Dominica Geothermal Development - Environmental and Social Impact Assessment

NZ Ministry of Foreign Affairs & Trade

ESIA Volume 1: Introduction

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Dominica Geothermal Development – Environmental and Social Impact Assessment

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Revision	Date	Description	By	Review	Approved
A	September 2017	Draft Issue to MFAT for review	P Gabriel / A Kubale	B Clarke	S Liddell
B	March 2018	Revisions to Report based on Post-Hurricane Maria Scenario	P Gabriel	B Clarke	B Clarke
V1	May 2018	Final Issue Addressing World Bank Comments	P Gabriel	B Clarke	B Clarke
V2	July 2018	Further revision following World Bank RSA Comments – Issue for Disclosure	B Clarke	A Brookes	A Brookes

Contents

Glossary

Term	Description
Baseload power plant	Electricity-generating units that are operated to meet the minimum load on the electricity supply system.
Binary-cycle plant	A geothermal electricity generating plant employing a closed-loop heat exchange system in which the heat of the geothermal fluid (the "primary fluid") is transferred to a lower-boiling-point fluid (the "secondary" or "working" fluid), which is thereby vaporised and used to drive a turbine/generator set.
Brine	A geothermal solution containing appreciable amounts of sodium chloride and/or other salts.
Commercial Operation Date (COD)	The date after which all testing and commissioning has been completed and the developer can start producing electricity for sale.
Condensate	Liquid water formed by condensation of steam.
Condenser	Equipment that condenses turbine exhaust steam into condensate.
Cooling tower	A structure in which heat is removed from hot condensate through heat exchange with air.
Drilling	Boring into the Earth to access geothermal resources, usually with oil and gas drilling equipment that has been modified to meet geothermal requirements.
Dry steam	Superheated steam without a water phase.
Efficiency	The ratio of the useful energy output of a machine or other energy-converting plant to the energy input. Technology with a higher efficiency will require less energy to do the same amount of work.
Emission	The release or discharge of a substance into the environment; generally, refers to the release of gases or particulates into the air.
Enthalpy	A measurement of energy in a thermodynamic system. It is the thermodynamic quantity equivalent to the total heat content of a system. It is equal to the internal energy of the system plus the product of pressure and volume.
Fault	A fracture or fracture zone in the Earth's crust along which slippage of adjacent rocks has occurred.
Flash plant	Pressure vessels designed to effectively separate flash steam from the liquid phase.
Flash steam / Flashing	Steam produced when the pressure on a geothermal liquid is reduced. Also called flashing.
Geothermal energy	The Earth's interior heat made available by extraction of geothermal fluids.
Geothermal power plant	A facility which uses geothermal steam or heat to drive turbine-generators to produce electricity. Three different types make use of the various temperature ranges of geothermal resources: dry steam, flash and binary.
Geothermal reserves	Energy from a geothermal resource that is commercially recoverable now
Geothermal reservoir	A large volume of underground hot water and steam in porous and fractured hot rock. The hot water in geothermal reservoirs occupies only 2 to 5% of the volume of rock, but if the reservoir is large enough and hot enough, it can be a powerful source of energy. Geothermal reservoirs are sometimes overlain by a layer of impermeable rock. While geothermal reservoirs usually have surface manifestations such as hot springs or fumaroles, some do not.
Geothermal resources	A resource of geothermal nature which requires further work to be classified as a geothermal reserve.

Term	Description
Geothermal well	Geothermal production and injection wells are constructed of pipes layered inside one another and cemented into the earth and to each other. This protects any shallow drinking water aquifers from mixing with deeper geothermal water.
Injection	The process of returning spent geothermal fluids to the subsurface; also referred to as reinjection.
Injection well	A well through which geothermal water is returned to an underground reservoir after use.
Kilowatt (kW)	One thousand watts of electricity (power).
Kilowatt hour (kWh)	One thousand watthours (energy).
Megawatt (MW)	A unit of power, equal to a thousand kilowatts (kW) or one million watts(W). The watt is a unit of power (energy/time), the rate energy is consumed or converted to electricity. Assessment of the energy in geothermal systems is commonly in terms of equivalent electrical power or MW, which takes into account the efficiency of conversion.
Megawatts under wellhead	A technical measure of the supply of geothermal fluids available at the well head valve, presented in megawatts of electrical energy as proven through testing.
Morne Trois Pitons National Park (MTPNP) World Heritage Site	A World Heritage Site is a natural or man-made site or structure recognised as being of outstanding international importance by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) and therefore designated as a site deserving of protection under international treaties.
Operations and maintenance (O&M) cost	Operating expenses are associated with operating a facility (e.g. engineering costs). Maintenance expenses are that portion of expenses consisting of labour, materials, and other direct and indirect expenses incurred for preserving the operating efficiency or physical condition of utility plants that are used for power production, transmission, and distribution of energy.
Permeability	The capacity of a substance (such as rock) to transmit a fluid. The degree of permeability depends on the number, size, and shape of the pores and/or fractures in the rock and their interconnections. It is measured by the time it takes a fluid of standard viscosity to move a given distance.
Production well	A well through which geothermal water, brine and steam is extracted from an underground reservoir to use in the generation of electricity.
Proven geothermal reserves	Defined as the electricity that can be generated and sold with reasonable certainty over the project life. Commonly used units are Mega Watt-hour.
Separator	A pressure vessel used to separate water and steam, normally by centrifugal action.
Slim hole	A geothermal exploration well which is drilled at a smaller diameter than a standard production well.
Steam	The vapour form of water that develops when water boils.
Subsidence	A sinking of an area of the Earth's crust due to fluid withdrawal and pressure decline.
Surface Exploration	Scientific activities to investigate the geothermal reservoir using non-invasive techniques. Typically surface exploration will include geology, geochemistry, geophysics and aerial surveys.
Transmission line	Structures and conductors that carry bulk supplies of electrical energy from power-generating units.
Turbine	A machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction, or a mixture of the two.
Well logging	Assessing the geologic, engineering, and physical properties and characteristics of geothermal reservoirs with instruments placed in the wellbore.
Wellhead pressure	A measure of the pressure of geothermal fluids being produced by the geothermal reservoir as measured at the valve opening from the wellhead.

List of Abbreviations

Acronym	Meaning
ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie
aMSL	Above Mean Sea Level
CITES	Convention on the International Trade in Endangered Species of Wild Fauna and Flora
DFID	United Kingdom Department for International Development
DGDC	Dominica Geothermal Development Company Limited
DOMLEC	Dominica Electricity Services Limited
DOWASCO	Dominica Water and Sewerage Company Limited
EDV	Emergency Dump Valves
EHS	Environmental Health and Safety
EIA	Environmental Impact Assessment
EP	Equator Principles III (2013)
EPC	Engineer, Procure and Construct
ESIA	Environmental and Social Impact Assessment
ESMP	Environmental and Social Management Plan
ESMS	Environmental and Social Management System
FCS	Fond Cole Power Station
FDI	Foreign Direct Investment
GoCD	Government of the Commonwealth of Dominica
GRG	Geothermal Resource Group
IFC	International Finance Corporation
IRC	Independent Regulatory Commission
ÍSOR	Íslenskar Orkurannsóknir
kV	Kilovolt
kW	Kilowatt
LHS	Laudat Hydro Station
MW	Mega Watt
NCG	Non-Condensable Gas
NDT	Non-Destructive Testing
NTS	Non-Technical Summary
OECS	Organisation of Eastern Caribbean States
ORC	Organic Rankine Cycle
PCV	Pressure Control Valves
PHS	Padu Hydro Station
PS	Performance Standard
RPS	Regional Partnership Strategy
SEP	Stakeholder Engagement Plan
SSI	Silica Saturation Index

Acronym	Meaning
THS	Trafalgar Hydro Station
ToR	Terms of Reference
WBG	World Bank Group
WHP	Well Head Pressure

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs New Zealand Limited ("Jacobs") is to describe the Environmental and Social Impact Assessment (ESIA) for the Dominica Geothermal Power Project development in accordance with the scope of services set out in the contract between Jacobs and the New Zealand Ministry of Foreign Affairs and Trade (the Client). That scope of services, as described in this report, was developed with the Client, the Government of the Commonwealth of Dominica (GoCD) and the Developer (Dominica Geothermal Development Company (DGDC) established and owned by the GoCD).

Jacobs has been contracted by the Client to undertake the conceptual design and overall project definition through their engineering team. In preparing this ESIA report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided. Except as otherwise stated in the ESIA report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced as noted in the ESIA volumes and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of, Jacobs' Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party. However, Jacobs may be able to extend reliance on this report to a third party provided that the third party enters into a third party reliance agreement with Jacobs on Jacobs' terms.

1. Introduction

1.1 Purpose

This Environmental and Social Impact Assessment (ESIA) has been prepared, in accordance with local legislation and international lending institution safeguards, to assess the environmental and social impacts and risks of the Dominica Geothermal Power Project Development (referred to hereafter as the ‘Project’) located in the Roseau Valley, Dominica. The Project comprises the construction, completion, testing, commissioning, ownership and operation of geothermal wells, steam gathering and reinjection system, power plant with capacity of 7 MW and connection to electrical grid and associated infrastructure.

1.2 Project Background

1.2.1 Project Progress to Date

The Commonwealth of Dominica is a small island developing state in the Caribbean Sea with a population of approximately 71,293 people (pre-Hurricane Maria 2011 census) and a land area of approximately 750 km^2. About 60% of the land is classified as a World Heritage site by UNESCO, due to its rich biodiversity. It is located near the centre of a string of islands known as the Lesser Antilles, between the neighbouring French territories of Martinique and Guadeloupe. The capital Roseau is located to the south-west of the island and has a population of around 15,000 people (Figure 1.1).

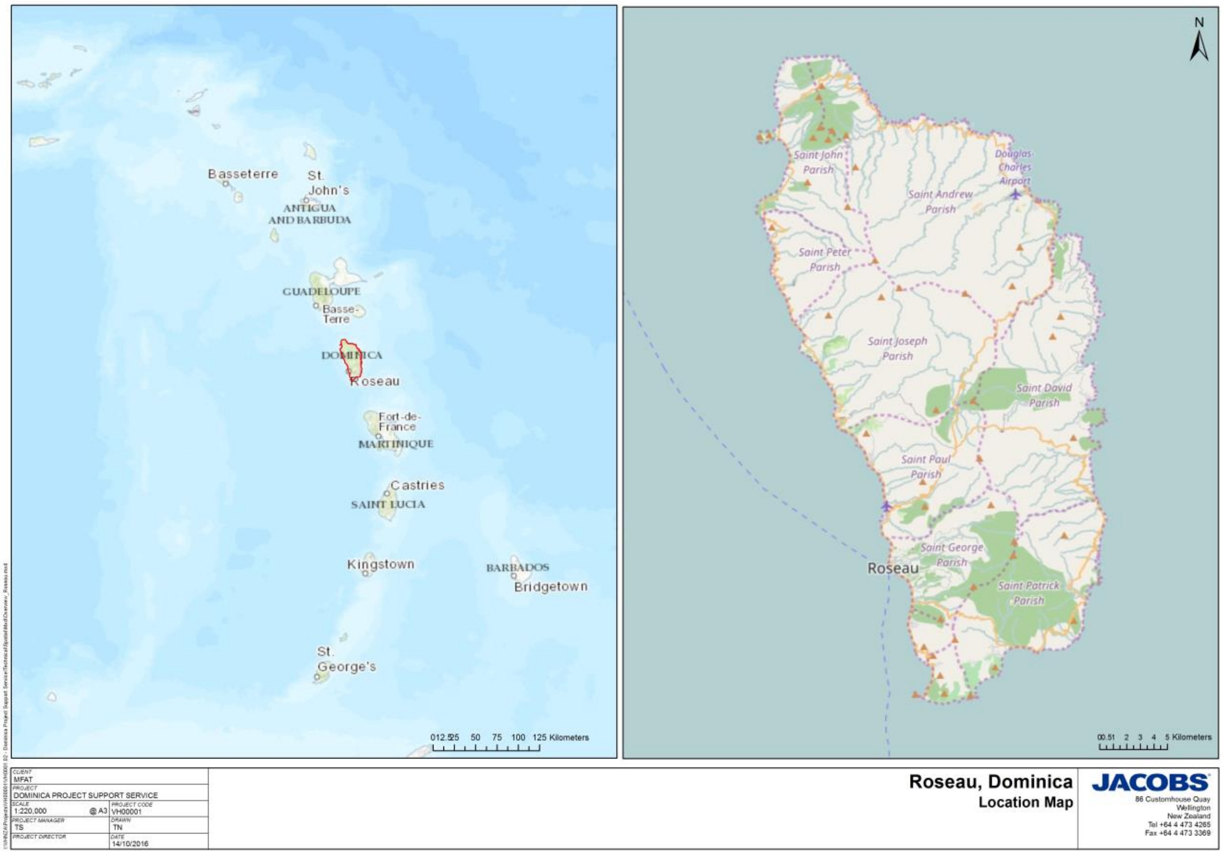

Figure 1.1 : Dominica’s location in the Caribbean

As with many other island nations, Dominica's primary source of electricity production is from diesel generation, which exposes the country's economy to uncertainty in regard to the cost and supply of diesel imports. Changing the power generation mix and reducing the cost and volatility of electricity prices have become development priorities for Dominica. Being a relatively young volcanic island, Dominica has significant geothermal resource potential. Therefore, since 2006 the Government of the Commonwealth of Dominica (GoCD) has pursued an exploration programme to evaluate the viability of geothermal resource in the Roseau Valley (Figure 1.2).

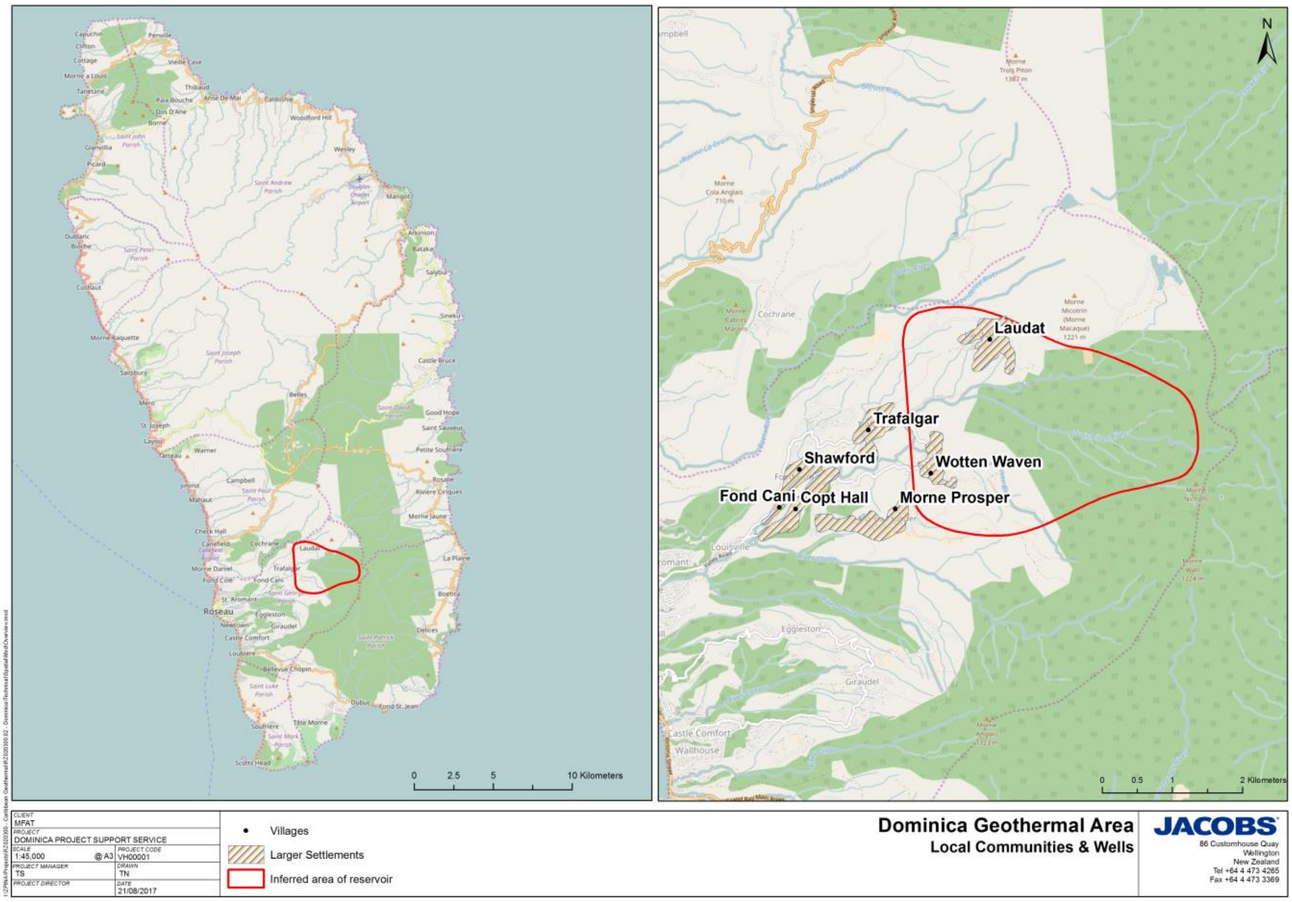

Figure 1.2 : Location of Roseau Valley and Inferred Area of Geothermal Reservoir (Site of proposed Geothermal Power Plant)

The exploration programme has been conducted in a phased manner over the course of approximately 10 years and is summarised in Table 1.1.

Table 1.1 : The phases of the Dominica geothermal exploration programme

No.	Phase	Activities	Status
1	Preparation	Project establishment, geoscientific investigations	Complete
2	Exploration	Exploration drilling of three slim hole wells and resource assessment	Complete
3	Production & Testing	Production drilling and testing of one full size well and drilling of one reinjection well	Complete
4	Planning / Construction	Present phase comprising power plant and reinjection pipeline construction and start-up	Ongoing

The geothermal project started as part of the European Cooperation Programme INTERREG III-B Caribbean space, in partnership with the Regional Councils of Guadeloupe and Martinique, the ‘Agence de l’Environnement et de la Maîtrise de l’Energie’ (ADEME), the ‘Bureau de Recherches Géologiques et Minières’ (BRGM) and the French company ‘CFG Services’. The geothermal study area of interest was identified in June 2008 by BRGM after evaluation of resources and exploratory drilling programme. Focused on the Roseau Valley geothermal field, and located about 8 km east north-east of the Capital of Roseau, it includes part of the high temperature reservoir (210-230°C) (Figure 1.2).

To prove the existence of a viable geothermal resource, an exploratory phase was launched between 2011 and 2012 and involved the drilling of three test (slim) wells in the villages of Wotten Waven (well site WW-01) and Laudat (well sites WW-02 and WW-03). The final drilling depths were between 1200 m and 1613 m and confirmed the presence of a geothermal resource with a 50% probability of having sufficient capacity for approximately 65 MW of power generation.

