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

Project No: RZ020300
Document Title: ESIA Volume 2: Environmental Impact Assessment
Document No.: RZ020300-002-NP-RPT-0005
Revision: V2
Date: July 2018
Client Name: NZ Ministry of Foreign Affairs and Trade
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Document history and status

Revision	Date	Description	By	Review	Approved
A	September 2017	Draft Environmental Impact Assessment	P Gabriel / A Kubale	B Clarke	B Clarke
B	September 2017	Draft Environmental Impact Assessment with Morne Trois Pitons Impacts and Terrestrial Ecology Impacts	P Gabriel / A Kubale	B Clarke	B Clarke
C	April 2018	Revisions to ESIA following Post-Maria scenarios. ISSUE TO DGDC.	P Gabriel	B Clarke	B Clarke
V1	June 2018	Revisions following World Bank Comments – FINAL ISSUE	P Gabriel	B Clarke	B Clarke
V2	July 2018	Further revision following World Bank RSA Comments – Issue for Disclosure	B Clarke	H Anderson	A Brookes

Contents

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.

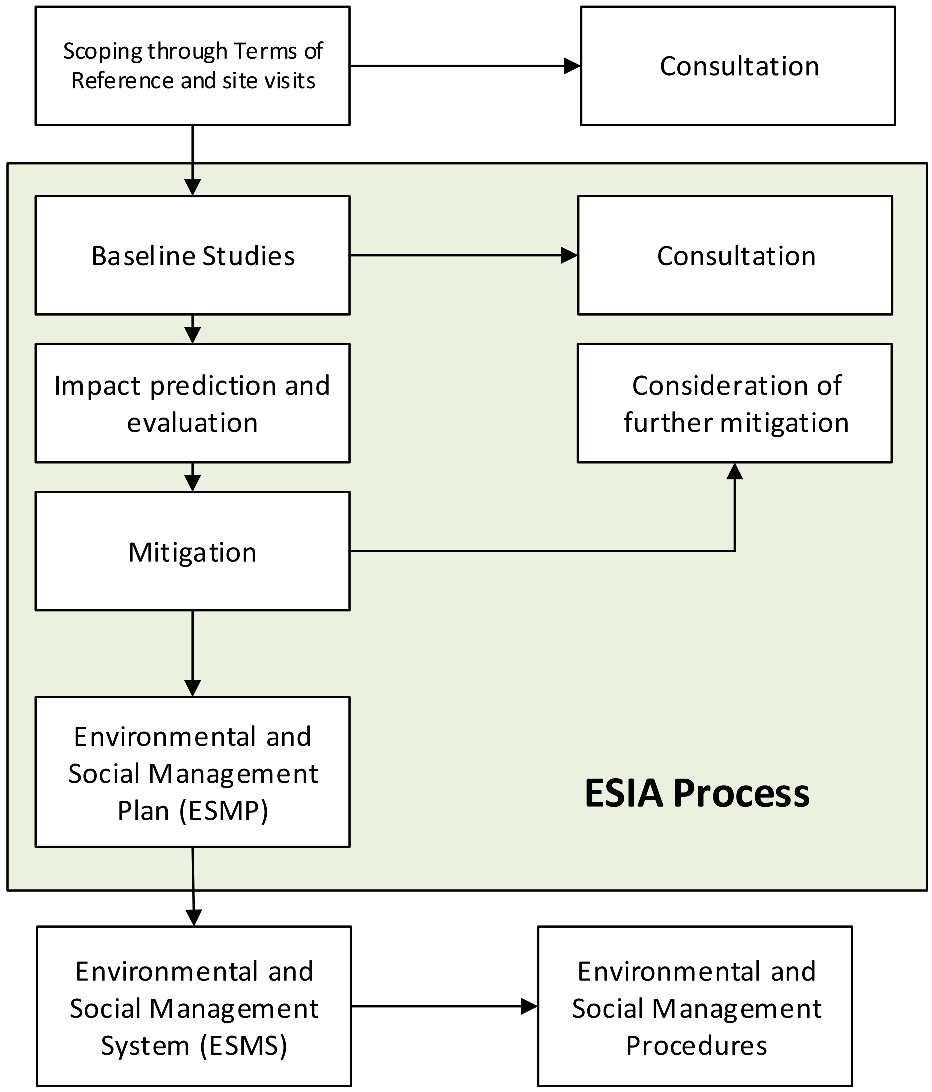


Figure 1.1 : General overview of the ESIA process

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).

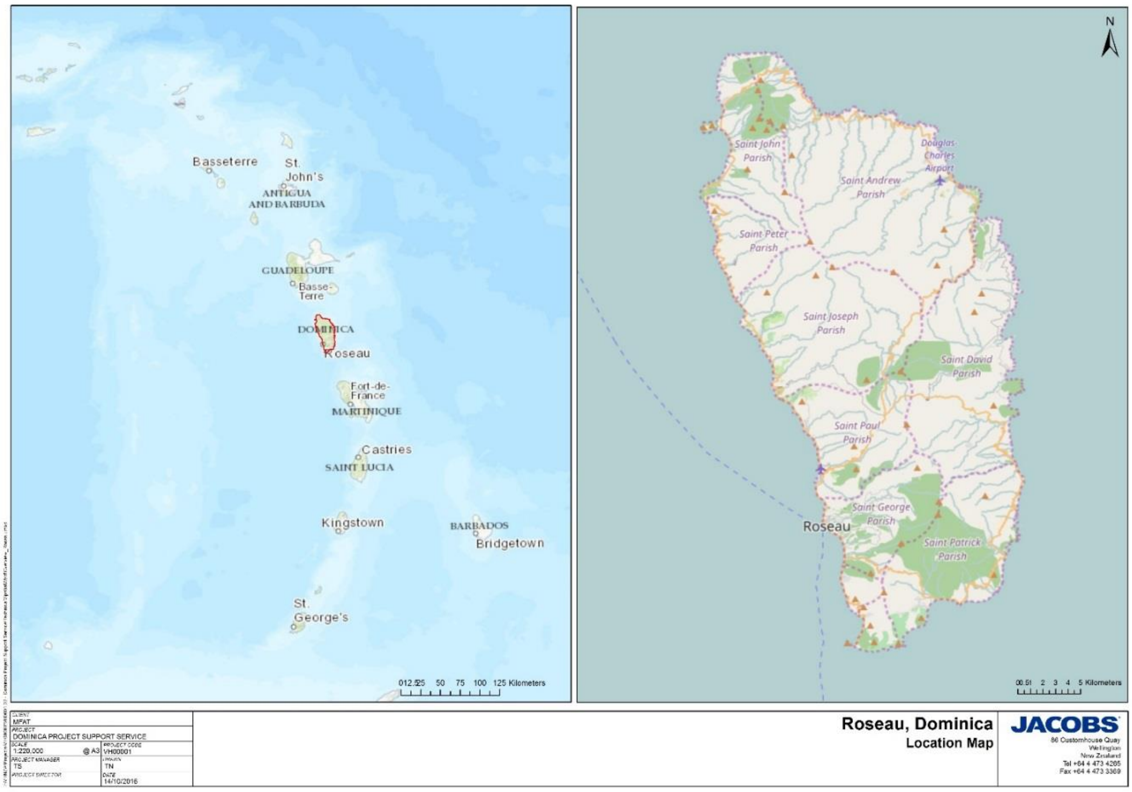


Figure 3.1 : Dominica’s location in the Caribbean

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.

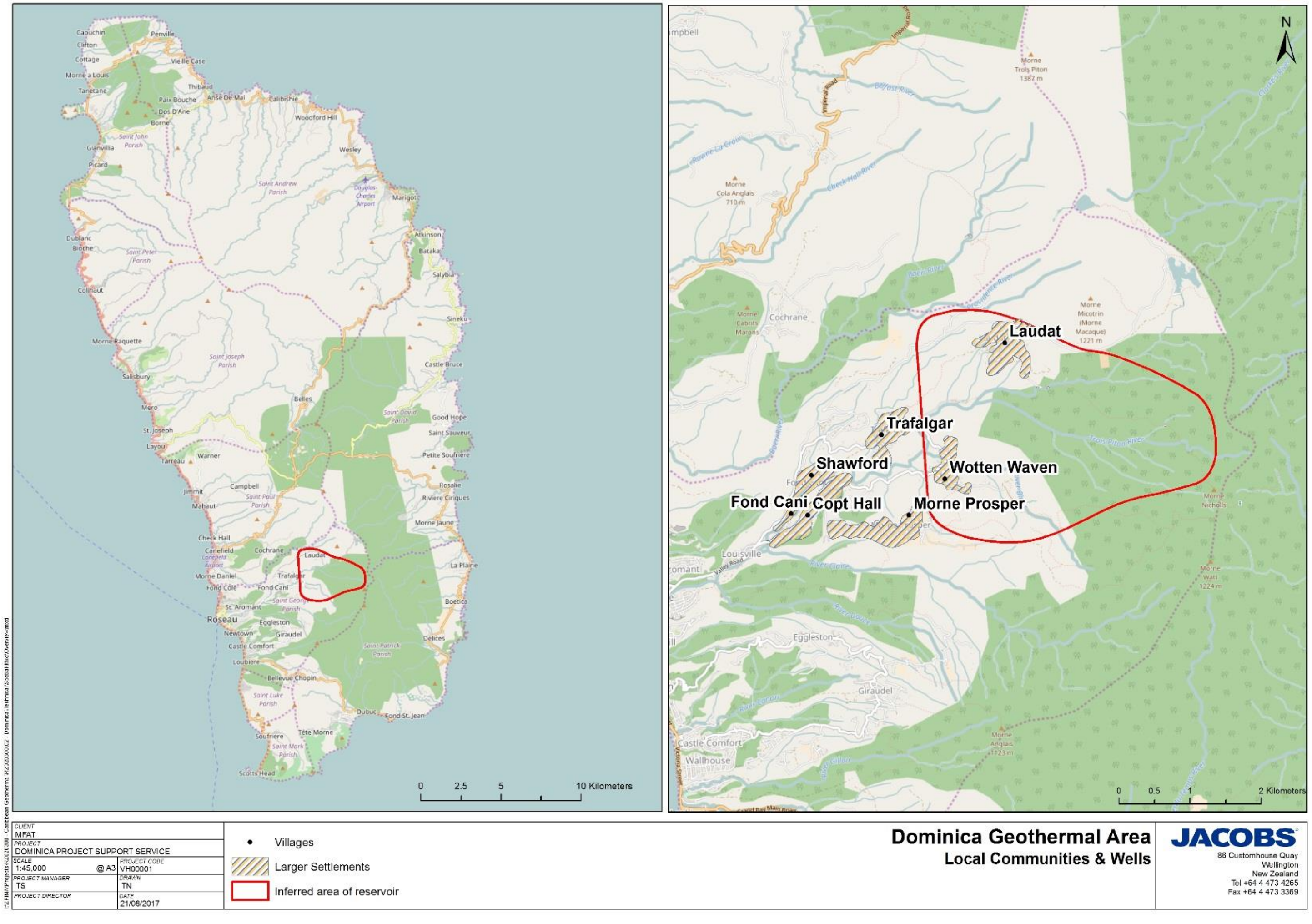


Figure 3.2 : Location of Roseau Valley (Site of proposed Geothermal Power Plant)

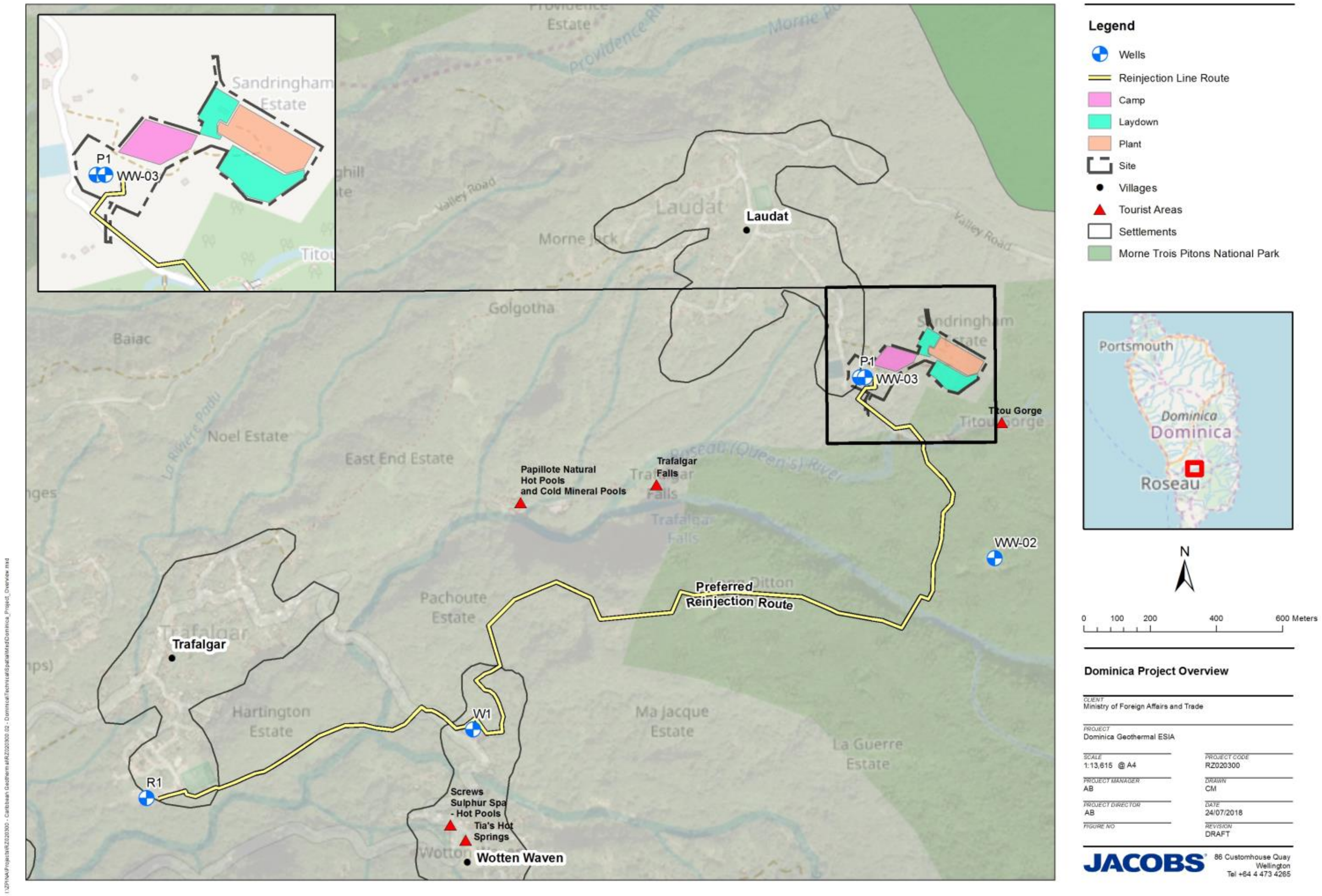


Figure 3.3 : Location of Power Plant and Reinjection Pipeline (the Project) in the Roseau Valley

3.3 Climate

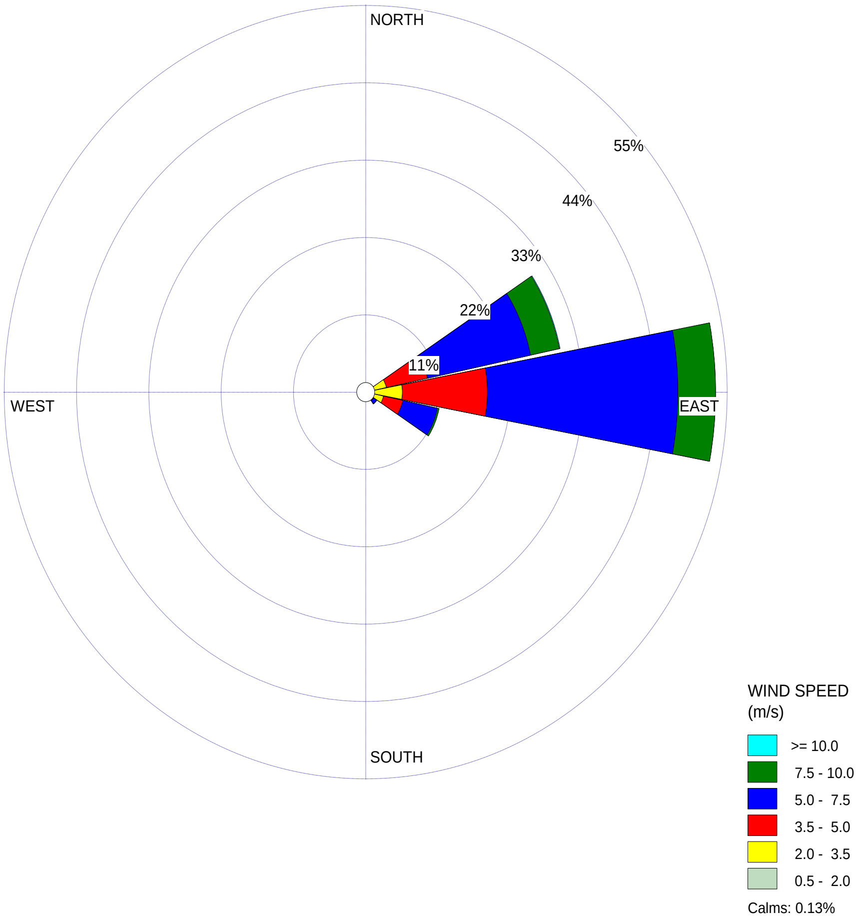
The climate of Dominica is tropical all year round, with high temperatures, high humidity and heavy rainfall. The magnitude of variation in ambient temperature is low, generally ranging from 26°C during the day in January to 32°C in June (Caraïbes Environnement Développement & Coll, 2015a/b). The relative 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).

