental Impact Assessment |
| EHS | Environmental Health and Safety |
| GoCD | Government of the Commonwealth of Dominica |
| EMS | Environmental Management System |
| EPFI | Equator Principle Financial Institutions |
| ESMP | Environmental and social management plan |
| ESIA | Environmental and social impact assessment |
| IFC | International Finance Corporation |
| MWe | Mega Watt |
| MWe | Mega Watt Electric |
| NGO | Non-Government Organisation |
| O&M | Operations & Maintenance |
| OP | World Bank Operational Policy |
| PAP | Project Affected Persons |
| PPA | Power Purchase Agreement |
| PS | Performance Standard |
| RoW | Right of Way |
| SEP | Stakeholder Engagement Plan |

# 1. Introduction

## 1.1 Background

The Commonwealth of Dominica is a small island developing state in the Caribbean Sea with a population of approximately 72,000 people and a land area of approximately 750 km$^2$. About 60% of the land is classified as a World Heritage site by UNESCO, due to its rich biodiversity. It is located near the centre of the string of islands known as the Lesser Antilles, between the neighbouring French territories of Martinique and Guadeloupe. The capital Roseau is located to the south west of the island and has a population of around 15,000 people.

Dominica's power system relies heavily on diesel imports to generate electricity. Improving the power generation mix and reducing the cost and volatility of electricity prices have become a development priority for Dominica. To this end, geothermal exploration has been conducted in the Laudat-Wotten Waven-Trafalgar geothermal field in the Roseau Valley (Figure 1-1) and has proven the existence of a geothermal resource suitable for power generation.

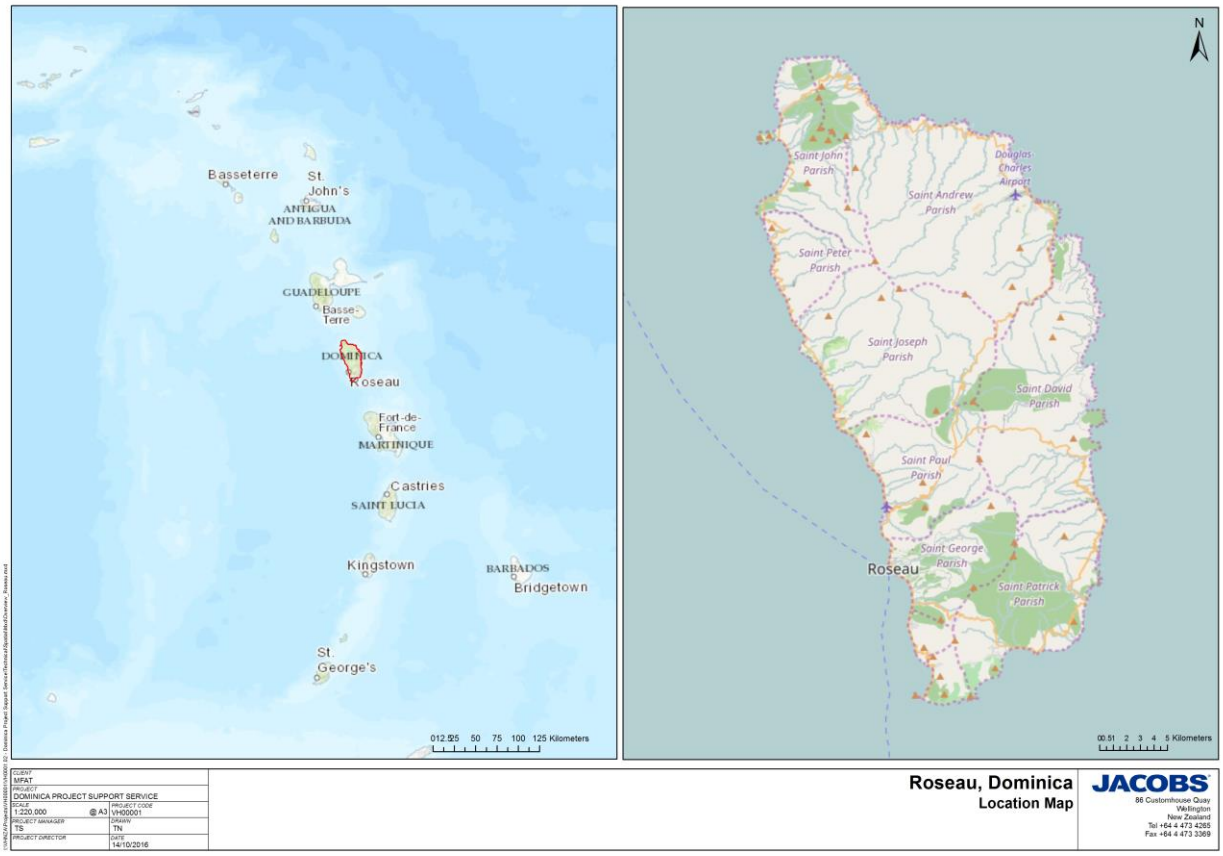



**Figure 1.1 : Dominica's location in the Caribbean**

As with many other island nations, Dominica's primary source of electricity production is from diesel generation, which exposes the country's economy to uncertainty in regard to the cost and supply of diesel imports. Changing the power generation mix and reducing the cost and volatility of electricity prices have become development priorities for Dominica. Being a relatively young volcanic island, Dominica has significant geothermal resource potential. Therefore, since 2006 the Government of the Commonwealth of Dominica (GoCD) has pursued an exploration programme to evaluate the viability of geothermal resource in the Roseau Valley.

## 1.2 Purpose

This document is a Stakeholder Engagement Plan (SEP) for the Dominica Geothermal Project that sets out the approach to stakeholder and community consultation and disclosure for the lifecycle of the Dominica Geothermal Power Project ("the Project").

The SEP was developed based upon a commitment to thorough stakeholder identification followed by open and comprehensive engagement activities to build trust with Project stakeholders. It sets out to define a framework of standardised measures to be undertaken to proactively engage Project stakeholders, undertake consultation and encourage participation in line with the relevant legal and regulatory requirements including good international industry practice and national legislation, while also being meaningful, well-coordinated and culturally appropriate. This process is critical to facilitate community understanding of the Project, manage expectations and concerns, and ensure that representation from all community groups including vulnerable stakeholders is included.

The SEP is an active working document which will be reviewed and updated on a regular basis by the Dominica Geothermal Development Company Ltd (DGDC) and the operator, should this ultimately be a different entity.

## 1.3 Objectives

The objectives of this SEP are to:

- Identify the local legal framework of consultation activities and disclosure requirements, particularly in respect of those public consultation activities that are directly required under the local permitting process;
- Identify potential stakeholders in the area of influence, as well as relevant interested parties such as government agencies and other key stakeholders;
- Record all consultation activities, including those prior to the commencement of the environmental and social impact assessment (ESIA) process;
- Describe how concerns or grievances will be handled;
- Provide an action plan for further consultation during preparation, construction and operational phases of the Project, including details on appropriate formats for effective and culturally meaningful interaction with the community and relevant stakeholders; and
- Provide a disclosure plan, including the identification of any locations where relevant Project documentation will be available locally and elsewhere as well as languages to be used.

## 1.4 Structure of Plan

The SEP is structured in accordance with the following chapters:

- Section 1 – Introduction
- Section 2 – Project Description
- Section 3 – Regulatory Requirements (public consultations and information disclosure requirements)
- Section 4 – Review of previous stakeholder engagement activities
- Section 5 – Stakeholder Identification
- Section 6 – Engagement Activities
- Section 7 – Implementation Timescales
- Section 8 – Grievance Mechanism
- Section 9 – Monitoring and Reporting

# 2. Project Overview

## 2.1 Geothermal Development Process

The overall geothermal development process is executed as follows (Table 2.1).

**Table 2 1 : Geothermal Development Phases**

| No | Phase Name | Activities |
|---|---|---|
| 1 | Preparation | Project establishment, geoscientific investigations |
| 2 | Exploration | Exploration drilling and resource assessment |
| 3 | Appraisal | Appraisal drilling and bankable feasibility study |
| 4 | Construction | Production drilling; power plant construction and start-up |

These phases are followed by commercial operation over the life of the plant and decommissioning in due course (or repowering if appropriate).

Transition from one phase to the next flows from a major investment decision, based on the prior work completed. Associated with this there will be a period during which funds are secured. The first phase culminates in the decision to undertake the exploration drilling programme (Phase 2). The second phase culminates in the decision to proceed with the appraisal drilling (Phase 3). The third phase culminates in the decision to construct the power plant (Phase 4). The fourth phase culminates in commercial operation of the power plant. For this project, the preparation and exploration phases are now complete.

## 2.2 Project Description

The Project comprises the development of a two-unit geothermal power plant with a gross capacity of 7 MWe in the Roseau Valley, Dominica. This covers the following stages: construction, completion, testing, commissioning, ownership, operation and decommissioning, including the steamfield, required electrical connections and integration with associated infrastructure. The preliminary design for the Project is ongoing, with detailed design to be completed following a formal tender process for an Engineer, Procure and Construct contractor(s) in 2018.

The power plant is proposed to be located in the village of Laudat. Three well pads will be used for the Project, located near Wotten Waven along with one reinjection well pad.

The Government has ownership of the existing well pads (WW-01, WW-02 and WW-03), whose locations are presented in Figure 2.1, along with the preferred injection line route. This route alignment will be finalised in close co-ordination with process engineering, mechanical, geotechnical and civil engineering design disciplines, along with the Government, Land and Survey Division and environmental and social scientists.

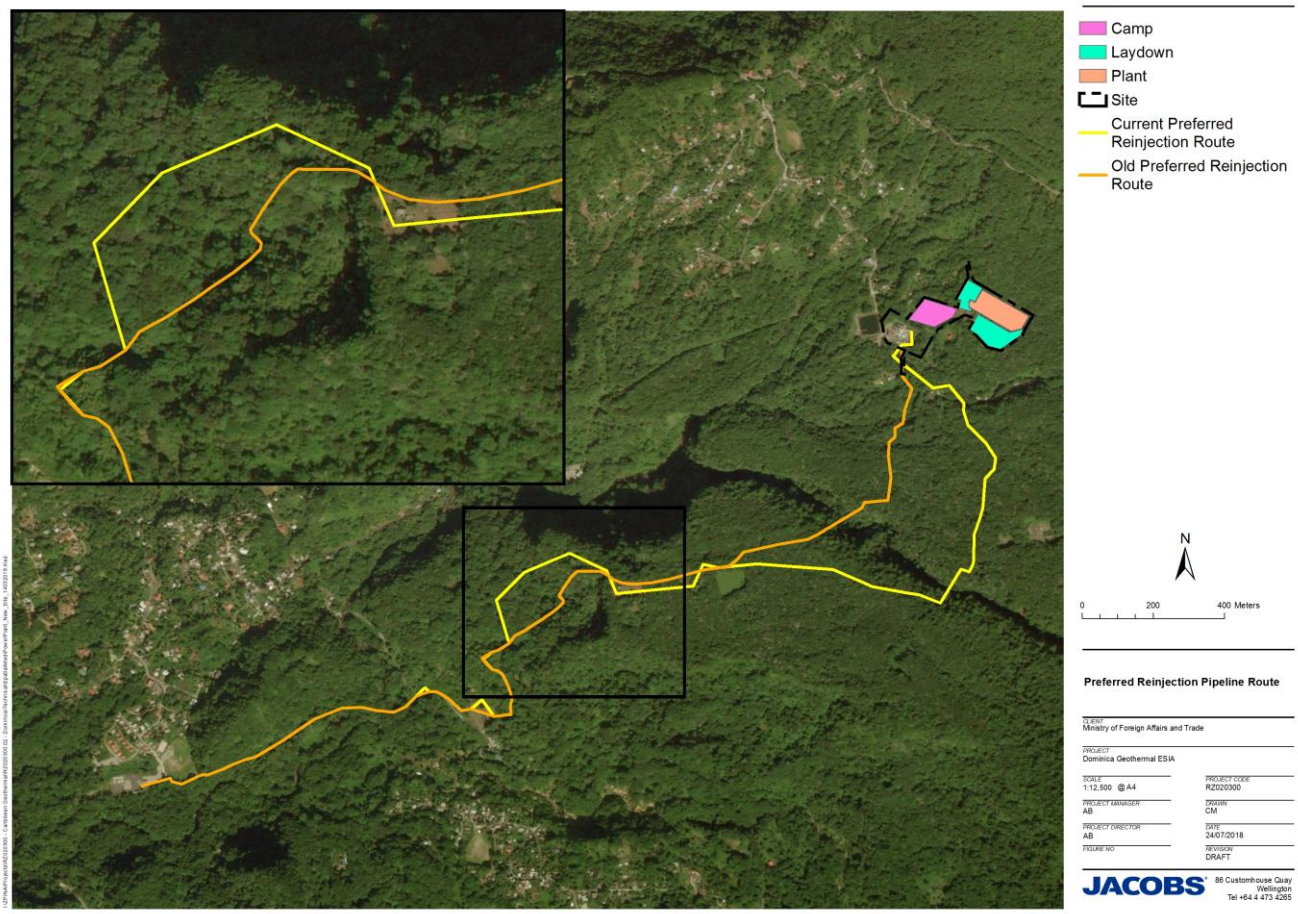



**Figure 2.1: Preferred injection pipeline route from WW-P1 to WW-01 and WW-R1**

The conceptual power plant layout is displayed in Figure 2.2 and land will have to be acquired to site the power plant and other associated infrastructure.

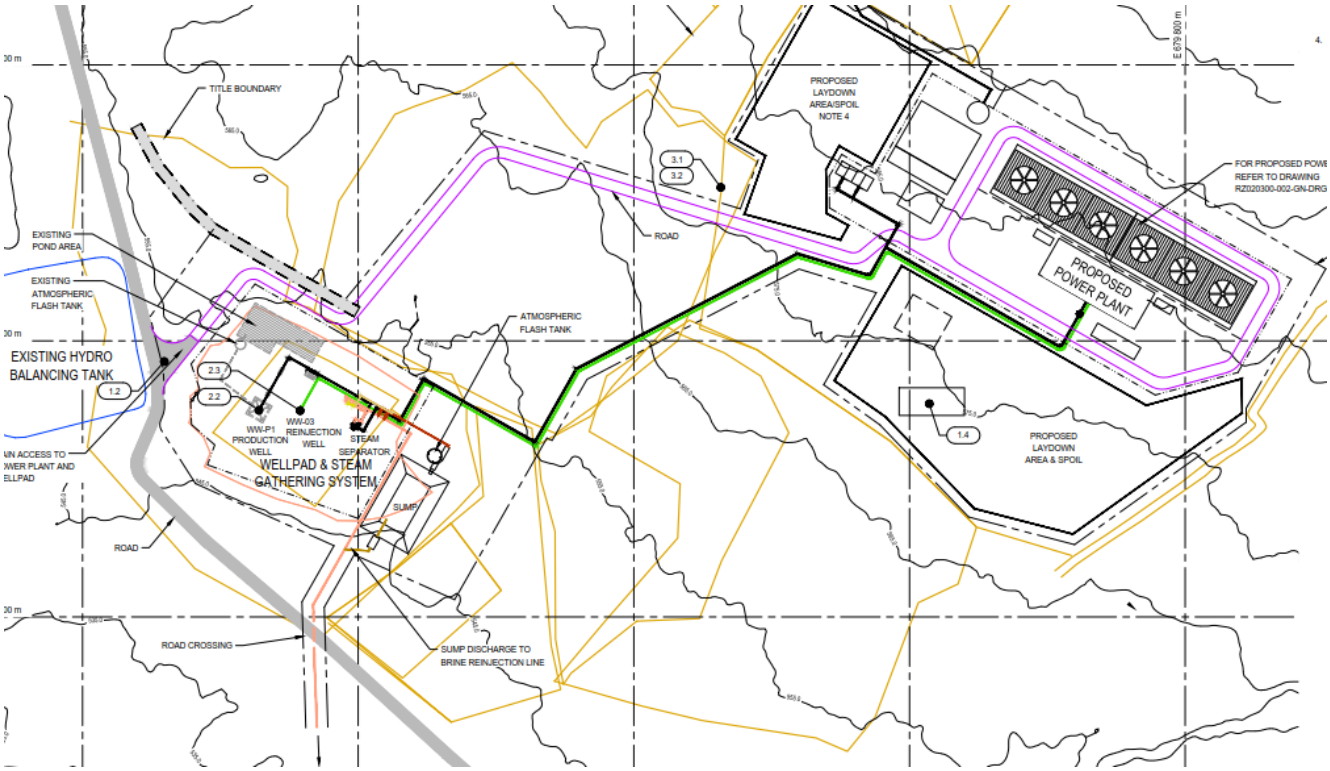



**Figure 2.2 : Proposed Power Plant Site and Production Steamfield Layout**

The area proposed for Project development is generally sparsely populated, characterised by some agroforestry and naturally vegetated areas. Brief descriptions of the main locations of Project infrastructure are as follows:

- Power plant comprising 2 x 3.5 $MW_e$ units (either single flash steam condensing cycle or organic Rankine cycle units (binary turbine), which will be adjacent to wells WW-P1 and WW-03. The binary power plants may use wet cooling or dry cooling;
- Production well WW-P1 – The existing geothermal production well at Laudat is indicated to have potential to generate 6 to 9 $MW_e$ and will be the sole production well for the project;
- Reinjection wells WW-R1 (located in Trafalgar) and WW-01 (located in Wotten Waven) – The used geothermal fluid (brine and possibly some steam condensate) produced from production well WW-P1 would be disposed of into reinjection wells WW-R1 and WW-01 via a 250 to 300 mm diameter reinjection pipeline of up to 3.5 km in length;
- Steamfield infrastructure including two phase piping, steam separator, atmospheric flash tank, brine collection and disposal system, condensate collection and disposal system, pressure relief system, storage sump and rock muffler;
- Supporting infrastructure including existing well pads, turbine building, primary and ancillary equipment, cooling system, and water supply; and
- 11 kV interconnection to the DOMLEC electricity grid at the power plant site.

Figure 2.3 provides the locations of the well pads (WW-P1, WW-03, WW-R1 and WW-01) and reinjection lines. For further details, reference should be made to the ESIA Volume 1: Introduction and ESIA Volume 5: Technical Appendices, Technical Report – Detailed Process Description

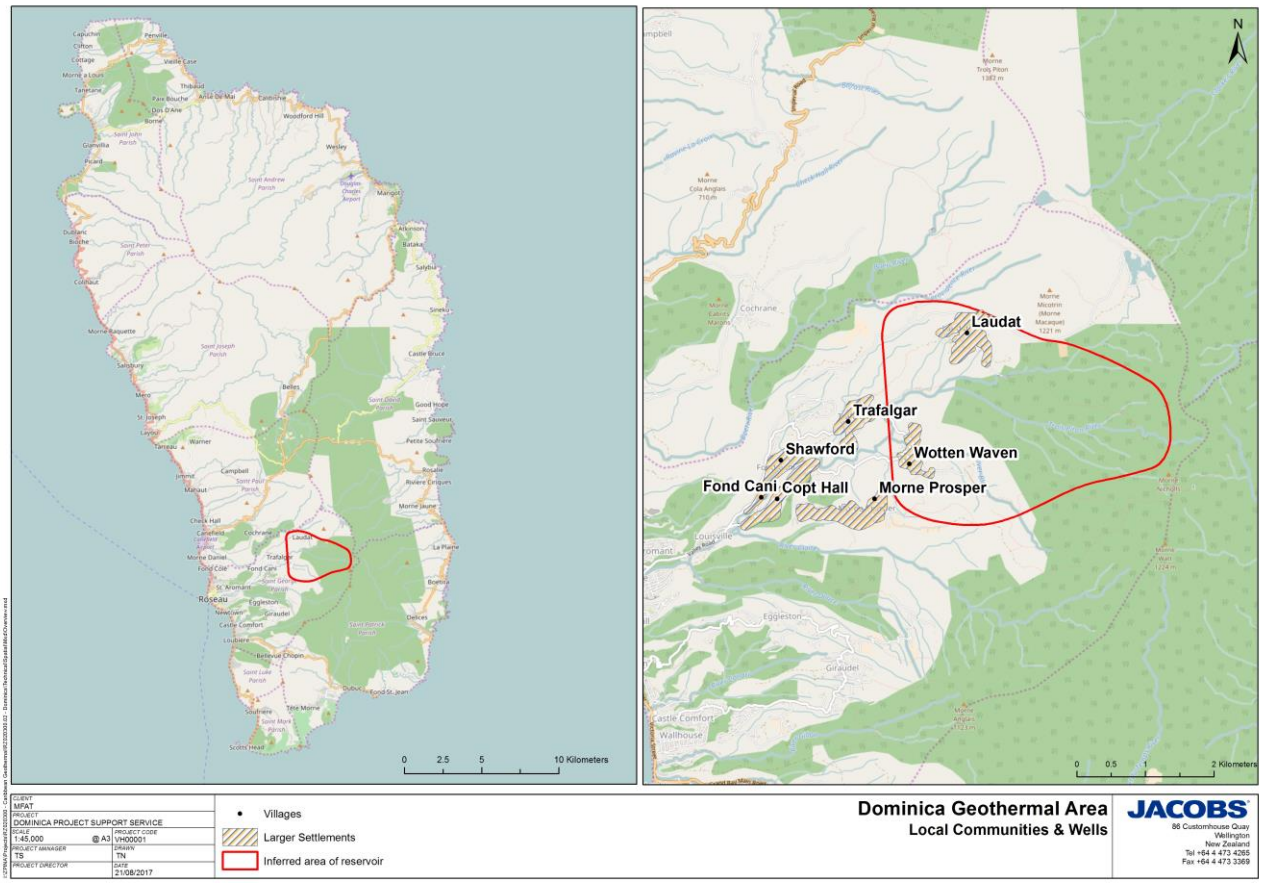



**Figure 2.3 : Location of Roseau Valley and Inferred Area of Geothermal Reservoir (Site of proposed Geothermal Power Plant)**

The exploration programme has been conducted in a phased manner over the course of approximately 10 years and is summarised in Table 2.2.

**Table 2 2 : The phases of the Dominica geothermal exploration programme.**

| No. | | Phase | Activities | Status |
|---|---|---|---|---|
| 1 | | Preparation | Project establishment, geoscientific investigations | Complete |
| 2 | | Exploration | Exploration drilling of three slim hole wells and resource assessment | Complete |
| 3 | | Production & Testing | Production drilling and testing of one full size well and drilling of one reinjection well | Complete |
| 4 | | Planning / Construction | Present phase comprising power plant and reinjection pipeline construction and start-up | Ongoing |

The geothermal project started as part of the European cooperation programme INTERREG III-B Caribbean space, in partnership with the Regional Councils of Guadeloupe and Martinique, the 'Agence de l'Environnement et de la Maîtrise de l'Energie' (ADEME), the 'Bureau de Recherches Géologiques et Minières' (BRGM) and the French company 'CFG Services'. The geothermal study area of interest was identified in June 2008 by BRGM after evaluation of resources and exploratory drilling programme. Focused on the Roseau Valley geothermal field, and located about 8 km east north east of the Capital of Roseau, it includes most part of the high temperature reservoir (210-230°C) (Figure 1.2).

To prove the existence of a viable geothermal resource, an exploratory phase was launched between 2011 and 2012 and involved the drilling of three test (slim) wells in the villages of Wotten Waven (well site WW-01) and Laudat (well sites WW-02 and WW-03). The final drilling depths were between 1200 m and 1613 m and

confirmed the presence of a geothermal resource with a 50% probability of having sufficient capacity for approximately 65 MW of power generation.

The next phase of the project commenced in 2013, included drilling and testing of two full size production wells, with a view to developing a 10-15 MW small geothermal power plant. It comprised the installation of a production platform, drilling and testing a production well in Laudat (WW-P1) and a re-injection well in Trafalgar (WW-R1). The drilling of these two full-size wells, with a depth comprised between 1501 m and 1915 m, was completed in 2014.

The GoCD has now proceeded with the planning and construction phase of the Project, establishing the Dominica Geothermal Development Company Ltd (DGDC), which is tasked with developing and operating a 7 MW geothermal power plant. DGDC will sell electricity to DOMLEC under the regulatory framework established through the Electricity Supply Act 2006. DGDC will operate as a private company under the laws of the Commonwealth of Dominica.

The Project will be financed using grant monies from international agencies (the New Zealand Aid Programme) and bilateral partners (United Kingdom Department for International Development (DFID), Small Island Development States (SIDSDOCK), the World Bank Group (WBG) and with the GoCD's own resources.

### 2.2.1 Environmental and Social Work Completed

The Project benefits from having a wealth of environmental studies data collected for environmental assessments for exploration and drilling phases. To date the following environmental and social studies have been completed:

- Caraïbes Environnement Développement & Coll (2009) Regulatory Impact Assessment on the Initial Environment - Environmental Feasibility Study.
- Caraïbes Environnement Développement & Coll (2011) Stage 1: Exploration Drilling Process – Environmental Impact Assessment.
- Caraïbes Environnement Développement & Coll (2013) Stage 2: Preliminary Environmental Impact Assessment of Geothermal Production and Re-Injection Drilling Wells in Dominica – Environmental Impact Assessment.

To support the preparation of an ESIA for the Project, baseline surveys of the social, physical and biological environment within the Roseau Valley were completed between October 2013 and April 2015. These were summarised in the following reports (collectively referred to as the 'Baseline Study'):

- Caraïbes Environnement Développement & Coll (2015a) Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production. Final report, May 2015. Section 3 Biodiversity / Terrestrial Flora and Fauna.
- Caraïbes Environnement Développement & Coll (2015b) Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production. Final summary report.

As part of the work undertaken by Jacobs in the ESIA Terms of Reference (TOR), a review of these previous studies was carried out (provided for reference in Appendix C of the ESIA). Further details of these studies are provided in Volume 2 – Environmental Impact Assessment.

A draft ESIA for the current Project was completed in September 2017. The ESIA has since been updated following Hurricane Maria, which devastated the island in September 2017. It was reported that the majority of the island's inhabitants have been affected by the Hurricane. Impacts include loss of homes, business, schools, social infrastructure and basic amenities such as water and electricity.

## 2.3 Project Governance

In line with the establishment of the DGDC, execution of the Project will be structured as follows:

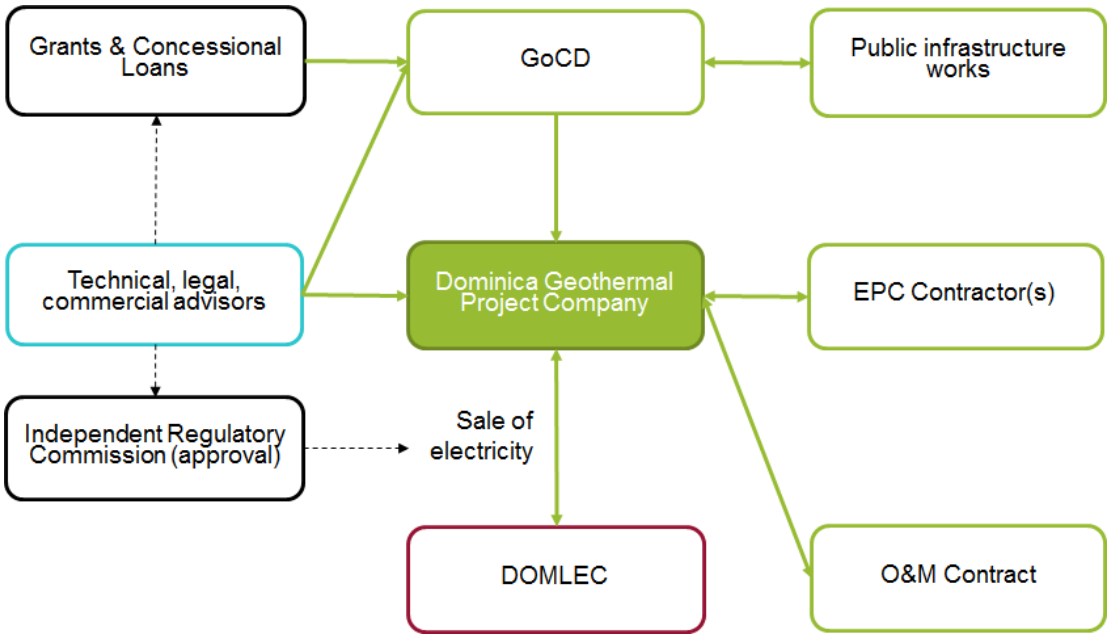



**Figure 2.4 :Proposed Project Structure**

## 2.4 Key Issues

The key environmental and social issues/risks associated with this Project, which were identified through a preliminary screening exercise, are highlighted in Table 2.3 below:

**Table 2 3 : Key Issues/Risks to be addressed in ESIA**

| Aspect | Potential Impact |
|---|---|
| Air Quality | • Emission of gases such as hydrogen sulphide from the power plant during operation<br>• Generation of dust through earth moving activities. |
| Natural Hazards | • Risks related from natural hazards, such as seismic activity, landslides, hurricanes and flood inundation. |
| Community Health | • Potential impacts on community health, such as through emission of hydrogen sulphide and generation of dust. |
| Social (including land acquisition) | • Any physical displacement of members of the community as a result of land acquisition for the development of the power plant and steamfield. Physically displaced parties may require assistance with relocation.<br>• Any economic displacement which may occur through construction of the geothermal power plant and steamfield inhibiting use of land acquired for the development.<br>• There is also the potential for temporary effects upon tourism if works inhibit access to tourist attractions.<br>• Appropriate consideration will be given to livelihood restoration for any parties that are economically displaced by the Project.<br>• Positive impacts upon the local community through the generation of employment opportunities. |
| Working Conditions | • Consideration of the working conditions of employees/contractors engaged in construction and operation. |

| Aspect | Potential Impact |
|---|---|
| Noise | • Construction and operation of the power plant will generate noise which may impact upon the surrounding communities and wildlife. |
| Pest species | • Importation of machinery/equipment for use in construction and operation can lead to introduction of pest species. |
| Soil and Groundwater | • Spillage of hazardous substances stored/used in construction and operation of the power plant. |
| Terrestrial flora and fauna | • Removal of vegetation and earthworks to enable construction of the re-injection pipeline, which could result in impacts on biodiversity. Special reference will be made to any rare or threatened species as well as endemic species of both animals and plants. |
| Visual Amenity | • Construction of new infrastructure will alter the visual landscape. |
| Water Quality | • Re-injection of brine and condensate.<br>• Sedimentation of water courses during construction as result of run-off from earthworks.<br>• Spillage of hazardous substances used during construction and operation of the power plant.<br>• Discharge of stormwater containing contaminants from the power plant to local water courses.<br>• Periodic release of cooling water to local water courses (if water cooling proposed). |
| Water resources | • Abstraction of water for use in cooling system (if water cooling proposed).<br>• Abstraction of water for domestic purposes within power plant. |

# 3. Regulations and Requirements

## 3.1 Introduction

The following provides a brief summary of the international and national legislation and standards applicable to consultation for the Project.

## 3.2 Legislation of the Commonwealth of Dominica

In accordance with the Commonwealth of Dominica Physical Planning Act 2002, development permission is required before the construction of the Project may commence. Clause 17 of the Act states:

'No person shall carry out any development of land except under and in accordance with the terms of a development permission granted in that behalf prior to the commencement of such development…'

Applications for development permission must be submitted to the Physical Planning Department within the Ministry of Agriculture and Environmental Protection along with an Environmental Impact Assessment (Clause 20(1)(b)).

Further, in accordance with Clause 22(3), where an Environmental Impact Assessment is required, the Authority shall:

a) publish a notice in at least one daily newspaper and affix a notice on the land to which the application relates that an application to develop land has been received and will be determined on a date specified in the notice; and

b) invite comments and representations either in writing or orally on such application.

## 3.3 World Bank Operational Policies

This study was conducted taking into account Dominica's regulations and the requirements of lenders, in this case the World Bank Group (WBG). This includes examination and verification of the project's compliance with WBG's Operational Policies. The applicable policies to this project are: OP4.03 (World Bank Group Performance Standards for Private Sector Activities) and OP4.12 (involuntary Resettlement). Under OP4.03, the applicable performance standards are:

- Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts;
- Performance Standard 2: Labour and Working Conditions;
- Performance Standard 3: Resource Efficiency and Pollution Prevention;
- Performance Standard 4: Community Health, Safety, and Security
- Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources;
- Performance Standard 7: Indigenous Peoples; and
- Performance Standard 8: Cultural Heritage.

PS 7 - Indigenous People does not apply to the Project. People living in the Project area are not categorized as Indigenous People. They are part of the mainstream Dominican society, and do not have any specific economic or cultural activity different from the rest of the society. They participate fully in the socioeconomic life of the society.

### 3.3.1 Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts

IFC Policy requires project proponents to engage with affected communities through disclosure of information, consultation, and informed participation, in a manner commensurate with the risks to and impacts on the affected communities. PS1 contains clear requirements for community engagement, disclosure of information and consultation. The key objectives of PS1 are given as follows:

- To identify and evaluate environmental and social risks and impacts of the project.
- To adopt a mitigation hierarchy to anticipate and avoid, or where avoidance is not possible, minimize, 5 and, where residual impacts remain, compensate/offset for risks and impacts to workers, Affected Communities, and the environment.
- To promote improved environmental and social performance of clients through the effective use of management systems.
- To ensure that grievances from Affected Communities and external communications from other stakeholders are responded to and managed appropriately.
- To promote and provide means for adequate engagement with Affected Communities throughout the project cycle on issues that could potentially affect them and to ensure that relevant environmental and social information is disclosed and disseminated.

Performance Standard 1 requires that particular attention be given to:

- *Vulnerability:* As part of ESIA, individuals and groups that may be differentially or disproportionately affected by the project because of their disadvantaged or vulnerable status must be identified. Where groups are identified as disadvantaged or vulnerable, the project must propose and implement differentiated measures if necessary so that adverse impacts do not fall disproportionately on them and they are not disadvantaged in sharing development benefits and opportunities.
- *Community engagement:* Community engagement must be undertaken with affected communities on an ongoing basis and must include disclosure of information. Engagement must be free of external manipulation, interference, coercion or intimidation, and must be conducted on the basis of timely, relevant, understandable and accessible information.
- *Disclosure:* During the process of Environmental and Social Assessment (ESIA), the Project must publicly disclose the ESIA document, including an Environmental and Social Management Plan (the document which describes the measures to be put in place to manage impacts). If communities may be affected by risks or adverse impacts from the Project, the Project must provide such communities with access to information on the purpose, nature and scale of the project, the duration of proposed project activities, and any risks to and potential impacts on such communities. This must be undertaken in a manner that allows sufficient time for the affected communities to consider the issues and provide feedback. For projects with adverse social or environmental impacts, disclosure must occur early in the ESIA process, in any event before the project construction commences, and on an ongoing basis.
- *Community risk and impact:* If affected communities may be subject to risks or adverse impacts from a project, the proponent must undertake a process of consultation in a manner that provides the affected communities with opportunities to express their views on project risks, impacts, and mitigation measures, and allows proponents to consider and respond to any comments received. Consultation must be undertaken in a manner that is inclusive and culturally appropriate.
- *Informed participation:* For projects with significant adverse impacts on affected communities, the consultation process must ensure that free, prior and informed consultation with affected communities occurs and that processes exist to facilitate participation by those affected. Informed participation involves organized and iterative consultation, leading to the proponent incorporating into their decision making process the views of the affected communities on matters that affect them directly, such as proposed mitigation measures, sharing of development benefits and opportunities, and implementation issues.
- *Grievance mechanism:* The proponent must establish a grievance mechanism to receive and facilitate resolution of the affected communities' concerns and grievances regarding the project's social and environmental performance. The grievance mechanism must be scaled to the risks and adverse impacts of

the project. It must address concerns promptly, using an understandable and transparent process that is culturally appropriate and readily accessible to all segments of the affected communities, at no cost and without retribution.

- *Broader stakeholder engagement:* The proponent must identify and engage with stakeholders that are not directly affected by the Project but those that have established relationships with local communities and/or interest in the Project – local government, civil society organisations, etc. – and establish a dialogue.
- *External reporting:* The proponent must provide periodic reports that describe progress with implementation of the Environmental and Social Management Plan on issues that involve ongoing risk to or impacts on affected communities, and on issues that the consultation process or grievance mechanism has identified as of concern to those communities. These reports must be in a format accessible to the affected communities. The frequency of these reports must be proportionate to the concerns of affected communities but not less than annually. During the construction period of the Project, feedback must be provided to the affected communities on a monthly basis.

### 3.3.2 OP 4.12- Involuntary Resettlement

According to OP 4.12, involuntary resettlement may cause severe long-term hardship, impoverishment, and environmental damage unless appropriate measures are carefully planned and carried out. For these reasons, the overall objectives of the Bank's policy on involuntary resettlement are the following:

(a) Involuntary resettlement should be avoided where feasible, or minimized, exploring all viable alternative project designs.

(b) Where it is not feasible to avoid resettlement, resettlement activities should be conceived and executed as sustainable development programs, providing sufficient investment resources to enable the persons displaced by the project to share in project benefits. Displaced persons should be meaningfully consulted
and should have opportunities to participate in planning and implementing resettlement programs.

(c) Displaced persons should be assisted in their efforts to improve their livelihoods and standards of living or at least to restore them, in real terms, to pre-displacement levels or to levels prevailing prior to the beginning of project implementation, whichever is higher.

OP 4.12 covers direct economic and social impacts that both result from Bank-assisted investment projects and are caused by:

(a) the involuntary taking of land resulting in relocation or loss of shelter;

(1) lost of assets or access to assets; or

(2) loss of income sources or means of livelihood, whether or not the affected persons must move to another location; or

(3) the involuntary restriction of access9 to legally designated parks and protected areas resulting in adverse

(b) impacts on the livelihoods of the displaced persons.

## 3.4 Good International Industry Practice

The preparation of this SEP has been informed by the following IFC good practice guidance documents:

- Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets (May 2007); and
- Doing Better Business Through Effective Public Consultation: A Good Practice Manual (November 1998).

World Bank Operational Policy (OP) 4.01 Environmental Assessment states that for all Category A and B Projects proposed for World Bank financing, during the ESIA process the borrower must consult Project-affected persons (PAPs) and groups and local non-governmental organizations (NGOs) about the Project's environmental aspects and takes their views into account. The borrower must initiate such consultations as early as possible.

WB OP 4.01 also specifies information disclosure requirements. For meaningful consultation between the borrower and Project-affected groups and local NGOs on all Category A and B Projects, the borrower must provide relevant material in a timely manner prior to consultation and in a form and language that are understandable and accessible to the groups being consulted.

# 4. Review of Stakeholder Activities to Date

## 4.1 Overview

The following presents a summary of the consultation activities undertaken to date and on-going for the Project.

## 4.2 General Project Consultation Activities and Consultation During Previous Geothermal Phases

During the geothermal drilling phase, eleven general public meetings were held in the potentially affected communities in November and December 2013 and January 2014. Five were held in Laudat, three in Trafalgar and three in Wotten-Waven. A visit to the current geothermal power plant in Guadeloupe was also conducted in 2012 with members of the community to experience first -hand the workings of an operational plant. Additionally, school visits were conducted in February and March 2012 from the Wotten Waven Primary School, Trafalgar Primary School, Morne Prosper Primary School, Laudat Primary School, and Laudat Primary School where students and staff toured the drilling sites. Press releases were published in June, August, and September 2017 informing the community about the Project and again in February, March and April 2018.

## 4.3 ESIA Consultation Activities

During the current Project development phase, a town hall meeting was held in Trafalgar in December 2016 with approximately 40 in attendance to discuss the current project and ESIA. Another town hall meeting was held in Laudat in July 2017 with 43 in attendance. A third town hall meeting was held in Wotten Waven in August 2017. A final townhall meeting will be held to present the findings of the ESIA in May or June 2018. In order to facilitate further understanding of community needs and conditions, focus group meetings were held in 2016, 2017 and 2018 in Wotten Waven, Trafalgar and Laudat, described in further detail below. Because the total population of the Project AOI is relatively small (approximately 1,600), and given that the general public and many of the focus groups and landowners that would be affected by the Project are the same parties, the four formal public meetings and 15 informal forums held on the Project were considered representative of the community.

A total of 15 focus group meetings were held as part of the ESIA baseline data collection. A meeting with six representative community leaders from all of the potentially affected communities was held in Trafalgar in November 2016 to discuss the Project and the most effective means of stakeholder engagement. Focus groups meetings were also held in June, July and August of 2017 including meetings with representatives of local hotels and resorts, handicraft vendors, hot springs businesses, and unemployed parties in the area. Groups consisted of 5-15 people and targeted questions were asked and recorded.

Five of the focus group meetings were held in the communities in March 2018 following Hurricane Maria. These included meetings with community women in Laudat, Wotton Waven and Trafalgar, and vendor meetings in Wotton Waven and Trafalgar, to identify the impacts on the community of Hurricane Maria which hit Dominica in September 2017 and to understand how conditions in the Project area have changed since the ESIA baseline data was collected pre-Hurricane Maria. A Table showing the types of comments made during the ESIA Consultation Activities and where subsequent responses can be found in the ESIA is included below.

**Table 4.1: Summary of Consultation Comments and where Further Information can be Found in the ESIA**

| Consultation | Comment Category | ESIA Reference |
|---|---|---|
| Laudat Community at Laudat Primary School (29/06/2017) | Noise level of the project and effect on the community | EIA (Volume 2) Section 12 – Noise (Section 12.5 – Assessment of Impacts) |
| Papillote Wilderness Retreat (30/06/2017) | | |
| Wotton Waven Spa Operators | | |
| Laudat Community at Laudat Primary School (29/06/2017) | Community benefits | Employment and community benefits: SIA (ESIA Volume 3) Section 6.1.1 – |
| Papillote Wilderness Retreat (30/06/2017) | | |

| Consultation | Comment Category | ESIA Reference |
|---|---|---|
| Wotton Waven Spa Operators | | Assessment of Impacts and SIA (ESIA Volume 3) Section 8.1.1 Employment and Tourism |
| Papillote Wilderness Retreat (30/06/2017) | Will there be a social/community development fund | Employment and community benefits: SIA (ESIA Volume 3) Section 6.1.1 – Assessment of Impacts and SIA (ESIA Volume 3) Section 8.1.1 Employment and Tourism |
| Laudat Community at Laudat Primary School (29/06/2017) | Will the re-injection pipeline pass through villages? | Preferred route of re-injection pipeline: SIA (ESIA Volume 3) Figure 4.3 Location of Power Plant and Reinjection Pipeline |
| Papillote Wilderness Retreat (30/06/2017) | What will be the visual impact of the project | EIA (ESIA Volume 2) Section 9 – Landscape and Visual (Section 9.3 – Assessment of Impacts) |
| Papillote Wilderness Retreat (30/06/2017) | What will the impact on tourism be? Concerns that it will have a negative impact | Tourism impacts: SIA (ESIA Volume 3) Section 6.2.5 Impacts to Tourism<br>Tourism enhancement and mitigation: SIA (ESIA Volume 3) Section 8.1.1 Employment and Tourism |
| Papillote Wilderness Retreat (30/06/2017)<br>Wotton Waven Spa Operators | Traffic impacts on the community and local businesses | Traffic impacts: EIA (ESIA Volume 2) Section 16 – Traffic and Access (Section 16.3 Assessment of Impacts) |
| Papillote Wilderness Retreat (30/06/2017)<br>Wotton Waven Spa Operators | Air quality impacts | Air Quality impacts: EIA (ESIA Volume 2) Section 4 – Air Quality (Section 4.3 Assessment of Impacts) |
| Papillote – Community Leaders of the Roseau Valley<br>Papillote Wilderness Retreat (30/06/2017)<br>Wotton Waven Spa Operators | Resettlement and land acquisition impacts and plans for the community and businesses | Resettlement mitigation plans: SIA (ESIA Volume 3) Section 8.1.2 Physical and Economic Displacement<br>Land acquisition impacts: SIA (ESIA Volume 3) Section 6.2 Land Acquisition, Physical Displacement and Resettlement Impacts |
| Wotton Waven Spa Operators | What happen if the reinjection pipe has a leak and dangerous fluids are flowing on the surface? | ESIA Volume 2, section 15, Hazardous Substances and Waste and ESIA Volume 3, SIA, Emergency Response Plan |
| Laudat Community at Laudat Primary School (29/06/2017) | When and how will payment be made for property and land acquisitions? | See the ARAP. |
| Laudat Community at Laudat Primary School (29/06/2017)<br>Papillote Wilderness Retreat (30/06/2017) | Potential for community shares in the Project | Outside of the scope of ESIA |
| Papillote Wilderness Retreat (30/06/2017) | Why was solar power not considered? | See ESIA Volume 1**:** Introduction. |
| Papillote Wilderness Retreat (30/06/2017) | Why was this type of consultation not done | See SEP for a full list of consultation activities in Appendix C of the ESIA. |

| Consultation | Comment Category | ESIA Reference |
|---|---|---|
| | before decision was made to drill? | |
| Papillote Wilderness Retreat (30/06/2017) | Total cost of the Project | Outside of the scope of ESIA |
| Wotton Waven Spa Operators | Project start date and duration | See ESIA Volume 1: Introduction. |

The details of consultation activities held as part of the ESIA process for the current Project are presented in the appendices to this report and include the following:

**Laudat** - Public Meetings:

- January 20, 2011;
- November 11, 2011;
- February 15, 2012,
- April 13 and 16th 2012;
- November 14, 2013;
- December 11th 2013;
- January 23, 2014;
- July 2017; and
- March 17, 2018.

**Trafalgar** - Public Meetings:

- January 12, 2011;
- November 8, 2011;
- March 28, 2012;
- November 12, 2013;
- December 12th, 2013;
- December 2016; and
- March 18 and 25, 2018.

**Wotten-Waven** - Public Meetings:

- January 16, 2011;
- November 10, 2011;
- June 13, 2012;
- December 13, 2013;
- March 24, 2018.

In addition, the following visits were conducted at the site with schools from Roseau Valley - presentation of Project and distribution of promotional items to students and staff:

- Wotten Waven Primary School: February 8, 2012;
- Trafalgar Primary School: February 16, 2012;
- Morne Prosper Primary School: February 8, 2012; and
- Laudat Primary School: March 8, 2012.

### 4.3.1 ESIA Disclosure

The ESIA Non-Technical Summary was disclosed to the communities of the Roseau Valley via three public meetings: one in Laudat, one in Trafalgar, and one in Wotten Waven in the first week of July. Meetings were attended by Jacobs, DGDC, and approximately 20 members of each community. The community had another opportunity to express concerns and ask questions about the Project and ESIA findings. Concerns generally included community health and safety issues, natural hazards, employment and construction impacts. A summary of the issues raised by each community is provided below.

#### 4.3.1.1 Laudat

In Laudat, a community meeting was held on Tuesday 4th July 2018. Concerns expressed by the community included technical questions about the pipeline and public health considerations associated with operations of the plant. Community members also voiced concerns about the risks associated with volcanic activity near the project, equipment failure, and other natural disasters. Community members also expressed the desire to see policy changes associated with the Project and the need for some community benefit projects that would be realised in the community. They also asked about land acquisition and noted that Laudat has been the location for several other projects where few benefits were realised in the local community. The DGDC Team explained the costs and the benefits of the project and the ESIA findings in terms of H2S. DGDC also explained the technology being utilised in the plant and the low risks associated with this type of equipment. The DGDC Team further explained the risks and the planning and design measures that were selected for this project given the topography, risk of landslides and recent flooding from Hurricane Maria and the EPC Contractor requirements that will be put in place to reduce nuisance and community health and safety impacts such as the emergency response and other planning procedures. The current status of land acquisition was also explained and the need to complete compensation before construction can begin, as per Op 4.12. Ongoing monitoring and preventative measures such as the traffic management plan and erosion control measures were also explained. Comments on policy and community benefits were noted, but it was explained that this is ultimately under the control of government and policymakers, rather than the project.

#### 4.3.1.2 Trafalgar

In Trafalgar, a community meeting was held on Wednesday 5th July 2018. Fewer comments were made at this meeting than in Laudat or Wotten Waven, likely because the community is further from the power plant site. The community asked a few technical questions about the distance of the pipeline and natural hazards that could affect the project. They also asked about the proximity to the nearby communities from the power plant and emergency response. The DGDC Team explained the risks and the planning and design measures that were selected given the topography, risk of landslides and recent flooding from Hurricane Maria. DGDC also explained the emergency response and planning procedures that will be put in place for the Project. Examples of other projects where a geothermal plant was located in close proximity to the community were given.

#### 4.3.1.3 Wotten Waven

In Wotten Waven, a community meeting was held on Thursday 6th July 2018. A lot of concern was expressed at the meeting particularly about public health issues, employment, and direct benefits to the community. Specifically, people asked about job requirements, accidents at the plant and/or the pipeline, detrimental effects on thermal spas, the expected lifespan of a well, consumer benefits on electricity bills, health impacts of construction and noise, and property acquisition. A community member also suggested the need for a weekly briefing in the community during the construction phase. The DGDC Team explained the design of the plant and reinjection route given the topography, risk of landslides and recent flooding from Hurricane Maria and to reduce noise and visual affects at properties near the power plant. DGDC also explained the technology being utilised in the plant and the low risks associated with this type of equipment. The lack of changes anticipated for the thermal surface features were also explained given the depth of the wells and associated activity and the plan to conduct ongoing monitoring of these features was also shared. The DGDC Team further explained in detail the noise associated with the steam blowing phase and the limited timeframe for this testing. The current status of land acquisition was also explained and the need to complete compensation before construction as per OP 4.12.

Following the disclosure of the NTS, the full ESIA will be made available to the community in August 2018 via the internet, a hard copy will be available at DGDC's offices, and additional public meetings will be held and publicised by the media.

# 5. Stakeholder Analysis

## 5.1 Socio-economic Profile of the Community

The Project is located in the Roseau Valley which consists of 1,823 residents. The Valley contains 4 hamlets including Laudat (population 321), Wotten Waven/Casseau (population 313), Copthal (population 230) and Trafalgar (population 959). The creole culture is predominant and 80% of the population speak Creole even if English remains the official language. Households in the area consist of 2.7 people and women are in the minority (representing 48 percent of the population). The area is rural, but located in close proximity to the town of Roseau and poverty is lower in this area compared to the rest of the country. Tourism is the predominant income source in the community followed by agriculture. Based upon consultation conducted to date, there is a great deal of community concern about the health and safety and the economic impacts of the Project.

## 5.2 Project Stakeholders

Stakeholders can be individuals and organisations that may be directly or indirectly affected by the Project either in a positive or negative way, and who may wish to express their views. DGDC has undertaken an initiative to identify key stakeholders relevant to the Project. As part of this process, it is important to identify individuals and groups outside of the mainstream who may find it more difficult to participate in public consultation activities and those who may be disproportionately affected by the Project because of their vulnerable status in society or the community.

Details of community stakeholders are described in more detail below. Baseline studies undertaken during the ESIA, land acquisition process and local level engagement were used to inform this process. Table 5-1 identifies potential stakeholders and their interest in the Project.

**Table 5.1 : Potential stakeholders and their interest in the Project**

| Group | Stakeholders | | Interest in Project |
|---|---|---|---|
| A. Directly or indirectly affected by the Project | A1. | Landowners and landowner family owners | Land acquisition, compensation |
| | A2. | Farmers cultivating land or animals in and around the Project site | Resettlement, loss of access to resources, compensation, environmental impact, employment and community benefits |
| | A3. | Communities within Roseau Valley | Environmental impact, employment and community benefits, possible overlap with A2 above |
| | A4. | Communities in the path of the transmission line | Resettlement, loss of access to resources, compensation, environmental impact, employment and community benefits |
| | A5. | Communities affected by the traffic of the construction and the transport of all materials for construction | Environmental impact, employment and community benefits |
| | A6. | Local Businesses, Tourism, Hotels in the Roseau Valley | Environmental Impact, Economic impact, regulate P |
| | A7. | Regulatory agencies | Environmental Impact, Economic development, regulate Project |
| | A8. | Local Authorities and Administrations (Roseau Valley Parliamentary) | Social & environmental impact, employment and community benefits, economic development |
| | A9. | Central Authorities and Administrations (Ministry of Public Works, Energy and Ports) | Environmental responsibility, economic development |

| Group | Stakeholders | | Interest in Project |
|---|---|---|---|
| B. Have an "interest" in the Project or Project Sponsor | B1. | Local NGOs, local political or community organizations (e.g. youth associations, environmental NGOs) | Environmental and social impacts, alternatives to the use of hydro-power |
| | B2. | International NGOs with general interest in the area | Environmental and social impacts, alternatives to the use of hydro-power |
| | B3. | Media | Already aware of the Project |
| | C1. | Local and Province level regulatory agencies | See A.7 above |
| C. Have the potential to influence Project outcomes | C2. | Local Authorities and Administrations | See A.8 above |
| | C3. | Other Ministries and government organizations (Ministry of Agriculture, etc.) | See A.9 above |

The relevance of each stakeholder to the Project has been considered in terms of whether they are:

- "Impact based" (typically primary stakeholders): directly affected stakeholders through adverse and beneficial Project impacts such as physically or economically displace groups or individuals – the intensity of engagement will be greatest with impact based stakeholders and special efforts will need to be made to reach out to disempowered, socially excluded and/or vulnerable groups who may not have a good understanding of their rights or entitlements and may not be familiar with engagement activities; or
- "Interest based" (typically secondary stakeholders): who may have an interest to influence the Project for their own objectives and be able to influence the Project or public perception, for example NGOs – it is important to ensure that potential critics of the Project and those who can positively influence the Project design are appropriately engaged at the correct moments in order to facilitate their effective input and to manage potential negative perceptions or outcomes (such as organised objection/disruption).

It is important to note that "impact-based" stakeholders are on the whole "interest based as well;" for example local communities may be impacted by construction activities and effects such noise and dust, whilst at the same time they have an interest in leveraging community benefits and employment opportunities.

The following stakeholders have participated in engagement activities to date:

**Table 5.2 : Stakeholders Engaged During the Drilling Phase**

| Sector | Type | Name | Organisation |
|---|---|---|---|
| Coordinating Authorities | Government Departments | Annie Edwards | Housing and Planning Division of Planning |
| | | Lloyd Pascal | Environmental Coordination Unit |
| | | Alexis George | Geothermal Project Management Unit |
| | | Michael Fadelle | Geothermal Project Management Unit |
| | | David Williams | Forestry Department |
| | | Michael Savarin | Invest Dominica Authority |
| | | Greg Steadman | Statistics Department |
| | | M Scotland | Environmental Health Department |
| | | Sylvester St Ville | Environmental Health Department |
| | | Colin Piper | Discover Dominica Authority |
| | | Defroy Williams | Ministry of Agriculture |
| Economic Partners | Locally Elected Officials | Trafalgar Counsellors | |
| | | Collin McIntyre | Roseau Valley Parliamentary Representative |

| Sector | Type | Name | Organisation |
|---|---|---|---|
| | Local Economic Partner Organisations | Magnus Williams | DOWASCO |
| | | Juliana Boston | DOWASCO |
| | | Colin Power | DOMLEC |
| | Professional Associations | Unnamed | Dominica Hotel and Tourism Association |
| | Financiers | Incomplete | |
| | Companies | Incomplete | |
| General Public | Residents of Trafalgar | Peter Madison Charles | Resident of Lily Valley, Trafalgar |
| | | Public Meeting 12/12/13 | |
| | Residents of Wotten Waven | Japson Rowl | |
| | | Richardson Charles | |
| | | Unnamed female resident | |
| | | Public Meeting 13/12/13 | |
| | Residents of Laudat | Thomas Jequental | |
| | | Ralph Magaw | |
| | | Francesca Magloire | |
| | | Public Meeting 11/12/13 | |
| | Ecologists | Athie Martin | Small hotel owner, environmental scientist, involved in the business of water, conservationist |
| | | Hadanauer Douglas | Free-lance consultant, involved in geothermal development |
| | Associations | Jeffrey Charles | Chairman of Geothermal Awareness Committee |
| | Political Parties | Lennox Linton | United Workers Party |
| | | Edison James | United Workers Party |

The parties were engaged during the current project phase.

**Table 5.3 : Government Stakeholders**

| Organisation | Name | Position |
|---|---|---|
| Government of Commonwealth of Dominica | Hon. Ian Douglas | Minister for Trade, Energy and Employment |
| Roseau Valley Constituency | Dr John Collin McIntyre | Parliamentary Representative<br>Minister for Planning, Economic Development and Investment |
| Independent Regulatory Commission | Mr Alan Khan | Executive Director |
| Dominica Water and Sewerage Company Ltd | Mr Bernard Etinoffe | General Manager |
| Ministry of Planning, Economic Development and Investment | Mr Keith Stephens | Chief Physical Planner |
| Environmental Coordinating Unit | Mr Lloyd Gabriel Pascal | Ambassador |
| Environmental Health Unit, Ministry of Health and Environment | Mr Anthony Scotland | Chief Environmental Health Officer |

| Organisation | Name | Position |
|---|---|---|
| Ministry of Housing, Lands and Water Resource Management and Ministry of Information, Science, Telecommunications and Technology | Mr Lucien Blackmoore | Permanent Secretary |
| Ministry of Lands, Housing, Settlements and Water Resource Management | Mr Marcus Lastrade | Director of Surveys and Commissioner of Lands |

**Table 5.4 : Community Groups**

| Community | Group | Contact |
|---|---|---|
| Laudat | Village Improvement Committee | Mr. Albert Noel |
| | Laudat Football Club | Mr. Berani Rolle |
| | Laudat Church Committee | Anthia Bertrand |
| | Laudat Farmers Group | Dr. Curlson George |
| | Laudat Primary School | Ms. Eugenia Richards |
| | Laudat Health Centre | |
| | Caldera Dining and Aquatic (Fresh Water Lake) | Ms. Claudette Rolle |
| | Café C'est Mon Plaisis | Mr. Garry Shillingford |
| | Rainforest Cottages | Mr. Nahgie Lafleur |
| Wotten Waven | Wotten Waven Improvement Committee | Mr. Kelvin Elize |
| | Wotten Waven Development Committee | Mr. Rudolph George |
| | Wotten Waven Farmers Group | |
| | Wotten Waven Football Club | |
| | Wotten Waven Rounders Club | |
| | Wotten Waven Primary School | |
| | | Mr. Jeffrey Charles |
| Trafalgar | Trafalgar Village Council | Ms. Joanne Bellot |
| | Trafalgar Vendors Association | Lilian Xavier |
| | Trafalgar Rounders Sports Club | |
| | Trafalgar Football Club | Mr. John Joseph |
| | SHAFOND Development Committee | |
| | Trafalgar Church Committee | Mr. Anthony Leblanc |
| | Trafalgar Farmers Group | |
| | Trafalgar Primary School | Ms. Doreen Watt |

**Table 5.5 : Accommodation providers, tour guides and local vendors**

| Community | Group | Contact |
|---|---|---|
| Laudat | Vendor | Bertha Boyer |
| Wotten Waven | Vendor | Minova Joseph |
| | Vendor | Catherine Joseph |
| | Vendor | Gloria Damier |
| Trafalgar | Vendor | Laura Denis |

| Community | Group | Contact |
|---|---|---|
| | Vendor | Sandrine Younis |
| | Vendor | Lilian Xavier |
| | Vendor | Theresa Anthony |
| Accommodation Providers and Restaurants | Chez Ophelia | McCarthy & Ophelia Marie |
| | Tia's Bamboo Cottages | Tia Joseph |
| | Le Petit Paradis | Joan Ducreay |
| | Cocoa Cottages | Iris Metawi |
| | Papillotte Wilderness Retreat | Ann Jno. Baptiste |
| | Sunshine Cottage & Restaurant | Sabine and Marco Ueker |
| | Symes Zee Villa | Timothy Symes |
| | Roxy's Mountain Lodge | Maria Hodge |
| | Rainforest Cottages | Mr. Nahgie Lafleur |
| | Caldera Dining and Aquatic (Fresh Water Lake) | Ms. Claudette Rolle |
| | Café C'est Mon Plaisis | Ms Patricia Rolle |
| Guides | Tour Guide | Simon Rolle |
| | Tour Guide | Garry Shillingford |
| | Tour Guide | Kelvin Noel |
| | Tour Guide | Naithan Rolle |
| | Tour Guide | Rudolph George |

## 5.3 Methods of Communication

Appropriate methods of engagement have been selected with consideration of each stakeholder group's relevance (the extent to which the Project will influence them or to which they can influence the Project), their level of literacy, comfort with engagement culture and environment (e.g. office meetings vs. community meetings) and the need for focussed topic specific meetings as opposed to disclosure of general information.

**Table 5.6 : Stakeholder Groups and Methods of Engagement**

| Stakeholder Group | Public Meetings and Exhibitions | Private Meetings and Workshops | Focus Groups | Mass Media Communications | Disclosure of Written Information | Community Liaison |
|---|---|---|---|---|---|---|
| National Government Departments | ✓ | ✓ | | ✓ | ✓ | |
| National Bodies | ✓ | ✓ | | ✓ | ✓ | |
| Provincial / Local Government Departments | ✓ | ✓ | | ✓ | ✓ | |
| Financial Institutions | ✓ | ✓ | | ✓ | ✓ | |
| Local Project Affected Communities | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Physically and economically displaced Project Affected People (PAPs) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Civil Society, NGOs & Research Bodies | ✓ | ✓ | ✓ | ✓ | ✓ | |

| Stakeholder Group | Public Meetings and Exhibitions | Private Meetings and Workshops | Focus Groups | Mass Media Communications | Disclosure of Written Information | Community Liaison |
|---|---|---|---|---|---|---|
| Employees and labour | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Industry & Business | ✓ | ✓ | ✓ | ✓ | | |
| Media & Press | ✓ | | | ✓ | | |

# 6. Stakeholder Engagement Program

## 6.1 Introduction

This section presents the programme for engaging stakeholders by describing the activities to be undertaken throughout the ESIA process and on an on-going basis throughout the life of the Project.