The next phase of the project commenced in 2013, included drilling and testing of two full size production wells, with a view to developing a 10-15 MW small geothermal power plant. It comprised the installation of a production platform, drilling and testing a production well in Laudat (WW-P1) and a re-injection well in Trafalgar (WW-R1). The drilling of these two full-size wells, with a depth comprised between 1501 m and 1915 m, was completed in 2014.

The GoCD is now proceeding with the planning and construction phase of the Project, establishing the Dominica Geothermal Development Company Ltd (DGDC), which is tasked with developing and operating a 7 MW geothermal power plant. DGDC will sell electricity to DOMLEC under the regulatory framework established through the Electricity Supply Act 2006. DGDC will operate as a private company under the laws of the Commonwealth of Dominica.

Financing for the Project has been arranged by the World Bank and include: $17.2 million IDA credit (principal source of funding); $10 million from CTF including a $1 million grant and $9 million contingent finance; and grants from DFID ($10 million) and SIDS DOCK ($2 million), both channelled through the World Bank. New Zealand has provided a parallel ‘in-kind’ grant covering project preparation costs and sponsoring the position of DGDC Project Manager.

1.2.2 Previous Environmental and Social Work Completed

The Project benefits from having a wealth of environmental studies data collected for environmental assessments for exploration and drilling phases. To date the following environmental and social studies have been completed:

- Caraïbes Environnement Développement & Coll (2009) Regulatory Impact Assessment on the Initial Environment - Environmental Feasibility Study;
- Caraïbes Environnement Développement & Coll (2011) Stage 1: Exploration Drilling Process – Environmental Impact Assessment; and
- Caraïbes Environnement Développement & Coll (2013) Stage 2: Preliminary Environmental Impact Assessment of Geothermal Production and Re-Injection Drilling Wells in Dominica – Environmental Impact Assessment.

To support the preparation of an ESIA for the Project, baseline surveys of the social, physical and biological environment within the Roseau Valley were completed between October 2013 and April 2015. These were summarised in the following reports (collectively referred to as the ‘Baseline Study’):

- Caraïbes Environnement Développement & Coll (2015a) Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production. Final report, May 2015. Section 3 Biodiversity / Terrestrial Flora and Fauna; and
- Caraïbes Environnement Développement & Coll (2015b) Initial environmental status of the Roseau Valley in Dominica, planned for development of geothermal electricity production. Final summary report.

As part of the work undertaken by Jacobs in the ESIA Terms of Reference (TOR), a review of these previous studies was carried out (provided for reference in Appendix C). Further details of these studies are provided in Volume 2 – Environmental Impact Assessment.

1.2.3 Hurricane Maria

The ESIA was originally finalised and submitted to the World Bank for comment in early September 2017. However, on 18 September 2017 Hurricane Maria (a Category 5 Hurricane) made landfall in Dominica. The hurricane devastated the island and fundamentally changed the environmental and social baseline (Figure 1.3). The assessment of impacts of the Project in the draft ESIA (submitted September 2017), were originally based on the environmental and social baseline in the Roseau Valley prior to Hurricane Maria. As such, a revision of the ESIA in the 'Post-Maria' scenario was required and was undertaken in March 2018.

Environmental Indicators

Some of the environmental indicators will be in a more degraded state than the 'Pre-Maria' situation. This may result in the impacts of the geothermal plant changing from that initially assessed (i.e. some impacts will be reduced and others increased). It was determined to be unrealistic to attempt collect detailed new environmental baseline data and re-evaluate the impacts. The situation in Dominica remains dynamic and trying to evaluate the impact of the Project against the rapidly occurring natural changes is unlikely to provide a sufficiently robust basis to evaluate which mitigation to implement or its effectiveness. In many cases, the logical outcome of this approach would be that the Project will improve the natural environment and as such no mitigations are required.

As part of the ESIA, additional desk and site based activities were undertaken post-Hurriane Maria. These are referred to in ESIA Volume 2: EIA.

Social Indicators

As a result of Hurricane Maria, the social situation has changed substantially with homes being lost, livelihoods being destroyed and many persons lacking access to basic services. The number of vulnerable people will have increased and basic priorities will have changed. It is also possible that the people of the Roseau Valley would want to see the Project now as part of the overall redevelopment of the Roseau Valley. Interested parties in the Project will need to think carefully about the messaging, involvement of the community, sharing benefits and ways to mitigate potential grievances.

As part of the ESIA, additional community consultation activities were undertaken post-Hurriane Maria, including Focused Discussion Groups (FDGs), census surveys for landowners and three public meetings to disclose the ESIA to affected communities in July 2018. These are referred to in ESIA Volume 3: SIA, and in the Stakeholder Engagement Plan (SEP), located in ESIA Volume 5: Technical Appendices, and Abbreviated Resettlement Action Plan (ARAP).

Figure 1.3 : The devastation caused by Hurricane Maria – Roseau Valley (taken in November 2017)

1.2.4 Updates to Project Design

Since the ESIA was originally completed in early September 2017, certain sections of the preferred reinjection pipeline route experienced extensive landslides as a result of Hurricane Maria and as a result the route was resurveyed in June 2018 and some adjustments to the route alignment made which is included in the ESIA However, the final alignment of the reinjection pipeline can only be determined following preliminary engineering design and geotechnical surveys prior to construction commencing. Further work is required to establish the feasibility of river crossings, alignment based on local topographical features, consideration of environmental impacts and alignment based on land boundaries. This will be completed in close co-ordination between environmental and social scientists and the process engineering, mechanical, geotechnical and civil engineering design disciplines, along with the Government, Land and Survey Division.

1.3 The Developer

1.3.1 Dominica Geothermal Development Company Limited

The Project will be developed by the DGDC, which was legally established by the GoCD in the last quarter of 2016 and became operational in June 2017. The Government's role is as equity provider and lender to the company. The GoCD has all shareholder rights with Directors appointed and replaceable by the shareholder. Initially, four Directors have been appointed, including an Executive Chairman.

1.3.2 Roles and Responsibilities

DGDC has five permanent staff members, a Board and a designated Project Manager. The company will operate under the guidance of technical, legal, strategic and commercial advisors. These roles are summarised below in Figure 1.4 (correct as of August 2017).

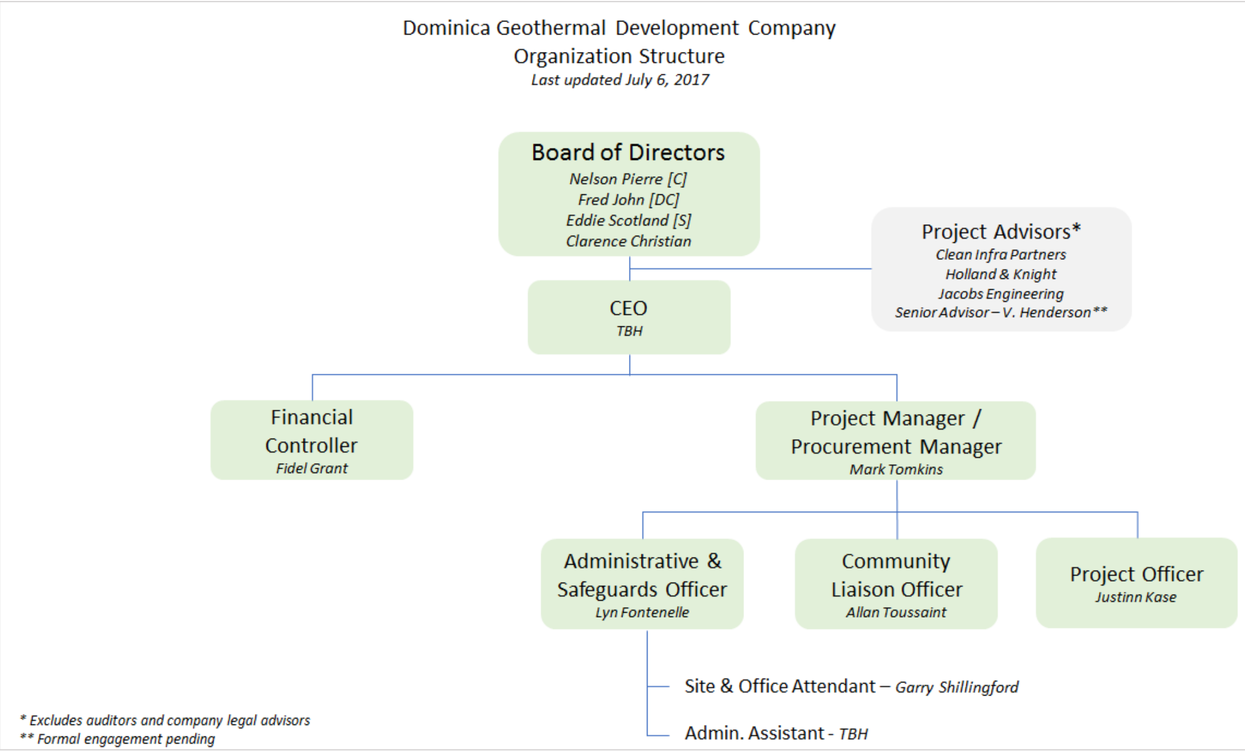

Figure 1.4 : Geothermal Project Governance

The Government of New Zealand is funding a Project Manager position for a period of two (plus one) years. The Project Manager will be based in Dominica and perform the following functions:

- Oversee the technical scope and engineering design of project, ensuring that the feasibility of the scope and structure of the project meets good industry practice and international standards;
- Oversee the overall construction of the power plant and its subsequent commissioning;
- Ensure the project meets the necessary environmental and social requirements and oversee the preparation of an ESIA;
- Responsible for overseeing the successful procurement of all goods, services, and skills necessary for the construction and operation of the geothermal power plant;
- Support finalisation of the financing arrangements, including responding to and meeting lender technical due diligence requirements in an efficient and timely manner;
- Work with advisors to finalise all off-take arrangements with DOMLEC; and
- Secure the services of and overseeing the work of various consultants.

DGDC will appoint a technical advisor acting as an Owner's Engineer who will be responsible for a wide range of services pre and post Financial Close. To date geothermal project development technical advisory services have been provided by Jacobs New Zealand Ltd (Jacobs), who were appointed by the Government of New Zealand following a competitive bidding process to deliver their Caribbean Geothermal Technical Assistance

Programme. At the time of writing Jacobs are currently in the final steps of formalising a role as Owner's Engineer to DGDC.

Clean Infra Partners has been appointed by DGDC as a business advisor to conduct Power Purchase Agreements (PPA) negotiations with DOMLEC, undertake financial analysis, and support development of the Financing Plan and business plan.

Holland & Knight has been retained as legal counsel to DGDC with services to include preparation and review of the Geothermal Concession Agreement, Power Purchase Agreement, EPC Contract, Operations & Maintenance contracts and financing agreements.

1.4 Structure of ESIA

The ESIA is structured into a Non-Technical Summary (NTS) and five Volumes, as set out in Table 1.2 below.

Table 1.2 : Structure of the ESIA

Non-Technical Summary		
Volume 1: Introduction	Introduction	A brief description of the Project, the location and the environmental setting
	Legal and Regulatory Framework	• Environmental law • Permits/Licences • Other relevant regulations and law
	Project Overview	• Project background • Project land requirements • Project schedule • Description of construction activities
	Project Justification and Assessment of Alternatives	• Project justification and site selection • Assessments of alternatives including the 'do-nothing' scenario
Volume 2 : Environmental Impact Assessment	Introduction	Overview
	Impact Assessment Methodology	• Baseline Environmental Conditions Previous Studies • Spatial and Temporary Scope • Impact Assessment Methodology • Impact Identification • Cumulative Impacts
	Environmental Impact Assessment	Environmental baseline for the following topics: • Climate • Air Quality • Noise • Natural Hazards • Geothermal Resource • Water Quality and Freshwater Ecology • Landscape and Visual • Terrestrial Ecology • MTPNP World Heritage Site • Soils, Geology and Groundwater • Greenhouse Gas Emissions • Hazardous Substances and Waste • Traffic and Access

		Each of the topics will contain the following: • Assessment of Impacts • Mitigation and Monitoring measures • Assessment of Residual Impacts
		Occupational Health and Safety & Working Conditions
		Cumulative Impacts
		Summary of Environmental Impacts
Volume 3 : Social Impact Assessment	Introduction	Overview
	Legal and Regulatory Framework	• National and International Requirements
	Impact Assessment Methodology	• Data sources • Spatial and Temporary Scope • Impact Assessment Methodology
	Social Impact Assessment	Social baseline for the following topics: • Demographic Overview • Ethnicity and Culture • Religion • Gender • Indigenous People • Ecosystem Services • Economic Profile • Educational Profile • Land Use and Tenure • Poverty, Deprivation and Vulnerable Groups
		Stakeholder Engagement
		Impact Assessment for the following: • Employment • Land Acquisition, Physical Displacement, and Resettlement Impacts • Cultural Heritage • Community Health, Safety and Security Impacts • Cumulative Impacts
		Mitigation, Enhancement Measures and Residual Impacts
		Assessment of Residual Impacts
Volume 4 : ESMP, ESMS and Compliance Assessment	Environmental and Social Management Plan (ESMP)	• Construction Mitigation and Monitoring • Operation Mitigation and Monitoring
	Framework Environmental and Social Management System (ESMS)	• Structure of Framework ESMS • Alignment with World Bank Performance Standards • Policies • Roles and Responsibilities • Legal and Other Requirements • Identification of Risks and Impacts

		• Management Programmes • Monitoring and Review • Stakeholder Engagement • Training • Administration
	Compliance Assessment	• Compliance with World Bank Performance Standards
Volume 5: Technical Appendices	Various Technical Appendices	• WB Performance Standards • Technical Report – Detailed Process Description • ESIA Terms of Reference • Biodiversity Survey Terms of Reference • Technical Report – Air Quality Impact Assessment • Technical Report – Noise Impact Assessment • Technical Report – Morne Trois Pitons National Park Impact Assessment • Technical Report – Terrestrial Ecology Impact Assessment • Occupational Health and Safety & Working Conditions • Stakeholder Engagement – Meeting Minutes • World Bank Performance Standard 5 • Stakeholder Engagement Plan including Community Grievance Mechanism • *Caraïbes Environnement Développement & Coll 2015 – Final Summary Report
Abbreviated Resettlement Action Plan (ARAP)	Abbreviated Resettlement Action Plan (ARAP)	• Socio-Economic Background of Affected Community and PAP Census • Identification of Project Impacts • Eligibility and Entitlements • Valuation and Compensation • Vulnerability Assistance • Stakeholder Engagement • Resettlement Sites • Roles and Responsibilities • Grievance Management • Monitoring and Evaluation • Budget and Schedule

2. Policy, Legal and Administrative Framework

2.1 Introduction

This ESIA has been prepared to meet the requirements of the World Bank Performance Standards for Private Sector Activities, OP 4.03 (2013), World Bank General (WBG) Environmental, Health and Safety (EHS) Guidelines (2013) and other associated guidelines, as well as the laws of Dominica.

Project financiers who have adopted the World Bank Guidelines commit to ensuring that projects are developed in a manner that is socially responsible and reflect sound environmental management practices.

DGDC is also required to obtain approvals in accordance with local, regional and national regulations. This chapter also provides an overview of the local regulatory framework for these Dominican approvals. DGDC is obtaining the requisite approvals under local regulations in parallel to the preparation of this ESIA. Both the requisite Dominican approvals and ESIA are based on the same underlying technical data.

2.2 Dominica National Legislation

2.2.1 Environmental Impact Assessment

With sole responsibility for physical development of land in Dominica, the GoCD manages physical development through the Physical Planning Act (2002). The Physical Planning Act (2002), makes provision for the orderly and progressive development of land in both urban and rural areas, and to preserve and improve the amenities thereof, for the grant of permission to develop land and for other powers of control over the use of land; for the regulation of the construction of buildings and regulated matters; to confer additional powers in respect of the land acquisitions and development of land for planning purposes; and for other matters connected therewith. In accordance with this Act, development permission is required before the construction of the Project may commence.

Applications for development permission must be submitted to the Physical Planning Department within the Ministry of Agriculture and Environmental Protection along with an Environmental Impact Assessment (Clause 20(1)(b)). As defined in the Act an Environmental Impact Assessment (EIA) requires an Environmental appraisal that identifies positive and negative impacts on the site, the immediate communities as well as on the wider regional context. The environmental assessment should also include the direct impact of each project component on the physical, socio-economic and socio-cultural features of the site, the immediate communities as well as the wider regional context.

Before carrying out an EIA a ToR should be submitted to the Ministry for review in order to confirm the scope of the EIA.

In accordance with Clause 22(1) the Chief Physical Planner may require the applicant to publish details of the application at such times and provide details of the application to such persons or authorities as specified in the notice. Further, as specified in Clause 22(3), where an EIA is required, the Authority will publish a notice in at least one daily newspaper and affix a notice on the land to which the application relates, that an application to develop land has been received and will be determined on a date specified in the notice; and invite comments and representations either in writing or orally on the application.

The Chief Physical Planner may also *'consult in writing any public officer or other person who appears to him to be able to provide information relevant to an application for development permission to enable the Chief Physical Planner to advise the Minister or the Authority, as appropriate, with regard to the application'* (Clause 24 (1)).

The Chief Physical Planner has been consulted in relation to the development of this ESIA including reviewing and commenting on the ESIA ToR. The ESIA will be approved by the Physical Planning Department of the

GoCD in consultation with relevant Departments (i.e. the Environmental Coordinating Unit, Lands and Surveys Department, Environmental Health and Safety Department). Monitoring of the implementation of Environmental and Social Management Systems will be conducted by the Environmental Health and Safety Department.

The latest version of the ESIA ToR (RZ020300-0000-NP-RPT-0001_V6) contains a summary of the gap analysis and baseline information at time of issue. It was submitted to the GoCD in April 2017 and minor comments were received. A ToR for a Biodiversity Survey (RZ020300-0001-NP-RPT-0002 Dominica Biodiversity ToR_V2) was developed for the completion of additional baseline biodiversity assessments. Both documents have been reviewed by the World Bank and are provided for reference in ESIA Volume 5: Technical Appendices.

2.2.2 Geothermal Resources Development Act 2016

In 2016, the government of Dominica in the Caribbean passed a new piece of geothermal legislation. The Geothermal Resources Development Act 2016 defines a regulatory framework surrounding *"the development, exploration and use of geothermal resources."* The Geothermal Resources Development Act 2016 does not replace or repeal the Physical Planning Act 2002, and development permission must usually be obtained in accordance with the procedure of Part IV of that Act.

The key content elements are:

1) Geothermal resources advisory committee;
2) Geothermal resources;
3) Management of geothermal resource development;
4) Geothermal resource allocation;
5) Procedure for obtaining a geothermal resource development agreement;
6) Fees, bonds and royalities;
7) Record keeping and publicity; and
8) Compliance and enforcement.