WIND ROSE PLOT:
CALMET Windrose 2015

DISPLAY:
Wind Speed
Direction (blowing from)



COMMENTS:	DATA PERIOD: **Start Date: 1/01/2015 - 00:00** **End Date: 31/12/2015 - 23:00**	COMPANY NAME: **Jacobs New Zealand Ltd**	
		MODELER:	
	CALM WINDS: **0.13%**	TOTAL COUNT: **8759 hrs.**	
	AVG. WIND SPEED: **5.38 m/s**	DATE: **20/12/2016**	PROJECT NO.:

WRPLOT View - Lakes Environmental Software

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).

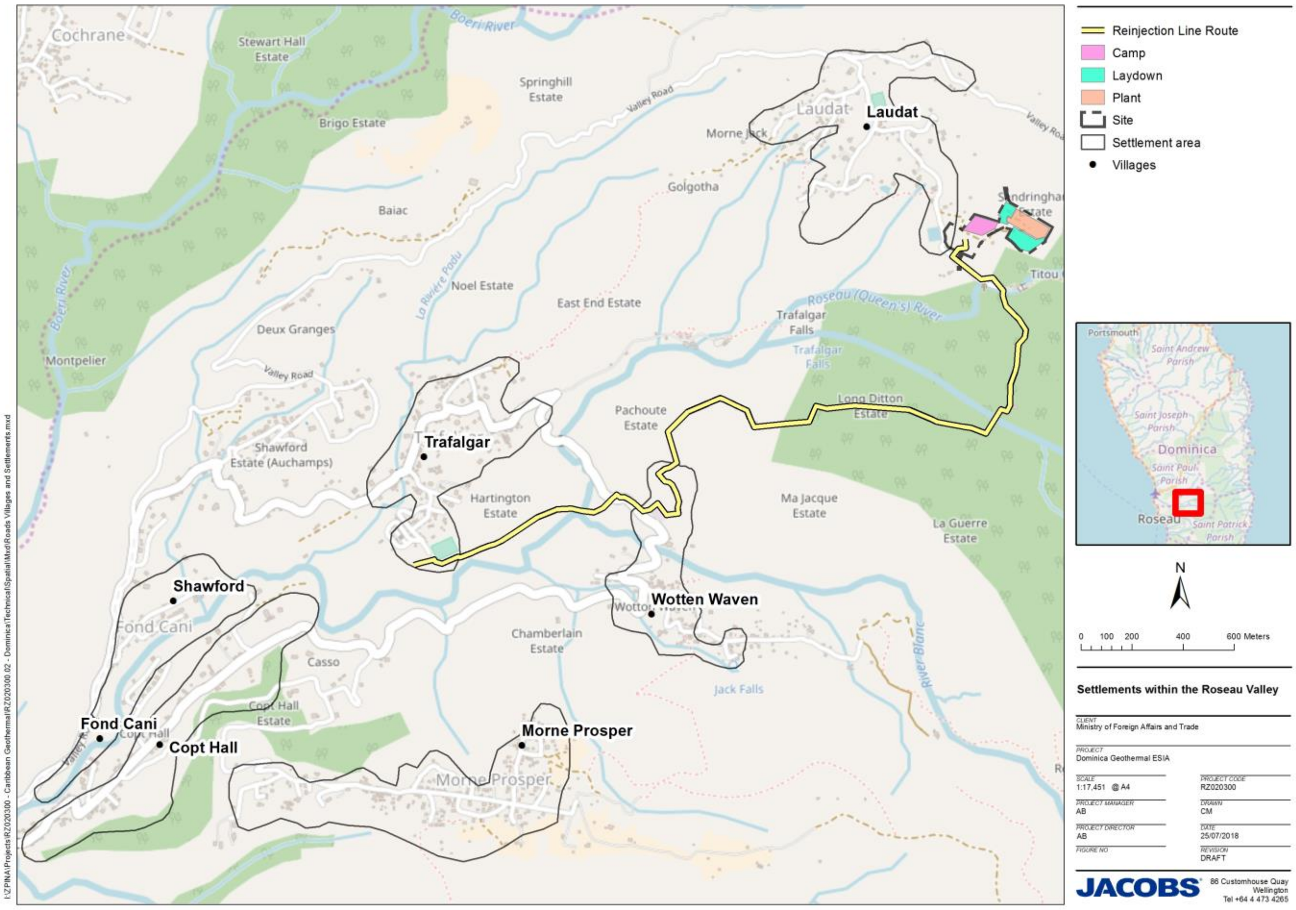


Figure 3.5 : Settlements within the Roseau Valley

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).

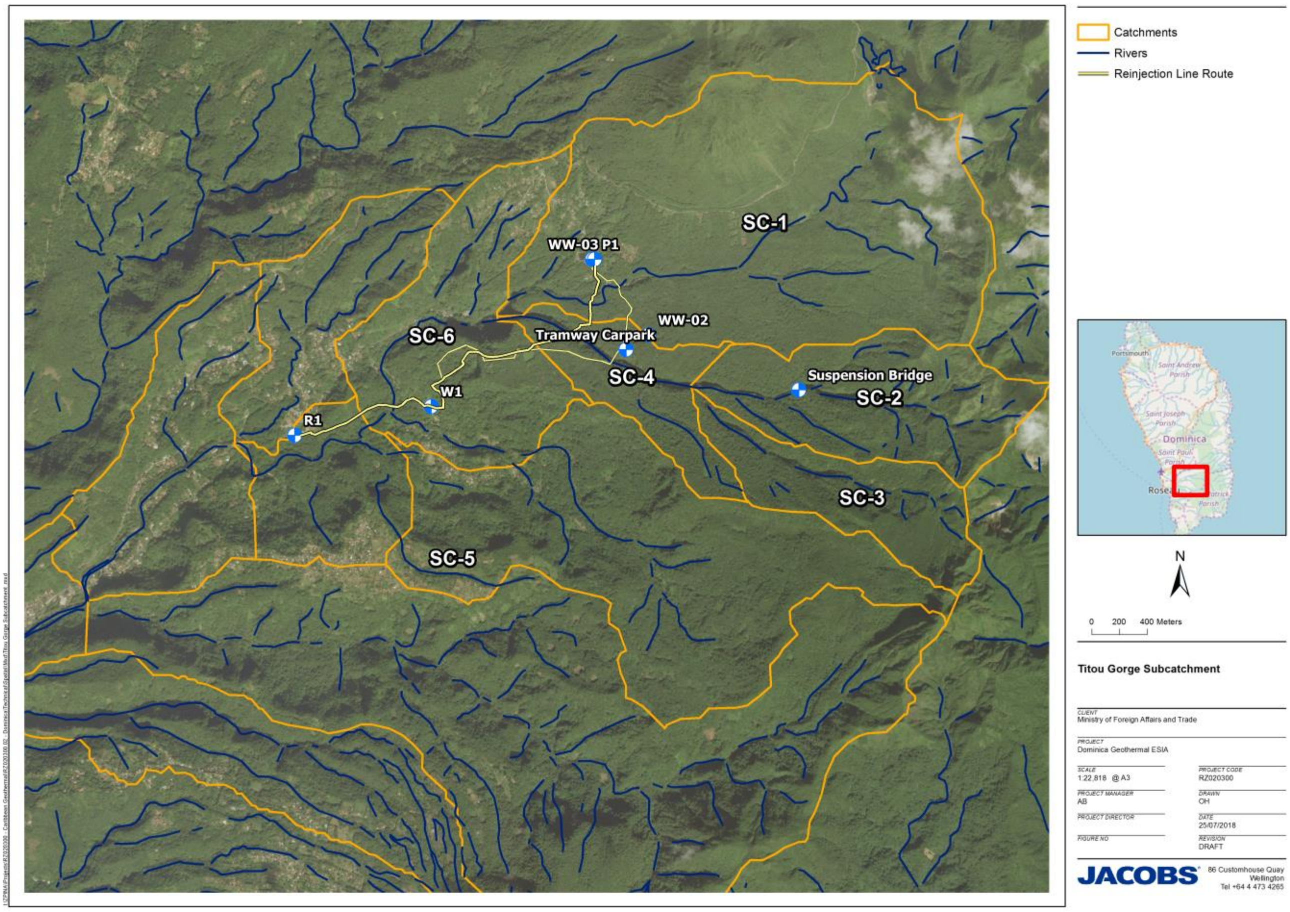


Figure 3.6 : Titou Gorge Subcatchment (Caraïbes Environnement Développement & Coll 2015b)

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 km². The estimated flow based on specific discharges in section 1.2 is 42 and 64.8 m³/s (10 and 100 year ARI).
- SC-6 with a total area of ~10.8 km² (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 m³/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.

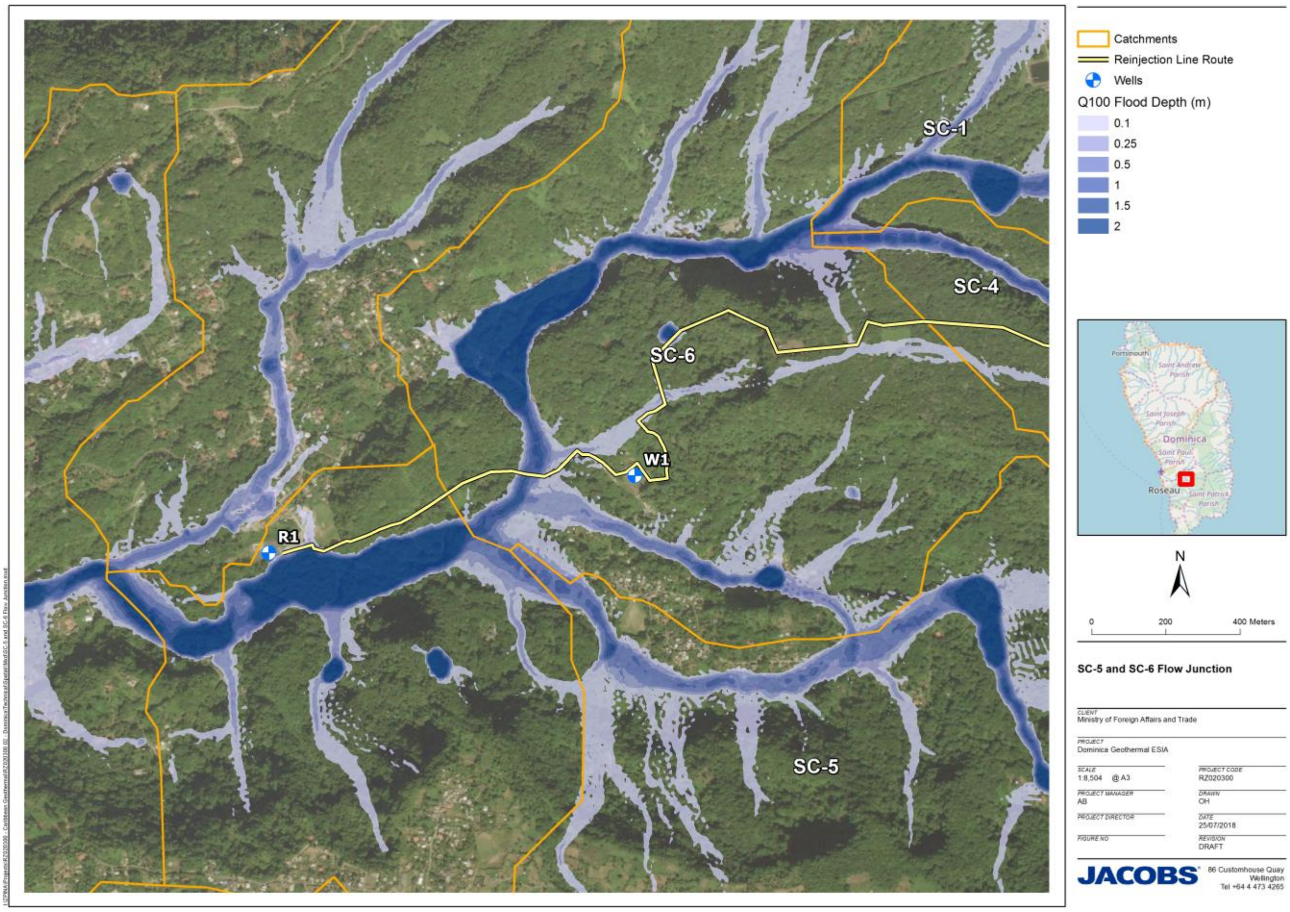


Figure 3.7 : SC-5 and SC-6 Flow Junction

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.

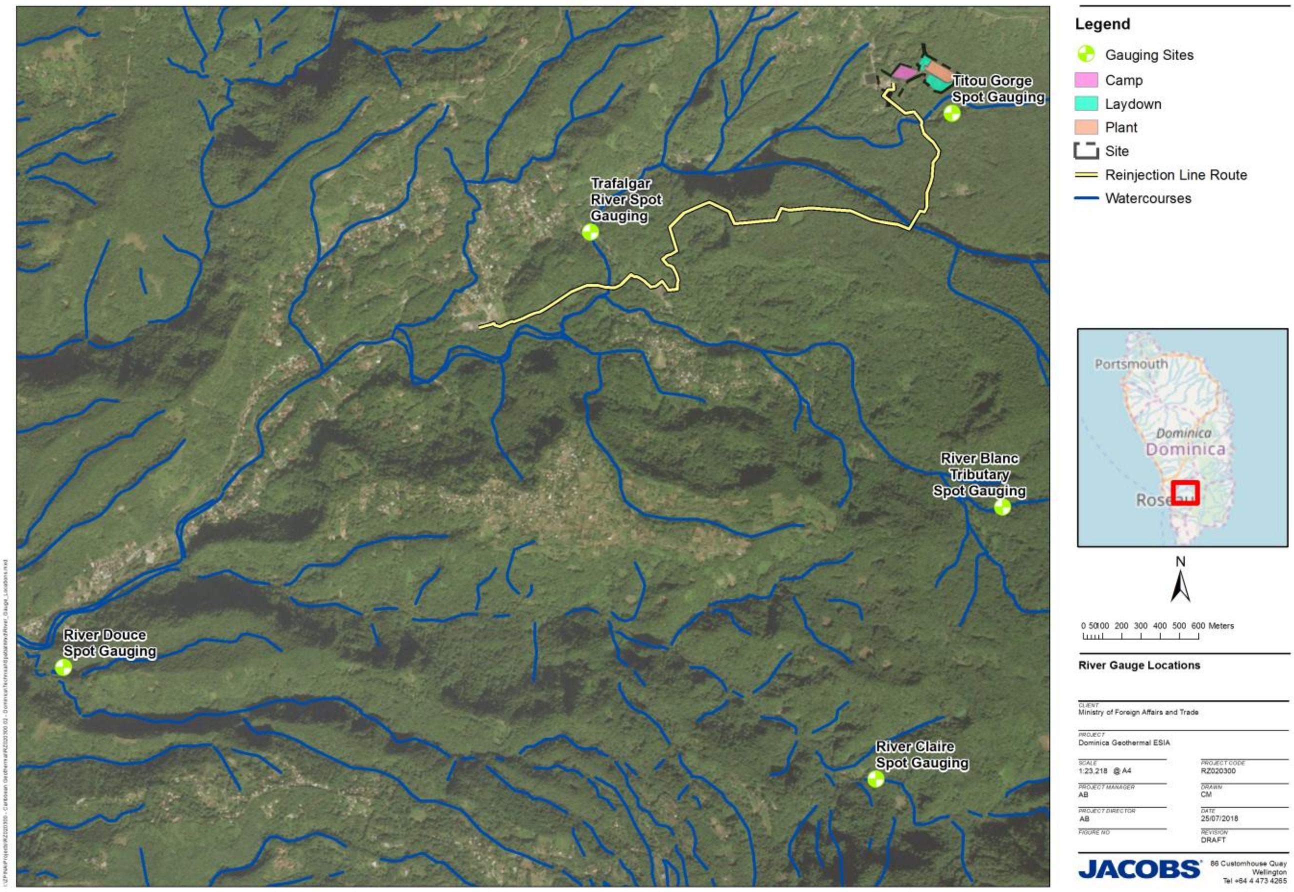


Figure 3.8 : Spot stream gauging locations

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.