A number of consultation activities have taken place throughout the ESIA process. The format of the meetings will generally be comprised of introductions, followed by a Project description (including phasing and timelines) and then a question and answer session regarding the ESIA approach with feedback from the stakeholder regarding the Project and potential environmental and social issues. Where practicable and/or appropriate, the responses from consultation activities will be considered in either the approach for the ESIA assessment or the mitigation measures included within the ESMP.

The stakeholder engagement process has also been used to gather socio-economic baseline data to inform the social impact assessment.

## 6.2 Stakeholder Engagement Plan Purpose, Goals and Key Principles

The purpose of the stakeholder engagement programme is to ensure that all key stakeholders are involved in the consultation process throughout the development of the Project and to minimise the Project impacts on key stakeholders, including landowners, nearby communities, and downstream river users.

This stakeholder engagement plan is about building and maintaining constructive relationships with Project stakeholders throughout the duration of the Project, including ensuring stakeholders are engaged with in a culturally appropriate manner and that relevant and understandable information is provided in a timely manner.

The key principles of stakeholder engagement are:

- Providing meaningful information in a format and language that is readily understandable and tailored to the needs of the target stakeholder group(s)
- Providing information in advance of consultation activities and decision-making
- Disseminating information in ways and locations that make it easy for stakeholders to access it
- Respect for local traditions, languages, timeframes, and decision-making processes
- Two-way dialogue that gives both sides the opportunity to exchange views and information, to listen, and to have their issues heard and addressed
- Inclusiveness in representation of views, including women, vulnerable and/or minority groups
- Processes free of intimidation or coercion
- Clear mechanisms for responding to people's concerns, suggestions, and grievances
- Incorporating feedback into project or program design, and reporting back to stakeholders.

## 6.3 Individual Meetings and Workshops

Individual meetings are targeted ways in which to engage with stakeholders. They permit in-depth meetings about Project plans and allow the opportunity to go into more detail about technical aspects of the Project or address specific concerns raised by one or a group of stakeholders. These meetings mainly involve interest-based stakeholders who have most influence over the Project such as government regulatory bodies or relevant industry leaders.

Regular workshops are also a constructive way in which to involve key stakeholders throughout the duration of the ESIA, construction and operation periods so that issues and any grievances can be raised and addressed as they emerge.

One to one meetings with individual stakeholders have been undertaken to inform the ESIA process and to discuss specific Project elements or concerns. Individual meetings will continue throughout the Project development phases as needed.

In addition to key stakeholders in the government, meetings have been and will continue to be held with the other commercial and industrial users in the area to share knowledge and concerns over the Project.

## 6.4 Focus Groups

Focus groups allow targeted dialogue with key stakeholders. They provide an opportunity to explore community concerns in further detail and facilitate better understanding of the Project components, the ESIA process and its requirements. As such, focus groups have been held in the potential Project impact zone including representatives from key stakeholder groups from the communities and settlements surrounding the Project.

The following groups of people within each community were identified for the focus group meetings:

- Village elders or community representatives;
- Religious groups;
- Women's groups;
- Farmers;
- Youth groups;
- Any vulnerable groups such as members of the Roseau Valley impacted by Hurricane Maria, those with disabilities, widows or elderly members of the community with access restrictions.

Familiar locations in each community have been used for the focus group meetings as these are conducive to productive and interactive consultation for the following reasons:

- They lend transparency to the process: community members can witness the process and stay informed about what is being discussed on their behalf, and what has been agreed at the close of consultation or negotiations.
- They increase accountability of local leaders: community members will know what they are entitled to, and they will be able to monitor its delivery.
- They send the message that companies value the input of communities enough to travel there and spend time there.
- They contribute to community members' empowerment and feeling of ownership over the engagement process: community members say that the opportunity to have input into the public meetings gives them a sense of having a role in the outcome of decisions.
- Finally, they allow community members to identify their own representatives, preventing illegitimate representation from persons claiming that they speak for communities.

The general proceedings and responses from focus groups that have been conducted to date are presented in Appendix B.

Focus group meetings will continue throughout the Project lifecycle and be conducted by DGDC and its Community Liaison Officer (CLO) as required to address topical issues and issues of interest / concern to local community groups.

## 6.5 Project Affected Persons (PAPs)

Physically and economically displaced people will be the most directly affected stakeholders and it is important that they are effectively engaged and that this engagement is planned well in order to avoid encroachment and to accurately assess impacts and determine entitlements and costs.

Face-to-face interviews and phone discussions were held in April 2018 with the PAPs to collect census level information and verify physical assets. Some of the PAPs could not be contacted as they now live overseas and so certain census survey data was unable to be obtained. Additionally, some other potentially affected property owners in the project vicinity were interviewed.

## 6.6 Communication Tools

### 6.6.1 Media and Disclosure of Written Information

DGDC will set up a Project specific website (address to be confirmed) which is regularly updated highlighting progress, minutes of meetings that have taken place, the latest grievances that have been raised and other issues as appropriate. This site will be functional throughout the duration of the scoping and construction periods and for at least the first years of operation.

### 6.6.2 Community Visual Aids

The DGDC will produce visual aids to support community engagement. Visual aids shall describe the Project and impacts using images and photographic examples of the types of activities and infrastructure planned. Images shall be used to facilitate discussion potential impacts.

### 6.6.3 Community Meeting Records

Records of community consultation meetings, meetings with government and civil society shall be kept in a separate document with the detailed stakeholder database. All records shall include attendance lists and photos.

### 6.6.4 Language

All community materials shall be translated into Creole and English to meet the needs of local stakeholders. Meetings shall be conducted in English and Creole as necessary. Materials for government and civil society stakeholders shall be in Creole and/or English.

# 7. Implementation

## 7.1 Overview

It is important that consultation and disclosure undertaken as part of the Project occurs at appropriate timescales to allow stakeholders to be informed and contribute to the appropriate management of environment and the development of the Project. This section assigns timescales and responsibilities to the activities identified in the previous section.

## 7.2 Timetable

Table 7-1 below provides an overview of engagement activities with suggestions regarding when they should be implemented and the various people who have responsibility. It should be noted that some activities have already been undertaken.

**Table 7.1 : Stakeholder Engagement Implementation Timescales and Responsibilities**

| Activity | Timing | Responsibility |
|---|---|---|
| **ESIA Engagement** | | |
| Draft ESIA disclosure on Project website | July/August 2018 | DGDC |
| Individual meetings with stakeholders | Undertaken as necessary over the duration of the ESIA process to collect data and register / concerns opinions with stakeholders. Meetings will continue as required throughout the Project development phase. | DGDC |
| Focus groups discussions with community representatives including vulnerable groups | November and December 2016, May-August 2017, March 20182017 | DGDC with support from Jacobs |
| Media communications | A Project specific website set up (address to be confirmed) which is regularly updated highlighting progress, minutes of meetings that have taken place, the latest grievances that have been raised and other issues as appropriate. This site will be functional throughout the duration of the feasibility, scoping and construction periods and for at least the first years of operation. | DGDC |
| **Construction Phase Engagement** | | |
| Grievance logging | Weekly grievance reporting during construction. | DGDC |
| Media notifications of Project progress | Prior to the start of construction<br>Prior to the completion of construction | DGDC |
| Updating SEP | Prior to the completion of construction | DGDC |
| **Operation and Decommissioning Phase Engagement** | | |
| Decommissioning consultation event with affected staff and communities | With staff prior to retrenchment proceedings<br>With communities prior to ceasing operations | DGDC |
| Updating SEP | Annually | DGDC |

## 7.3 Responsibilities

It is the responsibility of DGDC to ensure that documents are distributed to the appropriate stakeholders. During construction and operational activities, the DGDC and contractors will be responsible for meeting with stakeholders and implementing the grievance mechanism. Person(s) are to be appointed to document all interactions with stakeholders and log grievances. All grievances are to be resolved in a timely manner in collaboration with the EPC contractor and DGDC.

# 8. Responsibilities and Management Functions

## 8.1 The Developer

### 8.1.1 Dominica Geothermal Development Company Limited

The Project will be developed by the DGDC, which was legally established by the GoCD in the last quarter of 2016 and became operational in June 2017. The Government's role is as equity provider and lender to the company. The GoCD has all shareholder rights with Directors appointed and replaceable by the shareholder. Initially, four Directors have been appointed, including an Executive Chairman. The GoCD is also responsible for managing and implementing the acquisition of land for the Project.

### 8.1.2 Roles

DGDC has five permanent staff members, a Board and the Project Manager. The company will operate under the guidance of technical, legal, strategic and commercial advisors. The roles for the DGDC staff are as follows:

- A Board of Directors – company oversight to ensure it meets shareholder expectations;
- The Directors will have an Executive Chairman with decision making powers;
- Director of Accounts to establish the financial and administrative capabilities of the DGDC including financial control systems, corporate compliance, establishing the Code of Ethics, taxation and human resources. They will establish bank accounts, develop the annual budget and execute the financial transactions of the company;
- A Project Co-ordinator/Officer to work with Government agencies and assist the Project Manager as required;
- An Administration and Safeguards Officer to be responsible for office management and administration of stakeholder engagement systems;
- A Community Liaison Officer to be the first point of contact for community queries and to share information with community members; and
- A Site and Office Attendant to monitor sites for maintenance purposes, to provide local guiding services to visitors and undertake office activities as required.

The Government of New Zealand is funding a Project Manager position for a period of two (plus one) years. The Project Manager will be based in Dominica and perform the following functions:

- Oversee the technical scope and engineering design of project, ensuring that the feasibility of the scope and structure of the project meets good industry practice and international standards;
- Oversee the overall construction of the power plant and its subsequent commissioning;
- Ensure the project meets the necessary environmental and social requirements and oversee the preparation of an ESIA;
- Responsible for overseeing the successful procurement of all goods, services, and skills necessary for the construction and operation of the geothermal power plant;
- Support finalisation of the financing arrangements, including responding to and meeting lender technical due diligence requirements in an efficient and timely manner;
- Work with advisors to finalise all off-take arrangements with DOMLEC; and
- Secure the services of and overseeing the work of various consultants.

DGDC will appoint a technical advisor acting as an Owner's Engineer who will be responsible for a wide range of services pre and post Financial Close. To date geothermal project development technical advisory services have been provided by Jacobs New Zealand Ltd (Jacobs), who were appointed by the Government of New Zealand following a competitive bidding process to deliver their Caribbean Geothermal Technical Assistance

Programme. At the time of writing Jacobs are currently in the final steps of formalising a role as Owner's Engineer to DGDC.

Clean Infra Partners has been appointed by DGDC as a business advisor to conduct Power Purchase Agreements (PPA) negotiations with DOMLEC, undertake financial analysis, and support development of the Financing Plan and business plan.

Holland & Knight has been retained as legal counsel to DGDC with services to include preparation and review of the Geothermal Concession Agreement, Power Purchase Agreement, EPC Contract, Operations & Maintenance contracts and financing agreements.

These roles are summarised below in Figure 8.1 (correct as of August 2017).

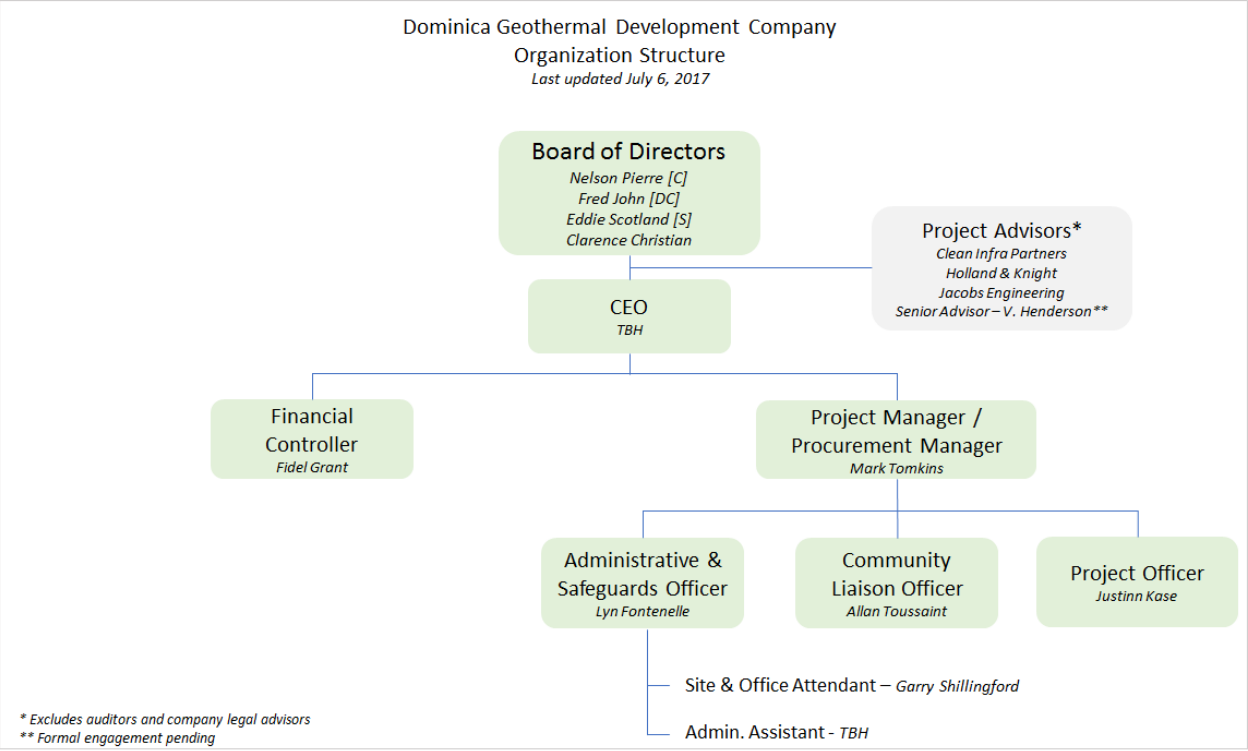



**Figure 8.1 : Geothermal Project Governance**

### 8.1.3 Overview

This section presents a preliminary structure for management and responsibilities in relation to the SEP. The Project Team structure will be confirmed in accordance with the consultation activities.

Specific members of the Project Team will be responsible for implementation of the SEP. The Project Team may include the following:

- The Project Sponsor's Executive Management Team
- The Senior Manager
- The Community Liaison Officer
- ESIA Consultants/Technical Specialists.

### 8.1.4 Executive Management Team

The Executive Management Team will have the overall responsibility for stakeholder engagement, including provision of the guiding principles for the stakeholder engagement, the allocation of budget for the effective implementation of the SEP and, if necessary, participation in the dialogue with administrations in the resolution of any issues.

### 8.1.5 Project Manager

The Project Manager will be responsible for the implementation of the SEP. His/her task will be overseeing the work carried out by the Community Liaison Officer, Social Safeguards Specialist, and rest of the Team. He or she will be the point of contact with the regional and local authorities with respect to public consultation.

The Project Manager's tasks will include:

- Managing implementation of the SEP;
- Managing response to concerns and ideas raised through public consultation;
- Allocating Project finance to public consultation, community development and training;
- Undertaking frequent and regular visits to the Project site and local communities with the Community Liaison Officer to demonstrate the Project's commitment of to the local economy;
- Liaising between the Community Liaison Officer and the Executive Management Team; and
- Ensuring that all public consultation and information disclosure requirements of investors have been met, including the documentation of results.

### 8.1.6 The Social Safeguards Specialist

Primary responsibility will include, monitoring the implementation of both the requirements of the SEP and preparing project related resettlement plans for the Project and evaluating and ensuring that appropriate actions are taken to address potential resettlement problems. He or she will also manage project recordkeeping and coordination with government agencies on related tasks. The Social Safeguards Specialist is a core and permanent member of the DGDC team.

### 8.1.7 Community Liaison Officer

The Community Liaison Officer's primary role is to act as an interface between the Project and the community. The Community Liaison Officer is an employee of DGDC, but the Community Liaison Officer will have an independent and positive relationship with community members. The Community Liaison Officer will be responsible for working alongside the Social Safeguard Specialist to gather the required information for resettlement planning needs, disclosing information and actions to the affected communities and acting as a go between the communities and DGDC on community grievances associated with the Project. He/she will also be responsible for documenting the results of public consultation and preparing reports internal and external for disclosure.

### 8.1.8 ESIA Consultants / Technical Specialists

The ESIA Consultants / Technical Specialists will assist the Project throughout the ESIA Processes.

The responsibilities will be:

- Researching local demographic, socioeconomic, and organizational environments;
- Identifying stakeholders and stakeholder representatives;
- Undertaking community consultation as part of the ESIA process;
- Undertaking environmental and social baseline studies;
- Preparing the ESIA and ESIA executive summary;

- Preparing the ESMP; and
- Providing capacity building and other support during the monitoring and implementation phases of the Project.

## 8.2 Management Functions

The execution of the SEP will be coordinated and systematic. The key elements of the management of the stakeholder engagement are discussed below.

### 8.2.1 Coordination of activities and overall responsibility

The Executive Management Team will have the oversight for the SEP. However, the Senior Manager will coordinate and have overall responsibility for the implementation of the SEP. The Senior Manager will have the high-level oversight of all activities involved in the SEP to ensure information provided to stakeholders and larger Project Team members is consistent and accurate.

### 8.2.2 Employment and Human Resources

The Senior Manager, with the oversight of the Executive Management Team, will also be responsible for ensuring appropriate staff are engaged throughout the duration of the SEP and ensuring staff are appropriately trained to consult with the range of different stakeholders.

The Senior Manager will also ensure the effective management of contractors with respect to local residents and maintenance of good relations through:

- Awareness training of all contractors to the respect of local people and communities' culture, way of life and beliefs;
- Providing all contractors will a copy of the SEP and any updates to stakeholder engagement activities; and
- Providing a line of reporting between contractors and the Community Liaison Officer to address any concerns raised by the community to contractors.

### 8.2.3 Internal Communications

Clear reporting lines will be established between members of the Project Team to ensure the stakeholder engagement activities are core to the implementation of the Project. This will include:

- Circulating the SEP to all members of the Project Team and the Project Sponsor;
- Ensuring all communications are filed in accordance with the Communications Protocol (examples referred to in Section 9 and Appendix E and F)**;** and
- Establishing direct reporting lines between the Community Liaison Officer and the Executive Management Team to effectively control risk.

### 8.2.4 Updating the SEP

The SEP will continue to be reviewed throughout the Project construction phases. Once the Project is operational, a review will be conducted annually by the CLO in order to assess whether:

- The type of consultation and disclosure activities are appropriate for the different stakeholder audiences;
- The frequency of consultation activities is sufficient; Grievances have been adequately dealt with; and.
- The stakeholder list remains appropriate and whether the engagement should cease or be extended to any stakeholders.

# 9. Monitoring and Reporting

## 9.1 Monitoring

Monitoring will be carried out in accordance with the Environmental and Social Management Plan, which is to be prepared through the ESIA process. This is likely to include:

- Monitoring environmental and social performance indicators defined in the ESIA;
- On-going monitoring of grievances through the grievance mechanism;
- On-going monitoring of stakeholder database;
- On-going monitoring of the commitments register; and
- Monitoring of concerns or issues expressed by local or governmental authorities.

## 9.2 Reporting

Key indicators will need to be reported internally, within the Project Company and externally, to the community, regulatory authorities and lenders. The following sections describes the minimum reporting to be conducted.

### 9.2.1 Meeting Minutes

Records of community consultation meetings, meetings with government and civil society shall be kept in a separate document with the detailed database maintained by the CLO. All records shall include attendance lists and photos.

### 9.2.2 Recording Grievances

A formal log of grievances will be developed and the CLO will be responsible for logging all grievances except those related to land acquisition which will be handled directly by designated government representative] of the GoCD. A comments sheet will also be provided for complaints or other comments. Comments or complaints can be made directly to DGDC or the contractor, through the CLO or through a community representative (e.g. through the village elders). See further detail of this process in Section 10.

### 9.2.3 Stakeholder Database

The Project Sponsor will maintain a current and regularly updated stakeholder engagement database. The database will contain:

- details of the various stakeholder groups (including their representatives, their interests and concerns);
- details of any consultations held (including when these took place, the topics discussed and the outcomes);
- any commitments made by the Project Sponsor to stakeholder groups, including outstanding commitments and commitments that have been delivered; and
- a record of specific grievances lodged and the status of their resolution.

### 9.2.4 Commitments Register

The Project Sponsor will maintain a commitments register that keeps track of the commitments made by the Project Sponsor throughout stakeholder consultation (including those made by any contractors or members of the Project Team).

## 9.3 Annual Reporting

The Community Liaison Officer will maintain engagement reports on a monthly basis. The objective of these engagement reports are to demonstrate and record the ongoing engagement process and progress made.

These shall be submitted monthly to the DGDC. These reports may include records of engagement including meeting registers, photographs.

These reports will be used to address and incorporate social issues into Project management. Engagement reports shall be stored with the detailed stakeholder database and retained for a minimum of five years.

At a minimum these reports will contain:

- Engagement activities undertaken;
- Grievances received as per grievance management;
- Updated stakeholder database;
- Feedback received during the engagement process;
- Update on complaints and grievances, expectations and requests,
- Investment made, and commitments and promises made; and
- Key records of communication with stakeholders.

## 9.4 Communications

Relevant communications with identified stakeholders will be recorded and documented in a timely manner. To ensure this is carried out consistently a Communications Protocol was developed. The communications protocol establishes how different communications are to be documented during the Project. The purpose of the Communications Protocol would be to provide a documented record of the communications that are involved in community consultation for the Project, in keeping with the requirements of the World Bank Group Guidelines A general communications flow chart is provided below in Figure 9.1. Details of the Communications Protocol are provided in Appendices E and F.

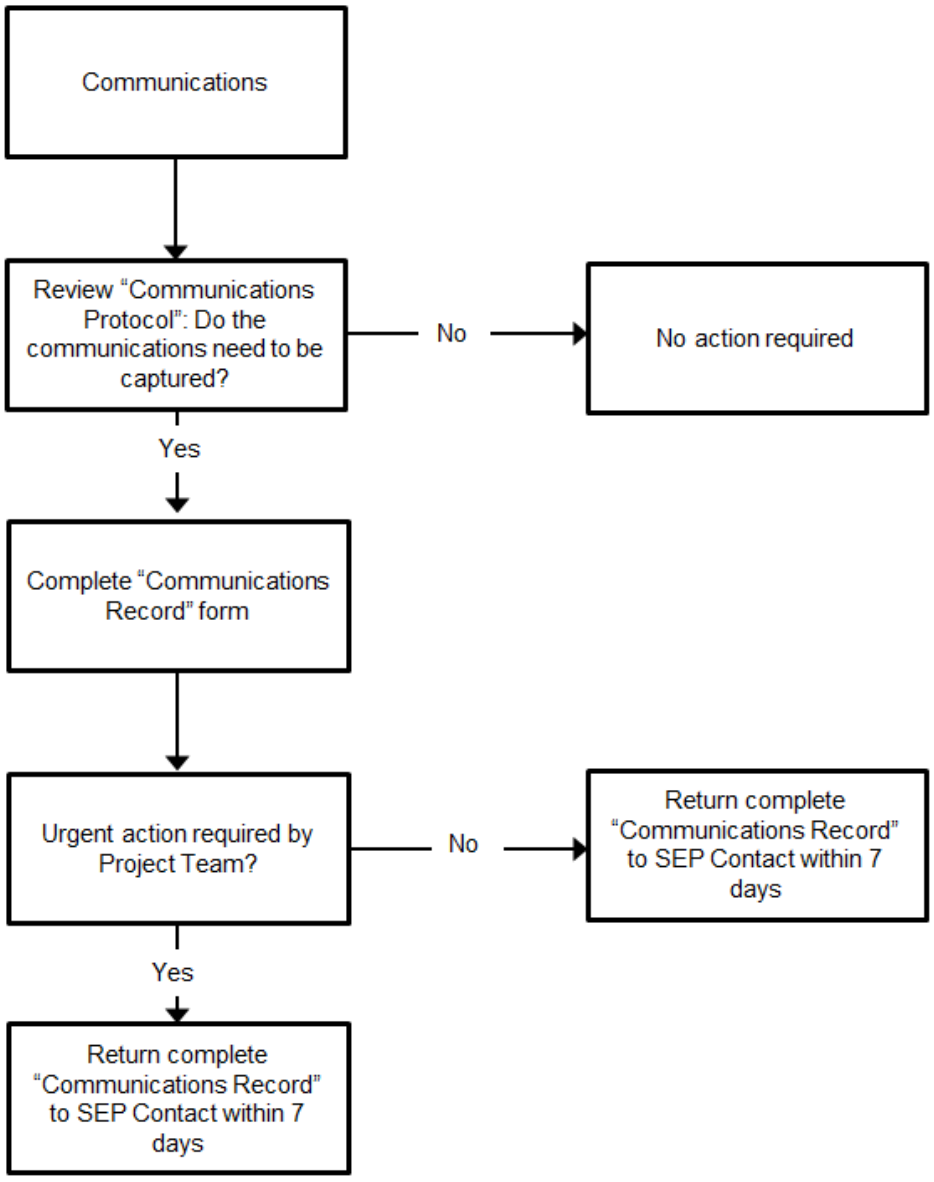



**Figure 9.1 : Communications Flow Chart**

# 10. Grievance Mechanisms

## 10.1 Overview

A grievance can be defined as an actual or perceived problem that might give grounds for complaint. As a general policy, DGDC will work proactively towards preventing grievances through the implementation of mitigation measures (as identified by the ESIA) and liaising with the community. These activities are designed to anticipate and address potential issues before they become grievances. This will be the responsibility of the Project Manager and the CLO. However, all grievance related to land acquisition will be handled directly by designated government representative] of the GoCD.

The sections below consider types of grievances that may arise, confidentiality and anonymity, and the Project's grievance resolution process.

The grievance mechanism covers the various aspects of the Project, including:

- The Project in general, including planning, construction and operation;
- The process of environmental impact assessment; and
- The compensation and resettlement processes.

Each affected person is free to register a grievance, in accordance with procedures specified below. The grievance process focuses on first identifying whether the grievance can be addressed through additional communication between the complainant and members of the Project Team, or by providing additional information to the complainant. If the grievance cannot be resolved internally, the Project Team will then seek to resolve the grievance through mediation by local authorities, and finally, if a resolution cannot be reached, judicial appeal.

The grievance flow chart is provided in Appendix D.

## 10.2 Type of Grievances

Potential impacts and effects that are most likely to give rise to grievances for this Project include:

- Resettlement/livelihood restoration;
- Noise of construction works;
- Presence, and potential disruption, of the construction labour force and the effects on communities, local services and infrastructure;
- Community health and safety in relation to impacts of increased traffic on nearby residents;
- Visual intrusion (construction and operation);
- Congestion of and access to local ports (construction and operation);
- Damage to surrounding natural environment (construction and operation); and
- Disappointment related to expectations about employment from the Project.

Anyone can submit a grievance to the Project if they believe it is causing a detrimental impact on the community, the environment, or on their quality of life. They may also submit comments and suggestions. Grievances could include:

- Negative impacts on a person or a community (e.g. financial loss, physical harm, nuisance);
- Dangers to health and safety or the environment;
- Failure of the DGDC, its sub-contractors and their workers or drivers to comply with standards or legal obligations;
- Harassment of any nature;

- Criminal activity;
- Improper conduct or unethical behaviour;
- Financial malpractice, impropriety or fraud; and
- Attempts to conceal any of the above.

During construction grievances will be investigated by DGDC, the GoCD and the CLO to determine the validity and associated responsibility. The CLO will explain in writing (or where, literacy is an issue, orally) the manner in which the review was carried out, the results of the review, any changes to activities that will be undertaken to address the grievance and how the issue will be managed to meet appropriate environmental and social management systems requirements. A template for a Grievance Complaint form is presented in Appendix C.

## 10.3 Confidentiality and Anonymity

The Project will aim to protect a person's confidentiality when requested and will guarantee anonymity in annual reporting. Individuals will be asked permission to disclose their identity. Investigations will be undertaken in a manner that is respectful of the aggrieved party and based upon the principle of confidentiality. There may be situations when disclosure of identity is required. If this is the case, the CLO and DGDC will identify this and ask if the aggrieved party wishes to continue with the investigation and resolution activities.

## 10.4 Grievance Reporting and Resolution

A formal log of grievances will be developed and the CLO will be responsible for logging all grievances. A comments sheet will also be provided for complaints or other comments. Comments or complaints can be made directly to DGDC or the contractor, through the CLO or through a community representative (e.g. through the village elders). The procedure for lodging grievances and their resolution will be included in appropriate Project communication materials such as non-technical summaries or the Project. In the first instance, grievances will be directed to the CLO who will classify grievance according to Table 10.1.

**Table 10.1 : Classification of Grievances**

| Classification | Risk Level | Validity | Response |
|---|---|---|---|
| Low | No or low | Unsubstantiated | CLO will conduct investigation, document findings and provide a response |
| Medium | Possible risk and likely a one off event | Possible substantiation | CLO and an appropriate investigation team will conduct investigation. The Site Manager or Occupation Health and Safety Manager may decide to stop work during the investigation to allow the corrective preventive actions to be determined. The CLO will provide a response. |
| High | Probable risk and could reoccur | Probable substantiation | CLO will get the contractor to organise a Major Investigation Team including DGDC for prompt investigation and resolution. Work will be stopped in the affected area. The CLO will provide a response. |

The CLO will log the receipt of a comment, formally acknowledge it, track progress on its investigation and resolution, and respond in writing with feedback to the aggrieved party. They will initiate the investigation and ensure its speedy conclusion aiming to provide a response with ten working days, unless there are exceptional circumstances. If the Project receives a large number of unsubstantiated grievances, the process will be reviewed to define instances when no response is needed.

Where investigations are required, Project staff and outside authorities as appropriate will assist with the process. The CLO will collaborate with DGDC to identify an appropriate investigation team with the correct skills to review the issue raised and to decide whether it is Project related or whether it is more appropriately addressed by a relevant authority outside the Project.

The investigation will also aim to identify whether the incident leading to the grievance is a singular occurrence or likely to reoccur. Identifying and implementing activities, procedures, equipment and training to address and prevent reoccurrence will be part of the investigation activities. In some cases it will be appropriate for the CLO to follow up at a later date to see if the person or organisation is satisfied with the resolution or remedial actions.

The CLO will summarise grievances to report on Project performance weekly during construction and bi-annually during operation, removing identification information to protect the confidentiality of the complainant and guaranteeing anonymity.

Comments relating to the Project can be addressed to the Community Liaison Officer at DGDC:

| **Name:** | **Allan Toussant** |
|---|---|
| **Address:** | PO Box 1454, 18 Kennedy Avenue, Roseau, Commonwealth of Dominica |
| **Email:** | allan.toussaint@geodominica.com |
| **Telephone Number:** | (767) 448-6178 / 79 |

# Appendix A. Stakeholder Engagement and Consultation Meeting Minutes

Refer to ESIA Volume 5: Technical Appendices  Appendix J. Stakeholder Engagement – Meeting Minutes

# Appendix B. Summary of Focus Group Meetings

Refer to ESIA Volume 5: Technical Appendices - Appendix J. Stakeholder Engagement – Meeting Minutes

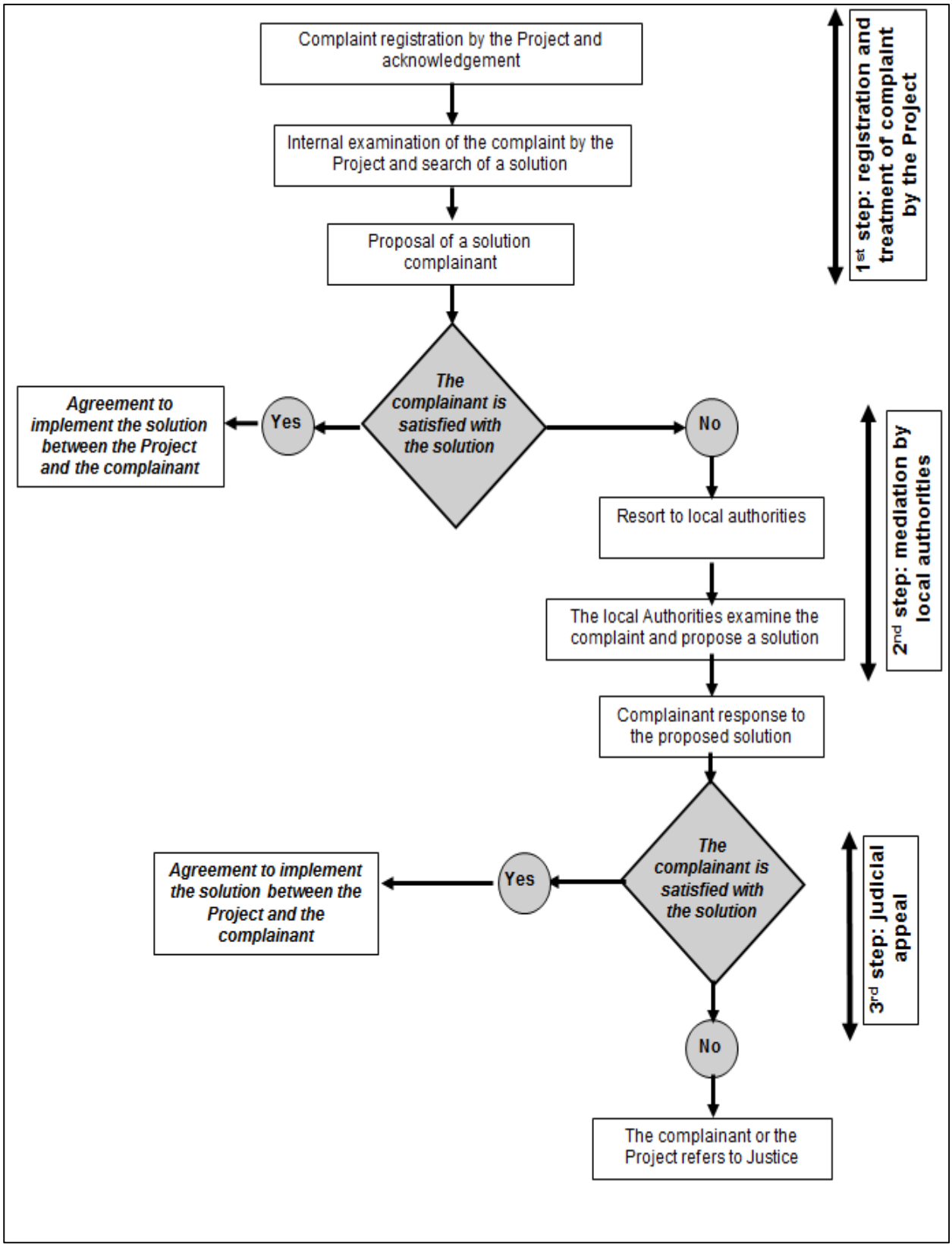
# Appendix C. Grievance Mechanism Complaint Form

| **GRIEVANCE REGISTRATION** | | |
|---|---|---|
| Date: | Filed by: | |
| Plaintiff's name : | Plaintiff's gender: M / F | Plaintiff occupation: |
| Plaintiff's contact (address, tel. number): | | |
| □ The plaintiff is filling an individual complain | | |
| □ The plaintiff is representing a group or a community<br>- Name of the group or community:<br>- Nature of the group or community:<br>- Location/address: | | |
| Description of the grievance: | | |

| **GRIEVANCE TREATMENT** | |
|---|---|
| Date of the response: | Filed by: |
| Proposed action(s) to remedy to the grievance: | |
| Plaintiff's acceptance of the proposed action: | |

| **GRIEVANCE CLOSURE** | |
|---|---|
| Date of grievance closure: | Filed by: |
| Ending of the grievance treatment: | |

# Appendix D. Grievance Mechanism Process



# Appendix E. Communications Protocol

## E.1 Introduction

Relevant communications with identified stakeholders must be documented in a timely manner. The purpose of this protocol is to create a documented record of the communications that are involved in the community consultation for the project. This is a requirement under the WB Performance Standards and needs to be followed.

When a piece of communications is to be conducted, a member of the Project Team should review the "Communications Flow Chart", see Figure 9.1, to ascertain if the communications needs to be documented as per the communications protocol.

The attached "Communications Record" reference in Appendix F is to be used when communications between a member of the Project Team and the wider community. Any communications that have been recorded are to be documented and forwarded as soon as practicable.

At all times the Project Team should make information free, prior and informed. Meaning that information supplied "should be "free" (free of external manipulation, interference or coercion, and intimidation), "prior" (timely disclosure of information) and "informed" (relevant, understandable and accessible information)".

This communications protocol is a fluid document which will be changed and updated as required.

## E.2 Stakeholders Involved

The following have been identified as stakeholders who are or are likely to be involved within the consultation process:

- Local community
- Local business and interest groups
- Local government
- Regional, Provincial and National government
- NGOs/Media
- General public
- Vulnerable people
- People affected by economic or physical displacement.

## E.3 Communications Capture

### E.3.1 What communications and consultation are to be captured?

The information supplied to the wider community is to be documented and recorded. When there is engagement with the community and disclosure about Project relevant information, these need to be captured by the "Communications Record". Examples of communications that must be captured are:

- Information exchange with the community: All information verbally or written that is supplied to the community about the Project must be captured. For example if a member of the local community requests information, questions, issues or makes comment on the Project, these communications must be recorded.
- Information exchange with government agencies: For example where a government agency contacts the Project Team for information, raises issues or makes statements regarding the Project
- Media requests: Any information placed in the media or when the media has requested information to be supplied must be recorded.

- Workshops: Responses from the wider community at the workshops.
- Individual meetings and interviews must be recorded including responses to community questions and concerns.
- Approvals from government departments or agencies: Agreements reached with government departments and/or agencies.
- Requests for action from the community: If an action is requested by the Project Team by the local community then this needs to be recorded.
- Formal meetings with community and government.

### E.3.2 What communication does not need to be captured?

When information about the Project is not supplied but communications have occurred with the community, this does not have to be captured. Examples of communications that does not need to be captured are:

- Meeting requests/appointments: For example, communications arranging an open day or meeting with the community
- Information about the process or Project Team Members: If the wider community is asking specific information on the process or the Project Team Members
- Data collection: Teams collecting data for the Project.

### E.3.3 Style of Communications Stakeholders

The following methods for communication to stakeholder may be used:

- Emails
- Phone
- Fax
- Face to face meetings
- Letter
- Media (Newspaper ads).

## E.4 How to capture the information

Appendix F provides the “Communications Record”. This sheet needs to be filled in the relevant areas to explain the communications that has occurred. If there are documents that are relevant to the communications (i.e. emails, faxes, letter, minutes of meetings etc) please make copies of the relevant documents and forward with the “Communications Record”. The “Communications Record” does not replace current practices (i.e. minutes of meetings) but is an extra document to track the flow of communications. Copies should be made both of the communications record and the documents supplied so both the Project Team and the person making the communications has a record.

The “Communications Record” will be kept by the Project Team and a communication spreadsheet will be created to track the communications and consultation documents for the project.

## E.5 Time Frames

“Urgent” communications that require action from a member of the Project Team needs to be forward to the Project Team within 24 hours.

“Non-Urgent” communications needs to be forwarded to the Project Team within 5 working days.

## E.6 Communications Contact List

### E.6.1 Points of contact

Points of contact for the communications protocol are provided in Table E.1**.**

**Table E.1: Communications contact table**

| Name | Position | Company | Role in Project | Email | Phone No. |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

# Appendix F. Communications Record

COMMUNICATIONS RECORD

Dominica Geothermal Project

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Project Team Member*** | | | | | | | |
| **Company** | | | | | | | |
| **Correspondence Type (Please Circle)*:** | Email | Fax | House Call | Letter | Meeting | Phone | Other |
| **Date of Communication*:** | | | | | | | |

| **Stakeholder Details*** | | | |
|---|---|---|---|
| **Name*:** | | | |
| **Position:** | | | |
| **Organisation:** | | | |
| **Phone:** | | **Fax:** | |
| **Mobile:** | | **Email:** | |

| **Property Address (If required)** | |
|---|---|
| **Address:** | |
| | |
| | |

| **Issue Raised in Communication (Please Circle)*** | | | | | |
|---|---|---|---|---|---|
| Property Value | Access | Water Pollution | Noise | Dust | Complaint |
| Employment Issues | Economic Effects | Traffic | General Information | Hours of Operation | Regulatory Requirements |
| | Other (Please list) | | | | |
| **What they said*:** | | | | | |
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| **What we said*:** | |
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| | |
| **Urgent Communications* (Report within 24 hours)** | |
| **Actions Requested:** | |
| | |
| | |

| | | | |
|---|---|---|---|
| **Document Attached?** | **Yes** | **No** | |
| If yes, please state document title | | | |
| **Document Reference Number (Office use only):** | # | | |

# Appendix L. Caraïbes Environnement Développement & Coll 2015 – Final Summary Report

GÉOTHERMIE CARAÏBE 2
PRODUIRE NOTRE ÉLECTRICITÉ AUTREMENT

PROGRAMME INTERREG CARAÏBES

l'Europe s'engage avec les Antilles-Guyane dans la Grande Caraïbe

REGION GUADELOUPE

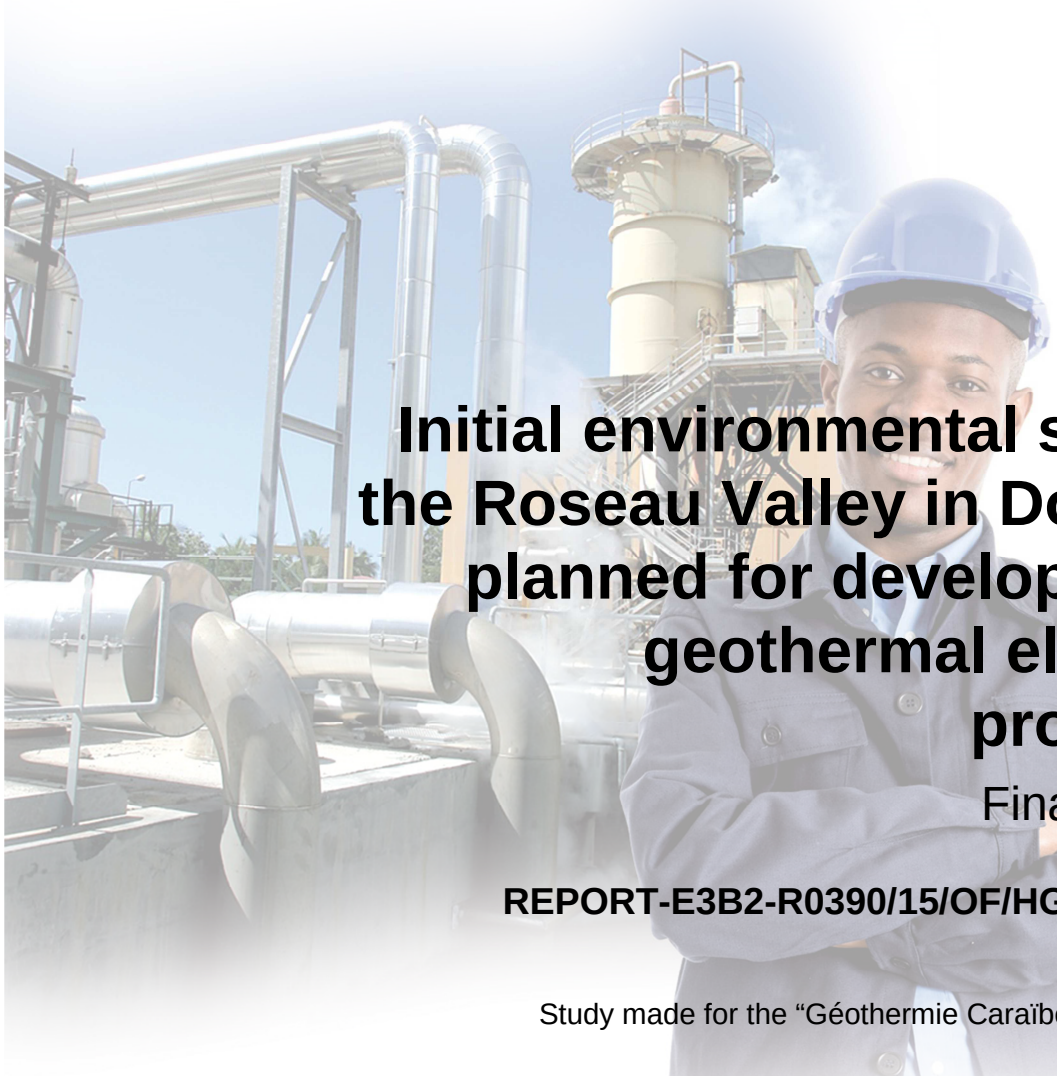


# Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production

Volet 1 - T.1.2.1.

Final Summary

May 2015



# Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production

## Final Summary

**REPORT-E3B2-R0390/15/OF/HG/SB/IB/VD-EN**
May 2015

Study made for the “Géothermie Caraïbes phase 2” project

**Caraïbes Environnement Développement**
In collaboration with
**Asconit Consultants, Teranov, IMSRN, Eclipse Inc., Adret & Territoires, SEGE Biodiversité, 2AF Gamba Acoustique, EnviroConsult et ISL**

In the bibliography, this report will be quoted as following :

**Caraïbes Environnement Développement & Coll.** (2015) – Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production. Final summary. REPORT-E3B2-R0390/15/OF/HG/SB/IB/VD-EN.

# INTRODUCTION

In 2005, Dominica initiated a programme for construction of a geothermal project in the Roseau Valley, in cooperation with France, in the framework of the inter-regional Caribbean cooperation objectives.

The ultimate goal of the project is to bring energy independence to Dominica and to supply neighbouring Guadeloupe and Martinique with additional renewable energy on an ad-hoc basis. These Caribbean Islands predominantly use fossil fuels (oil and coal) for electricity production.

Initial studies have shown the feasibility of such a project from a technical, financial and environmental point of view. Dominican regulations require that the project be subject to an environmental impact study.

The environmental pre-feasibility study carried out in 2009 revealed an absence of descriptive data necessary to characterise the initial status enabling an evaluation of the impact of this project on the environment.

In cooperation with the Dominican government, ADEME launched the following mission: Project Interreg IV “Caribbean Geothermal– Phase 2” - An initial environmental status report on the Roseau Valley in Dominica, planned for development of geothermal electricity production projects.

Issues for the study are as follows:

- Carry out a zero status environmental study in the Roseau Valley, serving as a base for future determination of impacts and measures.
- A need for quantitative data, of good quality, acquired through standard protocols, which can be reproduced over time. The themes involved are specifically natural risks (flooding, ground movements, and seismic), acoustics, aerology, climatology and hydrography.
- Particular attention to land and aquatic biodiversity, through inventories, as well as lifestyle, landscape and heritage. These elements are particularly sensitive for residents of the Roseau Valley and therefore essential for a dialogue with the local population.
- Facilitate the implementation of international cooperation between the State of Dominica and the French State, through regular communication on the implementation of studies and involvement of local players.

- Develop social acceptance of the geothermal project within the local population, transparently informing the population on the studies underway and involving the population in a genuine process of cooperation, based on participative meetings.
- Involve local human resources in the studies and ensure skills transfer.
- Technically enrich the debate on geothermal energy with a voluntary policy on energy transition in Guadeloupe and Martinique (notably through the presentation of studies in technical seminars).

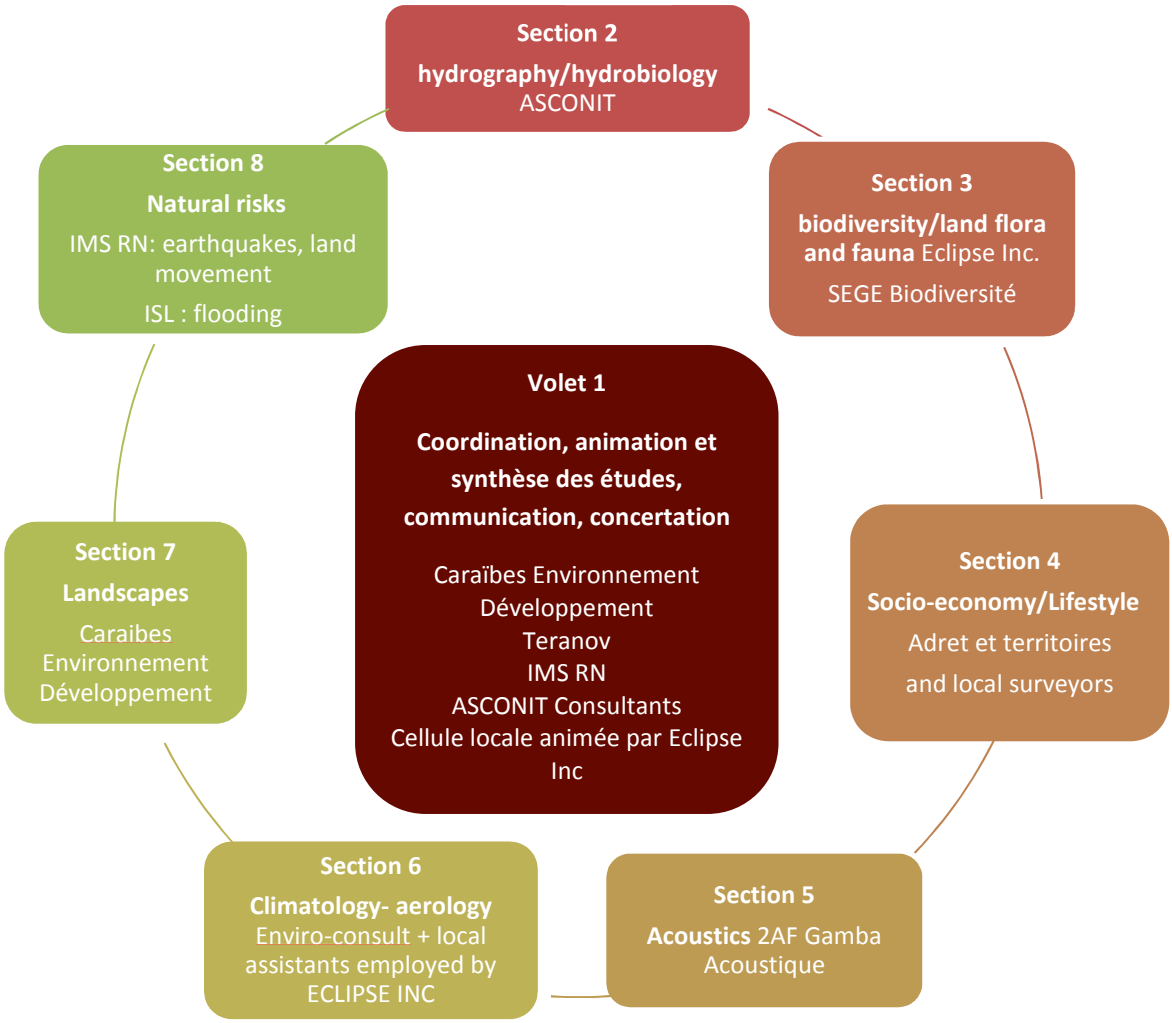
- For organisation of the study, the need for ADEME to have a single, long-lasting contact in Guadeloupe, Caraïbes Environnement Développement, who will relay advances in the study and ensure a coherence of reporting.

This mission should enable studies on the initial status of the Roseau Valley on the following themes

- Hydrography and hydrobiology;
- Land flora and fauna;
- Socio-economy and lifestyle;
- Acoustics;
- Climatology and aerology;
- Landscape;
- Natural risks.

This document summarises the initial environmental status study for the Roseau Valley.

# The 8 Sections of the study on the initial status of the Vallée de Roseau




## The study in figures

- A team of 10 multidisciplinary companies
- 18 months of studies, 8 months in the field
- Intervention of fifty phds, engineers, researchers and technicians (plus administrative staff)
- Around 900 cumulative work days
- 1 year of weather measurement
- 3 languages used English, French and Creole
- Teams in 2 countries: Dominica and France
- Teams in two geographical zones, mainland France and the Lesser Antilles (Dominica, Guadeloupe and Martinique)

# SECTION 1: COORDINATION, ANIMATION, STUDY SUMMARIES, COMMUNICATION/CONSULTATION

## Goal of consultation

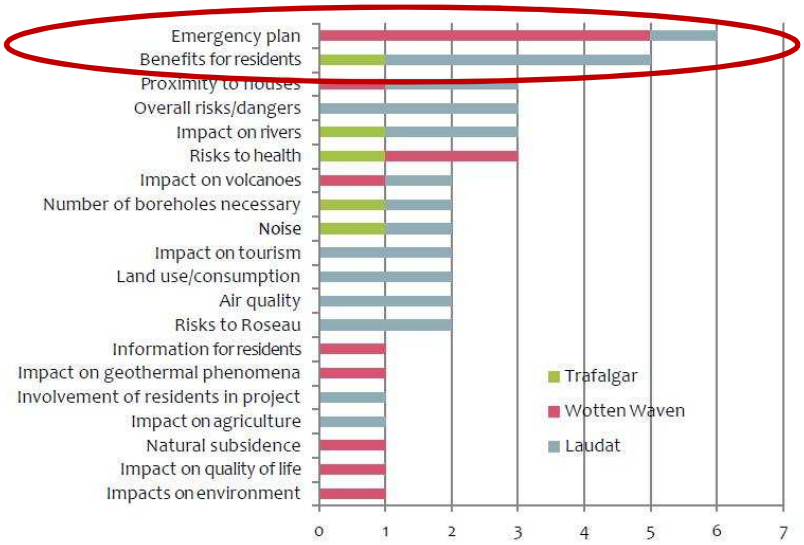
- To define the players involved in the project
- To understand their expectations in respect of the geothermal project in order to best target the fields of study
- To keep the parties informed of the progress of the study





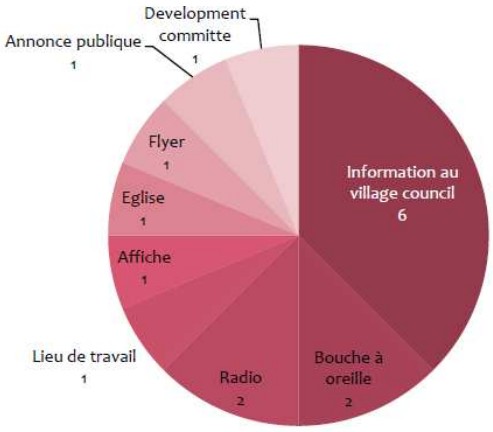

## Results of consultations

- Satisfaction of the population regarding the goal of carrying out studies to deepen understanding of the environment
- Great expectations of the results of these studies
- Request for a health study of valley populations.
- Full cooperation with the various Dominican services in order to find other applications




*Principal concerns of the population regarding the project:*

- Evacuation of the Valley in the event of major accident
- Benefits for residents

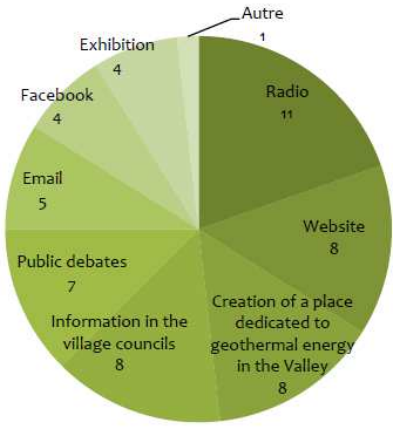



*How were you informed about this evening's meeting ?*

## Expectations of information tools

- Monthly or quarterly information rhythm

By radio and via Village Councils




*What methods would you like us to use to keep you updated ?*

## Numerous players, with different expectations, on several scales










| | | |
|---|---|---|
| COORDINATING AUTHORITIES | Government departments | 1. Annie Edwards – Housing & Planning, Division of planning<br>2. Lloyd Pascal, Environmental Coordination Unit<br>3. Alexis Georges & Michael Faudelle, GPMU<br>4. David Williams, Forestry Department<br>5. Michael Savarin, Senior Investor Services officer, Invest Dominica Authority<br>6. Greg Steadman, Statistics Department<br>7. M Scotland, head officer & Sylvester St Ville, Senior Environmental Health Officer, Environmental Health Department<br>8. Colin Piper, Discover Dominica Authority<br>9. Delroy Williams, Agricultural Officer with the Ministry of Agriculture |
| | Locally elected officials | 10. Trafalgar counsellors<br>11. Dr Collin McIntyre, Roseau Valley parliamentary representative (also Trade and Industry Minister) |
| ECONOMIC PARTNERS | Local economic partner organisations | 12. Magnus Williams, Chef Engineer & Juliana Boston, Financial Controler – DOWASCO<br>13. Colin Power, Domlec |
| | Professional associations | 14. Dominica Hotel and Tourism Association (DHTA) |
| | Financiers | *To be completed by ADEME, AFD, Guadeloupe and Martinique regions, and?* |
| | Companies | *To be completed by GDF Suez?* |
| GENERAL PUBLIC | Residents of Trafalgar | 15. Peter Madison Charles, resident of Lilly Valley, Trafalgar<br>16. Public meeting 12/12/13 |
| | Residents of Wotten Waven | 17. Japson Rowl, resident of Wotten Waven<br>18. Richardson Charles, resident of Wotton Waven<br>19. A female resident Wotton Waven (shopkeeper)<br>20. Public meeting 13/12/13 |
| | Residents of Laudat | 21. Thomas Jequental, Laudat<br>22. Ralph Magaw, resident of Laudat<br>23. Francesca Magloire, female resident of Laudat<br>24. Public meeting 11/12/13 |
| | Ecologists | 25. Athie Martin, small hotel owner, environmental scientist, involved in the business of water, conservationist<br>26. Hadenauer Douglas, free-lance consultant, involved in geothermal development |
| | Associations | 27. Jeffrey Charles, resident of Wotten Waven, chairman of Geothermal Awareness Committee |
| | Political parties | 28. Lennox Linton & Edison James, United Workers Party |

## Wide variety of expectations identified

- Players associate geothermal activity with around 40 issues
- One single issue is considered positive, the rest are considered to be negative

| | | |
|---|---|---|
| **SOCIO-ECONOMIC ISSUES** | *The ECONOMIC sphere looks to "human capital SERVICES" (and also "social capital") for economic well-being. This means, on the one hand, growing opportunities for wealth, income, property and services but, on the other hand, exploitation and disturbance of existing forms of community. For the SOCIAL sphere, the ECONOMIC sphere is a means, not an end in itself. The question is to know whether the "opportunities" provided by the latter maintain or threaten existing values and the FORMS OF COMMUNITY.* | 1. Job creation<br>2. Population displacement<br>3. Infrastructures<br>4. Tranquillity / Easy lifestyle<br>5. Noise<br>6. Risk of major accident<br>7. Health<br>8. Local skills |
| **SOCIO-ENVIRONMENTAL ISSUES** | *This interface is the domain of ENVIRONMENTAL VALUES and the "culture" matrix that determines the "MEANINGS OF NATURE" or the spectrum of "environmental functions" identified by or for a society, e.g. nature as a cosmology, roles as "sources" of well-being or wealth, a landscape's perceived quality. It is therefore the meanings' material and symbolic extent that (among other aspects) enables members of society to articulate "risks" and affirm values: the whys and wherefores of sustainability, and for whom (e.g. productive land usage, biodiversity conservation, love of nature; the right of today's generation to consume natural resources versus the duty to respect them for the sake of future generations, etc.).* | 9. Mother Nature |

| | | |
|---|---|---|
| **ECONOMIC ISSUES** | *Economic self-organisation, e.g. contracts, performance obligations such as efficiency, growth, production, transport and consumption.* | 10. Price of energy |
| | | 11. National revenues/Balance of trade |
| | | 12. Cost of project/ Investment |
| | | 13. Development of commercial relations |
| | | 14. Safeguarding of energy supplies |
| | | 15. Valley development |
| | | 16. Taxes and duties |
| | | 17. Agriculture |
| | | 18. Tourism |
| | | 19. DOMLEC development |
| **ECO-ENVIRONMENTAL ISSUES** | *The ECONOMIC sphere looks to the "SERVICES" of "natural resources" for economic well-being as a production factor. This causes "ENVIRONMENTAL PRESSURES" and "IMPACTS" on the functioning of the environment and on future services, including payback effects (sometimes interrupted) on the economy and the community.* | 20.Natural hazards |
| | | 21. Geothermal properties |
| | | 22. Land consumption |
| | | 23. Water |
| | | 24. Air |
| | | 25. Soil |
| | | 26. Visual impact |
| | | 27. Vibrations |
| | | 28. Waste |
| | | 29. Ecosystem / biodiversity |
| | | 30. Carbon credits |
| | | 31. Greenhouse gas emissions/Climate change |
| | | 32. Environmental hazards |

- Governance issues are rated negatively:
  - absence of consultation
  - problems with project management (*EIA after works*)
  - share of foreign countries and Dominica in the project

| | | |
|---|---|---|
| **GOVERNANCE ISSUES** | *An organisation's governance is expressed via the emergence of rules and procedures that regulate each sphere in relation to the others so as to ensure the simultaneous compliance with (or fulfilment of) each of the three spheres' performance/quality objectives. It is the sphere of mediation between different principles and of the communication of interests, created de facto or deliberately by using force or institutional arrangements ranging from cities or local councils to UN international agencies as well as national government structures.* | 33. Consultation<br>34. Corruption<br>35. Energy mix/policy<br>36. Project management<br>37. Project governance<br>38. Dominica's image<br>39. Regulatory framework<br>40. Operations monitoring<br>41. Alignment with national policy |