The Geothermal Resources Development Act of 2016 provides the legal basis for the development, exploration and use of geothermal resources. It replaces the Geothermal Energy Act of 1976. The Act's objectives are to: 1) enable the sustainable use of geothermal energy according to Dominica's population needs; 2) safeguard the life-supporting capacity of air, water, soil and ecosystems; and 3) avoid remedying or mitigating to any material with adverse effects on the environment. Additionally, the bill declares that all geothermal resources will always be vested in the state and subject to the control of the state which is consistent with part one, section two of the Mines and Minerals Act of 1996.

The Act establishes the Geothermal Resources Advisory Committee (made up of the permanent secretary of the Ministry responsible for energy, the Executive Director of the IRC, the Chief Physical Planner of the Physical Planning Division, a senior state attorney and other public officers, and private professionals as appointed by the Minister) and details its duties and attributions. It determines the rules relating to geothermal activities including the creation, acquisition, transfer, exercise and termination of rights. Activities must only be developed in special geothermal zones set out by the Minister in accordance with the Committee.

2.2.3 Other Relevant National Legislation

Relevant Dominica national regulations are summarised in Table 2.1.

Table 2.1 : Key Dominica National Regulations

Regulation (includes any Subsequent Amendments)	Summary
Development	
Physical Planning Act (2002)	The Physical Planning Act (2002), makes provision for the orderly and progressive development of land in both urban and rural areas and to preserve and improve the amenities thereof; for the grant of permission to develop land and for other powers of control over the use of land; for the regulation of the construction of buildings and regulated matters; to confer additional powers in respect of the land acquisitions and development of land for planning purposes and for other matters connected therewith.
Electricity Supply Act (2006), Act 10	Regulates the generation, transmission, distribution and supply of electricity services and for purposes connected therewith; establishes an independent regulatory commission; and repeals the electricity supply act 1996 (No. 21 of 1996).
Water and Wastewater	
Water and Sewerage Act (No. 17, 1989)	An Act to make provision for a national policy for water, for the granting of an exclusive licence to the Dominica Water and Sewerage Company Limited for the development and control of water supply and sewerage facilities in Dominica and for connected or incidental purposes.
Fauna and Flora	
Fisheries Act (1987), Chapter 61:60	An Act to provide for the promotion and regulation of fishing in the fishery waters of Dominica and for matters incidental thereto and connected therewith.
Forestry and Wildlife Act No. 12, (1976)	An Act to make provision for the protection, conservation and management of wild animals, amphibians, crustaceans, freshwater fishes, and reptiles, and for purposes connected therewith. States that the Forestry and Wildlife Division of the Ministry of Agriculture and Fisheries' shall promote forest and wildlife conservation and management in Dominica under the general supervision of the Permanent Secretary of Agriculture and Fisheries' and under the authority of the Minister.
Forest Act (1959), Chapter 60:01	An Act to make provision for the conservation and control of forests, defines the power of the President, the Director of Forestry and Wildlife and forest officers, which are assigned by this Act.
National Parks and Protected Areas Act (1975)	Designated the Morne Trois Piton National Park (MTPNP) as a National Park and provides for the establishment of National Park's Section under the Forestry and Wildlife Division, consisting on a National Parks Service, a National Parks Advisory Council and a Director of National Parks, working together with several part-time and full time park officers and a Park Superintendent. A zoning plan is in place for the Park, which determines activity areas with regard to existing land use patterns and interests and existing and allowable uses. Some of these provisions, namely the ones referring to the establishment of a National Parks Service have not been implemented due to budgetary reasons.
Noise	
Noise Abatement Act, Chapter 40:99	An Act to make provisions concerning the control of noise with a view to its abatement.
Solid waste	
Solid Waste Management Act, (2002)	An Act to establish a national solid waste management corporation and to provide for the management of solid waste in conformity with best environmental practices.
Social	
Culture Act (No. 22, 1981)	An Act to make provision for the further development of culture in the Commonwealth of Dominica and for the purposes connected therewith.

Regulation (includes any Subsequent Amendments)	Summary
Village Councils Ordinance (Cap. 190)	Responsibility within their jurisdictions for sanitation, waste removal, nuisance abatement, beach control.

2.3 Biodiversity Treaties and Legislation

In addition to being a State Party to the World Heritage Convention, Dominica is also a signatory to the following international biodiversity conventions:

- UN Convention on Biological Diversity;
- UN Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES);
- UN Framework Convention on Climate Change; and
- UN Convention to Combat Desertification Cartagena Protocol on Biosafety International Convention on Civil Liability for Oil Pollution Damage Basel Convention on the Control of Trans Boundary Movements of Hazardous Wastes and their Disposal.

2.4 International Guidelines

2.4.1 World Bank Performance Standards for Private Sector Activities

As the World Bank has indicated its intention to provide funding to the development, the project is required to demonstrate compliance with the World Bank Performance Standards for Private Sector Activities, OP 4.03, (WBG, 2013) and the WBG Environmental, Health, and Safety Guidelines (hereafter referred to as the ‘EHS Guidelines’).

Categorising the Project

In accordance with the WBG’s OP 4.03, the WBG undertakes environmental screening of each proposed project to determine the appropriate extent and type of Environmental Assessment (EA) needed. The WBG classifies the proposed project into one of three key categories, depending on the type, location, sensitivity, and scale of the project, as well as the nature and magnitude of its potential environmental impacts.

- **Category A:** A Category A project is likely to have significant adverse environmental impacts that are sensitive, diverse, or unprecedented. These impacts may affect an area broader than the sites or facilities subject to physical works. The EA for a Category A project examines the project's potential negative and positive environmental impacts, compares them with those of feasible alternatives (including the "without project" scenario), and recommends any measures needed to prevent, minimise, mitigate, or compensate for adverse impacts and improve environmental performance. For a Category A project, the borrower is responsible for preparing a report, normally an Environmental Impact Assessment (or a suitably comprehensive regional or sectoral EA).
- **Category B:** A Category B project has potential adverse environmental impacts on human populations or environmentally important areas - including wetlands, forests, grasslands, and other natural habitats - which are less adverse than those of Category A projects. These impacts are site-specific; few if any of them are irreversible; and in most cases mitigatory measures can be designed more readily than for Category A projects. The scope of EA for a Category B project may vary from project to project, but it is narrower than that of Category A assessment. Like Category A, a Category B environmental assessment examines the project's potential negative and positive environmental impacts and recommends any measures needed to prevent, minimize, mitigate, or compensate for adverse impacts and improve environmental performance. The findings and results of EA for Category B projects are described in the project documentation (Project Appraisal Document and Project Information Document).

- **Category C:** A Category C project is likely to have minimal or no adverse environmental impacts. Beyond screening, no further EA action is required.

All Category A and Category B Projects require an assessment process to address the relevant environmental and social risks and impacts of the proposed project in accordance with the applicable standards (i.e. WBG Performance Standards and/or the WBG Environmental and Social Framework and the WBG EHS Guidelines). The assessment documentation should propose measures to minimise, mitigate, and offset adverse impacts in a manner relevant and appropriate to the nature and scale of the proposed project. For Category A, and as appropriate, Category B Projects, the assessment documentation includes an Environmental and Social Impact Assessment (ESIA), Environmental and Social Management Plan (ESMP) with an Environmental and Social Management System (ESMS) usually prepared and implemented prior to construction commencing.

The assessment process should, in the first instance, address compliance with relevant host country (Dominica) laws, regulations and permits that pertain to environmental and social issues and with the WBG Performance Standards and EHS Guidelines.

The ESIA ToR (ESIA Volume 5: Technical Appendices) determined that based on a description of the Project, a review of previous studies and a preliminary risk assessment, the Project was given a preliminary classification of **Category A** (Jacobs, 2017). This was for the following reasons:

- Based on the initial preliminary risk assessment, most of the potential social and environmental impacts were determined to be of low risk (i.e. to be managed by routine procedures) and would therefore not require any additional design mitigation.
- The injection line route Option C (see Section 4 – Analysis of Alternatives) passed close to the residential area of Laudat and therefore there may be adverse impacts due to:
    - Potential physical relocation or infringement of land use for residents of Laudat.
    - Potential disturbance of habitat (i.e. through vegetation removal) that has been classified as ‘high’ sensitivity by Caraïbes Environnement Développement & Coll (2015a/b). High sensitivity areas were classified as those that contained the following:
        - ➢ A high number of protected species inside (International Union for Conservation of Nature (IUCN), French and Dominican legislation);
        - ➢ An area with very few anthropic influences; or
        - ➢ A high number of endemic species (Dominica and Caribbean).
- Three of the potential power plant sites (see Section 4 – Analysis of Alternatives) fell within habitat that has been classified as ‘high’ sensitivity by Caraïbes Environnement Développement & Coll (2015a/b).
- The power plant is located approximately 500 - 600 m) from the Morne Trois Pitons National Park World Heritage Site.

It should be noted that the habitat classification carried out by Caraïbes Environnement Développement & Coll in 2015 was done at a high level when the potential reinjection pipeline route and power plant site were not known. Assigning the project as Category A was a precautionary approach at the time based on the current level of uncertainty with the locations of the reinjection pipeline and the power plant site. This categorisation has been considered further during the ESIA process based on latest information and reclassification is proposed as part of the ESIA conclusion. For further details, reference should be made to the ESIA TOR (Volume 5 – Technical Appendices).

2.4.2 World Bank Group Performance Standards for Private Sector Activities, May 2013

As the Project is considered a private sector led economic development project, the following WBG Performance Standards would apply to the Project (note that these standards are equivalent to the International Finance Corporation (IFC) Performance Standards (IFC, 2012):

- Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts;
- Performance Standard 2: Labour and Working Conditions;
- Performance Standard 3: Resource Efficiency and Pollution Prevention;
- Performance Standard 4: Community Health, Safety, and Security
- Performance Standard 5: Land Acquisition and Involuntary Resettlement;
- Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources;
- Performance Standard 7: Indigenous Peoples; and
- Performance Standard 8: Cultural Heritage.

2.4.3 General and Industry Specific EHS Guidelines

In addition to the performance standards, the WBG has developed EHS Guidelines covering both general and industry specific issues. The EHS Guidelines contain the performance levels and measures that are normally acceptable to WBG and are generally considered to be achievable in new facilities at reasonable costs by existing technology. The environmental assessment process may recommend alternative (higher or lower) levels or measures, which, if acceptable to the financiers, become project or site-specific requirements.

In general, when host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures are appropriate in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

The General EHS Guidelines became available for use in April 2007 and will be used in the preparation of the ESIA Report and supporting technical analysis. The industry specific guidelines are as follows:

- Geothermal Power Generation; and
- Electric Power Transmission and Distribution.

2.4.4 Environmental, Health and Safety General Guidelines (April, 2007)

The EHS General Guidelines cover the following key areas:

Environmental

The general environmental guidelines are:

- Air Emissions and Ambient Air Quality;
- Energy Conservation;
- Wastewater and Ambient Water Quality;
- Water Conservation;
- Hazardous Materials Management;
- Waste Management; and
- Noise.

Occupational Health and Safety Guidelines

The general occupational health and safety guidelines are:

- General Facility and Design and Operation;
- Communication and Training;
- Physical Hazards;
- Chemical Hazards;
- Biological Hazards;
- Radiological Hazards;
- Personal Protective Equipment;
- Special Hazard Environments; and
- Monitoring.

Community Health and Safety Guidelines

The general community health and safety guidelines are:

- Water Quality and Availability;
- Structural Safety of Project Infrastructure;
- Life and Fire Safety;
- Traffic Safety;
- Transport of Hazardous Materials;
- Disease Prevention; and
- Emergency Preparedness and Response.

Construction and Demolition Guidelines

The general construction and demolition guidelines are:

- Environment;
- Occupational Health and Safety; and
- Community Health and Safety.

2.4.5 Environmental, Health and Safety Guidelines for Geothermal Power Plants (April, 2007)

These guidelines provide a summary of EHS issues associated with geothermal power generation and recommendations for their management. These include:

Environmental

Environmental issues that may occur during geothermal power generation projects, include the following:

- Effluents;
- Air emissions;
- Solid waste;
- Well blowouts and pipeline failures; and
- Water consumption and extraction.

Occupational Health and Safety

Occupational health and safety issues during the construction and decommissioning of geothermal power generation projects are common to those of other industrial facilities and their prevention and control are discussed in the General EHS Guidelines. Specific health and safety issues in geothermal power projects include the potential for exposure to:

- Geothermal gases;
- Confined spaces;
- Heat; and
- Noise.

Community Health and Safety

Community health and safety issues during the construction and decommissioning of geothermal power generation plants are common to those of large industrial facilities, and are discussed in the General EHS Guidelines. Community health and safety issues during the operation of geothermal power generation plants include:

- Exposure to hydrogen sulphide gas;
- Infrastructure safety; and
- Impacts on water resources.

Performance indicators and monitoring for each of the issues listed above follows the advice provided in the General EHS Guidelines.

2.4.6 Environmental, Health, and Safety Guidelines for Electric Power Transmission and Distribution

The EHS Guidelines for Electric Power Transmission and Distribution sets out relevant information that needs to be considered in the environmental and social impact assessment of transmission lines between a generation facility and a substation located within an electricity grid. Key issues covered include:

- Construction and maintenance of Right of Way and impacts on terrestrial habitats;
- Electric and magnetic fields;
- Hazardous materials; and
- Occupational health and safety.

2.5 International Labour Organisation (ILO) and United Nations Conventions

It is anticipated that a large portion of personnel working on the site through the construction phase will be employed through DGDC, the EPC Contractors and Subcontractors providing specific services to the Project. It will be a contractual requirement for all providers to the Project that they comply fully with the laws and regulations of the GoCD concerning employment of labour and working conditions. The Project policy for its own employees will also follow the laws and regulations of the GoCD and an employment policy framework will be developed which will comply with (at a minimum):

- ILO Convention 87 on Freedom of Association and Protection of the Right to Organise;
- ILO Convention 98 on the Right to Organise and Collective Bargaining;
- ILO Convention 29 on Forced Labour;
- ILO Convention 105 on the Abolition of Forced Labour;

- ILO Convention 138 on Minimum Age (of Employment);
- ILO Convention 182 on the Worst Forms of Child Labour;
- ILO Convention 100 on Equal Remuneration;
- ILO Convention 111 on Discrimination (Employment and Occupation);
- UN Convention on the Rights of the Child, Article 32.1; and
- UN Convention on the Protection of the Rights of all Migrant Workers and Members of their Families.

3. Project Description

3.1 Introduction

The purpose of this Section is to provide an overview of the construction, commissioning, operation and decommissioning of the Project. The full technical details used to inform the assessments of impacts are provided in ESIA Volume 5: Technical Appendices, Technical Report – Detailed Process Description. The engineering design for the Project is ongoing, with detailed design to be completed following a formal tender process for an Engineer, Procure and Construct (EPC) Contractor(s). Therefore, some of the descriptions provided in the Process Description are typical of a geothermal development in this setting and cover two power plant generation options. The consideration of design options has been taken forward into the impact assessment (ESIA: Volume 2 – Environmental Impact Assessment and ESIA: Volume 3 – Social Impact Assessment).

The process description covers the following major elements

- Overview;
- Site Location;
- Geothermal Resource – wells, reservoir capacity and production well testing;
- Land Requirements;
- Schedule;
- Construction – power plant and steamfield, reinjection pipeline, civils work at well pads, port to site access, local access and temporary facilities;
- Commissioning – steamfield, power plant and reinjection pipeline;
- Operation – general operating arrangements, well pad, steamfield, power plant (including technology options), use of water, road network, electrical equipment and interconnection, hazardous substances; and
- Decommissioning.

3.2 Overview

Geothermal projects connect production wells through a steamfield facility to a power plant, which is connected to an electricity grid. Geothermal fluids consist of steam, hot water (brine) and a small quantity of non-condensable gases (mostly carbon dioxide and trace gases). In this project, steam will be separated from the brine and used to drive a turbine. Used geothermal fluids produced by the geothermal projects (separated brine and steam condensate) are returned to the geothermal reservoir via reinjection wells, which may be located some distance away (i.e. over 1 km) from the production wells to avoid short-circuiting or premature cooling of the production wells.

For this Project, the key components of the proposed 7 MW power plant are summarised below and shown in Figure 3.1.

The key components of the proposed 7 MW power plant include:

- Power plant comprising 2 x 3.5 MW units (either single flash steam condensing cycle or organic Rankine cycle units (binary turbine), which will be adjacent to wells WW-P1 and WW-03. The binary power plants may use wet cooling or dry cooling;
- Production well WW-P1 – The existing geothermal production well at Laudat is indicated to have potential to generate 6 to 9 MW and will be the sole production well for the project;
- Cross-country brine reinjection piping – The 250 to 300 mm diameter reinjection pipeline will be carrying used geothermal fluid from Laudat to Trafalgar with approximate piping length of 3.5 km;

- Reinjection wells WW-R1 (located in Trafalgar) and WW-01 (located in Wotten Waven) – The used geothermal fluid (brine and possibly some steam condensate) produced from production well WW-P1 would be disposed of into reinjection wells WW-R1 and WW-01 transported to the wells via the reinjection pipeline;
- Steamfield infrastructure including two phase piping, steam piping, steam separator, atmospheric flash tank, brine collection and disposal system, condensate collection and disposal system, pressure relief system, storage sump and rock muffler;
- Supporting infrastructure including existing well pads, turbine building, primary and ancillary equipment, cooling system, and water supply; and
- 11 kV underground interconnection to the DOMLEC electricity grid at the power plant site.

