Environmental and Social Impact Assessment Report for the Paradise Found Development, Barbuda

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For Paradise Found LLC

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Contents

1 Introduction

Smith Warner International Limited (SWIL) was contracted by the proponents of the Paradise Found Development to prepare an environmental and social impact assessment (ESIA) for the establishment of a resort development on the south-west coast of Barbuda. This report was prepared in accordance with the Terms of Reference for an EIA as provided by the Department of Environment, Antigua & Barbuda, and presents the Environmental and Social and Environmental Impact Assessment (ESIA). Within the ESIA, baseline conditions are defined, anticipated project related impacts are identified, and mitigation and monitoring strategies presented.

In 2016 SWI was contracted to investigate coastal setbacks and a drainage master plan for the Paradise Found Development in Barbuda. In 2017 a major hurricane (Hurricane Irma) directly hit the island leading to widespread devastation, with resultant relocation of its population to Antigua. For the first time in over 300 years, Barbuda was uninhabited. As a result, the Paradise Found Development was also halted for a number of years, pending the rebuilding that was critically necessary.

Figure 1.1 Devastation in Barbuda after Hurricane Irma

In 2022 SWI was contracted to investigate how baseline conditions might have changed from the time of the previous contract and to carry out a full environmental impact assessment for the development.

The project site is located on the leeward side of the island to the north of Princess Diana beach and north-west of Coco Point. The property will have multiple phases starting with the construction of a hotel at the south end of the property. Following the hotel construction, ponds will be created that will act as retention ponds on the property for the storage of rainwater, and from which the excavated material will also provide earth fill for raising site elevations.

The project site is very remote and this factor, coupled with the requirement for importation of materials, became major drivers of the concept development. Due to a lack of connectivity to utilities, the property developers have included the following systems in their master plan:

- Reverse Osmosis Plant for the provision of potable water;
- Wastewater Treatment Plant for the collection and treatment of all wastewater on the site; and
- Solar Farm for the generation of electricity on site.

The remoteness of the site also factors into the design of coastal and drainage features. The guiding principles of the design phase were to use the material on the land in the most efficient way possible to reduce importation and equipment costs, and to ensure that there was minimal or no impacts to adjacent areas. In a previous report, SWI provided a detailed description of the baseline conditions and their implications on the design. In Chapter 7 of this report, options for concepts that were considered during the project development process, are discussed briefly. The “No Option” concept is also commented on.

The Project Application number and name are given as *G10-2021 Paradise Found Resort Development in Barbuda*. The site identified for the resort development is contained within approximately 391 acres, which have been (long-) leased to the developer to facilitate hotel and villa development. The application describes the project as a resort mixed-use property.[1]

The development is to be located at the site of the former K Club Development on the southwest coast of Barbuda (Figure 1.2). The terrain of the area is characteristic of Barbuda. The site is low-lying, and many wetland ecosystems and hydraulic features are present. The development is within an area zoned for tourism development.

The Plan application submitted for the development is for 39 individual guest villas (each with a private pool) located in a staggered formation along the beachfront, as well as a signature Nobu Restaurant, beach club and bar, spa and wellness centre, tennis pavilion and kids club. The resort property will also have a small farm and plant nursery, private homes and a back-of-house area with housing and amenities for staff.

[1] Review of Plan Application #G10-2021 (Paradise Found), Department of the Environment April 28, 2021. Department of the Environment, Ministry of Health Wellness and the Environment

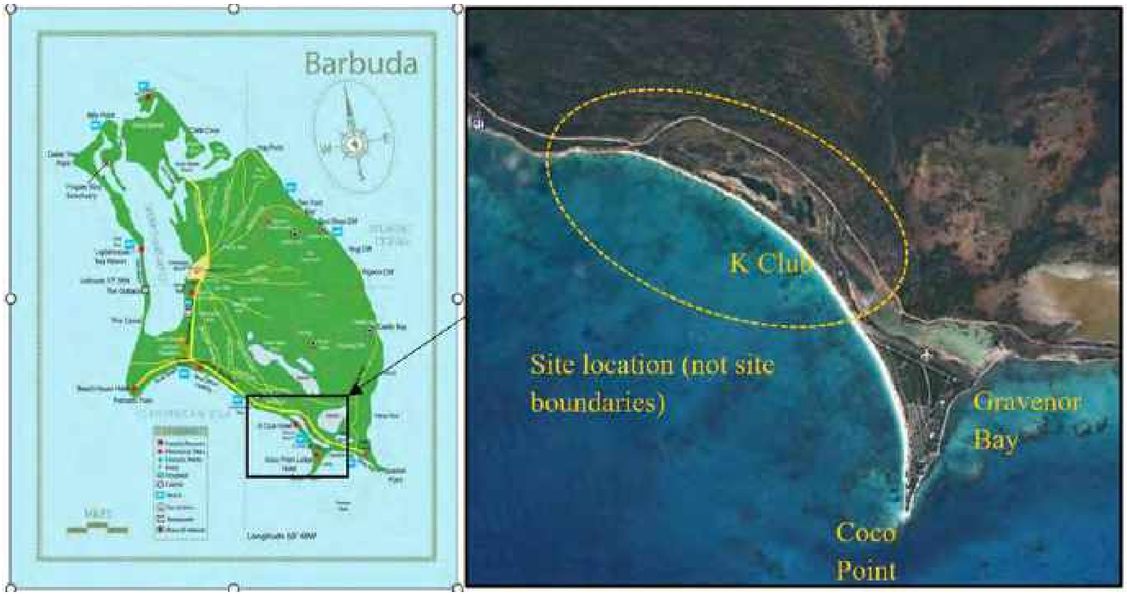

Figure 1.2 Map of Barbuda (left) with inset showing project location

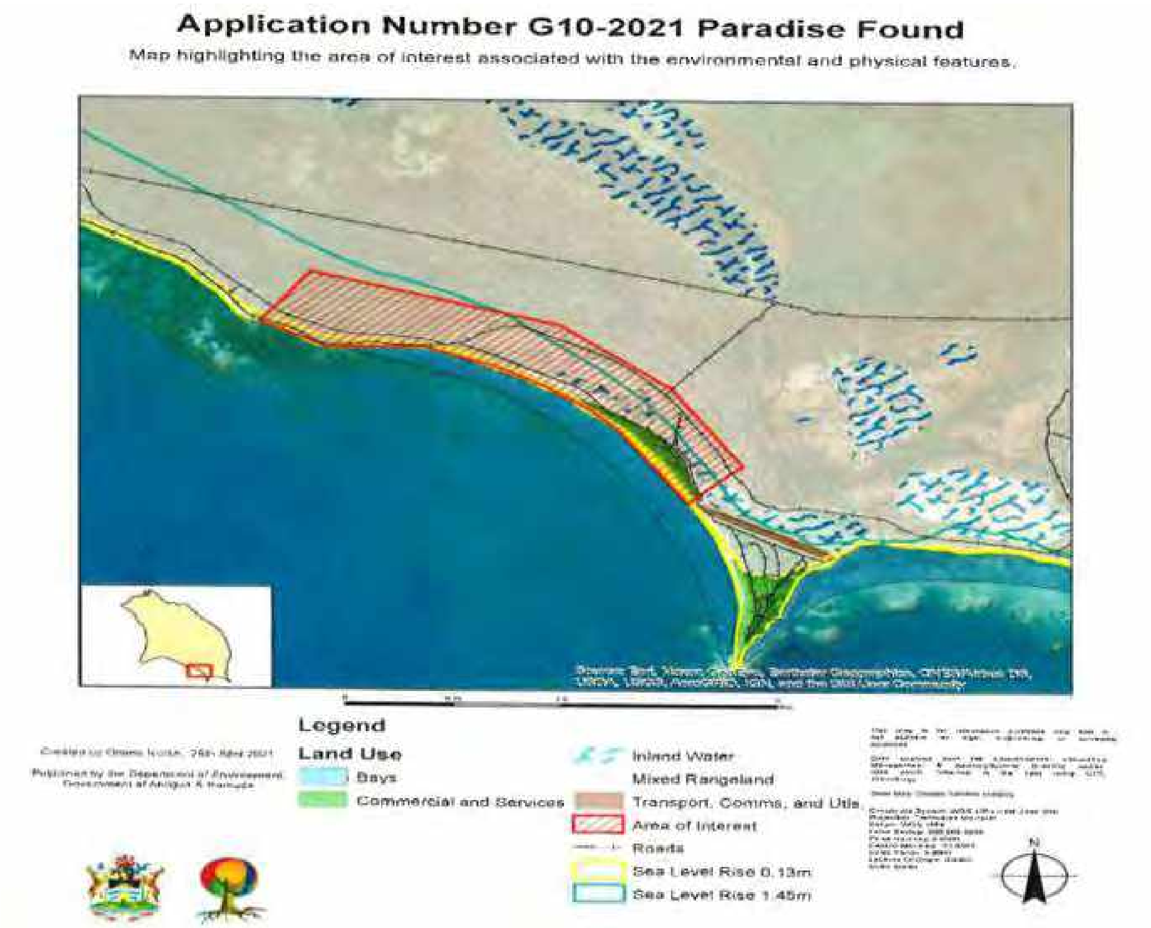

Figure 1.3 Paradise Found development property (in red hatch)

2 Project Description

This project description provides information on the proposed Paradise Found Development, to facilitate the identification of potential benefits and impacts for this ESIA. This present development proposal replaces an earlier version of the Master Plan which envisaged much more intensive/higher density development. As such, this new Plan will have a lower level of potential adverse impacts and will therefore be more "environmentally friendly".

2.1 Project Location

The proposed Paradise Found Development will be situated on the southwest coast of the island of Barbuda, in the vicinity of Gravenor's Bay, Coco Point and Princess Diana Beach (see Figure 2.1).

Figure 2.1 Location map

2.2 Options for Project Facilities, Services and Utilities

As shown in Figure 2.2 this development will include the following facilities:

- Nobu Beach Inn Clubhouse
- Guest Villas
- Arrival Area
- Beach Bar
- Nobu Restaurant / Satellite Restaurant
- Sales Village
- Spa
- Tennis and Kids Club
- Farm and Nursery
- Logistics and Staff Center, and
- Home Sites.

Figure 2.2 Development plan

Due to the remote location of the project and the current lack of infrastructure on the island of Barbuda, the project must develop much of its own infrastructure and support facilities. The ambition of the project is that it should ultimately be as independent as possible in food, water, and energy. The development will therefore include a road network, a drainage system, water supply, electricity supply and its own wastewater treatment facilities.

The following sub-sections provide information on these elements of the development, under the following headings:

- Built Facilities
- Farm and Nursery
- Road Network
- Drainage System
- Water Supply
- Electricity Supply, and
- Wastewater Treatment.

2.2.1 Built Facilities

The term "built facilities" is used here to include all the facilities listed above except the farm and nursery. The proposed numbers of accommodation units within the development are shown in Table 2-1.

Table 2-1 Number of accommodation units

Facility type	Previous Plan Available Number of Units	Current Plan Available number of units
Hotel suites	45	17
Hotel residences	12	17
Hotel estates	0	10
Inland Lots	40	27
Custom Lots	48	43
Golf Course	9 holes	0
Kid's Adventure Park	1	0
Water Park	1	0

Detailed structural designs have not yet been prepared for these built facilities, but the buildings are expected to be a combination of reinforced concrete and timber construction. Buildings will be designed to withstand Category 5 hurricane winds (252km/hour or higher). Similarly, for other project components, some details are still to be finalized. For example, a decision has not yet been made whether the tennis courts will be grass courts or hard courts. One important feature that has been finalized and which must be handled vis-à-vis project risk, is that LPG cylinders will be installed both at the new restaurant and at individual homes. Based on present practice, the cylinders at the new restaurant are expected to be 100-pound cylinders, while those at the individual homes are expected to be 20-pound cylinders.

2.2.2 Farm and Nursery

A farm / nursery will be established to grow plants for use in landscaping the development. A small nursery already exists on site with palms, succulents, and cacti (Figure 2.3).

Figure 2.3 Plants at the existing nursery

2.2.3 Road Network

Roads will be constructed within the site to service the various elements of the development. The roads will be left mostly in a natural state, with select paved areas (approximately 80% natural and 20% paved). In addition, in their Land Lease, Paradise Found was granted the right to re-route the existing boundary road that runs through this property (see Crown Lease dated 9 March 2017 and Memorandum of Agreement between Paradise Found LLC and the Government of Antigua and Barbuda dated 28 November 2014). The road realignment project will be completed in two phases (see Figure 2.5). Phase 1 of the road project will involve re-routing the road towards the perimeter of the property at the north end of the property boundary (adjacent to Barbuda Cottages) and following the perimeter boundary to the location at the center of the property where the existing road crosses to the outside of the property line (see Figure 2.6). The rest of the road location (which is existing and currently in use) would stay the same and follow the outside boundary fence until it reaches the old salt pond road at the south end of the property.

Phase 2 of the road realignment will involve improving and rehabilitating the old existing road that crosses the salt pond at the south end of the property (see Figure 2.7). Currently neglected and dilapidated, this road previously provided access to Coco Point and Princess Diana Beach, and the new road realignment will maintain access to Gravenor's Bay, Coco Point and Princess Diana Beach. The road in this area has existing pipes and culverts underneath that have been damaged because the pipes were uncovered and vulnerable to the elements. In recent years, this road section has been a dump site for construction waste and other debris to stabilize the roadway (see photographs in Figure 2.4). Paradise Found intends to remove all the construction waste and rubbish from the location, re-establish the road, add littoral shelves for planting mangroves and install culverts to assist with the flow of water in and out of the salt pond.

Old Road route

Typical "natural" road

Old culvert

Concrete rubble

Concrete rubble

Figure 2.4 Existing road that crosses the salt pond at the south end of the property

On July 6, 2020, the Department of Environment reviewed an application from Paradise Found to realign the road in the Phase 2 area and concluded that a road should not traverse a flash area (an area where the mangrove habitually overflows). It is clear upon further investigation that the location to which the Department of Environment refers is an existing road that pre-dates the Paradise Found development, not an untouched section of virgin land. Paradise Found therefore intends to restore the existing road while prioritizing the drainage and flow of water from the pond to the immediate north, under the road, and to the mangroves, thereby improving the ecological health and stability of the mangrove area.