- Valley residents appear the most unfavourable to the project.
- Other players appear more nuanced.

| | GENERAL PUBLIC | | | | | | COORDINATING AUTHORITIES | | | ECONOMIC PARTNERS | | SYNTHESIS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Laudat residents | Trafalgar residents | Wotten Waven residents | Associations | Ecologists | Political parties | GPMU | Government departments | Locally elected representatives | Partner companies | Regional economic actors | |
| Socio-economic issues | ☹ | ☹ | ☹ | ? | | | | 😐 | 🙂 | | ☹ | ☹ |
| Socio-environmental issues | ☹ | ☹ | ☹ | | | | | | | | | ☹ |
| Economic issues | ☹ | ☹ | ☹ | 😐 | 😐 | 🙂 | 🙂 | 🙂 | 🙂 | 🙂 | 😐 | 🙂 |
| Eco-environmental issues | ☹ | ☹ | ☹ | ☹ | ☹ | 😐 | 😐 | ? | ☹ | 😐 | | ☹ |
| Governance issues | ☹ | ☹ | ☹ | ☹ | ☹ | 😐 | ☹ | ☹ | 😐 | ☹ | ☹ | ☹ |
| **SYNTHESIS** | ☹ | ☹ | ☹ | ☹ | ☹ | 😐 | 😐 | 😐 | 🙂 | 😐 | ☹ | |

☹ Negative opinion 😐 Ambivalent opinion 🙂 Positive opinion ? Questions

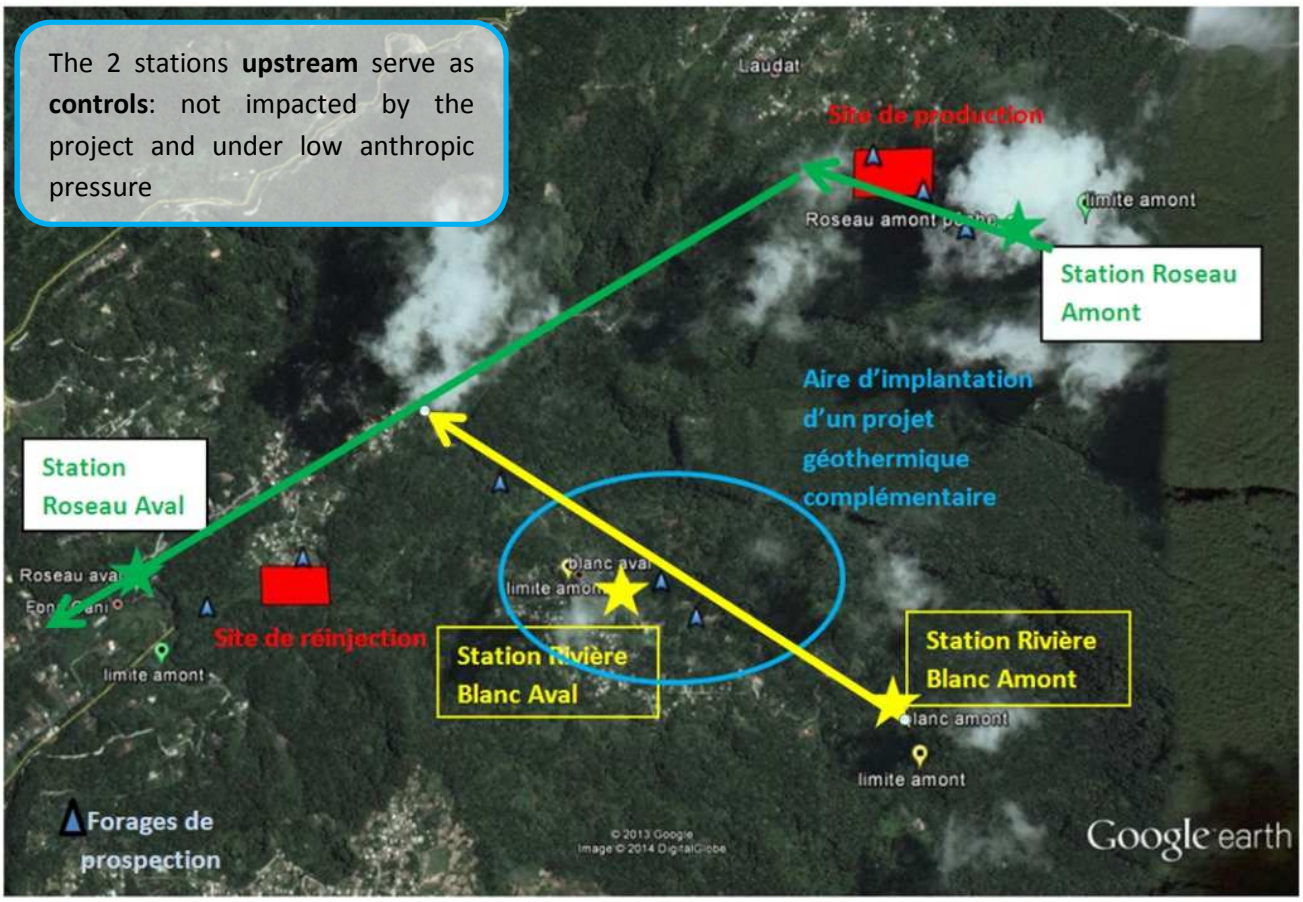
# SECTION 2: HYDROGRAPHY/HYDROBIOLOGY

## Goal of this section

- To set up a monitoring observatory
- To carry out the 1st situational analysis to serve as base for comparison
- To set out the ecological quality of water courses studied







# Results

## Ecological status of monitored watercourses

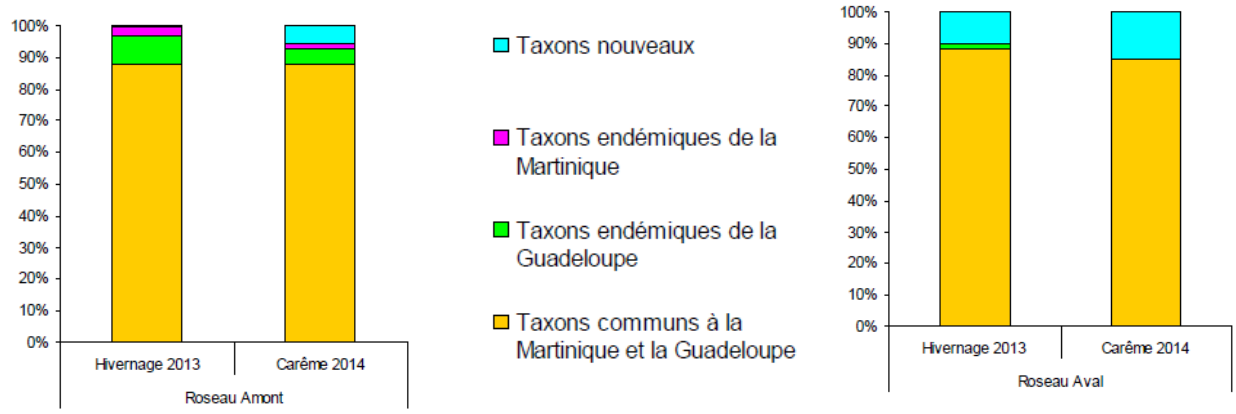
| | Hydromorphologie | Diatomées | Macro-invértébrés | Poisson et macro-crustacés | Qualité physico-chimique |
|---|---|---|---|---|---|
| **Roseau Amont** ☺ : état écologique au moins bon | 😐 impactée par les aménagements : écoulement perturbé (faciès d'écoulement lentisques), ripisylve préservée | ☺ bonne diversification (40 taxons) dominé par taxons polluant résistants **bon état** écologique | ☺ bonne diversification (31 taxons) **bon état** écologique | 😐 faible diversification (5 espèces) densités faibles | ☺ aucun micropolluant organique, Minéralisation importante **bonne qualité** |
| **Roseau Aval** ☺ : état écologique au moins bon | ☺ naturelle, non impactée par l'homme | 😐 faible diversification (23 taxons), taxons ubiquistes et polluant résistants | ☺ bonne diversification (34 taxons) **bon état** écologique | 😐 faible diversification (7 espèces) densités très faibles | |
| **Rivière Blanc Amont** ☺: état écologique au moins bon | ☺ naturelle, non impactée par l'homme | 😐 faible diversification (25 taxons), taxons ubiquistes et polluant résistants (indice peu fiable) | ☺ faible diversification (25 taxons) mais **très bon état** écologique | 😐 très faible diversification (3 espèces) densités faibles | Ø pas d'analyses |
| **Rivière Blanc Aval** 😐 : état écologique moyen | ☹ très impactée par les activités anthropiques : écoulement perturbé (érosion, colmatage minéral), ripisylve préservée | 😐 taxons ubiquiste et polluant résistants = apports organiques et minéraux importants (indice peu fiable, peut être dû à la proximité des sources thermales) | 😐/ ☺ « état médiocre » à « bon » bonne diversification (31 taxons) Mais légère perturbation dû au colmatage minéral : surabondance de *Chironomidae Orthocladiinae* | 😐 très faible diversification (4 espèces) densités faibles Composés sulfurés d'origine naturelle « impactent » les communautés biologiques : même si l'**eau est de bonne qualité physico-chimique**, la station est sans doute peu « apte à la biologie » tout en étant non perturbée. | ☺ aucun micropolluant organique, Minéralisation importante **bonne qualité** |

## The results obtained show a status of NOT DEGRADED BY MAN

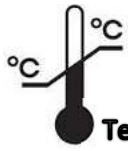


The ABSENCE of a local baseline means that the FRENCH BASELINE has to be used to establish the ecological status, though this is **not perfectly suited** (absence of reliability of the diatom index, conflicting results in the benthic macroinvertebrates index for the Blanc and Roseau rivers, etc.)

# Diatom population containing taxa present in Guadeloupe and/or Martinique and **new taxa**




## Water conditions:



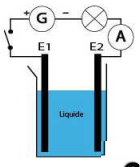

25,2°C 26,2°C

**Temperature**



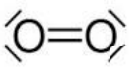
6,29 7,64

**PH**




204µS/cm 486µS/cm

**Conductivity**




7,25 mg/L 8,76 mg/L

**Oxygenation**

1 species of fish present in all stations and dominating populations

*Sicydium sp*



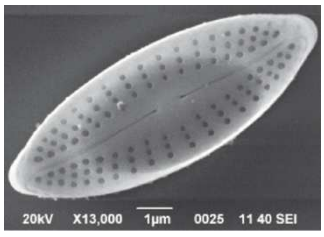
Species of crustacean
Widespread



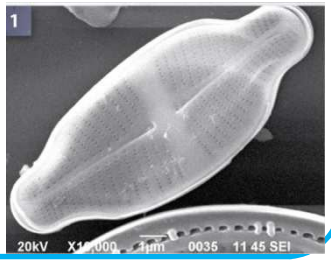
*Macrobrachium heterochirus*

Presence of pollutant-resistant diatoms in all stations

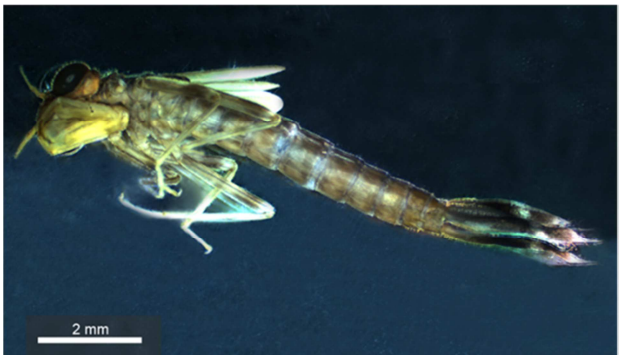
***Achnanthidium subhudsonis***




***Achnanthidium exiguum***



## 3 species of interest identified (native to the Lesser Antilles):





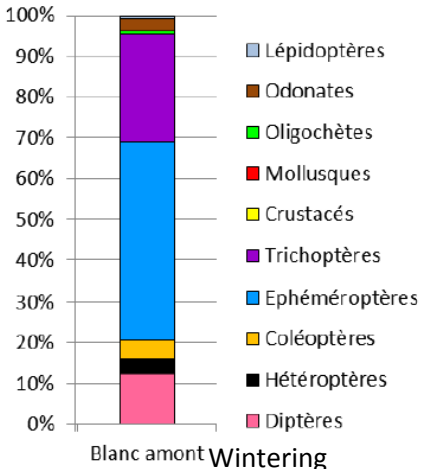

*Argia concinna*
*(present on all stations)*

*Xiphocaris elongata*
*(Roseau Upstream)*

*Guinotia dentata (Roseau Upstream)*



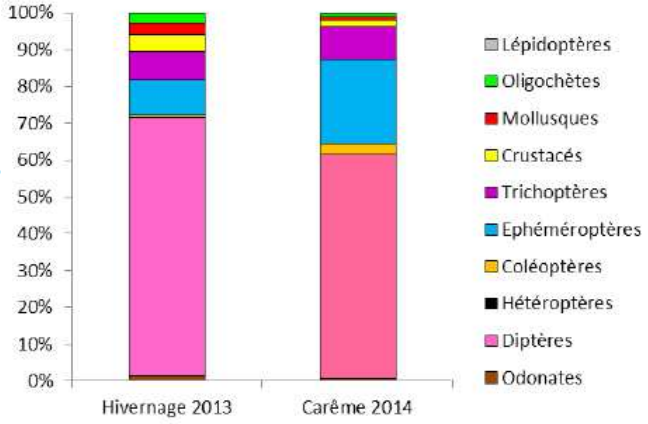

Dominance of **trichoptera** and **mayflies** shows a **good ecological status** (French baseline) on the Upstream **Station of Rivière Blanc**







Dominance of **Chironomidae** (diptera) and **Oligochaetes** shows an **average ecological status** (French baseline) **at the downstream station Blanc**






# SECTION 3 : BIODIVERSITY / LAND FLORA AND FAUNA

## Goal of the study

- To identify the flora and fauna of the region
- To determine the most sensitive sites in the Roseau Valley



**Rainforest of Long Ditton Plateau**

## Method used

An initial flora and fauna analysis was carried out in 2008 by Mr Arlington James, forest officer and expert in flora and fauna. The goal was to have an introduction to the Roseau Valley, the legal context related to forest clearing and protected natural spaces. Three sites were studied by Mr Arlington James assisted by Mr Phillip Matthew for field reconnaissance.

The botanist and ecologist Félix Lurel went further with this analysis by increasing the inventories on different sites and enlarging the panel of plant groups covered. His involvement permitted the examination of various aspects:

- Field inventory
- Phonological status
- List of species

Twelve areas were studied in an area bordered by:

- Morne Louis and Morne Bruce to the west of the valley (entrance downstream of valley);
- Morne Jack and Morne Micotrin to the north and north east;
- Boiling Lake to the east;
- Mount Watt and Morne John to the south east;
- Morne Prosper to the south.

The 12 study areas are listed on the map on the next page

The campaigns consisted of:

- 19 field prospections
- Identification of species by visual and vocal recognition (Fauna).

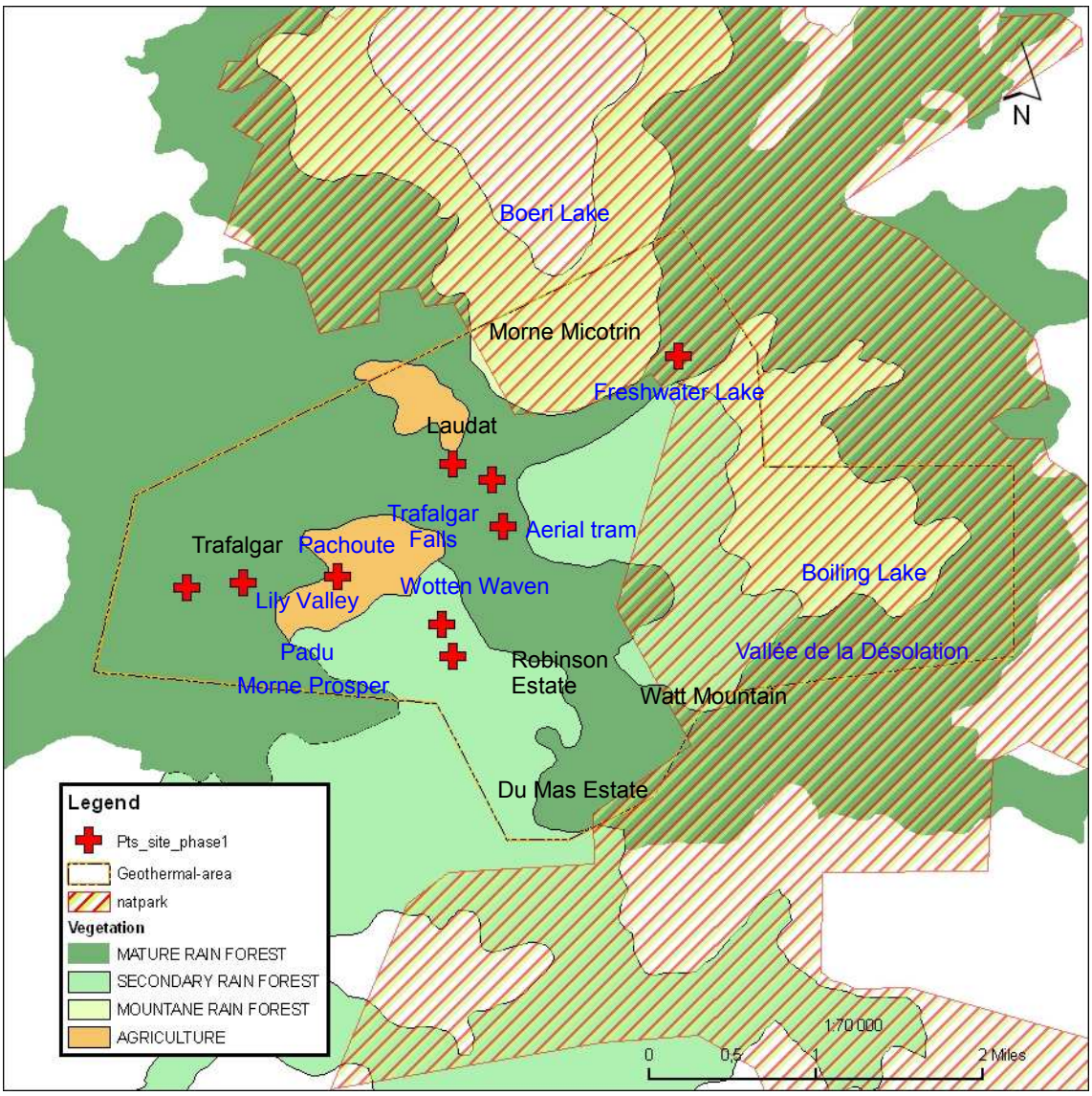
# 4 large zones identified

Large zone 1 is highly influenced by the Trafalgar and tourist activities. It is considerably degraded by past and present human activity.
Reed formations are regularly burned.
These are the natural areas and tourist sites that are most accessible.
All of Morne Prosper and Wotten Waven constitutes an agricultural sector.
This large zone 1 seems the most impacted by reeds which developed after roadworks.

Large zone 2 (Laudat, Aerial Tram, Titoo Gorge) is a sector of Rain forest where numerous trees are felled for development and economic reasons.

Large Zone 3 encloses a forest formation at different stages of development depending on the history of the individual place. The humid zone is a prairie with Symphonia globulifera trees, and whilst suffering the anthropic impacts, it merits special attention.

Large Zone 4 concerns hydrophilic mountain and summit forests, Elfin forest. It is extremely sensitive and is home to numerous native Dominican species. These species can also be found on the Island.
River banks and ravines are the key places for any environmental study. They exercise essential ecological functions such as the prevention of flooding and erosion, and the habitat for varied fauna, etc.




Sites in blue=area inspected for Fauna/flora expert study

## Habitats found:

- Mesophile forest
- Dense tropical hydrophilic forest: **Laudat**, **Middleham** and the **Heights of Wotten Waven**
- Hydrophilic mountain forest: **Morne Micotrin**
- Transitional forest: **Freshwater Lake** and **Boeri Lake**
- Vegetation specific to volcanic summits: **Valley of Desolation** and **Boiling Lake**
- Bromeliad summit prairies
- Vegetation of fumarole sites: certain zones of the **Valley of Desolation**, **Wotten Waven**
- Humid zones (prairies and swamps): **Morne Watt, Wotten Waven** and **Pachoute**
- Cultivated vegetation: **Wotten Waven** and **Pachoute, Aerial tram, Fond Cani & Lily Valley**

# Humid zones

## Open herbaceous prairies:

- Vegetation made up of plants, predominantly hydrophilic such as grasses and sedges.
- Characteristic taxa: ferns (*Nephrolepis multiflora*, *Pterolepis glomerata*, *Thelypteris reticulata*, *Ludwigia octovalvis*), rushes (*Fuirena umbellata*), sedges *Eleocharis mutata* et *Eleocharis flavescens*





***Eleocharis sp*. and *Pterolepis glomerata***

## Wooded wetlands:

- Wetland area colonised on its external borders by Pink apples *Syzygium jambos* or apricots *Clusia major*

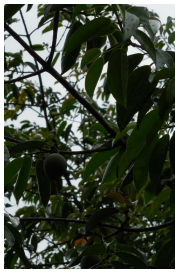




- Dominant taxa: Yellow mangroves (*Symphonia globulifera*) and epiphytes







# Rain forest

Luxuriant formation of tall trees. It reaches between 500 and 1 000 metres altitude with an annual rainfall of 2 000 to 5 000 mm and a temperature varying between 20 and 25°C

The dense forest is characterised by shelves of vegetation made up of different plant groups. The internal layout reflects the competition between species for space and light.

It is made up of nearly 300 species of trees and shrubs.

The dominant trees are the gum tree (*Dacryodes excelsa*), the Bwa dyad (*Licania ternatensis),* the Karapit (*Amanoa caribaea*), the "Chatannyé" (*Sloanea spp*.) and the "Bwa kot" (*Tapura latifolia*).



**Bwa kot Tapura latifolia**



**Bwa riviyè *Chimarrhis cymosa***







**Tectaria trifoliata, Epidendrum sp. and Erythrodes plantaginea**

It is also made up of a large number of ferns and orchids.

# High forest with low vegetation: Montan forest

The mountain forest is subject to fairly low nocturnal temperatures, winds that can be strong, rains (rainfall over 8 000 mm) and significant cloud at this altitude.

The vegetation has adapted to these difficult environmental conditions. The trees and bushes are smaller and sturdier, thanks to their ball shape. The forest appears closed, practically impenetrable with an abundance of shrubs.

Large herbaceous, other than grasses, with large leaves such as Heliconiaceae (*Heliconia bihai, Heliconia caribaea*), land Cyclanthaceae (*Asplundia insignis, Asplundia dussii*), Gesneriacea (*Besleria*), Zingiberaceaes (*Renealmia*, *Costus*) and Rubiaceaes (*Psychotria*) characterise this forest.



*Heliconia bihai*



*Besleria*



Anthurium



Elaphoglossum

Epiphytes, mainly vascular, and pseudo-lianas are very abundant.

The microclimate favours these plants, including Araceaes (Anthurium, Philodendron) and ferns, in this case Elaphoglossum, Polypodium, Trichomanes.

# Cultivated zones

Man has mainly cleared mid-humid forests for the requirements of urbanisation and to ensure a source of food (crops, pasture).



Miskad *Myristica fragrans*



Mango *Mangifera indica*



*Vangueria madagascariensis*

Cultivated species joined or replaced the original vegetation at this level. The landscape has been enriched by ornamental plants, fruit trees, food plants, herbs and stimulant plants.

Ancient degradation allowed the installation of species that were initially cultivated, or often escaped from garden settings. They are now widely naturalised to the point of becoming Alien Invasive Species.

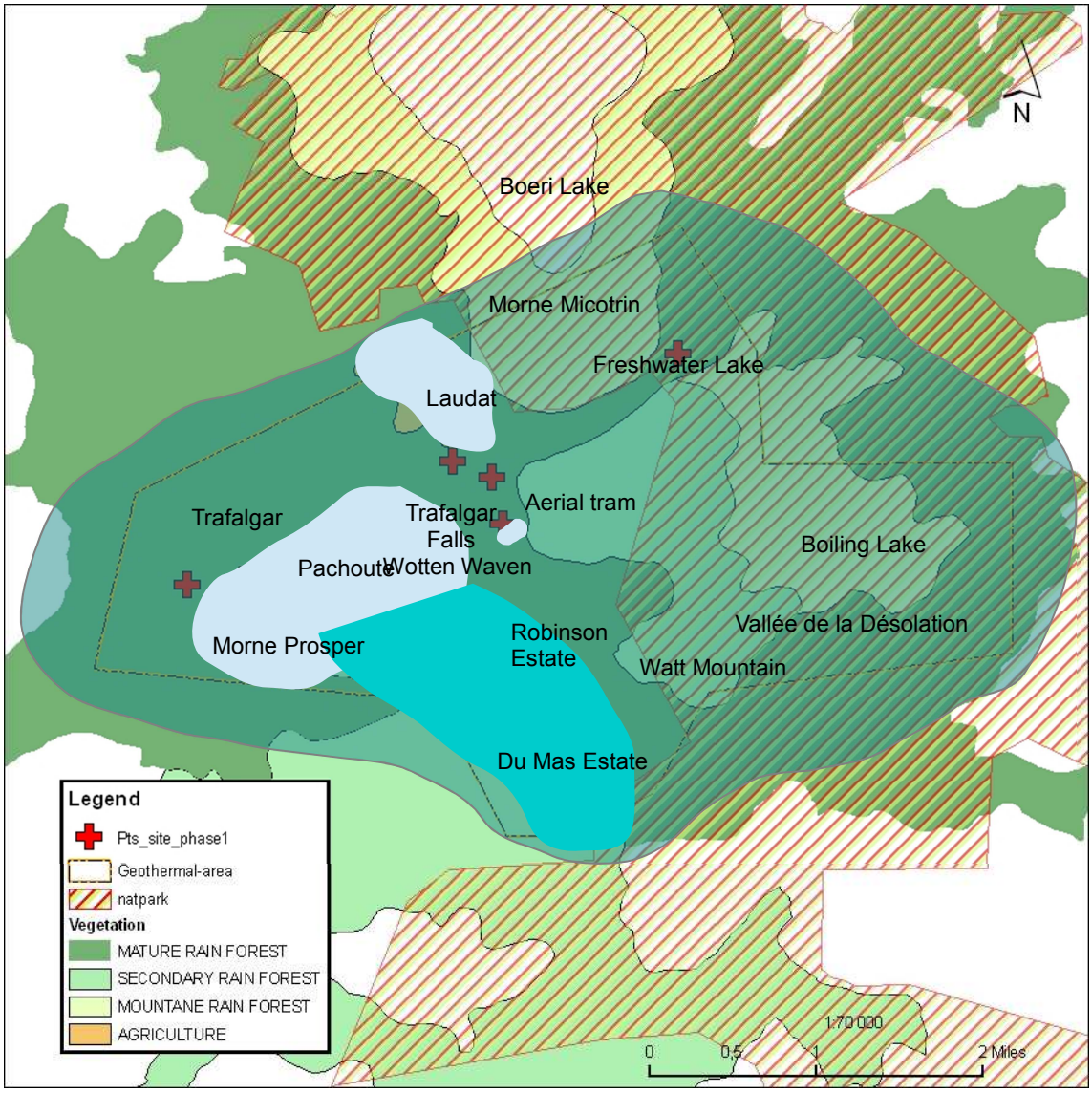


Coconut palms and Gabon tulip tree



Kè a bèf *Annona reticulata*

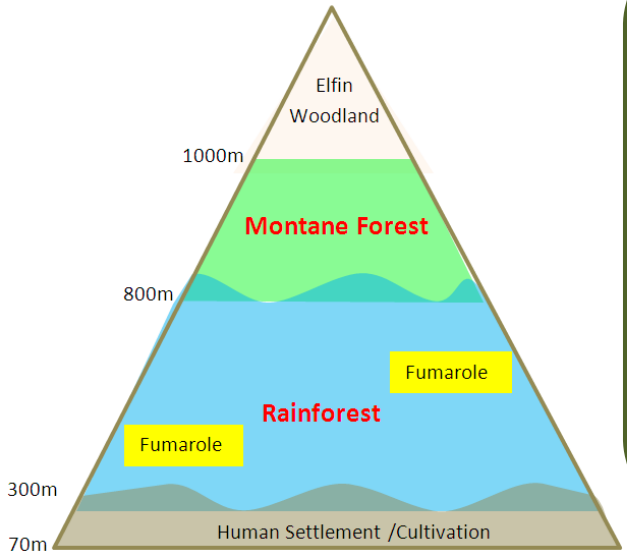
# Environmental sensitivity maps




Sensitivity 1 (low) = agricultural and urbanised environments under strong anthropic influence

Sensitivity 2 (medium) = lightly urbanised environments of mid altitude with almost unaltered vegetation

Sensitivity 3 (high) = sub climactic natural environments, mainly dense tropical forest and high altitude formations




## Most sensitive habitats for fauna:

The **Montane Forest** and the **Rainforest** are habitats presenting the greatest biodiversity and the largest abundance of individuals of interest (native, protected, etc.)

Other habitats are more inhospitable for fauna

**Location of 5 types of ecological habitats distributed by altitude in the project zone: Roseau Valley**


Montane Forest at Freshwater Lake



Boa constrictor Tet Chien (Boa Constrictor)



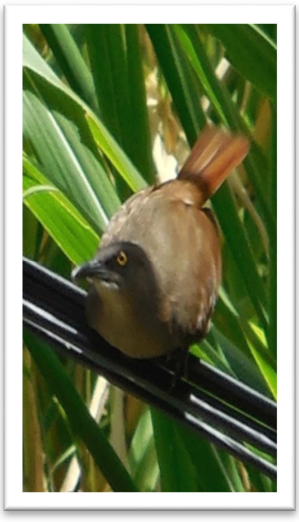
Tree Frog (Eleutherodactylus amplinympha



Hercules Beetle (Dynastes hercules)

## Valley fauna

- 4 types of vertebrates : birds, mammals, reptiles and amphibians
- Mammals and reptiles are uncommon (number of species and abundance). 12 species of bats are found in the Montane forest and the Rainforest. The study of their population is to be extended.
- Bird fauna is the best-represented group (176 species listed by Durand and Baptiste) with the most species of ecological interest: 3 species have the status of threatened at the UICN[1] and 2 are protected in Dominica, 10 species native to the Lesser Antilles.



Brown trembler



Sisserou parrot (Amaazona imperialis)



Blue headed Hummingbird (Cyanophaia bicolor)

[1] International Union for the Conservation of Nature - http://www.iucn.org/fr/

# Location of the most difficult fauna issues

- Primary forest (rich and serving as a biodiversity reservoir, e.g. Parc National–Central Forest Reserve)
- Corridors used by species to circulate between their principal habitats. The recommendation is to avoid fragmenting habitats
- Existence of some reservoir islands like Morne Prosper, the favoured habitat of the Red Parrot, to be preserved
- **band of 300m around the National Park** of Morne Trois Pitons

Other habitats are less favourable to the development of fauna

# SECTION 4: SOCIO-ECONOMY / LIFESTYLE

## Aims of this section

To present a socio-economic overview of the Roseau Valley taking account of the following components:

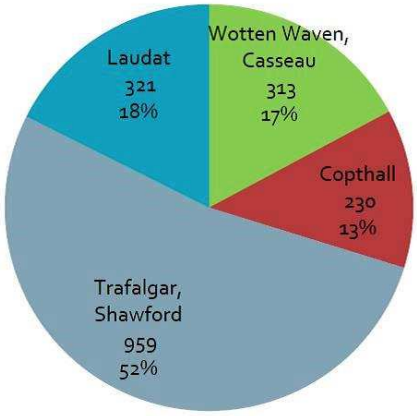
- Population and lifestyles
- Education
- Health
- Habitat
- Insecurity and criminality
- Employment
- Economy
- Governance

## Methods used

- Analysis of bibliographical sources
- Interviews (25)

## Population and lifestyles

- Half of the population is located in Trafalgar (Central statistical office, 2011) :




- Population development of 32% between 2001 and 2011, partly due to the proximity of Roseau
- Average 2.7 people per household
- Relatively high standard of living compared to the rest of Dominica
- 80 % of residents speak Creole as well as English, the official language

## Education

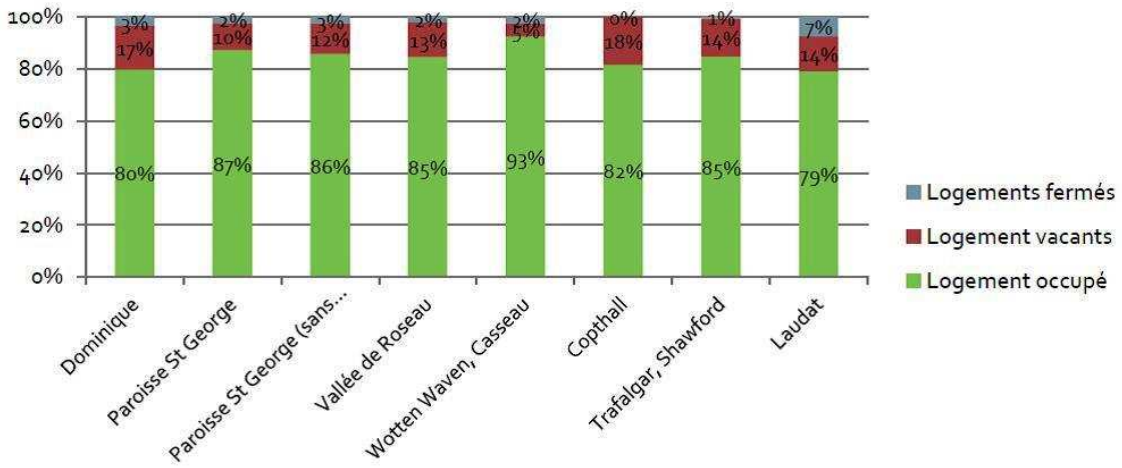
- Primary school in each village in the valley
- Secondary school at Roseau only
- High level of scolarity as school is mandatory to secondary level (97-98 %)

## Health

- Three health centres in the valley: Trafalgar, Wotten Waven and Laudat
- Proximity of the capital Roseau and particularly the Princess Margaret hospital
- No health data concerning the Roseau Valley
- A relatively high number of people over one hundred years old and a life expectancy among the highest in the Caribbean

# Habitat

- The valley had 769 dwellings in 2011 with low development over the past few years according to the Housing Ministry
- A little under one property in five is unoccupied or closed up (Central Statistical Office, 2012)




- All of the housing in the valley has electricity, with the exception of a few isolated houses.
- According to DOWASCO, all properties are connected to the drinking water in the valley
- Good quality of drinking water

# Employment

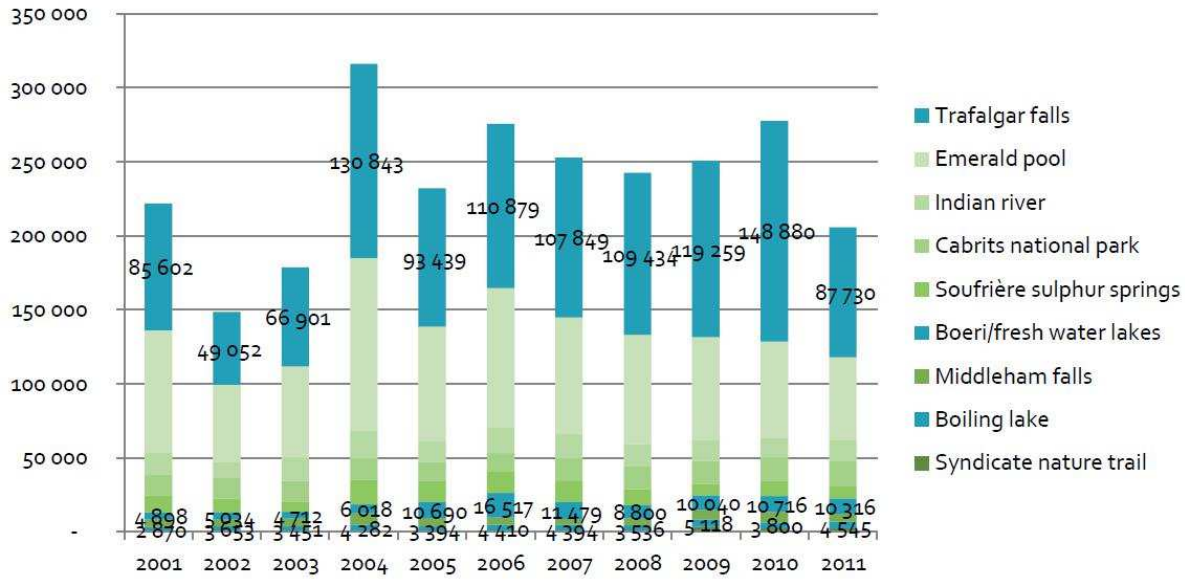
According to interviews, there is not sufficient employment in the valley, residents are obliged to travel to Roseau for work.

There is no data on unemployment rates in the Roseau Valley.

However, nationally, the unemployment rate is 11.1% for men and 17.6% for women.

# Economy

- Tourism and agriculture are the two pillars of the Dominican economy and, a fortiori, in the Valley which is the home of some of the most visited tourist sites on the Island (cf. Trafalgar Falls, Boiling Lake and Fresh water Lake)
- Visitor rates for the principal natural tourist sites in Dominica between 2001 and 2011 (sites in the Roseau Valley in blue) (Central Statistical Office, 2012)




- Increasing numbers of residents are leaving agriculture for tourism which they believe is more profitable.
- Like the rest of Dominica, the Valley suffers from certain economic problems: lack of employment and expensive accommodation. Young people are unable to stay.

# Governance

The Dominican political system allows significant participation of residents in public life. Its residents are therefore very involved politically. On a local scale, the territory is divided into districts, which are, themselves, divided into village councils. Officials in councils are appointed by the government they represent. One third of the officials, notably, are women.

# SECTION 5: ACOUSTIC

## Aims of this section

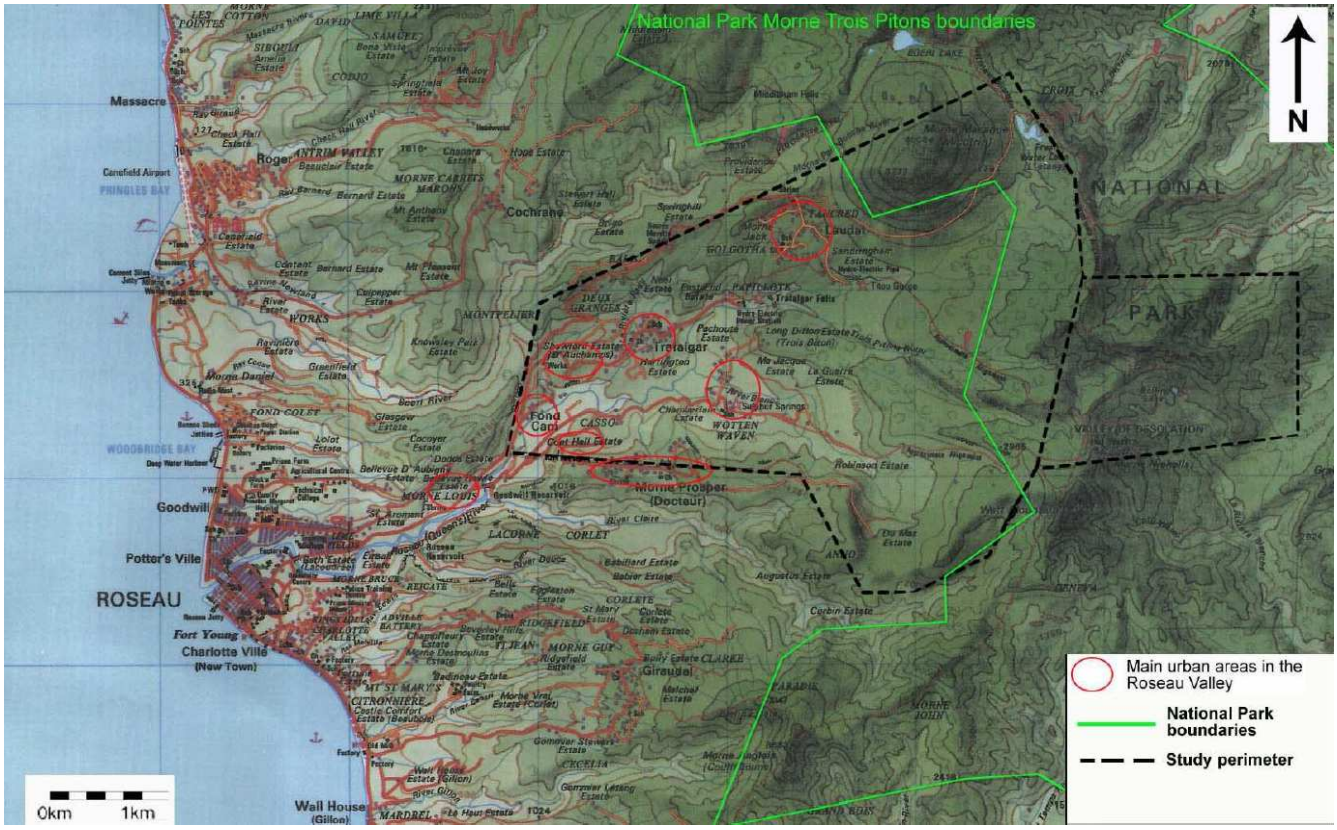
- Measurements of the sound level in the principal residential zones, the main tourist sites and valley hotels
- Determination of the initial “zero” acoustic level of the potential project zones
- Definition of the maximum sound levels to be authorised after the three geothermal installations are operative

## Methods used

- 2 noise measurement campaigns carried out in the tourist high season (December 2013) and low season (April 2014)
- 5 residential zones studied: Laudat, Fond Cani North / Fond Cani West & South, Trafalgar, Wotten Waven, Morne Prosper
- 54 acoustic measurement points analysed in day and night times










Trafalgar
Point 10: Trafalgar Falls



Fond Cani « West and South »
Point 7



Wotten Waven
Point 9

# Scenarios and standards used

- **Initial sound levels used:** minimum sound levels encountered during the two acoustic campaigns
- **Maximum authorised ambient sound levels:** the absence of Dominican standards means that the French standards for the limitation of noise in the environment by Installations Classified for Environmental Protection are applied.

# Key data regarding the initial sound level

- Ambient noise, mainly due to local fauna, human activity, wind noise in the vegetation and running water (rivers and waterfalls, etc.)
- Ambient sound levels are generally higher at night due to local fauna

  Ex: On Laudat, In December, sound levels close to property vary between 35.5 and 43.5 dB in the day and between 40 and 45 dB at night
- Higher ambient sound levels close to tourist sites and hotels

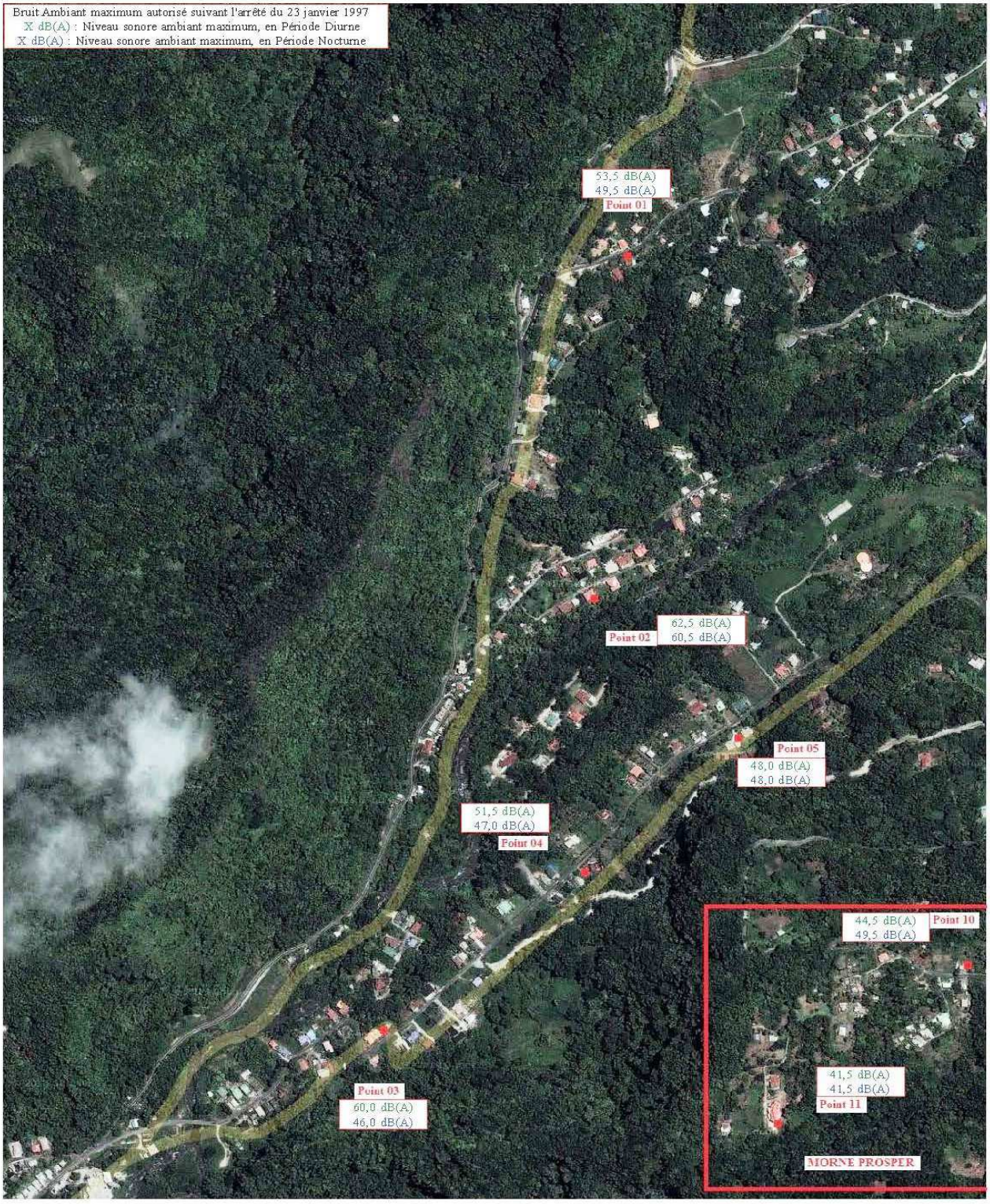
  Ex: Sound levels at Trafalgar Falls in April reach 55.5 dB




**Noise scale (source: www.bruitparif.fr)**

# Maximum authorised sound levels
# Example the site of Fond Cani "West and South"

**SITE DE FOND CANI « WEST & SOUTH » :**



# SECTION 6: CLIMATOLOGY – AEROLOGY

## Aims of this section

- Air quality measurement campaign enabling:
  - monitoring of concentrations of target pollutants
  - determination of potential health impact: sensitive or exposed zones, taking into account potential exposure to hydrogen sulphide
- Selection of the location and installation of a reference weather station, enabling measurement of the principal weather features over a year, in the absence of existing data.

## Pollutants considered

- Sulphur dioxide (SO2)
- Hydrogen sulphide (H2S)
- Nitrogen oxides (NOx)– Nitrogen dioxide (NO2)
- Fine dust PM10 and ultra-fine PM2.5
- Ozone (O3)

## Regulatory references

The absence of a local reference requires the definition of reference values using an analysis of the regulations in force in Europe as well as the United Kingdom, complemented by WHO recommendations.
Air quality data for the air in Guadeloupe and Martinique are also taken into account.



Weather station installation



## Methodological approach

- Situational analysis of environmental data in terms of air quality and weather, topographic and climate data, etc.
- Identification of potential measurement sites
- Technical implementation of the weather conditions monitoring station
- Technical implementation of campaigns for air quality assessment: two measurement campaigns for 30 measurement points; one in the dry period and the other in the humid period

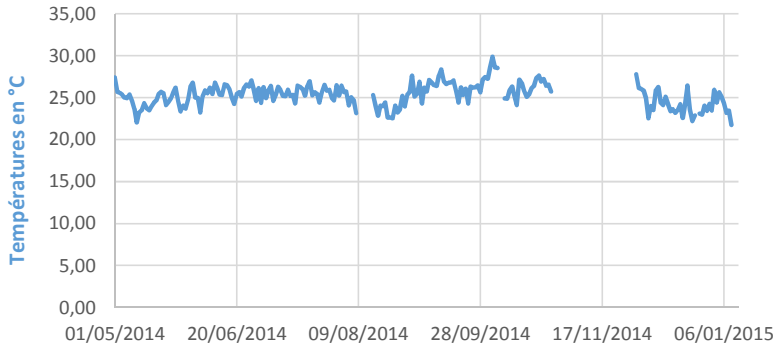


Air quality campaign measurement



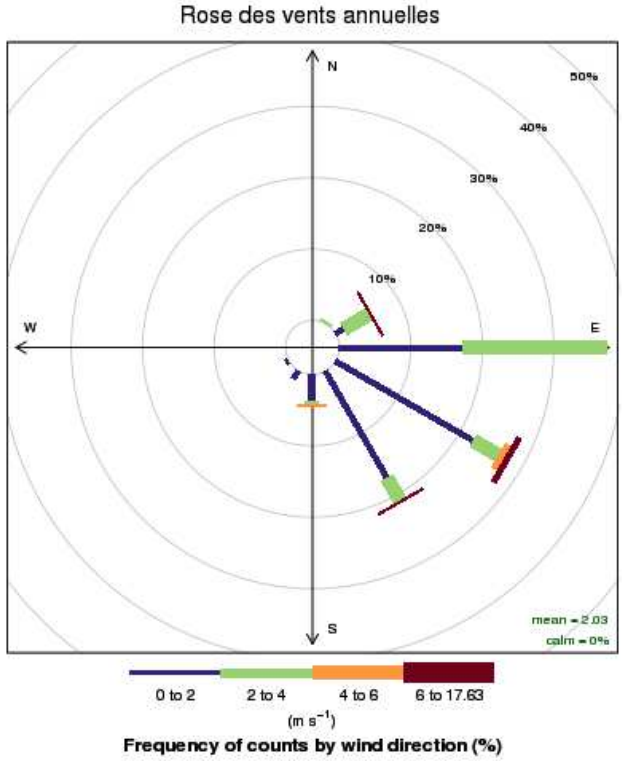
# Key weather data

Average daily temperature 25.3 °C




Low rainfall in 2014: daily average 0.08 mm

Elevated rain frequency in 2014: only 39 dry days in the year!




Predominantly south and south east sector winds with occasional south-south east sector winds in August and December; and north and north west in August and October.

Example of Trafalgar from 01/05/2014 to 09/01/2015

| Pollutants | Reference values considered for the study | |
|---|---|---|
| **PM10** | Limit value:<br>50 µg/m$^3$ average over 24 hours<br>40 µg/m$^3$ annual average | Recommendations WHO:<br>20 µg/m$^3$ annual average |
| **PM2.5** | Limit value:<br>25 µg/m$^3$ annual average | Recommendation WHO:<br>25 µg/m$^3$ 24 hrs<br>Quality goal and WHO recommendation:<br>10 µg/m$^3$ annual average |
| **$NO_2$** | Limit value – recommendations WHO:<br>40 µg/m$^3$ annual average | Limit value for vegetation:<br>30 µg/m$^3$ annual average |
| **$SO_2$** | Limit value:<br>125 µg/m$^3$/ day not to exceed 3 days pa | Quality goal :<br>50 µg/m$^3$ annual average<br>Recommendation WHO:<br>20 µg/m$^3$ average over 24 hrs |
| **$O_3$** | Target value:<br>120 µg/m$^3$ average over 8 hrs | Recommendations WHO:<br>100 µg/m$^3$ average over 8 hrs<br>French network reference values:<br>50 µg/m$^3$ annual average in urban station<br>60 µg/m$^3$ annual average in rural station<br>Reference values for the Guadeloupe and Martinique network:<br>34 µg/m$^3$ annual average in peri urban and urban stations |
| **$H_2S$** | Recommendation WHO for nuisance threshold:<br>7 µg/m$^3$ (over 24 hrs) | Recommendation WHO for the detection threshold:<br>0,2 µg/m$^3$ (over 30 mins) |

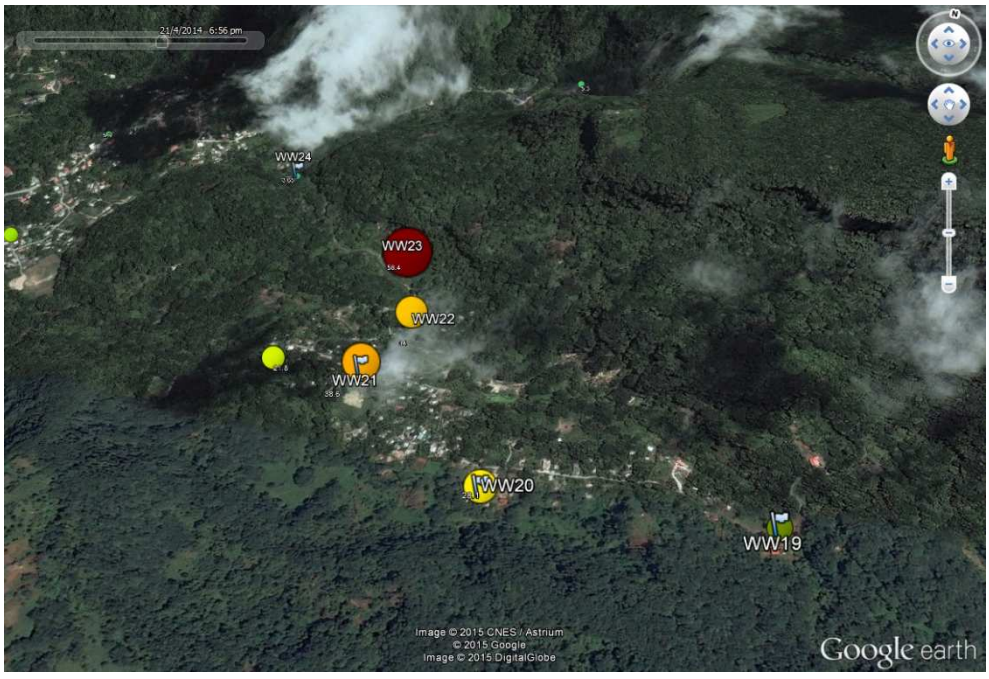
# Key data for measuring air quality

**The greatest pollutants are H2S and SO2:**

- Odour threshold 0.2µg/m3 systematically exceeded for H2S with 2 exceptions (Fresh Water Lake and a site in Laudat)
- Raised concentrations not related to drilling in December 2013 since higher levels measured in the second campaign (outside of drilling period)
- Natural emanation called “natural pollution” due to geothermal activity in the valley
- Possibility of odour nuisance for the population in view of the H2S peaks measured

Other pollutants did not have a threshold in excess of reference values.

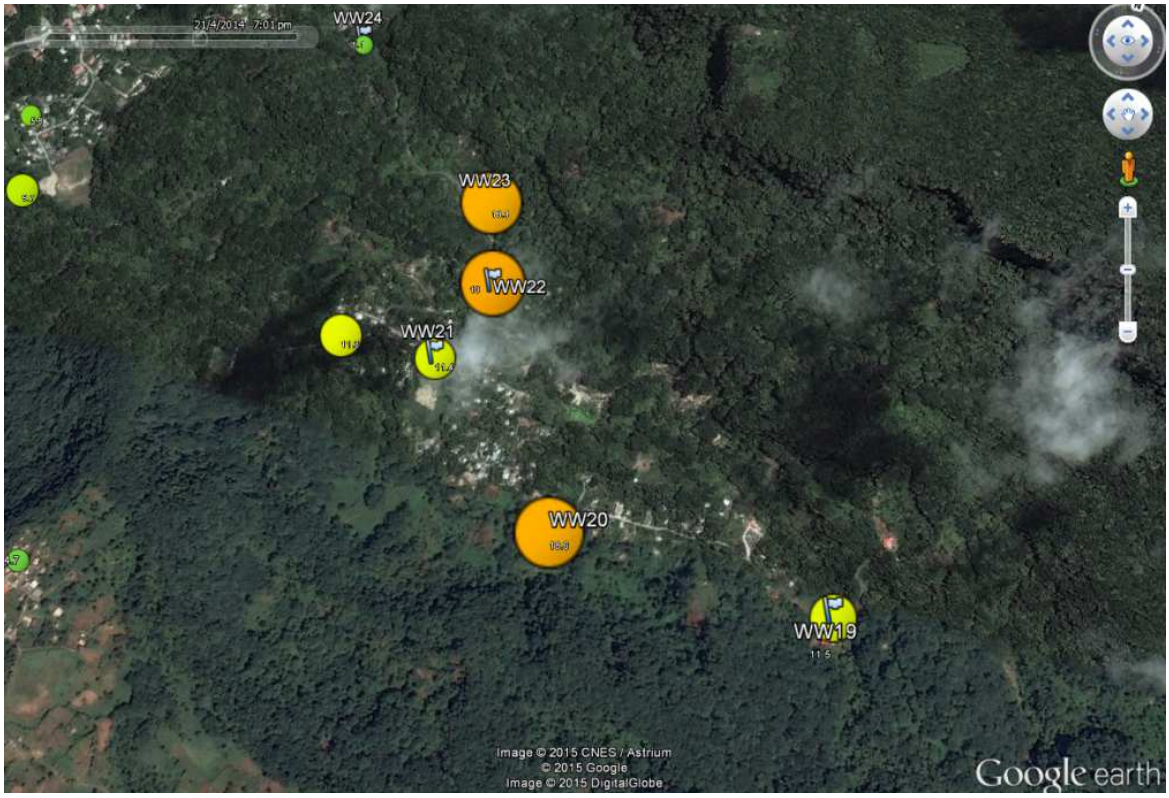
**The zones “sensitive” to SO2: Wotten Waven and Morne Prosper**; respectively 58.4µg/m3 and 64.3µg/m3 measured on average on the 2nd campaign, over the WHO threshold of 50µg/m3




Mapping focus on the Wotten Waven sites for average SO2 measurement

**Zones "sensitive" to H2S:** all sites are sensitive to H2S but the **Wotten Waven** site is more so than the others, with average values approaching 20µg/m3 and **30µg/m3** in certain residential sites.