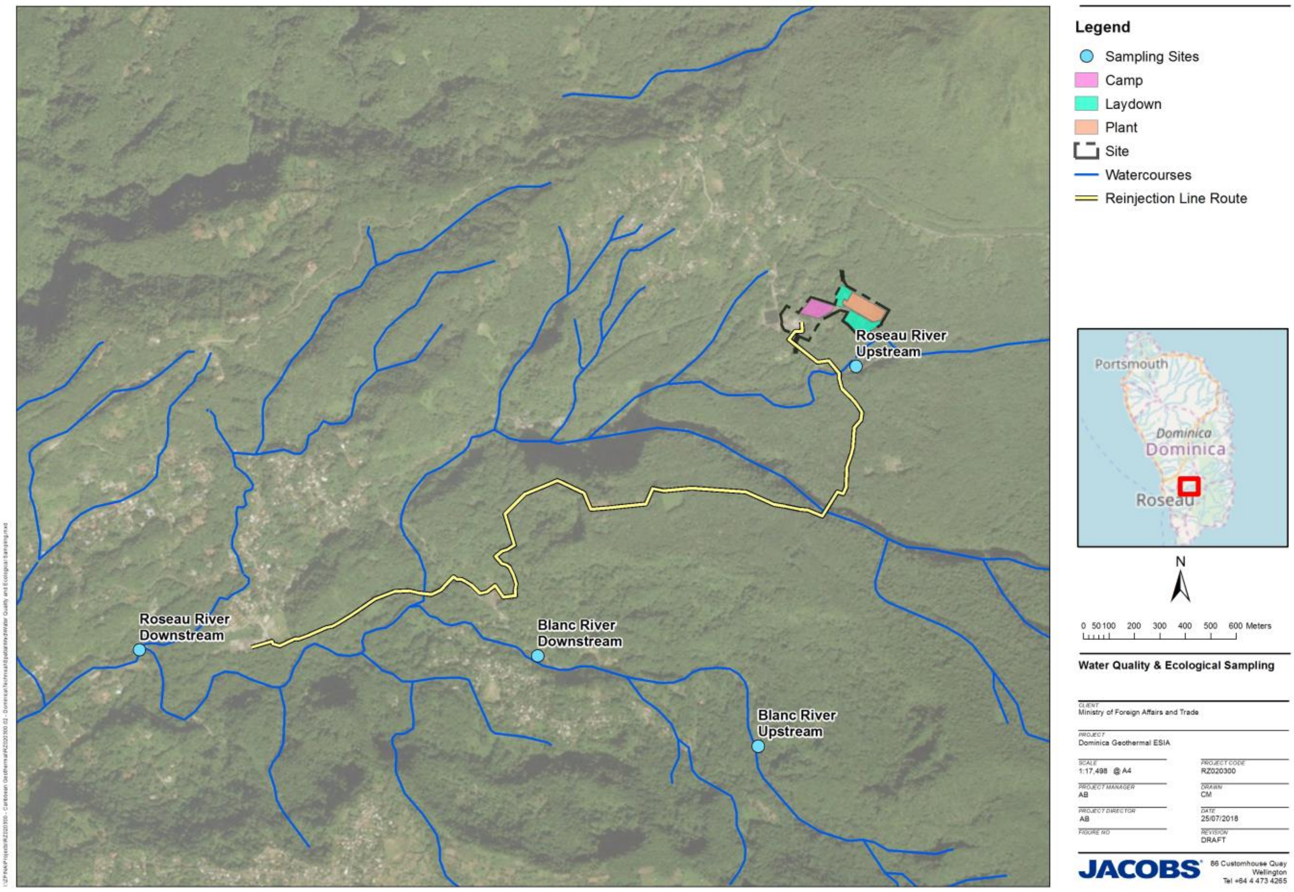


Figure 3.9 : Water quality and freshwater ecology sample points on the Roseau and Blanc Rivers.

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.

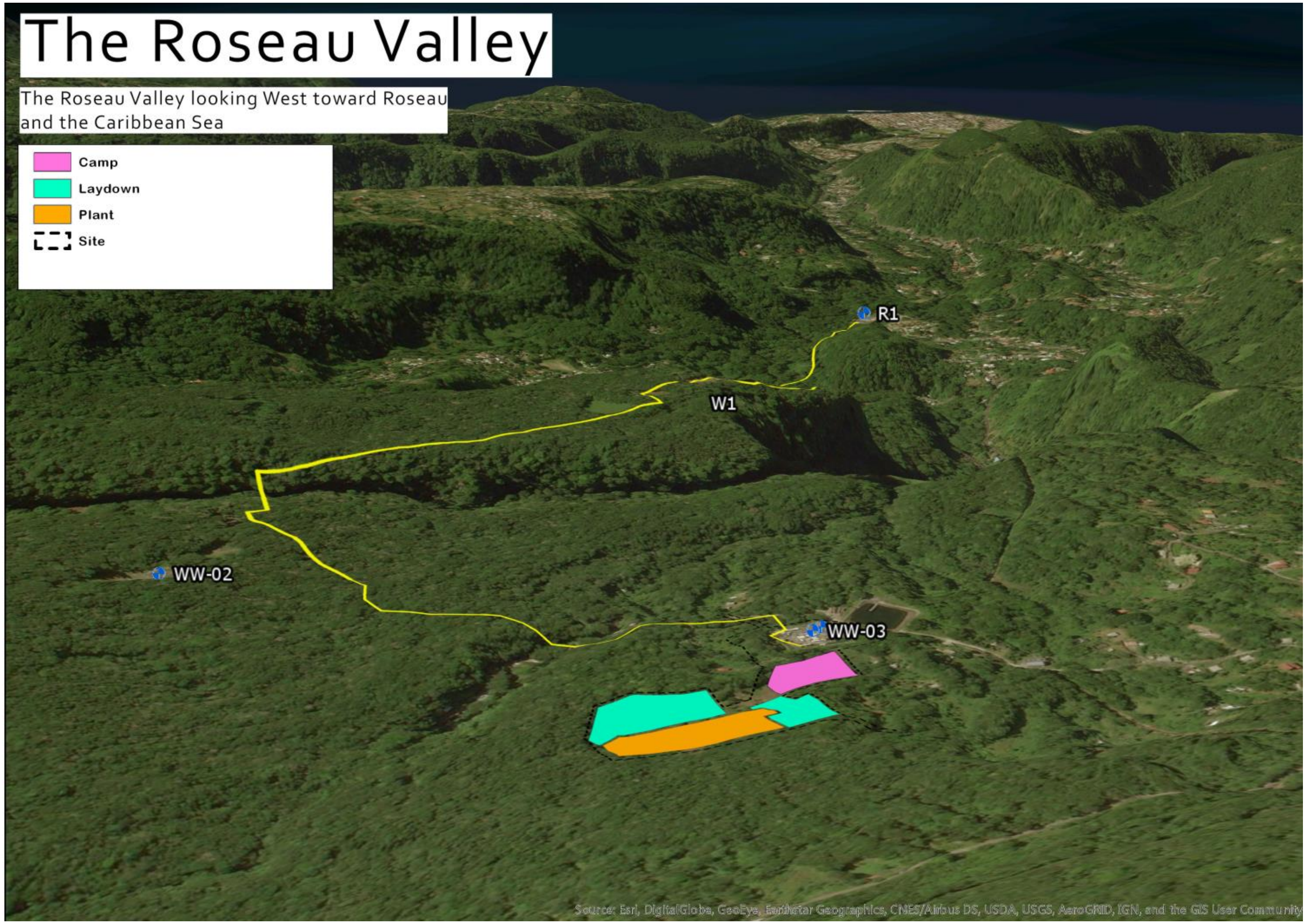


Figure 3.10 : The Roseau Valley looking west towards Roseau and the Caribbean Sea. The power plant and reinjection pipeline routes are also shown. Source: Google Earth, 2017

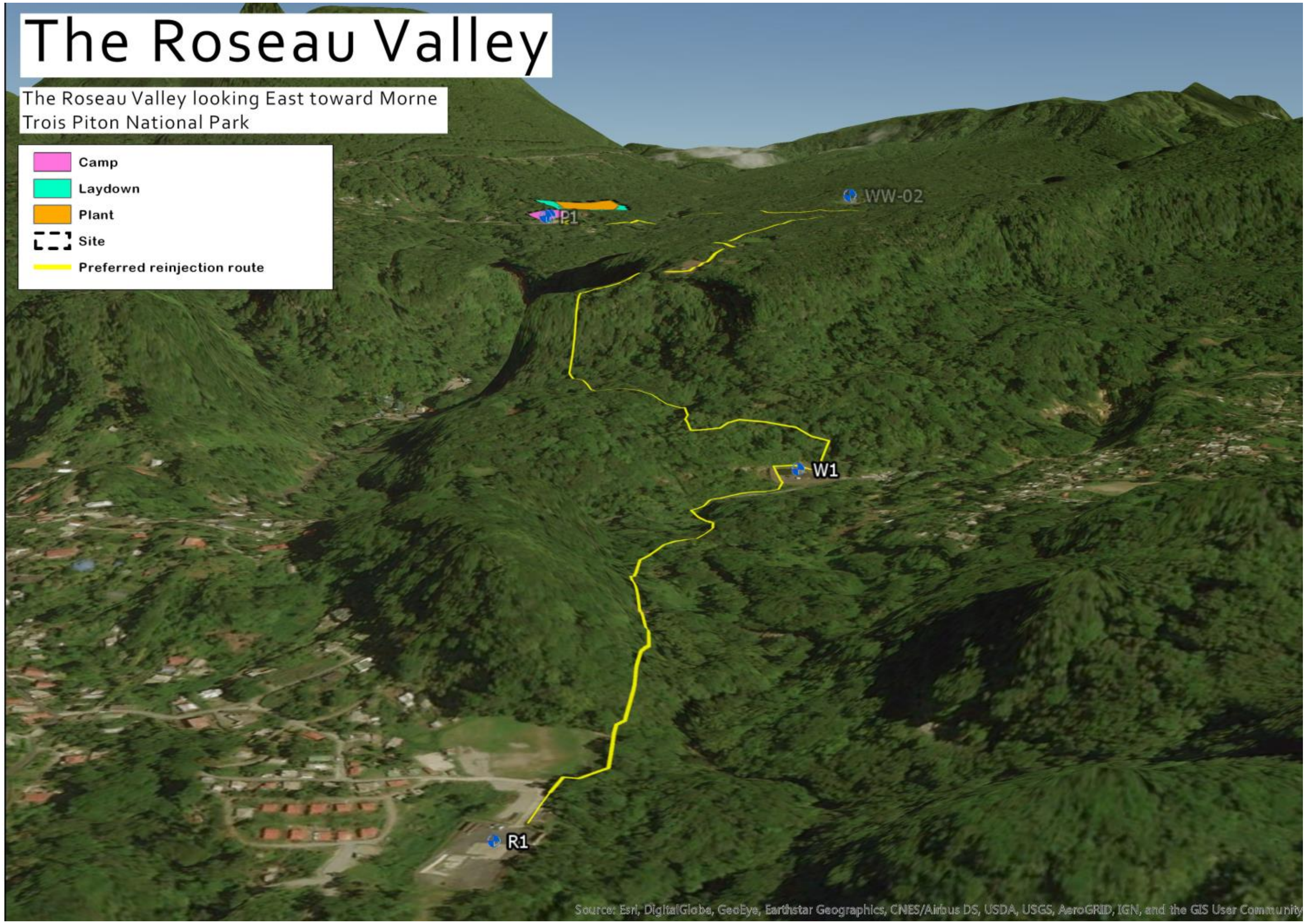


Figure 3.11 : The Roseau Valley looking west towards Morne Trois Piton National Park. The power plant and reinjection pipeline routes are also shown. Source: Google Earth, 2017

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).

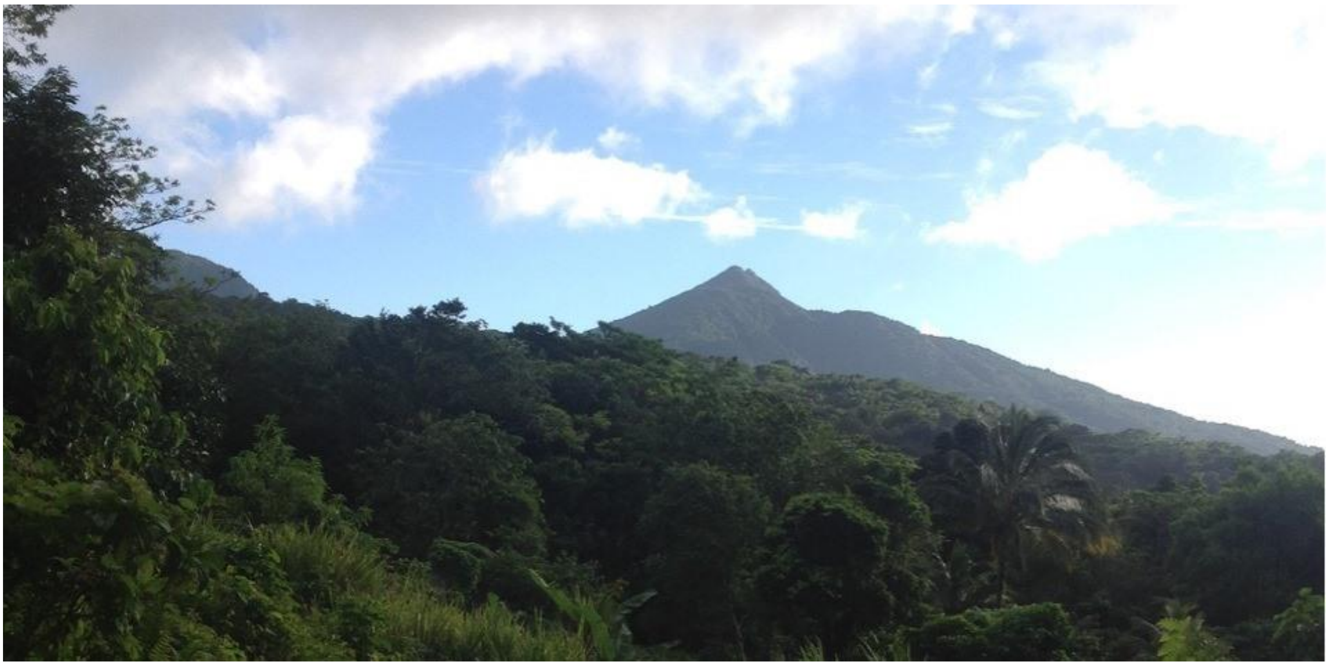


Figure 3.12 : Morne Watt (1,224 m). Source: Jacobs, December 2016

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)