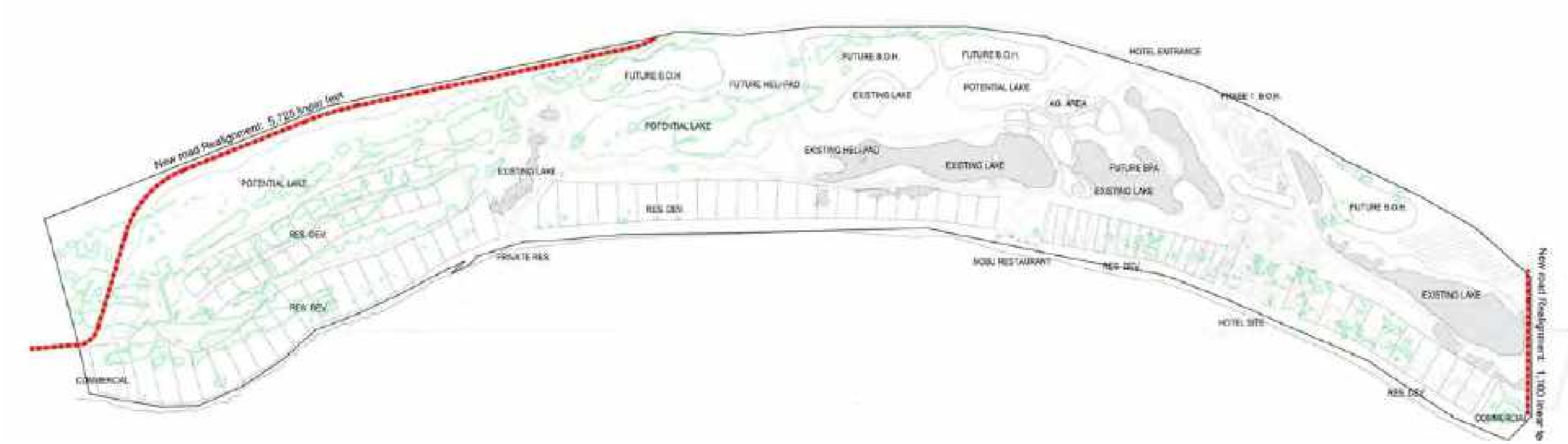

Figure 2.5 Road Realignments Phases 1 and 2

Figure 2.6 Road Realignment Phase 1

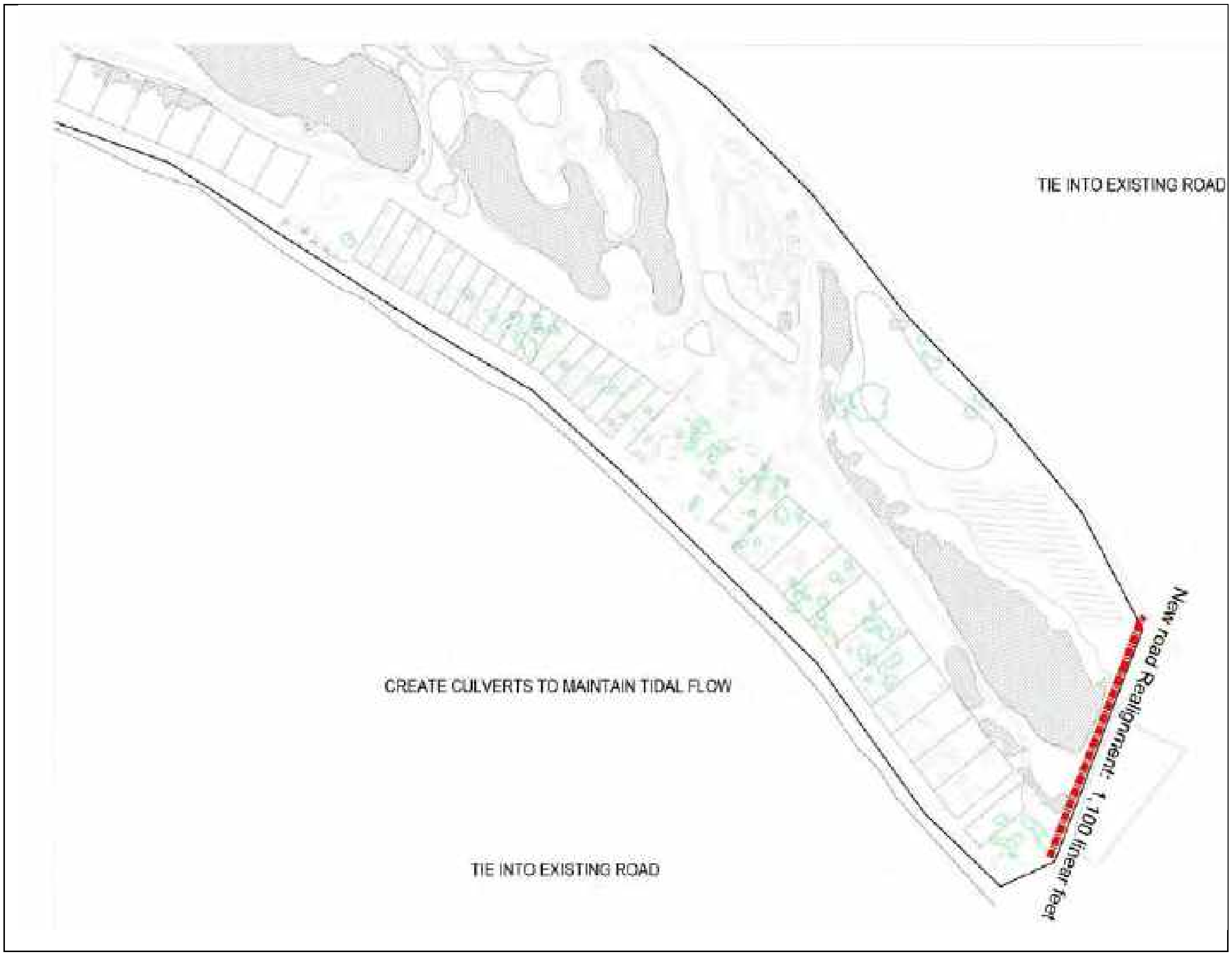

Figure 2.7 Road Realignment Phase 2

2.2.4 Drainage System

As the development is constructed, consideration will be given to the characteristics of catchment zones in each phase, collection of water, transportation or delivery of water, and disposal of water for both surface runoff and closed gravity pipe networks. Using the Rational Method of design, the use of closed pipe networks will be minimized as much as possible and reserved only for situations where the disposal of water is rapidly required, or where directional changes in the flow such as in and around buildings and associated hard-standing areas, decks, pathways, and parking zones is required. The collected water will typically be conveyed in a closed pipe or open channel system to a point of disposal such as a bio-swale, soak-away, detention pond, or a well. Hydraulic gradients, cover levels, and invert levels will be provided for these systems. The sizing of pipes, culverts, and disposal capacities will be determined using Time of Concentration (Tc) and peak flow calculations using IDF curves to determine design rainfall intensities.

The method assumes that when rainfall occurs on an impervious surface, the resulting runoff eventually reaches a rate equal to the rate of the rainfall. The time required to reach this equilibrium is the *Time of Concentration*, *Tc*, for the catchment area. The runoff coefficient *C* represents the components of evaporation, transpiration, interception, storage, detention, and infiltration of the portions of rainfall that do not occur as runoff. The average rainfall intensity, *i*, used in the formula is the rainfall intensity for the *Tc* of the catchment for the storm design frequency occurrence. These may be obtained from Intensity-Duration-Frequency curves such as are shown below for the VC Bird International Airport, Antigua.

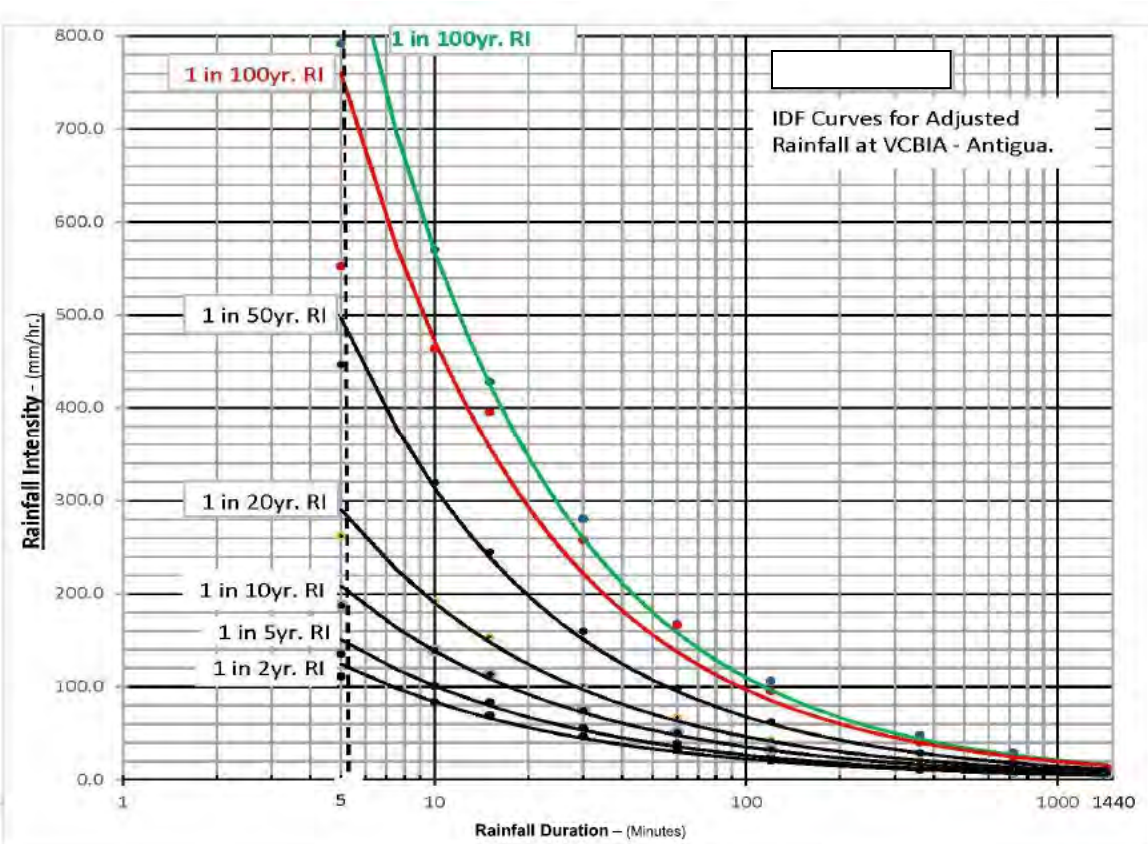

Figure 2.8 IDF Curves for VC Bird International Airport Antigua

The remaining areas of the development site will be addressed in a more holistic and non-disruptive way. Rainfall will be handled more naturally, incorporating surface runoff and subsurface runoff, with the understanding that the existing natural ground facilitates good percolation and subsurface runoff that conveys the water to the existing ponds and low-lying areas, filtering water as it travels. Storm water drainage designs will coordinate with architectural, utility, and landscaping designs as they pertain to manholes, trenches, and site grading, to ensure each discipline does not clash with the other. Rainwater harvesting systems can also be employed in this development, which will also assist in the management of stormwater runoff.

2.2.5 Pollution of Wetlands

The development intends to use structural, vegetative, and managerial solutions to treat, prevent, and reduce water pollution caused by stormwater runoff. Both primary drainage solutions (open channels and/or closed pipe networks) will consider areas of potential contamination such as petrochemical or grease deposits, and interceptors will be located as necessary. Erosion issues are not considered to be significant as hydraulic gradients will likely be small. Still, any final grading or drainage solution will carefully look at that potential and adopt soil stabilization solutions if required. Conversely, gradients will be examined to ensure that siltation issues do not become problematic. Protection of the existing pond ecology will be of paramount importance in any final storm drainage management solution.

Hurricane Irma in 2017 caused significant damage to the salt pond at the southern end of the property. Although Irma was an abnormally large and destructive storm, Paradise Found intends to bolster the strength and health of the mangroves surrounding the salt pond area to protect the pond and the adjacent regions from future storms of all sizes. Paradise Found intends to transplant mangrove plants where possible and restore the mangrove's health by ensuring that its tidal and freshwater hydrology is functioning normally, so that the mangroves can repair themselves over time.

2.2.6 Water Supply

During the operational phases (Phases 1, 2 and 3), the projected demand for potable water for the development is expected to be 250,000 gallons per day (USgpd) in total. Of this, 35,000 gpd will be required in Phase 1 and 115,000 gpd in Phase 2. Accounting for the scarcity of fresh water, this demand will be managed by employing water conservation techniques such as rainwater harvesting, installing water-efficient appliances, and using drought-tolerant landscape plants and turfgrass. The development plans to incorporate rainwater harvesting into as many community buildings as possible. Residential homes will also be encouraged to capture rainwater in individual cisterns for later use on landscape irrigation. These rainwater collection systems will reduce the demand for potable water and hence the need for imported water.

Potable water for the hotel and private residences will predominantly be supplied by Flowtronex on-site seawater reverse osmosis desalination plants (SWRO). There is currently a small SWRO unit (2500-gal capacity) and a well on the development site. To accommodate the new construction, additional wells and larger SWRO units will be required, which will be specified with Energy Recovery Devices (ERDs). The brine water from the current SWRO unit is discharged into the hypersaline salt pond on site. The additional SWRO units will be discharged into an injection well to be located on the property. A test well was drilled, and testing carried out in February 2023. Absorption rates for the development will be verified from this test dig.