N.B. : odour threshold fixed by WHO: 0.2µg/m3




Mapping focus on the sites of Wotten Waven for average H2S measurements

# SECTION 7: LANDSCAPE AND HERITAGE

## Aims of this section

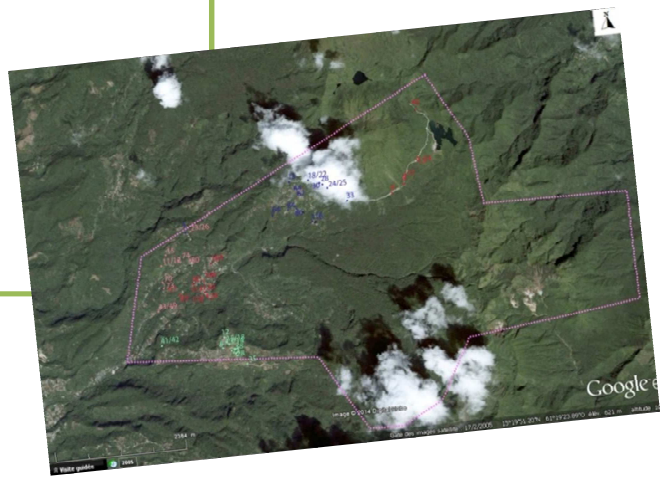
- Listing the historic heritage of the valley
- Listing archaeological/geological heritage of the valley
- Analysis of architectural developments of the valley under various influences
- Analysis of the landscape dynamic, past and present
- Listing landscapes of local interest/Analysis of iconographic representations of landscapes
- Listing visibility points

## Methods used

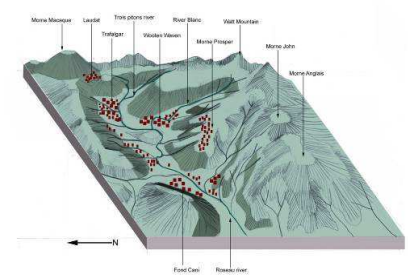
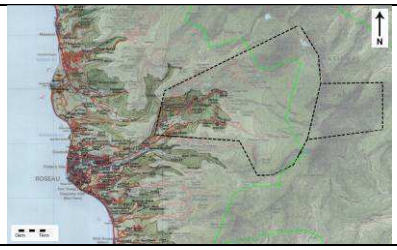
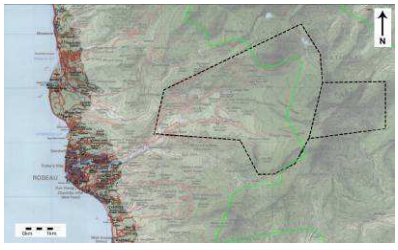
- Field campaigns:
  - Listing and location of view points over the valley from high points
  - Listing and analysis of landscape and architectural characteristics of the territory

- Meeting specialists and players on the territory:
  - A historian from Dominica, Mr Honychurch
  - A botanist, Mme Edwards
  - Residents, farmers from Laudat

- Documentary research and development:
  - For analysis of landscape development
  - For iconographic analysis
  - For analysis of architectural evolution



# Analysis of landscape components

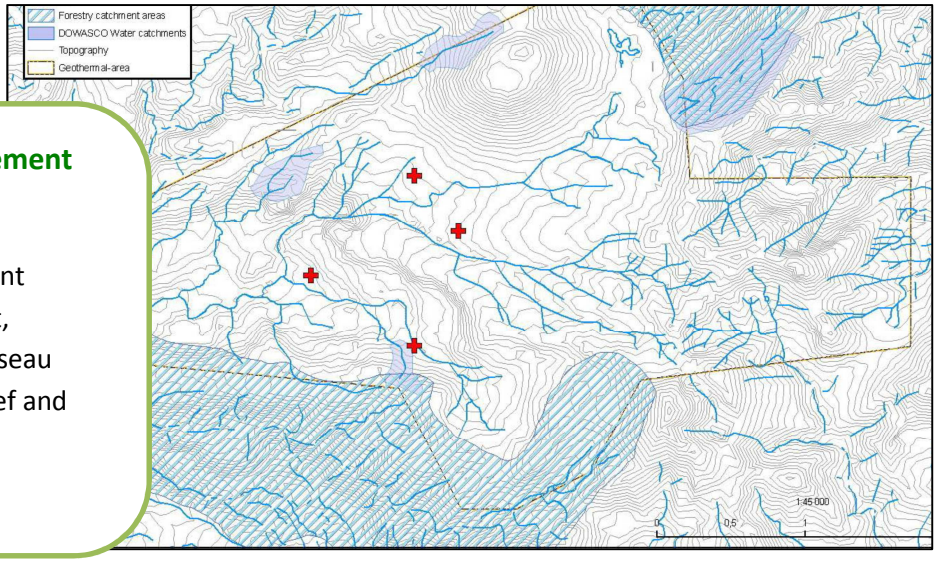
| *Landscape Units* | | *Characteristics* |
|---|---|---|
| *The majestic Mornes* |  | • Altitude up to 1 250 metres<br>• Organisation: series of mornes with westerly silhouettes<br>• Urbanisation: no urbanisation, inaccessible zones<br>• Perceptions: majesty, strength, respect, peace, Large landscape |
| *Powerful plateaux and foothills* |  | • Altitude: between 300 and 800 metres<br>• Organisation: two long main plateaux making transitions between the Roseau Valley and neighbouring valleys<br>• Urbanisation: urbanisation on the Morne Prosper plateau<br>• Perceptions: inaccessible, imposing foothills, balance (successive plateaux from successive levels), visibility (height) and open on the large landscape |
| *Urbanised areas* |  | • Altitude: between 150 and 250 metres<br>• Organisation: particularly in north and east part in the Roseau Valley<br>• Urbanisation: 8 urban communities distributed like clusters between the valley floors and the plateaux<br>• Perceptions: village spirit, tranquillity, small scale, residential, dynamism (constructions) |
| *Valleys perpendicular to the sea* |  | • Altitude: between 150 and 250 metres<br>• Organisation: series of narrow valleys perpendicular to the sea<br>• Urbanisation: at valley floor in clusters<br>• Perceptions: enclosed, shade, humidity in places, proximity to water |
| *Narrow urbanised plain* |  | • Altitude: between 0 and 150 metres<br>• Organisation: narrow and long, with sharp reliefs<br>• Urbanisation: spread out along the Roseau compared to valleys<br>• Perceptions: lively, heritage, architectural, markets, noise, travel (port and airport), opens to the sea |

## Presence of different forms of water in the Roseau Valley

- Lakes (Freshwater Lake)
- Rivers and Gorges (Titou Gorge)
- Boiling Lake
- Hot springs (Wotten Waven)
- Fumaroles (Valley of Desolation)
- Waterfalls (Trafalgar Falls)

## Water, structural element of the valley

**W**ater is an omnipresent structuring component, fundamental to the Roseau Valley sculpting its relief and influencing its human occupation.





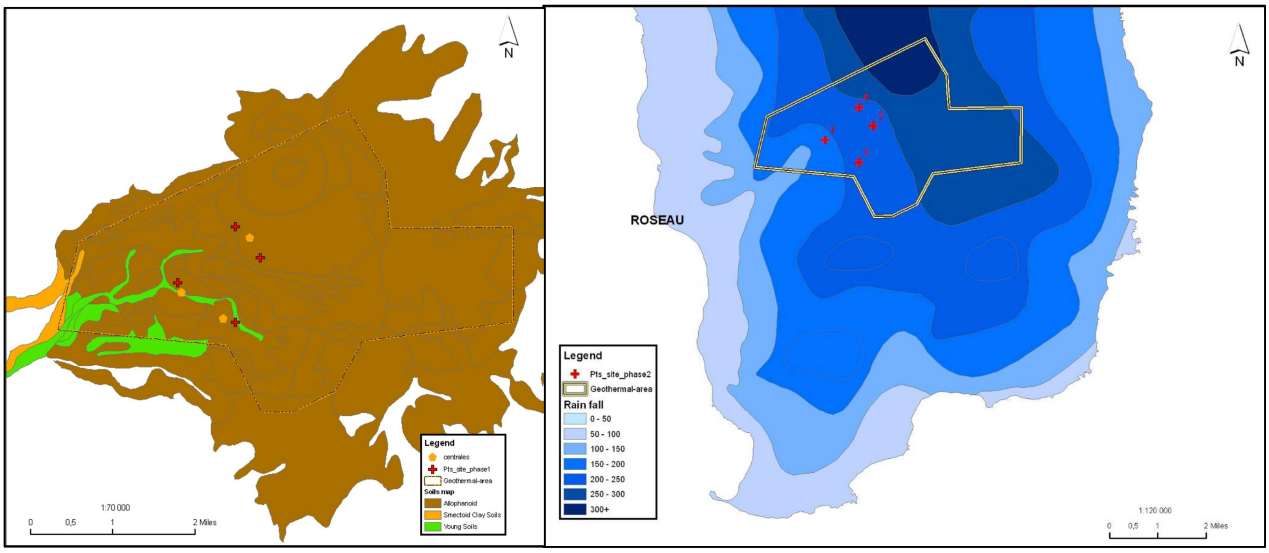

## Principal structured volcanic reliefs closing views above the Roseau Valley creating a sensation of unity:

- Morne Trois Pitons: 1423m
- Morne Micotrin 1221m
- Mont Watt: 1224m



**Geology, soil and climate characteristic of the Roseau Valley:** Land made of volcanic rocks with generally fertile and porous topsoil.

- Accidental landslip
- Young plateau soil, mornes and slopes made of clay to allophane
- Typical tropical humid climate: high temperatures and heavy rain
- Rainfall on the west coast (leeward coast) much more moderate




## Variable plant palette depending on reliefs, rainfall, soil nature, current and past use, enabling the following to be distinguished:

- Tropical forest
- Mountain forest
- Semi deciduous forest
- Vegetation of fumarole sites
- Swamp vegetation
- Savannah vegetation
- Vegetation of old fallow lands

### Luxuriant natural vegetation:

Rainfall, humidity and heat of the valley help create luxuriant landscapes, where vegetation is omnipresent. Whilst "natural" vegetation seems to erase most anthropic traces (houses etc.), it has been impacted by use and human activities, particularly urbanisation, the growing of crops and the creation of roads (cutting).

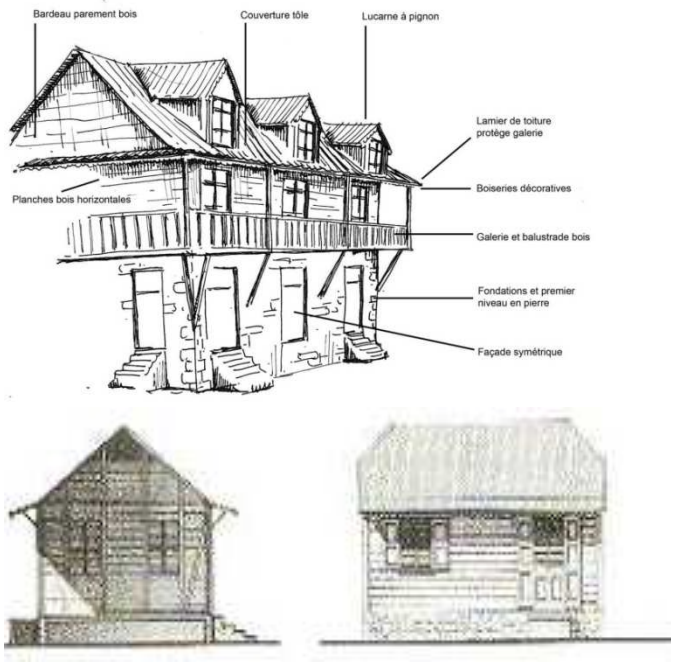


# Analysis of architectural developments in the valley in view of the various influences

**The complex and ancient history of human occupation of the island has led to numerous influences on current and past architecture in the Roseau Valley. We distinguish:**

- American Indian influences
- Colonial type houses
- Traditional XX$^{th}$ century houses
- Neo classic inspired contemporary villas

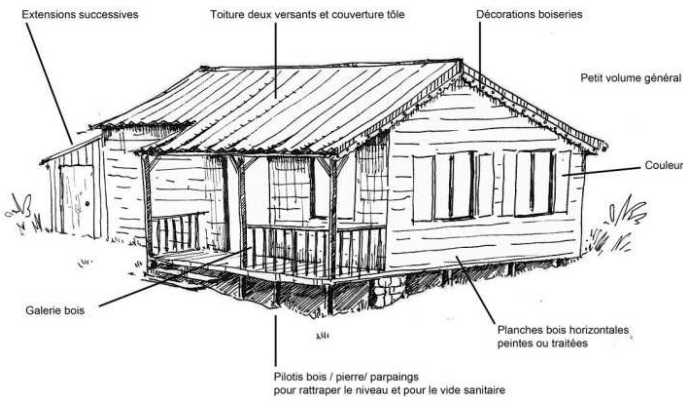
LA MAISON DE TYPE «COLONIALE»



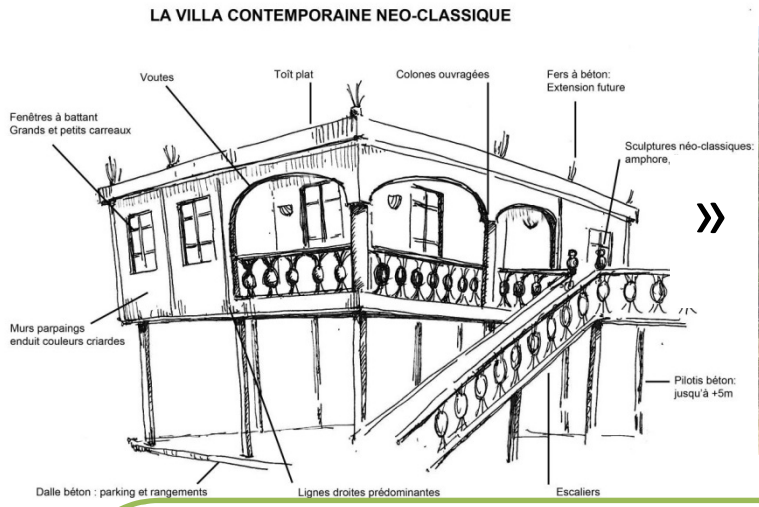





LA MAISON TRADITIONNELLE








### Multiple architectural influences:

The town of Roseau was built on the site of the former Sairi village of the Kalinago Indians, the oldest town on the island. It has a combination of contemporary, modern and colonial architecture in French and British styles, since the island was successively in the possession of France, until 1814, and then England.

Many architectural elements have traversed history, whilst continuously adapting to development and access to new construction materials to address the constraints and peculiarities of the environment (topography, humidity, heat, run-off, hurricanes forest cover).

## Infrastructures reflecting the constraints and natural advantages of the valley

### Equipment that shape and enhance the landscape:

- Mountain top roads (etc.)
- Valley bottom roads
- Electricity production equipment
- Aqueducts
- Bridges













## Agriculture characteristic and creative of landscapes:

With its humid climate, the Roseau Valley is favourable for the development of agricultural activity.

Agricultural use of the valley land is closely linked to its soil: younger soils are better for growing crops. This soil can be found mainly on the top of *Morne Prosper* and at the bottom of the valley of *Trafalgar* and *Wotten-Waven* where vegetables, condiments, herbs and orchards grow. These agricultural plots have great views over distant landscapes, limited by the valley hill crests.

However the steep slopes make the exploitation of land difficult. The types of cultivation are therefore very different: here small subsistence crops are grown related to the residential areas.

## Ornamental vegetation embellishing villages:

Cultivated vegetation, the mark of land appropriation, is widespread in the valley.

These initiatives, mainly personal and voluntary, which decorate the division between public and private areas, give a certain style and character to the valley.



# Visibility points

## A road network giving a view of the valley landscape:

- From hilltop roads
- From roads on the valley floor
- From valley villages

**Analysis of views across the valley and potential geothermal exploitation sites:**

The steep relief, crossed by several roads and lanes, gives remarkable visibility points over the Roseau Valley from a number of urban, rural or natural levels. Within the framework of the geothermal project it is important to record the most noteworthy views across the valley from the most frequently visited places, in order to identify the view points and take them into account when choosing potential geothermal production sites.

**Each noteworthy view point identified was described using the following criteria:**

- GPS coordinates
- Orientation of the photo
- Degrees of optical view
- Position on a map

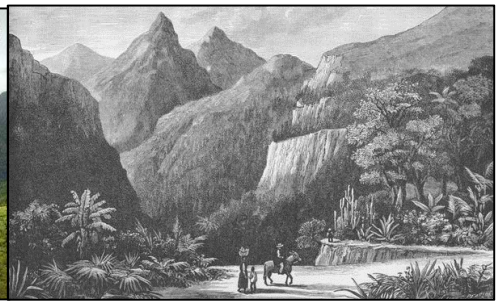


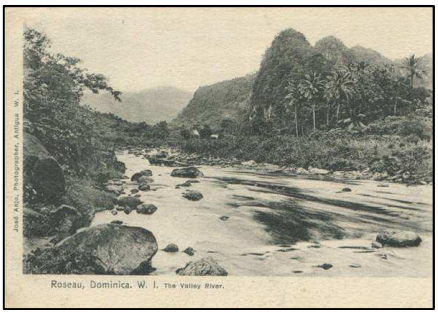
# Scenery of local interest





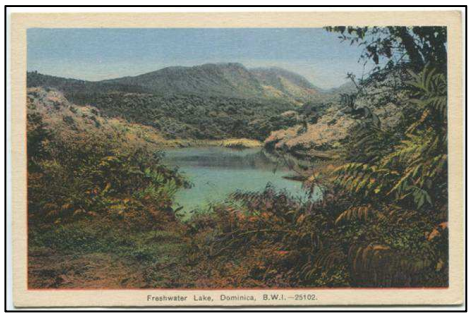













## Virgin nature landscape symbolic of the country across the Caribbean:

The iconographic and tourism documents considered during the study show a similar image of Dominica. Since the end of the XIXth century, the image commonly used to represent Dominica is the Garden of Eden. An almost virgin natural area where the sole anthropic presence takes the form of traditional occupation rooted in its territory and its scenery.

Water is, without a doubt, the element the most frequently represented in the iconography studied (drawings, postcards, antique books and magazines, etc.):

- Fumaroles of the Valley of Desolation
- Springs
- Mountain lakes, specifically Freshwater Lake
- Torrents and rivers, particularly the Roseau
- Waterfalls, particularly Trafalgar Falls
- Boiling Lake
- Forest crests of Trois Pitons National Park and the Waitukubuli National Trail

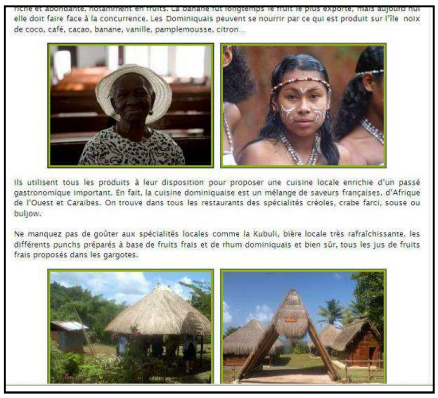
## Authentic scenery symbolic of a life philosophy rooted in tradition:

The idea of a people that has remained "authentic" is widespread in the various communications media and the introduction of Dominica and especially in the Roseau Valley.

We note that this imagery is not disconnected from the genuine respect that the population has for nature. There is a culture, even a shared ethic around the environment. This vision of the world may be viewed as the heritage of African populations sent to Dominica as slaves, whose religion was animism.

Today, the Rastafarian culture, with its Somalian roots, widespread in Dominica since the 1970s, particularly in the areas of the valley bottom more secluded than Roseau, is also the expression of an "environmentalist philosophy" of life.





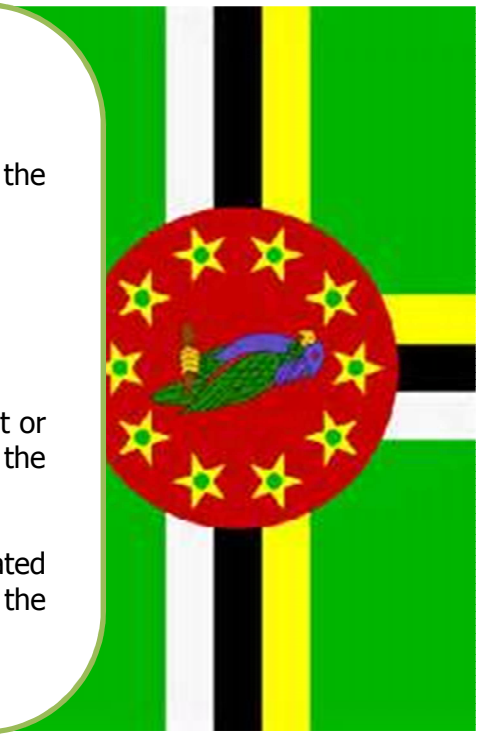

## National iconography: the flag

The three bands of colour represent the three major aspects of the Dominican island scenery:

- Yellow for the sun and the main crops of bananas and lemons
- Black for African heritage brought by colonisation
- White for European influences, rivers and waterfalls.

At the heart of the central red circle of the flag is the *Sisserou* parrot or *'Amazona imperialis'*, symbol of the Dominican equatorial forest and the national bird.

The image of the country provided by the national flag is orientated more towards the land than the sea. Green is very dominant and the blue of the sea is absent, unlike the flags of most Caribbean Islands.



# Anthropic landscape dynamics

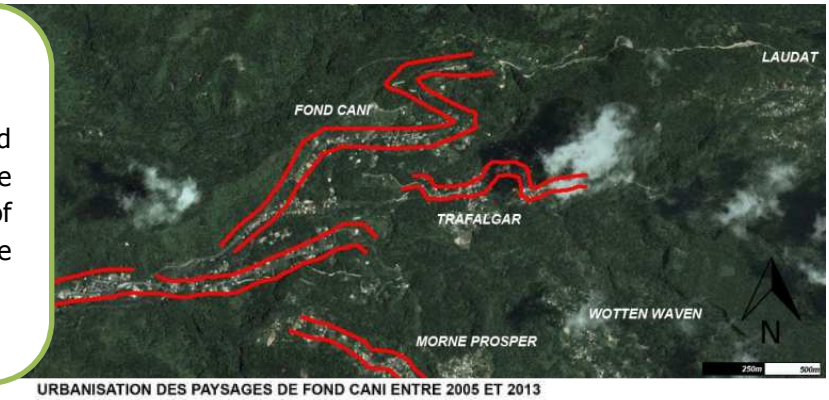
## Fallow agricultural plots

Mountain slopes at the bottom of the Roseau Valley are today only rarely cultivated. Some colonial exploitations remain, some isolated Creole gardens, but the trend is more towards abandoning inaccessible land and the shallow soil of the slopes.




## Linear urbanisation

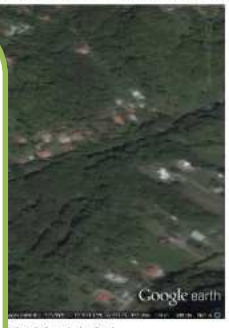
The search for a pleasant lifestyle encouraged suburban urbanisation of the Roseau Valley along the main road, expanding existing hamlets. The risk of this is the elimination of urban limits and the transformation of the scenery.




URBANISATION DES PAYSAGES DE FOND CANI ENTRE 2005 ET 2013

## Urban sprawl

Housing estates are the most visible representation of horizontal urbanisation in the area. These estates or groups of houses built at the same period are built independently and apart from traditional residential areas and call territorial organisation into question.




Cani depuis le Sud



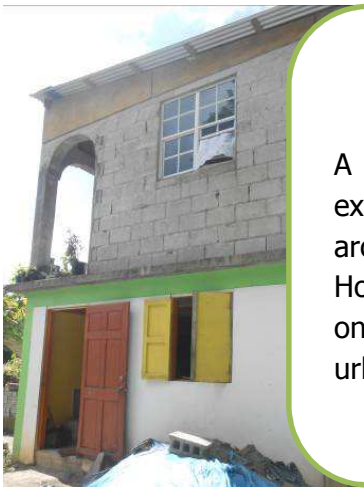

Photo aerienne 2013 Fond Cani depuis le Sud

## Modification of land use and occupation

The Roseau Valley is popular for addressing the growth of urbanisation. It shows signs of change (recent, non-concentrated urbanisation and a road network less and less suitable for users' needs).

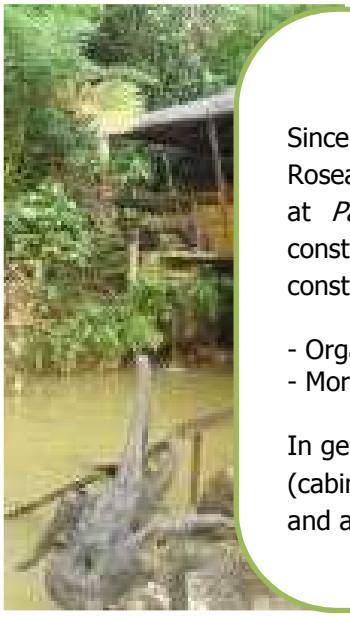
The population living the valley mainly works in the capital. On its doorstep this vast forest area offers free land and an exceptional lifestyle. The busier coastal plains have no more development potential and Dominica seems to be heading future development towards secondary valleys and some central plateaux.

Valley infrastructures dedicated to energy (hydroelectric stations, reservoirs), the various urban communities being developed as well as the development of tourism all bear witness to a real dynamism.



## Vertical urbanisation

A current pattern of construction can be seen in the Roseau Valley, the extension of existing habitats. A patchwork of materials colours and architectural styles in the same urban setting can be most unexpected. However the advantage of this vertical urbanisation is that it does not impinge on surrounding agricultural or forest lands. It even helps strengthen the urbanity of some underpopulated and undefined suburbs.



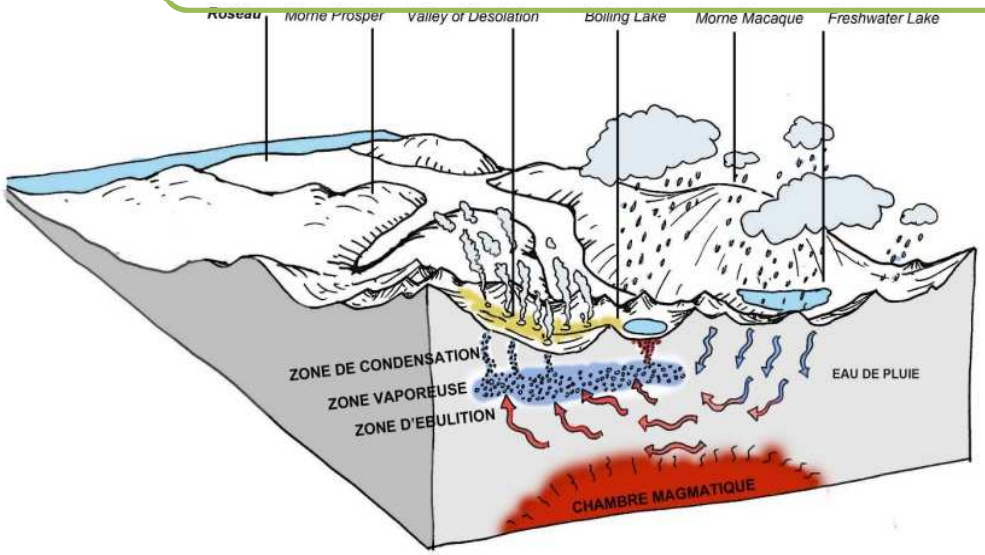
## Tourist development in the valley

Since the 1990s there has been a considerable development in tourism services in the Roseau Valley. This is centred on walking and the hot sulphur water spas particularly at *Papillote* and *Wotten Waven*. This development has been accompanied by construction in the area, or renovation of buildings for hotels and restaurants. This construction has different aspects:

- Organised and high-level and integrated into the valley scenery
- More spontaneous

In general, buildings and tourist amenities are created with genuine care. Architecture (cabins) and materials (wood) used integrate a natural aspect into this environment and add to the cachet of the valley.

# Natural landscape dynamics




## Hydro thermal influences

The *Valley of Desolation* is an uncertain landscape that is permanently evolving. From one day, month or year to another, the fumaroles and water table events are very irregular in both frequency and quantity.

# Historic heritage



## Agricultural heritage

In *Wotton Waven*, is one of the rare agricultural ruins to be seen in the Roseau Valley, dating from the XVIII$^{th}$ century. Today only the river-stone walls of this watermill remain.

This ruin evokes the agricultural and colonial past of this enclave.



## Architectural heritage

A few attractive town houses, some dwellings or publics buildings in stone have resisted the hurricanes to remain visible in the valley, especially in *Roseau*. These bring the external cultural influences that the country has known across the decades.



## Small heritage

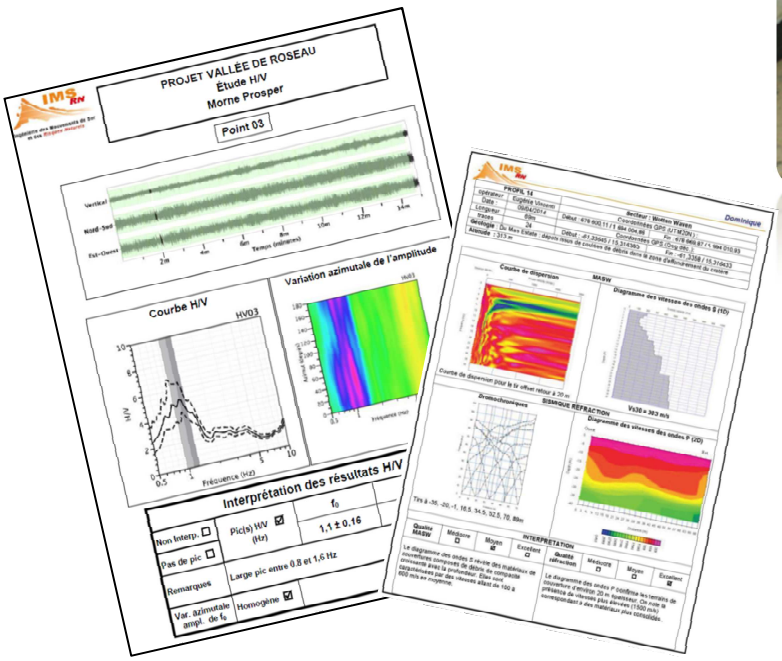
The history of the *Roseau Valley* has mostly been written by the farmers, slaves or otherwise, who, over the centuries, cultivated and sculpted mountain sides that have now mostly returned to forest.

The history of the territory and important events such as access to freedom and property for certain communities or major climate phenomena (devastating hurricanes, etc.) can be seen in numerous sculptures and markers.

# SECTION 8: NATURAL RISKS

## Aims of this section

- Listing historical events
- Identification of circumstances leading to these phenomena
- Hazard mapping









## Methodology

Collection of bibliographical data was carried out for the Roseau Valley. This enabled missing data to be identified, specifically:

- For flooding, the measurement and monitoring of water flow rates in the valley
- For earthquakes and land movements, historical documents recounting these hazards or a precise geological map of the valley.

This collection was complemented by field data amassed when travelling in Dominica.

This field data allowed the determination of:

- The hydrological characteristics of the valley (water tables, flooding zones, population survey).
- Natural phenomenon index (lithology, slope, geomorphology)
- Correlation with hazards observed on neighbouring islands

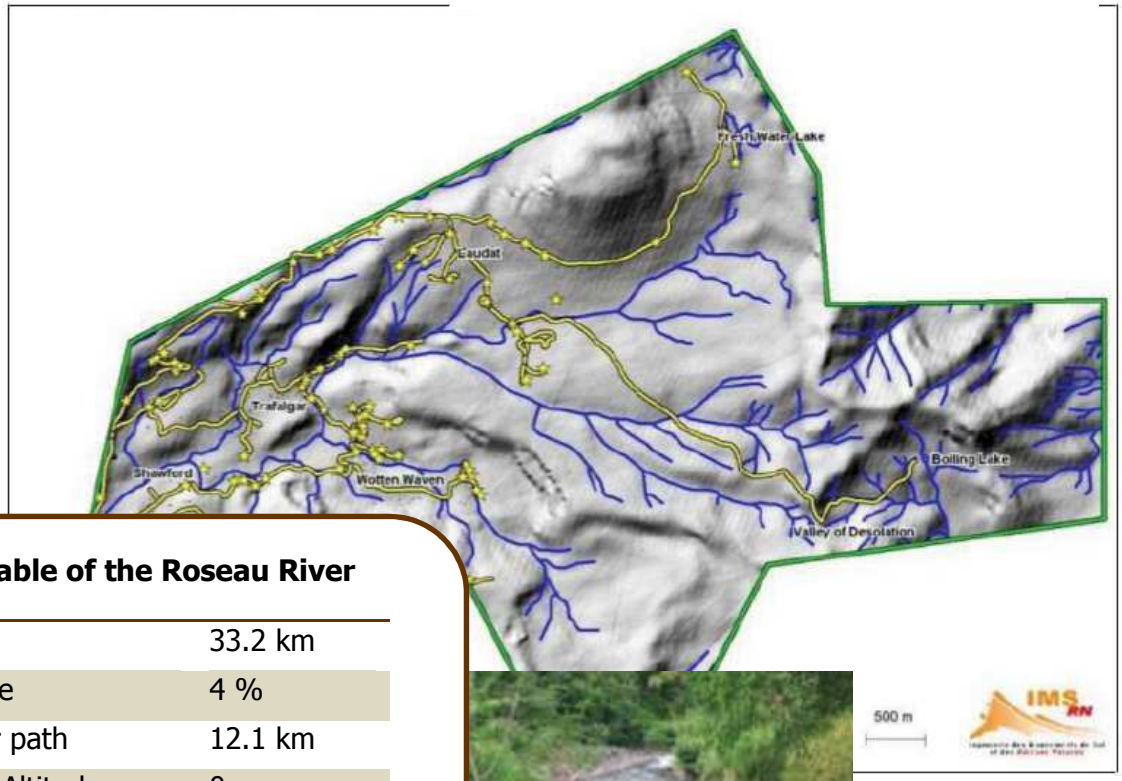
Analysis of this data led to the creation of modelling and hazard mapping for the valley.

## Methods used

- 4 field campaigns between December 2013 and April 2014
- Modelling of floods for ten and one hundred years in the Roseau Valley
- Geophysical measurements
- Analysis of aerial photos
- Analysis of geological maps
- Recognition of geological formations in the field
- Population survey on past hazards

# Results – Flood risks

*PATHWAYS AND OBSERVATION POINTS FOR GROUND MOVEMENTS*




**Water table of the Roseau River**

| | |
|---|---|
| Surface | 33.2 km |
| Average incline | 4 % |
| Longest water path | 12.1 km |
| Altitude min - Altitude max | 0 m - 1 200 m |
| Concentration time | 2.8 h |



*Rivière Roseau*



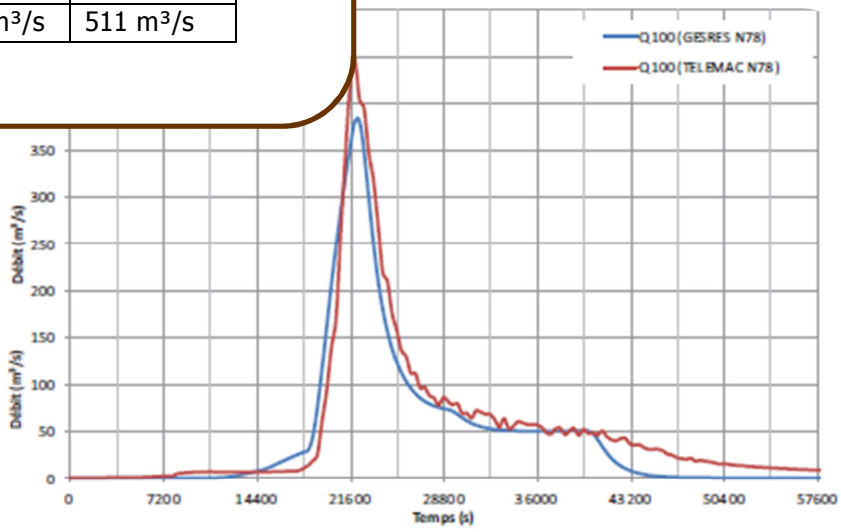
*Rivière Roseau dans la traversée du centre de Roseau*

## Hydrological modelling GESRES[ISL]

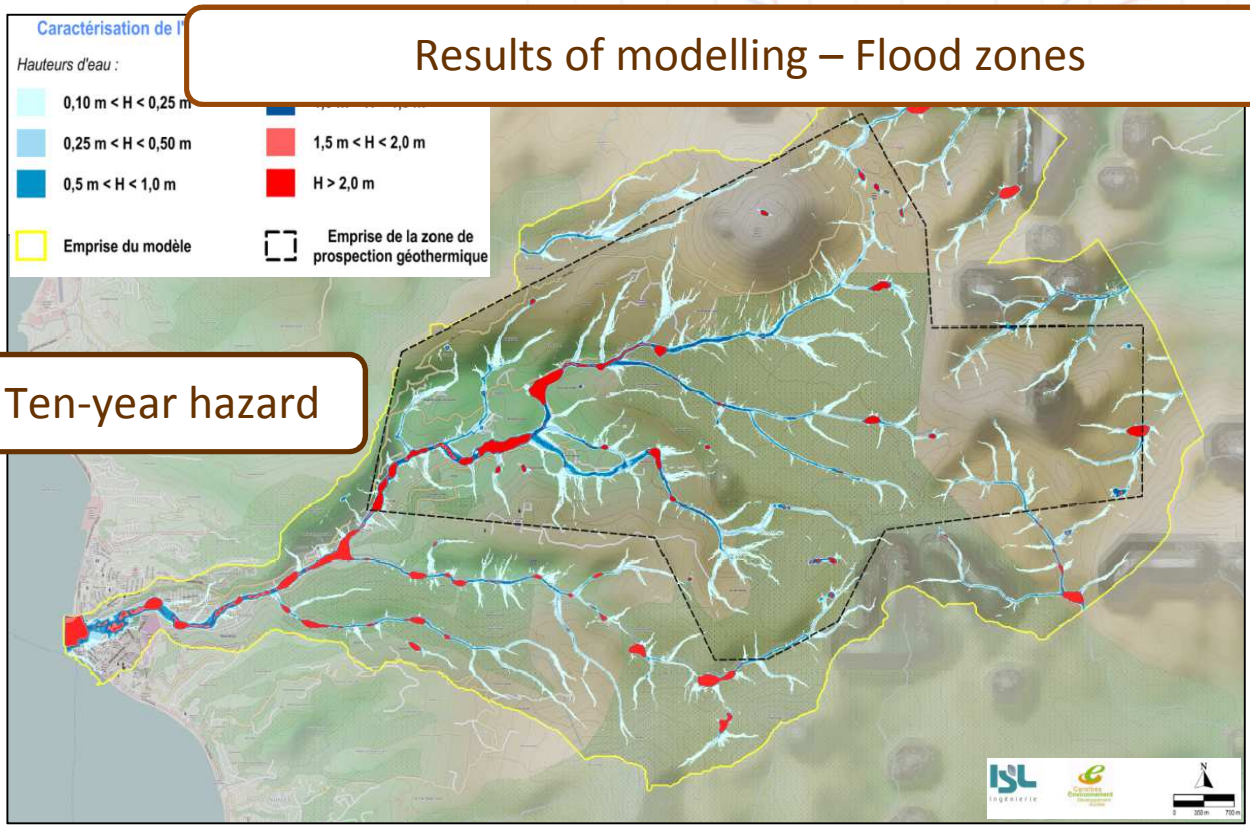
| | T = 10 yrs | T = 100 yrs |
|---|---|---|
| | | **Peak flow** |
| Downstream of study zone | 244 m³/s | 384 m³/s |
| Upstream of Roseau | 378 m³/s | 597 m³/s |
| Mouth of Caribbean sea | 324 m³/s | 511 m³/s |



*EXAMPLE: MODELLED HYDROGRAPHS*




## Results of modelling – Flood zones



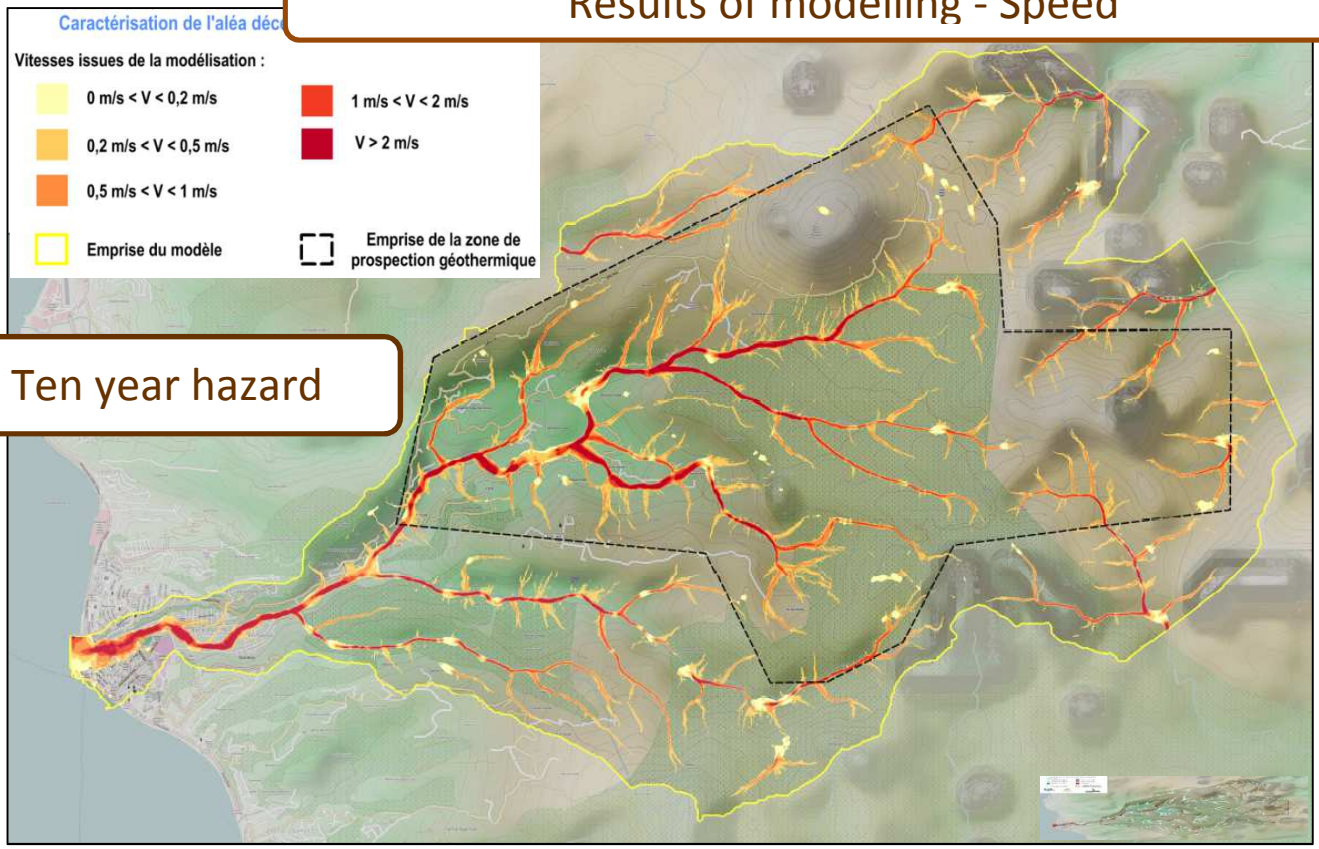

## Ten-year hazard

## Characteristics of floods

- Short response time between rain and flood
- Torrential watercourses
- Floodwater carrying material

## Results of modelling - Speed

Ten year hazard



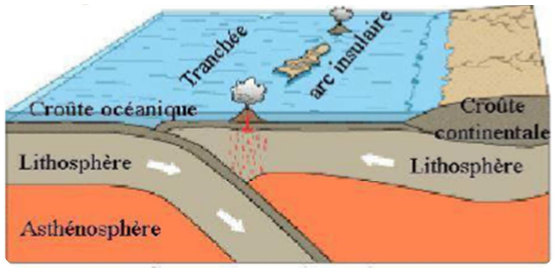
# Results – earthquake risks

## Three types of earthquake

- Subduction earthquakes
- Superficial local earthquakes
- Earthquakes linked to volcanic activity

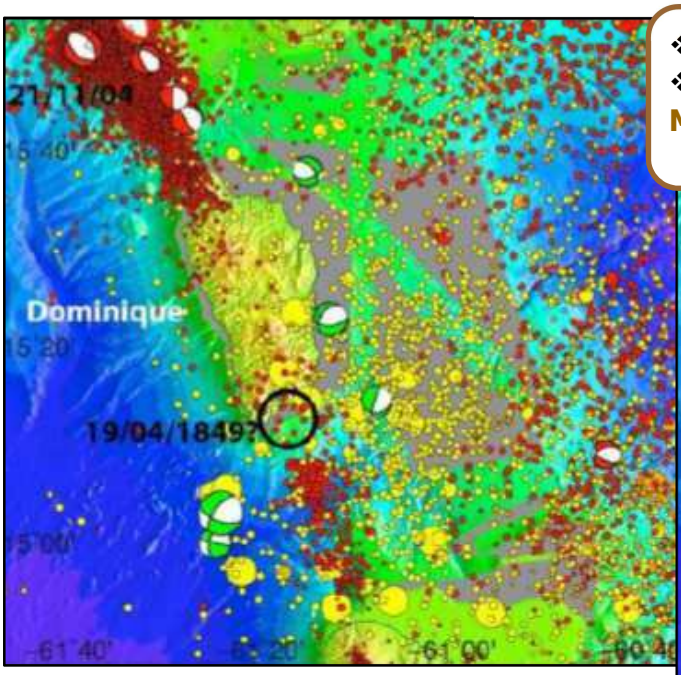
**Max magnitude for a subduction earthquake: 8.6**

*SIMPLIFIED SUBDUCTION DIAGRAM*

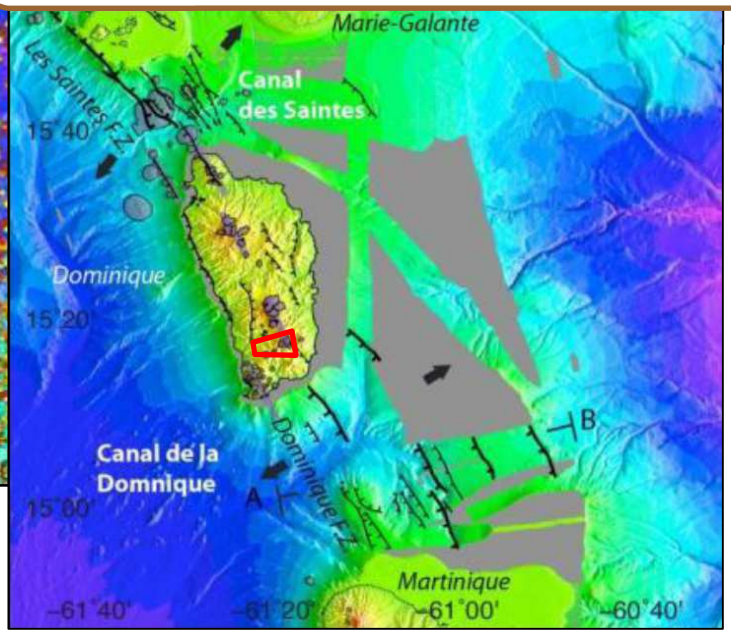



- NNE-SSE orientated faults
- Recent and active NE Extension

**Max estimated magnitude for local earthquakes: 7.5**




*MAP OF INSTRUMENTAL SEISMICITY REGISTERED IN 1950 AND 2014*



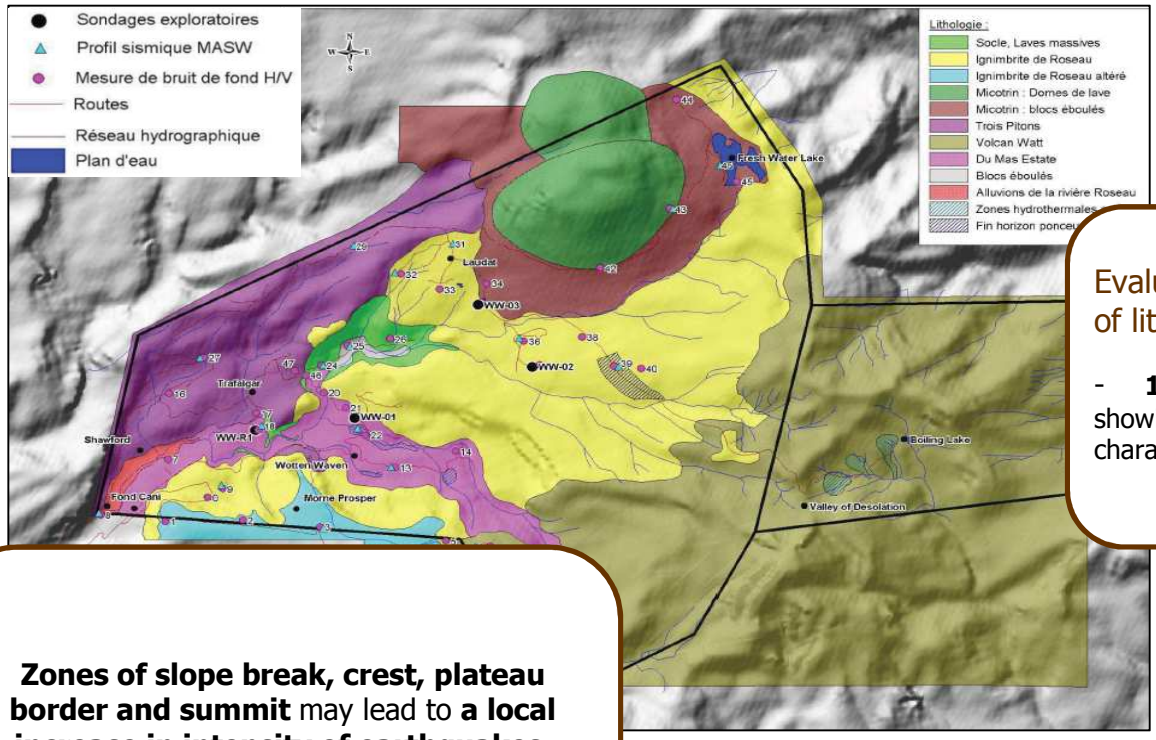

*MAP OF ACTIVE FAULTS AROUND DOMINICA*

**Estimate of maximum acceleration ground is likely to be subjected to** (rock acceleration)**:**

Determination of the recommended PSA for the site:
**Classified as zone 5 (high earthquake hazard) and buildings IV (Buildings providing public energy distribution)*, for earth A: rock**

**European earthquake resistant building standards (Eurocode 8: EC8)**

*CARTE LITHOLOGIQUE*



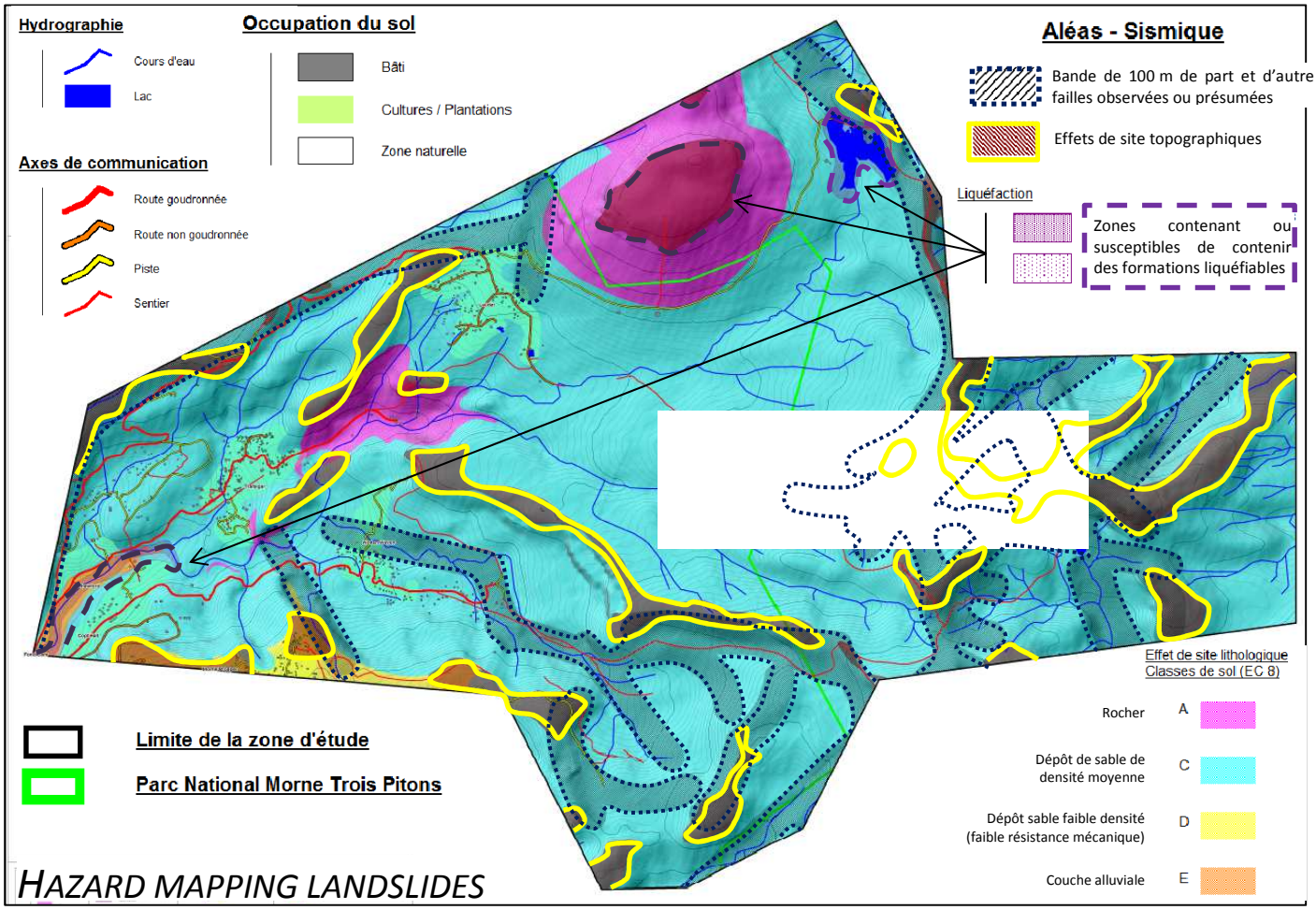

## Evaluation of the effects of lithological sites

- **10 uniform zones** showing geo mechanical characteristics

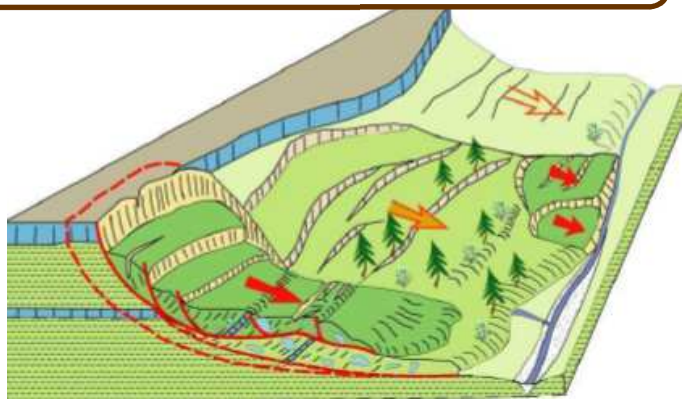
**Zones of slope break, crest, plateau border and summit** may lead to **a local increase in intensity of earthquakes.**

The increase is notable when the inclines are part of hills and slopes of **over 30m high.**

**Risk of local liquefaction** on the alluvial plain downstream of Trafalgar and on the perimeter of Fresh water Lake



# Results – Risks of land movements



*CCONCEPTUAL DIAGRAM OF LANDSLIDE PHENOMENON*

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# Part 2 - Employer’s Requirements

Section VII - Employer’s Requirements

# 10. Erica Study – Indirect Peak Discharge from Tropical Storm Erica

# Indirect Peak Discharge Measurements on the Island of Dominica Associated with Extreme Rainfall from Tropical Storm Erika, August 27, 2015, with Modeling and Analysis

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March 19, 2016
Revised April 19, 2016

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# ABSTRACT

August 27, 2015, the distant passage of Tropical Storm Erika saw over 450 mm rain fall over a 10 hour period on the island nation of Dominica. The result was widespread flooding, destruction of property, and considerable loss of life. In late October 2015, I traveled to Dominica to perform indirect peak discharge measurements on 10-20 impacted rivers for the purpose of providing flow data to aid in design of replacement bridges. I worked closely with two teams of Dominican surveyors, one from the Ministry of Public Works and one from Lands and Surveys. Over the approximately 10 days I was in Dominica, I visited most river sites where surveys were performed. Weather and time prevented me from visiting all the sites. I trained the two survey crews, and they submitted their surveys to me. The USGS Slope-Area method was employed to calculate indirect peak discharges. The slope-area method involves considerable uncertainty from both measurement and natural sources. This report provides those peak discharge values for the surveyed rivers, and provides a narrative that will help in interpreting the values. Radar-rainfall estimates were computed from observations by the MeteoFrance Le Moule weather radar on Guadeloupe. These radar-rainfall estimates were bias-adjusted using tipping bucket rain gauge data provided by the Dominican Meteorological Service. The U.S. Army Corps of Engineers Gridded Surface/Subsurface Hydrologic Analysis (GSSHA) model was employed as a diagnostic tool to (1) detect landslide-affected peak flows, and (2) reconstruct plausible runoff hydrographs. Analysis of 16 indirect peak discharges revealed that five of them were severely affected by landslide failure, producing peak flows significantly greater than the envelope curve values for the flood of record for identically-sized watersheds on the planet. For the remaining events, the GSSHA model simulated them with 38% mean absolute error, and validated that the indirect peak flow measurements varied from 40% to nearly 100% of the envelope curve value. The information contained within this report can be used to identify peak design flows for Dominica to design replacement bridges. Those replacement bridges should be designed to pass a reasonably large flow, such as some percentage of the maximum global envelope curve, through the bridge opening. The designs should also be resilient to the peak design flow, using low approaches that will allow a significant portion of flood flows to pass over the roadway and not through the bridge opening. Intelligent transportation systems can warn motorists of flooded roadway conditions.


# Introduction

The 2015 tropical Atlantic hurricane season was mostly quiet by most measures. However, one particularly devastating counterpoint is the impact of tropical storm Erika on the island nation of Dominica. Even though the center of TS Erika passed over 150 km north of Dominica, the synoptic scale mid-level flow produced a region of significant convergence in the vicinity of Dominica. Dominica has a pronounced orographic effect, and the net effect of regional convergence with topographic interactions on Dominica was over 500 mm of rainfall in 10 hours on 27 August, 2015 (Dominican Met. Services).

The rainfall was not accompanied by strong winds, because the center of circulation of TS Erika passed 150 km north, between Guadeloupe and Antigua. According to the US National

Weather Service, on 27 August the hurricane hunter flight from the U.S. had difficulty identifying the center of circulation. Furthermore, the storm was contained within a region of very high precipitable atmospheric water in excess of 60 mm (Votaw et al., 2015).

There was considerable forecast uncertainty (Franklin, 2015) but the storm was not forecast to be a significant weather event. When torrential rains fell overnight in Dominica on 27 August, 2015, most people were caught by surprise. The preceding two weeks were quite rainy, with about 200 mm of rain falling. The net result was an extreme rainfall event that caused the most significant flooding in Dominica since Hurricane David in 1979. Many of the bridges on the island were damaged or destroyed. Most portions of the island were impacted. The far northeast portion of Dominica was the only part of the island that did not experience damaging rains and subsequent floods.

# River Surveys

The scope of work called for post-flood high-water mark and cross-section surveys of between 12 to 20 rivers. The candidate rivers were identified by the Hydromet. Working Group of the Government of Dominica. Those rivers as identified by that group were provided as a compiled amalgamation of three lists, provided by Public Works, National Water Utility DOWASCO, and the Dominican Meteorological Service.

Table 1 lists the rivers where indirect peak discharge measurements were made. The actual location of the survey varies in terms of distance from the coast. This is because the suitability of a particular reach of a river depends upon local conditions, such as: identifiable high-water marks, access, post-event changes, channel morphology, presence of large woody or other debris. The 16 sites surveyed are shown in Figure 1 with an x-box symbol. This figure also shows watershed boundaries and their names in the legend. Appendix A contains detailed information about each river reach surveyed, photographs, and a simulated hydrograph containing relevant information.

**Table 1** List of Rivers Surveyed

| | |
|---|---|
| Belfast | Belle Fille |
| Boeri near Canefield | Castle Bruce |
| Check Hall | Colihaut |
| Coulibistrie | Dubuc |
| Geneva | Hampstead |
| Macoucherie | Malabuka |
| Melville Hall | Pointe Ronde |
| Rosalie | Roseau |

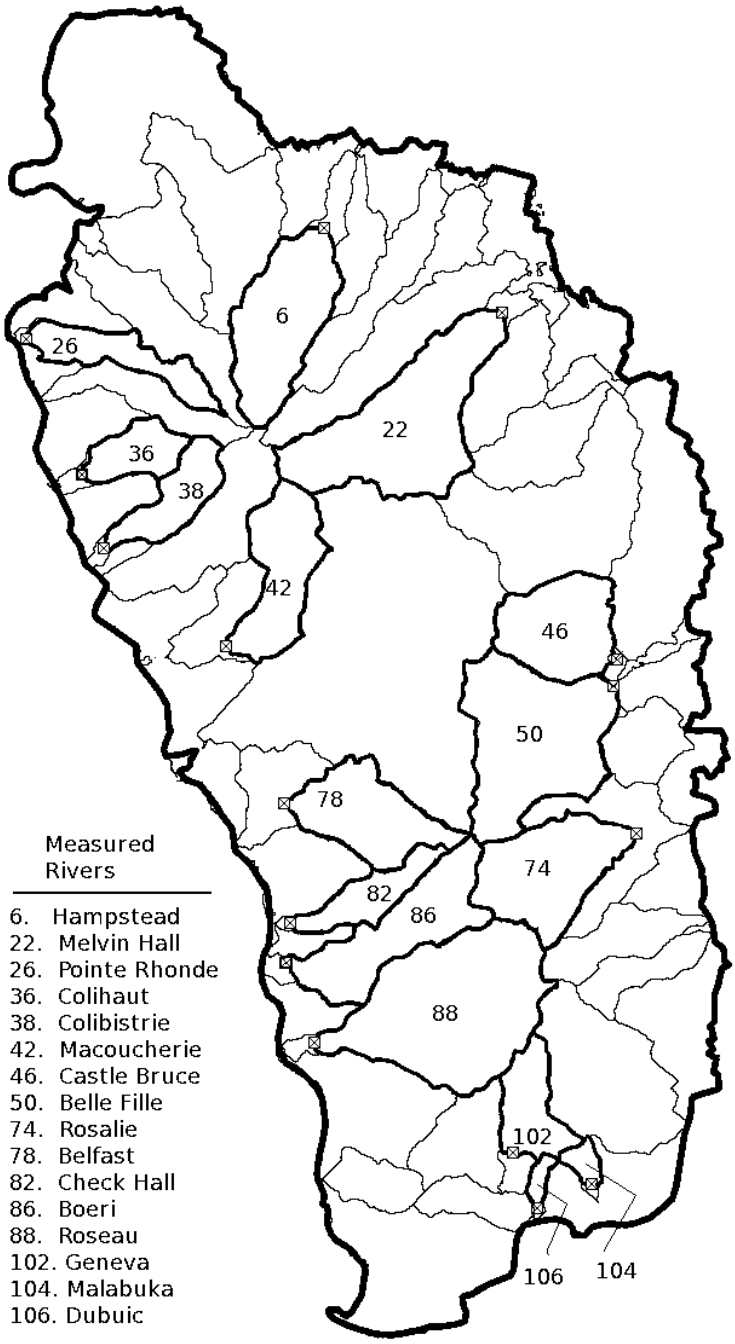


*Figure 1: Major watersheds in Dominica. Surveyed river reaches are shown with an x-in-box symbol. The name of the rivers where indirect peak measurements were made are given in the legend.*

## Methods

The two survey crews were given instructions and documents related to the U.S. Geological Survey (USGS) Slope-Area Method (USGS 1994). The essence of the method is that Manning's equation is used based on the channel cross-section and slope of the water surface. High water marks are identified, and surveyed using a total-station. If the high water marks on the left and right banks differ by more than 0.5 m in elevation, then it is likely that one of them was incorrectly identified. Identifying high water marks on vertical or near-vertical surfaces is difficult.