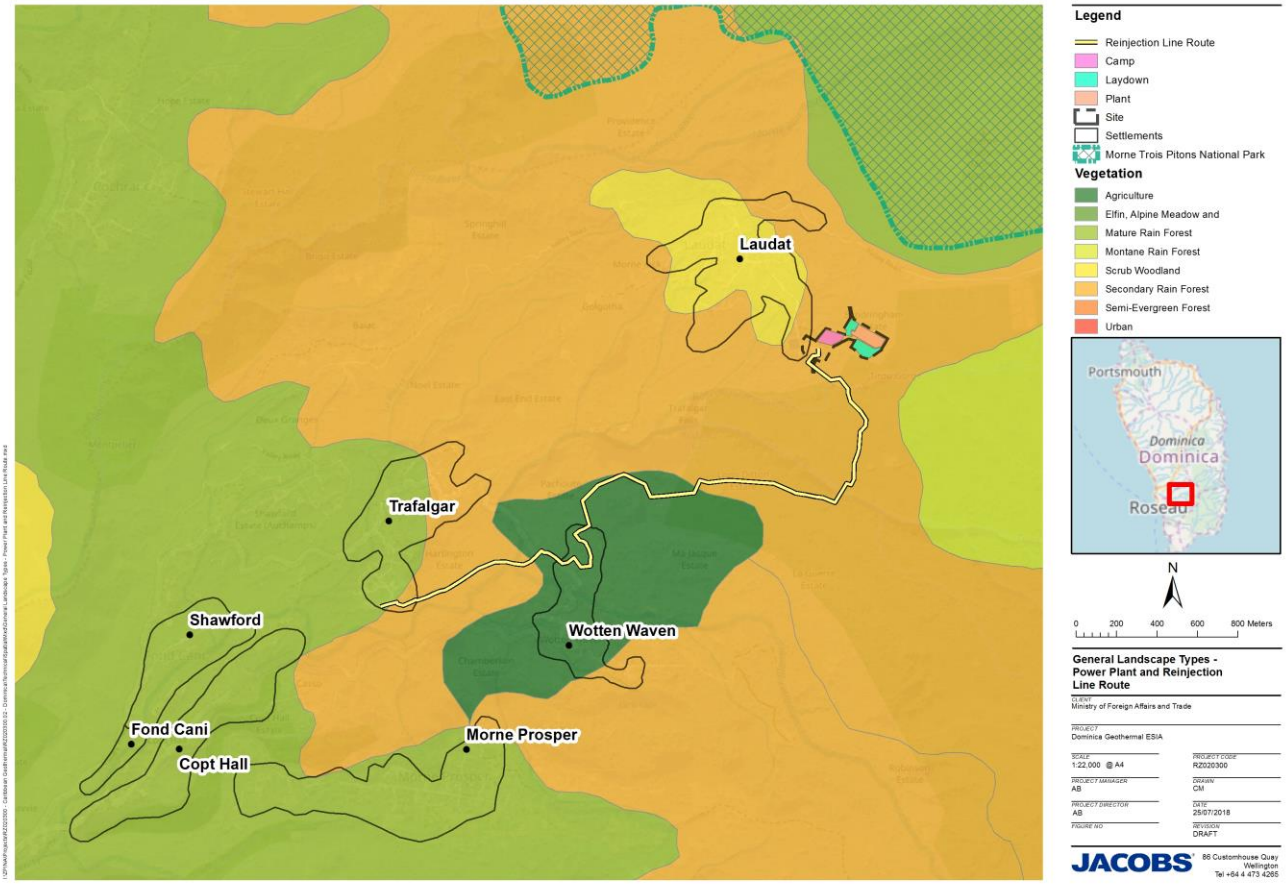


Figure 3.20 : General Landscape Types – Power Plant and Reinjection Pipeline Route. (Source: GoCD Website, 2017)

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).

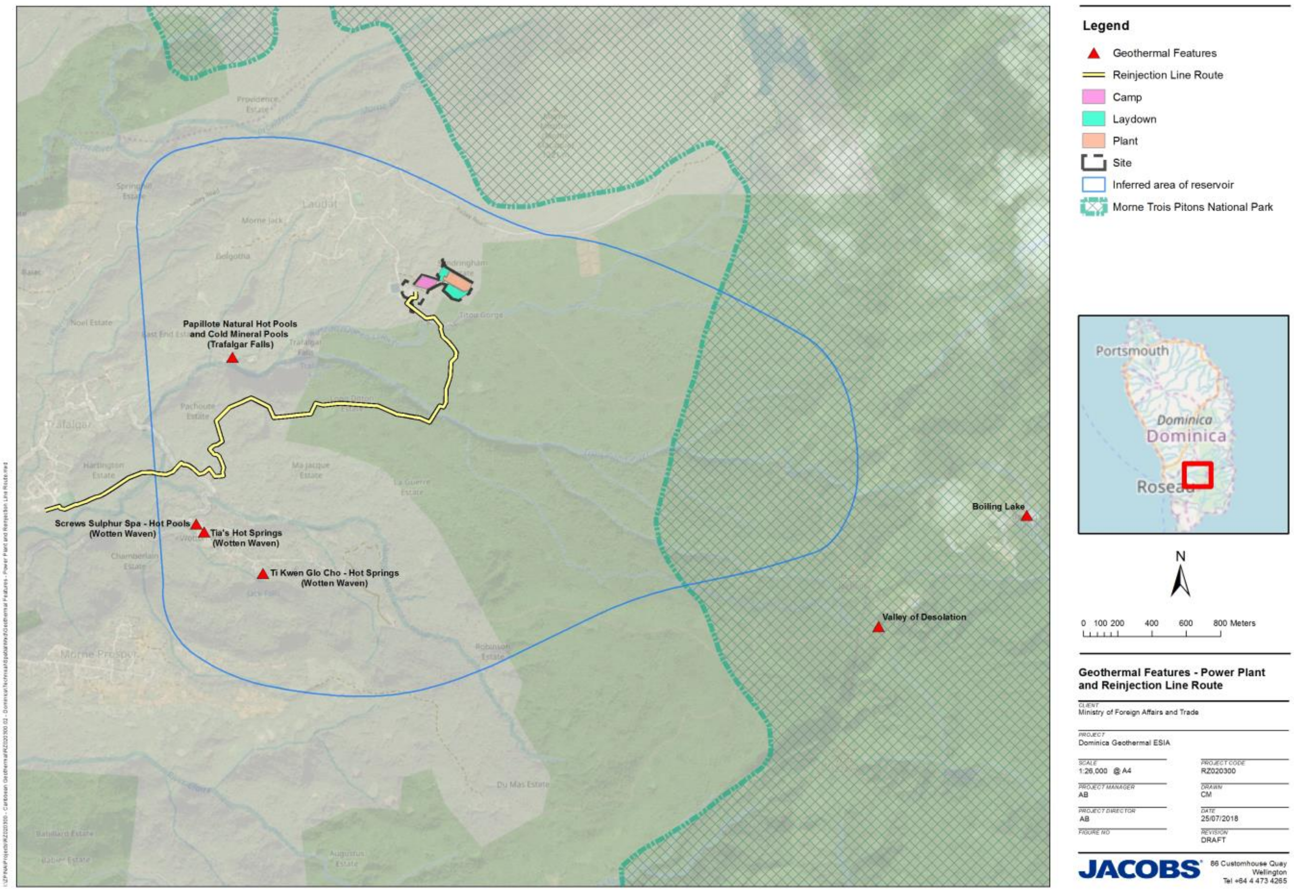


Figure 3.21 : Geothermal Features - Power Plant and Reinjection Pipeline Route

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).

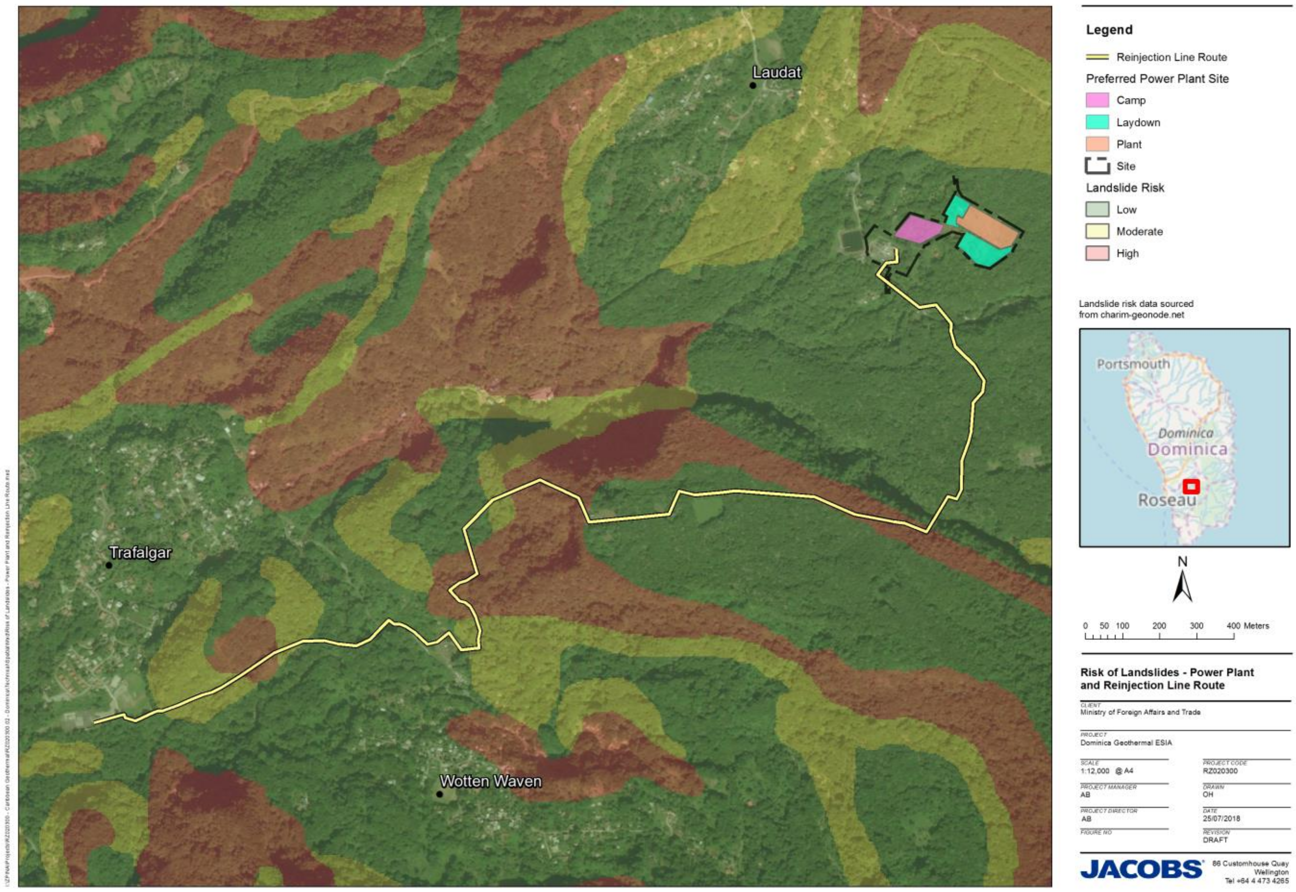


Figure 3.22 : Risk of Landslides - Power Plant and Reinjection Pipeline Route. (Source: GoCD Website, 2017)

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.

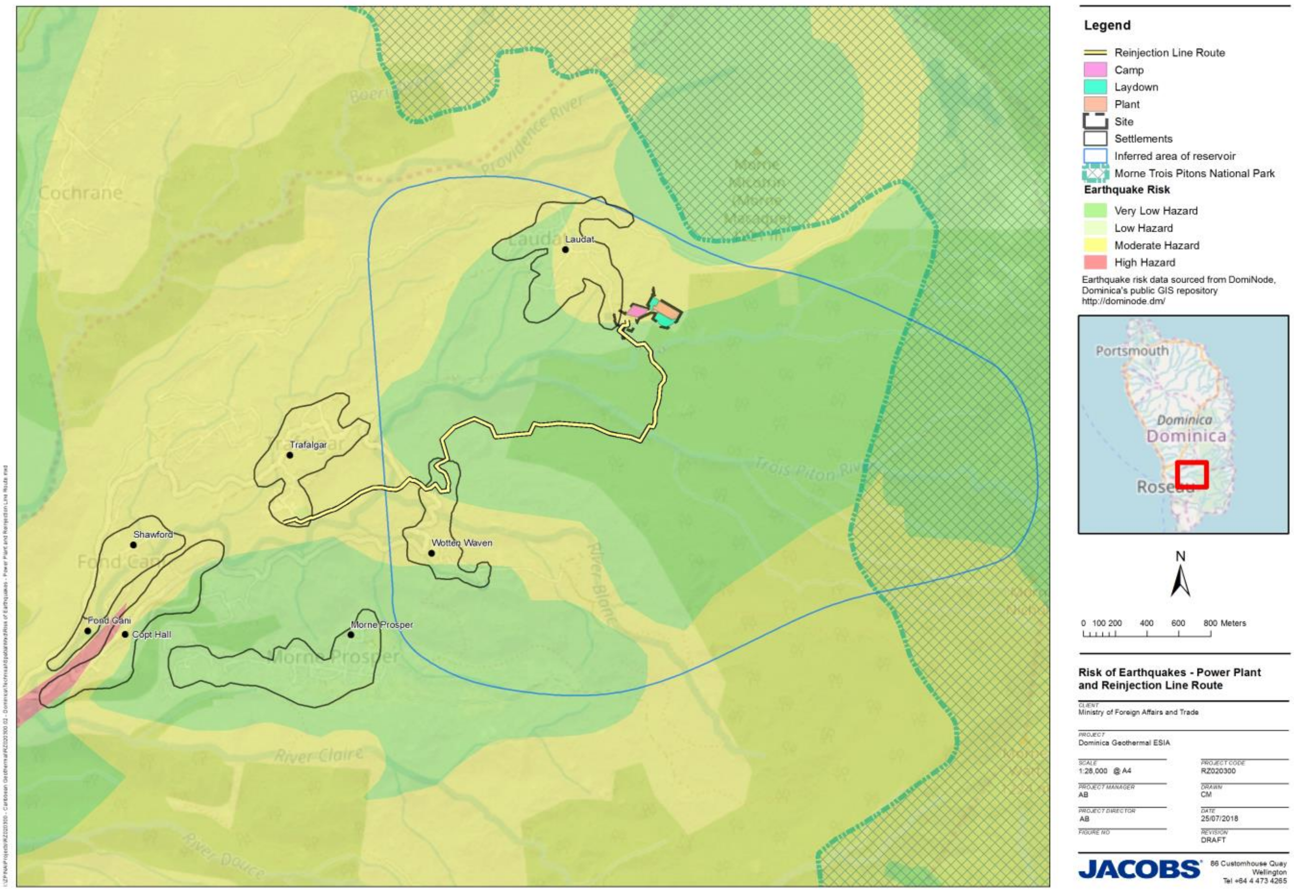


Figure 3.23 : Risk of Earthquakes - Power Plant and Reinjection Pipeline Route. (Source: GoCD Website, 2017)

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.

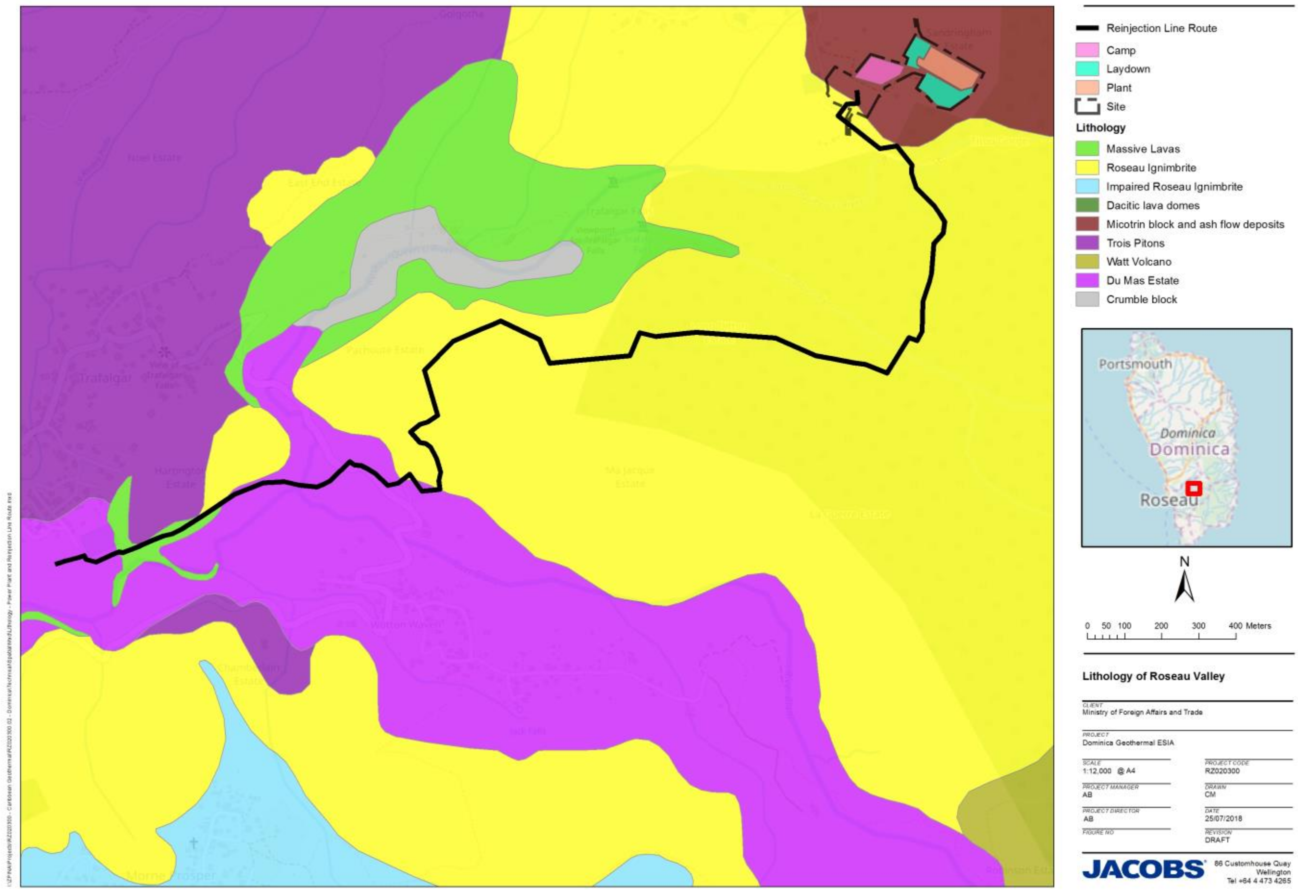


Figure 3.25 : Geology map of Roseau Valley (Source: Caraibes Environment Development, 2015a/b).