It is proposed that the SWRO plant be incorporated over three phases, with Phase 1 incorporating 2 x 36,000 gpd plants thereby providing 100% redundancy. Phase 2 will allow for a further 100,000 gpd production allowing for an uninterrupted water supply. Phase 3 is still to be determined as it will be heavily reliant on landscape requirements. At this stage, a further 100,000 gpd is being planned for.

A minimum of ten days storage supply is planned for the development. This is considered to be sufficiently conservative in the event of a disruption or natural disaster such as a major hurricane. Water from these storage tanks will be piped to individual facilities through a system of buried distribution pipelines, fitted with valves as required. It is envisaged that this flow will be largely by gravity, but pumps will be installed where gravity flow will not be effective.

2.2.7 Electricity Supply

When fully built out, the projected electrical load demand for the development will be 1.5MVA. Due to a lack of existing infrastructure on the island, the electrical power demand will initially be met using diesel generators. To fuel these generators, diesel fuel will be stored on site in 9.1m^3 volume (2,000 Imperial gallons / 2,400 US gallons) tanks. Over time, the reliance on generators will be phased out in favor of more sustainable options, including photovoltaic systems and battery storage. The development will eventually seek to be energy self-sufficient from these sustainable energy sources, while maintaining generators on-site for redundancy.

On developments of this type, overhead electricity cables are aesthetically unappealing, so the electricity distribution system within the development is likely to consist of buried cables installed within PVC pipes. Manholes will be constructed in this system to facilitate the installation of cables and to allow access to the cables for maintenance or repair.

2.2.8 Wastewater Treatment Plant

During the operation phase, the projected wastewater treatment demand for the development is 15,000 US gallons per day (gpd) for the Back-of-House (BOH) and Phase 1 and 2 of the Hotel Component only. As no municipal wastewater treatment option is available on Barbuda, the Paradise Found development will construct a private facility to treat wastewater produced from the resort, while individual beachfront villas will be connected to their own WWTPs. The selected WWTP for the hotel is a Bionest system, which is an aerobic treatment unit that removes wastewater contaminants with the help of biomass that grows on ribbon-shaped plastic supports. These systems will collect toilet waste as well as grey water. The systems for individual villas will likely be smaller Bionest systems if subsurface characteristics are suitable, or simple mechanical treatment systems if they are not.

The Bionest technology is certified to NSF (National Sanitation Foundation) Standards 40 & 245 to not exceed maximum averages of 25 mg/L of cBOD, 30 mg/L of TSS and a 50% Total Nitrogen removal. It also has certification under BNQ (Bureau de Normalisation du Québec) Class III and V for more stringent average effluent criteria of 15 mg/L of cBOD, 15 mg/L of TSS as well as disinfection of less than 200 CFU (colony forming units) of fecal coliform. The product also carries the CE mark which demonstrates it has met European product directives.

The extended aeration fixed film reactor of the Bionest system minimizes biological sludge production and results in a high-quality level of discharge water where 100% of the treated water can be reused. Bionest technology has been tested and verified by third-party entities against protocols recognized in Canada (ETV), the United States (NSF), and Europe (CE Mark) and consistently met and surpassed those standards. The treatment quality of the final effluent will always equal or exceed NSF Standard 40 Class 1. Design effluent quality reported on the Bionest website is summarized in Table 2-2.

Treated effluent will be further disinfected with UV or chlorine and pumped out for landscape irrigation. Excess activated sludge (biosolids) will periodically be pumped out by a sewage truck and safely disposed of on an as-needed basis. Based on Bionest installations of a similar capacity in the Turks and Caicos Islands, this may be required approximately once every 3 - 5 years. All wastewater from the commercial kitchens will pass through a grease trap to remove fats, oil, and grease to minimum levels.

The major advantages of the Bionest system are:

- High level of treatment,
- Clear and odorless effluent,
- Organic and hydraulic shock resistant,
- Small footprint, buried and usually no need for technical building,
- Media never need to be replaced,
- Reliable and long-lasting components, and
- Low operation and maintenance costs.

Table 2-2 Bionest design effluent quality

Parameter	Effluent concentration	EPMA Guidelines 2019
pH	6.6 to 7.8	Min. 6.5 Max. 8.5
Total Suspended Solids	<2 mg/L	
BOD5	<2 mg/L	
COD	<25 mg/L	
Total Nitrogen (as Nitrates)	<12.5 mg/L	50 mg/L
Faecal Coliform (after UV Disinfection)	20 UFC/100 mL	200 UFC/100mL
Faecal Coliform (after Chlorine Disinfection)	0 UFC/100 mL	200 UFC/100mL
Dissolved Oxygen	>3.2 mg/L	>6.0 mg/L
Chlorine Residual (after 30 min Contact Time)	>0.5 mg/L	

Water quality standards and guidelines for coastal waters of Antigua and Barbuda, taken from the Environmental Protection and Management Act, 2019 [No. 10 of 2019]

Given the arrangement of wastewater treatment at individual buildings, there will be no need to provide central sewerage throughout the development. Instead, toilet water and gray water will be routed to the wastewater treatment plants through relatively short lengths of buried sewers. Manholes will also be provided where required to facilitate flow or to permit inspection and clearing of chokes.

2.3 Construction Methods

This section describes methods that are likely to be used in constructing the Paradise Found Development. These are presented solely to facilitate the identification and understanding of potential benefits and adverse impacts of the development. They are not binding on the contractor(s) who will be engaged to undertake the construction works. Instead, each contractor will independently determine the most appropriate construction methods when construction works begin.

The following sub-sections describe likely methods for:

- Clearing and grubbing,

- Earthworks,
- Construction of roads,
- Construction of drainage system,
- Installation of utilities and sewers,
- Reinforced concrete construction,
- Timber construction,
- Finishing of buildings, and
- Installation of wastewater treatment plants.

2.3.1 Clearing and Grubbing

Clearing of vegetation will be required to facilitate the construction of roads, drainage, utilities and facilities, and topsoil containing roots must also be removed (grubbing). This will likely be done using the following methods:

- Mangrove trees will be cut using chain saws only after necessary approvals have been obtained from the relevant divisions of the Ministry of Agriculture, Lands, Fisheries and Barbuda.
- Smaller bushes and grass will either be cut manually or removed using bulldozers.
- Cleared vegetation will be removed from the site in dump trucks to a location where they can be composted, or to the landfill for disposal.
- Grubbing will be done using bulldozers. Grubbed topsoil will be temporarily stockpiled on site for use in landscaping.

2.3.2 Earthworks

Earthworks will be required in areas where the existing ground elevation must be adjusted upward or downward to facilitate construction work, likely using the following methods:

- Excavation to lower the existing ground elevation will likely be done using bulldozers or road graders. Surplus material from such excavation will either be reused on site or removed from site for beneficial reuse elsewhere.
- It is preferable to balance excavation and filling in the design so that all fill material will come from the site itself. If this is not possible, fill material will have to be brought from offsite in dump trucks or other means.
- Regardless of source, fill material will be spread in layers using bulldozers, road graders or front-end loaders and compacted using sheepsfoot rollers or smooth face rollers to achieve the required density and degree of compaction. Successive layers will then be spread and compacted until the target elevation is reached.

2.3.3 Construction of Roads

The cross-section of a typical road is shown in Figure 2.9. To construct this, the roadbed must be compacted using sheepsfoot or smooth rollers until the required density is achieved. Gravel will be brought to the site in dump trucks and spread and compacted in layers as described for filling in Section 2.3.2. If the road is to be paved with asphalt, this will be brought to the site in dump trucks, spread using asphalt spreaders and compacted using smooth face rollers. If the road is to be paved with concrete, the likely method will be as described below in Section 2.3.6.

Culverts will be required to facilitate drainage across specific roads, and the likely construction method for these is described below in Section 2.3.4

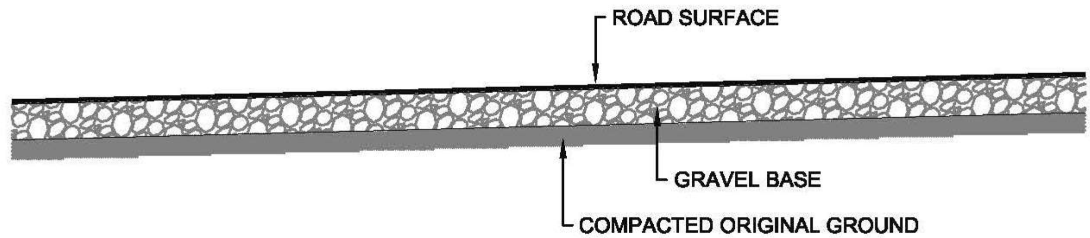

Figure 2.9 Cross-section of a typical road

2.3.4 Construction of Drainage System

This sub-section describes the likely construction methods for earthen drains, paved drains, buried pipe drains and culverts. For bioswales or earthen drains (Figure 2.10) the alignment will be prepared by clearing and grubbing (see Section 2.3.1) and excavation or filling (see Section 2.3.2). The drain itself will then be trenched using a backhoe or an excavator. Surplus material from trenching will be managed as described in Section 2.3.2.

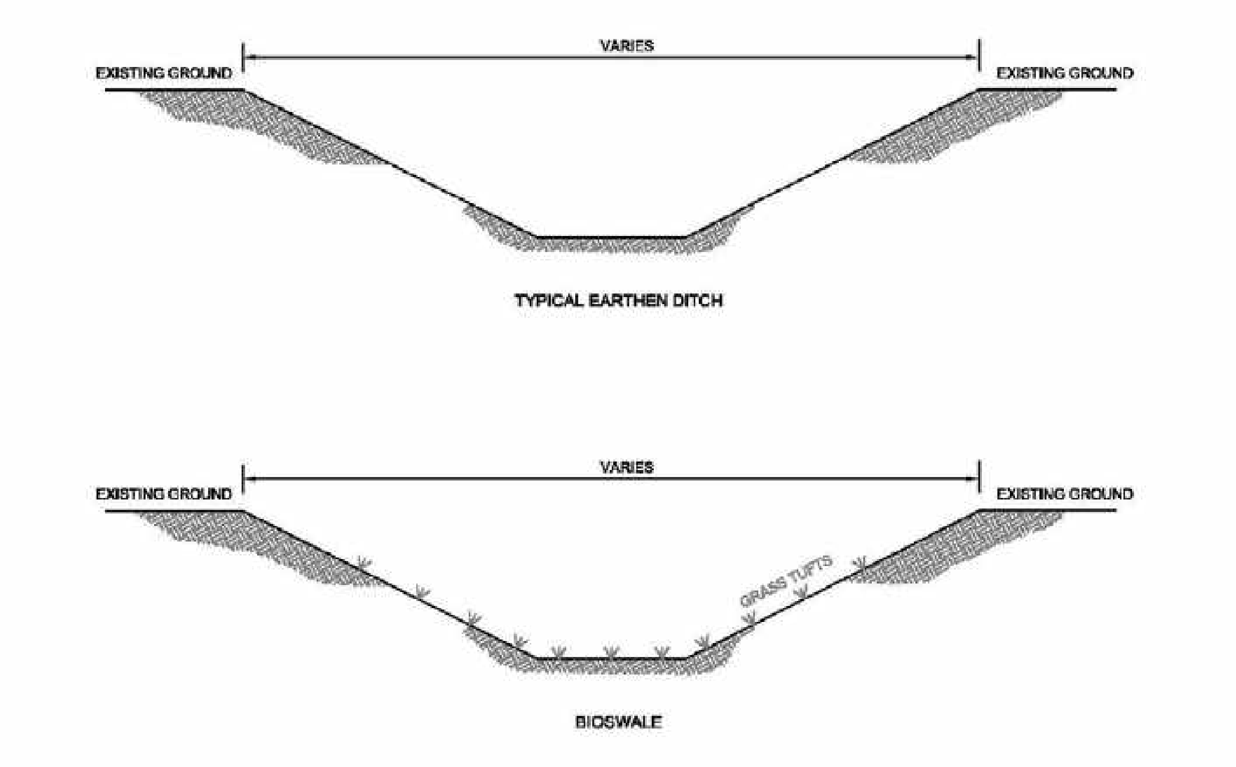

Figure 2.10 Cross-section of typical earthen ditch (top) and bioswale (bottom)

For French drains (buried pipe drains) (Figure 2.11) the precast concrete or PVC pipes must be imported to the site by ship and brought to the site on flatbed trucks. Trenches will be dug along the design alignments using backhoes or excavators, and the pipes lowered into the trenches using HIAB units (concrete pipes) or by hand (PVC pipes). Backfill will then be placed to the sides and over the pipes in layers, with each layer being compacted to the required density using whackers.

Buried drainpipes will be pressure tested in place after they are installed. Given the size and type of the pipes on this development, it is unlikely that chemical treatment of the hydrostatic test water will be required. As a result, the water will not be significantly contaminated after use and can be disposed directly to surface drains. However, if chemicals (such as anti-rusting agents) are mixed into the hydrostatic test water, it will be considered contaminated and cannot be discharged directly to surface drains after use.