The value of the Manning roughness coefficient was identified based on personal experience, and using visual clues from the USGS report entitled “Roughness Characteristics of Natural Channels”, which is available online at the following site: http://pubs.usgs.gov/wsp/wsp_1849/html/pdf.html . The USGS slope-area program “SAC” was compiled in Linux and run on the surveyed data sets. This program requires identification of Manning n values for the main channel, as well as the left- and right-overbank areas.

The quality of the indirect peak discharge measurement is noted in each instance. Factors considered include: agreement of the left- and right-hand high water marks, whether or not I have visited the site, obvious indications of large changes in cross-section during the event, uncertainty regarding roughness coefficient values, or the one-dimensionality of the flow. These quality indicators were used to subjectively indicate an uncertainty bound on the indirect peak flow measurement of ±25%, or ±50% as advised by the U.S. Geological Survey (USGS 1994).

## Results

The survey points are listed in Table 2. The confidence of the GPS survey coordinates are noted (good, fair, poor), as per how well they coincide with a stream location determined from the 10 m DEM. The 10 m DEM was obtained from Jerry Meyers of the World Bank, and was derived from a JICA Synthetic Aperture Radar project (J. Meyers, pers. comm.). Details of surveys, notes, and photos are given in Appendix A.

The indirect peak flow measurements determined using high-water marks, channel cross-section surveys, and the US Geological Survey slope-area method are listed in Table 3. This table also lists the subjective uncertainty associated with each measurement. Furthermore, this table compares against the global maximum envelope curve (ICOLD 2002, IAHS 1984) for instantaneous peak flood flows ($m^3\ s^{-1}$), as a function of watershed area ($km^2$). This comparison provides an indication of the appropriateness of the magnitude of the indirect peak discharge measurements. Only values below or near the envelope are valid. Values of peak flow in excess of the envelope curve are either erroneous, or the result of failure of a landslide dam above the measurement site.

The indirect peak discharge measurement is also listed as a ratio of the envelope value. This ratio should be less than 1.0 for realistic measurements. Ratios in excess of 1.0 are affected

by landslide dam failure, incorrect high-water mark identifications, survey blunders, or the use of incorrect roughness coefficients.

Table 2. Geographical coordinates of survey points WGS84 associated with the approximate locations of survey reaches.

| River Name | Latitude (N) | Longitude (W) | Easting (m) | Northing (m) |
|---|---|---|---|---|
| Belfast | 15:22:50 | 61:23:14 | 673100 | 1701100 |
| Belle Fille | 15:25:09 | 61:16:33 | 685000 | 1705400 |
| Boeri | 15:19:06 | 61:22:18 | 673200 | 1695683 |
| Castle Bruce | 15:25:42 | 61:16:35 | 684900 | 1706400 |
| Check Hall | 15:20:36 | 61:23:11 | 673100 | 1696800 |
| Colihaut | 15:29:24 | 61:27:18 | 665700 | 1713100 |
| Coulibistrie | 15:27:58 | 61:26:50 | 666600 | 1710500 |
| Dubuc | 15:15:00 | 61:18:19 | 682000 | 1686700 |
| Geneva | 15:15:56 | 61:18:36 | 681400 | 1688493 |
| Hampstead | 15:34:10 | 61:22:26 | 674400 | 1721990 |
| Macoucherie | 15:25:58 | 61:24:20 | 671100 | 1706800 |
| Malabuka | 15:15:18 | 61:17:08 | 684100 | 1687300 |
| Melville Hall | 15:32:28 | 61:18:49 | 680800 | 1718900 |
| Pointe Ronde | 15:32:09 | 61:28:23 | 663700 | 1717900 |
| Rosalie | 15:22:22 | 61:16:09 | 685700 | 1700300 |
| Roseau | 15:18:14 | 61:22:28 | 674500 | 1692600 |

The quality of the high water marks in the surveyed reaches varied considerably. The Belle Fille, Castle Bruce, Melville Hall, and Rosalie Rivers all had well defined high water marks, flows confined to one main channel, and a reasonably straight channel reach. For these reasons, indirect peak flow measurements in those channels are given 25% uncertainty. The high water elevations identified on the left and right banks of the Hampstead River below Chaudier's Pool, Malabuka River, and Rosalie River were about 2.0 m difference in elevation. For this reason, the uncertainty of the peak flow measurement in those rivers is given as 50%.

**Table 3.** Indirect Peak Discharge Measurements and Comparison with Global Envelope Curve with Uncertainty.

| River Name | Area (km2) | left over-bank n | main channel n | right over-bank n | Indirect Peak Q (m3/s) | Unit discharge Q/A (m3/s/km2) | Envelope Curve for A<300 sq. km Q env. m3/s | Ratio Q/Qenv | Uncert. ± |
|---|---|---|---|---|---|---|---|---|---|
| Belfast R. | 13.60 | 0.055 | 0.045 | 0.055 | 1320 | 97 | 868 | 152% | 25% |
| Belle Fille R. | 24.18 | 0.055 | 0.045 | 0.055 | 656 | 27 | 1368 | 48% | 25% |
| Boeri R. | 16.19 | 0.055 | 0.045 | 0.055 | 574 | 35 | 996 | 58% | 25% |
| Castle Bruce R. | 13.46 | 0.055 | 0.045 | 0.055 | 201 | 15 | 861 | 23% | 25% |
| Check Hall R. | 6.18 | 0.055 | 0.045 | 0.055 | 163 | 26 | 466 | 35% | 25% |
| Colihaut R. | 5.88 | 0.055 | 0.045 | 0.055 | 218 | 37 | 448 | 49% | 25% |
| Coulibistrie R. | 7.35 | 0.055 | 0.045 | 0.055 | 855 | 116 | 534 | 160% | 25% |
| Dubuc R. | 0.90 | 0.055 | 0.045 | 0.055 | 243 | 270 | 102 | 239% | 25% |
| Geneva R. | 7.26 | 0.060 | 0.055 | 0.060 | 1220 | 168 | 529 | 231% | 25% |
| Hampstead R. | 18.68 | 0.045 | 0.055 | 0.045 | 677 | 36 | 1115 | 61% | 50% |
| Macoucherie R. | 12.12 | 0.055 | 0.045 | 0.055 | 742 | 61 | 793 | 94% | 25% |
| Malabuka R. | 1.63 | 0.055 | 0.045 | 0.055 | 1287 | 790 | 162 | 792% | 50% |
| Melville Hall R. | 27.01 | 0.055 | 0.045 | 0.055 | 1196 | 44 | 1493 | 80% | 25% |
| Pointe Ronde R. | 6.16 | 0.055 | 0.045 | 0.055 | 232 | 38 | 464 | 50% | 25% |
| Rosalie R. | 22.82 | 0.060 | 0.055 | 0.060 | 1233 | 40 | 1307 | 71% | 50% |
| Roseau R. | 31.38 | 0.045 | 0.037 | 0.045 | 923 | 39 | 1680 | 73% | 25% |

Notes on Table 3: "-" in the column denoted as "Uncert." indicates that the indirect peak discharge was likely affected by the failure of a land-slide dam above the indirect peak discharge measurement site, as indicated by a Q/Qenv ratio in excess of 100%. This is clearly the case in the Malabuka, Geneva, Dubuc, Coulibistrie and Belfast Rivers. The global maximum envelope curve peak discharge values as a function of drainage basin area were calculated from the International Conference on Large Dams (ICOLD, 2002) for watersheds less than 300 $km^2$ in area. Differences in high water mark elevations on left and right banks of Hampstead, Malabuka and Rosalie rivers were greater than 2 m.

# Discussion

The global peak discharge envelope curve provides an excellent measure by which to detect high outlier indirect peak discharge measurements. The global envelope curve and supporting data from ICOLD (2002) and the International Association for Hydraulic Research (IAHR) is shown in Figure 2. The blue triangles in Fig. 2 represent indirect peak discharge measurements in this study. Those blue triangles above and to the left of the ICOLD (2002) envelope are most certainly landslide dam-failure affected peaks.

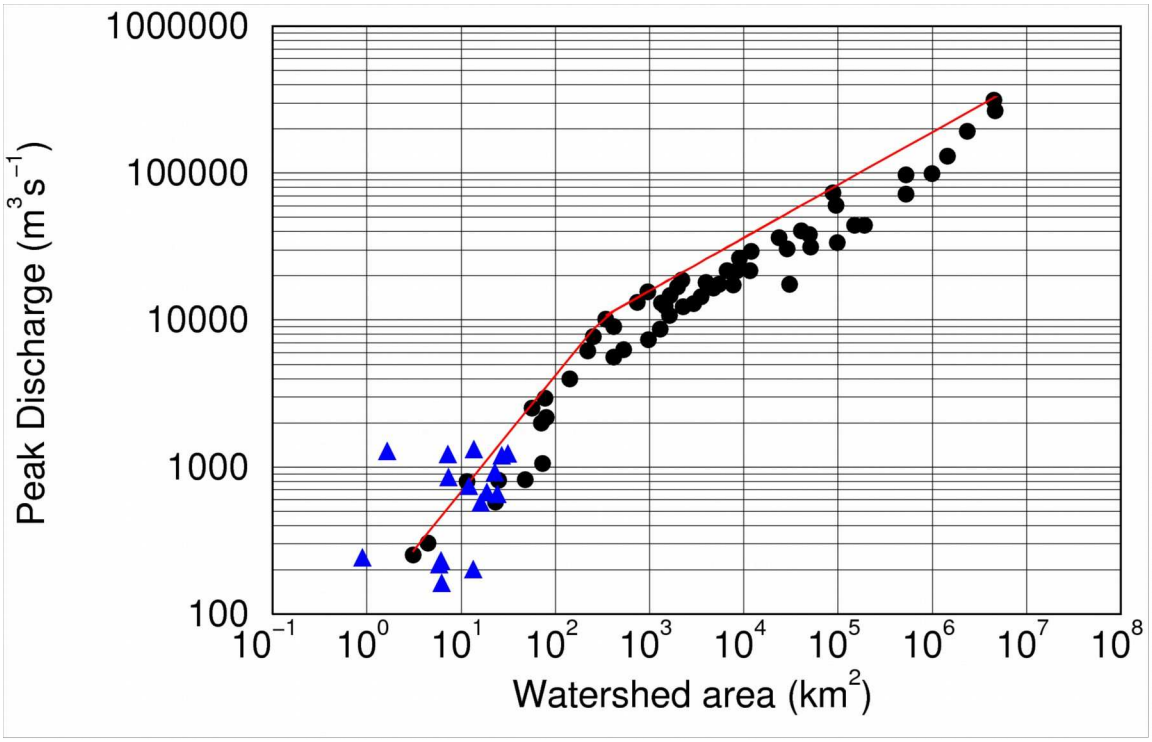


*Figure 2: Global peak flood discharge envelope curve (red line), and supporting data points (black). The blue triangles represent Dominica watersheds during TS Erika based on indirect peak discharge measurements from Table 3.*

The peak flood discharge $Q$ envelope curve below 300 km$^2$ watershed area is constructed using Equation 1. This is the portion of the envelope curve above the blue triangles shown in Figure 2 for the watersheds in Dominica where indirect peak discharge measurements are valid.

$$\frac{Q}{Q_1} = \left(\frac{A}{A_1}\right)^{1-\frac{R}{10}} \quad (1)$$

with:
$A$ = watershed area km$^2$
$Q_1$ = 10000 m$^3$ s$^{-1}$
$A_1$= 300 km$^2$
$R$ = 2.1 (coefficient)

The indirect peak discharges from Dominica during TS Erika above the envelope curve shown in Fig. 2 are almost certainly affected by landslide dam failure. Flows below the envelope curve range from 23% to 94% of the envelope curve, with a mean value of 59%. It is not possible to assign a probability of exceedance to this percentage of the envelope curve value, because it depends on a host of factors that are not well understood such as climate and runoff generation mechanism, as well as the period of record (Castellarin et al. 2005). It is safe to say

that 59% of the envelope curve is an extreme event, as demonstrated by the extent of the destruction seen during TS Erika.

## Indirect Peak Discharge Measurement Conclusions

Indirect peak discharge measurements were made in 16 rivers in Dominica following Tropical Storm Erika, which impacted the island on 27 August, 2015. These measurements will provide guidance flows for re-designing failed bridges and other infrastructure on the island. Two surveying teams were trained in post-event high-water mark identification and cross-section surveys. Survey data were used as input, together with professional judgment based on personal experience, with the USGS SAC slope-area method computer program to compute peak discharges.

Results indicate that peak discharges in a subset of five of the 16 rivers surveyed, the Belfast, Coulibistrie, Dubuc, Geneva and Malabuka, were impacted by the failure of large landslide dams in upstream areas. Those are shown in the results listed in Table 3 as having peak flows larger than any ever observed for catchments of that size, the so-called “envelope curve”.

Design using the envelope curve is justified for truly high-risk infrastructure, but probably cost-prohibitive for most highway bridges. Designing for some fraction of the envelope peak discharge given by Eqn. 1 is a way to advance. Empirical data from this study have demonstrated that flows ranging from 23% to 94% of the envelope curve occurred as the result of rainfall from TS Erika. The mean percentage value of the envelope discharge observed was 52%. Some fraction of the envelope curve value might provide a suitable design standard.

Note that in addition to design standards based on peak discharges, the lessons of the past should be heeded. Roadway embankments that do not completely block the flood plain and force all flood flows to pass through the bridge opening are preferable in that they help to promote flood survivability of infrastructure. When combined with proper warnings and road closure mechanisms during floods, the safety of life can be protected.

The analysis presented in this report does not represent design. Selection of a suitable design percentage of the peak discharge envelope curve shall be the responsibility of an engineer licensed to practice engineering in the Republic of Dominica. The designer is encouraged to design bridges that are resilient in the face of extreme events. The best example from TS Erika is the condition that exists at the Macoucherie River. The 1909 bridge is still standing, while the more contemporary bridge has failed. The difference in the resilience of the design of these two bridges is stark.

The 1909 bridge was designed so that it did not block the entire flood plain and force all the flow through the bridge opening. The approaches of the 1909 bridge are at an elevation that is considerably lower than the bridge itself. This design allows extreme flows to pass over the highway, reducing flow magnitudes, velocities, and erosive potential through the bridge opening. This is exemplified in Figure 3.

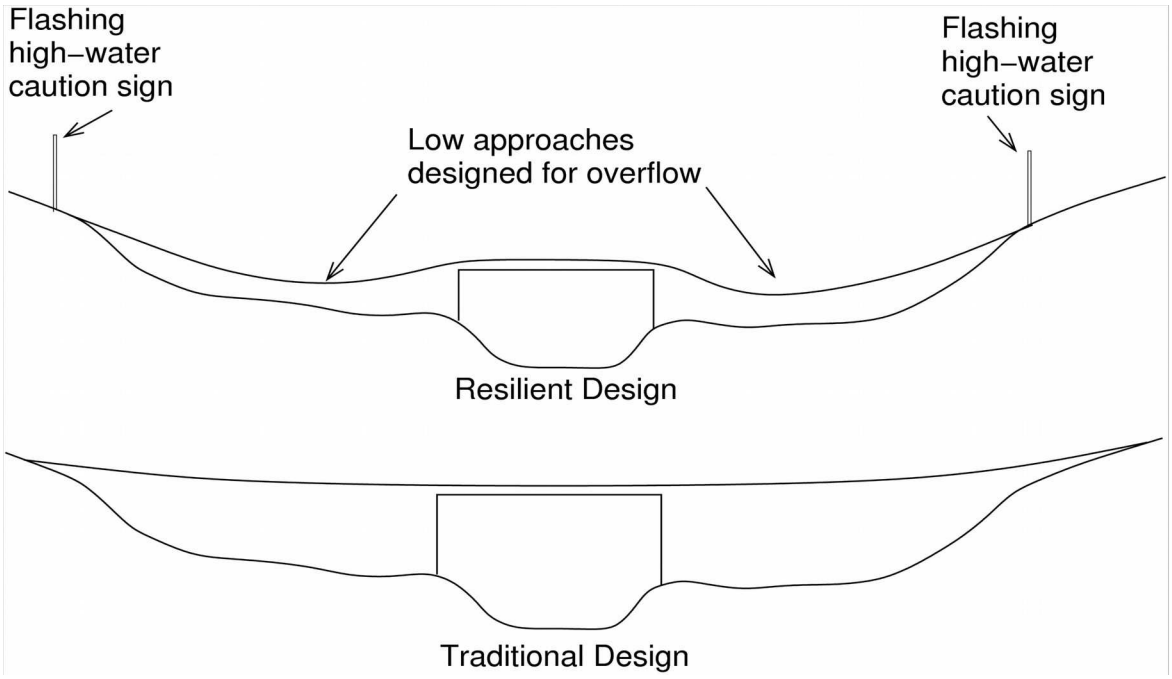


*Figure 3: Example design of resilient bridges that are less likely to completely fail during extreme events.*

The resilient bridge design represents a driving hazard when water is passing over the roadway. Flashing warning signs at both approaches can warn of dangerous conditions. These signs extol drivers to “Turn Around, Don't Drown”. Intelligent transportation systems can detect roadway flooding and activate solar-powered high-intensity solar-LED flashing lights on the caution signs.

Resilience includes deep abutment/pier foundations designed to withstand the probable maximum scour depth. The roadway approaches shall be designed to withstand overtopping. The downstream slope of the roadway embankment should employ grouted rip-rap to protect from erosion. Energy dissipation is necessary on the downslope side of the roadway to prevent scour and undermining.

## Flow Calculation Example:

Given a watershed area of 11.5 $km^2$ above a bridge site, determine the stream flow corresponding to 60% of the peak discharge envelope curve.

Solution:

Using Eqn. 1 with A=11.5 $km^2$ , $Q_1$ = 10000 $m^3 s^{-1}$, $A_1$= 300 $km^2$, and R = 2.1, gives:

$$Q = = 10000\left(\frac{11.5}{300}\right)^{1-\frac{2.1}{10}} = 760.37\, m^3 s^{-1}$$

.

This is the envelope discharge for the 11.5 $km^2$ watershed area. If we want to use 60% of this value, we must multiply by 0.6:

$Q_{design} = 0.6(760.37) = 456\, m^3 s^{-1}$ . This is the calculated discharge.

# Analysis of *MeteoFrance* Radar Data from TS Erika

The French Meteorological Agency *MeteoFrance* operates two S-band weather radars on the islands that are adjacent to Dominica. The best radar is the one on Martinique, which is called "Daimant". This is a very nice S-band radar with a 1.3- degree beamwidth antenna, that is installed on a 10 m tower that is at 380 m elevation at coordinates 14.50139N 61.0750W. Unfortunately, this radar site results in significant beam blockage over the entire west coast of Dominica as shown in Figure 4.

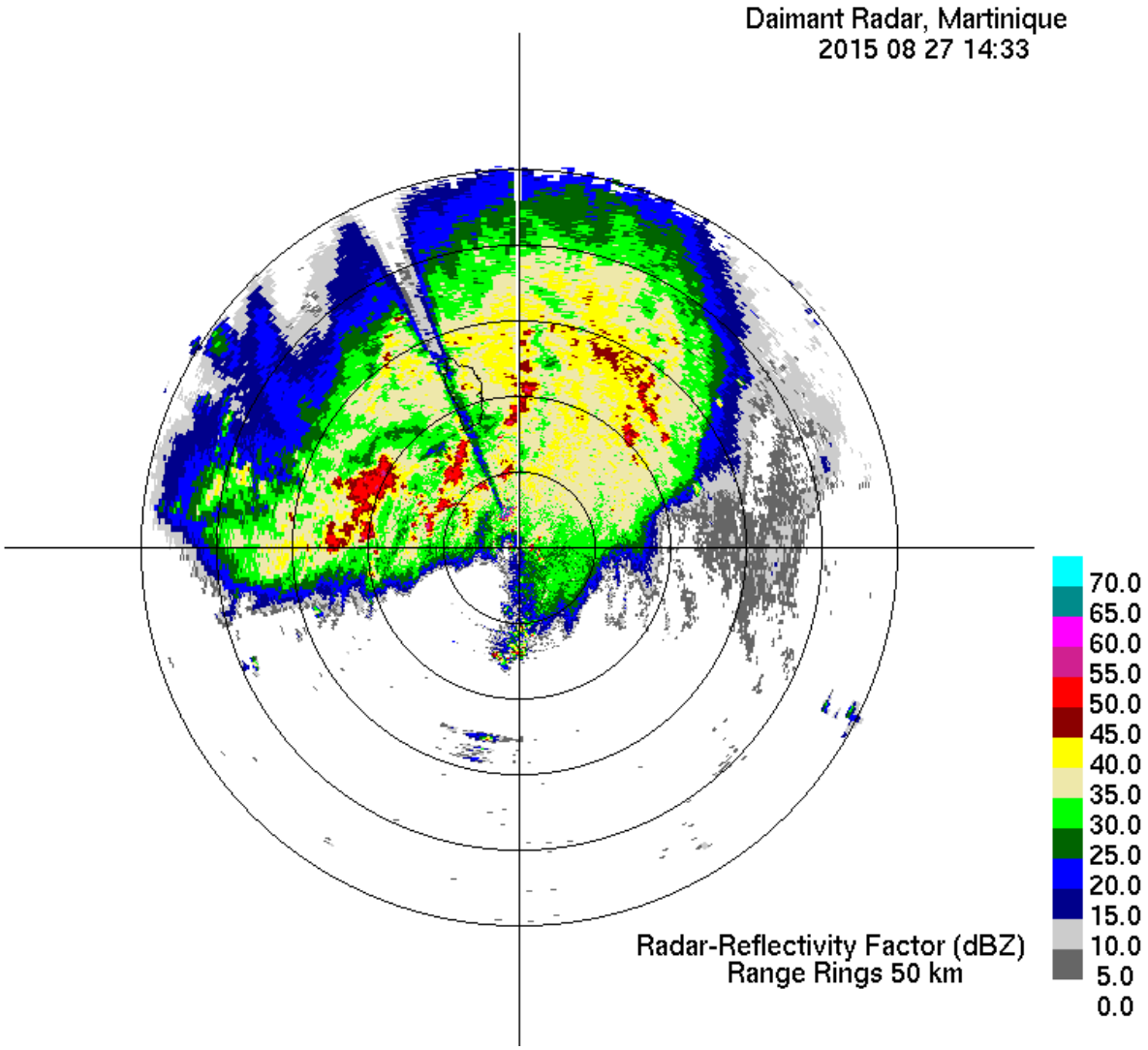


*Figure 4: Radar image from the Daimant Radar on the French island of Martinique, during tropical storm Erika. This image shows significant beam blockage over the western coastal regions of Dominica. Note outline of Dominica under beam blockage path.*

The blockage in the direction of Dominica from the Daimant radar is severe. Analysis of the radar reflectivities from 27 August 2015, revealed that this radar greatly underestimated the storm-total rainfall. The underestimation was so severe as to render observations of TS Erika by the Daimant radar worthless over Dominica.

The MeteoFrance radar on Guadeloupe is called “Le Moule”. This S-band radar has a smaller parabolic reflector than the Daimant radar, which results in a larger beam width of 2.1 degrees. This larger beam width is less desirable because it results in a number of negative factors with regards to radar-rainfall estimation. However, the Le Moule radar in Guadeloupe is much better sited for observing precipitation over Dominica. This radar is sited at 16.31611N 61.34583W, at an elevation of 30 m, and the pedestal holding the reflector is 13 m above ground level.

MeteoFrance stores and transfers data files in the 'BUFR' file format, which is one of the worst file formats imaginable for transferring radar data. It is enormously inefficient and results in huge data files that are poorly defined, incompatible with standard radar data processing software, and virtually impenetrable by any potential data user without a lot of assistance from someone who knows the transformations employed by MeteoFrance to get the radar data into the BUFR format. Processing the original radar data was an extremely difficult process, and I have processed a lot of weather radar data.

The sequence of images below show the progression of TS Erika across Dominica on 27 August, 2015, all times in UTC, as observed by Le Moule radar on Guadeloupe. As the storm approaches, the center of circulation is about 125 km northeast of the radar at 05:37 UTC. However, before 08:00 UTC, a secondary center of circulation becomes established over the island of Dominica as orographic convection triggers a local surface low pressure center over the island. I placed on YouTube: https://www.youtube.com/watch?v=WOA0lF30oms an animation of the radar observations from Guadeloupe of TS Erika.

One important consideration is selection of radar data from an antenna elevation angle that does not result in significant ground clutter. Because the mountains on Dominica are quite tall, the 0-degree elevation angle is likely not satisfactory. To answer this question, a radar path analysis was performed using atmospheric soundings recorded at 12:00 UTC on 27 August, 2015.

The results of that beam path analysis are shown in Figure 5. The atmospheric sounding values used were from Guadeloupe. Atmospheric variables used in the beam path analysis are listed in Table 1. Note that the atmosphere is very nearly saturated below 605 mb (4323 m elev.). This condition was noted by the US National Oceanic and Atmospheric Administration as one of the factors that led to extreme rainfall in the case of TS Erika in their post-event analysis.

Table 1. Atmospheric soundings from Station 78897, La Raizet, Guadeloupe, 12:00 UTC 27 August 2015. [Data source: Atmospheric Science Dept., University of Wyoming]

| Height (m) | Temperature (C) | Pressure (hPa) | Rel. Humidity (%) |
|---|---|---|---|
| 11 | 25 | 1008 | 95 |
| 73 | 24.8 | 1000 | 95 |
| 719 | 21.6 | 929 | 96 |
| 1428 | 18.3 | 856 | 97 |
| 1828 | 16.4 | 817 | 97 |
| 2672 | 10.3 | 739 | 98 |
| 3123 | 8.6 | 700 | 98 |
| 3609 | 7.2 | 660 | 99 |
| 3914 | 6.4 | 636 | 99 |
| 4323 | 4.2 | 605 | 99 |
| 5152 | -0.2 | 546 | 83 |
| 5405 | -2.1 | 529 | 78 |
| 5850 | -5.7 | 500 | 84 |
| 6433 | -9.5 | 464 | 92 |
| 7570 | -15.7 | 400 | 85 |

Figure 5 shows calculated radar beam paths for different antenna elevation angles (degrees). Notice that the 0-degree beam path is completely intercepted by the island of Dominica. In fact, the first beam elevation angle that completely clears the island is the 0.8-degree angle. However, because Le Moule radar has a 2.1-degree beam width, then the first beam elevation angle that completely clears the topography of Dominica is the 2.0-degree beam path. However, this beam path is 3 km above sea level at the north end of Dominica and 5 km above sea level at the south end of Dominica. At the time of this sounding, the precipitable water amount was 67 mm. This is a high amount of precipitable water for the tropics (Vatow et al. 2015, Fig. 6), which indicates that the circulation associated with TS Erika encountered abundant moisture over Dominica.

Evaluation of the 2.0-degree beam path data revealed that this beam elevation angle results in the radar overshooting the precipitation and having generally poor returns over the southern two-thirds of Dominica. Because of the 2.1-degree beam width of Le Moule radar, the 1.6-degree beam path does slightly encounter the highest peak in Dominica, Morne Diablotins, which is 1,447 m in height. However this is minimal and can be avoided with the use of a clutter filter.

During TS Erika on 27 August, some episodes of abnormal propagation were observed when the radar beam from Le Moule radar on Guadeloupe did strike the mountains of Dominica. The clutter filter also helped to remove that influence, but the extent is slightly uncertain.

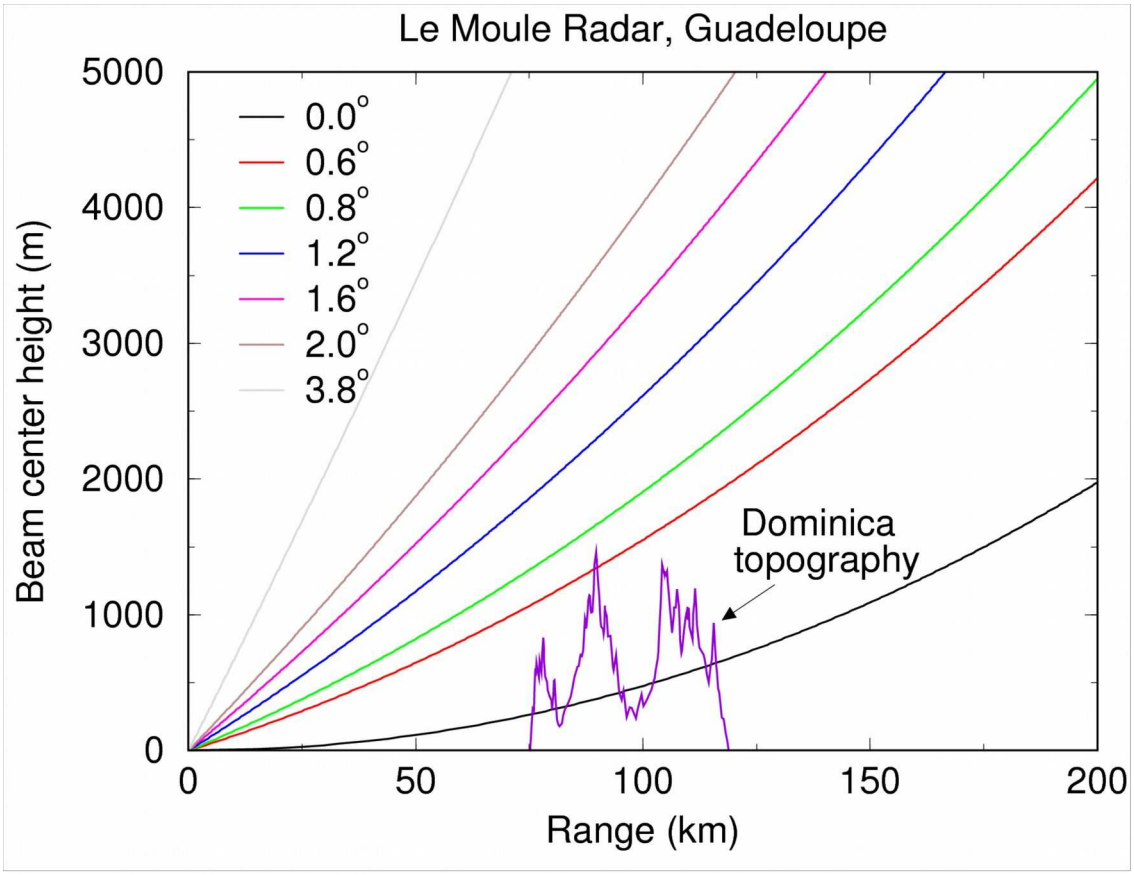


*Figure 5: Beam path analysis for Le Moule radar, Guadeloupe, at an azimuth of approximately 180-degrees. Shown on the figure is the spine of the island of Dominica.*

The radar reflectivity factor Z is proportional to the sixth moment of the raindrop size distribution. For this reason, *Z* can take on a very wide range of values. The data shown in Figs. 6-9 represent a time series of the radar reflectivity factor *Z* shown in decibel units (dB*Z*). The conversion between *Z* and dB*Z* is given by the equation: $dBZ=10\log_{10}Z$, where log10 denotes the logarithm base 10 of the radar reflectivity factor *Z*. The units of *Z* are $mm^6\ m^{-3}$.

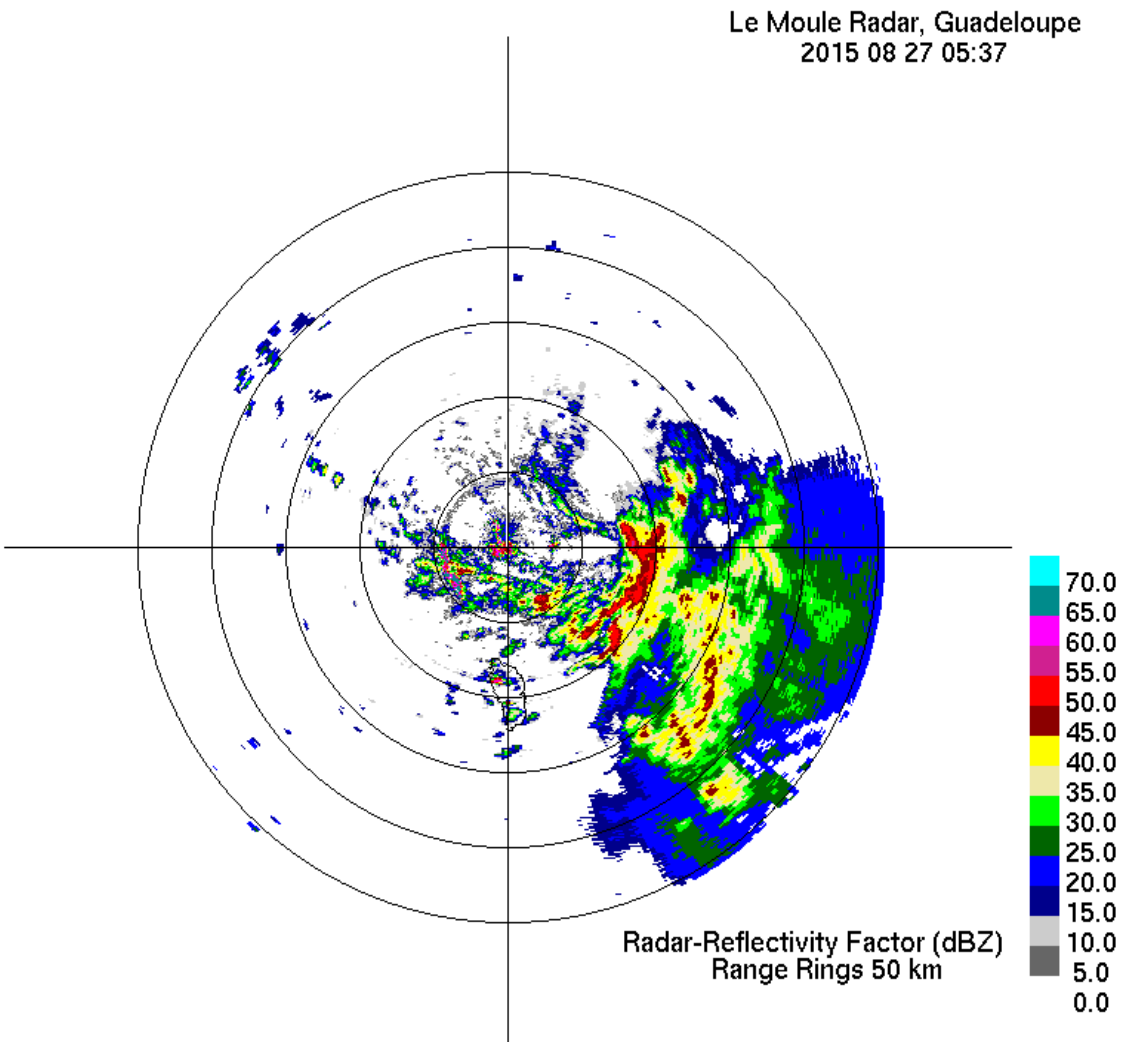


*Figure 6: Early approach on 27 August, at 05:37 UTC. The center of circulation is at about 45-degrees, and 100 km range. Note outline of Dominica directly south of the radar site between 75 and 125 km range.*

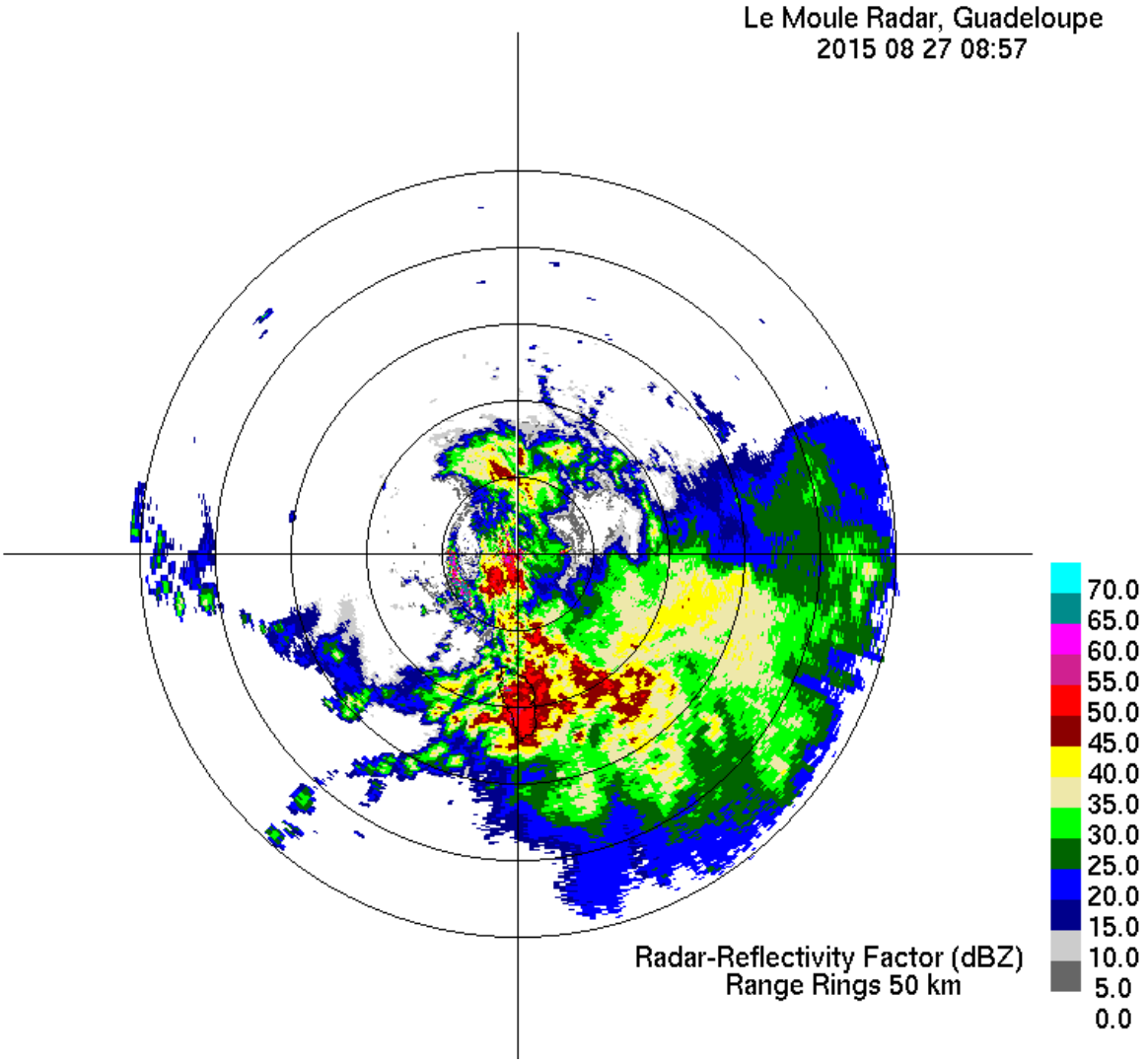


*Figure 7: Le Moule radar image of TS Erika causing heavy rainfall over Dominica at 08:57 UTC on 27 August, 2015. Note that almost the entire island is covered by > 45 dBZ reflectivity that is indicative of heavy rainfall.*

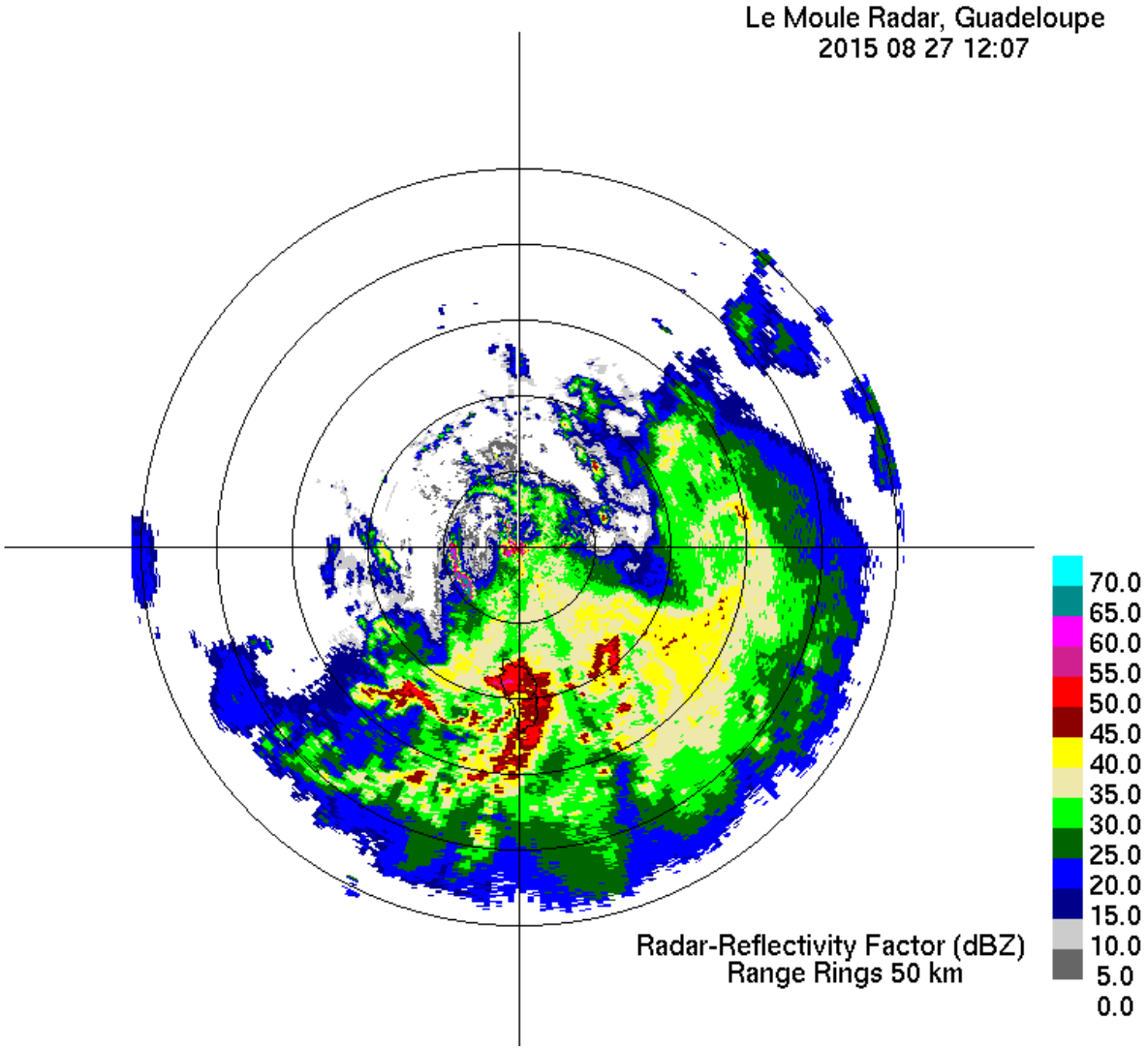


*Figure 8: Le Moule radar image of TS Erika causing heavy rainfall over Dominica at 12:07 UTC on 27 August, 2015. Note that despite the passing of three hours since the radar image shown in Figure 5, that almost the entire island is still covered by > 45 dBZ reflectivity that is indicative of heavy rainfall.*

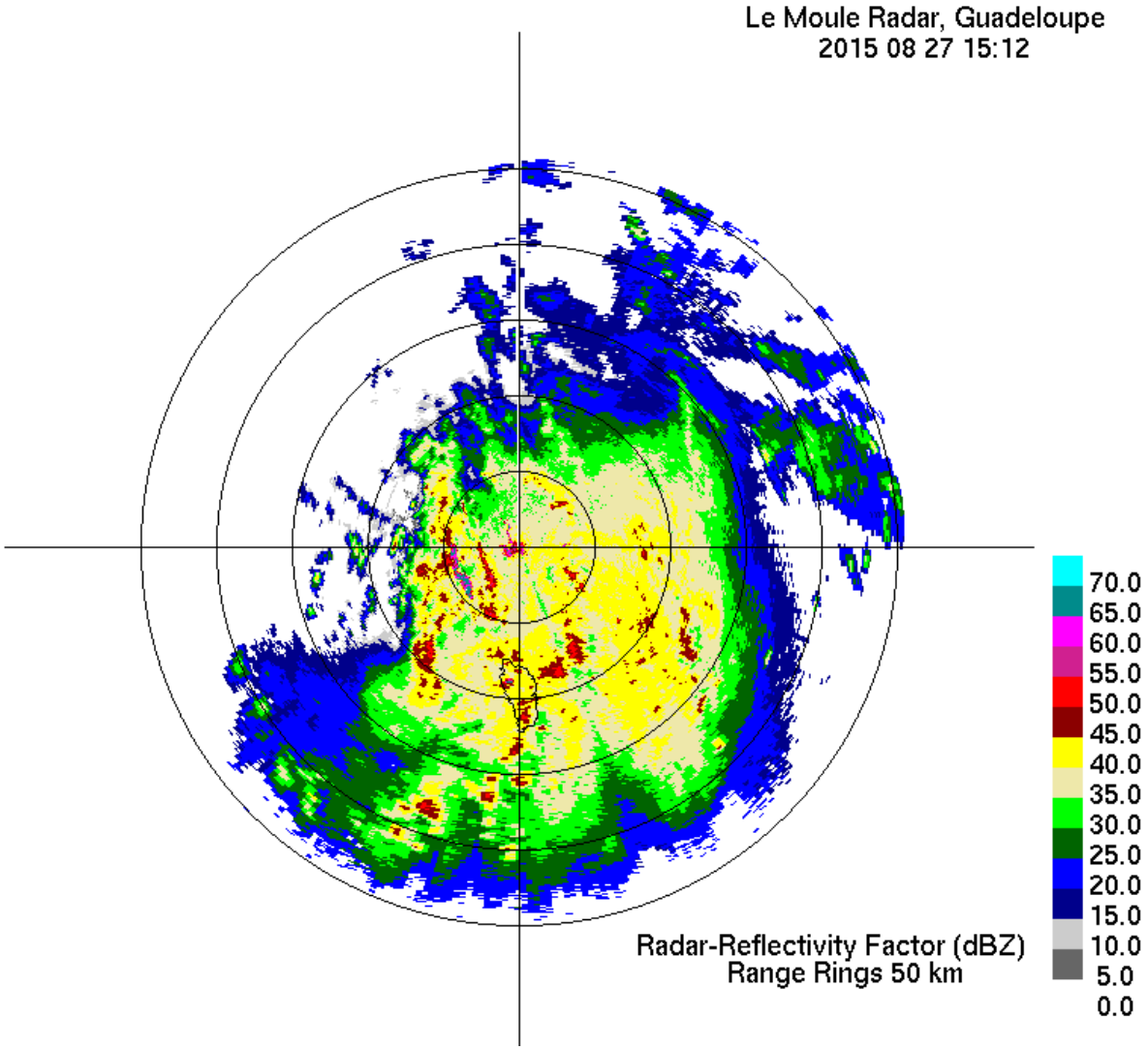


*Figure 9: Le Moule radar image of TS Erika at 15:12 UTC. The island of Dominica is covered at this time by reflectivies >40 dBZ, which indicates moderate to some heavy imbedded rainfall where the reflectivity is > 45 dBZ as indicated by the red areas.*

The form of the widely used radar reflectivity $Z$ vs. rainfall rate $R$ relation is:

$$Z = \alpha R^{\beta} \qquad (1)$$

Where:

$Z$= radar reflectivity factor ($mm^6\ m^{-3}$),
$R$= rainfall rate ($mm\ h^{-1}$),
$\alpha$= empirical coefficient, and
$\beta$= empirical exponent.

There are published Z-R relations to cover many different situations, but in reality the relationship between radar reflectivity factor and the rainfall rate varies in both space and time. The standard "tropical" Z-R relation uses $\alpha$=250 and $\beta$=1.2, with the reflectivity in decibel units (dBZ) limited to 50 dBZ.

## Comparison Against Hourly Rain Gauge Data

This standard tropical Z-R relation was applied to the Le Moule radar data set and compared at the hourly level against 8 rain gages operated by Dominican Met. Services for the duration of TS Erika. Those results are shown in Fig. 10.

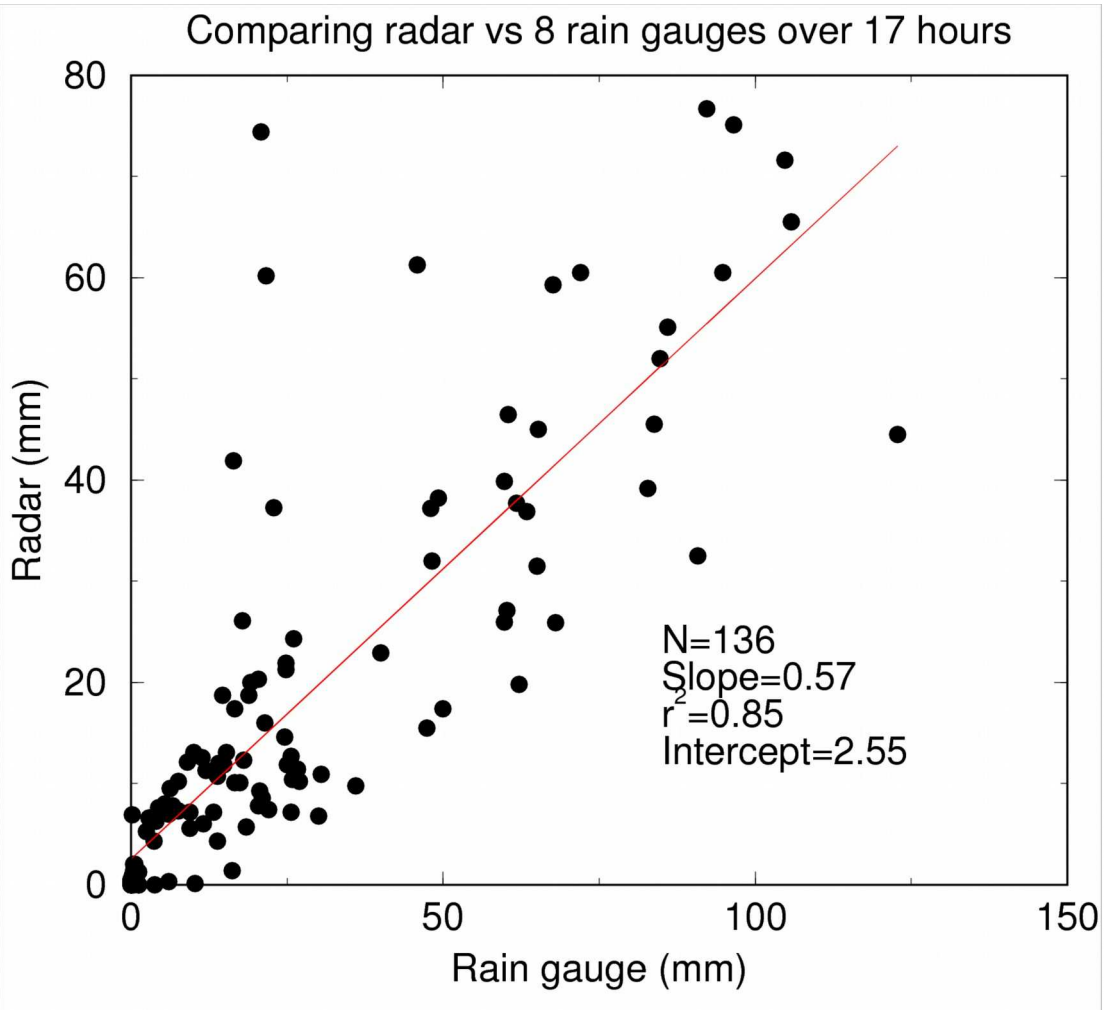


*Figure 10: Comparison of 17 hourly radar rainfall estimates calculated using the standard tropical reflectivity-rainfall relation $Z=250R^{1.2}$ against 8 tipping bucket rain gauges.*

The slope of the best fit line in Figure 10 is 0.57, which indicates that the standard tropical Z-R relationship underestimated the rainfall on average relative to the rain gauges. Adjusting the leading coefficient in the *Z-R* relationship for a particular storm to force the slope of the radar vs. gauge regression line to be 1.0 is known as mean field bias adjustment (Steiner et al. 1999). This approach was taken by varying the value of the coefficient $\alpha$ in Eqn. 1 until the slope of the regression line is 1.0. Another step that was taken was to evaluate outliers before regressing the best fit line. In the case of this storm, four hours of data from the Springfield rain gage were eliminated from the regression as outliers, where the rain gauge greatly undermeasured the rainfall values for those four hours compared to all other gauges in the network and the radar. The reason for this gauge undercatch is unknown.

The resulting best fit set was found when the coefficient $\alpha$ was equal to 132. Those hourly radar-vs. rain gauge values are shown in Fig. 11, and the outliers from the Springfield rain gauge are noted. A reflectivity factor limit of 50dBZ was applied as is traditional for use of the tropical *Z-R* relation.

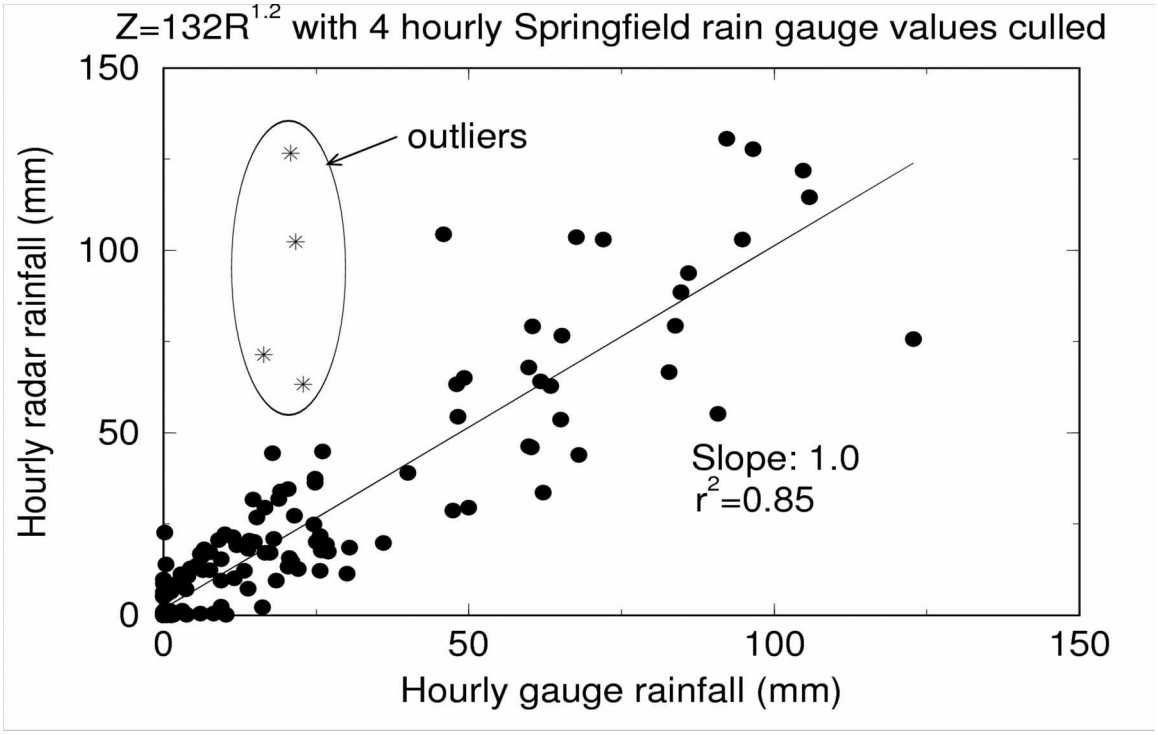


*Figure 11: Radar vs. rain gage comparison with 17 hourly rainfall accumulations at 8 rain gauges during tropical storm Erika, with four hourly values from the Springfield rain gauge removed as outliers as shown. Z<= 50dBZ.*

The results shown in Figure 11 indicate that the Le Moule radar in Guadeloupe does a reasonably good job of estimating the rainfall from TS Erika over the rain gauge sites. This is despite the relatively large 2.1-degree beam width, approximately 100 km range, and the necessity of using a relatively large 1.6-degree elevation angle to avoid topographic

contamination of the radar signal. The calibrated exponent eliminated the bias, and the coefficient of determination ($r^2$ =0.85) indicates an acceptable linear fit. This Z-R relation was used to calculate the time-series of radar-rainfall values across the island of Dominica.

## Storm Total Rainfall Hyetograph

The total rainfall amount over the island for TS Erika was integrated at individual radar rainfall pixels. The first cut did not consider the possibility of beam abnormal propagation (AP) leading to the radar beam striking the terrain and producing false echoes. At several times during the storm of 27 August, 2015, AP occurred in significant amounts. Analysis of those time periods allowed creation of a clutter mask, wherein radar-reflectivity values in those pixels that are affected by AP were ignored, and the rainfall rate calculated from surrounding non-clutter influenced pixels were interpolated to estimate the missing values in clutter prone regions. This method can result in significant underestimation of orographic precipitation near mountaintops where AP is most likely to occur. The clutter mask applied is shown in Figure 12, with clutter prone areas shown in pink. Rainall within the clutter-prone regions were interpolated from the three nearest pixels outside of the clutter mask using the inverse-distance squared method.

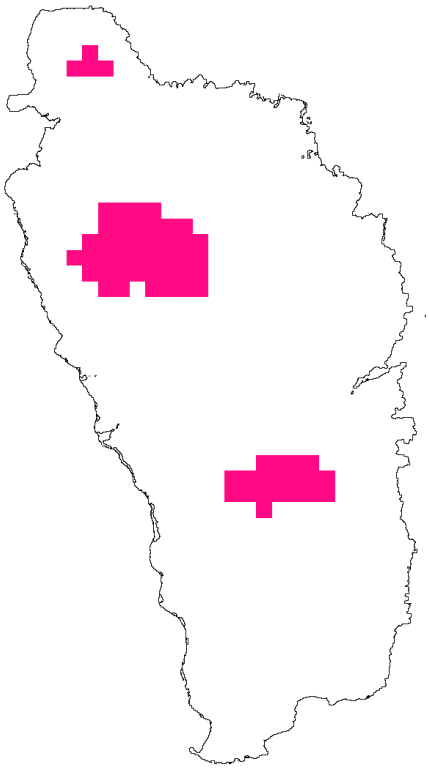

*Figure 12: Clutter prone areas. Pixel size 1 km$^2$.*

The storm-total rainfall spatial distribution after clutter removal is shown in Figure 13. This figure shows that the topography of the island clearly played a dominant role in triggering precipitation.

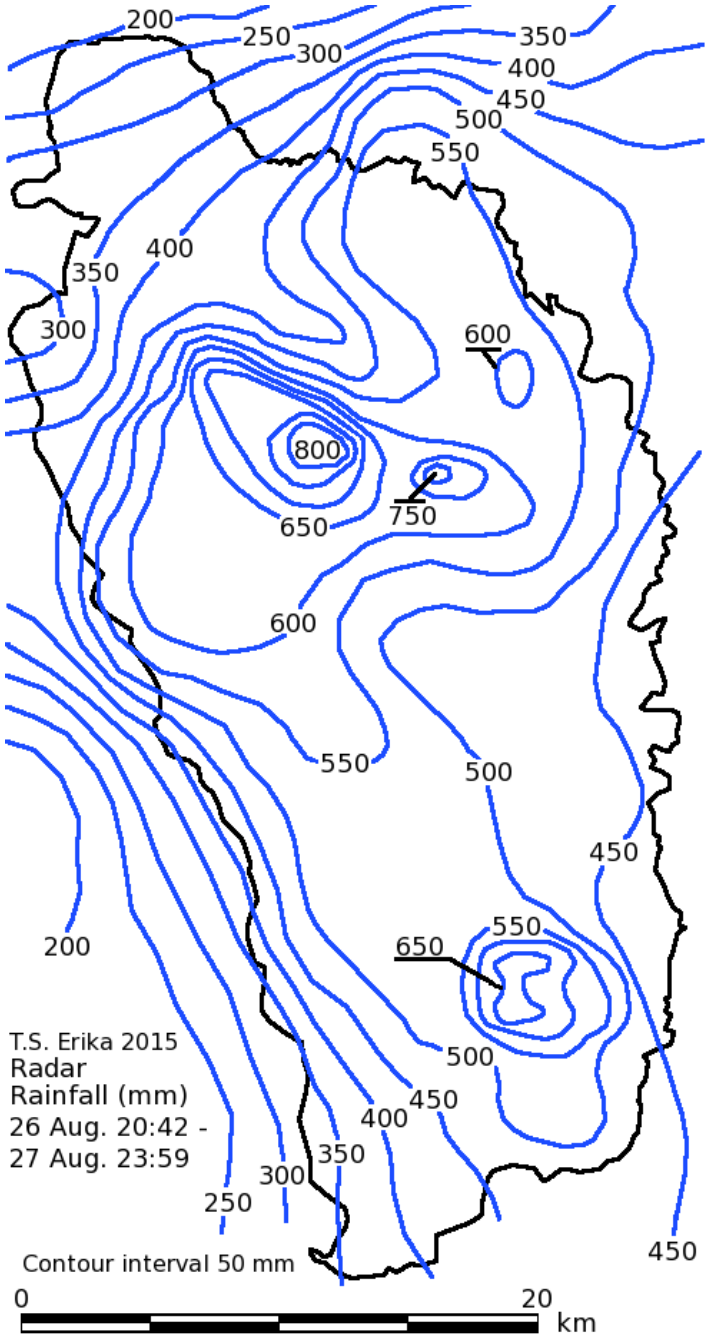


*Figure 13: Isohyetal map for TS Erika rainfall (mm) over the island of Dominica, August, 2015. Note two maxima near the highest mountains on the island. Contour interval 50 mm. Rainfall estimated using radar data from Le Moule radar on Guadeloupe, with $Z=132R^{1.2}$.with $Z \leq 50dBZ$.*

The temporal distribution of island-wide rainfall from TS Erika is shown in Figure 14. Hourly average island-wide rainfall rates were integrated from the Le Moule radar data, with

rainfall rates calculated using $Z=132R^{1.2}$. For three contiguous hours the average rainfall rate over the entire island of Dominica exceeded 90 mm $h^{-1}$ for an entire hour.