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.

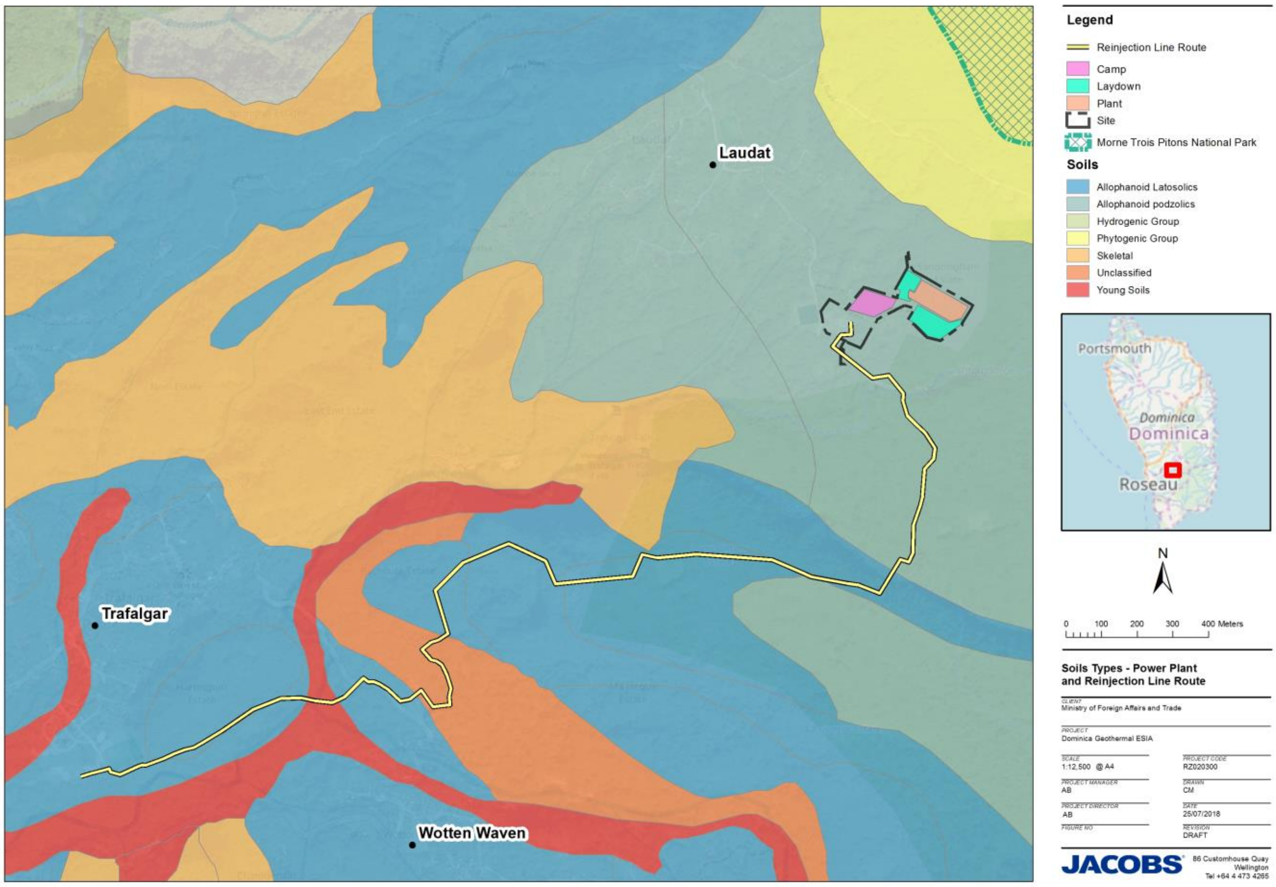


Figure 3.26 : Soil types of the Roseau Valley. (Source: GoCD Website, 2017).

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.

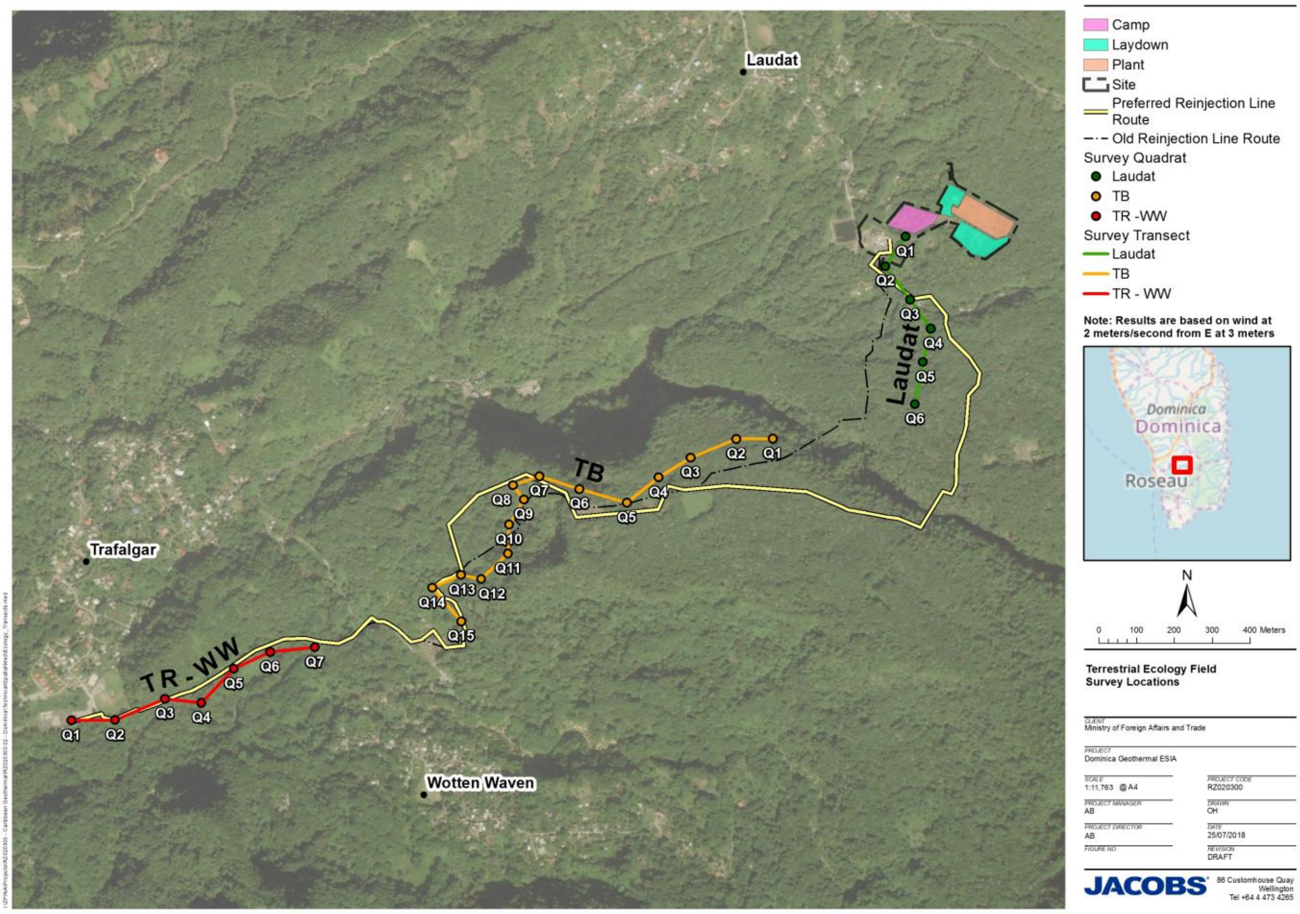


Figure 3.27 : Field survey locations

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: • array of geomorphologic features • the distinctive geology and landforms • the spectrum of volcanic activity including streams, fumaroles, mud ponds and hot springs • the ongoing geomorphological processes	No
	Threatened species and their habitats	Yes
Integrity	• intact nature of geomorphologic features • largely undisturbed setting • natural attributes considered to be whole and intact • site includes all elements necessary to express its outstanding universal value • 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.

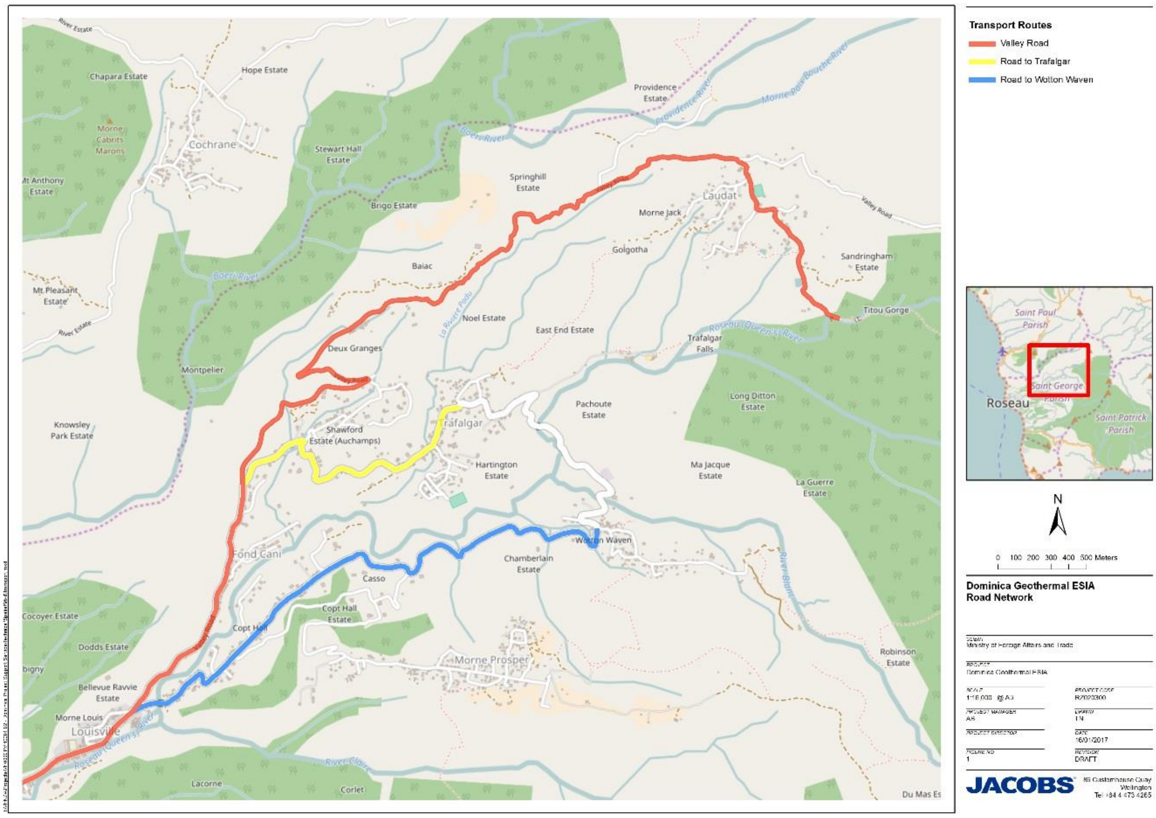


Figure 3.28 : Existing Road Network

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.

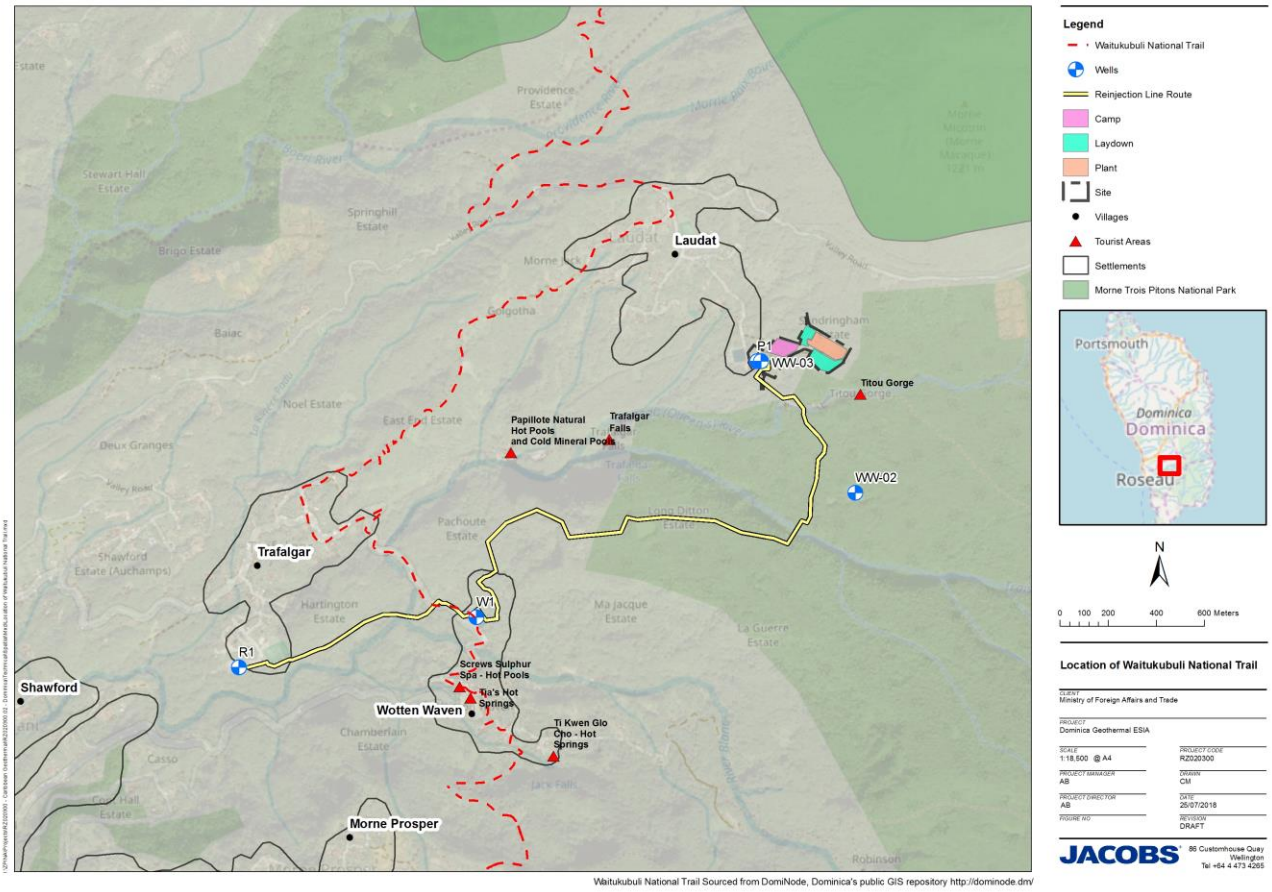


Figure 3.36 : The location of the Waitukubuli National Trail.