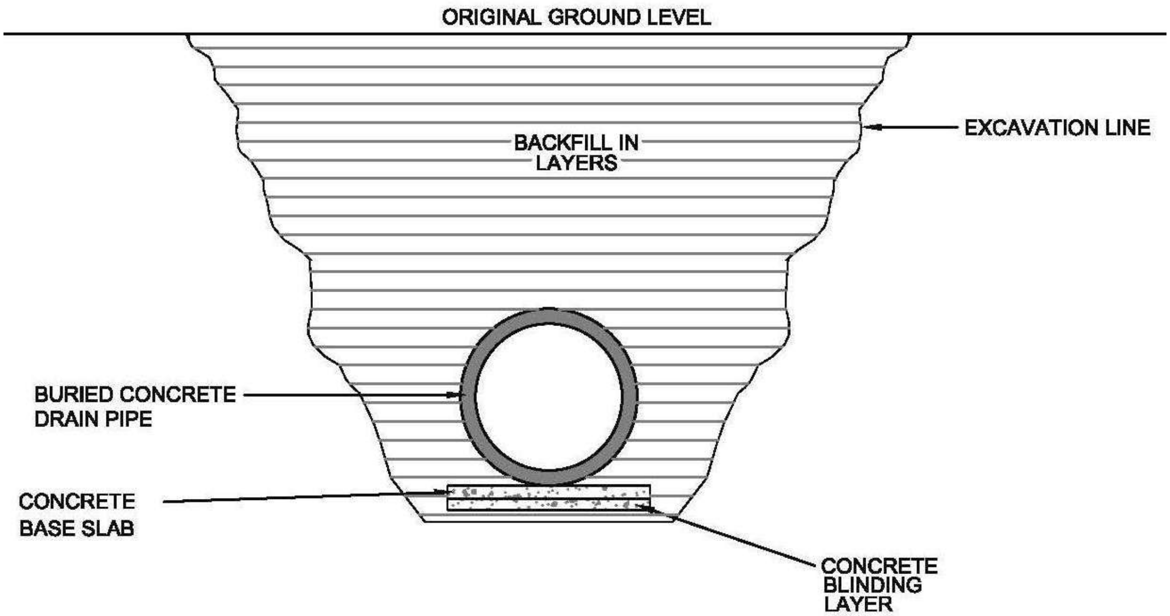

Figure 2.11 Cross-section of a buried concrete pipe drain

Culverts will be constructed of HDPE pipes and installed using the same methods as just described for buried pipe drains. In addition, a head wall with wing walls and apron (Figure 2.12) will be constructed at each end of each culvert using methods as described in Section 2.3.6. Since water flows through culverts by gravity rather than under pressure, there is no need for hydrostatic testing when construction is complete.

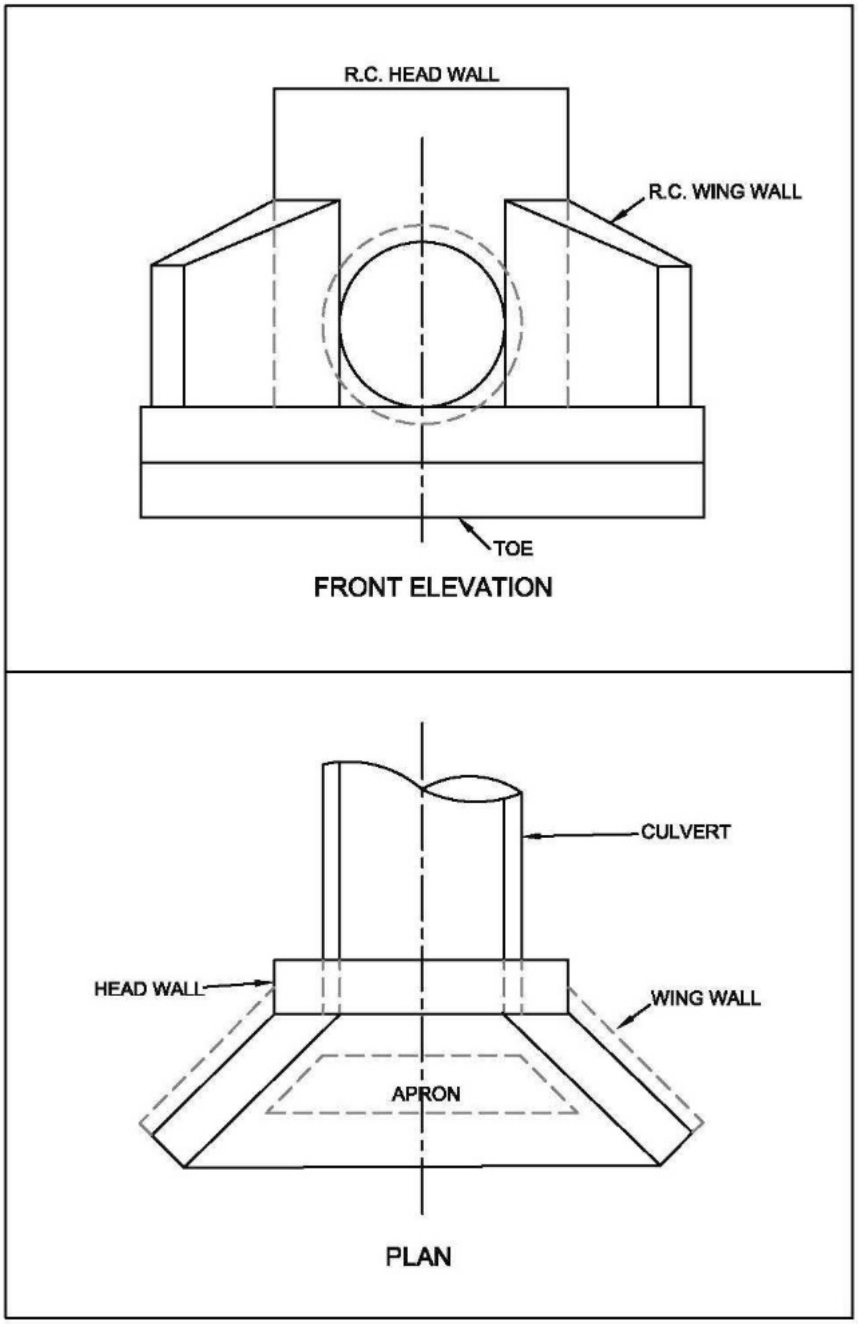

Figure 2.12 Front elevation and plan of the end of a culvert

2.3.5 Installation of Utilities and Sewers

Water pipes, electricity cables and sewers will all be buried on this development, with manholes provided in each case. Likely construction methods will be as follows:

- PVC water pipes will be imported to the island by ship, either in shipping containers or as bulk cargo. These pipes will be brought to the site either in shipping containers or on flatbed trucks. Trenches will be dug, the pipes lowered into the trenches and glued together, and the trenches backfilled, using methods as described for buried pipe drains in Section 2.3.4.
- Electricity cables and PVC pipes will be imported and transported to the site as described above for PVC water pipes. Once the PVC pipes have been installed into the trenches and the manholes constructed, the electricity cables will be unspooled and pulled through the PVC pipes. The cables will then be connected to the electricity system at each end.
- Sewers will be installed as described above for water pipes.
- Manholes will be constructed of reinforced concrete, as described in Section 2.3.6, below.
- As with buried drains, other buried pipes must also be hydrostatically tested (see Section 2.3.4). The comments pertaining to disposal of this water after use in that section are also relevant here.

2.3.6 Reinforced Concrete Construction

Reinforced concrete structures on this development will include building foundations and floor slabs, manholes and head walls on culverts. These may be constructed of premixed concrete or mixed-on-site concrete. In either case, formwork and reinforcing steel will be brought to the site in flatbed trucks. Reinforcing steel will be cut and bent to the required lengths and shapes. Formwork will be installed to receive the concrete and reinforcing steel placed within the formwork. Concrete will then be placed into the formwork and compacted using vibrators.

Where premixed concrete is used, this will be mixed offsite at a batch plant and brought to the site in mixer trucks. Where concrete is mixed on site, the mixers must be brought to site on flatbed trucks and assembled at the selected locations. Sand and gravel will be brought to the site in dump trucks and water brought to the site in tankers. Cement will be imported to the island in ships, most likely in shipping containers. These containers will then be brought to the site by road. Concrete can then be batched on site in mixers using these materials.

After any concrete work, the equipment (including the mixer trucks and concrete mixers) and tools must be washed to avoid the concrete hardening on them. Throughout the West Indies, improper disposal of this wash water has created a contamination problem in receiving surface water bodies. To avoid this, the wash water and any surplus concrete must be placed in a plastic-lined area and allowed to evaporate or harden. It can then be disposed of as a relatively inert solid.

2.3.7 Timber Construction

The design of the villas and some of the hotel buildings may include significant structural timber construction above the foundations and floor slabs. Wooden posts, beams and planks will be imported to the island in ships either in shipping containers or as bulk cargo. This timber will be transported to the site by road either in shipping containers or on flatbed trucks. Carpentry will then be done on site to install the timbers.

2.3.8 Finishing of Buildings

This involves the construction of external and internal walls and the roof, as well as the installation of plumbing and electricals. The material required for this work includes bricks, eaves and roofing sheets, water pipes and plumbing fixtures and electricity wiring and electrical features. All these items will be imported to the island in ships, most likely in shipping containers. They will be transported to the site by road in containers, and installed by masons, carpenters, plumbers, and electricians.

2.3.9 Installation of Wastewater Treatment Plants

Wastewater treatment plants of this type are shipped to site in shipping containers, completely assembled for smaller units and in parts for larger units. The units will be formed from poured concrete and will be sized to treat the anticipated wastewater volumes from the development. Units are to be located completely underground, allowing landscaping (i.e., native grass, plants, etc.) or parking atop (Figure 2.13). The units will be transported to the site by road. Smaller units will be ready to install and connect to the incoming plumbing. Larger units will require some on-site assembly. Tanks and piping on these units are normally pressure tested at the factory before shipping, so in the case of fully assembled units there is no need for repeat hydrostatic testing on site. However, for units that are assembled on site it will be necessary to conduct hydrostatic testing after assembly. The volume of water required for hydrostatic testing of wastewater treatment plants will be significantly more than what is required for testing of piping, and the comments on potential contamination of surface water in Section 2.3.4 are also relevant here.

Figure 2.13 Installation of Bionest System

2.4 Staffing and Training

This facility will be staffed as much as possible by Barbuda residents. Currently, 25 of the 28 operational team members at the property are from Barbuda. One member of the management team, a Barbudan, was sent to Miami for management training, which she recently completed. Paradise Found is committed to training and hiring local staff as much as possible.

On the food service operations, local staff have been trained by Nobu trainers to ensure the consistently high quality of food and service for which Nobu is known. Globally, Nobu restaurants aim to reflect their local culture. The best way to do this is to hire and train local employees to drive what the local experience is about. The same applies at Nobu Barbuda.

In terms of the construction and monitoring phases of the works, personnel in Barbuda will be trained to implement mitigation measures and monitoring activities as stipulated in this ESIA. This would include:

- Use of monitoring equipment – noise meters, water quality meters and air quality meters. This would include field calibration of certain pieces of equipment where appropriate.
- Sampling of fresh and sea water, handling and packaging of those samples and dispatching them to the laboratory.
- Use and filling out of checklists to verify that mitigation measures are being undertaken on a timely basis and highlighting and reporting any observed non-compliances.

3 Regulatory Framework

There are several pieces of legislation, new and existing regulations, and local, regional, and international guidelines which together provide a framework that informs the environmental and social impact assessment and its outcomes on the island of Barbuda in the State of Antigua and Barbuda. The following subsections present the most relevant of these and the succinct points within each.

3.1 Antigua and Barbuda Act No. 6 of 2003

This Act makes provision:

- for the orderly and progressive development of land and the preservation and improvement of the amenities thereof;
- for the grant of permission to develop land and for other powers of control over the use of the land;
- for the regulation of the construction of buildings and other related matters;
- for the conferring of additional powers in respect of the acquisition and development of land for planning; and
- for purposes connected with the matters aforesaid.

Additionally, the Director of the Department of Environment may also require, in consultation with the Chief Town and Country Planner, that any matter that is likely to cause any serious social impact, or harm to the environment or to human health to be subject to an environmental impact assessment. The third schedule of the Act (Section 23) notes matters for which environmental impact assessment shall be required includes (number 10) “a hotel or resort complex”.

As a general rule any proposed developments, undertakings and other activities, which are likely to cause an adverse impact on human health, society or the environment, should be subject to the EIA process, including *inter alia:*

- *Proposals that could harm or destroy important cultural resources including archaeological sites, cemeteries, historic sites, and landmarks; and*

- *Proposals that would challenge or contravene customary controls over the use of environmental resources.*

3.2 Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean (Escazu Agreement 2018)

Article 1 sets out the Objective of the Agreement as follows:

“The objective of the present Agreement is to guarantee the full and effective implementation in Latin America and the Caribbean of the rights of access to environmental information, public participation in the environmental decision-making process and access to justice in environmental matters, and the creation and strengthening of capacities and cooperation, contributing to the protection of the right of every person of present and future generations to live in a healthy environment and to sustainable development."

Article 6, Generation and Dissemination of Environmental Information, notes that "Each Party shall promote access to environmental information contained in concessions, contracts, agreements, or authorizations granted, which involve the use of public goods, services or resources, in accordance with domestic legislation.

Article 7 indicates that "Each Party shall ensure the public's right to participation and, for that purpose, commits to implement open and inclusive participation in environmental decision-making processes based on domestic and international normative frameworks."

The Government of Antigua and Barbuda is a signatory to this Agreement.

3.3 Medium-Term Development Strategy 2016 to 2020

The Medium-Term Development Strategy (MTDS) represents a set of strategies and actions to be undertaken by Antigua and Barbuda over the Medium-Term (2016 to 2020) in moving the country towards its long-term goals. Within such a framework, Antigua and Barbuda will strive to become a developed country within fifteen to twenty years, guided by the vision of "A harmonious, prosperous and modern Antigua and Barbuda founded on the principles of sustainability and inclusive growth; where equality of opportunity, peace, and justice prevail for all citizens and residents". The attainment of this vision must be guided by a sustainable development approach in which we treat our public sector machinery as a single system working towards a singular, overarching goal, which is "To improve the quality of life for all Antiguans and Barbudans and their posterity".

Flagship Priority Three: Transform Barbuda into a Green, Low Density, High-End Tourism Destination. Barbuda is a natural paradise with unique pink sand beaches, lagoons, salt ponds and unique flora and fauna species, including one of the world's largest bird sanctuaries. Barbuda is virtually untouched with significant growth potential which, if exploited in a sustainable manner, can substantially transform the way of life for Barbudans while at the same time, protecting and preserving its natural beauty.

3.4 IUCN Environmental and Social management System (ESM) Standard on Cultural Heritage (Version 2.1 – December 2019)[2]

The purpose of the Standard on Cultural heritage is to assure that projects:

I. Anticipate and avoid negative impacts on cultural resources or, if avoidance is not possible, minimise and compensate for such impacts.
II. Avoid restrictions of people's ability to legitimately use and/or access cultural resources.