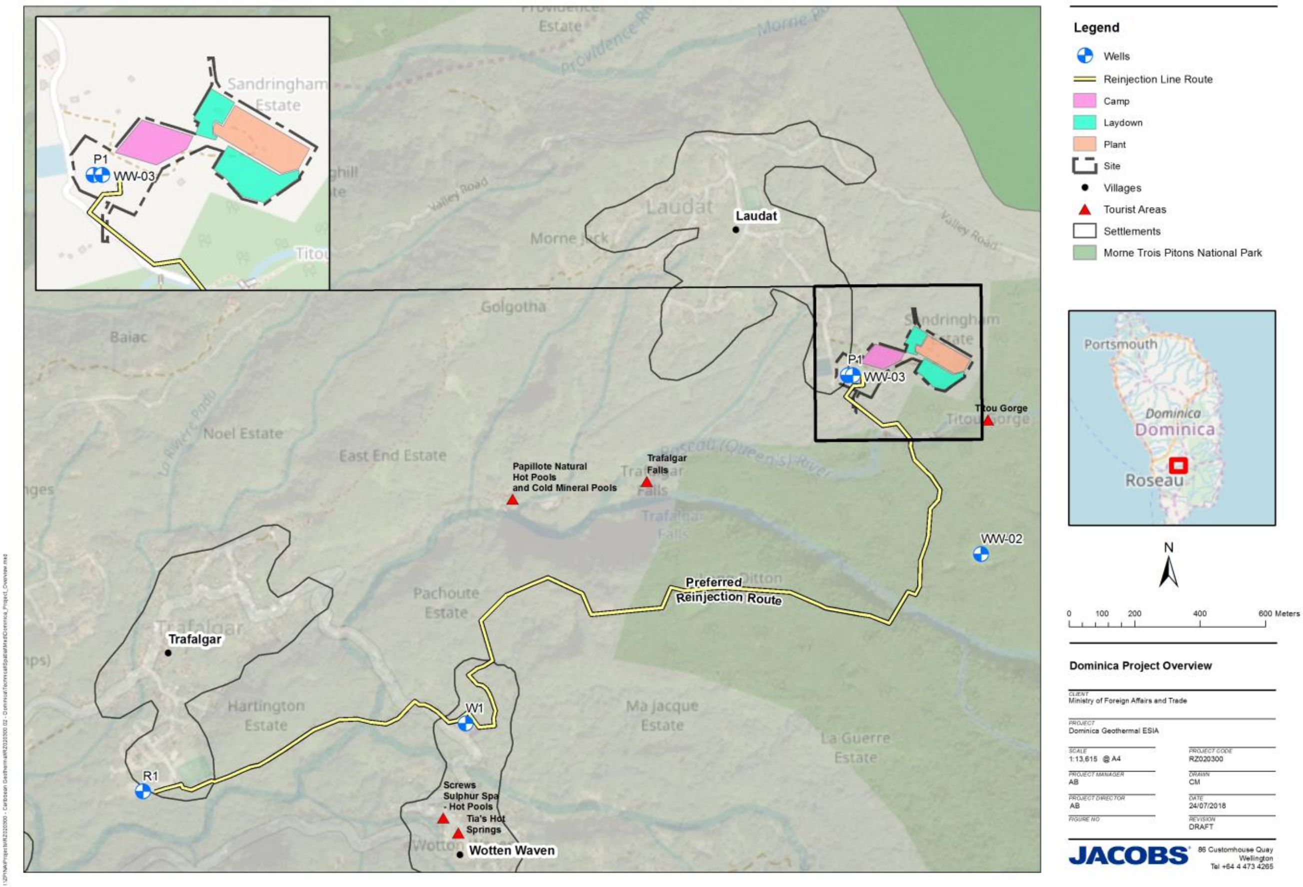

Figure 3.1 : Project Overview

3.3 Site Location

The Project is located in the Roseau Valley of Dominica, as outlined in Section 1.2. The Project is situated within or in close vicinity to a number of villages: the production well pad and power plant site are partially within the village boundary of Laudat and the reinjection pipeline passes through the villages of Wotten Waven and Trafalgar. Listed below are the approximate distances of the well pads WW-R1, WW-01 and the power plant to the nearest properties:

- WW-P1 & power plant – located 150 m south of residential properties;
- WW-R1 – located 50 m south of residential properties; and

- WW-01 – located 200 m north of residential properties.

The power plant is situated at an estimated elevation of 550 m above mean sea level (aMSL), the ~3.5 km reinjection pipeline route runs down the Roseau Valley starting at the power plant, passing through WW-01 at 235 m aMSL and ending at WW-R1 at 187 m aMSL. Figure 3.2 and Figure 3.3 provide some topographical context to the Roseau Valley and the location of the Project components.

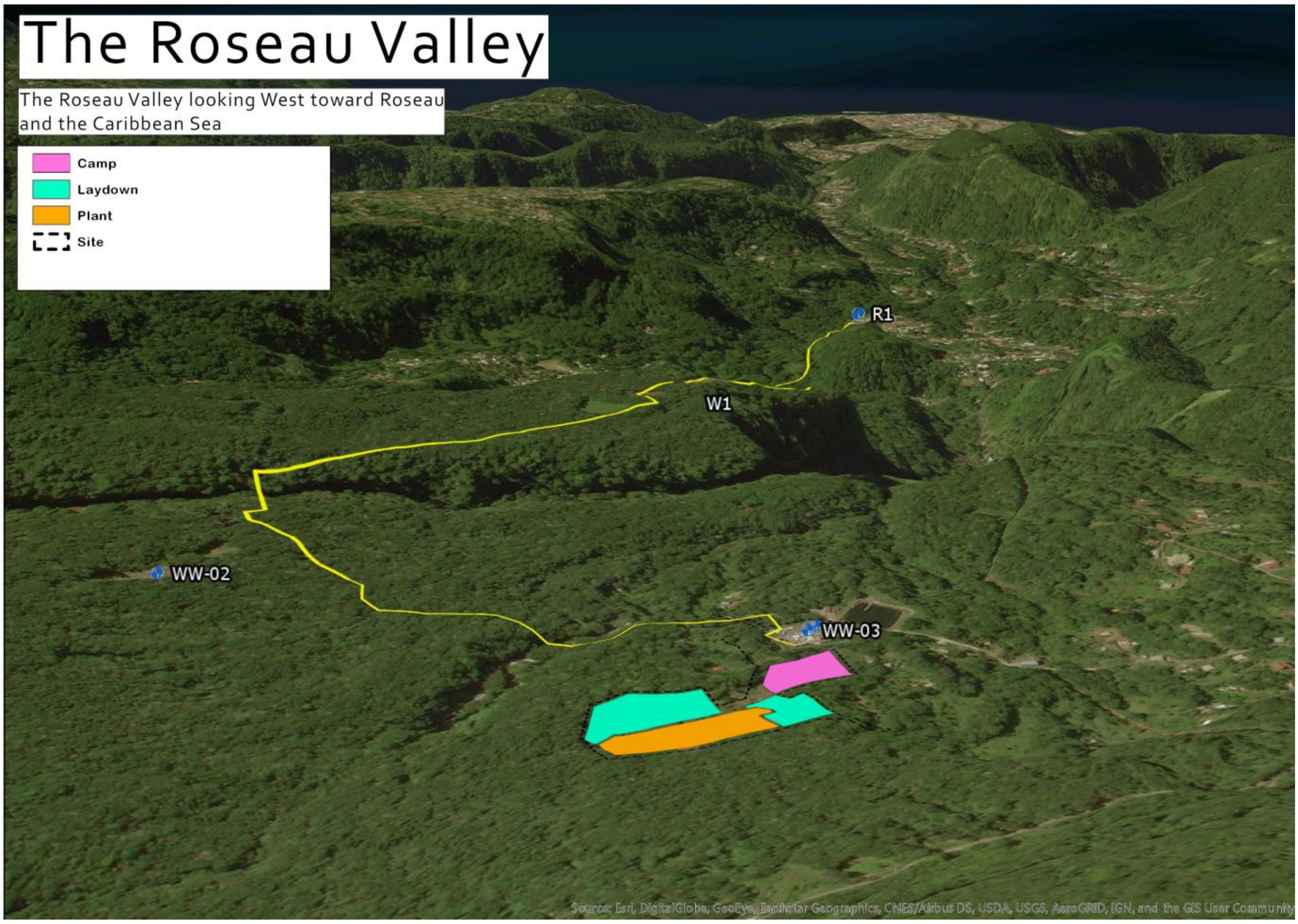

Figure 3.2 : The Roseau Valley looking west towards Roseau and the Caribbean Sea. The power plant and reinjection pipeline routes are also shown. Source: Google Earth, 2017

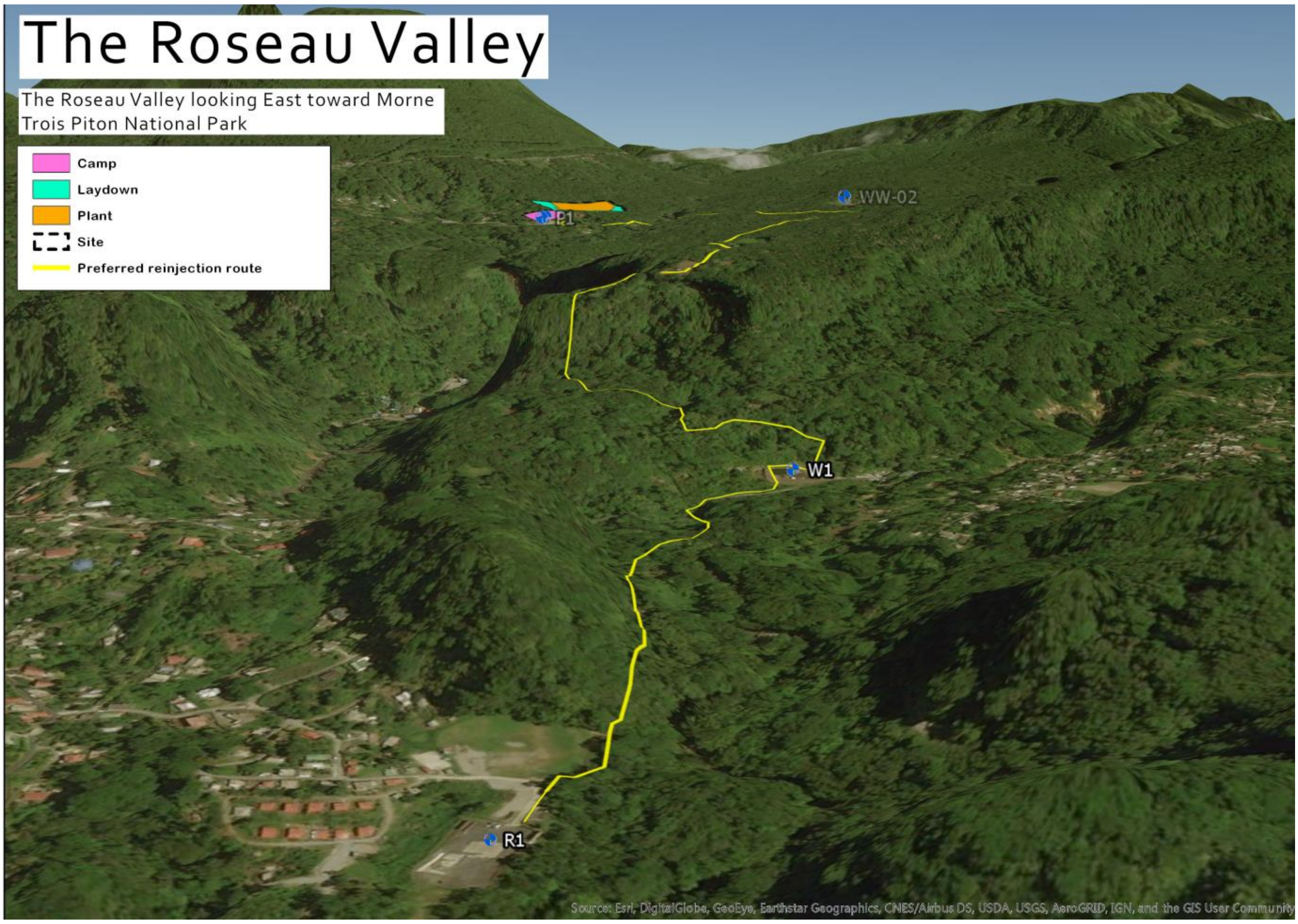

Figure 3.3 : The Roseau Valley looking west towards Morne Trois Piton National Park. The power plant and reinjection pipeline routes are also shown. Source: Google Earth, 2017

3.4 Geothermal Resource

3.4.1 Wells

As outlined in Section 1.2, five wells have been drilled to date as part of the exploratory phase: three slimhole exploration / production wells (WW-01, WW-02 and WW-03), one standard diameter production well (WW-P1) and one standard diameter injection well (WW-R1). The details of these are provided in Table 3.1 below.

Table 3.1 : Well physical parameters

Parameter	WW-01	WW-02	WW-03	WW-P1	WW-R1
Wellhead, Easting (m)	678,302	679,822	n/a	679,461	677,321
Wellhead, Northing (m)	1,694,864	1,695,029	n/a	1,695,567	1,694,334
Wellhead elevation (aMSL)	235	580	543	552	187
Total depth (mRKB)	1,200	1,469	1,613	1,505	1,914
Azimuth (°)	-	-	-	190	-
Throw (m)	-	-	-	465	-
Casing size (in)	7	7	7	9-5/8	9-5/8

Casing shoe depth (m)	303	427.5	590.6	726	607
Liner size (in)	4-1/2	4-1/2	4-1/2	7	Open hole
Liner depth (m)	269-1,200	281-1,337	569-1,612	700-1,505	1,914

Production well pad WW-P1 and re-injection well pads WW-R1 and WW-01 will be utilised as part of the development. The ESIA assesses workover operations, however, no additional drilling is anticipated to be required as part of the Project. If additional drilling is deemed necessary in the future, this will be subject to a supplementary ESIA.

3.4.2 Reservoir Capacity

Following drilling of exploratory wells WW-01, WW-02 and WW-03, the Wotten Waven geothermal system was described in the ELC Preliminary Resource Assessment (ELC, 2012) and the Feasibility Study – Small Geothermal Report (ELC, 2013), together with gap analysis and commentary by World Bank experts (World Bank, 2013).

The reservoir temperatures and pressures measured in the existing in-field wells (excluding WW-R1) are nearly uniform and the deep permeability in these wells is generally good so the indicated (measured) reservoir area corresponds to an area of 3 km^2 and is considered to be sufficiently proven to be used as a basis for a small development using existing wells.

ELC estimated that there is a 90% probability that the indicated resource is at least 25 MW, and a 50% probability of supporting 41 MW. These estimates provide sufficient confidence for a small scale development using existing wells to be sustainable for 30 years, although there is a low risk that recharge by low temperature or acidic fluids could prematurely reduce the output of the wells.

3.4.3 Production Well Testing

Production well testing was undertaken on well WW-P1 by Geothermal Resource Group (GRG) in June 2014. Using step flow data undertaken from well testing, Íslenskar Orkurannsóknir, Iceland Geosurvey (ÍSOR) calculated the discharge at a Well Head Pressure (WHP) of between 13.0 and 17.0 bara. At atmospheric separation pressure and a WHP of 13.0 bara the estimated steam flow is 22 kg/s. At 7 bara separation pressure the steam flow is calculated (using industry standard to be ~14-18 kg/s. Depending on the type of power plant technology to be installed, ÍSOR found that a separation pressure of 7 bara would generate between 7 and 9 MW (assuming a usage of ~2 kg/s of steam for each MW) (ÍSOR, 2014).

3.4.4 Geothermal Fluid Chemistry

Based on the chemical tests ÍSOR concluded that:

- Due to limited changes in the conductivity of the liquid phase throughout the test, the similar chemical composition of the samples collected during the test and the good agreement between geothermometers and logged reservoir temperature indicates that the discharge is representative for the reservoir fluid;
- The deep liquid (reservoir liquid) is relatively dilute with Cl and Na concentrations close to 2,600 mg/L and 1,500 mg/L respectively;
- Boiling due to depressurisation within the well is expected to cause calcite scaling at or slightly above the boiling level; and
- The overall gas content of the steam at 150°C (4.8 bara) based on calculations from samples was 1.6 wt% (at 4.8 bara) or approximately 8 L gas/kg condensate.

3.5 Land Requirements

3.5.1 Power Plant

The GoCD has ownership of the existing well pads, however, additional land will be required for the power plant site and for the reinjection pipeline right of way. The land required for the power plant, and hence civil works required to prepare the site, will depend on the power plant technology selected and design by the EPC contractor. Figure 3.4 provides nominal land area requirements for the 2 x 3.5 MW power plant, with binary plant requiring an area of approximately 115 m x 60 m (~60 m x 175 m including laydown area) and steam condensing plant requiring approximately 50 m x 60 m (60 m x 90 m including laydown area). This gives estimated minimum land requirements (including laydown) of:

- Steam Condensing Plant: 5,400m^2
- Binary Plant: 10,500m^2

However, taking into consideration local site factors and specific plant requirements (terrain characteristics, operations facilities, maintenance facilities etc.), the proposed plant layout as presented in Figure 3.4 has a land requirement estimate of 20,000 m^2, for the largest case binary plant option – including laydown / spoil areas. Approximately 10% of the power plant site will be concreted and the rest covered with gravel. The remaining areas of the site will be landscaped and replanted.

The proposed power plant site layout based on the largest case binary plant option, is shown in Figure 3.4.

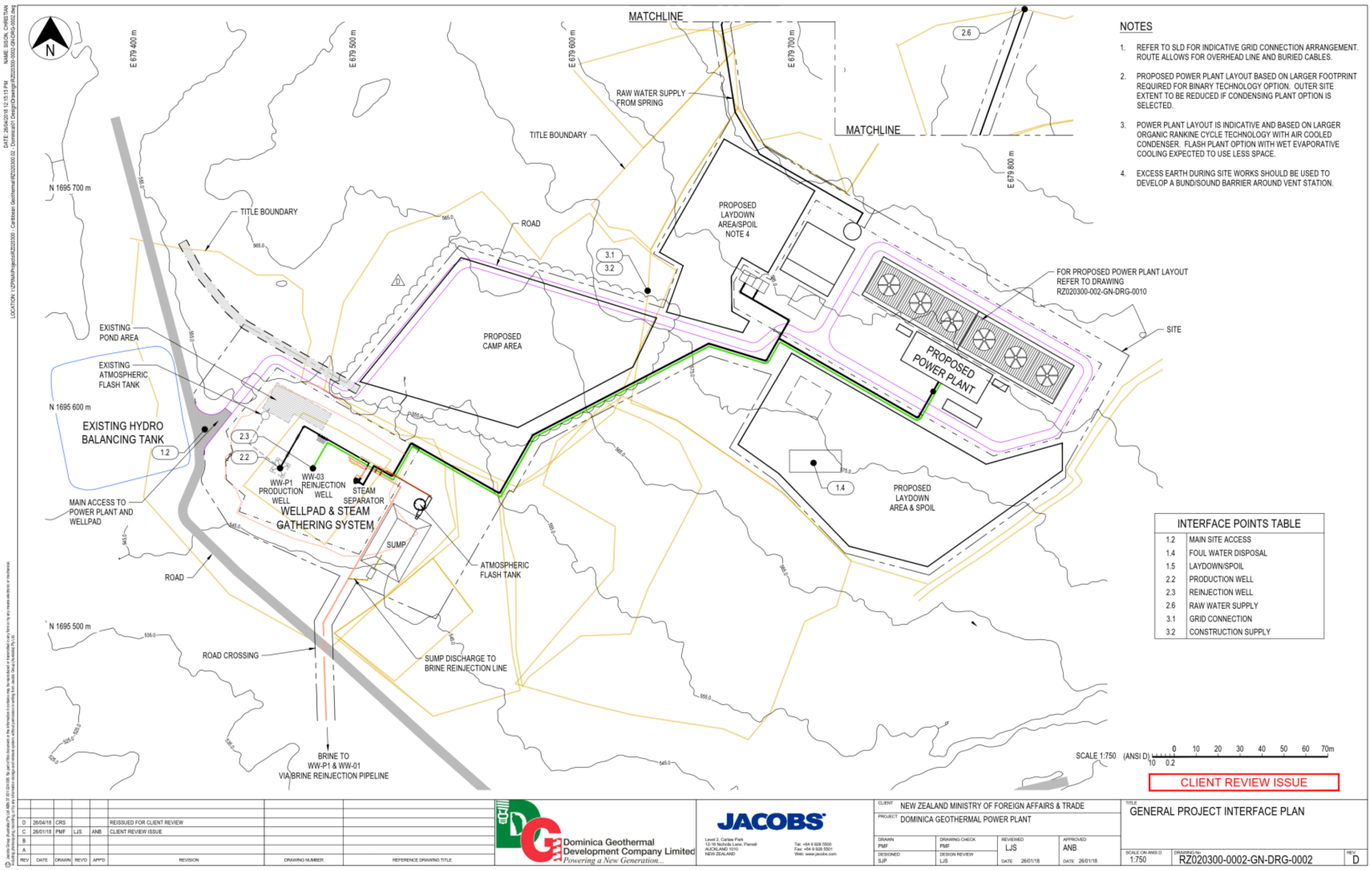

Figure 3.4 : Proposed Power Plant Site and Production Steamfield Layout

3.5.2 Steamfield and Reinjection Pipeline

The land requirements for the steamfield piping system are dominated by the reinjection pipeline, which will run 3.25 km from WW-P1 to WW-01 and WW-R1. The diameter of the pipeline will be approximately 250 to 300 mm (10 to 12 inches). A corridor of 10 m wide will be required to enable access during construction therefore total land requirements for the reinjection pipeline are approximately 32,500 m^2. However, for operation a 4 m wide corridor is required. Expansion loops are required every ~100 m to account for expansion of the steel on contact with the hot brine. A number of trees will need to be felled to allow for space and construction access. A replanting programme along the reinjection route will be undertaken as part of rehabilitating the land, associated with the reduced corridor width required for operation.