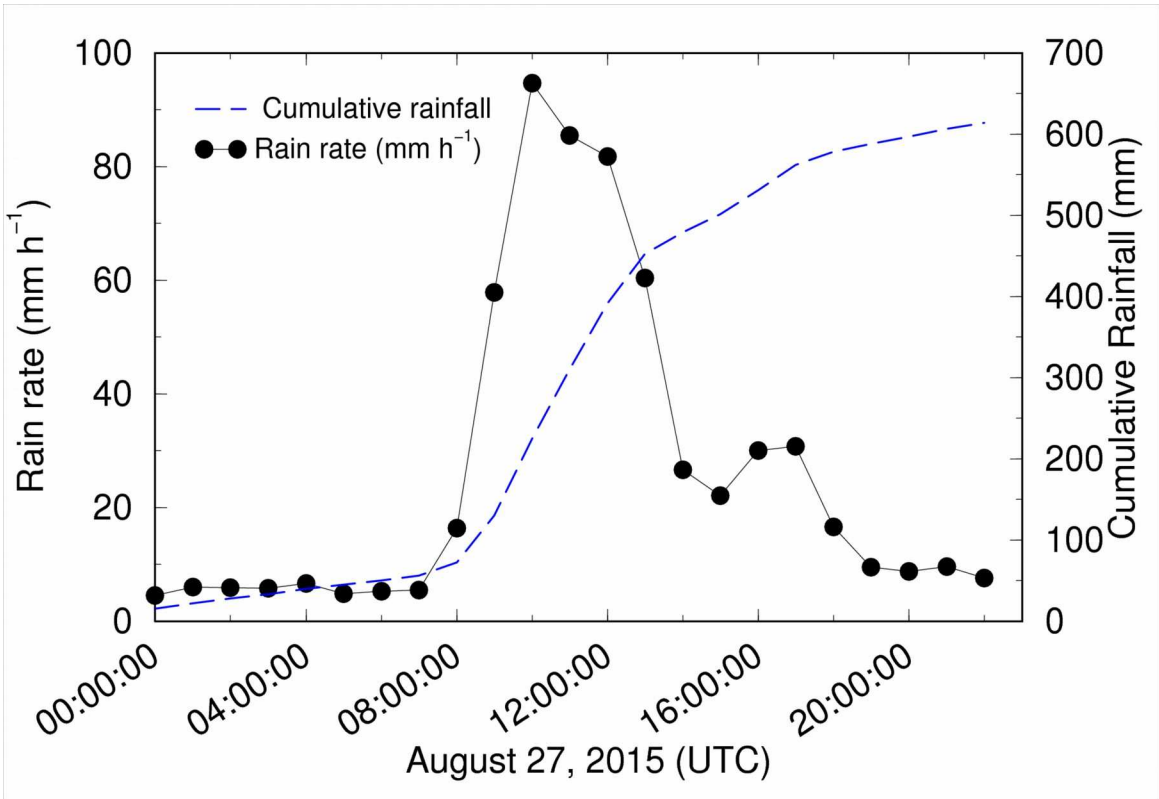


*Figure 14: Temporal distribution of island-wide average rain rate and cumulative rainfall from TS Erika on 27 August, 2015.*

Also shown on Fig. 14 is the cumulative island-wide average rainfall. Note that the cumulative island-wide average rainfall was 610 mm. This estimate was produced by bias-adjusted radar rainfall, and is likely contaminated by unknown errors. The radar-rainfall estimation accuracy as determined by correlation of radar-rainfall estimates within 25 km of rain gauges used in bias adjustment has a mean of 0.56 (Rogalus and Ogden, 2013).

# GSSHA Modeling

The Gridded Surface/Subsurface Hydrological Analysis (GSSHA) model is a process-based numerical hydrological simulator (Downer and Ogden, 2006). GSSHA is maintained by the US Army Corps of Engineers for Engineering hydrology studies and hydraulic design (Fatichi et al. 2016).

# Landslide Dam Failure Identification

Regarding the flood peaks shown in Figure 2, some of them may have been affected by landslide dam failure. This happens when naturally occurring landslides block the channel, fill with water, then fail. This failure releases a torrent of water that represents a much larger flood peak than what would have occurred due solely to rainfall-runoff processes.

On 27 August, 2015, many landslides occurred throughout most of Dominica. This provides strong evidence enough rain fell to fill most of the pore space in tropical saprolitic soils, because soil saturation is associated with the occurrence of landslides. Previous studies indicate that the saturated hydraulic conductivity of tropical saprolites in the absence of macropores is approximately 2.0 cm $h^{-1}$ (Hassler et al. 2011). The GSSHA model was run with a very small value of soil saturated hydraulic conductivity ($K_s$ = 0.001 cm $h^{-1}$). If the model using this small value of $K_s$ and driven by bias-adjusted radar-rainfall could not produce a peak larger than that which was indirectly measured, then it is certain that the peak was influenced by landslide dam failure.

In general, it is possible with the GSSHA model to simulate any range of soil or land-use dependent parameter values. The model is quite sensitive to the soil hydraulic conductivity, overland and channel roughness coefficient, retention storage and plant interception of rainfall. In this study we neglected interception. In most studies, tropical forest intercepts about 17 percent of rainfall, which evaporates off the leaves before falling to the ground as throughfall. However, in truly extreme events such as TS Erika, it was highly unlikely that 17 percent of rainfall is evaporated during the event because the lower troposphere was nearly saturated with water vapor. Interception was most likely greatly reduced during TS Erika.

GSSHA is sensitive to channel cross-section parameters, particularly the channel width and roughness coefficient. Because we do not have channel width data except at the sixteen surveyed cross sections, I constructed a subjective empirical channel model that is a function of drainage area. The same channel width estimator was used for all channels in all watersheds.

The Watershed Modeling System interface was used to set up the GSSHA models. A 10 m digital elevation model provided by Mr. Jerry Meyer of the World Bank was aggregated to 30 m, smoothed and watershed delineated using the TauDEM package. Channels were identified using a channel initiation threshold of 0.1 $km^2$ in watersheds greater than 3 $km^2$ in area and 0.04 $km^2$ in smaller watersheds. The identified channel network was trimmed to eliminate short channels and smoothed to eliminate adverse slopes. The channels were assumed trapezoidal in shape with side slopes of 1.0 H:V and channel bottom widths $b$ (m) assigned based on the contributing area $A$ ($km^2$) using:

$$b = 16.7A^{0.3} \text{ (m)} \qquad (1)$$

## GSSHA Model Results

Using the mean-field bias-adjusted Le Moule radar-rainfall estimates, and a saturated hydraulic conductivity value of 0.001 cm $h^{-1}$, the GSSHA model was used as a diagnostic tool to identify obviously landslide-affected peak flows. Given the reasonable radar-rainfall estimates, uniform soils and land use, this is an appropriate use of the GSSHA model. The sixteen watersheds where indirect peak discharges were made are shown in Figure 15. GSSHA model results are listed in Table 2.

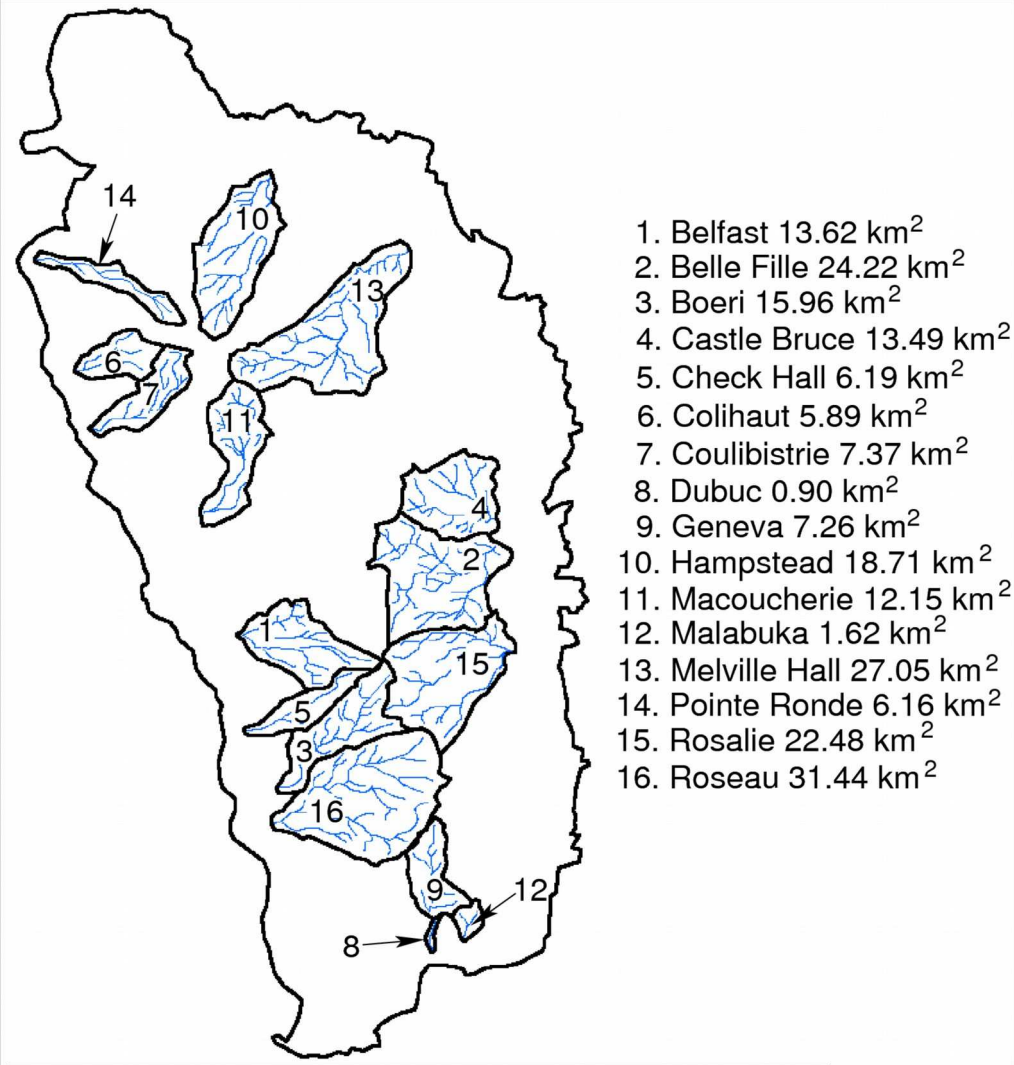


*Figure 15: Watersheds where indirect peak discharge measurements were made.*

The same 16 watersheds with indirect peak discharge measurements were simulated using GSSHA using literature parameter values were used because of the lack of infiltration parameters or calibration data. Infiltration was simulated using the Green & Ampt with Redistribution method (Ogden and Saghafian, 1997), assuming the soil saturated hydraulic

conductivity $K_s$=2.0 cm $h^{-1}$, the Green and Ampt soil capillary head parameter $H_c$=10 cm, pore distribution index $\lambda$=0.234, residual saturation $\theta_r$=0.015, field capacity $\theta_f$=0.30, and wilting point water content $\theta_w$=0.15. Those simulation results are shown in Table 3.

**Table 2.** Comparison of indirect peak discharge measurements vs GSSHA simulations assuming relatively impervious or waterlogged soils. Relative difference defined as ((GSSHA)/Indirect-1.0)*100%.

| Watershed Name | Drainage Area $km^2$ | Indirect peak discharge $m^3\ s^{-1}$ | GSSHA peak discharge with $K_s$=0.001 cm $h^{-1}$ | Relative difference (%) | Obviously landslide dam affected? (Y/N) |
|---|---|---|---|---|---|
| Belfast | 13.62 | 1320 | 650 | -51 | Y |
| Belle Fille | 24.22 | 656 | 991 | 51 | N |
| Boeri | 15.96 | 574 | 741 | 29 | N |
| Castle Bruce | 13.49 | 201 | 471 | 134 | N |
| Check Hall | 6.19 | 163 | 285 | 75 | N |
| Colihaut | 5.89 | 218 | 374 | 72 | N |
| Coulibistrie | 7.37 | 855 | 508 | -41 | Y |
| Dubuc | 0.90 | 243 | 42 | -83 | Y |
| Geneva | 7.26 | 1220 | 354 | -71 | Y |
| Hampstead | 18.71 | 677 | 1042 | 54 | N |
| Macoucherie | 12.12 | 742 | 777 | 5 | N |
| Malabuka | 1.62 | 2876 | 72 | -97 | Y |
| Melville Hall | 27.05 | 1196 | 1229 | 3 | N |
| Pointe Ronde | 6.16 | 232 | 251 | 8 | N |
| Rosalie | 22.48 | 1233 | 1017 | -18 | Y |
| Roseau | 31.44 | 923 | 1425 | 54 | N |

Twenty four other watersheds were simulated using GSSHA with channel widths predicted using Eqn. 1, with uniform $K_s$=2.0 cm $h^{-1}$ (Hassler et al., 2011). Some of the watersheds from Table 2 were repeated because the indirect peak discharge measurements were made were far enough from the coast that the watershed area changed appreciably.

Land use effects were not considered because most of the watersheds simulated are predominantly intact tropical forest. Except in coastal regions, Dominica is largely forested. Interception of rainfall by forest canopy is important for average rainfall events. Prediction of interception during extreme rainfall events when the atmosphere is nearly saturated with water vapor and evaporation is limited (Table 1) is highly uncertain, and was not simulated. This is

because the reason why interception is important in tropical forests during average rainfall events is that the wet canopy is a very efficient evaporating surface. This results in significant evaporation of intercepted water during rainfall. However, during extreme events with rainfall rates in excess of 100 mm $h^{-1}$ and relative humidity ≥ 95%, the evaporation rate from the canopy is likely insignificant compared to the rainfall rate (Ogden et al. 2013).

**Table 3.** Peak flow results of GSSHA simulations with soil saturated hydraulic conductivity $K_s$=2.0 cm $h^{-1}$ on 16 watersheds compared with indirect peak discharge measurements.

| Watershed Name | Drainage Area $km^2$ | Indirect peak discharge $m^3\ s^{-1}$ | GSSHA peak discharge with $K_s$=2.0 cm $h^{-1}$ | Relative difference (%) | Obviously landslide dam affected? (Y/N) |
|---|---|---|---|---|---|
| Belfast | 13.62 | 1320 | 561 | -58 | Y |
| Belle Fille | 24.22 | 656 | 827 | 26 | N |
| Boeri | 15.96 | 574 | 634 | 10 | N |
| Castle Bruce | 13.49 | 201 | 363 | 81 | N |
| Check Hall | 6.19 | 163 | 245 | 50 | N |
| Colihaut | 5.89 | 218 | 341 | 56 | N |
| Coulibistrie | 7.37 | 855 | 465 | -46 | Y |
| Dubuc | 0.90 | 243 | 36 | -85 | Y |
| Geneva | 7.26 | 1220 | 306 | -75 | Y |
| Hampstead | 18.71 | 677 | 936 | 38 | N |
| Macoucherie | 12.15 | 742 | 705 | -5 | N |
| Malabuka | 1.62 | 2876 | 62 | -98 | Y |
| Melville Hall | 27.05 | 1196 | 1168 | -2 | N |
| Pointe Ronde | 6.16 | 232 | 201 | -13 | N |
| Rosalie | 22.48 | 1233 | 870 | -29 | Y |
| Roseau | 31.44 | 923 | 1222 | 32 | N |

The mean relative difference of the non-landslide affected watersheds in Table 3 is 27 percent. The mean absolute relative difference for the non landslide-affected events in Table 3 is 31 percent.

The losses associated with simulating infiltration are indistinguishable from those associated with interception, because in the GSSHA simulations both abstractions are removed and cannot become runoff, because the GSSHA simulations did not simulate groundwater. While strictly not correct, the effect is equivalent. However, with an atmosphere near saturation

and rainfall in excess of 450 mm over most of the island (Fig. 13), the amount of interception after the initial storage (a few mm) is filled, will be small.

Differences between GSSHA simulated peak discharge and the indirect peak discharge measurement can be caused by a large number of factors. Radar-rainfall estimation errors and uncertainty in soil hydraulic properties are the most likely error sources. Because the GSSHA model was driven with literature soil hydraulic properties and assumed initial relative soil moisture equal to 80%, and neglected land-use effects.

Assuming that landslide dam failure affected peaks if the indirect peak measurement was more than 15 percent greater than the GSSHA simulated peak discharge, then 10 of the 16 watersheds represent plausible GSSHA simulations. The error calculations on those are given in Table 4.

**Table 4.** Comparing GSSHA simulated peak discharges versus indirect peak discharge measurements for likely non-landslide affected peaks. GSSHA simulations assumed soil saturated hydraulic conductivity of 2.0 cm $h^{-1}$.

| Watershed | $Q_p$ indirect ($m^3$ $s^{-1}$) | $Q_p$ GSSHA ($m^3$ $s^{-1}$) | Difference (%) |
|---|---|---|---|
| Belle Fille | 656±160 | 827 | 26% |
| Boeri | 574±140 | 633 | 10% |
| Castle Bruce | 200±50 | 362 | 80% |
| Check Hall | 163±40 | 246 | 51% |
| Colihaut | 218±55 | 341 | 56% |
| Hampstead | 677±340 | 936 | 38% |
| Macoucherie | 742±190 | 705 | -5% |
| Melville Hall | 1196±300 | 1168 | -2% |
| Pointe Ronde | 232±60 | 201 | -13% |
| Roseau | 923±230 | 1222 | 32% |

The sign on the difference in Table 4 is positive if GSSHA overestimated the peak flow rate and negative if GSSHA underestimated it. The average difference of the simulations tabulated in Table 4 is 27%, while the average absolute difference is 32%. These differences are less than the 25% nominal indirect peak discharge measure uncertainty in four of the 11 watersheds. The hydrographs are plotted in Appendix A for these watersheds. These results indicate that the GSSHA model has some skill using literature soil parameters, radar-rainfall estimates, and geomorphologically-estimated channel cross-section properties.

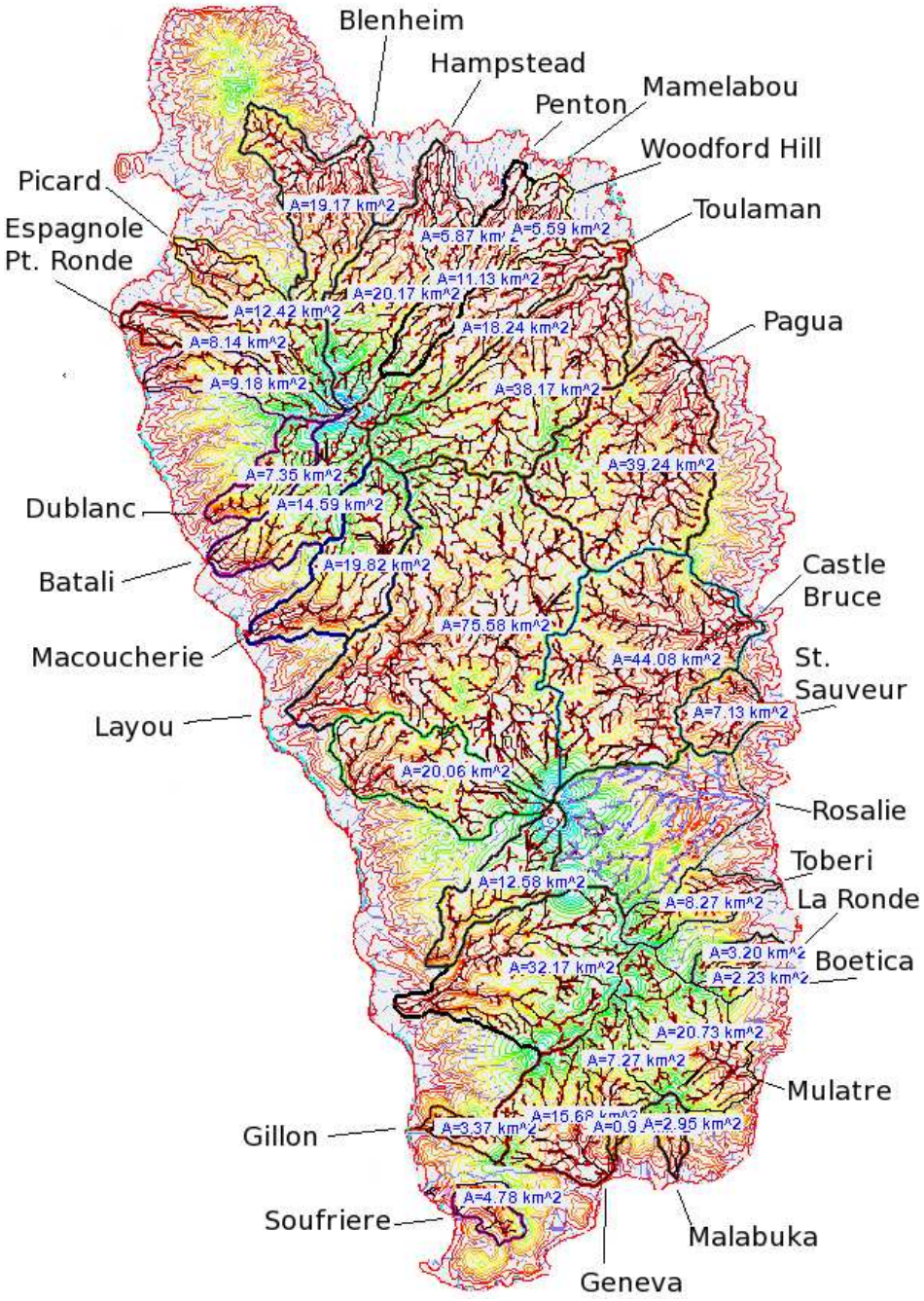


*Figure 16: The 24 watersheds simulated with watershed outlet near the coast as part of this project. The colors correspond to elevation, with red being lowest and blue being highest terrain.*

The watersheds in Figure 16 were simulated and the results are listed in Table 5, including the latitude and longitude of the simulated outlet point of the watershed at the coastline. Also included in the Table 4 are the simulated watershed area, modeled peak

discharge, watershed average rainfall, runoff, and runoff efficiency. The runoff efficiency was calculated as the depth of runoff (mm) divided by the watershed average rainfall (mm) and converted to a percentage. These simulations were driven by radar-rainfall estimates calculated using $Z=132R^{1.2}$.

**Table 4.** Modeled runoff for 24 additional watersheds around Dominica shown in Figure 16. River names taken from map by Government of Dominica Ordinance Survey, 1991.

| Watershed | Area $km^2$ | $Q_p$ ($m^3s^{-1}$) | Rainfall (mm) | Runoff (mm) | Runoff eff. (%) | Latitude (N) | Longitude (W) |
|---|---|---|---|---|---|---|---|
| Layou | 75.40 | 2495 | 564 | 348 | 62 | 15:24:09 | 61:24:42 |
| Macoucherie | 19.12 | 1061 | 630 | 416 | 66 | 15:25:45 | 61:25:37 |
| Batali | 14.20 | 905 | 654 | 427 | 65 | 15:27:12 | 61:26:39 |
| Dublanc | 7.45 | 338 | 514 | 270 | 53 | 15:30:53 | 61:27:57 |
| Pointe Ronde | 8.12 | 246 | 405 | 206 | 51 | 15:31:58 | 61:38:36 |
| Picard | 12.41 | 382 | 501 | 262 | 52 | 15:33:36 | 61:27:22 |
| Blenheim | 18.91 | 863 | 442 | 252 | 57 | 15:35:32 | 61:23:27 |
| Hampstead | 19.54 | 931 | 534 | 291 | 55 | 15:35:29 | 61:21:57 |
| Penton | 5.85 | 266 | 527 | 340 | 65 | 15:35:26 | 61:21:49 |
| Mamelabou | 10.81 | 522 | 529 | 318 | 60 | 15:35:06 | 61:20:08 |
| WoodfordHill | 5.59 | 240 | 585 | 368 | 63 | 15:34:51 | 61:19:20 |
| Toulaman | 16.52 | 722 | 591 | 330 | 56 | 15:33:16 | 61:18:27 |
| Pagua | 38.11 | 1319 | 625 | 362 | 58 | 15:32:50 | 61:17:52 |
| Castle Bruce | 44.07 | 855 | 483 | 263 | 54 | 15:31:03 | 61:16:29 |
| St. Sauveur | 7.13 | 211 | 459 | 244 | 53 | 15:24:16 | 61:15:14 |
| Rosalie | 29.87 | 987 | 494 | 272 | 55 | 15:22:19 | 61:15:11 |
| Toberi | 8.27 | 221 | 478 | 255 | 53 | 15:20:31 | 61:14:53 |
| La Ronde | 3.20 | 88 | 468 | 247 | 53 | 15:19:14 | 61:14:46 |
| Boetica | 2.23 | 75 | 499 | 274 | 55 | 15:18:37 | 61:14:48 |
| Mulatre | 20.70 | 739 | 567 | 317 | 56 | 15:16:35 | 61:15:23 |
| Geneva | 22.92 | 724 | 491 | 258 | 52 | 15:14:39 | 61:18:26 |
| Soufriere | 4.77 | 121 | 399 | 174 | 44 | 15:14:17 | 61:18:53 |
| Gillon | 3.36 | 89 | 366 | 146 | 40 | 15:15:33 | 61:22:27 |
| Malabuka | 2.96 | 111 | 512 | 298 | 58 | 15:14:35 | 61:16:59 |

Results in Table 4 show that simulated runoff efficiencies varied from a low of 34 percent in the case of the Gillon watershed, to a high of 69 percent in the Batali and Macoucherie river watersheds. The organization of the watersheds in Table 4 largely follows a clockwise path around the island starting from the Layou, which at 75.4 km$^2$ is the largest watershed on the island and drains to the Caribbean sea. The GSSHA simulated peak discharge values from the 24 watersheds listed in Table 4 plus the 16 watersheds listed in Table 3 are plotted vs. drainage area in Figure 17. This figure also includes the ICOLD peak discharge envelope for watersheds less than 300 km$^2$ in area. The best fit line through the simulated flood peaks has a slope of 1.02 on log-log axes.

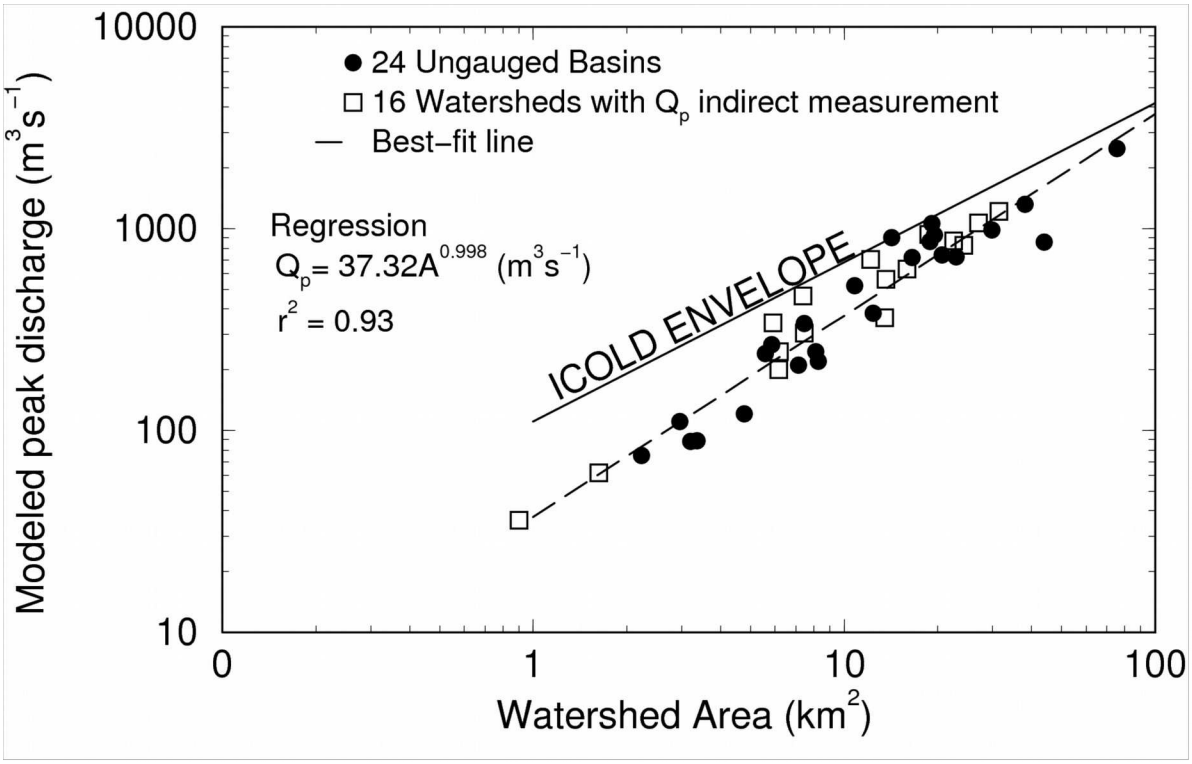


*Figure 17: Simulated peak discharges using GSSHA with soil saturated hydraulic conductivity $K_s$=2.0 cm h$^{-1}$ driven by TS Erika radar-rainfall on 16 watersheds were indirect peak discharge measurements were made plus the 24 ungauged watersheds (40 total).*

The results in Figure 17 provide an indication that the GSSHA simulations of ungauged basins with soil hydraulic parameters previously given provide plausible peak discharges relative to the ICOLD maximum discharge envelope. The regression line through the peak discharges indicate that if the GSSHA model represents the response of watersheds in Dominica to extreme rainfall, then the peak discharge scales approximately linearly with drainage area.

This linear response is likely an artifact of the relatively small range of basin sizes. Studies in the U.S. have indicated area scaling relationships with an exponent up to 0.77 (Ogden and Dawdy, 2003) up to 20 km$^2$. The relationship given in Figure 17, taken in the context of indirect peak discharge measurements shown in Figure 2, provides a basis for flow calculations

that may be used in design. Resilient bridge designs such as that shown in Figure 3 could accommodate a much smaller flow on average, but be designed to pass a much higher discharge and survive the event.

## Analysis of GSSHA Simulated Peak Runoff Extremity

Truly extreme runoff events approach a condition where the amount of water leaving the watershed is very nearly the amount of rainfall entering the watershed less some constant loss rate. This is the physical justification behind the concept of the peak runoff rate envelope curve.

In smaller catchments, the envelope limit is reached when the atmosphere provides the maximum possible rainfall rate for a long enough time that the entire watershed area contributes to runoff. The 300 $km^2$ break in the ICOLD envelope curve is approximately the upper limit of the areal extent at which atmosphere can produce torrential rainfall. Above this 300 $km^2$ limit, the likelihood that torrential rainfall covers the watershed is diminishingly small.

The radar-rainfall data from TS Erika, were analyzed in terms of the watershed-average peak rainfall rate $i_p$ in mm $h^{-1}$. Similarly, the peak discharge from GSSHA simulations were converted to peak runoff rates $r_p$ in mm $h^{-1}$. A key dimensionless parameter is the dimensionless runoff rate $r_p$*, which is calculated as:

$$r_p * \frac{r_p}{\left(i_p - K_s\right)} \tag{2}$$

The independent variable of interest is the peak runoff rate $Q_p$ that is normalized by the envelope curve peak runoff rate $Q_{pe}$ that is assumed to be solely a function of watershed area A to produce a dimensionless peak discharge $Q_p$*:

$$Q_p * \frac{Q_p}{Q_{pe}\left(A\right)} \tag{3}$$

Figure 18 plots $Q_p$* versus $r$* to identify which watersheds more closely approached equilibrium conditions, and were therefore more severely impacted by the rainfall from TS Erika. These results provide a visual indication of which watersheds were most impacted by the storm. Those watersheds in the upper right-hand portion of the figure were most severely affected with Q*>80%, which include the Macoucherie, Coulibistrie, Hampstead and Colihaut watersheds. A second group with 50<Q*<80% include the Belfast, Belle Fille, Melville Hall, Roseau, Rosalie, and Boeri. Those watersheds with Q* less than 0.5, the Pointe Ronde, Castle Bruce, Dubuc and Malabuka received considerably less rainfall that the other watersheds and the GSSHA models had notably lower peak flow values compared to the envelope maximum.

As previously stated, the peak flows in the Dubuc, Geneva, and Malabuka watersheds were obviously affected by landslide dam failures. If it were not for these landslide dam failures, the peak discharge in those watersheds would have been less than 40% of the envelope for the

Dubuc and Malabuka river, and about 60% in the case of the Geneva River. In actuality, the peak discharge in those three rivers was considerably greater than the envelope value because of landslide dam failures.

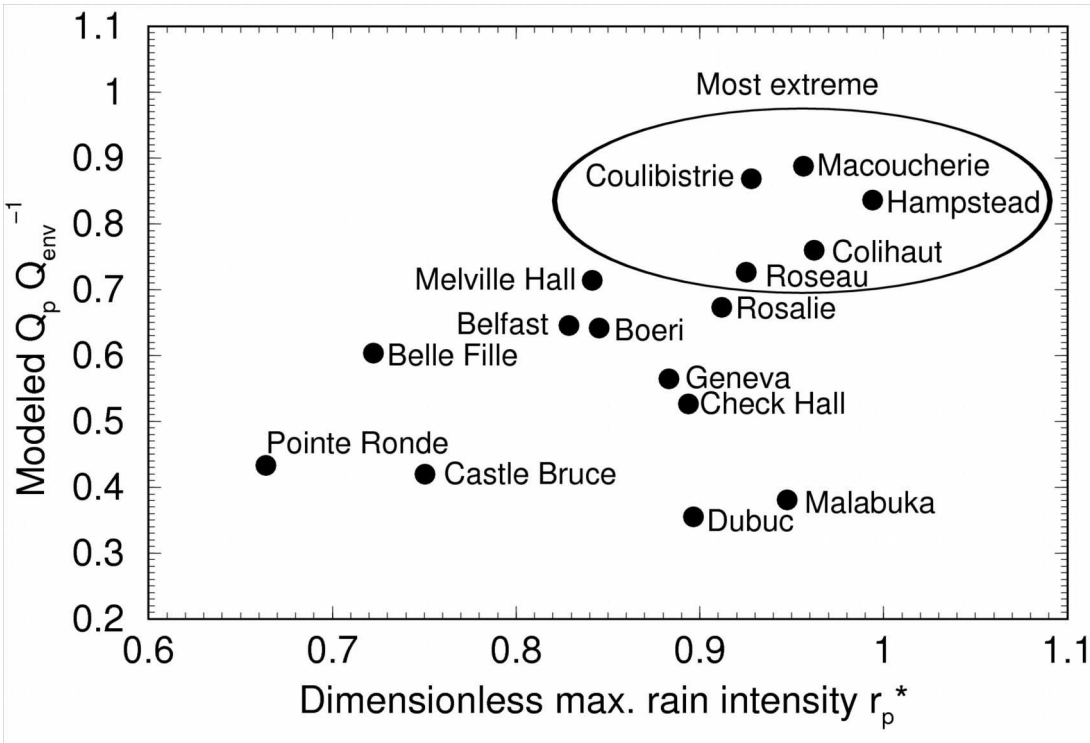


*Figure 18: Simulated peak discharge normalized by the envelope peak discharge (Q*) versus the peak observed runoff rate normalized by the peak instantaneous excess rainfall rate (R*). Both quantities are dimensionless. Watersheds with larger Q* values were worst affected. Effects of landslide dam failure not included.*

The rainfall and runoff rates (mm $h^{-1}$) for the Macoucherie river, one of the worst affected are plotted together in Figure 19. This figure indicates that the peak rate of runoff was very nearly the same as the peak rainfall rate.

The severity of TS Erika in the Macoucherie river watershed is apparent in Figure 19. The peak runoff rate from GSSHA is 238 mm $h^{-1}$, while the peak rainfall rate is 270 mm $h^{-1}$. The difference is only 32 mm $h^{-1}$, which is only 10 mm $h^{-1}$ less than the simulated infiltration rate of approximately 20 mm $h^{-1}$ at this point in the storm. This is seldom seen, and indicates that for the Macoucherie watershed and others with $Q_p$* values near 1.0 on Figure 18, the event was near the envelope curve maximum value.

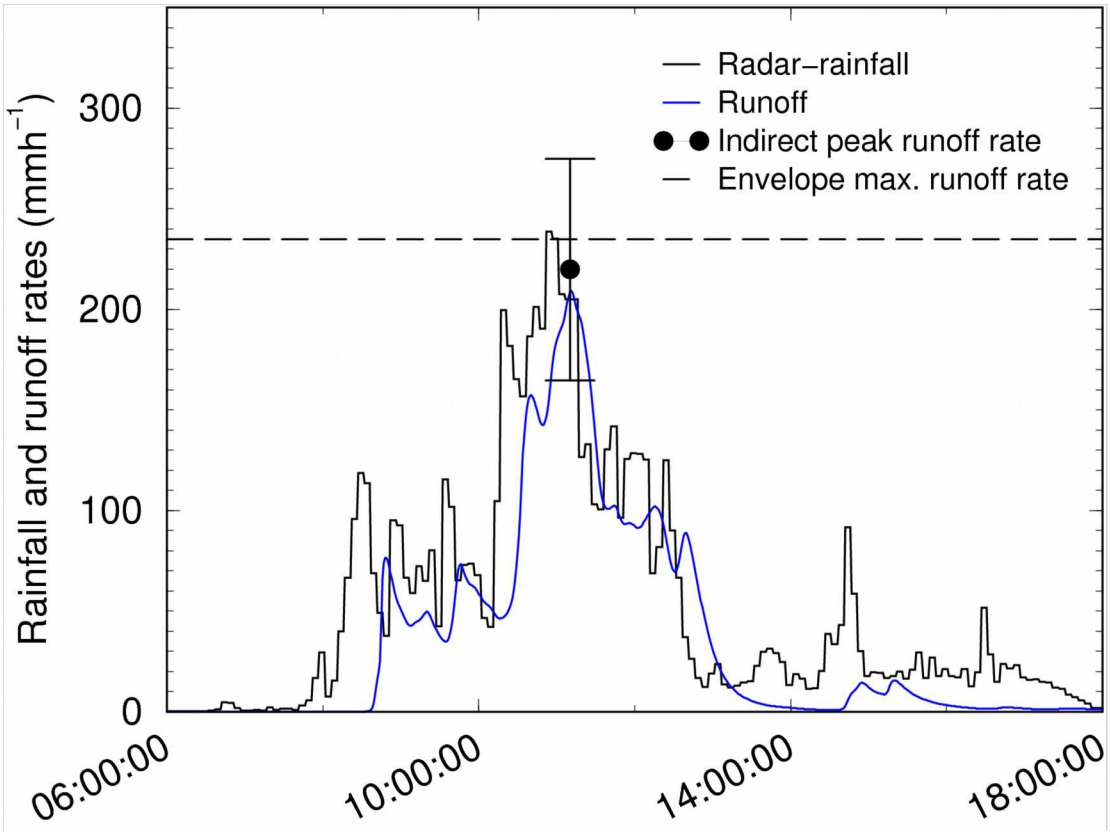


*Figure 19: The 12.15 km$^2$ Macoucherie River watershed neared equilibrium conditions during TS Erika, with runoff rate nearing rainfall rate during peak flow. Error bars on indirect peak discharge measurement represent ±25 percent.*

# Conclusions

The results from the indirect peak discharge measurements indicate that with some uncertainty, the peak flows resulting from the extreme rainfall associated with TS Erika were near the ICOLD envelope of maximum flood events recorded anywhere on the planet. In five of the 16 watersheds the failure of landslide dams led to much larger peak flows than the ICOLD envelope. Those events are random and unpredictable. Furthermore the peak flows from landslide dam failures are typically of low volume and short duration. Designs that appropriately incorporate features of resilience including resistance to scour, erosion, and overtopping that incorporate low elevation approaches can withstand these short-duration high-intensity flood peaks due to landslide dam failures.

The bias adjusted radar-rainfall estimates obtained by processing radar data from the Le Moule radar on Guadeloupe represent reasonably accurate values. The rain gauge data set provided by the Dominican Meteorological Service and used to perform the bias adjustment are located in the southern half of Dominica, which provides an indication that range effects from Le Moule radar were not a significant impediment to accurate radar-rainfall estimation for this

event. Beam propagation analysis indicated that the 1.6-degree elevation angle from Le Moule barely contacts the top of Morne Diablotins with the 2.1-degree radar half-power beamwidth. However, data analysis indicated episodes of abnormal propagation that resulted in false echoes near mountaintops. Those false echoes were mostly removed with the application of a clutter mask. The rainfall isohyetal map shown in Figure 13 may contain some effects of radar ground clutter. Far from mountain peaks it does not.

The bias-adjusted radar-rainfall estimates exhibit a coefficient of determination $r^2$=0.85 at the hourly level, using 17 hours of radar-rainfall accumulations evaluated over 8 tipping bucket rain gauges. Spatial analysis of rainfall indicated that portions of Dominica received over 750 mm of rainfall, and the island-wide average rainfall for the event was 610 mm, almost twice the preliminary 320 mm reported in the aftermath of the event based on the recorded accumulation at the Canefield airport.

The U.S. Army Corps of Engineers, Gridded Surface/Subsurface Hydrological Analysis (GSSHA) model was used to simulate the 16 basins where indirect peak discharge measurements were made. These simulations served two purposes. The first set of simulations, which were driven by radar-rainfall estimates, assumed that the soil was relatively impervious and saturated with a very small value of saturated hydraulic conductivity $K_s$=0.001 cm $h^{-1}$. The purpose of those simulations was to compare the worst-case, saturated soil condition against the indirect peak discharge measurements. This comparison provided a diagnostic to identify the likely occurrence of landslide dam failure affected peak flows. This diagnostic test agreed quite closely with the comparison against the ICOLD envelope curve, and similarly identified that five of the 16 indirectly measured peak flows were influenced by landslide dam failure.

The GSSHA model was next used to simulate the 16 measured catchment, using a value of soil saturated hydraulic conductivity measured for saprolitic soils of $K_s$=2.0 cm $h^{-1}$, (Hassler et al. 2013) and literature values of other soil hydraulic parameters. 11 of 16 simulations with peaks of similar magnitudes to the measurements had an average error of 38% and a mean absolute error of 39%. This error is similar to the 25% error that is attributed to indirect peak discharge measurements. This supports the notion that GSSHA peak discharge estimates with the assumed soil hydraulic parameters are plausible indirect peak discharge estimates.

The atmospheric conditions that caused tropical storm Erika to drop extreme rainfall on the island of Dominica probably were due at least in part to the topography of the island. It is likely that events such as Erika are not particularly rare in the context of extreme events. The height of the topography of Dominica seemed to trigger convection that created low level convergence and local circulation that lingered over Dominica for several hours.

The peak discharge values shown in Figure 17 might be used by the appropriate licensed professional to design replacement bridges in Dominica. The GSSHA model will allow transposition of different rainfall fields from TS Erika or other tropical storms/hurricane onto Dominican watersheds or possibly other Caribbean islands. The designer of replacement bridges shall focus on resiliency. Designs that can pass both the annual average discharge and survive

large flows that are a significant fraction of the envelope peak discharge are ideal, using contemporary intelligent transportation systems to protect the public from flooded waterways.

The linear regression shown in Fig. 17 indicates that the simulated peak discharges scaled linearly with the drainage area for TS Erika in Dominica. This result supports the hypothesis that the watersheds simulated throughout the island approached equilibrium conditions, where the peak outflow was determined by the peak rainfall rate minus a small constant abstraction rate. This condition indicates both that the event was truly extreme, and that the non-landslide-affected estimate of the peak discharge depended solely on the constant specific discharge of 37.3 $m^3 s^{-1} km^{-2}$.

The design of replacement bridges in Dominica shall include features to promote resiliency. These features shall include: low approaches that allow overtopping and that are designed to prevent erosion due to overtopping, scour resistant abutments and piers, and solar-powered blinking signs to warn against overtopping conditions.

# Acknowledgments

The work reported upon in this report was a team effort. The two survey crews from the Government of Dominica, from the Ministry of Lands and Surveys and Public Works led by Mr. Ali Cuffy and Mr. Malcolm Belle, respectively performed the survey work. Michelle Ogden performed admirably as field assistant during our expedition in late October and helped in documenting field conditions and preparing the appendices of this report. Samantha Marquard Ogden assisted with setup of the GSSHA models and prepared the tutorial for the GSSHA modeling 1-day short course. Mr. Collin Guiste, and Ms. Andrea Marie and the other staff from the DVRP office in Roseau provided excellent support for field activities including coordination of personnel, provision of transport and lunches, without which those intense days in the field would not have been possible. Mr. Steven Durand and Mr. Octave Joseph both provided invaluable assistance in the field for their knowledge of the country. Mr. Jerry Meyer and Mr. Mike Fedak of the World Bank provided key technical support. Aquaveo LLC provided the WMS software used to set up the GSSHA model. All this support is gratefully acknowledged.

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# Appendix A

# Description of Cross Sections Surveyed with Photographs including GSSHA Simulated Hydrographs

## Table of Contents

Site Name: Belfast River.....A-2
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Site Name: Rosalie River.....A-39
Site Name: Roseau River near Elms Hall.....A-42

**Site Name: Belfast River**

**GPS Coordinates:**

| Latitude (N) | Longitude (W) | Quality of Reach |
|---|---|---|
| DD:MM:SS | DD:MMSS | Good, Fair, Poor |
| 15:22:50 | 61:23:14 | G |

**GPS Used:**
Garmin Model 60

**Channel Properties:**
Well defined according to survey data.

**High Water Marks:** Not described.

**Other remarks:**
No photos provided.

**Comments from field book:**
Unknown

Belfast River continued

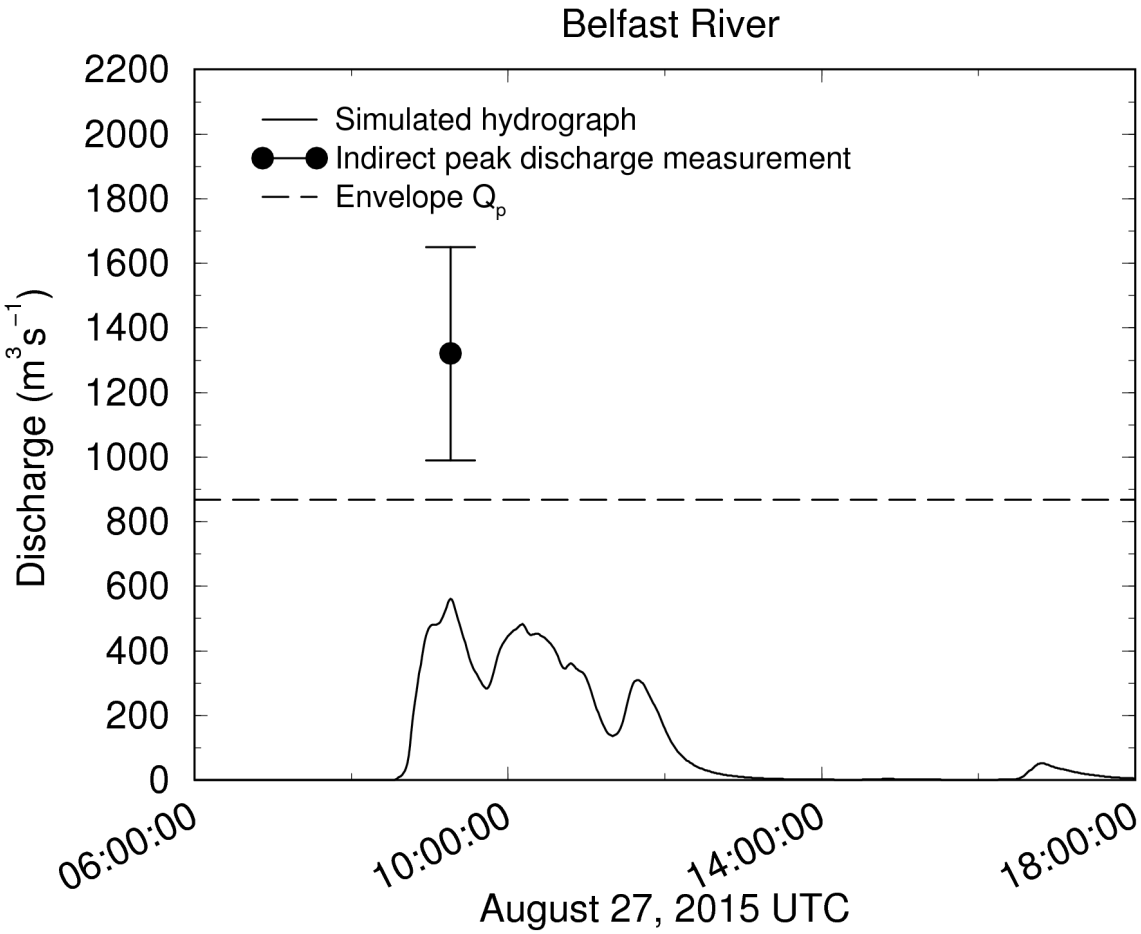



***Figure A-1.*** *Belfast R. GSSHA Simulation with saturated hydraulic conductivity 2 cm/h.*

**Model conclusion:** Obviously landslide affected.

**Site Name: Belle Fille River**

**GPS Coordinates:**

| Latitude (N) | Longitude (W) | Quality of Reach |
|---|---|---|
| DD:MM:SS | DD:MMSS | Good, Fair, Poor |
| 15:25:09 | 61:16:33 | G |

**GPS Used:**
Garmin Model 60CSx

**Channel Properties:**
Narrow, well contained on right side where steep banks and cliffs present, otherwise poorly contained. Near encroachment of a banana plantation, river bank erosion, sand of deposition, large woody debris.

**High Water Marks:**
High water marks on right bank sparse. On left bank there were plenty of signs of river flow in the root field.

**Other remarks:**
Photo#: P1090776, P1090782, P1090785, P1090786, P1090797, P1090798, P1090801, P1090807, P1090813, P1090816

**Comments from field book:**
Survey site located ~1.5 km above confluence with Castle Bruce River. Mr. Ali Cuffy, et al. started alone as per Stephen Durand went upstream quite far. When I visited them it seemed to be a very 2-D reach. Sure enough there was an island in the channel with significant bypass flow.: Moved D.S. about 300 - 400 m to a spot by a cliff that was less 2-D, more 1-D.





Belle Fille River continued










Belle Fille River continued

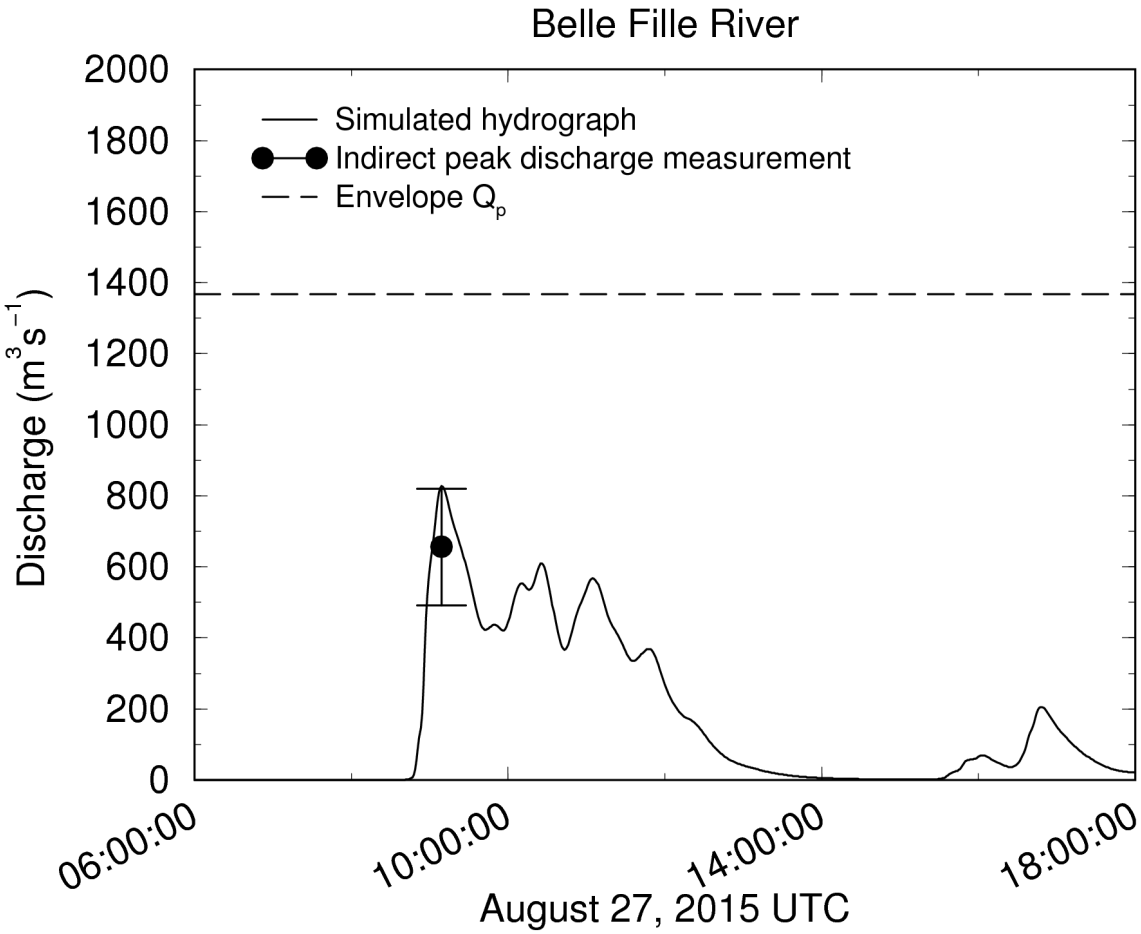



***Figure A-2.*** *Belle Fille R. GSSHA Simulation with saturated hydraulic conductivity 2 cm/h.*

**Model conclusion:** Not landslide affected.

**Site Name: Boeri River near Canefield**

**GPS Coordinates:**

| Latitude (N) | Longitude (W) | Quality of Reach |
|---|---|---|
| DD:MM:SS | DD:MMSS | Good, Fair, Poor |
| 15:19:06 | 61:22:18 | G |

**GPS Used:**
Garmin 60

**Channel Properties:**
See photos

**High Water Marks:**
Not described.

**Other remarks:**
Photo#: Boeri River, Boeri R1, Boeri R5

**Comments from field book:**
None







Boeri River near Canefield continued

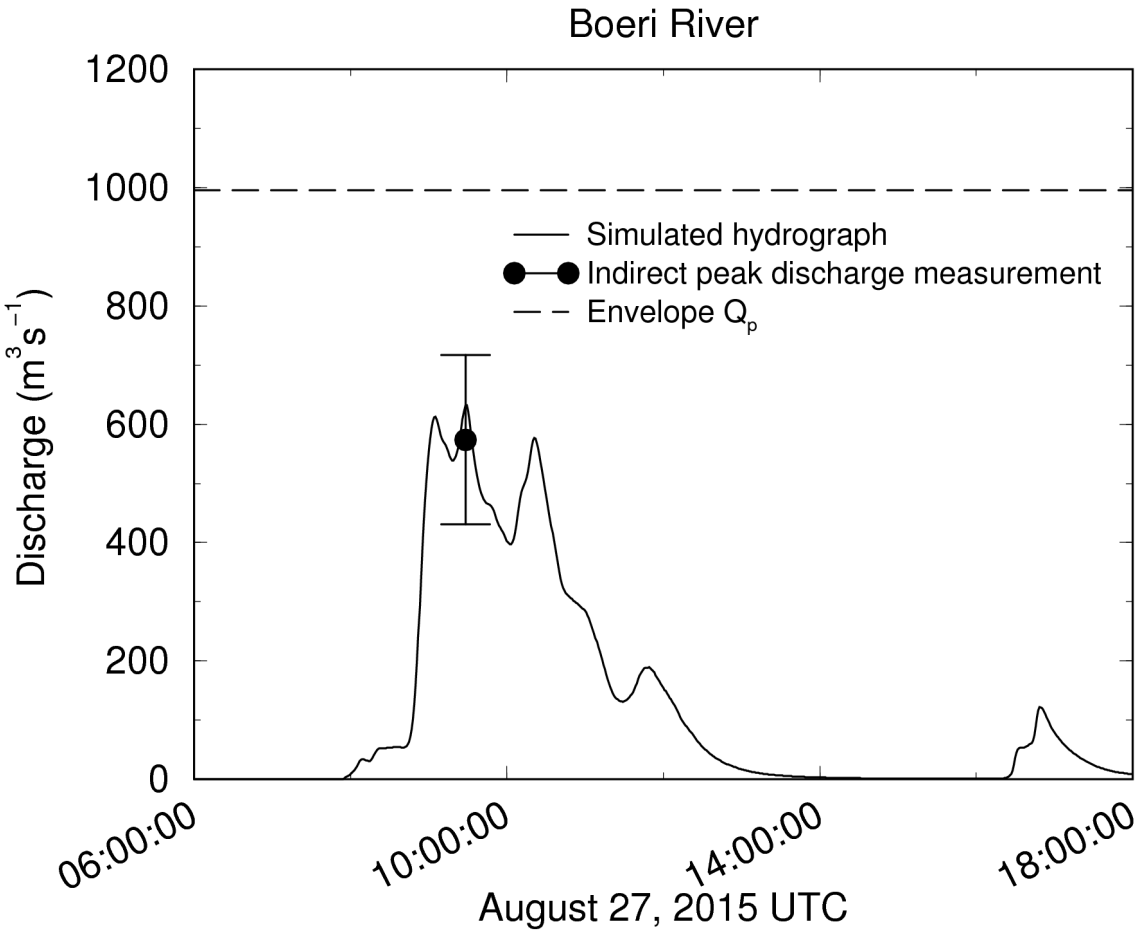



***Figure A-3.*** *Boeri R. GSSHA Simulation with saturated hydraulic conductivity 2 cm/h.*

**Model conclusion:** Not landslide affected.

**Site Name: Castle Bruce River**

**GPS Coordinates:**

| Latitude (N) | Longitude (W) | Quality of Reach |
|---|---|---|
| DD:MM:SS | DD:MMSS | Good, Fair, Poor |
| 15:25:42 | 61:16:35 | G |

**GPS Used:**
Other (Survey completed by Public Works team)

**Channel Properties:**
Narrow, well contained, river bank erosion, woody debris, damage to bridge.

**High Water Marks:**
Flow contained within channel. One huge boulder in the channel- did not seem to move. High water marks fairly easy to find on both banks consisting of wedged vegetation or linear debris deposition.

**Other remarks:**
Photo#: 1090760,1090761, 1090766

**Comments from field book:**
Survey completed by Public Works, Mr. Malcolm Belle, et al. at site located about ~1 km upstream from 1st bridge over Castle Bruce River.





Castle Bruce River continued



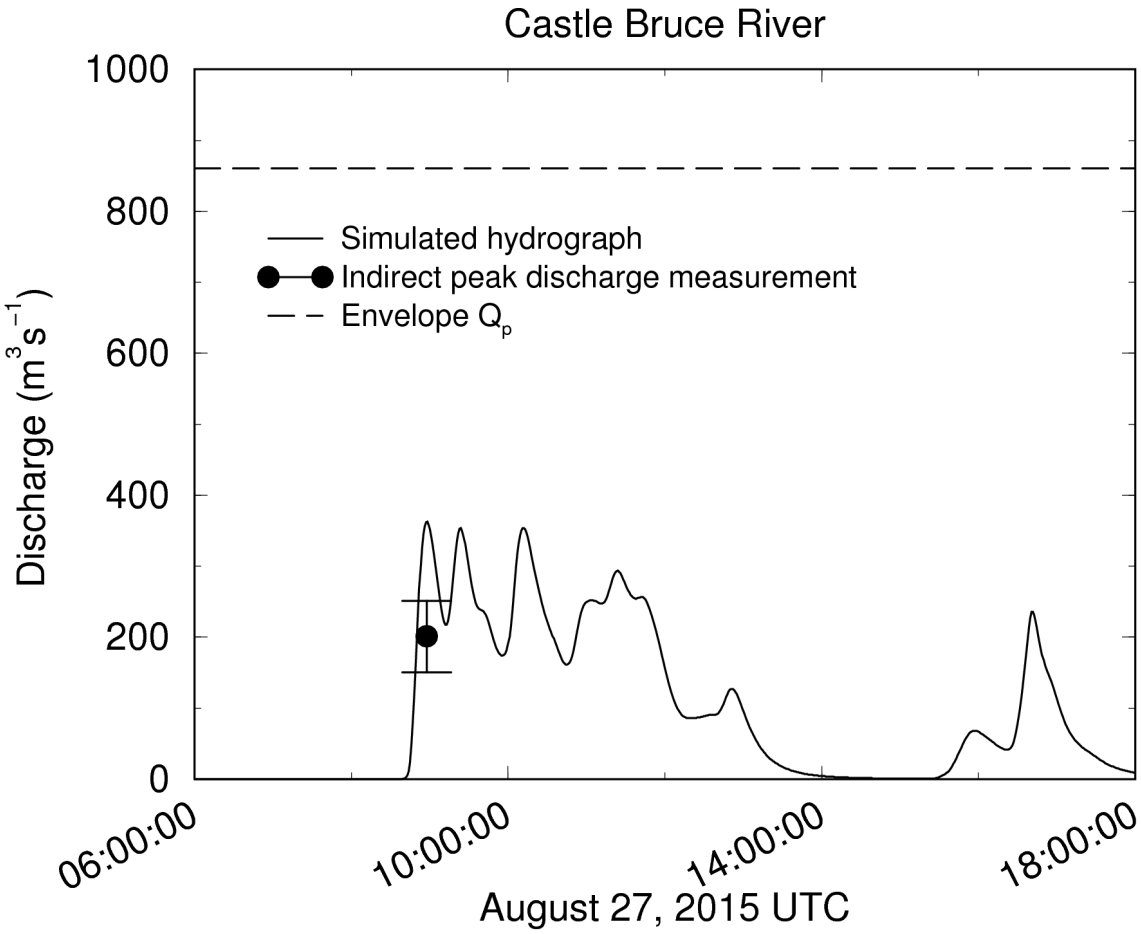



***Figure A-4.*** *Castle Bruce R. GSSHA Simulation with saturated hydraulic conductivity 2 cm/h.*

**Model conclusion:** Not landslide affected.

**Site Name: Check Hall River north of Canefield**

**GPS Coordinates:**

| Latitude (N) | Longitude (W) | Quality of Reach |
|---|---|---|
| DD:MM:SS | DD:MMSS | Good, Fair, Poor |
| 15:20:36 | 61:23:11 | G |

**GPS Used:**
Garmin Model 60CSx

**Channel Properties:**
Narrow, well contained canyon above head of alluvial fan, river bank erosion, signs of deposition, large woody debris

**High Water Marks:**
The group received good training on high water mark identification at this site. High water marks were relatively easy to find. Channel was well confined within valley walls above the head of the alluvial fan. STEEP.