[2] This standard is consistent with internationally accepted social safeguard standards related to cultural heritage, notably International Finance Corporation's Performance Standard 8 on Cultural Heritage and the World Bank's Operational Manual section on Physical Cultural Resources, among others.

III. Assure a fair and equitable sharing of benefits if existing and new uses of cultural resources generate economic, cultural, and social benefits.

For this Standard, cultural heritage refers to:

i. A tangible, moveable or immovable cultural resource or site with paleontological, archaeological, historical, cultural, artistic, religious, spiritual, or symbolic value for a nation, people, or community; or

ii. A natural feature or resource with cultural, religious, spiritual, or symbolic significance for a nation, people or community associated with that feature.

Examples of the first category are burial sites, monuments, buildings, groups of buildings, urban areas, and cultural landscapes. Examples of the second are sacred mountains, forests, trees, or landscapes.

For the People of Barbuda their island has historic, cultural, spiritual, and symbolic value for its people.

4 Baseline Conditions

4.1 Physical Environment

4.1.1 Climate Change

Barbuda has a tropical marine climate and maintains a generally dry environment. Climate change resulting from global warming is expected to have an effect on this existing climate. Specifically, impacts are expected to include warmer air and sea surface temperatures, rising sea levels, longer periods of drought, potentially torrential rainfall when it does occur, and more frequent Category 3, 4 and 5 hurricanes, potentially leading to increased incidences of coastal flooding and shoreline erosion. Climate change data analyses and predictions have been done by the Intergovernmental Panel on Climate Change (IPCC), and their latest IPCC report (AR6 Synthesis Report, 2023) provides some guidance for the selection of appropriate scenarios for coastal flooding and erosion risk. Some of their findings are summarised in the following figures.

Figure 4.1 indicates that between AR5 and AR6 new research has revealed that the risk/impacts for various "Reasons for Concern" have increased for the same level of global warming or put another way, moderate to high risks/impacts are now predicted to occur at even lower global warming levels than previously expected. Looking at extreme weather events, the newer science (2022 vs 2014) has revealed that high risks will occur at 1.5°C warming, whereas in the AR5, these were predicted to occur above 2°C.

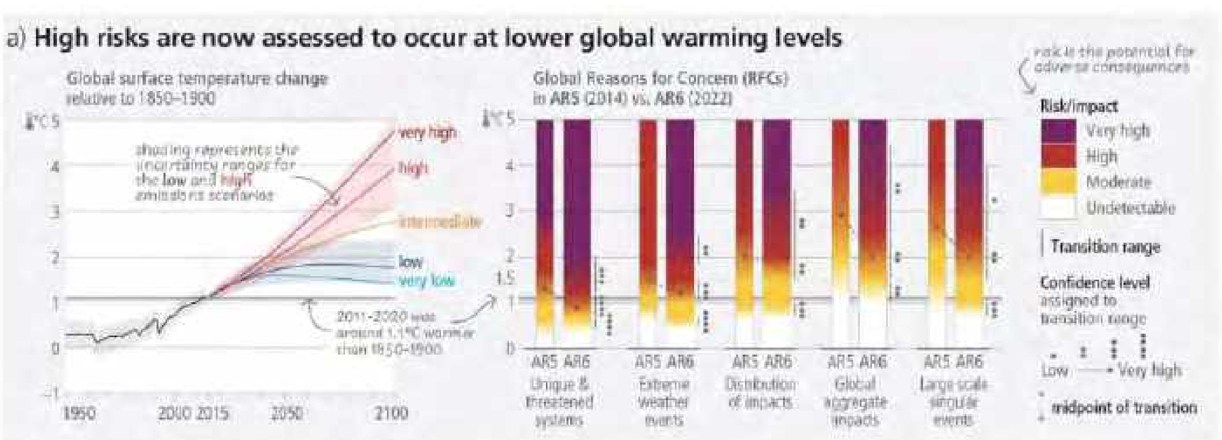

Figure 4.1 Increase in risk from IPCC's AR5 to AR6 reports for given global surface temperature change scenarios[3].

A comparison of the figures of temperature and mean sea level rise between 1950 and 2100 shows a rather disturbing correlation – even if a low emission pathway occurs, which could see global temperatures decrease in the latter half of this century, mean sea levels will continue to increase, and

[3] IPCC 2022.

this trend will continue well into the next century and beyond. AR6 includes the following figure, which summarises the risks until the end of the century, and an assessment of the years beyond:

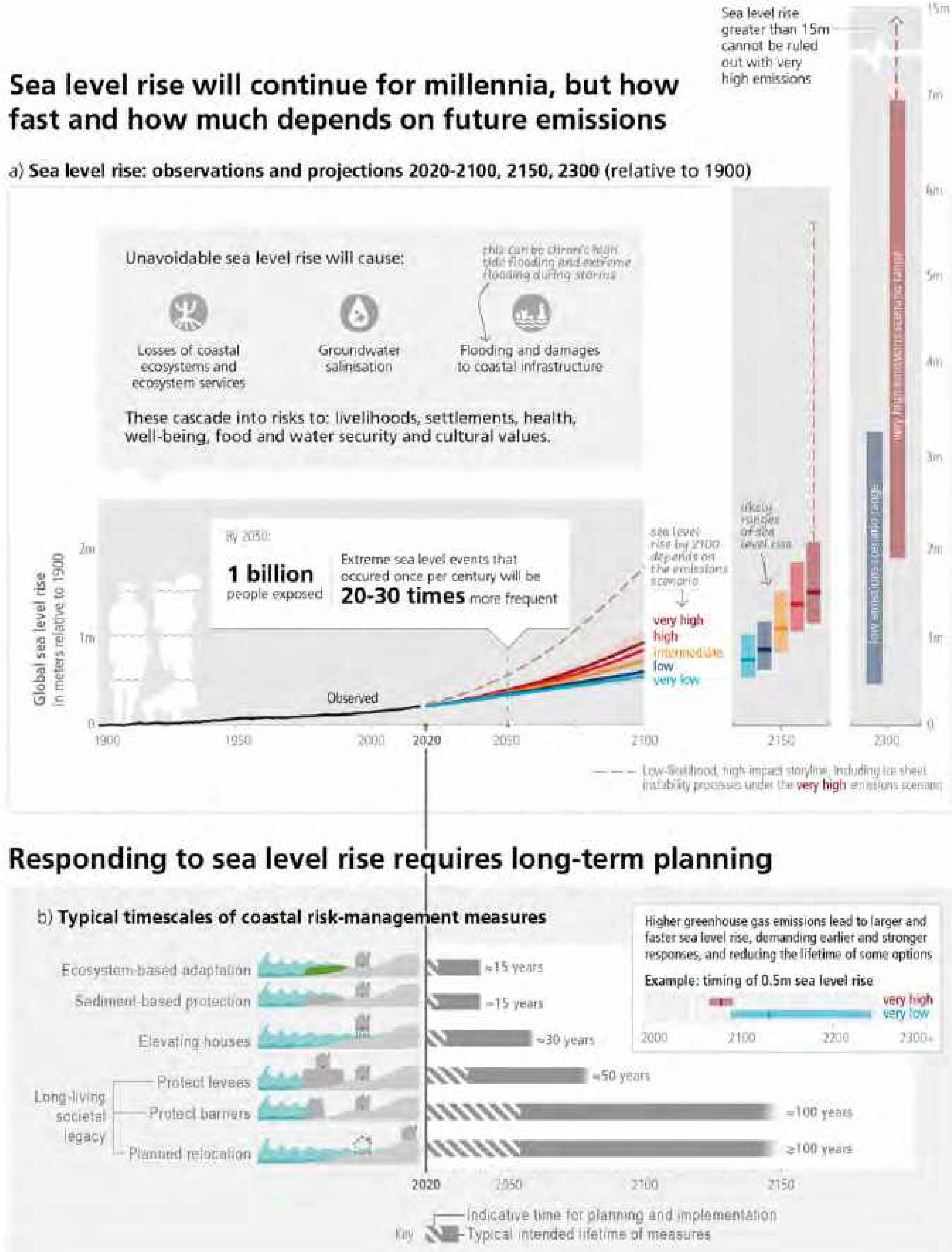

Figure 4.2 Summary of risks from sea level rise over the next century (IPCC 2022)

By 2050, the mean sea level is predicted to be at least 0.3m above its present value and by the end of this century, it will increase to be at least 0.5m above present value, for all climate change scenarios. The intermediate climate change scenario has a median level that rises to 0.75m above present in 2100. The slow and steadily rising sea levels that appear to lag the rise in temperature suggest that a precautionary approach for sea level rise is appropriate for national and local level planning.

For this report, SWI adopted the Representative Concentration Pathways (RCP) framework as presented in the 2014 IPCC climate change report. RCPs are factor amalgamated greenhouse gas emission (GHG) scenarios used by the IPCC, which categorize possible future climates of the world. Factors weighed into the scenarios include energy use, economic activity, and land use. There are four (4) defined scenarios, namely RCP 2.6, 4.5, 6 and 8.5, each representing a future subjected to a specific radiative forcing value because of the predicted cumulative GHG emission quantities. The chosen RCP scenario for this evaluation was RCP8.5:

- RCP8.5 is the highest of the RCPs and with high climate sensitivity represents the greatest level of climate risk.

Also of note, in the latest IPCC reports, the trend to describe climate change scenarios now moves from RCPs to “Shared Socio-economic Pathways” (SSPs). SSPs are a new method of assessing future scenarios which seeks to combine the knowledge of the physical sciences of climate change with the societal impacts brought on by the vulnerability caused by climate change. SSPs incorporate adaptation and mitigation research to create a more holistic approach to future projections by combining them with future emission and concentration scenarios with socio-economic development pathways.

- SSP1-2.6 is described as the ‘sustainability’ development pathway. Under SSP-2.6 global warming stays just below 2°C at the end of the century when compared to pre-industrial (pre-1900) levels.
- SSP2-4.5 referred to as the ‘middle of the road’ development pathway. SSP2-4.5 corresponds to emissions reductions which are roughly in line with the upper bounds of the latest Nationally Determined Contributions and global warming of around 2.7°C at the end of the 21st century.
- SSP3-7.0 referred to as ‘regional rivalry’ development pathway. SSP3-7.0 corresponds with a medium-high development pathway. Under this SSP no additional climate change policy is put in place and there are high non-CO2 related emissions which leads to a pathway which would be roughly in the middle of the previous RCP6.0 and RCP8.5
- SSP4-6.0 referred to as ‘inequality’ development pathway and
- SSP5-8.5 described as a ‘fossil fuel intensive’ development pathway. (See Riahi et al., 2017 for more details on SSPs). SSP5-8.5 corresponds to very high emissions, no additional climate policy and intensive fossil fuel dependent development which is the worst-case scenario pathway.

Forty years of historical rainfall data show that Barbuda has low rainfall frequency with most months registering under 100mm of rainfall. Climate change projections indicate that Barbuda will experience longer dry periods, with January to March slated to be the driest. Extreme rainfall events such as those that occur during tropical storms and hurricanes are likely to become more intense, with larger peak wind speeds and heavier precipitation.

4.1.2 Rainfall

Rainfall trend graphs were plotted using available long-term precipitation data (Figure 4.3 and Figure 4.4). Barbuda has a dry season from January to April and a primary wet season from August through to November. The wet season coincides with peak tropical storm activity. The largest recorded value for the Coco Point station was in November 1999 where 483mm of rainfall was recorded. This was due to Hurricane Lenny passing south of the island.