The reinjection line route alignment will be finalised in close co-ordination with process engineering, mechanical, geotechnical and civil engineering design disciplines, along with the GoCD, Land and Survey Division and environmental and social scientists (Figure 3.5).

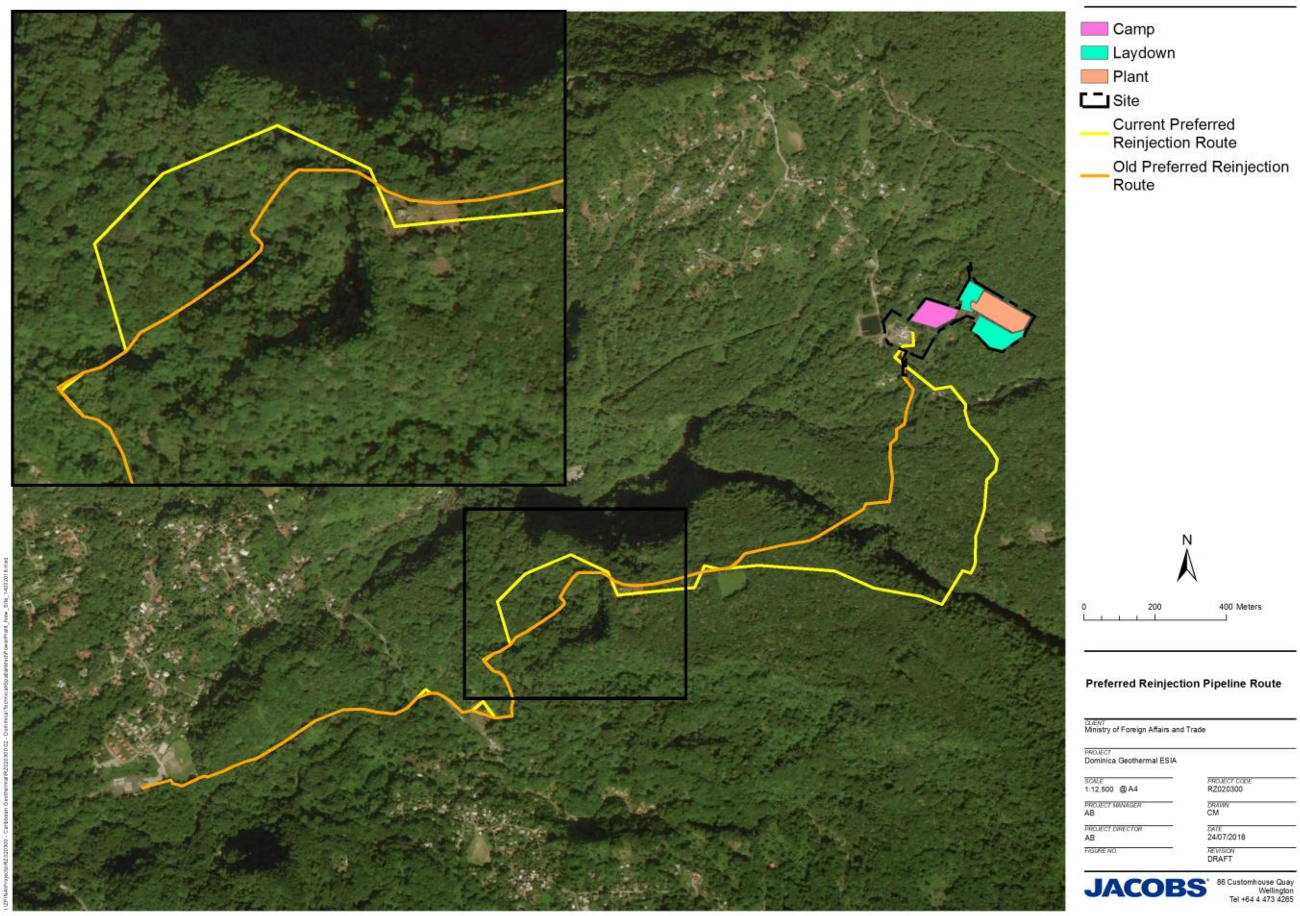

Figure 3.5 : Preferred injection pipeline route from WW-P1 to WW-01 and WW-R1

Land requirements for other elements of the steamfield include: wellpads, the sumps, separator and atmospheric flash tanks:

- Steamfield Equipment: 1,700 m^2
- Sump at Power Plant: 600 m^2
- Wellpad WW-R1 & associated equipment: 2,000 m^2

- Wellpad WW-01 & associated equipment: 2,000 m^2

This ESIA assumes a 10-metre-wide reinjection pipeline corridor is required. The final alignment of the reinjection pipeline can only be determined following preliminary engineering design and subsequently during detailed design prior to construction.

3.5.3 Switchroom & Transmission Line

The Project includes an indoor switchroom that will be located at the power plant site. This will connect to the underground transmission line that will connect to Laudat Hydropower Station to the north. The estimated land requirements are:

- Switchroom: 250 m^2
- 300 m Underground Transmission line: 300 m^2

3.6 Schedule

The construction of the project is anticipated to last 18 months to two years, as outlined in the indicative schedule in Table 3.2 below. The operational life of the geothermal development is anticipated to be 25 years.

Table 3.2 : Indicative Construction Schedule

Phase	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Off-site preparatory work	■							
Site preparation		■	■					
Foundations for equipment and pipelines			■	■				
Powerhouse & permanent buildings				■	■			
Major equipment installation					■	■		
Interconnecting piping, wiring and instrumentation						■	■	
Switchyard and transmission line								■

3.7 Construction

3.7.1 Power Plant and Steamfield

The majority of the construction activities will be concentrated on the main power plant, switchyard and separator station sites, but other work is required at the individual well-sites and in the piping corridors linking the wells to the power plant. Construction lay-down areas will be required for storage of equipment required for construction. The equipment for the construction works will include small drilling rigs, excavators, trucks, rollers, compactors, cranes, portable welders and generators and other items that are normal for such construction activities.

Site preparation involves bulk earthworks, upgrades to roads, and establishment of temporary construction facilities, security fencing, drainage controls, access control and a worker's camp that will house an estimated 50 workers (Figure 3.4). Construction facilities include lay-down space for storage of equipment and materials awaiting installation, amenities (washrooms, lunchrooms, car-parking) for construction workforce, and construction management offices.

Sediment and erosion control measures will be constructed in accordance with the Sediment and Rrosion Control Plan and any local regulatory requirements. Specific disposal areas for washing out empty concrete trucks would be set up, with a hose and bunded area for discharge of washwater. The EPC Contractor will regularly remove accumulated concrete washings and these will be disposed of to landfill, while the water will percolate through the base of the bunded area to the ground.

Site construction work will involve the following:

- Construction of foundations for major structures, equipment and pipelines;
- Construction of the powerhouse and permanent ancillary and amenity buildings;
- Erection of major and ancillary equipment such as steam-turbine generators, cooling towers, pumps;
- Interconnecting piping, electrical wiring and instrument installation; and
- Switchyard and underground transmission line construction and connection to the grid.

The power plant will be constructed on a concrete pad designed to withstand the weight and movement of large pieces of mechanical equipment. It is anticipated that 10% of the power plant site will be concreted with the rest covered by gravel. At this stage no concrete batching plant is anticipated, concrete will be sourced from local plants. The turbine hall may be fully or partly covered and will be constructed to accommodate 2 x 3.5 MW turbines. Some elements of the balance of plant equipment, including circulating water cooling systems and gas extraction systems may be outside but under appropriate cover.

The steamfield comprises the wellpad and separator station. WW-P1 will contain the majority of fluid production and separation equipment. Concrete foundations for the separator station will be constructed, followed by the set up and welding of steel pipes to transport steam and fluids such as brine, condensate, two-phase fluid to and from the power plant. Separator station plant and equipment will also be installed. At the separator station the excavation of a lined holding pond (lining material yet to be determined) for geothermal fluid discharges will be required (refer to Figure 3.4 for overview of the steamfield).

3.7.2 Reinjection Pipeline

Connection to wells WW-01 and WW-R1 would be undertaken during construction and installation of the brine injection pipeline. The injection pipeline will be insulated using aluminium or other appropriate material in order to reduce heat loss. The injection pipeline must operate at high temperature and pressure and needs to be carefully designed with suitable supports and guides which safely allow for thermal expansion of the pipe between its hot and cold states. This will require vertical or horizontal u-bends every ~100 m.

The EPC Contractor will form walking tracks within the reinjection pipeline corridor (up to 10 m wide) and install infrastructure services between the track and pipeline route. Concrete foundations for the pipeline will be constructed, followed by the set up and welding of steel pipes to transport the separated brine. The volume of water required for these foundations is minimal and will be sourced from local watercourses. It will be necessary to construct a pipe bridge over Breakfast River Gorge which is anticipated to be 70-100 m in length. Further pipe bridges will be constructed over the intermittent watercourses within the site as appropriate, and dependent on final steamfield configuration. Local ponds (lined) to drain accumulated geothermal fluid during the shutdown of the reinjection pipeline will be excavated at low points in the pipeline. It is anticipated that the pipeline will also contain ubends and culverts, examples of which are shown in Figure 3.6 (however, note that these show pipelines of larger width than proposed for the reinjection pipeline in the Project).

Figure 3.6 : Examples of a reinjection line culvert underneath a road (left) and a u-bend in a reinjection line (right)

The plant required for the reinjection pipeline construction works will include small drilling rigs for creating foundations, mobile cranes, trucks to transport materials and equipment, generators for pipe welding as well as excavators and trucks for foundation excavations. This will require manual cartage or potentially use of a helicopter to transport materials into some of the more remote areas. The felling of trees and other shrubs will be necessary in constructing a reinjection pipe corridor for the 250 – 300 mm diameter pipe.

3.7.3 Existing Well Pads

Three existing well pads will be used for the development: WW-03 (containing wells WW-P1 and WW-03), WW-01 and WW-R1. Much of the steamfield equipment will be located by WW-P1 including the separator and rock muffler.

The sites will each require remedial works to bring them up to standard and into their original condition. The scope of work will be determined by the DGDC, with the initial indication being as follows:

- Site WW-P1: Site improvement, slope stabilisation, drainage works, fencing, security lighting;
- Site WW-01: Site fencing, slope stabilisation, drain pond; and
- Site WW-R1: Site fencing, security lighting, disposal of material/ general cleanup.

3.7.4 Port to Site Access

During construction, all equipment will be required to be transported by sea to the island. Dominica's main port is at Woodbridge Bay, about 2 km north of Roseau. The berth at Woodbridge Bay is used by both cargo and cruise vessels. The port has two shore cranes with capacities of 27 tonnes and 46 tonnes respectively, see Figure 3.7. The port is capable of handling breakbulk, containers, bagged cargo and pallets (Vertraco Shipping website, 2017).

Figure 3.7 : Woodbridge Bay Port

Access roads to the well sites have already been established as part of the drilling phase and no further widening is anticipated. Some repair work to the access roads damaged by Hurricane Maria may be required. However, road side foliage may create challenges for machinery and transporters. The access road to WW-P1 is used by locals as it enables access to the forest from the village of Laudat, as well as being the access road for two tourist sites (Titou Gorge and walking track to the Boiling Lake) (Figure 3.8). Access to the power plant site will require the improvement of existing tracks.

Figure 3.8 : Panoramic view from east of WW-P1 (Caraïbes Environnement Développement & Coll , 2013)

The reinjection sites WW-01 and WW-R1 (see Figure 3.9 below) are located adjacent to the villages of Wotten Waven and Trafalgar respectively. Both sites are located near to existing road networks.

Figure 3.9 : Site WW-01 (left). View over Trafalgar (WW-R1) reinjection site (right) (Caraïbes Environnement Développement & Coll, 2013)

3.7.5 Temporary Facilities

The following temporary facilities will be present and utilised during the construction phase:

- Construction laydown area: At present two flat construction laydown areas are being considered adjacent to the power plant site. Other smaller laydown areas may be required along the reinjection pipeline during construction in order to store construction materials.
- Worker's camp:
  - Canteen and showers with hot water facilities;
  - Sleeping quarters (to support an estimated 50 workers);
  - Recreational/games room;
  - Potable water supplies from either a tanker-supplied storage tank, or a dedicated treatment plant; and
  - Septic tanks (on-site) and/or portable latrines (off-site disposal).
- Utility services (telecommunications and electricity).
- Water and wastewater systems.

3.7.6 Water and Wastewater Systems

Raw water will be required during construction and ongoing operation and maintenance of the plant. Water abstraction for the Project will require an authorisation application to the "Minister for Housing Lands Settlement and Water Resource Management" (Caraïbes Environnement Développement, 2013).

Raw water for construction and permanent works shall be drawn from a naturally occurring spring located at a higher elevation above the site (location shown in Table 3.3).

DGDC shall be responsible for obtaining the permit to use the water for construction and permanent works. The EPC Contractor shall be responsible for the design, execution and completion of the raw water intake structure and piping required to transfer to the Site.

Table 3.3: Proposed raw water supply information

Item	Natural Spring	Unit
Raw Water Source Location		
Latitude	15°19’58.20”	N
Easting	61°19’34.22”	W
Elevation	623	mASL
Water take limits		
Daily	10,000	Litres
Monthly	200,000	Litres
Maximum instant	5	Litres/s

Domestic wastewater from amenities at the power plant site including the worker’s camp will need be collected and treated in a package plant to meet discharge requirements. The EPC Contractor will need to maintain the package plant and associated effluent disposal system to meet international guidelines discharge criteria (i.e. WBG EHS Guidelines) and to prevent odour or other nuisance to the community during the period of construction. The EPC Contractor will typically be responsible for decommissioning and removing the unit at the end of the construction period.

3.8 Commissioning

As the power plant construction phase nears completion, commissioning commences as described in the sections below. Once the entire plant has been brought into operation a range of performance and reliability tests are undertaken. Having completed and passed performance and reliability tests the plant is handed over for commercial operation.

3.8.1 Steamfield

Two Phase Pipeline from WW-P1 to Separator

The production well WW-P1 will be brought on-line and used to flush the two phase lines up to the separator.

The brine at the separator station will be discharged to a local flash tank and collected in the wellpad sump for the duration of the blow. Either temporary spool pieces will be installed in place of the separator Emergency Dump Valves (EDV’s) or a temporary manual valve in place of an EDV for the initial brine flush, but thereafter the EDVs would be reinstated and would be used to control separator level.

During commissioning, brine disposal is initially to the wellpad sump, therefore, the duration of steam blowing or other tests will be limited by the available sump capacity. If necessary, testing may need to be suspended to allow the sump to be emptied via discharge to an injection well.

Steam Blow

Solid particles present within the piping will be removed before connecting the pipework to the steam turbine. Removal of these solid particles from the pipe interior is through steam blowing where hot steam is passed through the piping at high velocity for a sustained period. Repeated exposure to the combination of thermal expansion / contraction and high fluid velocity is able to dislodge and remove the solid contaminants from the bore of the pipework. The source of steam for pipeline cleaning is from the geothermal field, meaning that steam blowing occurs in the early stages of commissioning. A temporary rock muffler will be used to discharge the steam blowing vent to reduce noise emission. As the steam line is quite short it may also be possible to manually clean the line prior to commissioning.

Pressure control valves (PCVs) provide steam pressure control. The PCVs will be removed and replaced by temporary spool pieces to allow steam blowing of the steam piping through to just upstream of the rock muffler. A temporary spool piece will also be installed on the end of the line to vent the steam above and away from ground level. Steam blow of the PCV lines can be done in conjunction with the main steam line.

3.8.2 Power Plant

Commissioning of the power plant will involve the following:

- Turbine oil systems – The turbine oil systems will be circulated and flushed through temporary filters in the lines. The only waste generated will be the temporary filters used during the process;
- Cooling water pipes – Cooling water pipes will be flushed and the water will be circulated. Water used during the cleaning will be obtained from the site raw water supply and is usually discharged to the stormwater system. This water is then typically discharged to grade, pending environmental approval. No chemicals will be added during this process. Strainers will collect the minimal (handfuls) amount of debris expected to be generated and the debris will be taken to landfill;
- Wet cooling towers (if selected during tender process) – The cooling towers will have their first basin fill during commissioning. This will come from the site raw water supply. It is expected the fill would be completed over a 24 hour period;
- Biocide and caustic systems – These systems will receive first fill during commissioning. They will be located in separate areas that will be bunded so any potential spillage would be captured by this secondary containment system;
- Electrical systems – The power plant and switchyard electrical systems will be energised under defined and controlled conditions according to contractor and grid operator guidelines; and
- Auxiliary steam blow – Required to clean the power plant piping associated with systems such as steam ejectors. This will be done as per the procedure for the main steamfield blowing and may be carried out simultaneously. The remaining steam piping in the power plant from the governor valves to the turbine is then manually cleaned after the steam blows.