**Other remarks:**
Photo#: (includes high water mark*): 1090626, 1090628, 1090631*, 1090639, 1090648, 1090663, 1090667, 1090668

**Comments from field book:**
Check Hall River north of Canefield is a straight and uniform reach in a canyon above head of alluvial fan. Crew from Lands & Surveys Department led by Mr. Ali Cuffy.





Check Hall River north of Canefield continued








Check Hall River north of Canefield continued

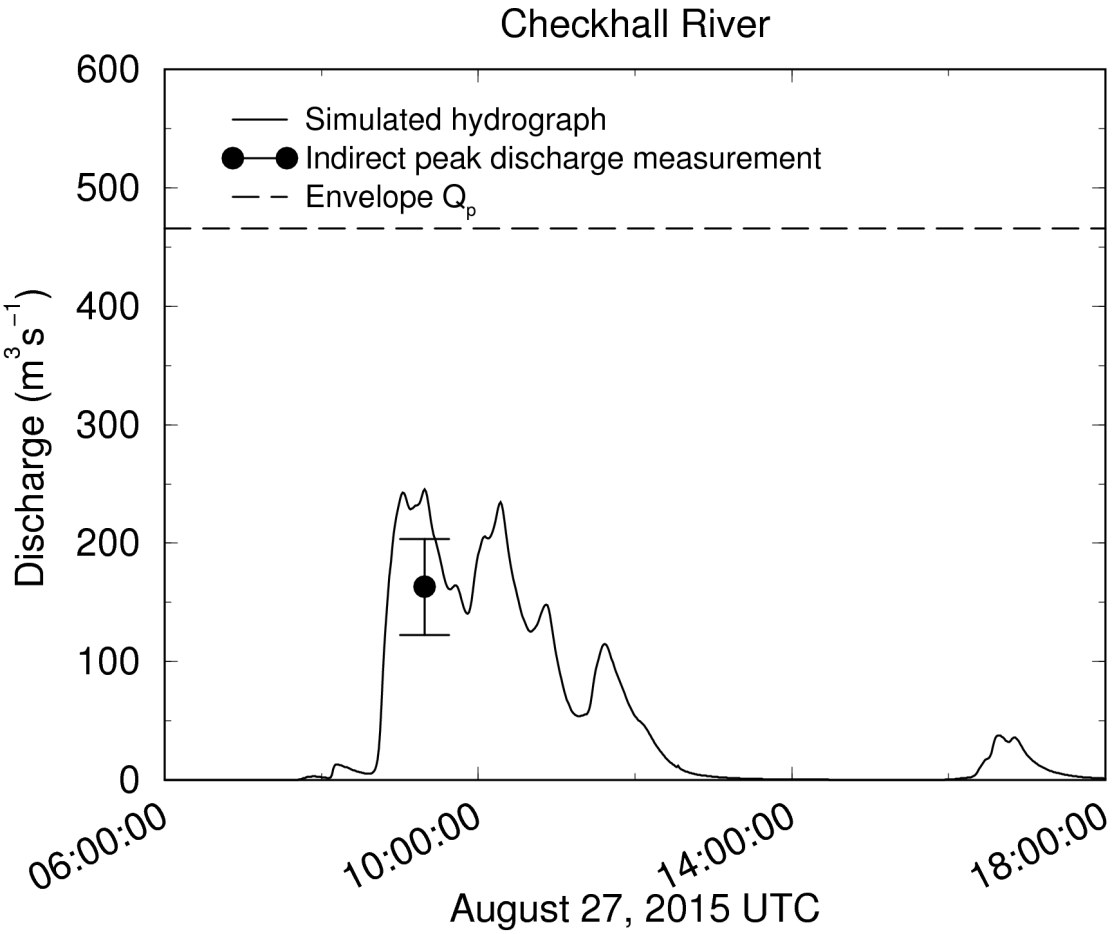



***Figure A-5.*** *Checkhall R. GSSHA Simulation with saturated hydraulic conductivity 2 cm/h.*

**Model conclusion:** Not landslide affected.

**Site Name: Colihaut River**

**GPS Coordinates:**

| Latitude (N) | Longitude (W) | Quality of Reach |
|---|---|---|
| DD:MM:SS | DD:MMSS | Good, Fair, Poor |
| 15:29:24 | 61:27:18 | F |

**GPS Used:**
Garmin Model 60CSx

**Channel Properties:**
Wide, river flowed out of former river path, extensive river bank erosion and sand-gravel deposition, submerged buried bridges, road damage, undercut concrete footings or curbs, large woody debris present.

**High Water Marks:**
High water mark identification pretty easy. Lots of signs consisting of clean swept surfaces and linear deposits of floating matter. One major question is when did this large gravel bar deposit, there is some uncertainty regarding when it eroded. For this reason given Fair rating.

**Other remarks:**
Photo#: 1090946, 1090953, 1090963, 1090970, 1090977

**Comments from field book:**
River path change?, submerged buried bridges, x-sec drawing=river bed filled with sediment which was a nearly vertical wall 1.0-2.0 in height.





Colihaut River continued







Colihaut River continued

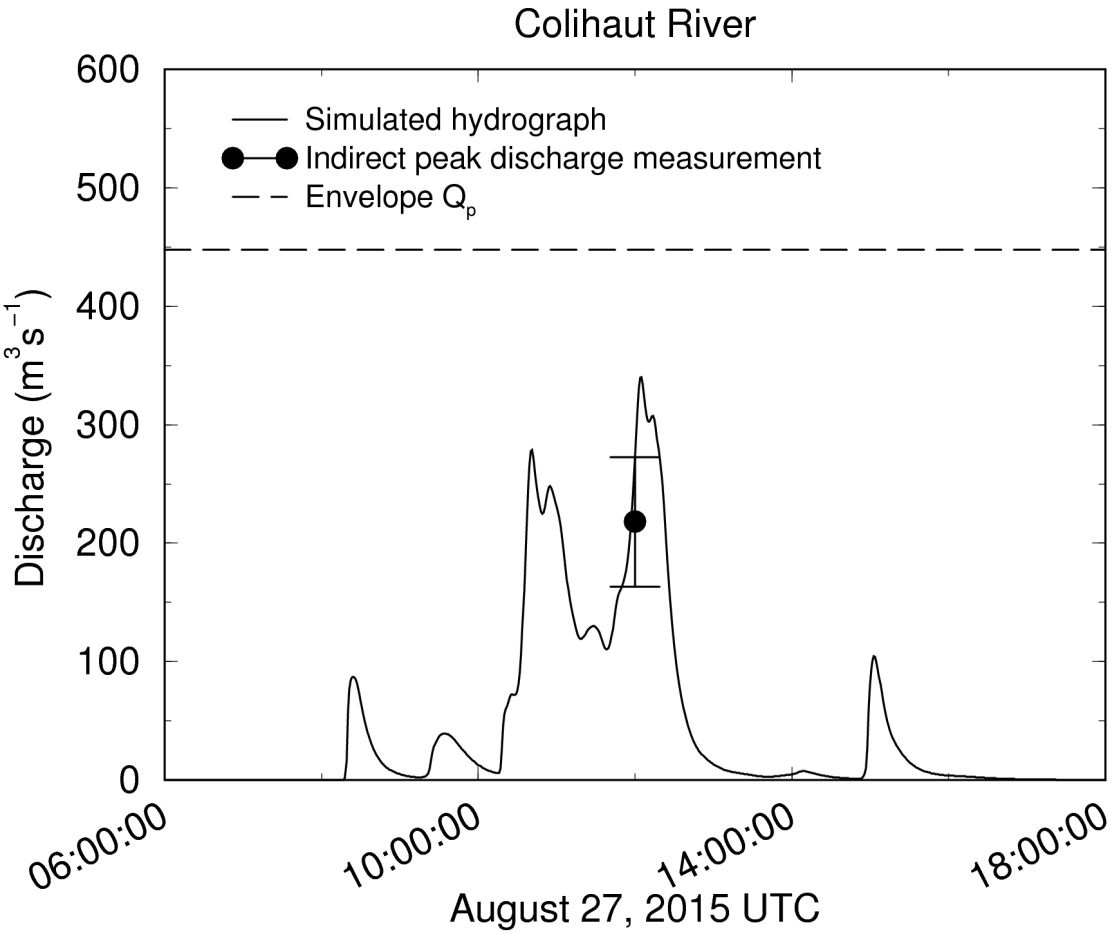



***Figure A-6.*** *Colihaut R. GSSHA Simulation with saturated hydraulic conductivity 2 cm/h.*

**Model conclusion:** Not landslide affected.

**Site Name: Coulibistrie River**

**GPS Coordinates:**

| Latitude (N) | Longitude (W) | Quality of Reach |
|---|---|---|
| DD:MM:SS | DD:MMSS | Good, Fair, Poor |
| 15:27:58 | 61:26:50 | F |

**GPS Used:**
Garmin Model 60CSx

**Channel Properties:**
Narrow, above the head of an alluvial fan. Well contained on left and right banks where cliffs or deep banks are present, poorly contained in other areas, extensive river bank erosion and sand-gravel-rock deposition, large woody debris, property debris in alluvial area. Post-event channel changes, extensive flood damage to infrastructure and buildings in the town of Coulibistrie.

**High Water Marks:**
High water marks abound on remnants of large trees bashed and broken by this extreme flow. Pure devastation. Influence of large woody debris makes one wonder what this wild flow looked like, and how much it was affected by the woody debris.

**Other remarks:**
Photo# (includes high water mark*): 1090870, 1090872, 1090874, 1090882,1090883, 1090889, 1090891*, 1090902, 1090903, 1090922*, 1090924, 1090942

**Comments from field book:**
None





Coulibistrie River continued










Coulibistrie River continued





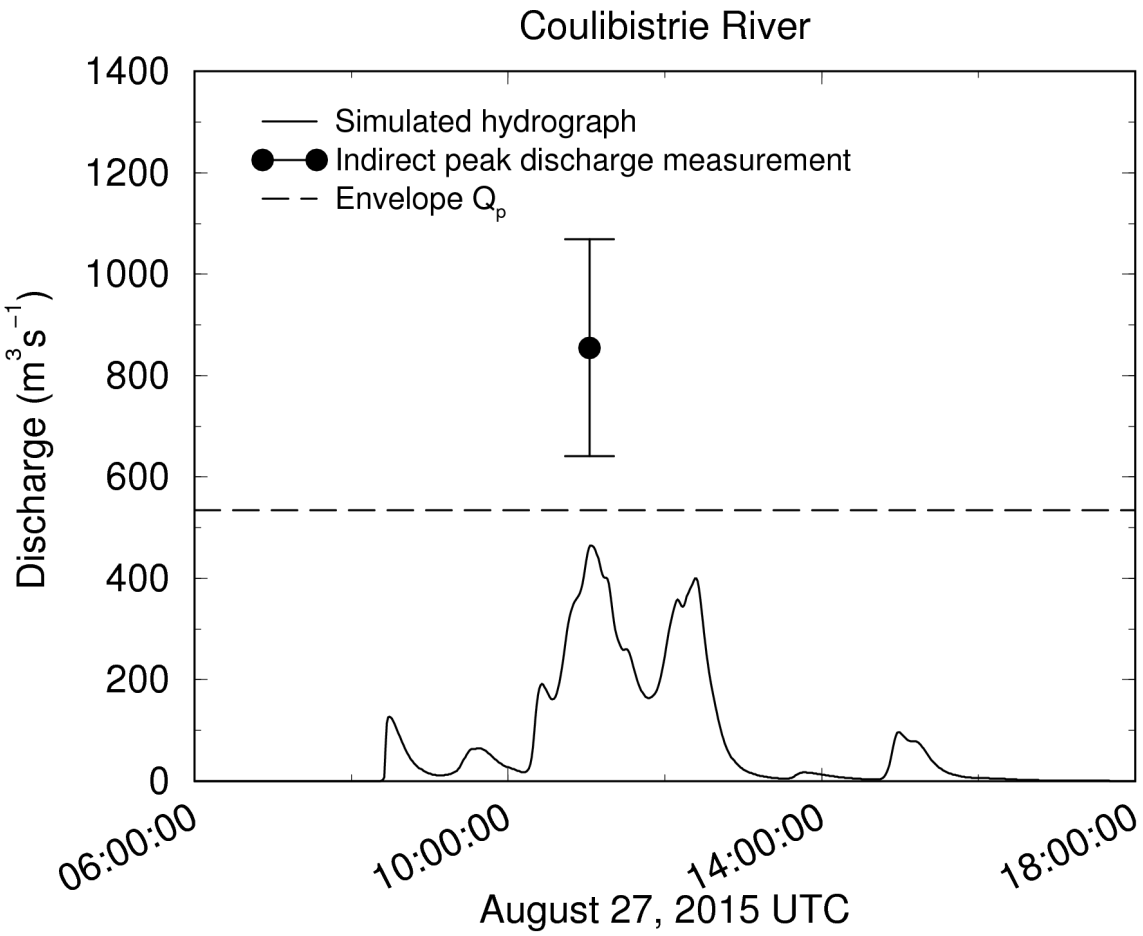



***Figure A-7.*** *Coulibistrie R. GSSHA Simulation with saturated hydraulic conductivity 2 cm/h.*

**Model conclusion:** Obviously landslide affected.

**Site Name: Dubuc River**

**GPS Coordinates:**

| Latitude (N) | Longitude (W) | Quality of Reach |
|---|---|---|
| DD:MM:SS | DD:MMSS | Good, Fair, Poor |
| 15:15:00 | 61:18:19 | G |

**GPS Used:**
Other

**Channel Properties:**
Well confined channel.

**High Water Marks:**
Good visibility.

**Other remarks:**
Photo#: Dubique R1, P1100703, P1100705, P1100706, P1100708, P1100709

**Comments from field book:**
None






Dubuc River continued





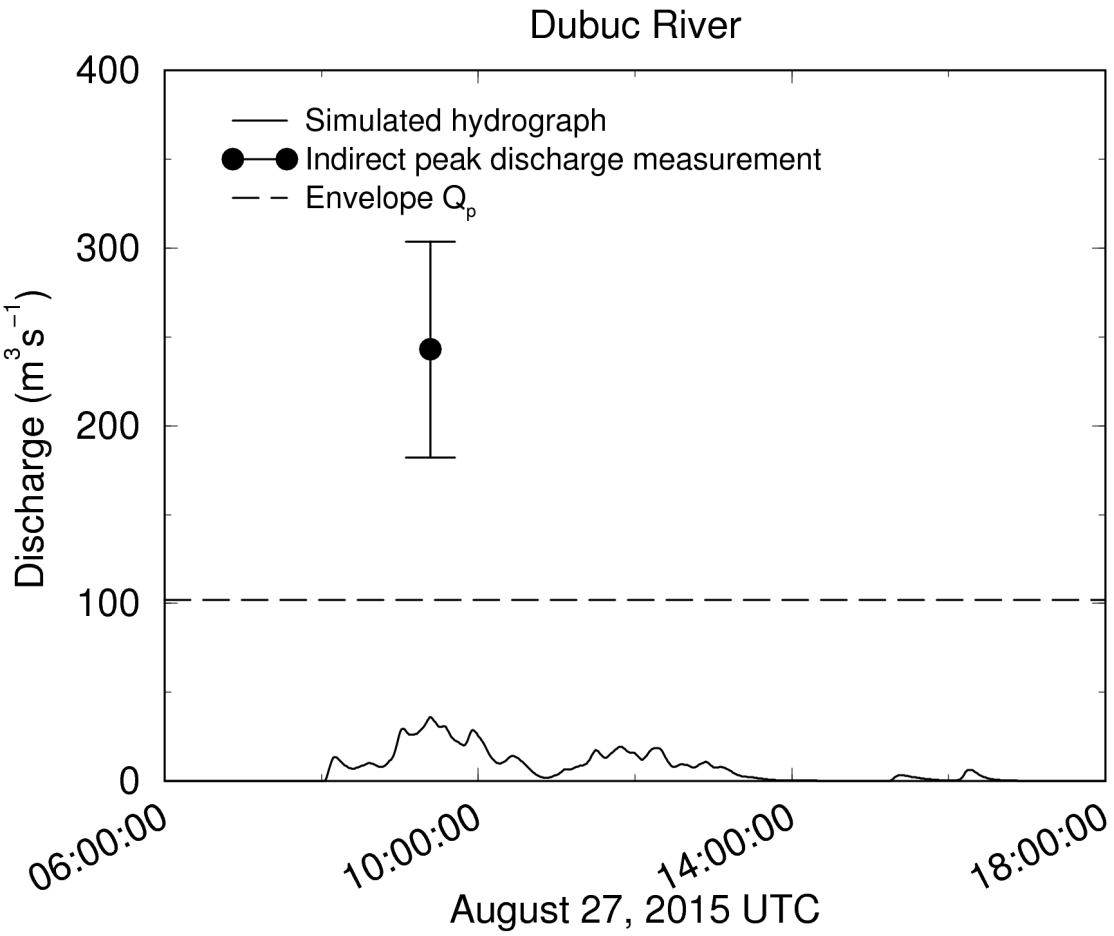



***Figure A-8.*** *Dubuc R. GSSHA Simulation with saturated hydraulic conductivity 2 cm/h.*

**Model conclusion:** Obviously landslide affected.

**Site Name: Geneva River**

**GPS Coordinates:**

| Latitude (N) | Longitude (W) | Quality of Reach |
|---|---|---|
| DD:MM:SS | DD:MMSS | Good, Fair, Poor |
| 15:15:56 | 61:18:36 | G |

**GPS Used:**
Garmin 60CSx

**Channel Properties:**
Broad, very large sediment. Massive distruction along banks.

**High Water Marks:**
Good visibility, even in March, 2016.

**Other remarks:**
Photo#: Geneva 1, Geneva 2, Geneva 3, Geneva 5, Geneva 7, Geneva R1, P1100611, P1100615, P1100617, P1100619

**Comments from field book:**
Stephen Durand reported that people living upstream said at approximately 5:00 am on August, 27, 2015, the river sounded like a train.






Geneva River continued








Geneva River continued

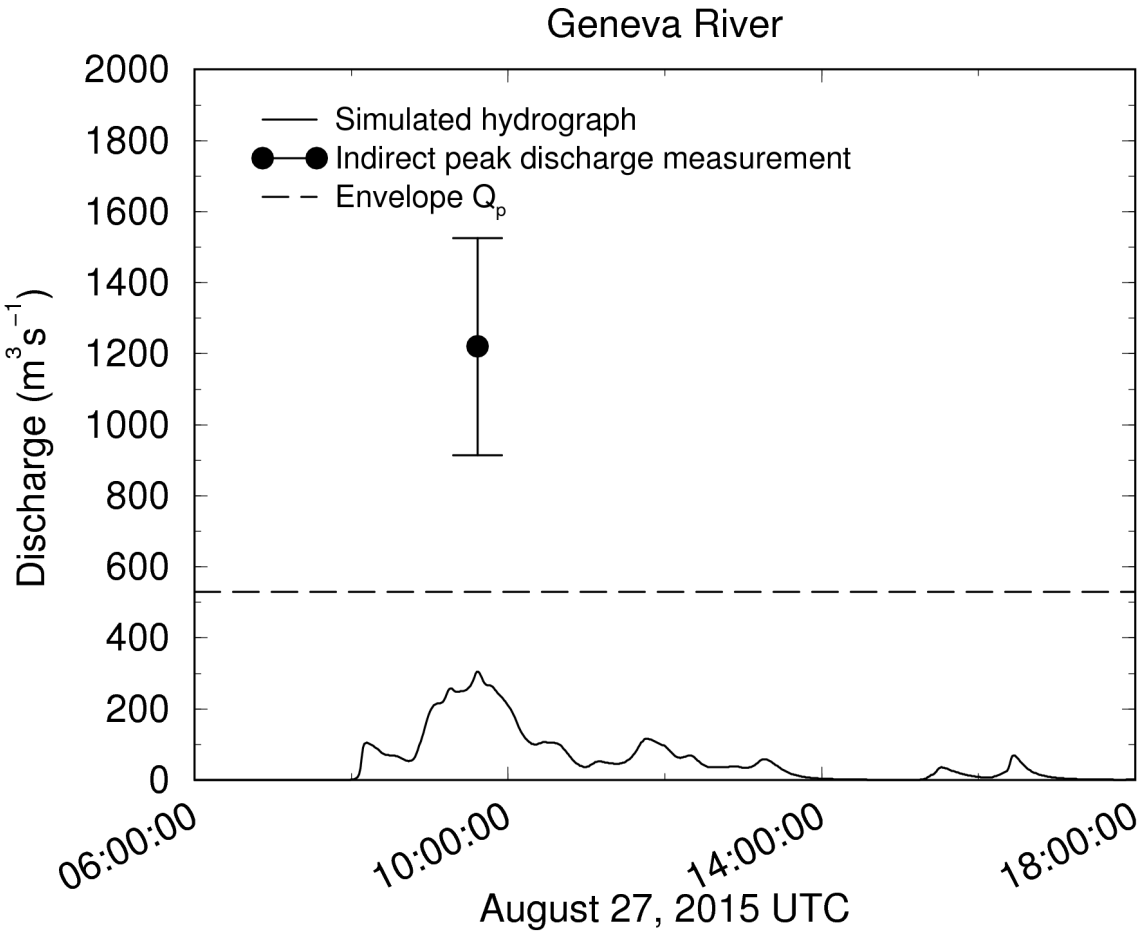



***Figure A-9.*** *Geneva R. GSSHA Simulation with saturated hydraulic conductivity 2 cm/h.*

**Model conclusion:** Obviously landslide affected.

**Site Name: Hampstead River**

**GPS Coordinates:**

| Latitude (N) | Longitude (W) | Quality of Reach |
|---|---|---|
| DD:MM:SS | DD:MMSS | Good, Fair, Poor |
| 15:34:10 | 61:22:26 | P |

**GPS Used:**
Garmin Model 60CSx

**Channel Properties:**
Narrow, well contained due to steep and deep rock wall outcrops and cliffs, river bank erosion, signs of sand deposition, large woody debris

**High Water Marks:**
High water marks sparse on steep left bank. Thought I saw a raft of deposited twigs atop left bank. Right bank flows were into the trees, and there were many high water marks. Floating objects hung up in stiff vegetation in a linear fashion. Left and right bank high water marks at this site did not agree particularly well. For this reason site is classified as Poor.

**Other remarks:**
Photo# (from below Chaudiere's Pool): 1090739, 1090742, P1090749

**Comments from field book:**
I went with team from Public Works to survey Hampstead River. Walked upriver from bridge over ~1km and saw much overbank flow and large woody debris. Stephen Durand suggested another point a couple of km upriver near the town of Bense. We found a good reach on Hampstead River just below a tributary that enters just below Chaudiere's Pool.





Hampstead River continued



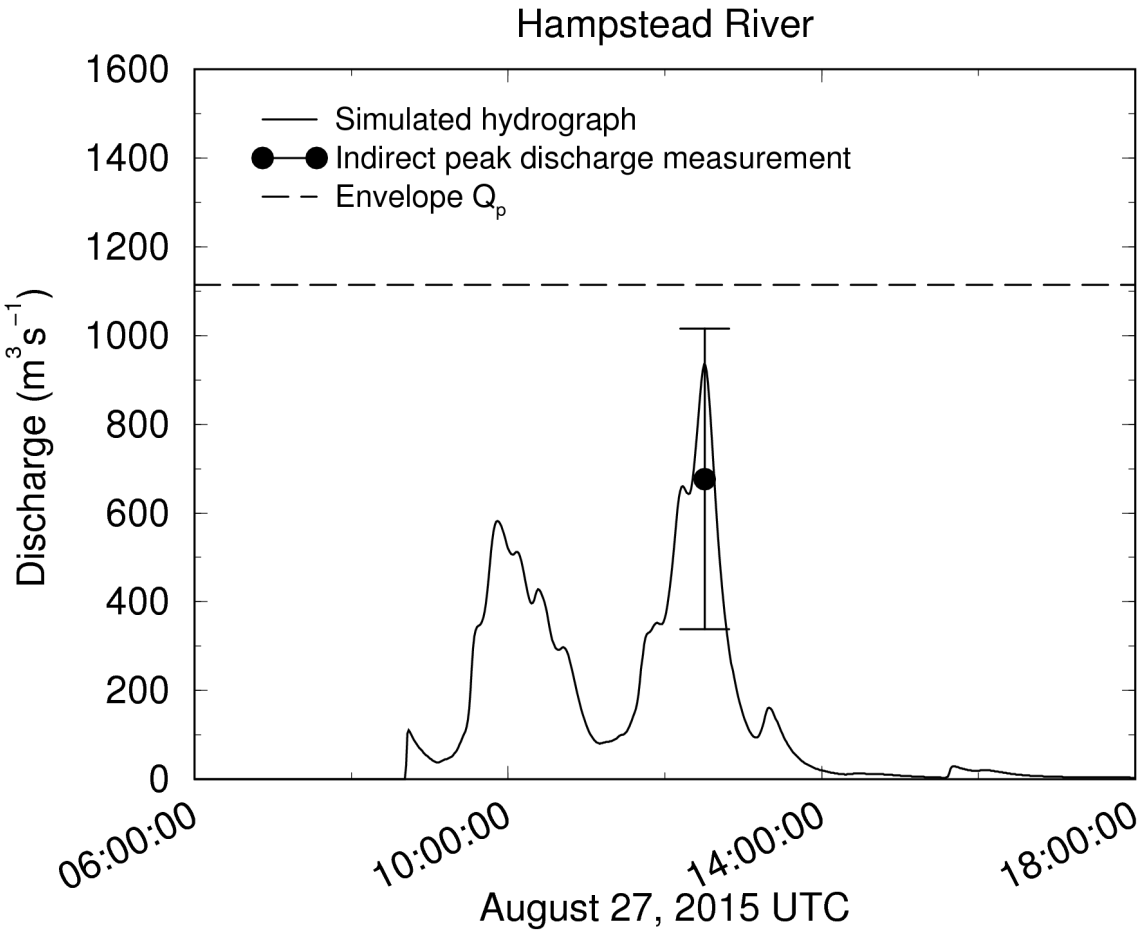



***Figure A-10.*** *Hampstead R. GSSHA Simulation with saturated hydraulic conductivity 2 cm/h.*

**Model conclusion:** Not landslide affected.

**Site Name: Macoucherie River**

**GPS Coordinates:**

| Latitude (N) | Longitude (W) | Quality of Reach |
|---|---|---|
| DD:MM:SS | DD:MMSS | Good, Fair, Poor |
| 15:25:58 | 61:24:20 | Good |

**GPS Used:**
Garmin Model 60CSx , Other

**Channel Properties:**
Canaliform. Bedrock control. Steep. Excellent hydraulics.

**High Water Marks:** Apparent on both banks.

**Other remarks:**
Photo#: Macoucherie, Macoucherie 1, Macoucherie 2, Macoucherie - first S point, P1100776, P1100778, P1100780, P1100781, P1100782, P1100783

**Comments from field book:**
None






Macoucherie River continued













Macoucherie River continued

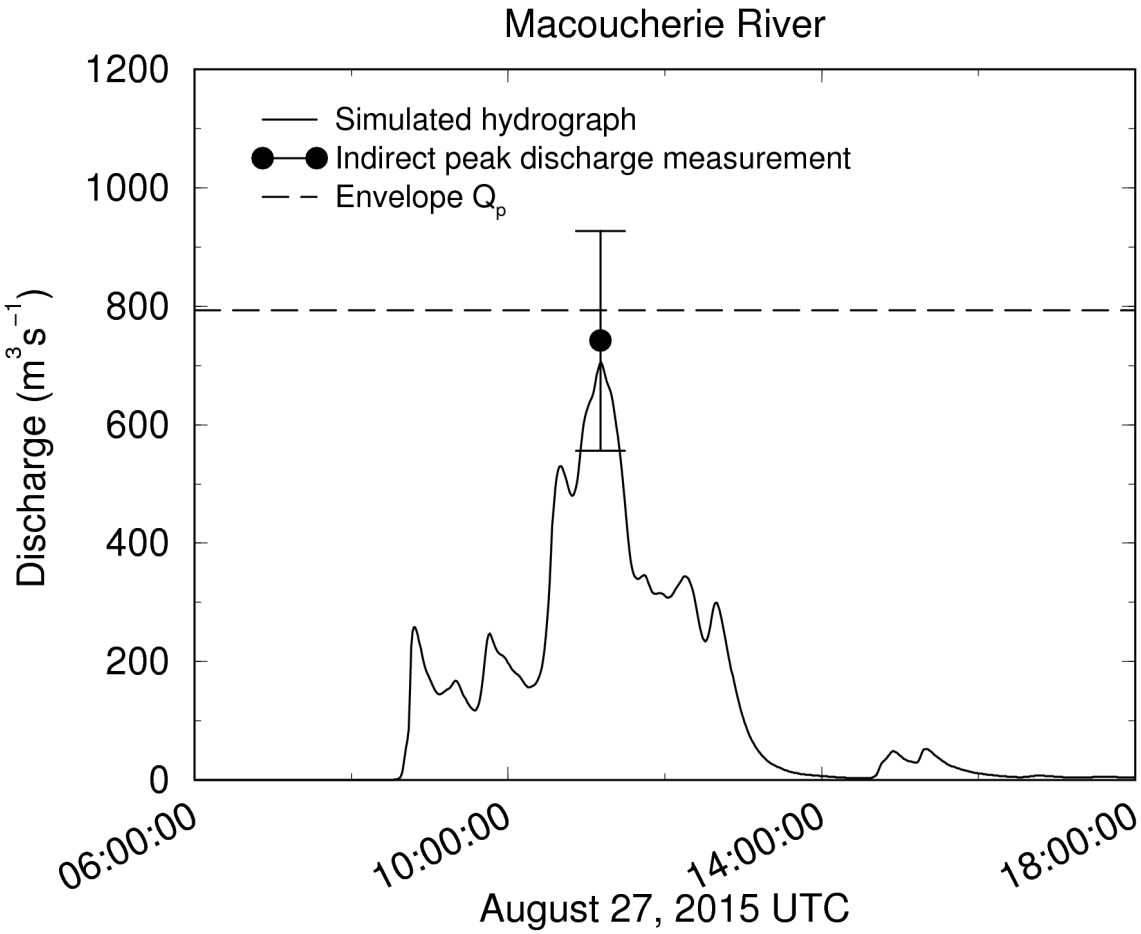



***Figure A-11.*** *Macoucherie R. GSSHA Simulation with saturated hydraulic conductivity 2 cm/h.*

**Model conclusion:** Not landslide affected.

**Site Name: Malabuka River**

**GPS Coordinates:**

| Latitude (N) | Longitude (W) | Quality of Reach |
|---|---|---|
| DD:MM:SS | DD:MMSS | Good, Fair, Poor |
| 15:15:18 | 61:17:08 | F |

**GPS Used:**
Garmin 60CSx

**Channel Properties:**
Broad, massively disturbed. Automobile-sized sediment jumbled.

**High Water Marks:**
Apparent on both banks.

**Other remarks:**
Photo#: Malabuka 2, P1100739, P1100741, P1100743, P1100744, P1100745, P1100748, P1100751, P1100752, P1100753, P1100755, P1100756

**Comments from field book:**
None






Malabuka River continued










Malabuka River continued

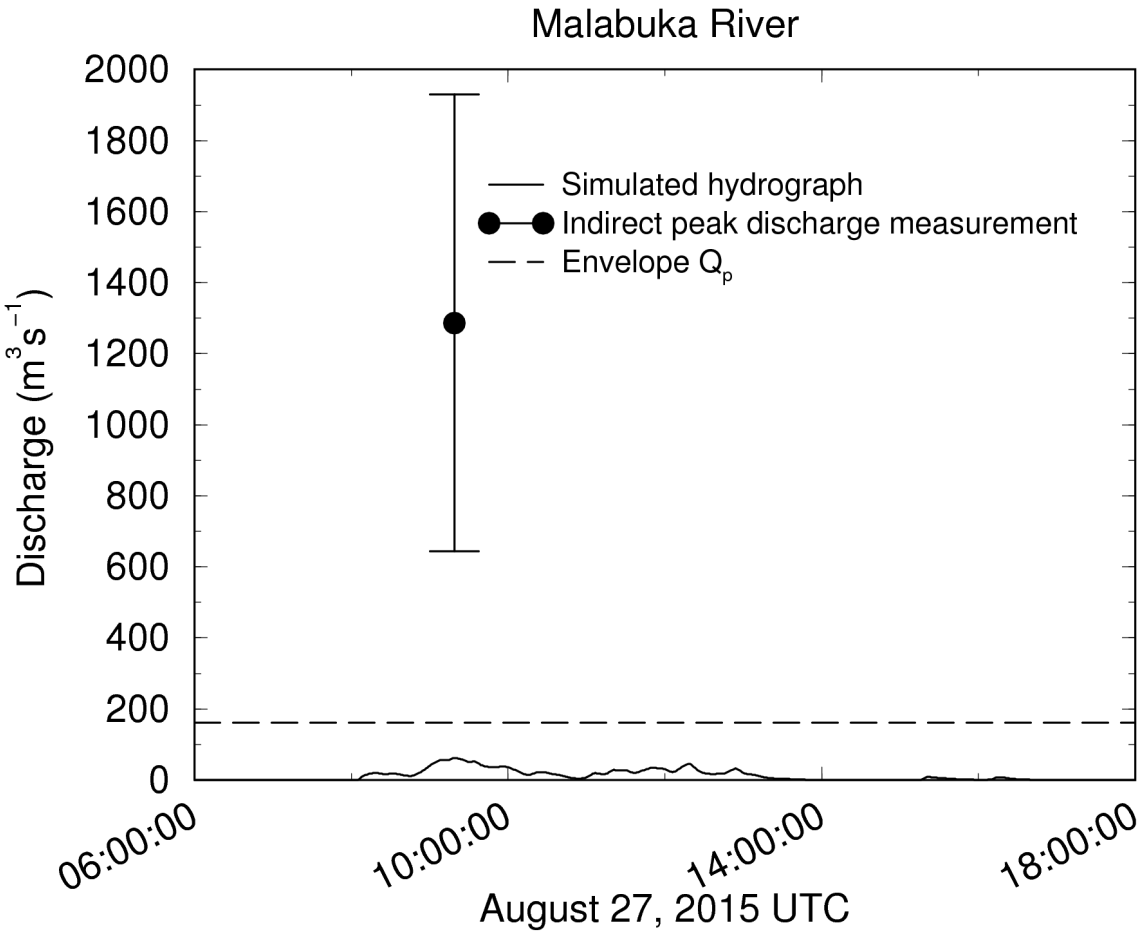



***Figure A-12.*** *Malabuka R. GSSHA Simulation with saturated hydraulic conductivity 2 cm/h.*

**Model conclusion:** Obviously landslide affected.

**Site Name: Melville Hall River**

**GPS Coordinates:**

| Latitude (N) | Longitude (W) | Quality of Reach |
|---|---|---|
| DD:MM:SS | DD:MMSS | Good, Fair, Poor |
| 15:32:28 | 61:18:49 | G |

**GPS Used:**
Garmin Model 60CSx

**Channel Properties:**
Narrow, contained where cliffs present, evidence of over flow in low and deep banks, extensive river bank erosion, sand-gravel-deposition, extensive flood damage to Douglas-Charles Airport and surrounding infrastructure, large woody debris.

**High Water Marks:**
High water marks were a bit hard to find here. Along steep left bank there were few signs. Some cleaned leaf fall. On right bank, slackwater deposits were obvious. Right bank flows were over bank and in grass and trees on the right flood plain for some distance.

**Other remarks:**
Photo#: 1090669, 1090671, 1090675, 1090680, 1090682, 1090686, 1090688, 1090691, 1090695, 1090697, 1090698, 1090702

**Comments from field book:**
Melville Hall River above Douglas-Charles Airport. Crew from Lands & Surveys Department was led by Mr. Ali Cuffy. Looked at a point upstream from airport about 1.5 km where bridge was destroyed: Too much out-of-bank flow and large woody debris. Selected reach about 200 m upstream from diversion channel inlet at south end of the runway. Selected reach is 5 m or more higher than the top of the failed diversion wall so it is unlikely in a supercritcal channel that there were any effects on the water surface. Excellent survey site. Some out-of-bank flow or right bank.





Melville Hall River continued










Melville Hall River continued





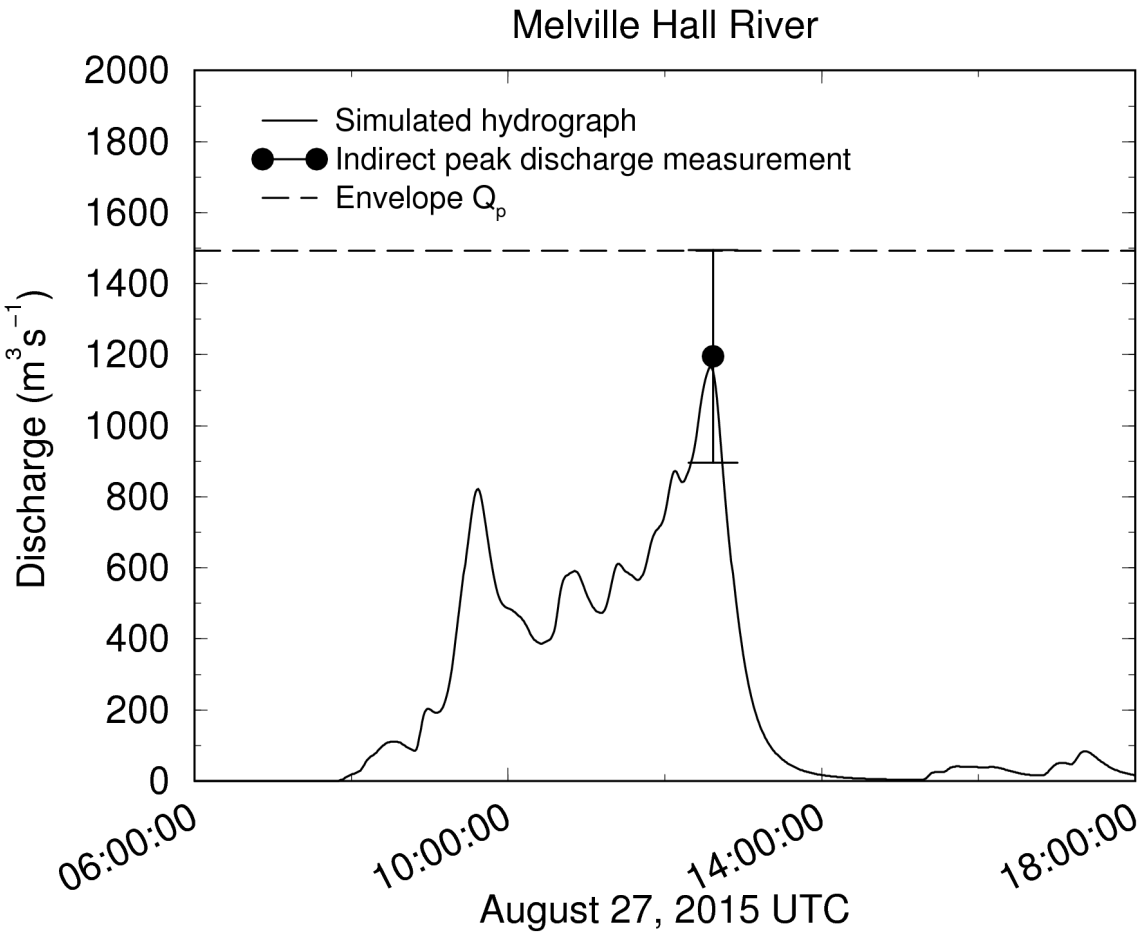



***Figure A-13.*** *Melville Hall R. GSSHA Simulation with saturated hydraulic conductivity 2 cm/h.*

**Model conclusion:** Not landslide affected.

**Site Name: Pointe Ronde River**

**GPS Coordinates:**

| Latitude (N) | Longitude (W) | Quality of Reach |
|---|---|---|
| DD:MM:SS | DD:MMSS | Good, Fair, Poor |
| 15:32:09 | 61:28:23 | G |

**GPS Used:**
Other (Survey completed by Lands & Survey team)

**Channel Properties:**
Well confined.

**High Water Marks:**
Apparent on both banks.

**Other remarks:**
Photo#: 20151027_150953, 20151027_151021, 20151027_151148, 20151027_151458, 20151027_151513, 20151027_151753, 20151027_151825, 20151027_152918, Point Ronde R3, Pointe Ronde R5, Pointe Ronde R6, Pointe Ronde R7

**Comments from field book:**
Survey completed by Lands and Surveys personnel, Mr. Cuffy, et al.






Pointe Ronde River continued










Pointe Ronde River continued

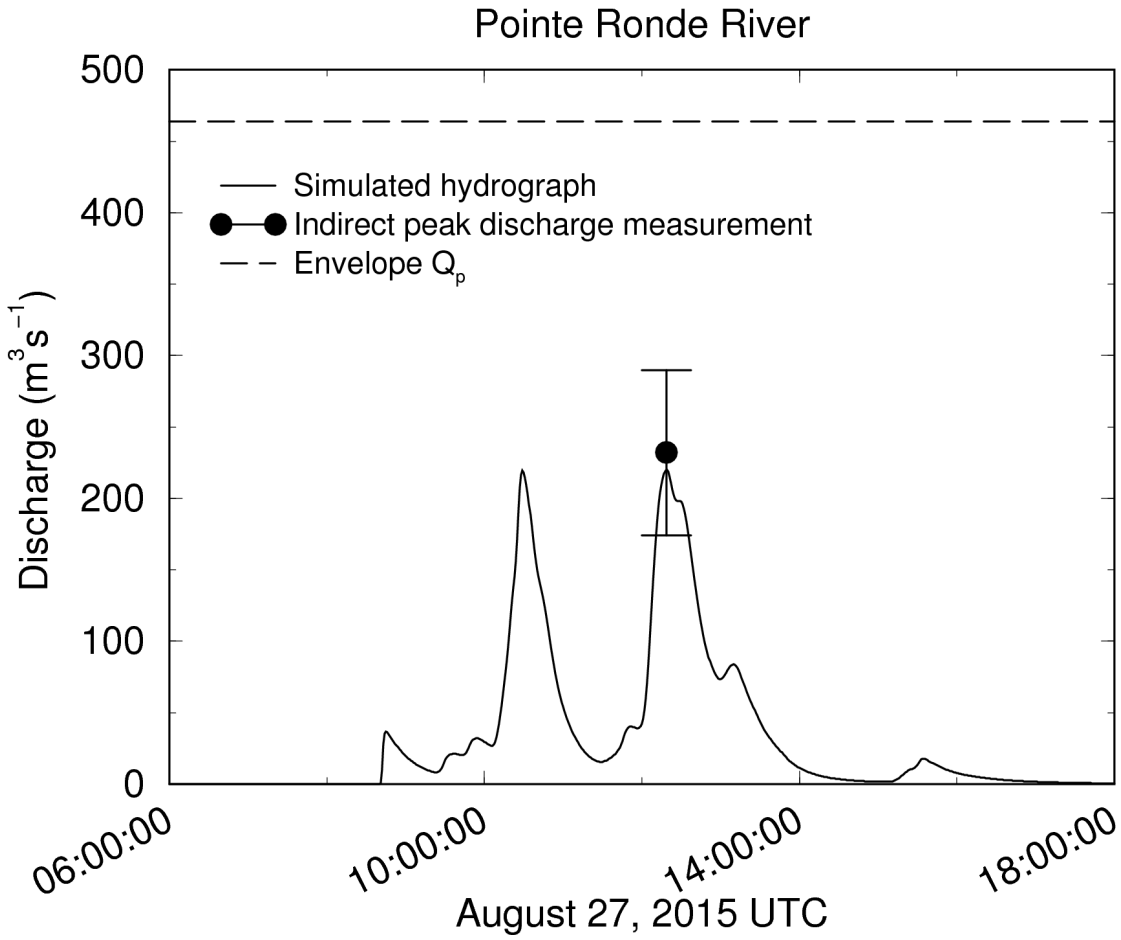



***Figure A-14.*** *Pointe Ronde R. GSSHA Simulation with saturated hydraulic conductivity 2 cm/h.*

**Model conclusion:** Not landslide affected.

**Site Name: Rosalie River**

**GPS Coordinates:**

| Latitude (N) | Longitude (W) | Quality of Reach |
|---|---|---|
| DD:MM:SS | DD:MMSS | Good, Fair, Poor |
| 15:22:22 | 61:16:09 | F |

**GPS Used:**
Garmin Model 60CSx

**Channel Properties:**
Wide, out of banks, river bank erosion, sand-gravel deposition, damage to infrastructure, large woody debris.

**High Water Marks:**
Readily apparent on both banks.

**Other remarks:**
Photo#: P1090370, P1090832, P1090834, P1100838, P1100840, P1100841, P1100842, P1100843, Rosalie 2

**Comments from field book:**
Survey site very near Three-Rivers Resort, just downstream from damaged bridge. Differences between high water mark elevations on left and right banks differ by more than 2 m. Rated Fair.






Rosalie River continued
The photos on the previous page were taken during first visit in October, 2015, near coast. The photos below were taken in March, 2016, in site where survey was actually done, about 2 km upstream from coast.








Rosalie River continued



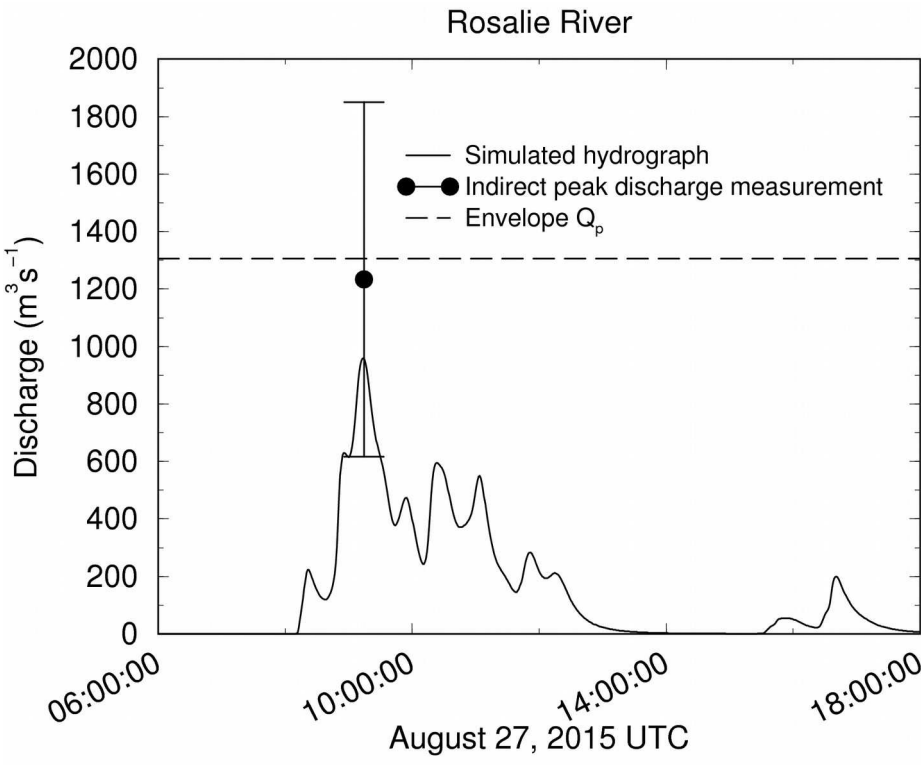



***Figure A-15.*** *Rosalie R. GSSHA Simulation with saturated hydraulic conductivity 2 cm/h.*

**Model conclusion:** Not landslide affected.

**Site Name: Roseau River near Elms Hall**

**GPS Coordinates:**

| Latitude (N) | Longitude (W) | Quality of Reach |
|---|---|---|
| DD:MM:SS | DD:MMSS | Good, Fair, Poor |
| 15:18:14 | 61:22:28 | G |

**GPS Used:**
Garmin Model 60CSx

**Channel Properties:**
Runs through the nation's capital, Roseau. Narrow, well contained on left bank, poorly contained on right bank, extensive river bank erosion, sand-gravel deposition, flood damage to buildings and infrastructure, property debris, large woody debris.

**High Water Marks:**
A small raft of twigs deposited on top of left bank at first cross section. Swept plastic debris on near-vertical right bank at first cross section very indeterminate. Second cross section deposited small branches on 45-degree slope left bank. See photo with range pole. At third cross section, the flow was not well contained atop left bank with some sand deposition noting slackwater elevation in back yard of home.

**Other remarks:**
Photo# (includes high water mark*): 1090616, 1090618*, 1090622*, 20151023_132753, 20151023_132801, 20151023_132804, 20151023_132947**,** 20151023_P1090855

**Comments from field book:**
Survey Roseau River near Elms Hall. Crew from Lands & Surveys Department led by Mr. Ali Cuffy.





Photos of damaged infrastructure taken near Roseau.

Roseau River continued








Roseau River continued

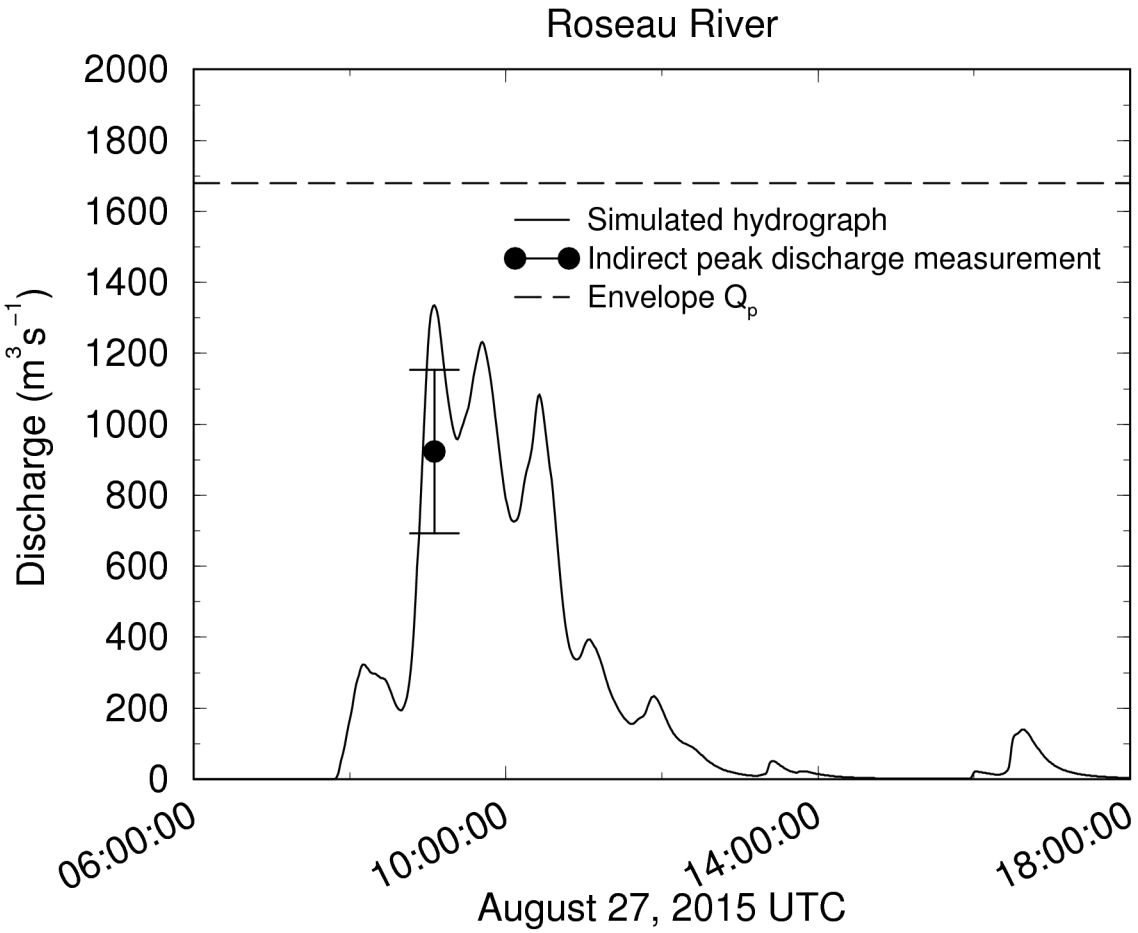
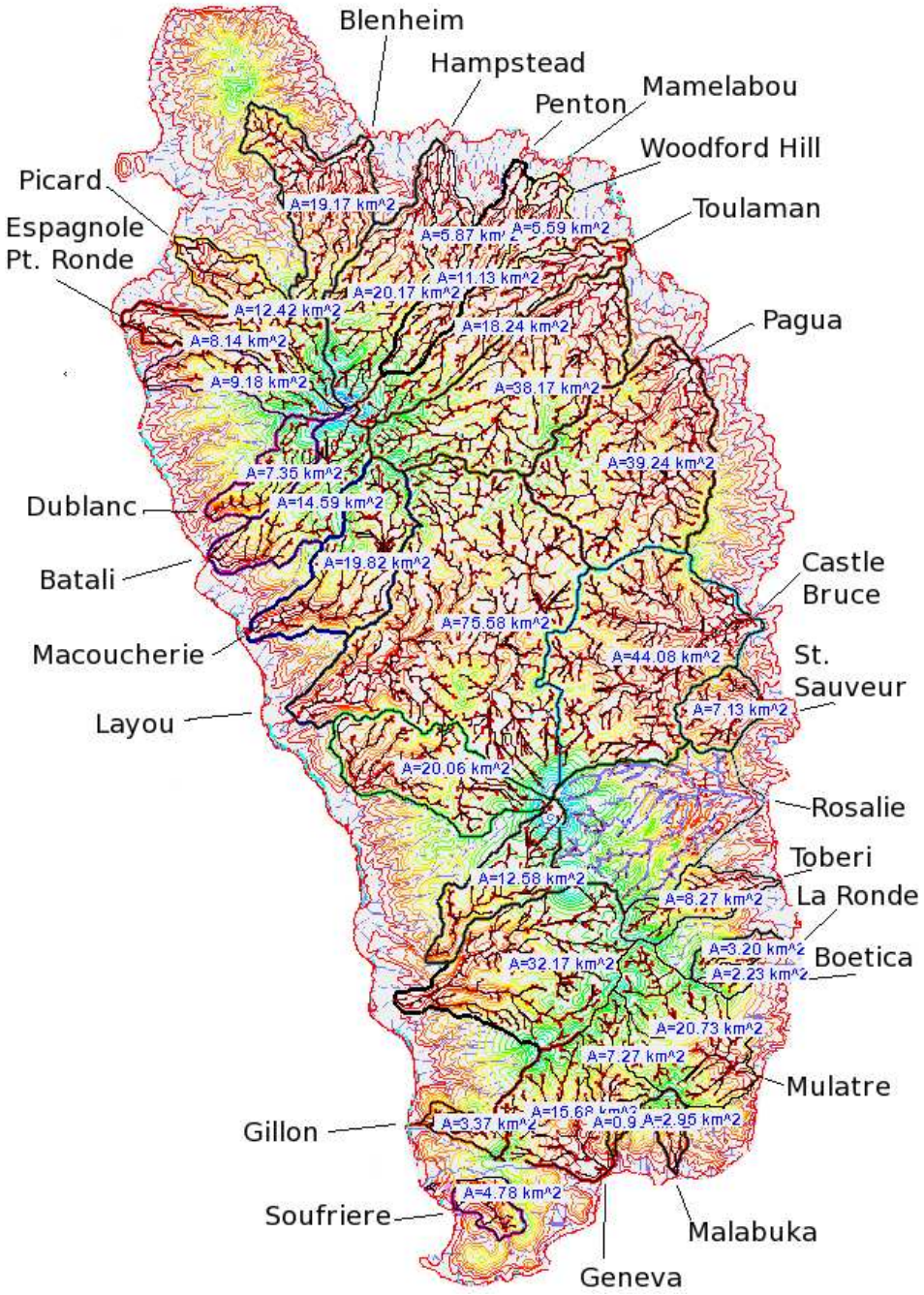



***Figure A-16.*** *Roseau R. GSSHA Simulation with saturated hydraulic conductivity 2 cm/h.*

**Model conclusion:** Not landslide affected.

# Appendix B

# GSSHA Simulated Hydrographs on 24 Rivers at the Coast using Radar-Rainfall Estimates from TS Erika 27 August 2015



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**Disclaimer:** The results shown in this appendix do not represent engineering design. Rather, these results are an analysis using calibrated radar-rainfall estimates and literature hydrological model parameter values, and are shown as examples. Insufficient data exist to calibrate GSSHA on these watersheds for this event. Hydrographs are compared against the ICOLD envelope curve upper limit for example only.