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).

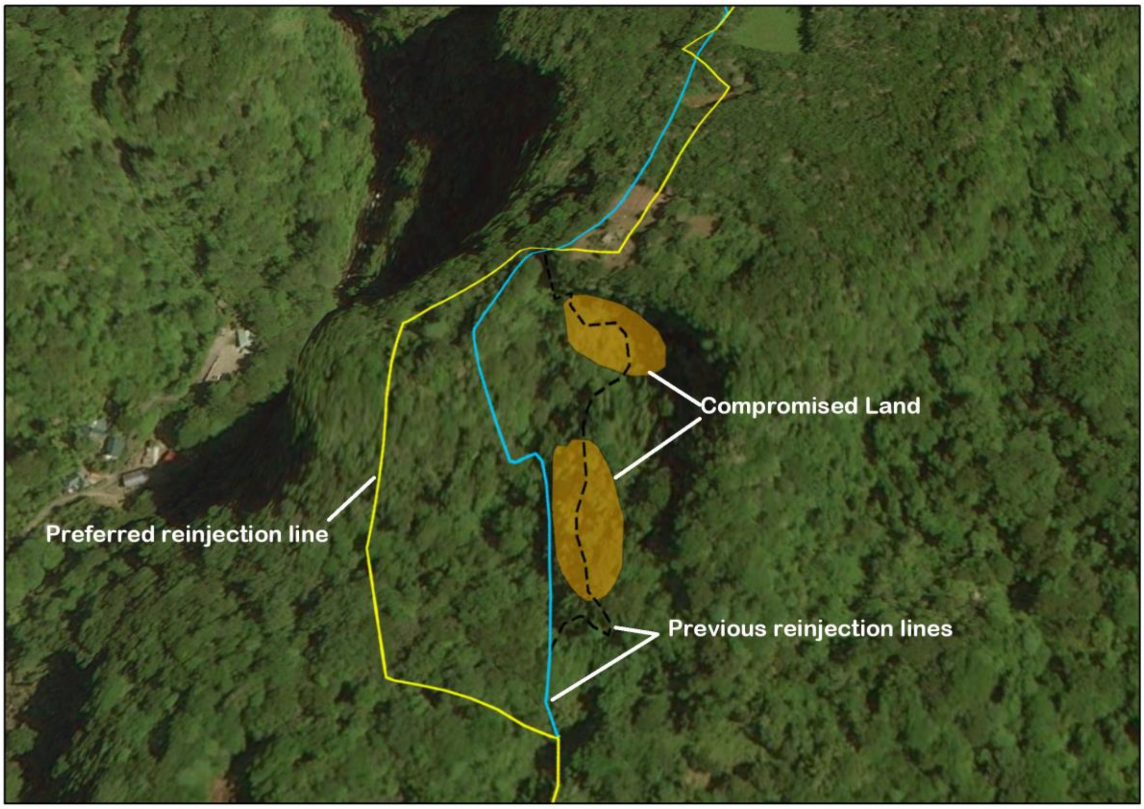


Figure 3.39 : Area of compromised on reinjection line (red areas) (adapted from the DGDC Post Hurricane Maria Report, 2017)

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 $\mu g/m^3$ 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 99.9th 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 99.9th 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 (99.9th 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

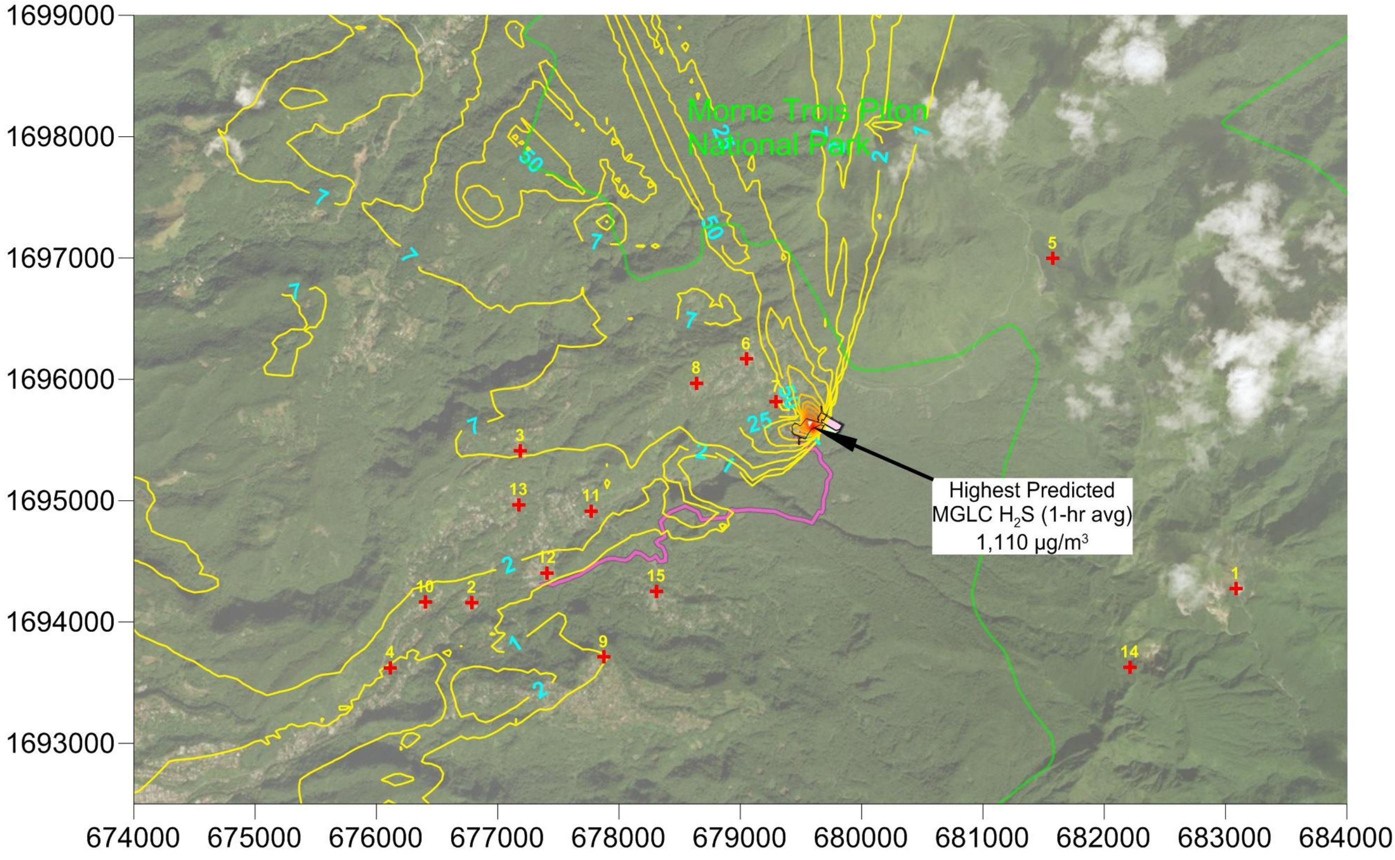


Figure 4.1 : Predicted MGLCs as a 99.9th %ile 1-hour average of H_2S (µg/m^3) from 7 MWe Geothermal Plant Operation (Rankine Steam Condensing Option)

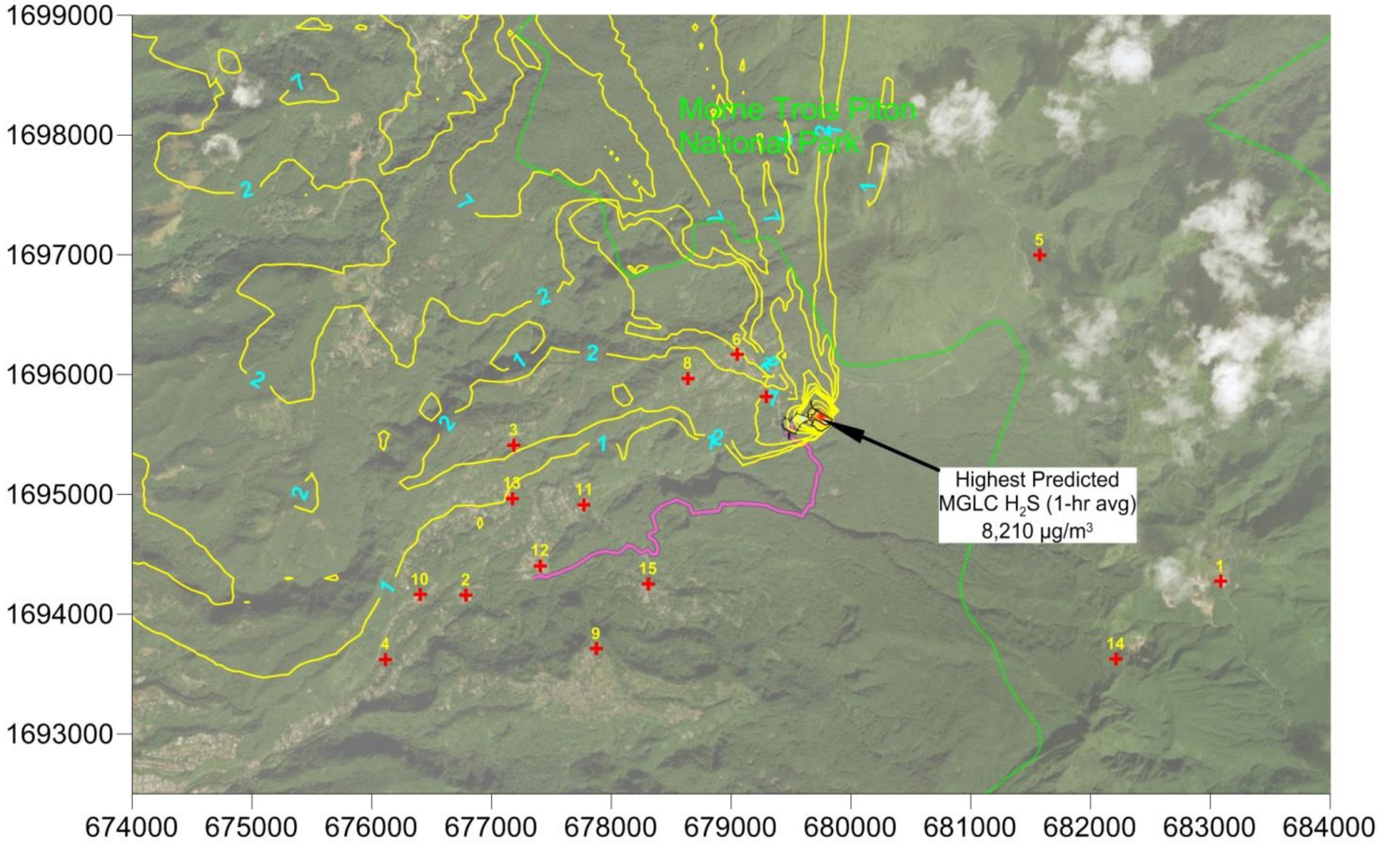


Figure 4.2 : Predicted MGLCs as a 99.9th %ile 1-hour average of H_2S (µg/m^3) from 7 MWe Geothermal Plant Operation (ORC Option)

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/m^3 at all sensitive receptors. Concentrations near the power plant are predicted to exceed this guideline value, with the 150 µg/m^3 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/m^3 for the ORC option and 23 µg/m^3 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/m^3) from 7 MWe Geothermal Plant Operation

Receptor ID	Description	Predicted 1-hour average (99.9th percentile) H_2S Concentration (µm^3)	
		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 (µm^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 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. This is therefore considered to have a **Negligible** level of potential impact on the surrounding environment.

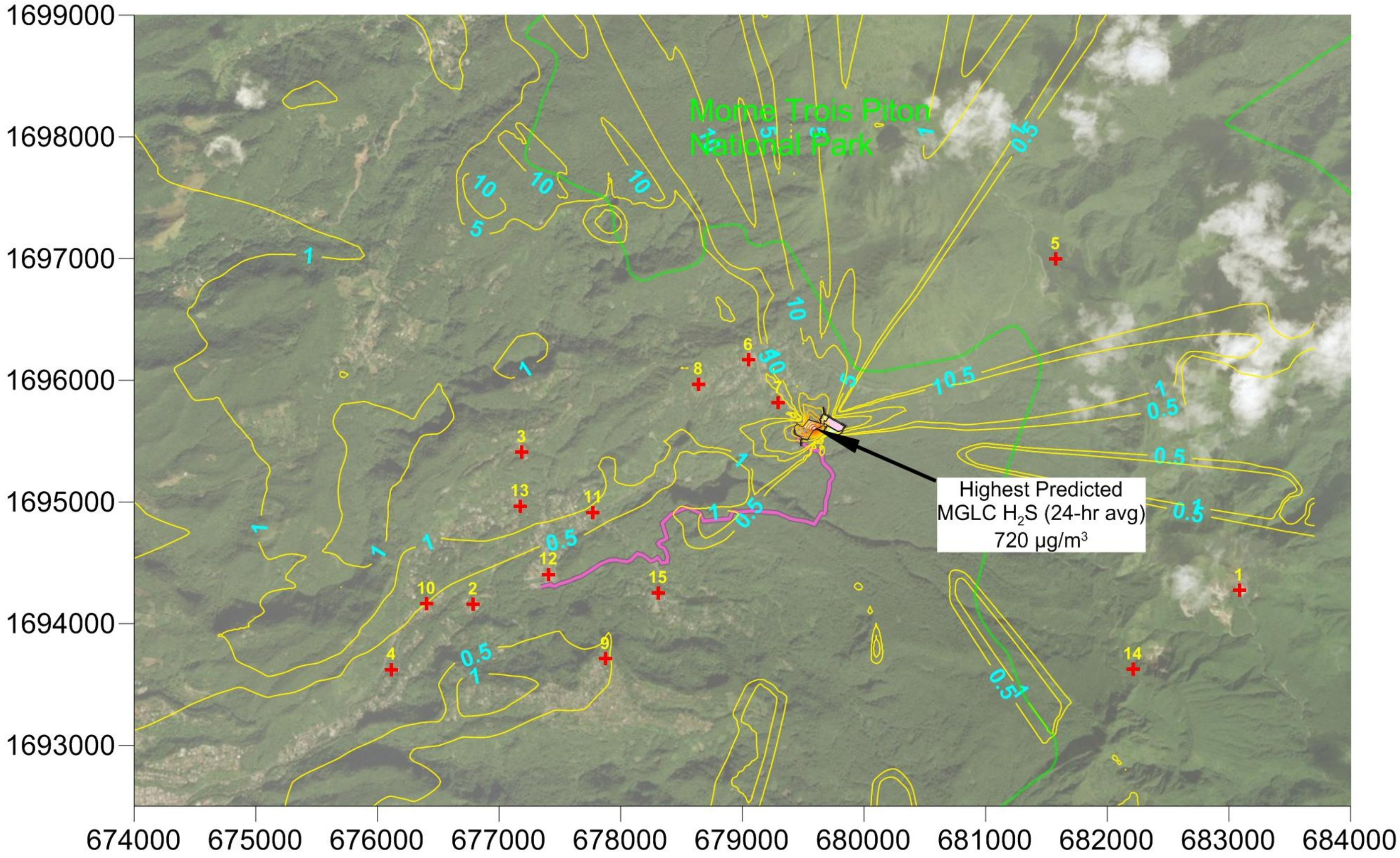


Figure 4.3 : Predicted MGLCs of 24-hour average H_2S ($\mu g/m^3$) from 7 MWe Geothermal Plant Operation (Rankine Steam Condensing Option)