3.8.3 Reinjection Pipeline

The reinjection pipeline will be flushed after construction and as part of a hydro-test. Location of a suitable discharge point will depend on the site piping layout and geometry, but is expected to be into one of the sumps at the reinjection wellpad.

3.9 Operation

3.9.1 General Operating Arrangements

The operation of the steamfield and power plant covers three phases:

1) Start-up;
2) Operation; and
3) Shut-down.

Start-up

The start-up operation involves the start-up of production wells and the introduction of steam into the piping systems. Process drain valves are generally left open to remove condensate from the pipes and vessels, draining to storage sumps. Brine from separator vessels and silencers are discharged to the storage sumps at the power plant and separator station locations. Steam is vented to atmosphere through the steam vent valves located at high point vents as well as at the rock mufflers located at the power plant.

Operation

During normal operation minimal steam venting occurs, the production steam is sent to the power plant and brine is sent to the power plant or directly to reinjection wells. When all power plant systems are in operation, the power plant generates electricity which is exported to the grid.

Shut-down

Shut-down may be planned or due to unscheduled maintenance / outage or in some instances may involve a major transmission line outage. During shut-down the unit(s) stops generating electricity for export. The power plant vent valves will emit steam until the production wells are trimmed back to match the required remaining station demand. For a complete station shut-down the steamfield will likely be closed down and the steamfield piping systems will be drained to local storage sumps as well as to the separator stations' and power plant brine sumps. The production well will be either shut in or placed on bleed.

Emergency Shut Down

If conditions arise that requires the power plant to immediately shut down, the plant systems will trip the power plant and steam will be directed away to the vent station. If during the emergency shutdown, the pressure continues to rise in the steamfield due to major equipment failure, the bursting discs may activate to release steam vertically to atmosphere. Under this situation the steam venting from the bursting disc will create a significant noise until the wells are shut in and geothermal fluids stop flowing. This event is considered an emergency and unlikely event.

Maintenance

The power plant and its components must be operated, monitored, managed and maintained in accordance with sound industry practice and Original Equipment Manufacturer (OEM) guidelines. The plant will be designed to be operated unmanned with automated emergency shutdown and remote dispatch. Remote monitoring will be provided to raise alarms for plant malfunctioning, fires, unauthorised visitors and so on.

This will be further supported by regular monitoring of critical pieces of equipment is required through daily walk overs to ensure safe operation. An annual outage of several days is required to inspect wellheads, remove silica scaling from the steam gathering system and overhaul pumps, valves, motors and other fittings. Some specialised equipment (e.g. cranes) would be brought onto site for this work.

Major overhauls of the turbines are periodically required (typically every 2-5 years) and are best undertaken by specialist firms. The exception to this is just before the initial defects liability period is to expire when the plant will be inspected carefully by the EPC contractor and DGDC. The four yearly interval unit works takes about two to four weeks to perform (for a typical flash plant) and an increased work force would be required. Additional labour resources would be engaged from local contractors and specialist providers.

Major steamfield maintenance and inspections will be undertaken during power plant unit shutdowns. The steamfield will be taken out of service during which time the separators, scrubbers and flash tanks will be inspected, cleaned and Non-Destructive Testing (NDT) would be carried out. Brine pumps and motors, valves and actuators will be inspected, overhauled and tested.

Other major maintenance work is associated with the steam production and reinjection / injection wells, which require periodic workovers to remove any scale deposition.

3.9.2 Well Maintenance

During the life of the station, it will be necessary to undertake cleanouts and workovers to maintain the output from production wells or injection capacity. There may be a requirement to drill additional production or reinjection wells, however this is unknown and not considered as part of this ESIA.

Cleanouts

In the course of the productive life of the wells, operational problems such as deposition of scale, silica, or calcite may develop in the wells affecting their operation. When this occurs, cleanouts using a drilling rig are sometimes required to restore the well's productivity or injectivity. Work-over operations are of a relatively short duration (3 days to 15 days) and much of the ancillary equipment required to drill a new well is not required. A basic rig, substructure, BOP, pump and tank are generally sufficient. Water is used as the drilling fluid to avoid damaging permeable formations with drilling mud.

Workover

A drilling workover generally entails some form of well repair which may require removing scale in the wellbore, removing the production liner, repairing the casing, deepening or side tracking the original bore, or plugging and abandoning all or part of the well.

A drilling workover operation falls somewhere between a new well and a cleanout. Most of the ancillary equipment, i.e. cementing and mud handling equipment, and drilling consumables are often required.

Rather than scheduling periodic workovers or cleanouts, downhole antiscalant equipment may be fitted to wells. This will require regular site visits, both by operations staff and inhibitor delivering trucks. They will also require a small hut on the wellpad to store the antiscalant.

Master Valve Change

Master valve changes can generally be undertaken without a drilling rig. The well is quenched by injecting cold water down the well in a controlled manner to prevent thermal stressing of the casing. Once the well is off-pressure the valve can be changed using a small crane. An alternative method used to change the master valve is installing a retrievable packer in the casing to isolate the well bore and so enabling the valve to be removed. The latter method requires a small drilling rig or other specialist packer installation equipment.

3.9.3 Steamfield

The steamfield will be designed, procured and constructed for the full capacity of the 7 MW power plant. The two-phase fluid will be sent to a separator where it is divided into steam and brine phases. Steam will be directed to the power plant, and brine to the injection pipeline. The steamfield will be identical for either option of power plant technology selected. A simplified typical steamfield arrangement is shown in Figure 3.10. The individual systems and typical infrastructure are described in the following sections.

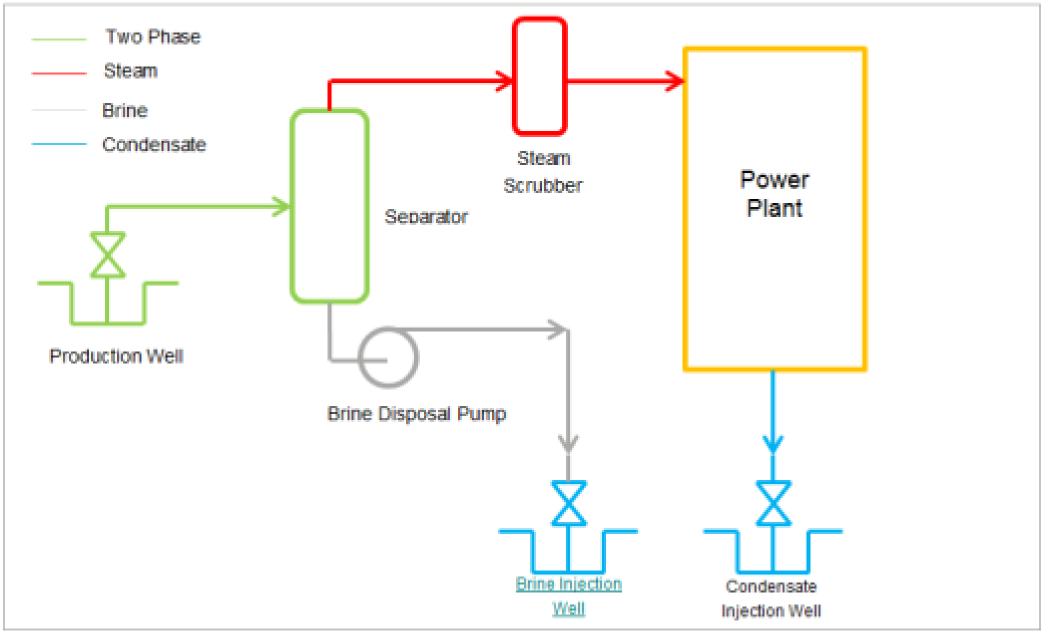

Figure 3.10 : Typical Steamfield Arrangement (utilising energy in steam phase only)

Two phase collection and separation

Two phase collection and separation system including the following:

- production well WW-P1;
- two-phase piping;
- steam separator; and
- atmospheric flash tank (AFT).

The separator to be used on this Project will be located on the WW-P1 well pad and is anticipated to be 7.5-10 m high and approximately 1.5 m in diameter, as shown in Figure 3.7 below. The atmospheric flash tank will be between 1 m and 3 m in diameter and is typically used as a vessel to receive fluid e.g. brine during well testing, start-up or in the event of operational issues. The brine will flash inside the vessel and the steam component will discharge to atmosphere. Brine collected in the AFT is pumped to the reinjection wells for disposal (see Figure 3.11).

Figure 3.11 : Typical geothermal separator and Atmospheric Flash Tank (AFT / Silencer)

Steam gathering system

Steam exiting the separator is collected in a steam header and transported to the power plant. Condensate collection drain pots (CCDPs) located at low points on the piping will be used to collect condensate generated in the piping system. These will be discharged to a storage sump for disposal. High point vents (HPVs) will be used to collect non-condensable gases (NCGs). The piping is typically wrapped in calcium silicate and / or fibre-glass insulation material and an aluminium cladding.

Upstream of the power plant, a steam scrubber is utilised as a final condensate removal stage to ensure that the moisture content of steam is as low as possible prior to admission to the turbine. The geothermal condensate removed from the steam will typically be sent to storage sumps and pumped away for injection at WW-03.

The steam venting and pressure control system is used for the following:

- "Trim" system pressure by venting steam to maintain the desired interface pressure on entry to the turbine;
- Vent steam in the event of system upsets (i.e. turbine trips); and
- steam is vented to a rock muffler to control the release of pressurised steam and attenuate noise associated with this.

During normal operation there will be a small flowrate of steam through the vent system to maintain steam pressure on entry to the turbine. A typical vent system, vent valves and rock muffler from a large steamfield is shown in Figure 3.12.

Figure 3.12 : Vent system

Storage sumps

Storage sumps are used to collect brine or condensate that is discharged due to operational issues. Storage sumps will be located at each of the well pads. It is anticipated that emptying of the sump at WW-P1 will be to reinjection wells WW-01 and WW-R1 via the reinjection pipeline. A typical sump is shown in Figure 3.13 and is approximately 20 m x 40 m x 3 m deep.

Figure 3.13 : Storage sump

Condensate collection and disposal system

Condensate is typically produced in two locations:

- within steam pipes due to temperature differences within the pipe and surrounding atmosphere; and
- discharge of excess condensate from the cooling tower basin.

Condensate is produced within steam pipelines and collected via a Condensate Collection Drain Pot (CCDP), found at local low points on the route, and then disposed to the storage sump. A typical CCDP is shown in

Figure 3.14. If a steam condensing turbine option is selected condensate will be collected from the cooling tower basin. While some of this condensate is re-used inside the cooling tower to make up for losses due to evaporation and drift, the balance will be disposed of via a dedicated pipeline to WW-03. The volume of condensate produced is low compared with brine produced and therefore will not impact on performance of WW-P1.

Figure 3.14 : Condensate collection drain pot (CCDP)

Brine Collection and Reinjection System

The brine from the separator passes through a brine collection drum into a network of pipes that will feed the brine to wells WW-01 and WW-R1 via gravity. There is a degree of uncertainty around the injection capacities of the two wells and the volume of brine produced. In the unlikely event that the injection capacity does not meet the requirement two possible solutions can be implemented. Firstly, a pump station could be installed at WW-R1 prior to operation in order to increase the brine pressure into WW-R1 and increase the combined injection capacity of WW-R1. The quantity of pumps required is a decision made later in the project design. Secondly well WW-R1 may be stimulated by pumping cold water from the Roseau River at a rate of 20 litres per second over a one month period.

The pipeline will also have drains at any low points for draining down the line on shutdown in order to prevent silica polymerising in the lines due to stagnant conditions. These drain points will be connected to the sumps at the injection well pads for subsequent disposal into the injection wells.

3.9.4 Power Plant

This section discusses the options for electricity generation to allow various impacts for each of the two suitable technologies to be established and assessed in the ESIA. The feasibility analysis identified two suitable power plant technology options:

1) Single flash steam condensing cycle; and

2) Organic Rankine Cycle.

It is proposed that suppliers will be invited to offer power plants based on a clear set of technical specifications for the project. That while not prescriptive of the technology to be used, the technical constraints will result in one of the two options above being utilised on the Project.

Single Flash Steam Condensing Cycle

Geothermal steam from the separator is used directly in a steam turbine connected to a generator. After the steam passes through the steam turbine it is condensed for reinjection. Figure 3.15 presents the single flash plant process.

Steam enters the turbine from the steamfield and the flow rate is modulated by a control valve called a governor valve. Excess steam is vented through an upstream steam vent system consisting of a pressure control valve and rock muffler (which is part of the “steamfield”). Immediately upstream of the governor valve is a main stop valve that shuts if the turbine trips. The geothermal steam is passed through the turbine providing motive force to rotate the turbine and generator. The steam then exhausts into a condenser at a pressure of about 0.1 bara (i.e. under high vacuum). Figure 3.16 provides an indication of the size of plant envisaged for the Dominica project.

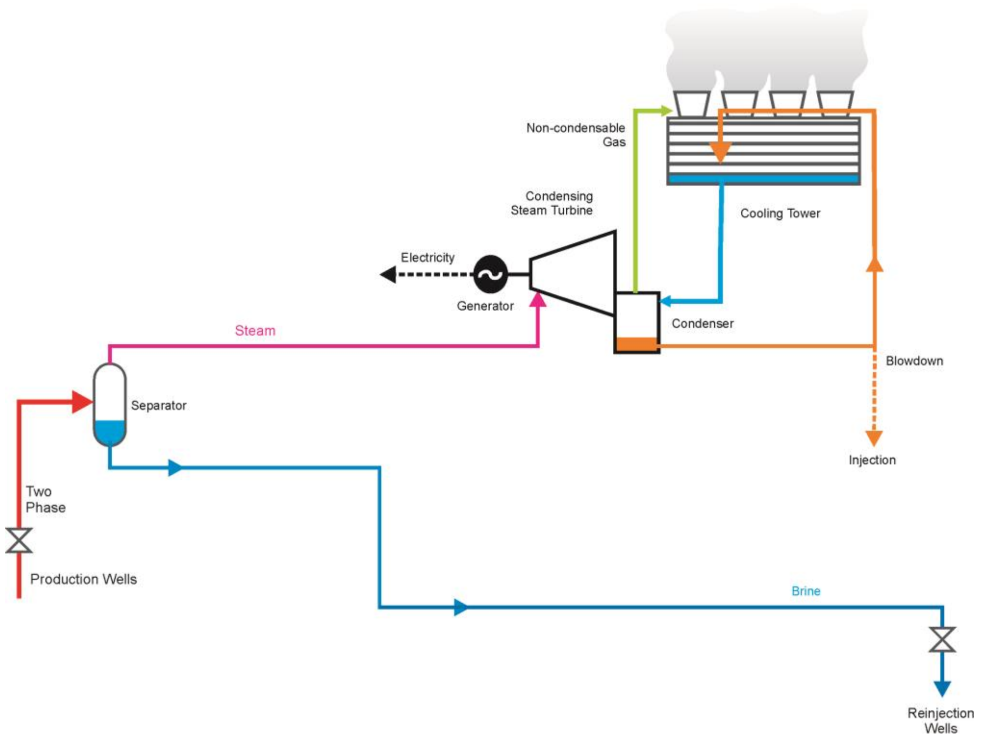

Figure 3.15 : Typical geothermal single flash steam condensing cycle

Figure 3.16 : Condensing Steam Turbine (Source: GDA - http://www.gdareno.com)

Condenser

The purpose of the condenser is to condense the steam, creating a vacuum and thereby generate more power due to the higher pressure differential and higher heat drop across the turbine. They rely on cool water (which comes from previously condensed steam that has passed through the turbine) being directly sprayed into the steam to condense it.

Gas Extraction Equipment

In order to maintain the vacuum in the condenser, the non-condensable gases (NCGs) must be continuously removed from the condenser. This is accomplished by use of a gas extraction system, steam-driven ejector or steam ejector / ring pump (hybrid). The type of system is determined during the bidding for the plant, and can be influenced by the value attached to steam used in the ejectors.

Whatever the approach, the NCGs extracted from the condenser are piped to the cooling tower where they are discharged to the atmosphere in the warm plume of moist air and dispersed to the environment.

Oil System

A lubricating oil system is required for the turbine generator units. The system includes pumps, coolers, oil tank, filters and purifiers. As mitigation for leakage or spills, oil containment bunds / trays are normally specified around or under all lube oil equipment to contain at least 110% of the total oil system capacity.

Fire Detection and Protection

The plant will include a fire detection and protection system to prevent damage to the cooling towers and oil containing equipment including the turbine-generators and oil filled transformers. This would likely comprise a fire ring main and include monitors (spray cannons) covering the cooling tower.

A fire-fighting water tank will be required and sized in accordance with NFPA 850 (Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations). Monitoring systems associated with the fire protection system will be spaced around the site as required by the relevant fire service standards.

Organic Rankine Cycle

This technology requires geothermal fluids to pass heat to an organic working fluid which boils and the organic vapour then drives a turbine connected to a generator. These are often also called ‘Binary Cycle’ plants because they use two fluids (the original steam and the organic secondary fluid). Figure 3.17 shows a typical binary plant which uses steam as is proposed for Dominica.

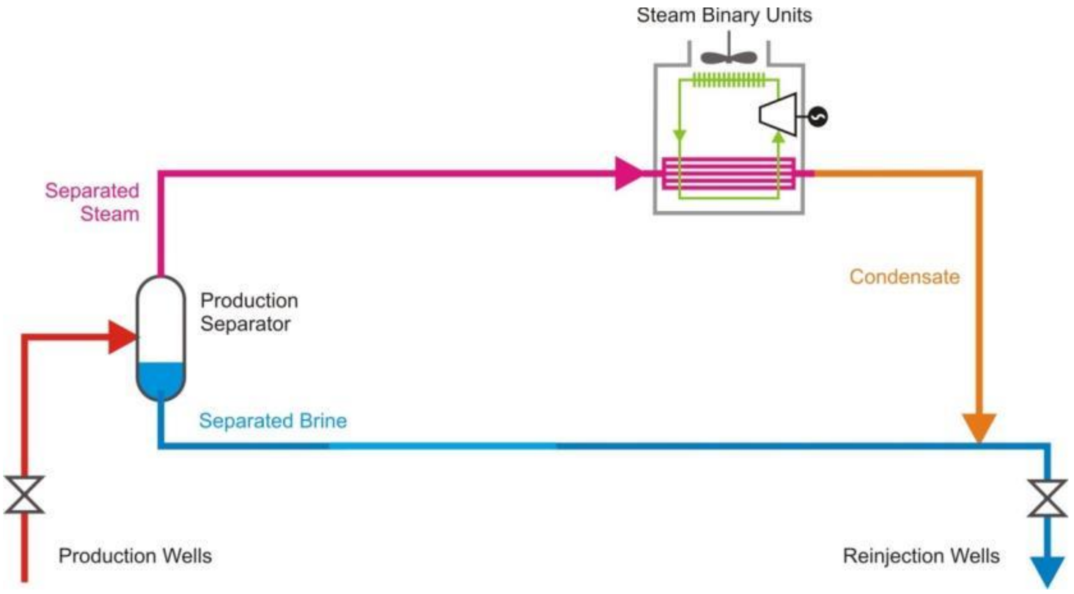

Figure 3.17 : Typical geothermal Organic Rankine cycle

Most working fluids employed for power generation with binary processes are flammable. Isopentane or N-pentane is a typical working fluid and is recommended for this Project. Being flammable it brings requirements for safe design, construction, operation and maintenance. The working fluid must be topped-up on an ongoing basis which means that the fluid must be imported and stored safely over the life of the project.