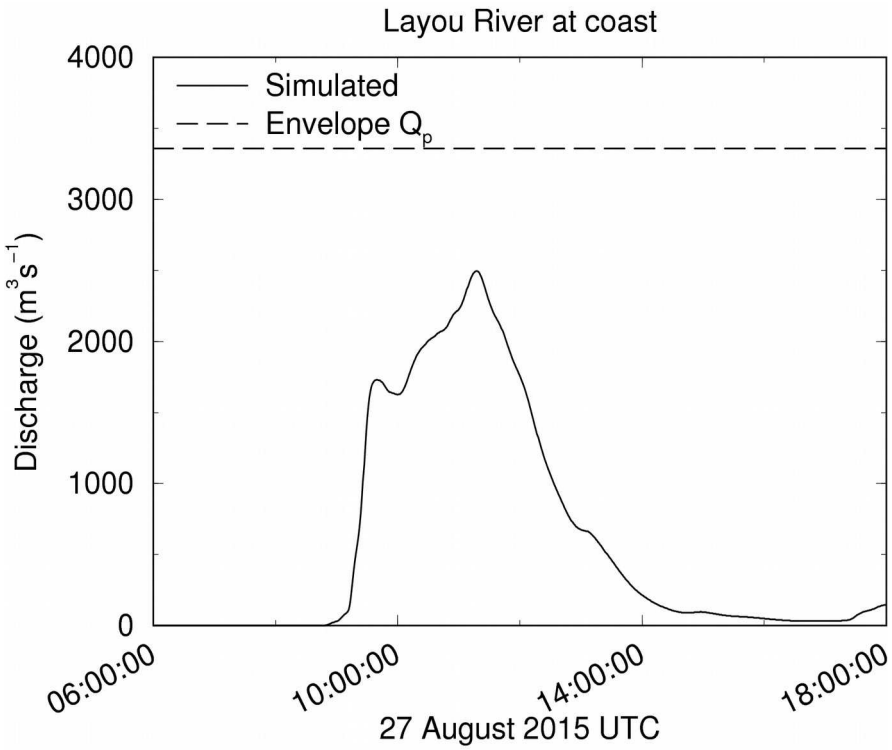


***Figure B-1.*** *Layou R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

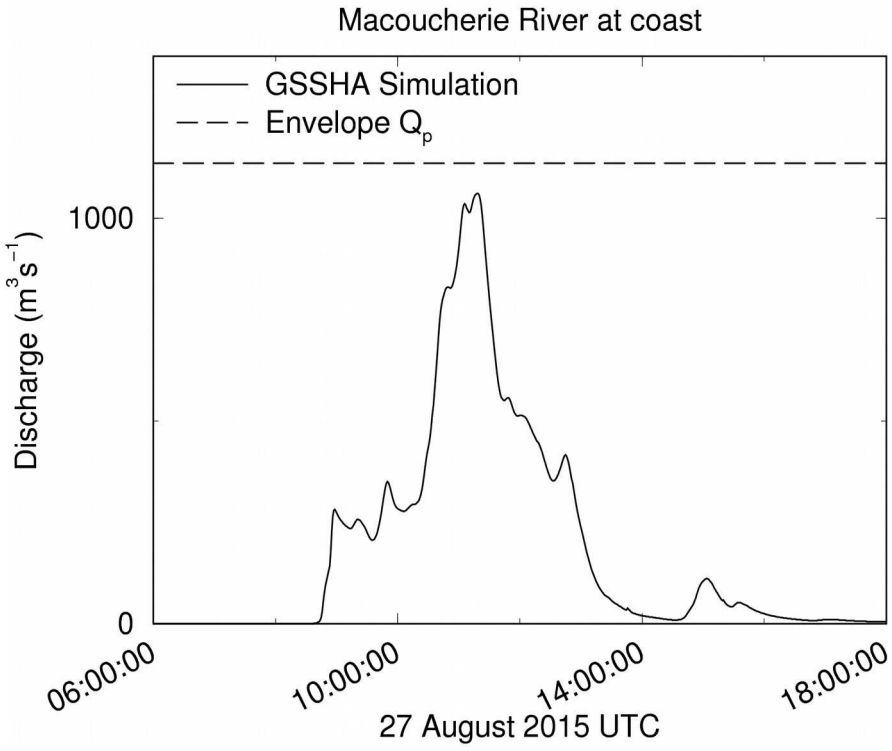


***Figure B-2.*** *Macoucherie R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

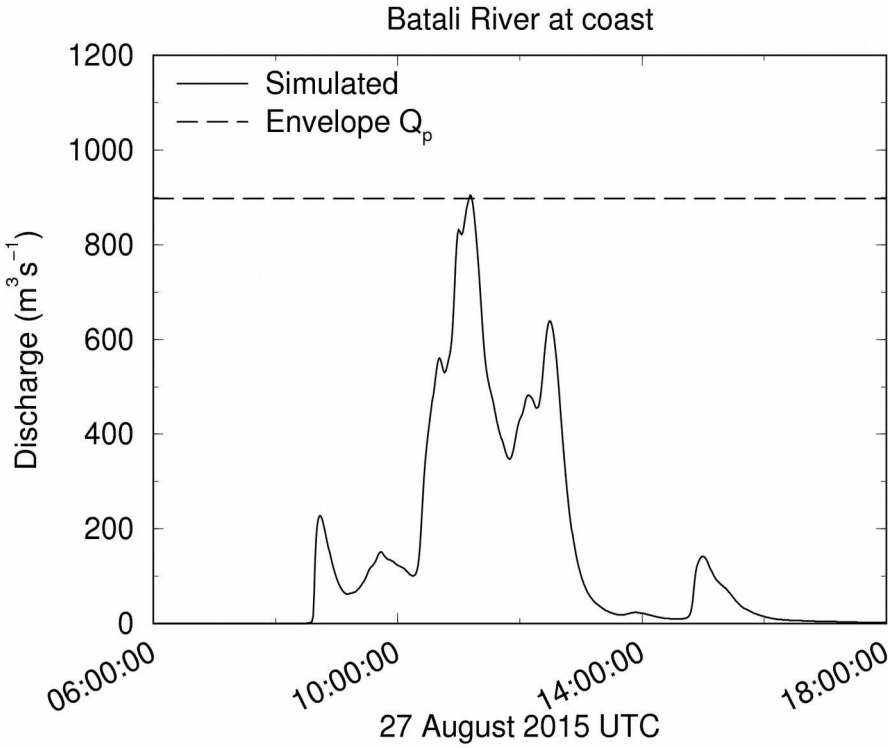


***Figure B-3.*** *Batali R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

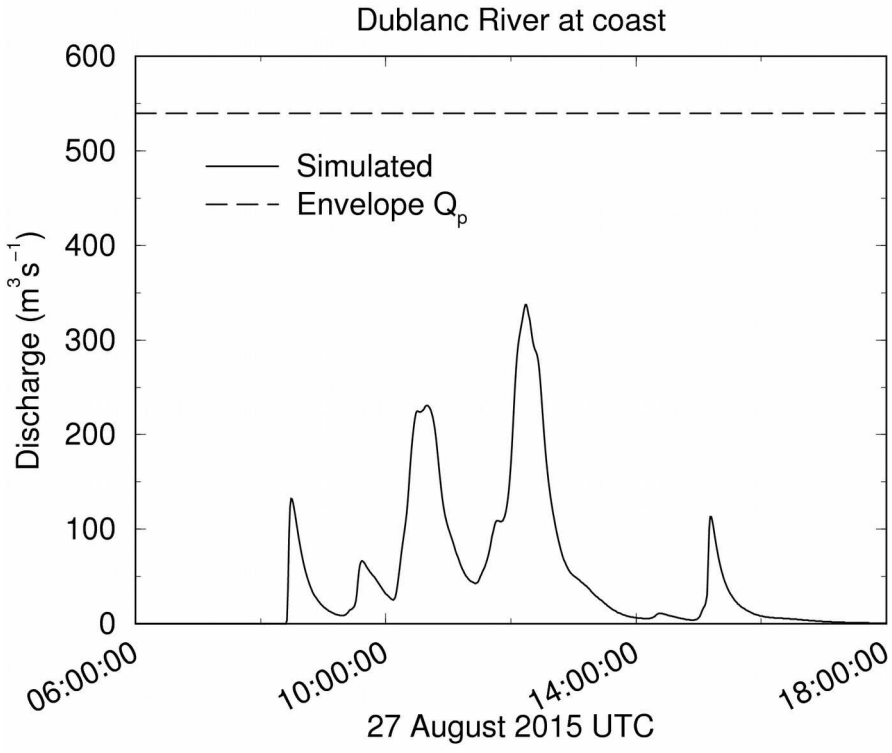


***Figure B-4.*** *Dublanc R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

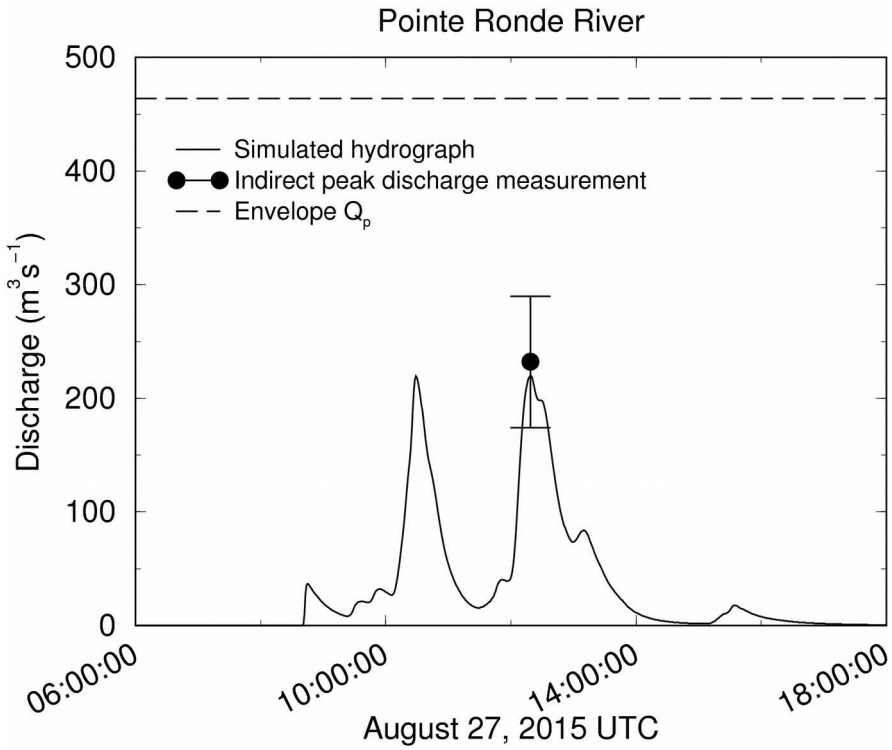


***Figure B-5.*** *Pointe Ronde R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

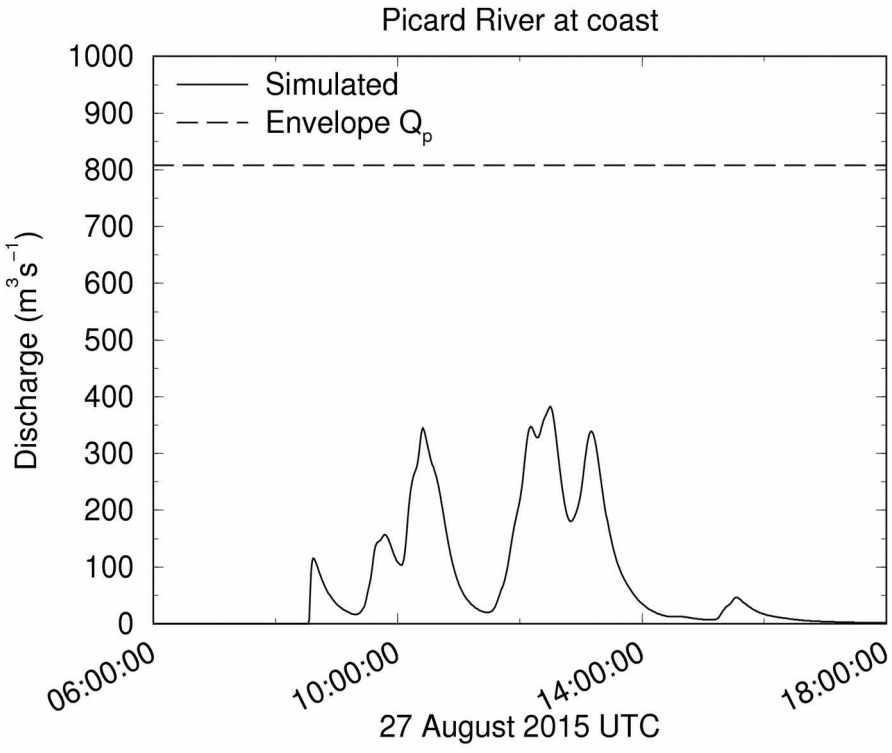


***Figure B-6.*** *Picard R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

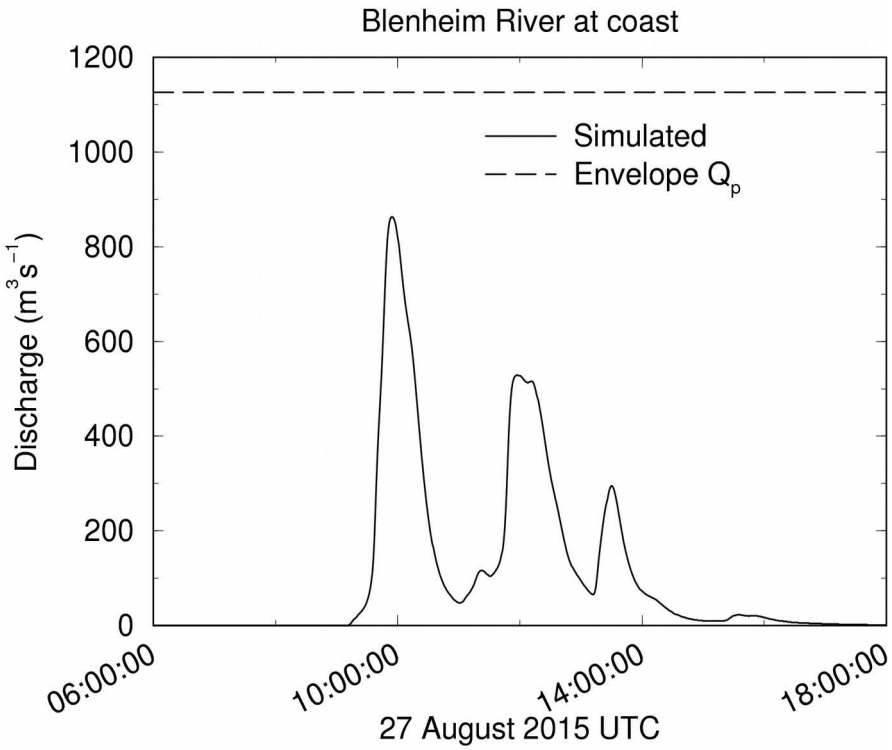


***Figure B-7.*** *Blenheim R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

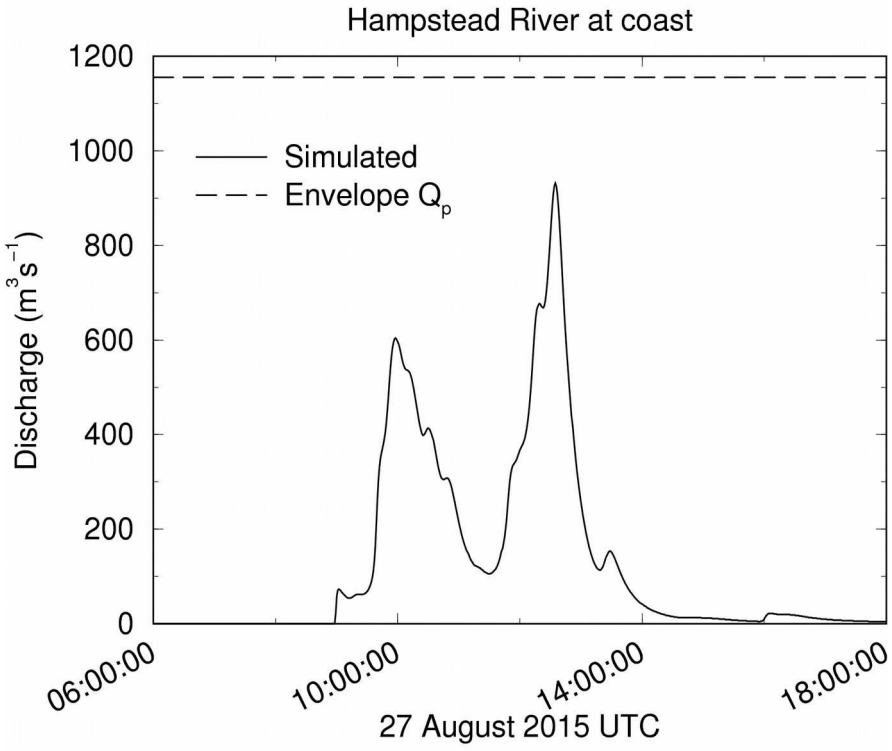


***Figure B-8.*** *Hampstead R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

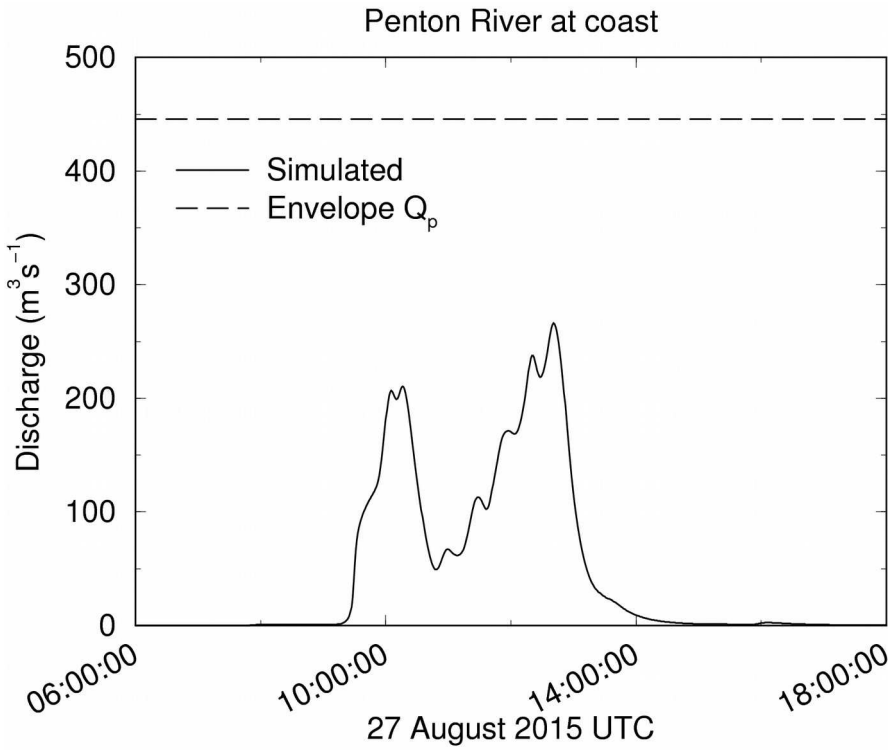


***Figure B-9.*** *Penton R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

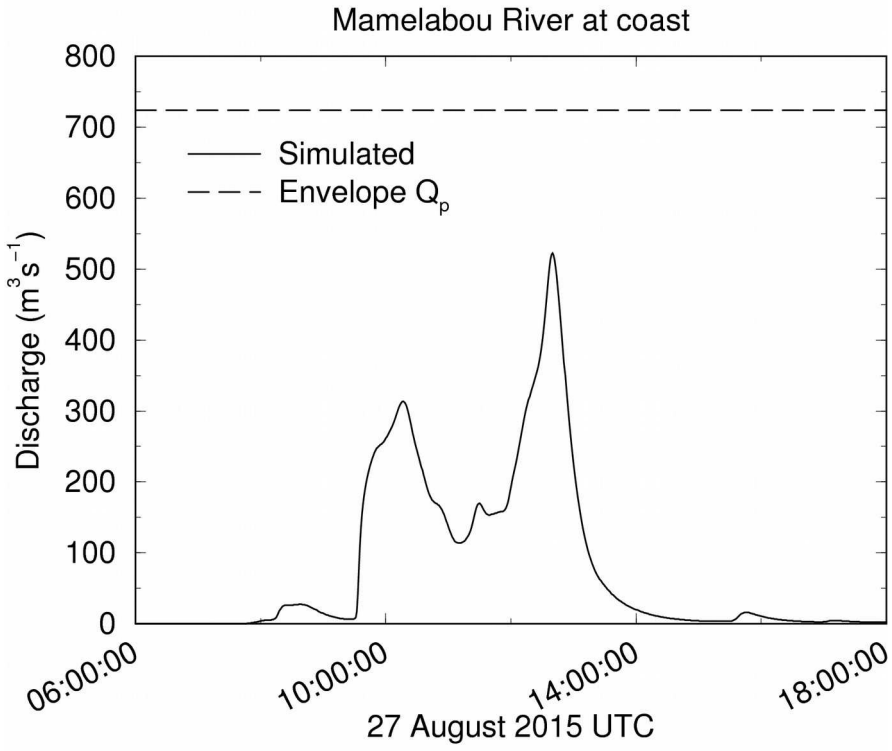


***Figure B-10.*** *Mamelabou R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

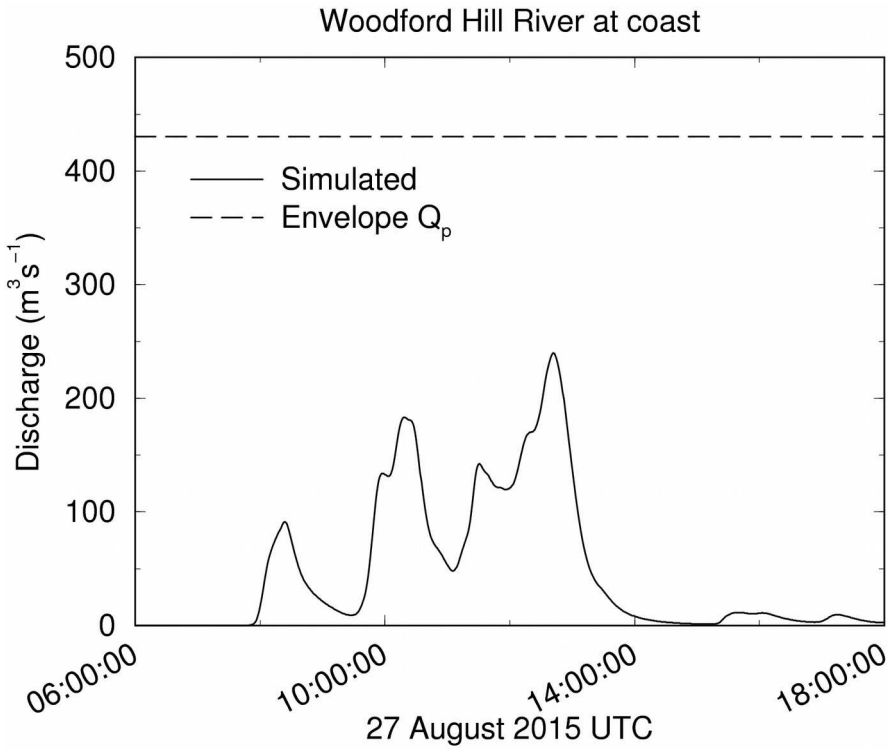


***Figure B-11.*** *Woodford Hill R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

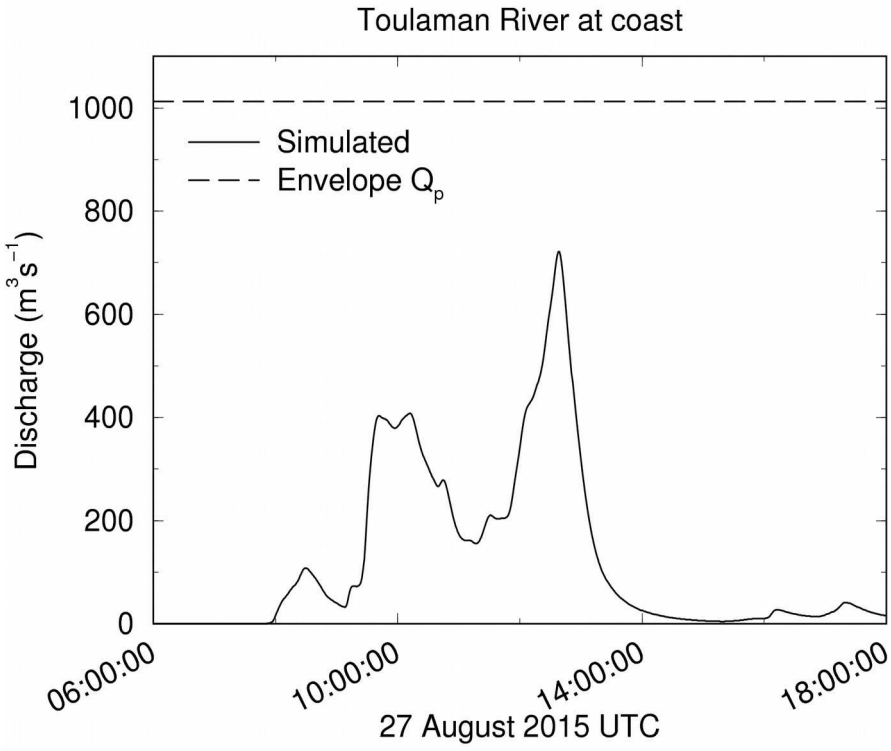


***Figure B-12.*** *Toulaman R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

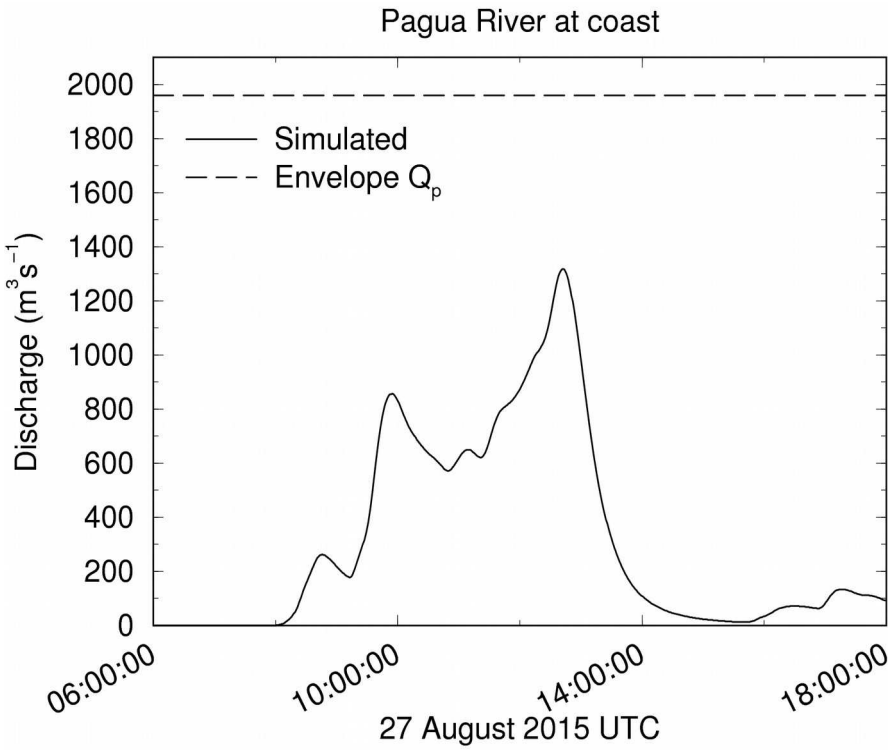


***Figure B-13.*** *Pagua R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

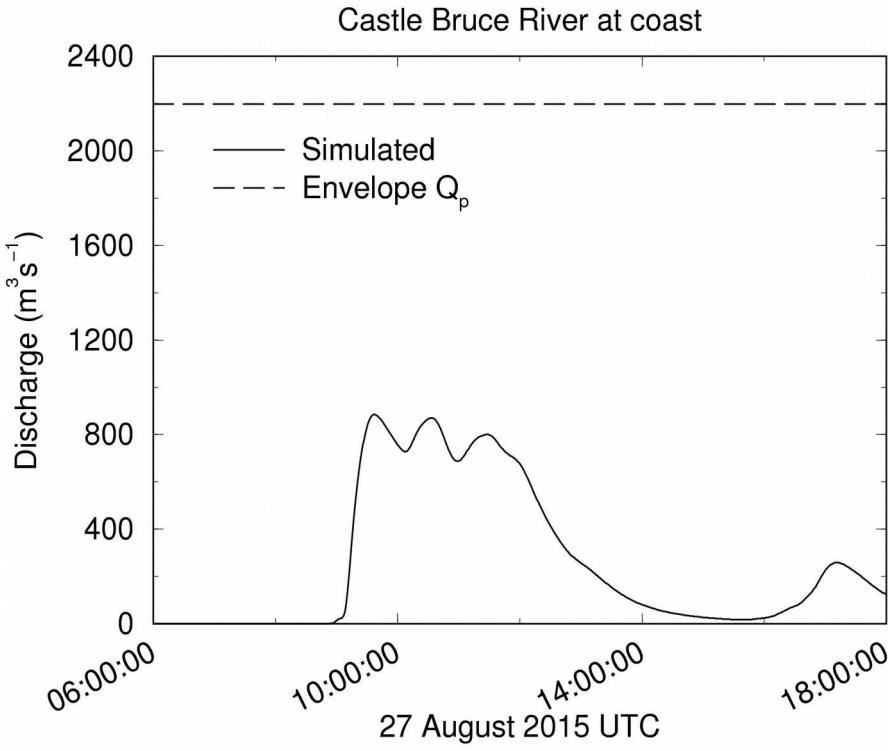


***Figure B-14.*** *Castle Bruce R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

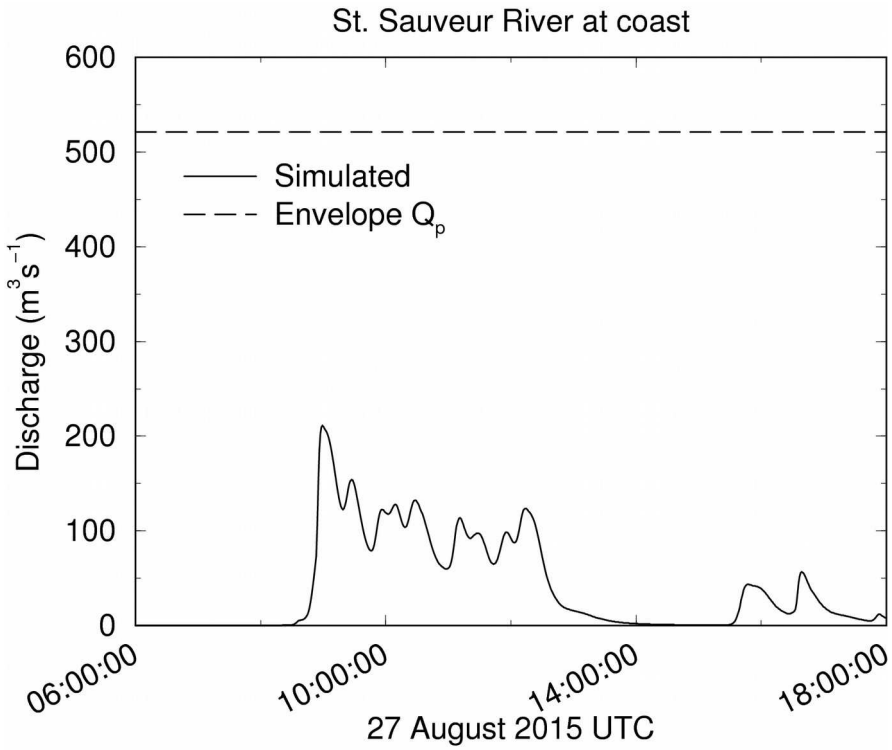


***Figure B-15.*** *St. Sauveur R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

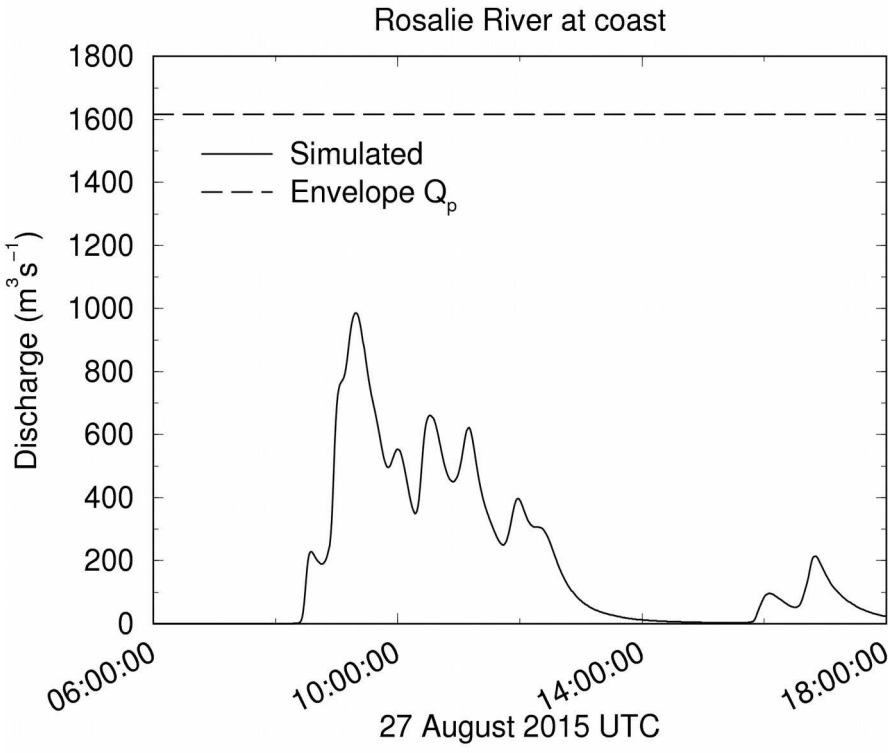


***Figure B-16.*** *Rosalie R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

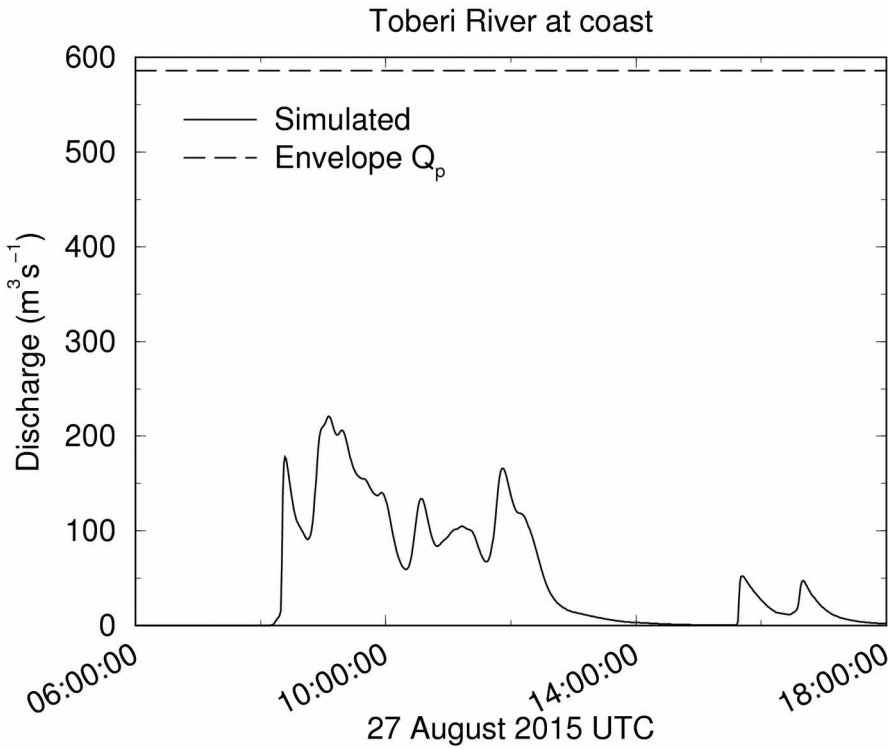


***Figure B-17.*** *Toberi R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

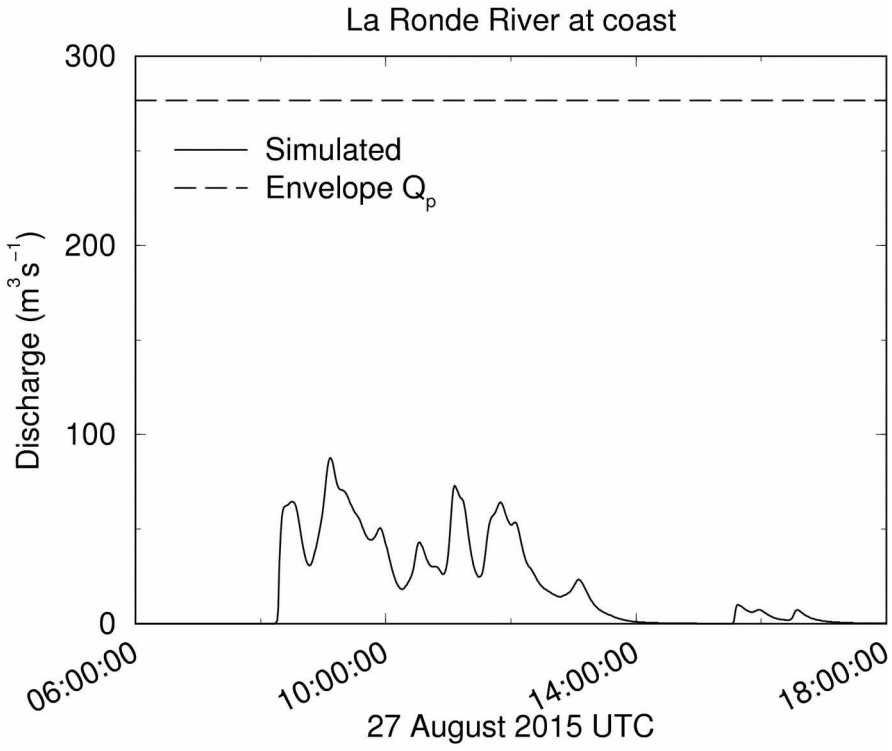


***Figure B-18.*** *La Ronde R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

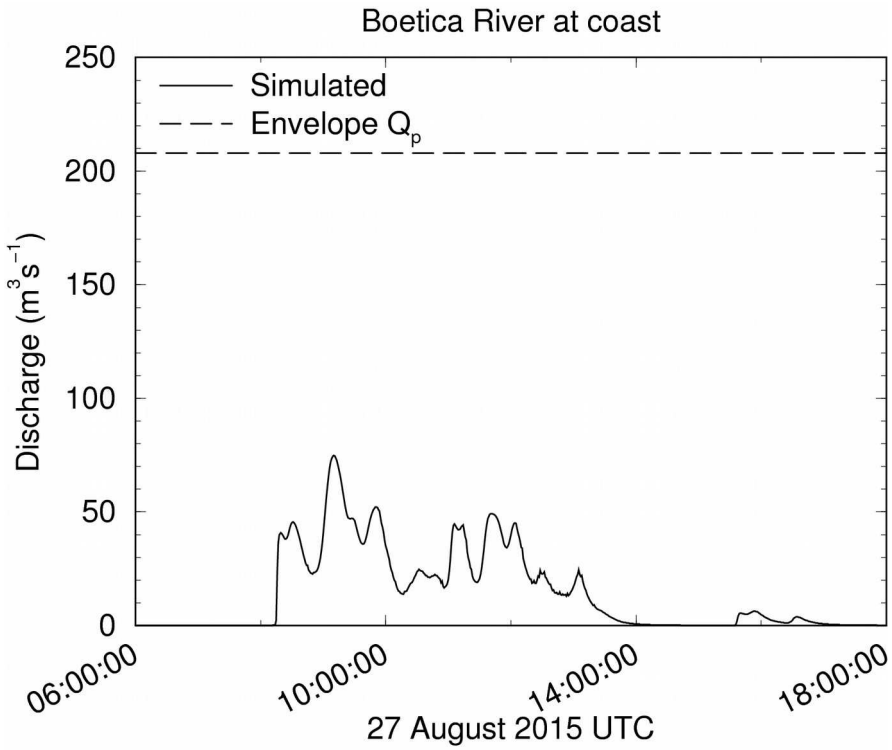


***Figure B-19.*** *Boetica R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

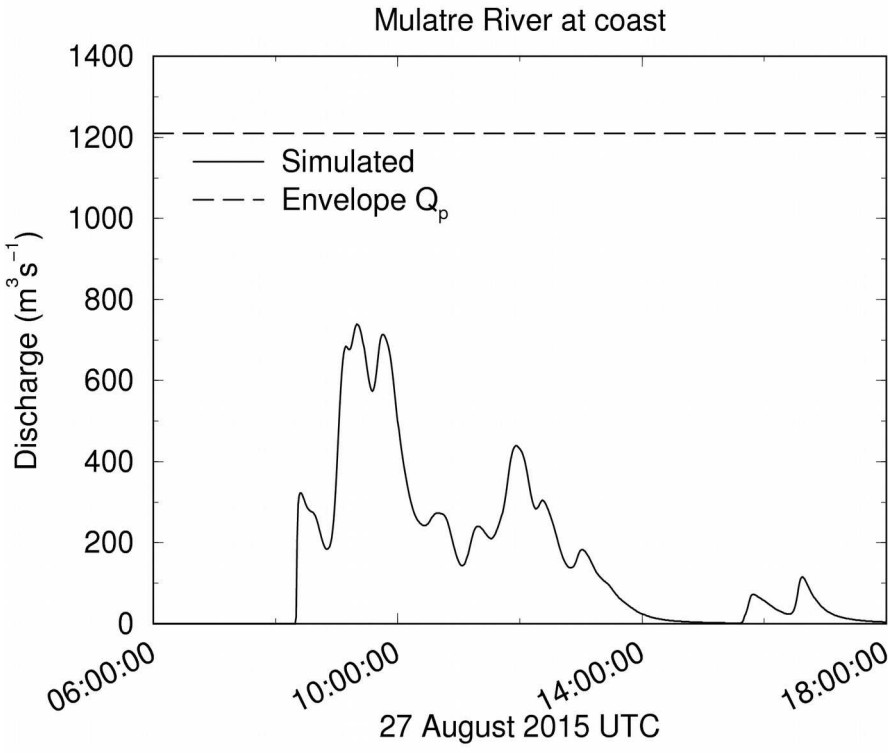


***Figure B-20.*** *Mulatre R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

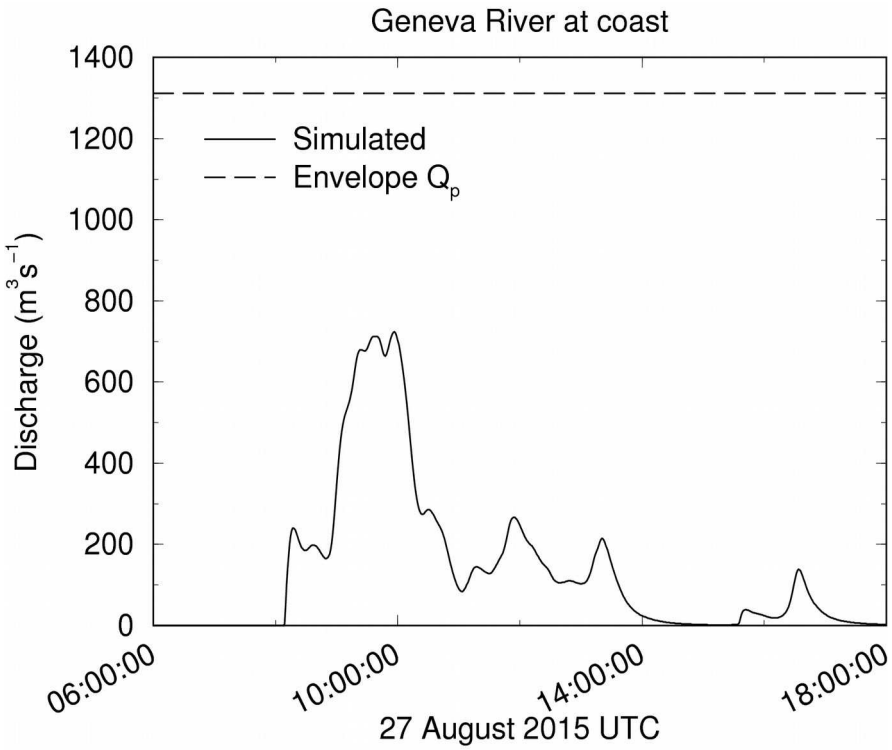


***Figure B-21.*** *Geneva R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

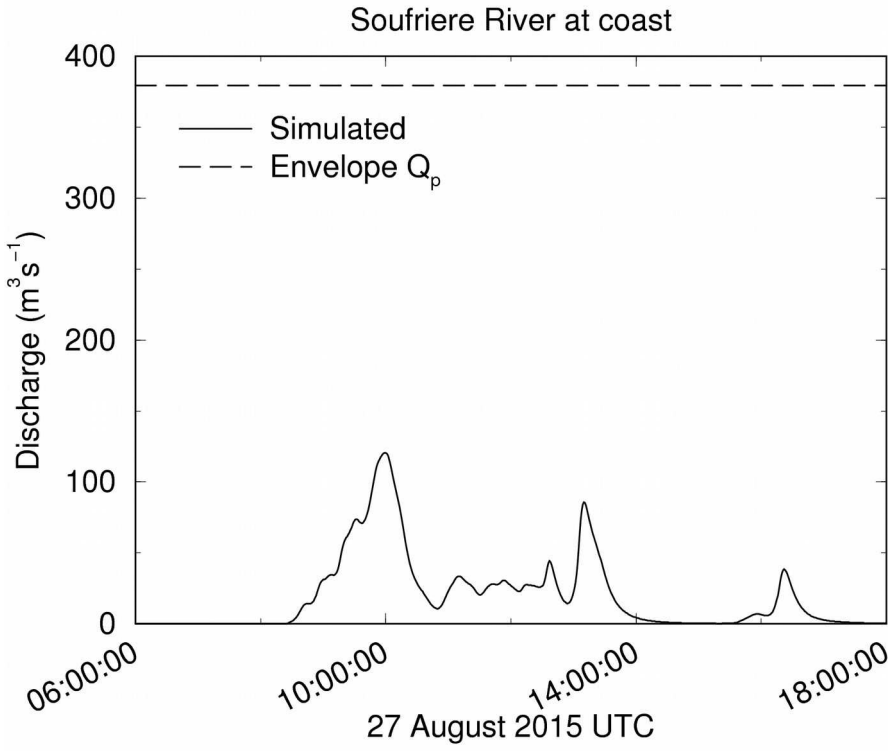


***Figure B-22.*** *Soufriere R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

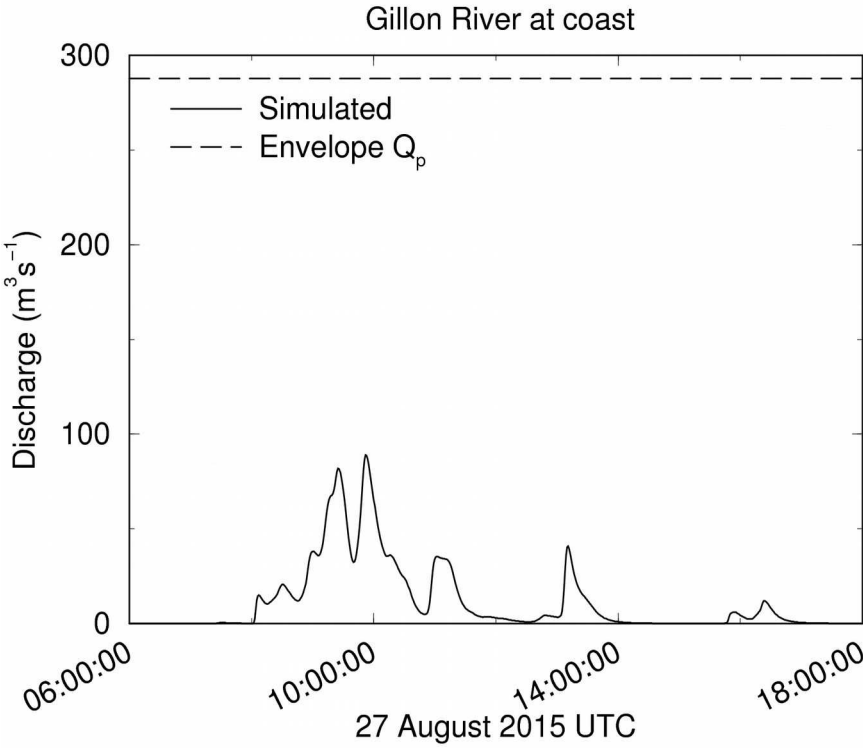


***Figure B-23.*** *Gillon R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

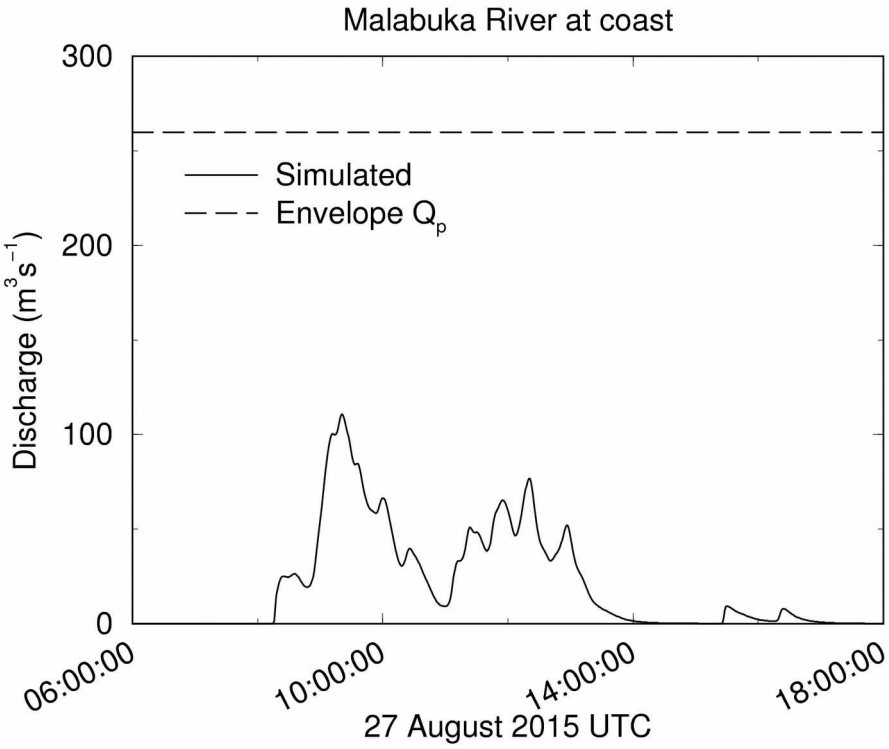


***Figure B-24.*** *Malabuka R. at coast. GSSHA simulation $K_s$=2.0 cm/h.*

**Appendix C**. Rain gauge observations used to perform bias adjustment of radar data.

Tipping bucket rain gauge data binned to hourly data. Data provided by Met. Services of Dominica.
Coordinate system WGS84, UTM Zone 20N. Hourly rainfall accumulations in mm. Time: UTC

| YYYY | MO | DA | HR | Sta. Name: | Boeri | Botanical | Canefield | Grandbay | Grand Fond | Laudat | Pond Casse | Springfield |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Northing (m): | 1697920.6 | 1692011.0 | 1696044.7 | 1686148.4 | 1698953.9 | 1695882.7 | 1701112.2 | 1697440.9 |
| | | | | Easting (m): | 680317.0 | 673683.5 | 672547.4 | 680069.7 | 685071.0 | 678920.7 | 677782.1 | 675186.0 |
| 2015 | 8 | 26 | 22 | | 0 | 0 | 0 | 0 | 0.2 | 0 | 0.2 | 0 |
| 2015 | 8 | 26 | 23 | | 1.6 | 8.2 | 0 | 3 | 9.4 | 1 | 1.6 | 0.6 |
| 2015 | 8 | 27 | 0 | | 0 | 0.2 | 0 | 1.2 | 0 | 0 | 0.2 | 0 |
| 2015 | 8 | 27 | 1 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 |
| 2015 | 8 | 27 | 2 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2015 | 8 | 27 | 3 | | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2015 | 8 | 27 | 4 | | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 |
| 2015 | 8 | 27 | 5 | | 0 | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 |
| 2015 | 8 | 27 | 6 | | 1.2 | 0 | 0 | 0 | 0 | 1.2 | 0.2 | 0 |
| 2015 | 8 | 27 | 7 | | 0.6 | 16.2 | 0.8 | 6 | 0 | 1.2 | 0 | 0.4 |
| 2015 | 8 | 27 | 8 | | 47.4 | 25.6 | 13.8 | 26.6 | 13.8 | 50 | 27 | 11.4 |
| 2015 | 8 | 27 | 9 | | 83.8 | 24.8 | 17.8 | 48.2 | 86 | 84.8 | 65.2 | 16.4 |
| 2015 | 8 | 27 | 10 | | 105.8 | 48 | 45.8 | 94.8 | 122.8 | 92.2 | 104.8 | 20.8 |
| 2015 | 8 | 27 | 11 | | 67.6 | 49.2 | 60.4 | 68 | 59.8 | 72 | 96.6 | 21.6 |
| 2015 | 8 | 27 | 12 | | 59.8 | 40 | 61.8 | 65 | 82.8 | 60.2 | 63.4 | 22.8 |
| 2015 | 8 | 27 | 13 | | 36 | 30 | 25.6 | 90.8 | 62.2 | 25.8 | 21 | 22 |
| 2015 | 8 | 27 | 14 | | 9.4 | 30.4 | 20.6 | 24.8 | 18.4 | 16.6 | 11.6 | 20.4 |
| 2015 | 8 | 27 | 15 | | 6.6 | 7.6 | 6.2 | 9.4 | 6.4 | 5.4 | 7.6 | 17.4 |
| 2015 | 8 | 27 | 16 | | 15.2 | 14 | 12 | 25 | 20.4 | 10 | 9 | 14.8 |
| 2015 | 8 | 27 | 17 | | 26 | 24.6 | 21.4 | 18 | 16.6 | 19.2 | 18.8 | 14.6 |
| 2015 | 8 | 27 | 18 | | 6 | 3 | 2.8 | 3.6 | 4 | 2.4 | 4.4 | 13.2 |
| 2015 | 8 | 27 | 19 | | 0.2 | 0.2 | 0 | 0.2 | 0.2 | 0 | 0 | 10.2 |
| 2015 | 8 | 27 | 20 | | 0.2 | 0 | 0 | 0.2 | 0.6 | 0 | 0 | 3.8 |
| 2015 | 8 | 27 | 21 | | 0.4 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 |
| 2015 | 8 | 27 | 22 | | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | TOTALS: | 468.4 | 322 | 289 | 485.2 | 504 | 442 | 431.6 | 210.6 |

# Part 2 - Employer’s Requirements

Section VII - Employer’s Requirements

# 11. DGDC Document Numbering Procedure

# Dominica Geothermal Power Project

Dominica Geothermal Development Company

## Document Requirements

RZ042100-JP-PCD-0001 | 0

July 23, 2018

**Document history and status**

| Revision | Date | Description | By | Review | Approved |
|---|---|---|---|---|---|
| 0 | 23 July 18 | Issued for EPC Bid | SJP | LJS | LJS |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

**Distribution of copies**

| Revision | Issue approved | Date issued | Issued to | Comments |
|---|---|---|---|---|
| 0 | 23 July 2018 | 23 July 2018 | DGDC | For use |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

JACOBS

# Dominica Geothermal Power Project

| | |
|---|---|
| Project No: | RZ042100 |
| Document Title: | Document Requirements |
| Document No.: | RZ042100-JP-PCD-0001 |
| Revision: | 0 |
| Date: | July 23, 2018 |
| Client Name: | Dominica Geothermal Development Company |
| Client No: | |
| Project Manager: | Lindsay Stanfield |
| Author: | Sam Pearce |
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2.2 Contract Administration ..... 3

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A.1 Table 1: Technical Document Type
A.2 Table 2: Area or Location
A.3 Table 3: System
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A.6 Table 6: Administration document type

# 1. Introduction

This document instruction covers the minimum requirements for the documents to be provided for the Dominica Geothermal Power Project.

This document aligns with the project document numbering system that will be implemented on Aconex during the EPC Contract execution phase. Aconex will provide the functionality storing and managing of the document meta data, such as revision number, originating organisation, review status and similar data.

All Contractor, vendor and OEM documents shall include a unique DGDC document number in accordance with these requirements. This DGDC document number shall be in addition to the Contractor, vendor or OEM standard document numbering conventions.

The Contractor shall submit a document numbering system for the Employer's review and approval within four weeks of the Effective Date. This document numbering system shall be conformed to the power plant technology type offered. The Contractor shall be responsible for managing all the Contractor's and equipment vendor's documentation including a register of the Contractor and OEM document number including the associated DGDC document number.

Should conflicts exist between the requirements of this Instruction and other specifications, the Contractor shall seek clarification from the Employer.

The document numbering system shall be kept as a "live" document throughout the project execution and may be amended from time to time by the Employer.

## 1.1 Language and Units / Quantities

The Employer's Specification describes these requirements as well as the paper sizes required for this project.

# 2. Document Numbering Format

Different numbering protocols shall be used for different types of documents and records as outlined below.

- General Documents
- Contract Administration

## 2.1 General Document and file numbering

- This applies to all the types of documents listed in the tables below including deliverables from Contractors / Consultant.
- The document number shall also be applied to the electronic file name. The file name shall include an additional (-R) which shall designate the latest document revision.
- Numbering format is as follows:

# RV1-TTT-AAA-SSS-DD-NNN(-R)

| | | |
|---|---|---|
| **RV1** | The Employer's project code for this project. | |
| **TTT** | Document type (Alpha characters) | Table 1 |
| **AAA** | Area or location | Table 2 |
| **SSS** | System | Table 3 |
| **DD** | Discipline | Table 4 |
| **NNN** | Sequential Number for this series of documents.<br><br>Sequential Sheet Number for drawing number NNN (Optional – only if several sheets are used for the exact same drawing title) | |
| **R** | Revision alpha/numeric for the electronic file name only. When Aconex is used for the project execution Aconex will store the revision number in the document meta data, in which case the "-R" appendix will not be used.<br><br>Increase sequentially, starting at A (record in document electronic file, transmittals and Aconex database) during development of the document<br><br>Use numeric starting at 0, following approval of the document for construction, procurement or "use" | |

## 2.2 Contract Administration

1) This applies to all documents which are directly associated with administration.

2) The document number shall also be applied to the electronic file name. The file name shall include an additional (-R) which shall designate the latest document revision.

3) Numbering format is as follows:

# RV1-CCC-MMM-NNN(-R)

| | | |
|---|---|---|
| **RV1** | The Employer's project code for this project. | |
| **CCC** | A three digit alpha field for the originator of the document | Table 5 |
| **MMM** | Administration document type document type (Alpha characters) | Table 6 |
| **NNN** | Sequential number for this series of documents | |
| **R** | Revision alpha/numeric for the electronic file name only. When Aconex is used for the project execution Aconex will store the revision number in the document meta data, in which case the "-R" appendix will not be used.<br><br>Increase sequentially, starting at A (record in document electronic file, transmittals and Aconex database) for Draft revisions of the document<br><br>Use numeric starting at 0, following approval of the document for construction, procurement or "use" | |

# Appendix A. Tables

## A.1 Table 1: Technical Document Type

Note: This table may be modified by the Employer based on request from the Contractor.

| Document Type | TTT |
|---|---|
| Calculation | CAL |
| Design Criteria | DCR |
| Drawing General Arrangement | DGA |
| Drawing Model (2D,3D) | DML |
| Drawing | DRG |
| Data Sheet | DST |
| Functional Description | FDE |
| GIS Data | GIS |
| Drawing Isometric | ISO |
| List | LST |
| Manual | MAN |
| Material Take Off | MTO |
| Process Flow Diagram | PFD |
| P&ID | PID |
| Report | RPT |
| Sketch | SKT |
| Single Line Diagram | SLD |
| Scope of Work | SOW |
| Specification | SPC |
| Other (Contractor to advise) | DOC |

## A.2 Table 2: Area or Location

| Document Type | AAA |
|---|---|
| Area wide or not area specific | XXX |
| Steam Gathering System | SGS |
| Brine Pump Station | BPS |
| Power Plant | PPP |
| Brine Reinjection Line (main) | BRL |
| Wellpad WW-01 | W01 |
| Wellpad WW-R1 | WR1 |

| Document Type | AAA |
|---|---|
| *Other areas to be added* | |
| | |

## A.3 Table 3: System

The System type shall generally follow the guidelines of KKS – Identification system for Power Plants.

Some examples are provided below and this table shall be updated by the Contractor to conform with the power plant technology provided and its associated systems.

| System | SSS |
|---|---|
| Measuring equipment | ASM |
| Auxiliary power supply | ASN |
| Metering | ASQ |
| Protection | ASR |
| Synchronization | ASS |
| Indication, manual operation, monitoring | ASW |
| Remote control system | AYG |
| General gas detection system (if not assigned to specific system | AYQ |
| Generator circuit breaker, | BAC |
| LV main distribution board | BFA |
| LV auxiliary power transformer | BFT |
| LV distribution board | BGA |
| Power installations for variable-speed drives | BPA |
| LV distribution board, uninterruptible (converter) power supply | BRA |
| Batteries | BTA |
| DC distribution board | BUA |
| Control and protection equipment | BYA |
| Cabinets for automation systems, e.g. unit control level, function unit | CRA |
| Telephone system (PABX) | CYA |
| Fire alarm system | CYE |
| Piping and channel system (Raw Water) | GAC |
| Piping system, temporary storage system, pump system for main fluid | GCK |
| Storage, forwarding, distribution system (or Potable water distribution system) | GKB |
| Drinking water supply (e.g. assigned to structures) | GKD |
| Plant drainage system (e.g. assigned to structures or Central disposal system) | GMA |

| System | SSS |
|---|---|
| Domestic waste water collection and drainage system | GQA |
| Evaporator system | HAD |
| Reheat system | HAJ |
| Main steam piping system | LBA |
| Auxiliary steam piping system | LBG |
| Main condensate piping system (excl. main condensate pump system | LCA |
| Steam generator drains system | LCL |
| Auxiliary steam condensate system (collecting and return system | LCN |
| Sealing and cooling drains system | LCW |
| LP turbine | MAC |
| Bearing | MAD |
| Transmission gear between prime mover and driven machine, incl. turning gear | MAK |
| Circulating (main cooling) water pump system | PAC |
| Cooling tower blowdown system | PSA |
| Central compressed air and carrier air distribution system | QEB |
| | |

## A.4 Table 4: Discipline

| Document Type | DD |
|---|---|
| Building Utility / Services | BS |
| Civil Engineering | CE |
| Control, Instrumentation, Communication | CI |
| Electrical Engineering | EE |
| General Management | GM |
| Geography/GIS | GI |
| Geoscience | GS |
| Mechanical Engineering | ME |
| Process Engineering | PE |
| Structural Engineering | SE |

| Document Type | DD |
|---|---|
| | |

## A.5 Table 5: Document Originator

| Document Orignator | BBB |
|---|---|
| Dominica Geothermal Development Company | DGC |
| Jacobs | JAC |
| *Remainder of table to be completed* | |
| | |
| | |

## A.6 Table 6: Administration document type

| Administration Document Type | MMM |
|---|---|
| Agenda | AGE |
| Agreement | AGR |
| Corrective Action Request | CAR |
| Curriculum Vitae | CUR |
| Document Transmittal | DTX |
| Estimate | EST |
| File Note | FNT |
| Job Safety and Environmental Analysis | JSE |
| Letter | LTR |
| Memo | MEM |
| Meeting Minutes | MIN |
| Project Action Advice Note | PAN |
| Progress Claim | PCL |
| Project Change Request | PCR |
| Project Schedule | SCH |
| Proposal | PRO |
| Progress Report | PRT |
| Register | REG |
| Request for Information | RFI |
| Resource Plan | RPL |
| Site Instruction | SIN |
| Cost Report | CRT |
| Engineering Change Notice | ECN |
| Internal Discipline Review | IDR |
| Monthly Report | MRT |

## Document Requirements

| Administration Document Type | MMM |
|---|---|
| Project Change Notice | PCN |
| | |