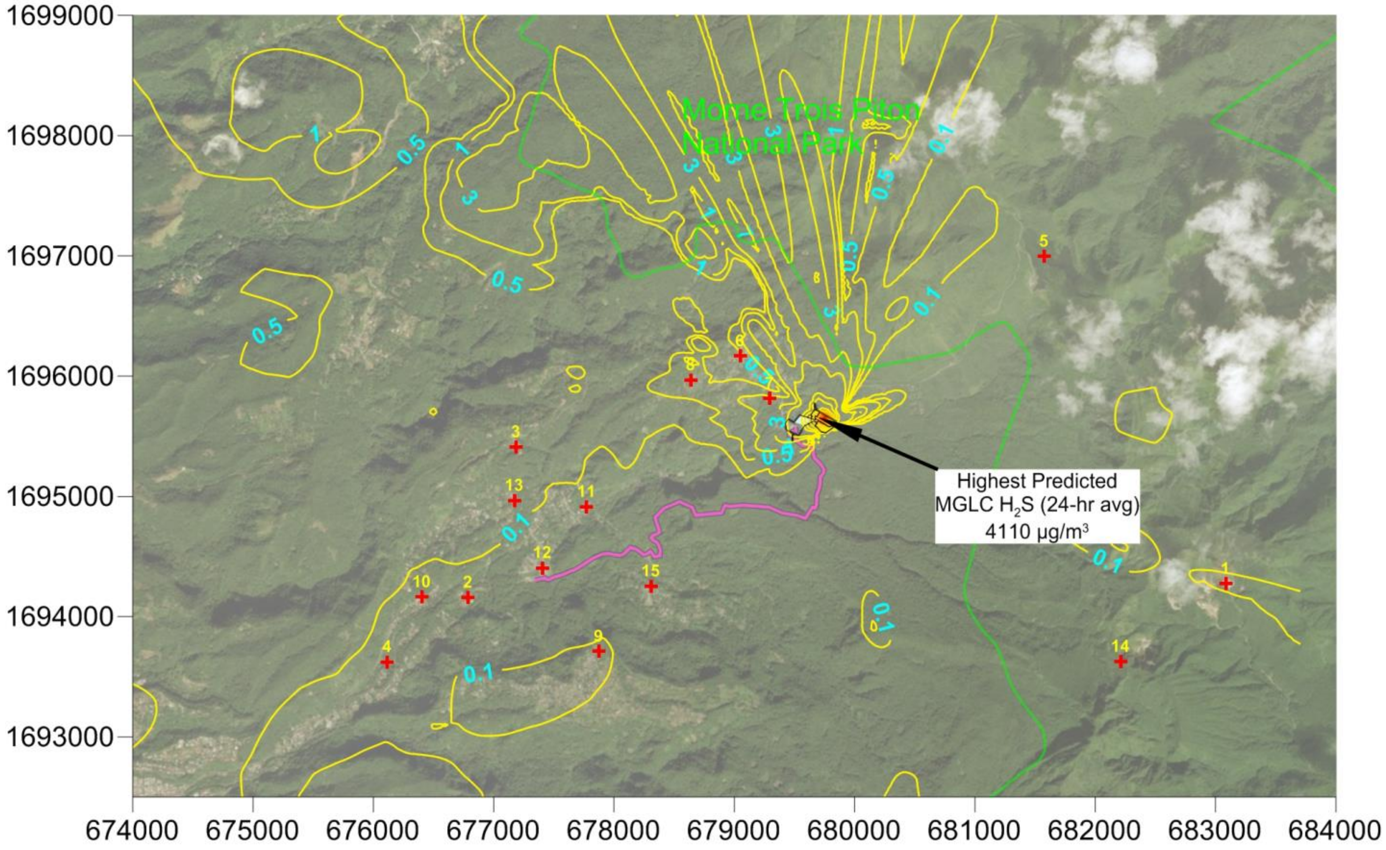


Figure 4.4 : Predicted MGLCs of 24-hour average H_2S (µg/m³) from 7 MWe Geothermal Plant Operation (ORC Option)

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 (µm³)	
		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/m³ 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/m³ 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.

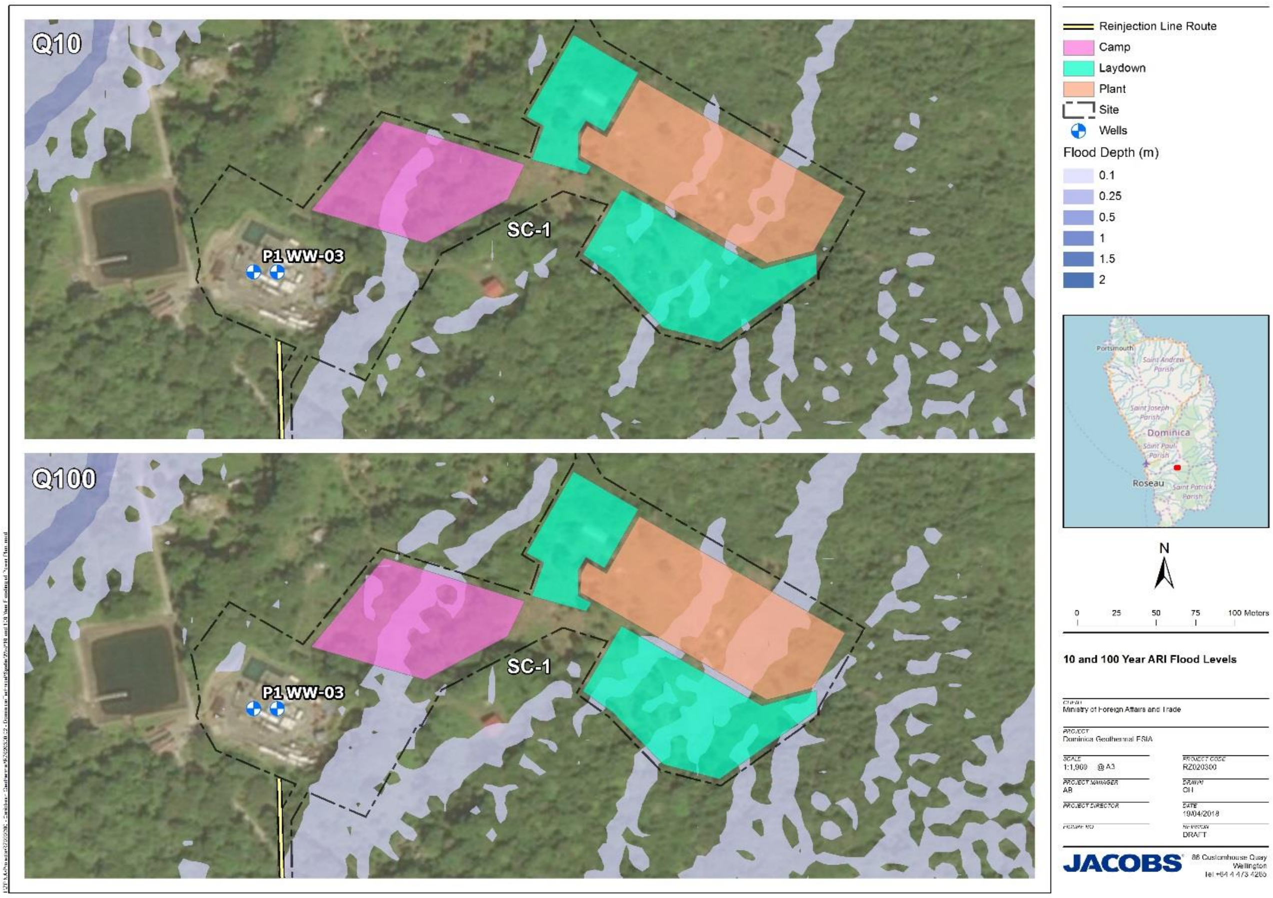


Figure 7.2 : 10 and 100 yr ARI flood water level maps

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.

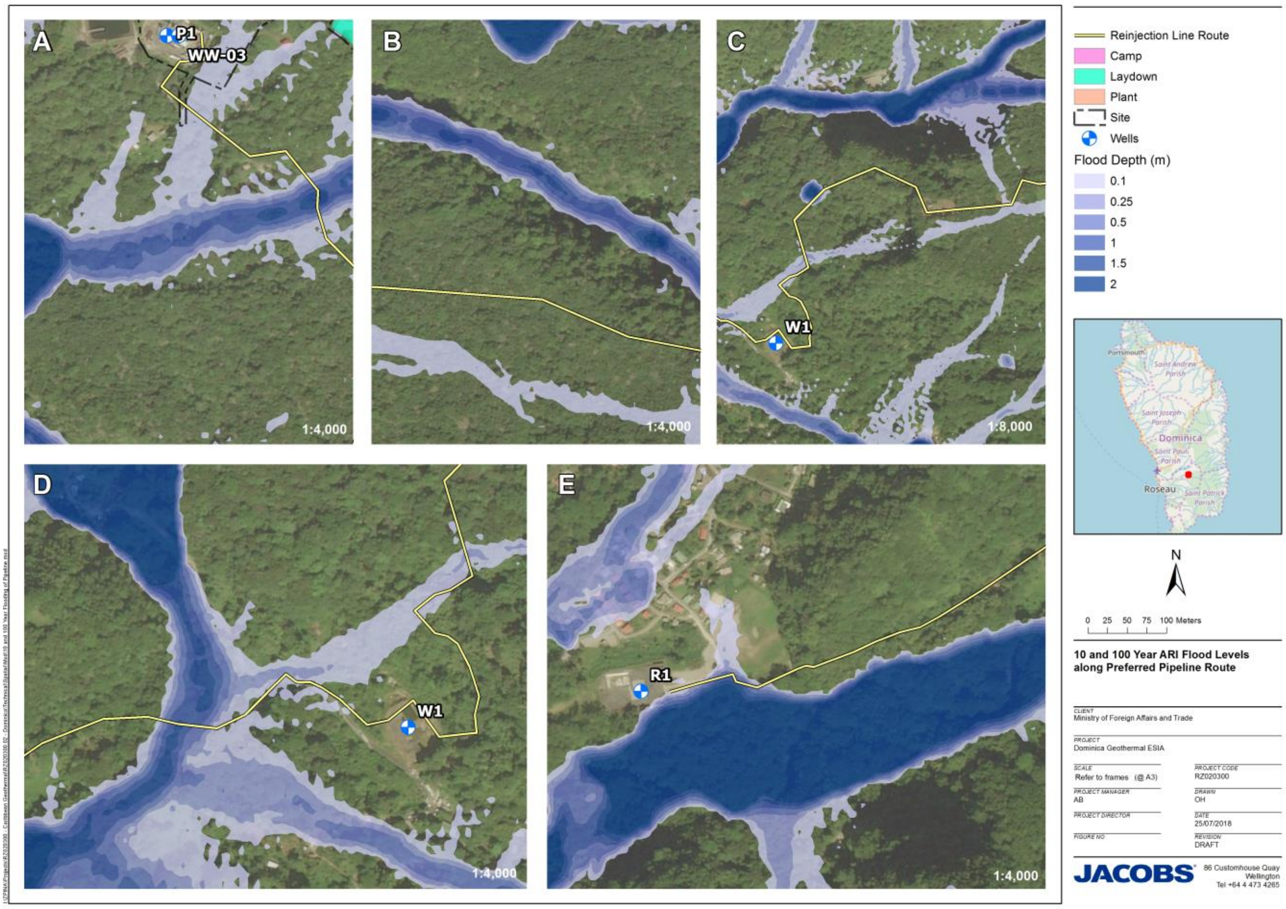


Figure 7.3 : 100 yr ARI 12 hour flood water levels and the at risk areas of preferred pipeline route.

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.

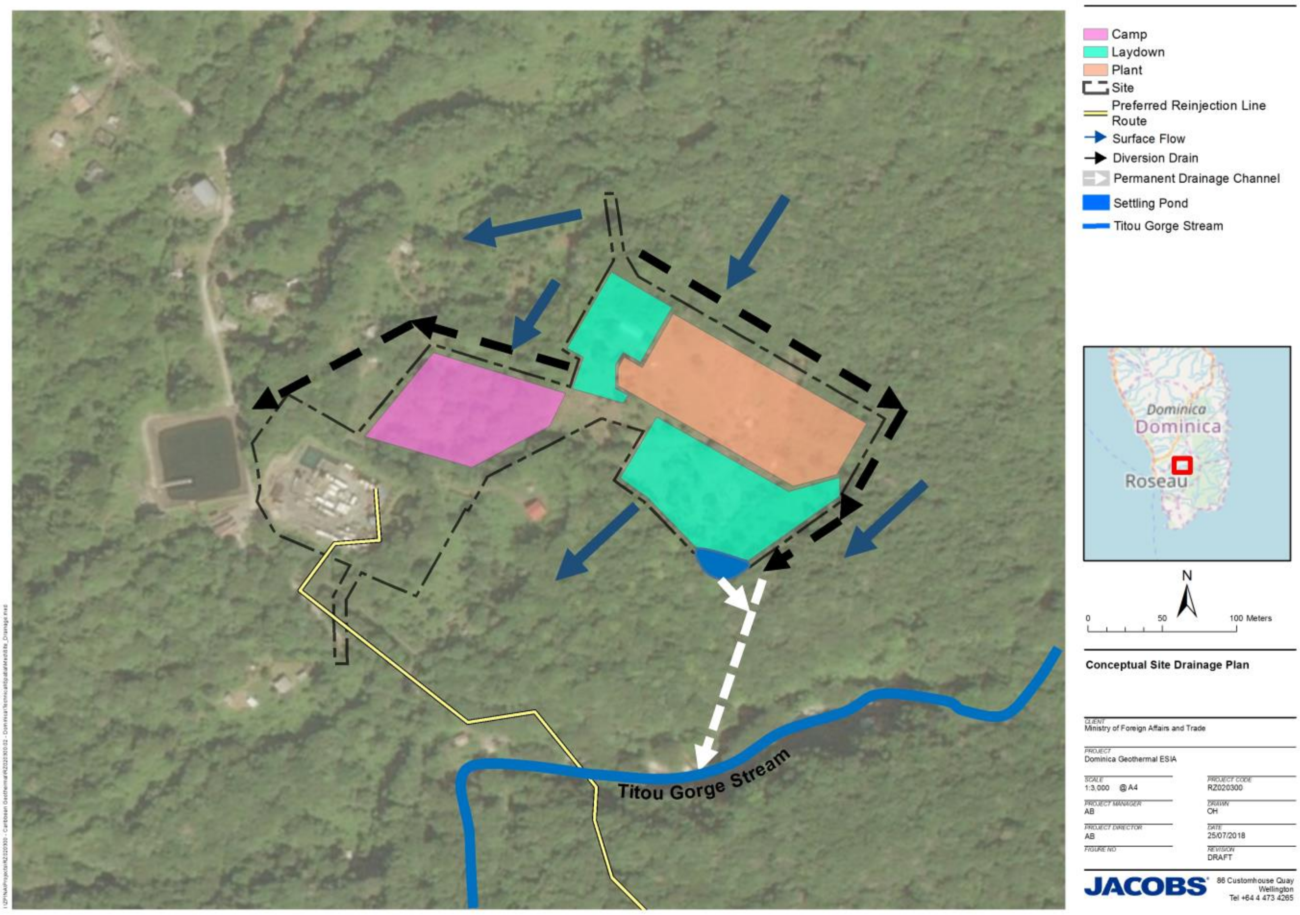


Figure 7.4 : Conceptual diversion drain and stormwater capture pond

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: • Clearing of site vegetation. • Bulk earthworks to level the site, form roads, create temporary construction facilities, formation of drains and create washroom amenities. • Foundations for pipeline and equipment. • 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: • Clearing of a 3-5 m wide corridor. • Provision of a gravelled road network to access the steam line and reinjection site. • Earthworks including excavation of foundation holes, drilling and vehicle tracking along route including stream crossing of vehicles during construction. • Construction of the pipeline over a number of waterbodies. • Concrete use for foundation construction. 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. Direct physical disturbance could also occur at stream crossing locations within the tributaries of the Roseau River and within the Blanc River.
Water supply: • 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: • 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: • 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: • 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: • Treatment by package plant then discharged to land via soakaway.	Limited potential discharge to the Roseau River.
Process wastewaters (condensate and brine): • These include condensate captured in sumps along pipeline route and on well pad. • Sumps will also be provided at the wellpads to store brine or condensate that is discharged accidentally. • 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: • 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: • 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: • Geothermal fluids which will be captured and re-injected. • Working fluid will be stored in bunded tanks. • 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.