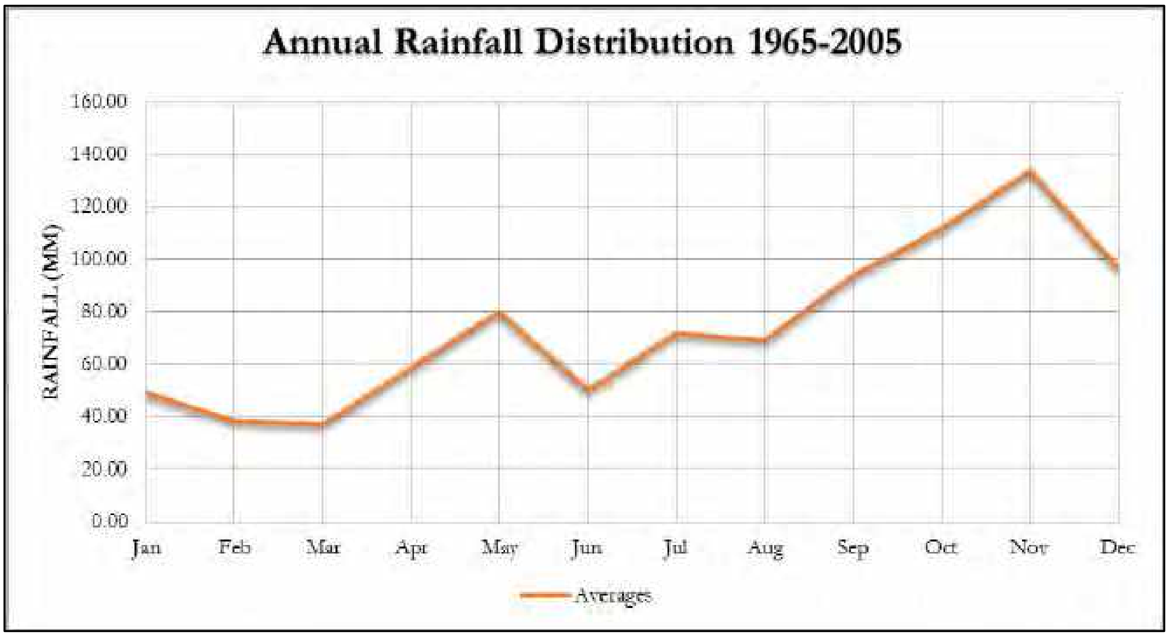

Figure 4.3 Annual rainfall distribution for the period 1965-2005

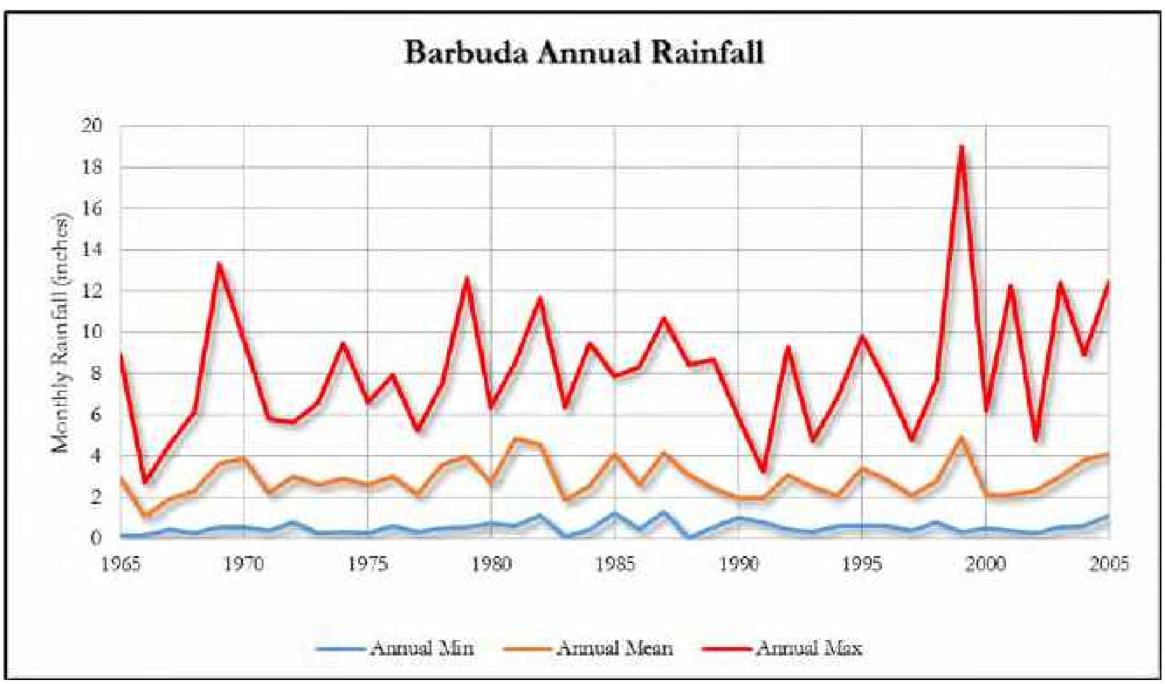

Figure 4.4 Annual minimum, mean and maximum for the period 1965 to 2005

Barbuda does not experience high rainfall, but rather is characterised by many periods of drought. As a result, rainfall values are much lower there than for other Caribbean nations. Rainfall values computed for return periods varying from 2 years to 100 years, are shown in Table 4-1.

Table 4-1 Rainfall levels for varying return period events

Return Period (years)	Rainfall	
	(mm)	(in)
T2	142	5.6
T5	192	7.6
T10	223	8.8
T25	240	9.4
T50	330	13
T100	533	21

4.1.3 Hydrogeology

The hydro-stratigraphic units of Barbuda, their stratigraphic sequence, subsurface relationships, and hydraulic character have been described by previous investigators. These were examined in the field for this ESIA and found to be generally accurate. However, wells recently drilled through the Palmetto Sand Aquifer in the Palmetto Point headland at the southwest end of Barbuda indicated that the Central Plains Limestone Aquiclude was absent, requiring a possible re-interpretation of the stratigraphic sequence in that area, and the depositional history of Barbuda.

The determination, or knowledge, of well head elevations for data points in the Highland Limestone Aquifer, the Central Plains Limestone Aquiclude and the Palmetto Sand Aquifer could allow computation of the water table elevation in the respective hydro-stratigraphic units and a better understanding of the hydraulic relationship between them.

Field determinations of specific conductance (i.e., electrical conductivity) allowed characterisation of the water quality in the water table sections of the Highland Limestone Aquifer, Central Plains Limestone Aquiclude and the Palmetto Sand Aquifer. The fresh groundwater in the Palmetto Sand Aquifer reported by previous investigators up to 1992 no longer existed but was now moderately saline, believed to be because of the extensive mining of the sand and the exposure of the water table to direct evaporation.

Paradise Found Development proposes to obtain the freshwater needed for construction and subsequent operation of the development facility by desalination/reverse osmosis. Disposal of the generated brine effluent is intended primarily to be to a disposal well, and if that is not possible, then to a retention pond. Under this ESIA, both source and disposal wells were drilled to evaluate this component of the project.

SWI's hydrogeological sub-consultant, HydroConsult, carried out a Reconnaissance Water Resources Study of Barbuda in Jul/Aug 2022 the results of which were presented in a report that defined the baseline hydrogeological conditions on the island, particularly as it affected the proposed Paradise

Found Development. That report (attached as Appendix A) recommended that the source water be obtained from, and the brine effluent be disposed of, via tube wells in a karstic limestone aquifer underlying the Paradise Found property at acceptable depth, and that exploratory wells be established to demonstrate the viability and minimum environmental impact.

These recommendations were accepted by Paradise Found and they entered into a well contract with Walker Wells Limited (Walker Wells) to establish the wells. Walker Wells had been successfully constructing such wells for a number of years in Barbuda, under similar hydrogeological conditions as obtained at the Paradise Found property. As such, a source well and a brine disposal well were proved by Walker Wells on Paradise Found property in Mar/Apr 2023 (Figure 4.5). HydroConsult personnel monitored the well construction and directed yield testing of the wells. The full report is included in Appendix A.

Evaluation of the yield productivity of the source water well was based on the results of a constant rate test. This test involved the pumping of the well at a continuous constant rate of 286 USgpm, for a period of six (6) hours, after measuring its initial non-pumping water level and monitoring the pumping water level at regular intervals. On the cessation of pumping, the recovery of the water level was monitored for one (1) hour.

Figure 4.5 Locations of disposal and production wells

The following observations are worthy of note:

- The non-pumping water level in the source water well fluctuated in sync with tidal fluctuations, indicating that the Highland Limestone Aquifer is in direct hydraulic continuity with the sea. This is illustrated in Figure 4.6 below.
- However, the tidal fluctuations complicate the well water level response under pumping conditions. Pumping during a period of declining tide causes an increase in drawdown in excess of that which would have occurred if there was no tidal influence, as occurred during the constant rate test of the source water well on 28 Mar 2023.
- The specific capacity (or yield) of the source water well was determined to be 286USgpm, with a drawdown of 0.14m (0.46 ft). At the design discharge of 375USgpm, the associated drawdown can be expected to be about 0.21m (0.7 ft).
- This relatively high well yield for the source water well no doubt reflects the interception of conduit flow permeability at a depth of 22.2m (73 ft) below ground level (bgl), indicated by the loss of drilling circulation at that depth.

For the brine disposal well, the following observations are worthy of note:

- The Basal Clay strata encountered at the base of the Palmetto Sands in the source water well was missing from the hydro-stratigraphic sequence in the brine disposal well, so that the Palmetto Sands rests directly on top of the Highland Limestone.
- The loss of circulation at a depth of 37.2m (122 ft bgl) (36.3m below msl / -119 ft msl), indicated the interception of significant conduit permeability, typical of a cavern in karstic limestone.
- The non-pumping water level in the brine disposal well fluctuated in sync with tidal fluctuations, indicating that the Highland Limestone Aquifer is in direct hydraulic continuity with the sea, as shown in Figure 4.6, below.
- However, the tidal fluctuations complicate the well water level response under pumping conditions. Pumping during a period of increasing tide causes a decrease in drawdown to values lower than that which would have occurred if there was no tidal influence, as occurred during the constant rate test of the brine disposal well on 7 April 2023. The drawdown (i.e., the difference between the non-pumping water level just prior to the start of pumping and the pumping water level at the cessation of pumping) was 0.12m (0.39 ft), and the change in the elevation of the tide for the same time period was 0.19m (0.62 ft), indicating that the actual drawdown was 0.31m (1.01 ft), i.e., 0.12m plus 0.19m.
- The specific capacity (or yield) of the brine disposal well was determined to be 315 USgpm, with a drawdown of 0.3m (1.0 ft). At the design injection rate of 225USgpm, the associated increase in water level can be expected to be about 0.21m (0.7 ft).
- This relatively high productivity of the brine disposal well no doubt reflects the interception of conduit flow permeability at a depth of 37.2m (122 ft bgl) (36.3m below msl / -119 ft msl), indicated by the loss of drilling circulation at that depth.

Figure 4.6 Tidal and well water level fluctuations

4.1.4 Air Quality

Ambient air quality was monitored to:

- Establish baseline air quality conditions within the study area for the proposed Paradise Found Development; and
- Compare baseline air quality results with air quality guidelines developed by the World Health Organization/ World Bank.

The air quality parameter monitored was Particulate Matter, which refers to a mixture of solid particles and liquid droplets found in the air. These include:

- **PM_{10}**: particles with diameters that are generally 10 micrometers and smaller and
- **$PM_{2.5}$**: particles, with diameters that are generally 2.5 micrometers and smaller.

These particles are so small they can be inhaled and cause serious health issues, such as aggravated asthma, lung disease and heart complications. Particulate matter such as dust can also be a public nuisance. At high concentrations, dust can also affect plants by coating the leaves and impeding photosynthesis. PM_{10} and $PM_{2.5}$ are emitted directly from sources such as unpaved roads or construction sites. Therefore, since this is a construction project, these parameters were monitored at strategic locations within the study area to establish the baseline. The four monitoring locations are shown in Figure 4.7 below.

Figure 4.7 Air monitoring locations

These locations were selected based on the site boundaries and existing and proposed activities within the area. A&N 1 and A&N 4 respectively are representative of the northern and southern boundaries of the site and A&N 2 is representative of the nearest sensitive receptor, which in this case was a house with occupants who could be affected by particulate matter. A&N 3 was also selected, as construction works were on-going near this area.

A DustTrak II aerosol monitor (Model 8530) was used to measure Particulate matter ($PM_{2.5}$ and PM_{10}) at each of the four monitoring locations. For each monitoring event, the DustTrak II was zero calibrated, placed in an enclosure (to protect from rainfall) and mounted onto a surveyor's tripod. Each parameter was monitored at all locations for a 1-hour period and at a one (1) minute logging interval. Following the field monitoring, data was downloaded to a laptop and 24-hour concentrations of $PM_{2.5}$ and PM_{10} at each location were calculated.

In the absence of national laws for air quality, World Health Organization (WHO) and World Bank (WB) Guidelines were used for comparison purposes.

The WHO guidelines present recommended key air pollutant limits (both outdoors and inside buildings) based on global scientific evidence and for which concentrations greater than these are considered to be harmful to human health. Relevant parameters and their respective WHO Guidelines are presented in Table 4-2.

Table 4-2 WHO air quality guidelines

Parameter		Averaging Period	Guideline ($\mu g/m^3$)
Particulate Matter	PM_{10}	24-hour	50
	$PM_{2.5}$	24-hour	25

The main sources of air emissions identified within the study area were due to: (i) the road network (vehicular exhaust and the kick-up of dust from trucks transporting material); and (ii) dust from construction sites.

Since monitoring of each parameter was only conducted for 1 hour at each location, the Time Weighted Average (TWA) was used to calculate estimated concentrations of $PM_{2.5}$ and PM_{10} for a 24-hour period at each location.

Based on the results obtained, the following was determined:

- The main sources of air emissions identified within the study area were from the road network (vehicular exhaust and the kick-up of dust from trucks transporting material), and dust from construction sites.
- Concentrations of both $PM_{2.5}$ and PM_{10} were highest at A&N1.
- However, estimated 24-hour concentrations of $PM_{2.5}$ and PM_{10} at all four monitoring locations were less than the respective WHO Guidelines for a 24-hour averaging period.
- None of the sources of air emissions identified appear to significantly impact the ambient concentrations of $PM_{2.5}$ and PM_{10} within the study area.
- Given that the proposed project site is situated on the coast and vegetation is sparsely distributed, the site experiences good dispersion characteristics.

4.1.5 Ambient Noise

Ambient noise monitoring was carried out to:

- Establish baseline noise conditions within the study area for the proposed Paradise Found Development and
- Compare baseline noise results with noise guidelines developed by the World Health Organization/ World Bank Group.

Noise monitoring was conducted for one (1) hour during the daytime and one (1) hour during the nighttime at the same four (4) locations within the study area as for the air quality. A SoundPro sound meter manufactured by Quest Technologies (DL Series) was used to monitor noise levels at each of the four monitoring locations. For each monitoring event, the sound meter was calibrated, mounted onto a tripod, and set to record equivalent continuous sound pressure level (L_{eq}) for a one (1) hour period at one (1) minute logging interval.

After field monitoring, data was downloaded onto a laptop and compared to the World Bank Group's *Environmental Noise Management Guidelines*.

In the absence of national laws for noise, limits listed in the World Bank Group-*Environmental Health and Safety Guidelines-Environmental Noise Management Guidelines* were used for comparison purposes. The EHS Guidelines state that noise impacts should not exceed the levels presented in Table 4-3 below or result in a maximum increase in background levels of 3 dB at the nearest receptor location off-site.

Table 4-3 World Bank Group noise guidelines

Receptor	**One (1) hour L_{eq} (dBA)**	
	Daytime (7:00 a.m.-22:00 p.m.)	*Nighttime (22:00 p.m.-7:00 a.m.)*
Residential; Institutional; Educational	55	45
Industrial; Commercial	70	70

The study area has been zoned for tourism, but currently commercial activity in the area is sparse. Further, residential homes are few and far between. However, it should be noted that the nearest sensitive receptor was a house located at A&N 2.

Given the presence of both residential and commercial buildings within the study area, the results of this noise monitoring exercise were compared to the guidelines for commercial areas as well as residential areas.

Table 4-4 lists the sources of noise identified at each monitoring location.