The heat exchangers in a binary plant transfer the energy of the geothermal fluids to the working fluid, see Figure 3.18. They are usually shell and tube type. In a typical plant a pre-heater and a vaporiser will be utilised. Typically, the brine will pass through the pre-heater and heat the working fluid to its boiling point. The steam condensing in the vaporiser will then vaporise the working fluid after which it is delivered to the turbine or expander. The number of heat exchangers will be at the discretion of the EPC Contractor.

Figure 3.18 : Binary plant heat exchangers (large plant example)

Working Fluid Pumps

The working fluid is circulated in a closed system at elevated pressures in order to extract the maximum amount of power for a given resource condition. Pumps are used to circulate the working fluid around the cycle. The pumps will be supplied by the EPC Contractor.

Fire Protection

Due to the flammable nature of the likely working fluid a comprehensive fire protection system will be required. A binary plant using hydrocarbon working fluid such as n-pentane will require a full firefighting system comprising water storage tank (up to two hours supply), fire water pump and jockey pump, fire-water mains, and hydrant/monitors. There will also need to be a fire detection system, plus hydrocarbon gas detectors that would identify any potential leakage.

At the power plant, the fire protection system comprises a fire ring main and spray system that covers the physical plant, and an inert gas (CO_2, “inergen” containing a mixture of nitrogen, argon and CO_2, or similar) discharge system for the control room and building annex.

A fire-fighting water tank will be required and sized in accordance with NFPA 850 (Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations). Monitoring systems associated with the fire protection system will be spaced around the site as required by the relevant fire standards and regulations.

3.9.5 Power Plant Cooling Options

A cooling system is required to reject heat which cannot be converted to electric power. In the case of the condensing steam turbine plant this is always an evaporative water cooling system because cooled water for subsequent heat rejection by evaporation is freely available from the steam which is previously condensed in the process.

In the case of the binary plant the cooling system is almost always air cooling. This is because the binary fluid leaves the binary turbine as a vapour which must then be condensed without direct contact with another fluid because it is reused again in the process. The condensation can be achieved either by air (dry) cooling or water (evaporative) cooling. The cooling process will be confirmed by the EPC Contractor during bidding.

The main differences between the evaporative (wet) cooling option and the air (dry) cooling options are: the land area required for the cooling towers; overall efficiency; visual emissions or plumes, the reinjection load and the total installed cost (Figure 3.19).

- Wet cooling towers are typically used with condensing steam Rankine cycle plants. Water cooling towers have a visible plume of water vapour when the relative humidity of the atmosphere is high and are particularly visible on cool mornings – this is because the air flow leaving the tower is 100% humid. Towers can be configured so that there is some sensible heating of the air flow leaving the tower which reduces the humidity below 100% and alleviates the visible plume as it leaves the tower. As a large part of the steam condensate is evaporated, the total amount of liquid to be reinjected is less than for air cooling.
- Air coolers have a larger land footprint than water coolers. Air coolers do not have a visible plume of water vapour or emit condensate, but may exhibit a heat haze.

Figure 3.19 : Air cooling for 9MW binary plant (left). Evaporative cooling tower – only 1-2 cells likely required for Dominica project (right)

3.9.6 Use of Water

Potable Water Supply

A potable water supply will be required for the geothermal development for drinking water, showers, toilets and kitchen facilities. The quantities of water required will be small as only a small work force (2 or 3 staff) would be required. Options for water sources include taking water from local streams or rivers, rain water or deliveries of bottled water. Water take from local streams will require filtration and biological treatment. The most likely solution is:

- drinking water delivered; and
- rainwater collection for showers (if permitted) and cleaning.

Sewage Treatment

Due to the number of workers living on the site at the worker's camp, a package plant will be required for sewage treatment. The package plant will be located on ground designated for the worker's camp. All fluids discharged from the package plant will comply with international standards (i.e. the WBG EHS Guidelines).

Supply for Fire Water

Fire water supply is likely to require tank water consisting of a minimum 500 m^3 to be on standby. A tank size in the realm of 12 x 5 m is envisaged and this is likely to provide 1.5 hours of firefighting capacity. Water requirements for fire protection will be aligned with the power plant technology choice and specified in bidding documentation.

Stormwater Management

Stormwater management will be required throughout construction and operation of the project infrastructure, taking account of well pads, steamfield equipment and power plant location. Stormwater run-off from buildings and yards will be collected and discharged to local watercourse. Contaminated stormwater (e.g. oily water, hazardous substances) will go to a three stage interceptor before discharge to watercourse. It is not considered feasible to use the reinjection line for any contaminated stormwater.

3.9.7 Road Network

The road and track network for the Project existed prior to the geothermal drilling campaigns, although works were required to allow passage of the drilling rig. Road access to the well pads and power plant site has previously been established by the Government. Minor remedial works may be required for the existing road and track network, especially around the preferred reinjection pipeline route, but no new roads or tracks are needed.

3.9.8 Electrical Equipment

For each technology option, the layout and design of the electrical equipment will be similar but subject to constraints imposed by the technology chosen. The energy contained within geothermal steam is converted to electrical energy using a steam turbine that is mechanically coupled to a generator. Figure 3.20 shows a typical generator. The electrical power from the generator will be transmitted from the power plant using insulated cables, at 11 kV, allowing connection to the existing DOMLEC 11 kV network at the Trafalgar and Laudat Hydro stations without adding a step-up transformer.

In order to safely operate and transmit electrical power from one location to another an indoor switchroom will be built. This facility will house equipment required to de-energise and protect incoming / outgoing lines / cables etc. Typical switchroom equipment includes circuit breakers, surge arrestors, current transformers and voltage transformers. During operation little work is required to maintain the electrical systems

Figure 3.20 : Typical 5.8 MW generator (Ngawha Power Station, New Zealand)

3.9.9 Grid Connection

The new geothermal power plant will evacuate power at 11 kV through new three underground cables that will connect to the existing 11 kV switchgear at Laudat Hydro Station. These three new underground cables will run through land to be acquired for the power plant and through land owned by DOMLEC. They will be run under or directly alongside the proposed access road into the Project site. The length of this route is approximately 440 m. The proposed connection arrangement is provided in Figure 4-13.

For installation, trenches will be dug in which the cables will be laid and the trench backfilled. There is the potential to create sediment containing run-off when the trenches are open. This run-off will be handled as part of the mitigation measures proposed for civil construction works in general. Once installed, there will be no visual impact, nor impact on the use of the roads or amenities as they are underground. Therefore, no mitigation specific measures are required.

In addition to the 11 kV underground cable connection to the Laudat Hydro Station, DOMLEC are to also carry out ancillary works on the network. This includes the rebuild of the existing transmission line from Trafalgar Hydro Station to Fond Cole Power Station, which was destroyed by Hurricane Maria. As it represents an opportunity to build back better, DOMLEC have opted to upgrade the line to be capable of operating at 33 kV as part of this rebuild. That entails fitting slightly longer insulators which suspend the transmission wires from the poles. Also, they will extend the line from Trafalgar Hydro Station to Laudat Hydro Station to provide a 2nd circuit using the existing poles. These measures are to improve DOMLEC’s network capacity, capability and flexibility and will be carried out even if the geothermal power plant is not developed and as such are not considered to be an associated facility as defined under Performance Standard 1. The construction method to be used for the rebuild will be determined by DOMLEC.

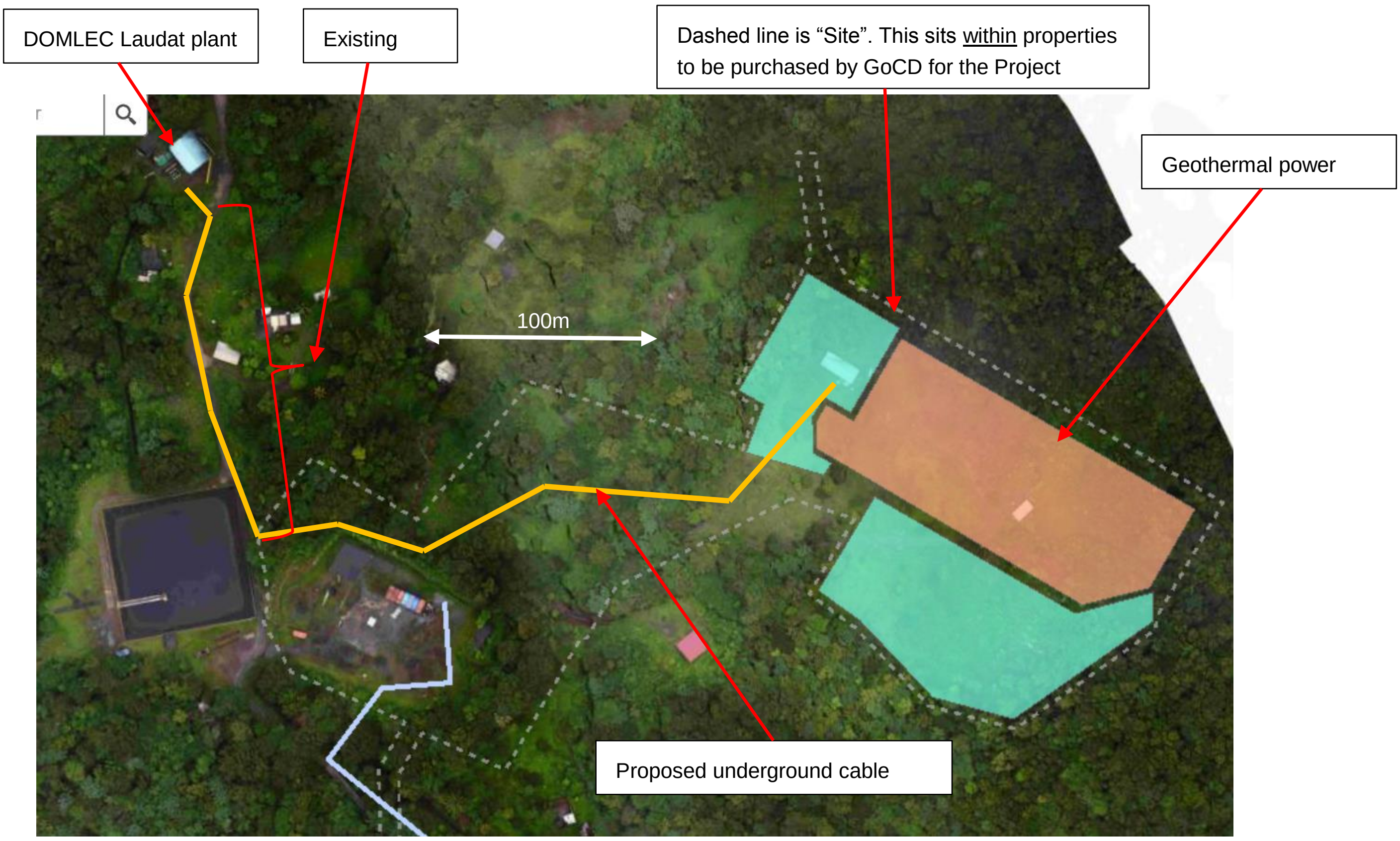

Figure 3.21 : Proposed connection with DOMLEC Grid

3.9.10 Hazardous Substances

Once upfront design measures for hazardous substances include: secure safe storage (tanks) in a bunded area with signage in place. Bunding is usually specified to contain at least 110% of the volume of the largest tank and piping inside the bunded area. Hazardous substances which require management include:

- All geothermal fluid should be captured and sent to injection wells for re-injection. This is standard practice at most geothermal developments. Geothermal condensate contains few hazardous materials, although they can be rich in boron which will tend to accumulate in the cooling tower sludge. The pH of this fluid is between 6.0 and 8.5.
- Working fluids for ORC cycle power plants. It is anticipated that n-pentane will be used as the working fluid and therefore this is considered as part of the ESIA assessment.
- Acid (normally sulphuric acid) for pH modification of geothermal fluids to avoid silica scaling. This is not expected to be an issue for the envisaged steam separation pressures and so acid use and storage is unlikely.
- Antiscalant for prevention of calcite formation in the production well is likely to be required. This will be a poly-acrylate or poly maleic acid.
- Sodium Hydroxide / Caustic for dosing to ensure the pH of the cooling water circuit is kept within appropriate limits. A system using pre-mixed sodium hydroxide is typical, although this may not be available in Dominica and it may be necessary to pre-mix the solution on site using bagged caustic soda.
- Biocide dosing for wet cooling towers to prevent build-up of biologic growth such as algae. Sodium Hypochlorite (NaOCl) is typically used.
- Cooling tower water dispersant(s) are chemicals that inhibit or prevent scale formation in the tower. As with caustic soda and biocide a bunded storage area is typical for all chemical storage tanks or containers.

Sumps would be provided to allow removal of hazardous chemicals with permanently located submersible pump(s) discharging into the cooling tower basin.

- Lubricating oil can cause adverse environmental impacts if leakage occurs. Plant areas will be bunded and have oily water separators to ensure any leaked or spilled fluids do not contaminate the site.

3.10 Decommissioning

Geothermal developments by their nature and design are intended to be renewable and sustainable operations for developing electricity. Decommissioning whole geothermal developments is a rare operation as generally, if the resource conditions are still favourable, equipment can be refurbished or replaced. Power plants can undergo mid or end of life refurbishment at the end of their design life to upgrade and repair equipment to enable operation and generation to continue.

Decommissioning or replacement of equipment throughout the life of a geothermal development is a common occurrence as most equipment, such as pumps, valves etc will have design lives of about 15 years.

For the Dominica geothermal development, it is assumed that design practices will allow for the full decommissioning of the power plant and steamfield, should that be required at the end of the plants design life or before if unforeseen conditions make the development uneconomic.

Due to the uncertainty of when the processes will occur, the potential impacts of decommissioning activities will not be considered in the ESIA.

4. Project Justification and Assessment of Alternatives

4.1 Project Justification

4.1.1 Policy Background

Dominica has struggled to keep pace with other economies in the Eastern Caribbean region. For a number of years, all Organisation of Eastern Caribbean States (OECS) countries have been experiencing a cycle of low growth, high debt, limited fiscal space, exacerbated by a number of exogenous shocks such as the loss of preferential access to European markets; contraction of foreign direct investment due to the 2008 global economic crisis; and natural hazards that frequent the Caribbean. In this context, economic growth in Dominica has been poor. Dominica's development prospects critically hinge upon improving productivity that will enhance its competiveness in traditional economic sectors and assist in developing new ones.

The proposed project is consistent with the Regional Partnership Strategy for the OECS for the period FY15-19, which focuses on three main areas of engagement:

- Competitiveness;
- Public sector modernisation; and
- Resilience.

The RPS has identified the development of geothermal in the OECS, and specifically in Dominica, as a priority area for support.

The project also aligns with the GoCD's Growth and Social Protection Strategy (GSPS) for 2014-2018, which seeks to increase the use of geothermal to improve growth. The GSPS highlights three main objectives for the energy sector, which include:

- Containing energy costs;
- Encouraging energy conservation; and
- Diversifying energy sources and reducing reliance on fossil fuels.

Developing renewable energy, especially geothermal, is considered a solution to achieve several of these objectives and ultimately help achieve Dominica's quest for greater competiveness, higher growth and long-term sustainability.

The proposed project is also consistent with and supports regional and global development objectives including:

- It fulfils part of the Nationally Developed Contributions made by Dominica to address global climate change under the Paris Agreement;
- The affordable and clean energy and the climate action goals of the Sustainable Development Goals; and
- The efforts to double the share of renewables in the energy mix by 2030 under the 'Sustainable Energy for All' (SE4ALL) initiative – both efforts established under the auspices of the United Nations.

4.1.2 Power System

Dominica's power system relies heavily on diesel fuel imports to generate electricity. As with many other island nations, Dominica's primary source of electricity production is from diesel generation, which exposes the country's economy to price uncertainty in regard to the cost of diesel imports. The power system is operated by DOMLEC, a privately owned organisation that has the exclusive licence to transmit, distribute and supply electricity on the island, and a non-exclusive licence to generate electricity. The electricity industry is regulated by the Independent Regulatory Commission.

Changing the power generation mix and reducing the cost and volatility of electricity prices have become development priorities for Dominica. Being a relatively young volcanic island, Dominica has significant geothermal resource potential. Therefore, the GoCD has pursued an exploration programme to evaluate the viability of geothermal resource in the Roseau Valley. Geothermal power projects typically connect production wells through a steamfield facility to a power plant which, in turn, is connected to an electricity grid. Geothermal energy extracted from below the ground may take the form of steam, hot water (brine) or a combination of both, and often a quantity of non-condensable gases (mostly carbon dioxide and trace gases). Used geothermal fluids produced by the project are returned to the geothermal reservoir via reinjection wells, which may be located some distance away (i.e. over 1 km) from the production wells.

GoCD is actively moving towards renewable sources of energy such as geothermal energy and away from reliance on fossil fuel energy generation such as diesel. This will assist GoCD meet its development priorities and in reducing greenhouse gas emissions.

4.2 Assessment of Alternatives

The preferred power plant site and reinjection pipeline route were selected through a multi-criteria assessment process. The assessment covered a range of issues including:

- Technical aspects – site characteristics, topographical data, geological conditions, geothermal operating conditions and access requirements.
- Socio-economic aspects – existing land tenure, land acquisition requirements, effects on local employment, health of the local population, impact on tourism operators and safety during construction.
- Environmental aspects – air quality and noise impacts, visual intrusion, the Outstanding Universal Values of the UNESCO World Heritage site, meteorological conditions and traffic volumes.

4.2.1 Do Nothing Option

The do nothing option for the Project would result in the continued ‘status-quo’ for energy generation and reliance on diesel power within Dominica. The proposed Project represents a step change for the GoCD in moving towards renewable sources of energy generation, increase competitiveness and provide improved energy security. Therefore, the do nothing option is not considered viable as it does not meet the Government’s policy objectives.