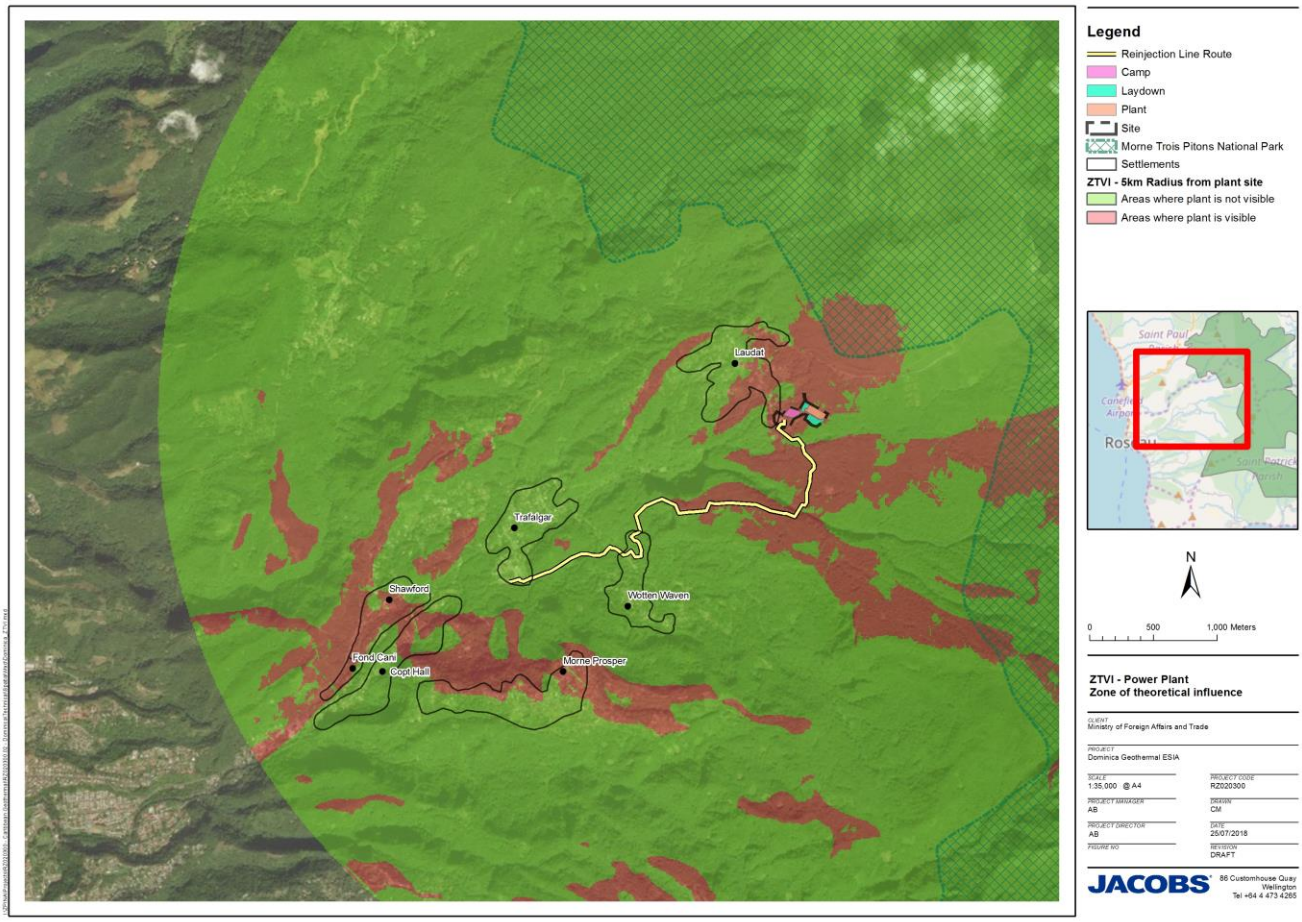


Figure 9.1 : The ZTI for the Power Plant

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 30t Excavator 40t Road dump truck 20t Vibratory roller	115
Plant construction	100T Mobile crane Gas cutter x2 Ratchet gun x2	109
Building construction	Concrete truck and pump Concrete drill Welder Nail gun Truck mounted crane	110

Construction stage	Noisiest equipment	Sound Power Level dB(A)
Reinjection pipeline		
Earthworks	Bobcat <10t Vibratory roller	111
Footings	Concrete truck and pump Concrete drill	109
Placement of pipe sections	100T Mobile crane Gas cutter Ratchet gun	107
Production / Reinjection well		
Earthworks	Bobcat <10t Vibratory roller	111
Finishing works	100T Mobile crane Gas cutter Ratchet gun	107
Suspension Bridge		
Earthworks	Bobcat <10t Vibratory roller	111
Footings	Concrete truck and pump Concrete drill	109
Placement of cables and platform	100T Mobile crane Gas cutter Ratchet gun	107
Tramway carpark		
Earthworks	15t Road grader 30t Excavator 40t Road dump truck 2 x 20t Vibratory roller	116
Asphalting	Asphalt paving machine 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 Zoos, botanical gardens Quiet areas for the preservation of habitat 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

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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)]*

[red] = Major Significance of Impact; [orange] = Moderate Significance of Impact; [yellow] = Minor Significance of Impact; [green] = 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)]*

[red] = Major Significance of Impact; [orange] = Moderate Significance of Impact; [yellow] = Minor Significance of Impact; [green] = 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. • Earthworks for the power plant site, laydown areas, reinjection route and creation of access tracks for the reinjection line. • Operation of construction plant. • Increased presence of vehicles. • Increased human presence. • Release of run-off or sediments during construction. • Accidental spillage of chemical or hydrocarbon loads. • 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. • 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. • Water abstraction – possible requirement to pump cold water from the Roseau River to increase well injection capacity. • Increased human presence. • Emissions to air of non-condensable gases. • 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. • Other routine maintenance works. • 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 • Dust • Night-time illumination of platforms	Air emissions and dust during construction have been modelled for receptor locations at and around the source points. 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. There is a small potential for cumulative impacts of SO_2 and particulate matter, however the effect would be highly localised. 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. 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 • Dust • Emissions to the air • Collision with animals	Effects from noise, vibration and dust would be as above, but not on a scale greater than negligible. 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 • 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. 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. 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 • 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. 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 • Noise • Vibration	In high concentrations hydrogen sulphide can result in necrosis and mortality. 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. 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. 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 unusal 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) • 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. 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. 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 • Dust • 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. Air emissions and dust during construction have been modelled for three points within the MTPNP: Boiling Lake, Valley of Desolation and Freshwater Lake. Maximum predicted concentrations of hydrogen sulphide (H_2S) decrease rapidly with distance from the power plant and adverse impacts are not expected. 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. There is a small potential for cumulative impacts of SO_2 and particulate matter, however the effect at the MTPNP would be negligible. 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. 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. 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 • Dust • Emissions to the air • Collision with animals	Effects would be as above, but not on a scale that would be noticeable at the MTPNP. 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. Air emissions and dust during construction have been modelled for three points within the MTPNP: Boiling Lake, Valley of Desolation and Freshwater Lake. 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 • Noise • Vibration	In high concentrations hydrogen sulphide can result in necrosis and mortality. Vibration, noise and lighting may affect fauna, resulting in stress, behavioural changes, reduced breeding success. 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 • 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. 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 • 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. 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. 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]. • Habitat cleared should be the minimum possible, with any way-leave area required of the minimum width necessary. • 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.	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. • 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. 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. • 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.	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: - Installation of pentane sensors and leak detectors; - Fire extinguishing controls - Induction and training; - Standard Operating Procedures; - Routine inspections; - Good record keeping; and - 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.

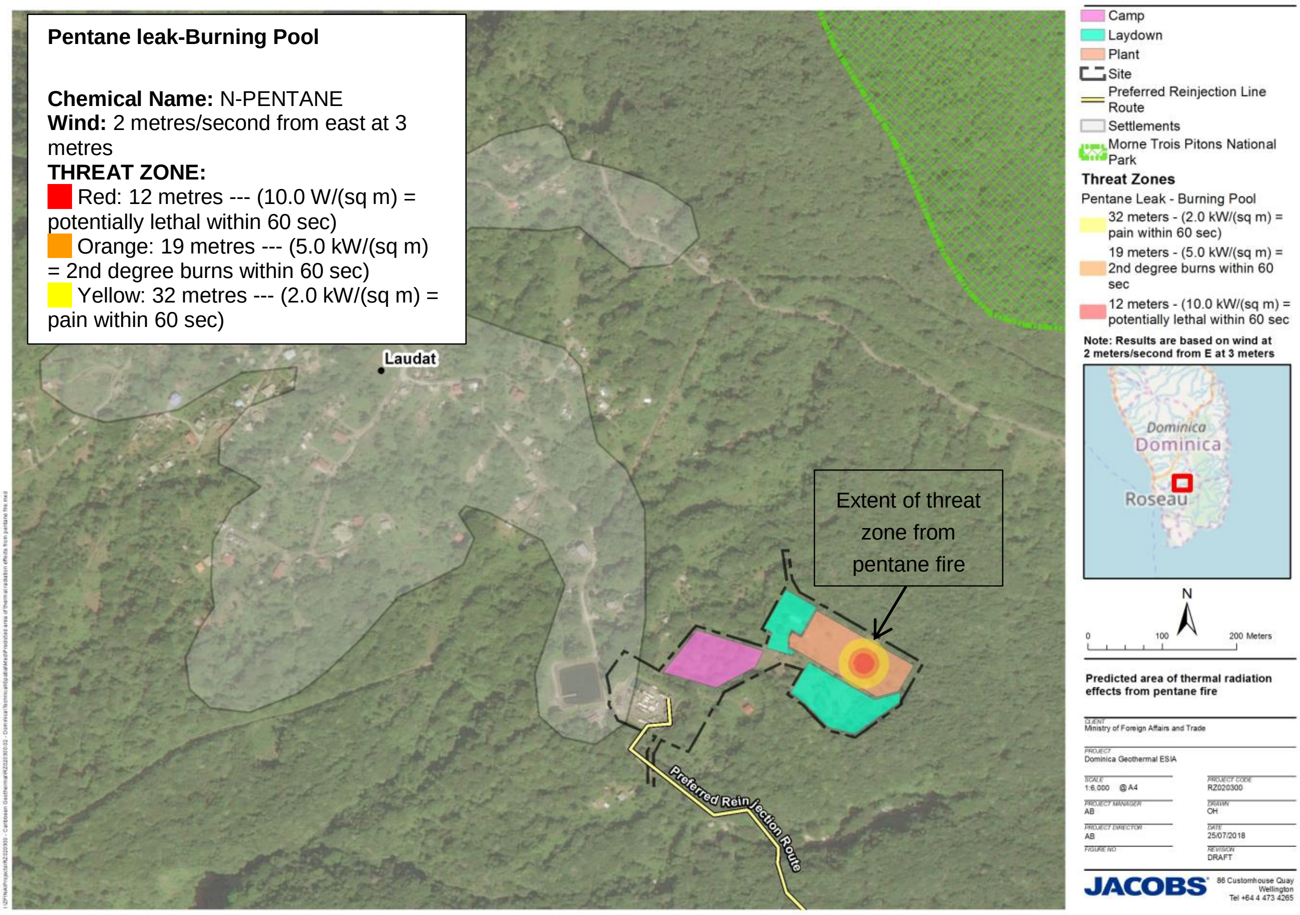

Figure 15.2 : Predicted area of thermal radiation effects from pentane fire

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.

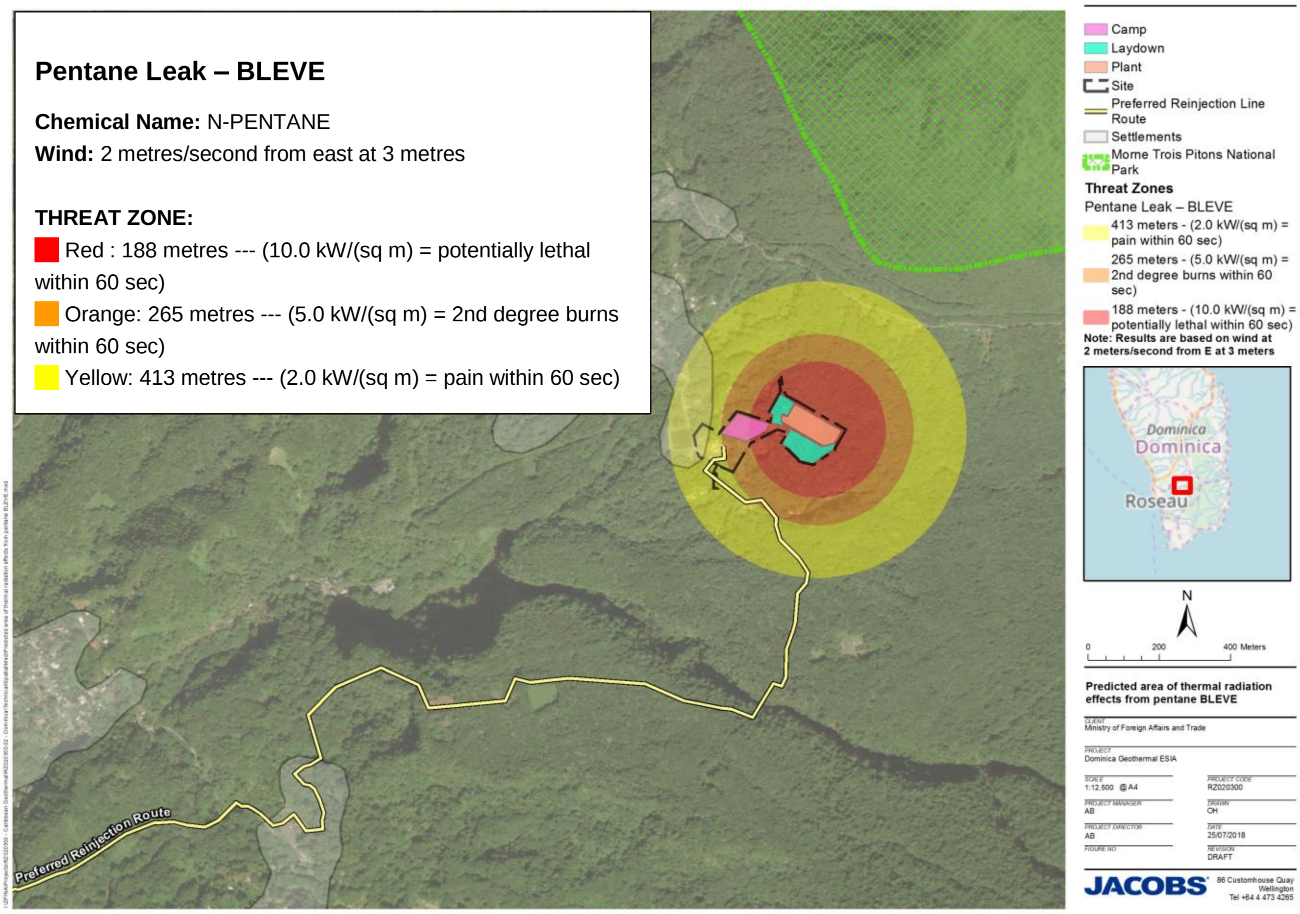

Figure 15.3 : Predicted area of thermal radiation effects from pentane BLEVE

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.

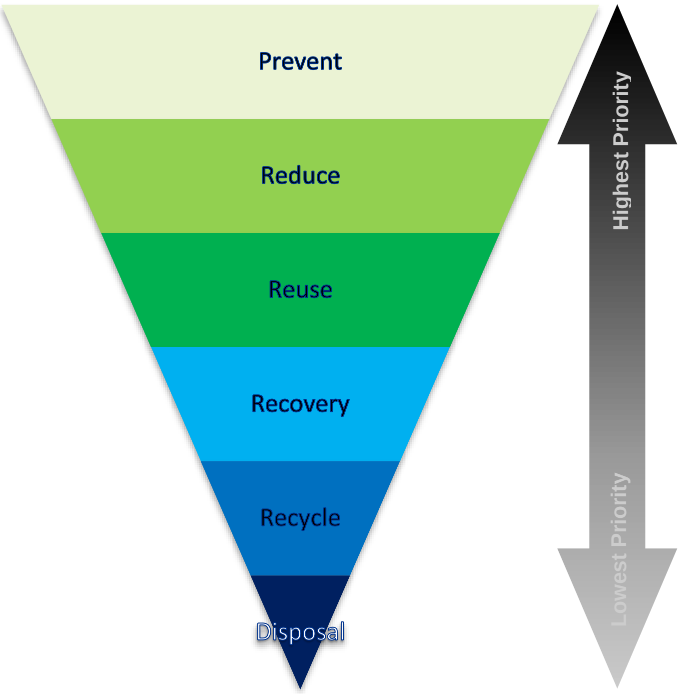

Figure 15.4 : The waste management hierarchy

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. 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. Generally made up of Inorganic substances: cement, broken rock plastic, metal, glass; fabrics, synthetic resins, earth, sand, cardboard, paper, inert and nontoxic waste. 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 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. 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. 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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