Figure 4.8 compares the daytime L_{eq} values recorded at each monitoring location to the World Bank Group's Noise Guidelines. The figure indicates that daytime L_{eq} values recorded at the four monitoring locations were below the daytime limit for commercial areas. However, L_{eq} values recorded at A&N1, A&N3 and A&N4 were at, or slightly above, the daytime limit for residential areas.

Table 4-4 Sources of noise within the study area

Monitoring Location	Sources of Noise	
	Daytime	***Nighttime***
A&N1	• Vehicles traversing roadway (mainly trucks) • Wind • Birds Chirping	• Vehicles traversing roadway • Insects • Crab catchers
A&N2	• Birds Chirping • Vehicles • Persons Chatting • Heavy Equipment working in the distance	• Vehicle • Wind
A&N3	• Music • Construction work (on Helipad) • Birds chirping	• Music in the distance • Vehicle
A&N4	• Vehicles traversing roadway • Truck horns • Wind • Birds chirping	• Music in the distance • Vehicles traversing roadway

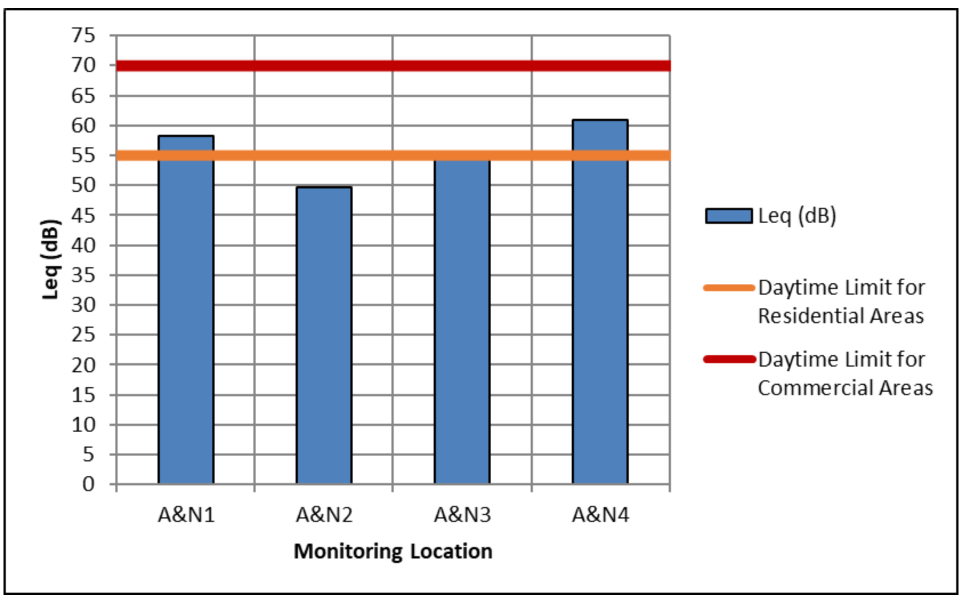

Figure 4.8 Ambient noise monitoring results & comparison to recommended daytime limits

Figure 4.9 compares the nighttime L_{eq} values recorded at each monitoring location to the World Bank Group's Noise Guidelines. Similar to the daytime, nighttime L_{eq} values recorded at all four monitoring locations were also below the limit for commercial areas. However, L_{eq} values recorded at A&N1, A&N2 and A&N4 were slightly above the nighttime limit for residential areas.

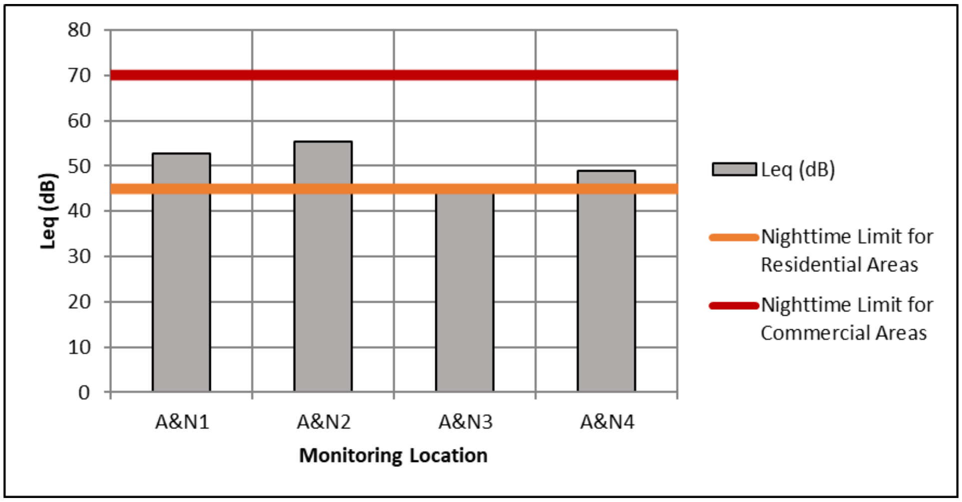

Figure 4.9 Ambient noise monitoring results & comparison to recommended nighttime limits

Based on the results of the noise monitoring, the following can be concluded:

- Equivalent continuous sound pressure levels (L_{eq}) were higher during the daytime than the nighttime at all monitoring locations except A&N2.
- Daytime L_{eq} values recorded at the four monitoring locations were below the daytime limit for commercial areas. However, L_{eq} values recorded at A&N1, A&N3 and A&N4 were slightly above the daytime limit for residential areas.
- Similar to the daytime, nighttime L_{eq} values recorded at all four monitoring locations were also below the limit for commercial areas. However, L_{eq} values recorded at A&N1, A&N2 and A&N4 were slightly above the daytime limit for residential areas.
- These results provide an envelope of noise ranges during the day and night, which will be used to assess the impacts of the proposed development on the noise regime.

4.1.6 Metocean and Coastal Parameters

Baseline coastal zone modelling is required to gain an understanding of the baseline coastal processes acting along the shoreline of the project site. Waves, currents, and sediments all interact to affect shoreline morphology, resulting in actions such as erosion or accretion. This section of the report describes the additional work that was done to enhance the 2016 study.

Especially when considering climate change and projected sea level rise (of particular relevance to coastal developments in small island states such as Barbuda), the vulnerability of the proposed development is a function of its setback from the shoreline. The vulnerabilities typically include:

- Increased storm surge and coastal erosion from more frequent Category 3, 4 and 5 hurricane activity.

- Long term shoreline erosion from higher waves due to higher sea levels.
- Natural trends of shoreline change.
- Exacerbating coastal erosion by building too close to the sea, or by the destruction of natural dunes and coastal vegetation

The text in this chapter provides an assessment of the site's exposure to these risks and provides recommendations to reduce its vulnerability. Specifically, appropriate **setback** limits are derived. The horizontal setback is the distance from the high-water mark (or line of permanent vegetation) to the location of the development. The **vertical step-up** refers to the floor elevation level above high-water mark that should be maintained to reduce vulnerability. This analysis also includes projected climate change impacts on sea level rise.

Coastal Setback - Background

Coastal setback is a designated area of no construction between the high-water mark and permanent construction. Coastal setbacks are implemented as a coastal management and planning tool to protect the ecology of the land and to reduce the impact of natural hazards on a development. Setbacks vary based on the location, topography and wave climate and planning legislation and guidelines. They also affect where construction may begin and guides the vertical elevation of floor levels. Guidelines usually require that all development falls behind (i.e., landward of) the coastal setback line.

Under the previous contract, a regulatory value for coastal setback was difficult to justify as current legislation had not specifically stated what this value should be. Nevertheless, the Department of Environment (DOE) specified in an undated "brochure for developers", stamped as "Draft Policy", that beachfront developments should be 100 feet from the first vegetation line[4]. The DOE also provided as reference "Model OECS Coastal Development Setback Guidelines – with specific recommendations for Antigua and Barbuda" from January 12, 2016, which provides recommendations for determining setback limits on a site-specific basis. This approach considers the projected coastal change (i.e., recession) from expected rising sea level. The document also references the setback guidelines developed by Cambers (1998) which requires 100 to 130 feet setback from the line of permanent vegetation for sandy beaches.

Previous Approach

A site-specific approach to develop the setback limits for the Paradise Found Development similar to that recommended in the OECS guidelines was carried out. Setbacks were developed for 25, 50 and 100-year storm return period conditions and were compared to the standard DOE draft policy guideline of 100ft from first line of vegetation. The approach involved the following:

a) Understanding the daily and seasonal wave conditions for the site since they relate to potential shoreline erosion.

b) Understanding the general trends of sand transport along the shoreline to assess potential for coastal erosion or growth of the shoreline.

[4] Investor's Brochure, Department of Environment

c) Assessment of the potential for storm surge inundation from hurricanes for i) the existing site; and ii) the proposed development masterplan with surge risk reduction recommendation measures in place with a higher sea level from climate change accounted for.

d) Evaluation of potential long term and storm surge erosion due to sea level rise and its associated impacts such as higher waves at the shoreline on a day-to-day basis and during hurricanes.

These coastal investigations required data collection, historical hurricane analysis and numerical modelling. The site topography and nearshore bathymetry data was the baseline data used to set up a model domain for MIKE 21, a hydrodynamic modelling software developed by the Danish Hydraulic Institute. The results were three recommendations for setback which were based on climate change projections and long-term shoreline retreat, corresponding to the three return period events investigated.

The current contract received approvals as per the Paradise Found (Project) Act, 2015, section 9(2)(d). This ordinance allows for construction based on established setbacks that were used for the previous K-Club development.

Setback Component - Shoreline Change (Longer-Term)

Historical shoreline change for the project site was analysed to determine the long-term observed changes in beach width along the site's coast. Aerial imagery was obtained from Google Earth and georeferenced to the UTM 20 system. Fixed reference points were established at road intersections and reference lines drawn to show relative change. The years retrieved were 2003, 2005, 2009 and 2013, 2016, 2019 and 2020. These shorelines were overlaid on the current site imagery.

Figure 4.10 to Figure 4.14 shows that the shoreline fluctuates. Between 2003 and 2005 the shoreline eroded 15-20m but then accreted almost to the 2003 shoreline by 2009. There was again erosion between 2009 and 2013 and the 2016 shoreline seems to enjoy a wider beach than the 2013 shoreline. Between 2016 and 2020 the shoreline shows signs of erosion of 45m to 47m. This is likely because of recent hurricanes (Irma and Jose 2017) and tropical storms that passed within 300km of the site. It should be noted that the fluctuations observed might have been just from seasonal variations rather than over a period of years as just a single point in time for a year is being observed. It would require a longer period of imagery to determine a long-term trend in shoreline change and to say whether the erosion seen between 2003 and present is an ongoing trend. This analysis, however, illustrates that the beach does vary by up to 45m seasonally or annually.

Figure 4.10 Paradise Found shoreline change

Figure 4.11 Paradise Found shoreline change profile 1

Figure 4.12 Paradise Found shoreline change profile 2

Figure 4.13 Paradise Found shoreline change profile 3

Setback Component - Storm Erosion

Storm surge inundation also causes beach erosion. This recession of the shoreline increases the ingress of surge inland. As such, determining the potential erosion during a storm is critical to determine setback limits. Shoreline erosion may also occur over the long-term due to projected sea level rise. Increased sea level means the water line is farther inland and larger waves are able to reach the beach, contributing to progressive coastal erosion. This vulnerability is evaluated in this section.

Shoreline recession was quantified based on three categories: sea level rise, beach erosion from storms and long-term recession. Sea level rise will result in a narrowing beach. The narrowing observed is a function of the slope of the beach. Beach slopes were extracted along the length of the shoreline and the maximum horizontal recession for each profile calculated.

Nearshore wave conditions were extracted from the selected MIKE 21 plots and used to assess beach erosion for each storm event. Five profile lines were chosen for analysis with four being on the sandy section of the site and one on the rock coast. The numerical model tool, sBEACH, which simulates cross-shore beach change was used.

Long-term recession was calculated using the Bruun Rule for coastal retreat. The Bruun model was applicable as it is relevant to sandy coastlines. For the application of this model, the wave climate from the previous analysis was applied to measured beach profiles and estimates of coastal retreat for the 25-year, 50-year and 100-year return periods were made. Table 4-5, Figure 4.14 and Figure 4.15 show the results of this analysis.