4.3 Power Plant Siting Options

In July 2016, land around WW-P1 was examined by a field team for suitability to site the geothermal power plant. It was proposed that the new separation plant be located on the western end of the existing wellpad. The remaining space on the wellpad should be conserved for future production drilling. Three areas were identified that may be suitable sites for the development, with relatively modest slope and located in close proximity to existing wellpad, these are described below:

1) **Option 1** - immediately north of WW-P1 is large enough to accommodate a steam condensing plant, with provision to include the Option 1A site for ancillary requirements such as offices and maintenance facilities. Some of this site (1A) is in the ownership of the government as a 3.8 acre parcel of land was acquired for WW-P1;
2) **Option 2 -** is to the south-east of WW-P1 and on approximately the same elevation. Ready access could be formed from WW-P1. The site would be suitable for a condensing plant, but also has a potential use as an extended wellpad for future drilling programs. The local preference expressed by the Site Attendant, following community consultation, was that this area be reserved for potential future drilling; and
3) **Option 3 -** is a larger site suitable for a binary plant. It is located some 100 m north-east of WW-P1 and has a 12° slope to the north which could be readily levelled to form a platform. It is currently used for small scale agriculture.

The preliminary locations of power plant options are shown in Figure 4.1 below.

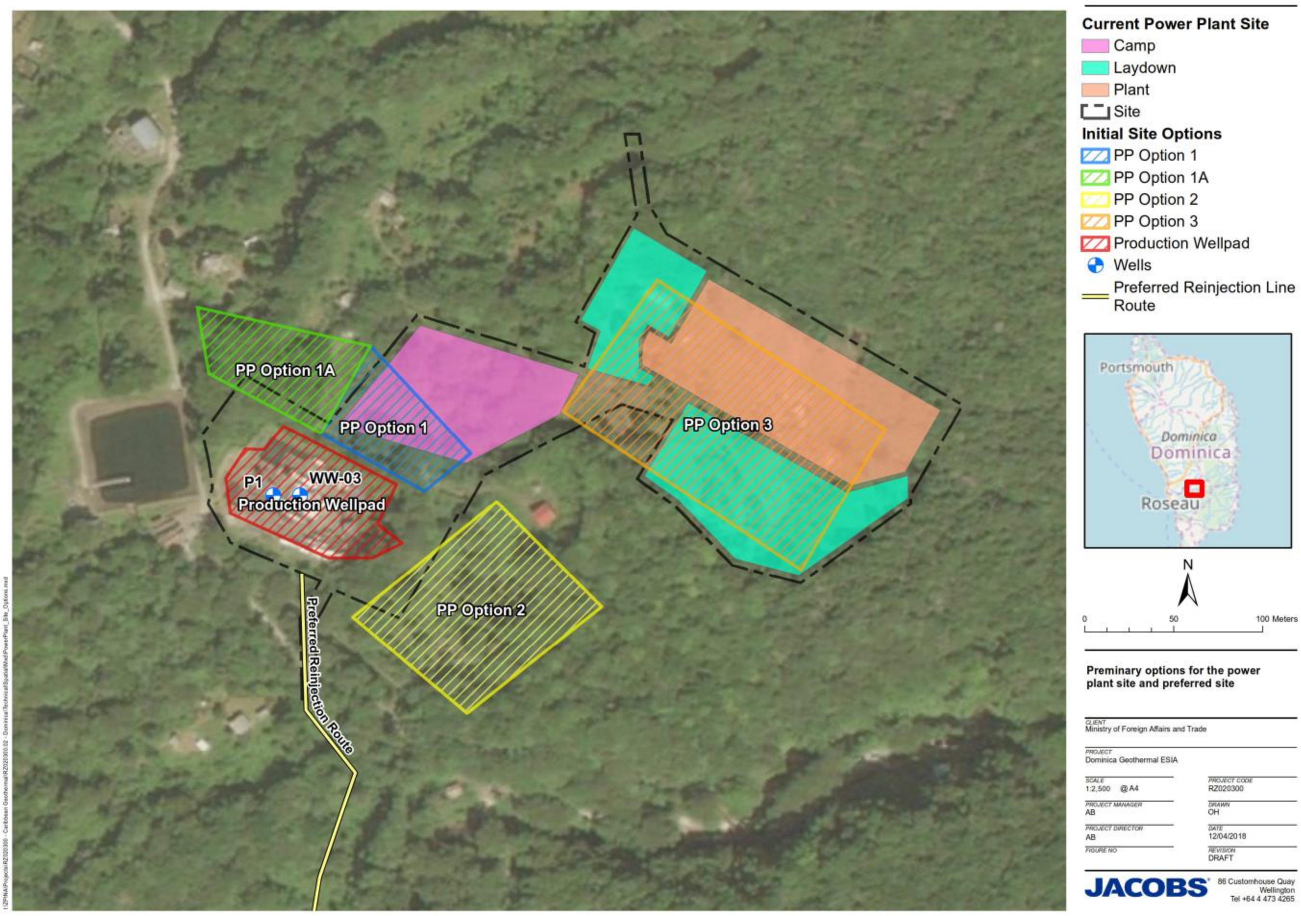

Figure 4.1 : Power plant site options (source: Google Earth, 2017)

After the initial identification of these power plant options, a process commenced to identify potentially affected landowners. No cadastral maps exist for this area and so existing titles were obtained from the Department of Land and Surveys. A surveyor was employed to survey the land and demarcate the areas on a map. Subsequently topographic, environmental and social data was collected to help with the evaluation of the site.

The preferred power plant site (Option 3) was selected was based on an evaluation of technical and non-technical considerations. Technical considerations include the topography of the land, civil works requirements, access constraints, proximity to the production well, alignment with prevailing wind direction and future development considerations. A civil engineer undertook a site visit to evaluate the volume of earthworks required to prepare different options such to minimise disruption and removal of soil. Preliminary process engineering was undertaken to assess impacts of the selected site on the steam gathering system and brine injection line routing.

Social factors include the proximity to the local population, use of topography to shield the site, and the lower/lowest number of affected land owners to reduce acquisition requirements. Biodiversity factors included that the site was highly modified habitat currently 100% used for agricultural purposes and as such there was no impact on natural habitat. This resulted in selection of Option 3 for the power plant site.

Table 4.1 provides a brief comparison of the different power plant site options.

Table 4.1 : Comparison of the Power Plant Options

Item	Option 1/1A	Option 2	Option 3	Comment
Area required	0.70 ha	0.82 ha	1.43	N/A
Proximity to residential properties	• Number of properties within 100 m of residential receivers: 5 • Closer proximity of Option 1/1A to residential receptors than Options 2 and 3. Potential for noise, air quality and visual impacts higher for Option 1/1A than Option 2 and 3. • Modified Habitat	• Number of properties within 100 m of residential receivers: 3 • Closer proximity of Option 2 to residential receptors than Option 3 but further proximity than Option 1/1A. Potential for noise, air quality and visual impacts lower for Option 2 over Option 1/1A and higher for Option 3. • Predominately modified habitat with small amount of low grade natural habitat.	• Number of properties within 100 m of residential receivers: 2 • Option 3 further from residential receptors than Options 1/1A and Option 2. Potential for noise, air quality and visual impacts lower for Option 3 than Option 1/1A and 2. • Modified Habitat	Option 3 considered preferable.
Ease of acquisition	Land owned by multiple owners >2)	Land owned by multiple owners (>2)	Land owned by two owners.	Option 3 considered preferable.

4.4 Steamfield and Reinjection Pipeline Siting Options

Options for steam/brine separation, steam pressure control, steam scrubbing, and start-up, normal and emergency shutdown operations were considered and the land required to achieve these operations, has been determined through a preliminary steamfield design exercise. These are essentially the same for both power plant technology options.

In July 2016, site visits by mechanical and geotechnical disciplines identified eight possible pipeline routes. The routes were evaluated on the basis of the constructability, topography, geohazard exposure (i.e. landslides, rock falls, etc.), estimated capital costs, operational considerations and social and environmental constraints.

From the original eight routes identified, an initial evaluation considering constructability, topography and proximity to local villages reduced these to three options (Figure 4.2)

1) Option A, D and F;
2) Option C, D and F; and
3) Option H and F.

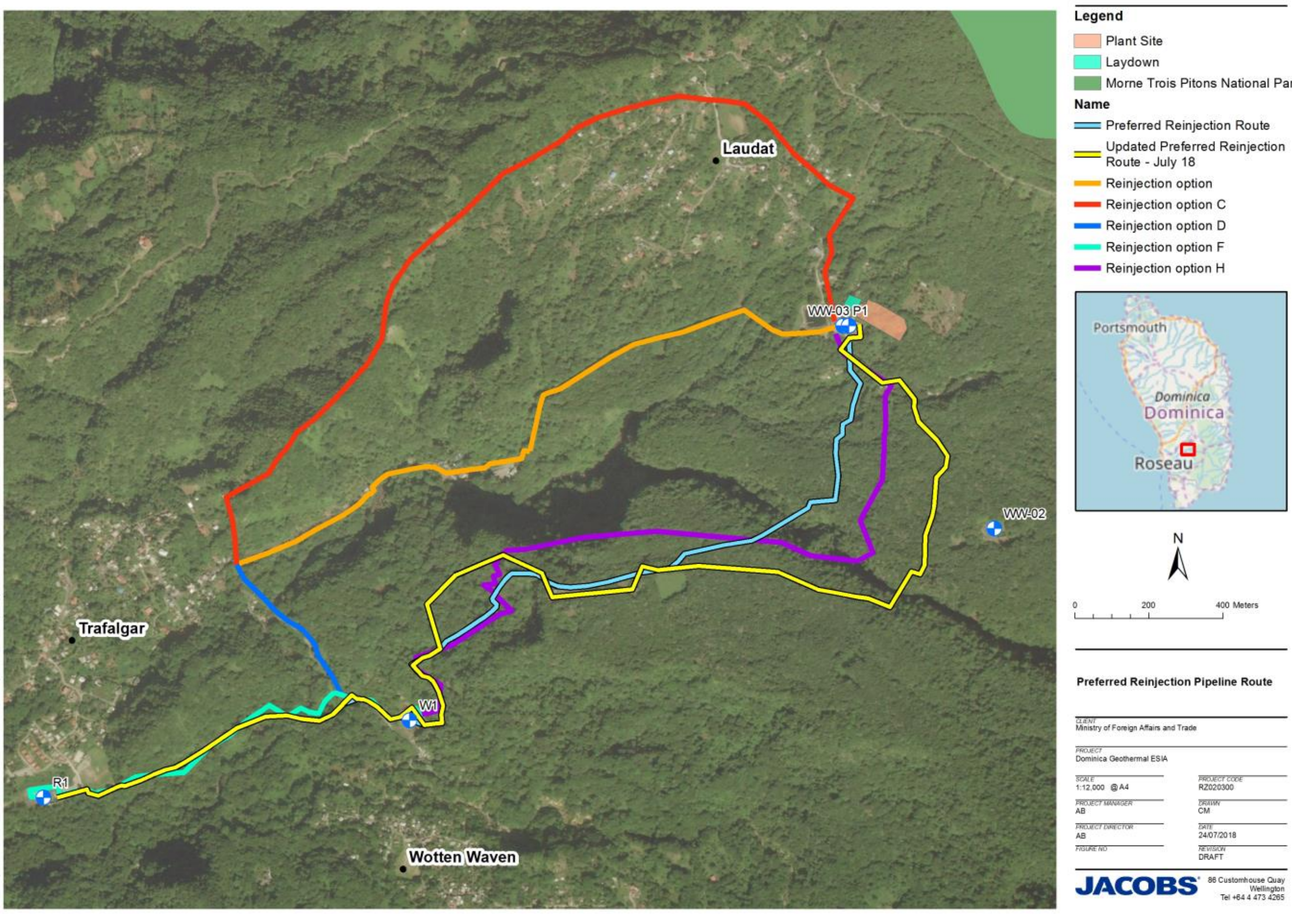

Figure 4.2 : Main re-injection line options investigated in July 2016. Note that this Figure shows a previous location of the power plant.

Option A - Follows DOMLEC's hydropower pipelines across easily navigated topography and would need to utilise DOMLECs existing bridge which currently carries the penstock. Construction would be simpler in this section and there is adequate space for expansion loops. The pipeline would then need to descend the 60 – 80 m vertical cliff, alongside the existing hydro pipeline (Figure 4.3). Once the cliff has been descended, the route runs alongside the river and the road to Trafalgar Falls. Route runs primarily through modified habitat and moderate grade regenerated natural habitat.

Option C – This is the longest route and would require pumping of brine (~80 kW – 100 kW load) from WW-P1 at 554 m ASL to 615 m ASL. The route would follow the existing penstock route, before traversing to the north and west of Laudat to avoid the village itself and associated road/access way crossings. The pipeline would descend down a steep and narrow ridge line on which the Waitukubuli National Trail presently runs. This route is the closest to the Morne Trois Piton National Park boundary and could result in indirect impacts during construction of the reinjection line on the park's biodiversity.

Option D – From the point where the Waitukubuki Trail meets the road, the pipeline would cross the river, suspended above the new Bailey Bridge, before following the road to Wotten Waven and pad WW-01. Route runs primarily through moderate grade regenerated natural habitat with some modified habitat.

Option F – This section of pipeline would go from WW-01 to WW-R1. The pipeline would cross under the road and follow the river before crossing the gorge with a pipe bridge near the river junction. The last 200 m before the football field would follow a narrow track with minimal space for expansion loops. The track has steep slopes and would require rockfall protection. Space for construction in this part of the trail is limited. Route runs through a mix of mainly modified habitat with some pockets of regenerated natural habitat.

Option H - This route would traverse cross country from WW-P1 to near the old aerial tram station. From there the pipe would cross the Breakfast River Gorge using a suspension bridge of 70 – 100 m. The pipeline would then cross relatively flat terrain before descending down a short section of narrow pathway, which broadens and eventually comes out by WW-01. Route runs for 300m along DOMLEC water pipeline, around 500m along the old tramway, and through a mix of regenerated natural habitat and modified habitat being mainly used for horticulture.

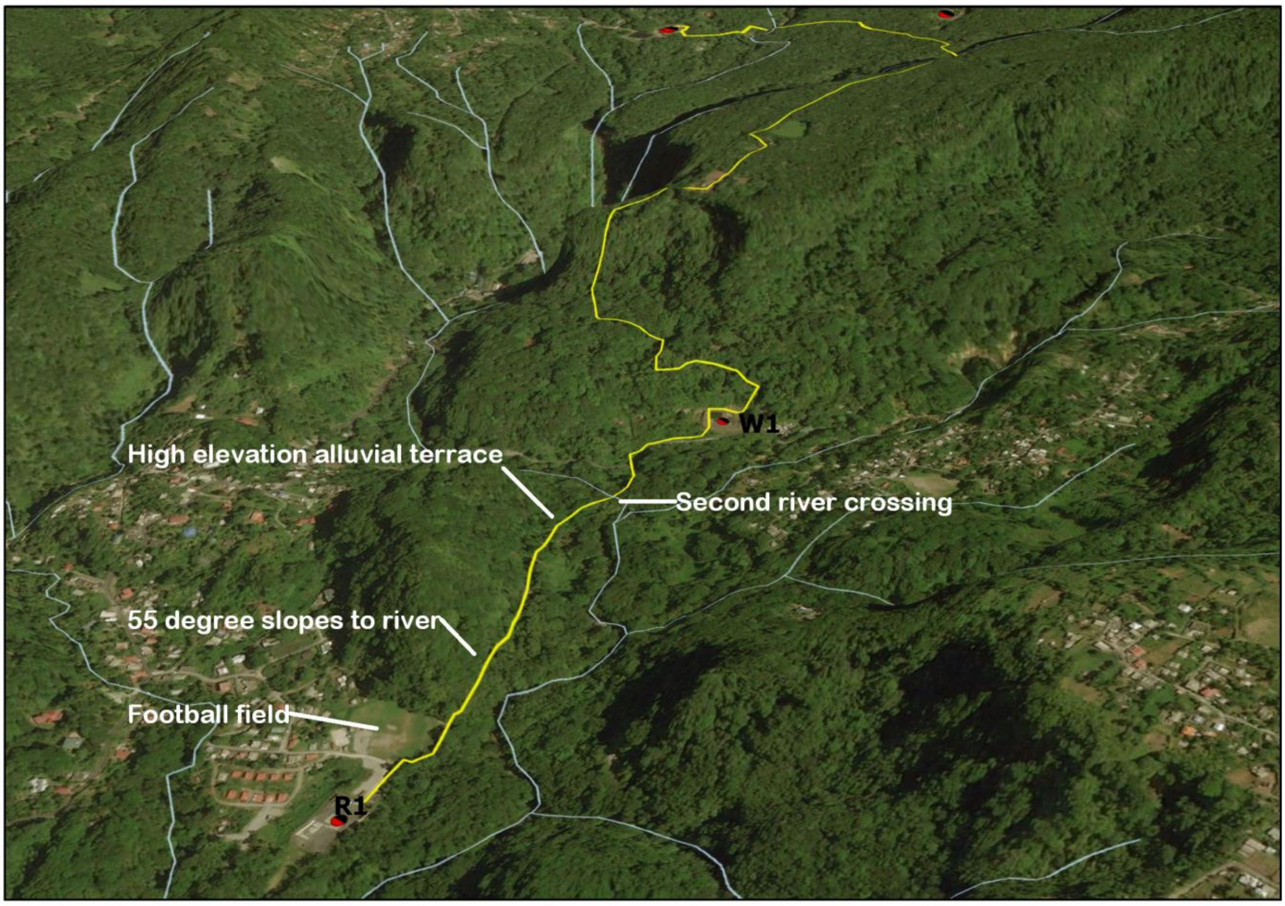

Figure 4.3 : Recommended reinjection pipeline route from WW-01 to WW-R1.

The three shortlisted options were discussed at a public meeting in December 2016 to obtain feedback from the community. This resulted in the removal of Option C (red) as it was deemed to interfere too much with the village. The remaining two options are both technically challenging, requiring steep descents, construction of pipe bridges and river crossings.

In May 2017 a LIDAR survey was flown and the results provided the impetus to select the 'Preferred Option' which has some slight modification as a result of the June 2018 survey (shown in yellow in Figure 4.2), principally based on the detailed topographical data obtained. The Preferred Option also provides benefits over the second placed option (Option A/D) in terms of: disturbance to the local community; potential for interference with existing infrastructure (DOMLEC's hydro power pipelines); possible impacts on tourism at Trafalgar falls; reducing the amount of regenerate natural habitat being removed and long term resilience, by avoiding flooding events which may damage infrastructure. The Preferred Option also avoids areas most severely impacted by flooding and soil erosion from Hurricane Maria, however there are still geotechnical assessments required to be undertaken for the route prior to construction.

4.4.1 Finalising the Reinjection Pipeline Route

The final alignment of the reinjection pipeline can only be determined following preliminary engineering design and subsequently during construction. Further work is required to establish the feasibility of river crossings, alignment based on local topographical features, consideration of environmental impacts and alignment based on land boundaries. This will be completed in close co-ordination between environmental and social scientists and the process engineering, mechanical, geotechnical and civil engineering design disciplines, along with the Government, Land and Survey Division.

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