Table 4-5 Components of setback

Setback						
Coast Type	Return Period	Bruun Recession (m)	Storm Erosion (m)	SLR Component (m)	Total Setback	
					(m)	(ft)
Beach	25	5.1	31.0	4.4	41	133
	50	5.4	41.8	4.4	52	169
	100	6.3	59.8	4.4	70	231
Rock	25	5.3	16.0	1.0	22	73
	50	6.1	18.5	1.0	26	84
	100	6.9	23.5	1.0	31	103

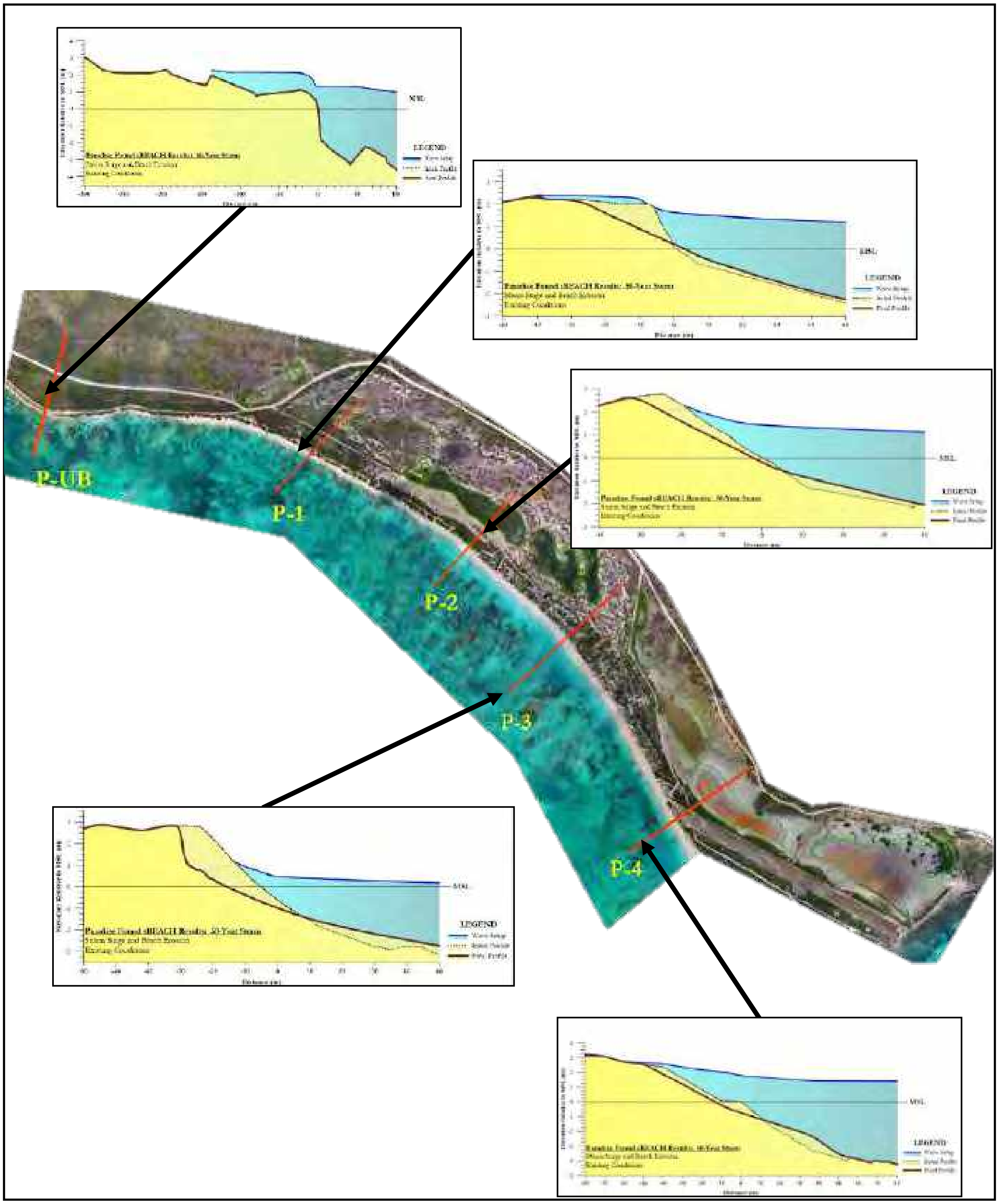

Figure 4.14 Plan with profile lines and beach erosion for a 50-year event

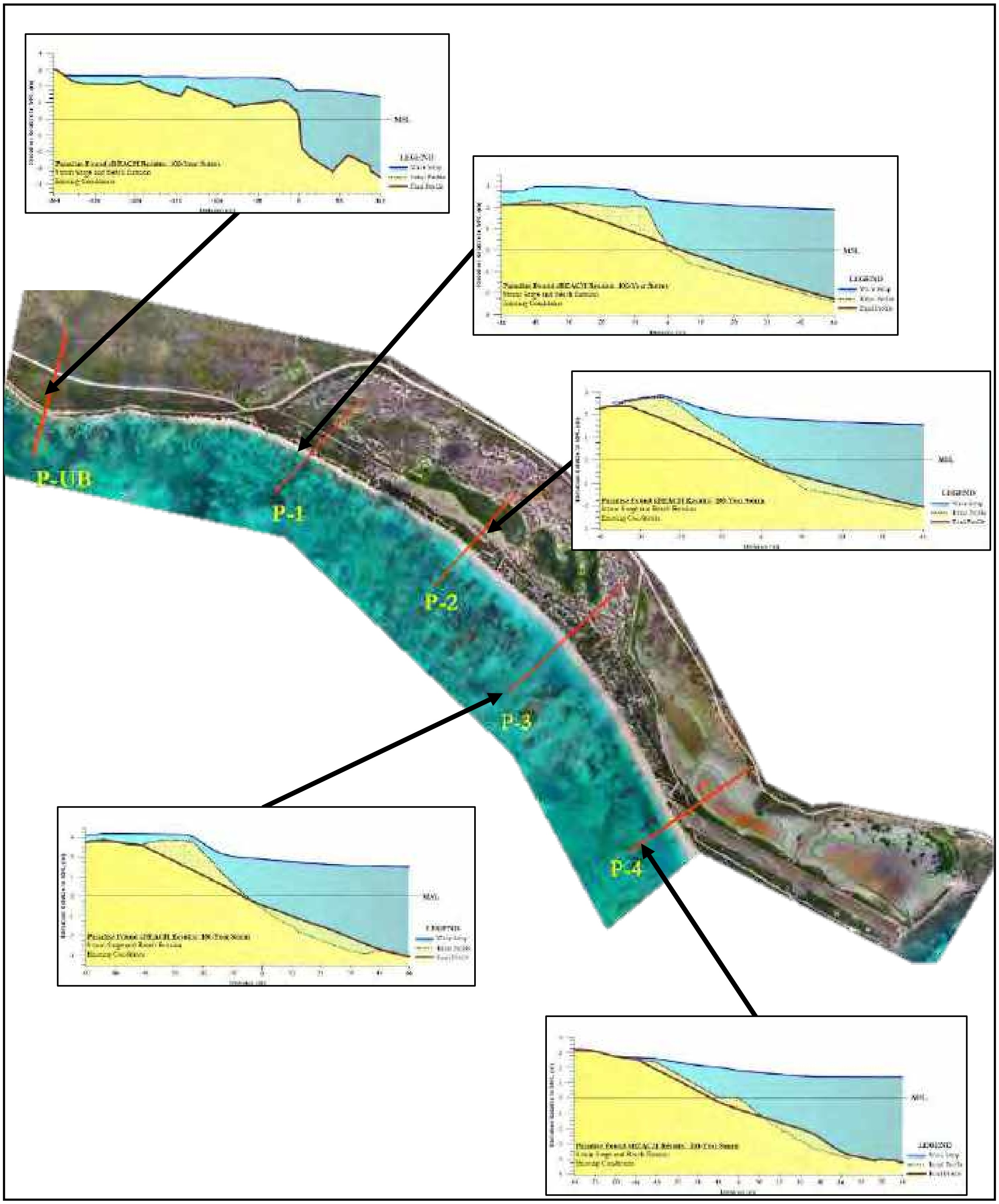

Figure 4.15 Plan with profile lines and beach erosion for a 100-year event

The dunes along the coastline will be inundated during extreme storms. It is therefore necessary to enforce a setback limit for development along the shoreline.

Calculated Setback Distances and Step-Up Elevations

Under the previous contract, the mean high-water mark was used as the horizontal datum for the calculated 25-year, 50-year and 100-year setback lines. Analysis of tide data from long-term tidal records (19 years) produced a mean high-water level at +0.09m and tidal range of 0.3m. The high-water mark was plotted by using the point data from the Digital Elevation Model (DEM) to trace an accurate 0.09m contour line, and the line was checked against the drone image. The calculated setback values were then offset from the high-water mark to specify the setback lines.

Calculated setback lines were compared with the Department of Environment regulations. This was done by assessing the historical vegetation lines to determine the furthest that vegetation has been from the coast. That line was offset by 30m to define the vegetation setback line. Sandy coastlines were differentiated from rocky coastlines due to the predominant factors in their reach that would affect setback values.

Sandy coastlines experienced mainly beach erosion while rocky coastlines experienced large values of wave run-up. The final computed setback values are shown in Table 4-6 and Table 4-7.

Table 4-6 Horizontal setback values based on long-term sea level rise, beach type and incorporating predicted hurricane erosion

Return Period	Beach Setback		Rock Setback	
	(m)	(ft)	(m)	(ft)
25	41	133	22	73
50	52	169	26	84
100	70	231	31	103

Table 4-7 Vertical step-up values for development along beach

Return Period	Minimum Suggested Building Floor Level	
	(m)	(ft)
25	2.6	8.5
50	2.9	9.5
100	4.1	13.5

Outcomes and Implications

The regulatory vegetation setback line mainly coincides with the 50-year setback line and does not exceed the 100-year setback line. Figure 4.16 shows the recommended distances for each return period.

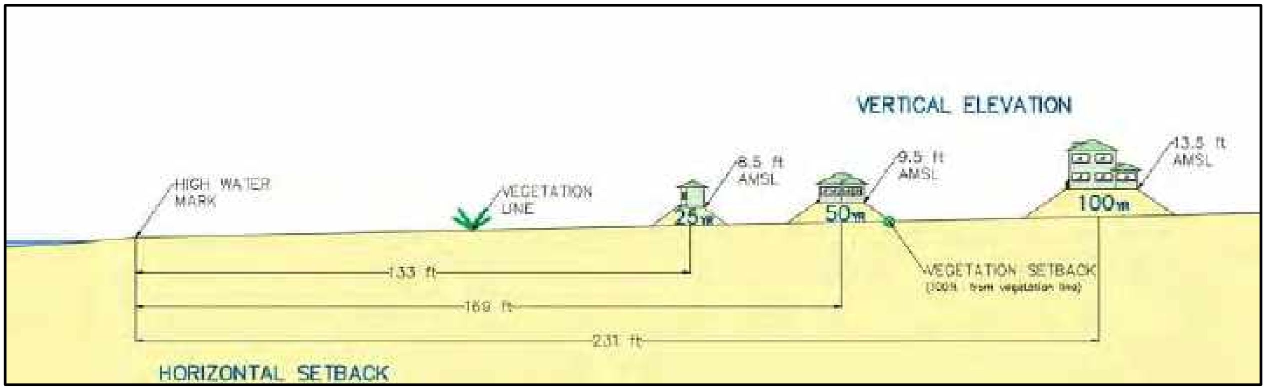

Figure 4.16 Final setback values relative to the vegetation setback line (units of measurement shown in feet)

Updated Coastal Setback

A key outcome of the 2016 study was the prescription of coastal setback distances and elevations. These elevations were based on typical beach profiles at the southern shores. These levels included a consideration for hurricane surge levels. With the passage of major storms in 2017, it was determined that the levels should be updated to include the hurricanes that passed in the time since the prior study. Additionally, climate change projections have changed since 2016, the Intergovernmental Panel on Climate Change (IPCC) Sixth Annual Report (AR6) was used to update the projected sea level rise. With these new formulations, the proposed setback and elevations were calculated (summarised in Table 4-8).

Table 4-8 Coastal setback and floor elevations calculated for shoreline areas

Design Scenario	Coastal Setback (m inland from high waterline)	Floor Elevations (m above mean sea level)
50-year storm	52	3.7
100-year storm	70	4.5

The final levels also include water increases related to high tide, sea level rise and a freeboard of 0.3m (1'). The freeboard was added to provide a buffer between possible surge and the base of structures.

The design narrative for this property shows that there is a focus on enhancing the property while being cognizant of typical building practices. On Barbuda, many homes are built atop stilts. This is expected to be utilized in the plan as it would reduce the amount of fill needed on the lots. The land will be graded towards the existing (and future) ponds to allow for proper drainage of the site.

The current project has been granted permission to construct its buildings along the current setbacks previously established at the K-Club. That setback value was around 30m (100ft - 130ft) from the mean sea level (MSL). This setback corresponds to approximately a 25-year return condition when compared to the calculated setback. Buildings have also been prescribed with a finished floor level of 3.4m (11ft) above MSL. This level corresponds to about a 75-year return condition when compared to the calculated setback.

Sand Movement

A general understanding of the patterns of sand movement along the shoreline is essential to understanding vulnerabilities of the beach. The previous section illustrated that the beach undergoes significant variations in profile and width, seasonally or annually. A preliminary analysis was carried out to gather a general insight into the patterns of sediment movement around the southwest coast of Barbuda.

Waves propagate towards the coastline at an angle and this action drives currents that transport sediment in the cross-shore or alongshore direction. Barbuda's coastline has two main wave climates: (i) higher energy waves from the Atlantic Ocean affect the eastern side, while (ii) the western side is calmer. The proposed site is sheltered by both Coco Point to the southeast and Palmetto Point to the northwest. Simulation of sediment movement around Barbuda can help in understanding the long-term behavior of the Paradise Found shoreline.

Sediment transport modelling was done using the Sand Transport Module of the DHI MIKE21 Software Suite. This module incorporates hydrodynamics and the annual statistical wave conditions for each defined direction. The output from the run showed the maximum load and the direction of transport. The output received was post-processed using a weighted average algorithm that provided the mean annual transport for the sea floor. The final plot showed total sediment load magnitude and direction of transport.

The plot shows that the potential for sand transport is most prevalent on the east side of Barbuda given the more energetic wave climate that prevails there. There is a general westerly movement of sand into Gravenor Bay, which would explain why this bay has a sandy beach that blocks the outlet of the salt pond to the sea. A large sediment flow also moves towards and around Coco Point. A portion of these sediments would move onto the beach at Coco Point, explaining why this end of the bay has a wider and gentler slope. A portion of the sand is deposited onto Coco Point beach and the nearshore area, however, the remainder is transported northwards to the Paradise Found beach. The sediment flow seems to bypass the northern end of the Paradise Found property, which explains why there is not a sandy beach in this area.

As such, the supply of sand, as expected, is from the south. Any structure across the beach south of the Paradise Found property that would interrupt this sediment flow would have an adverse impact on the Paradise Found beach. Further, if the Paradise Found beach is to be extended northwards along the property, artificial interventions would have to be implemented to achieve this objective.

Storm Surge Inundation

A review of historical hurricane data showed that hurricanes have typically approached from the east or southeast. The eastern side of the island experiences higher water levels and wave heights during these hurricane events. Hurricane conditions from the south were however found to produce the highest storm surge elevations, and this direction was used in further modelling of impacts. Storm surge was mainly observed by the outlet at Gravenor Bay and the break in the berm near the roadway to the north.

Figure 4.17 below shows the 50-year storm event pre- and post-development. The proposed master plan would introduce a dyke behind Pond 1 and then raise the berms; modelling has shown that this would prevent inundation on site from static storm surge.

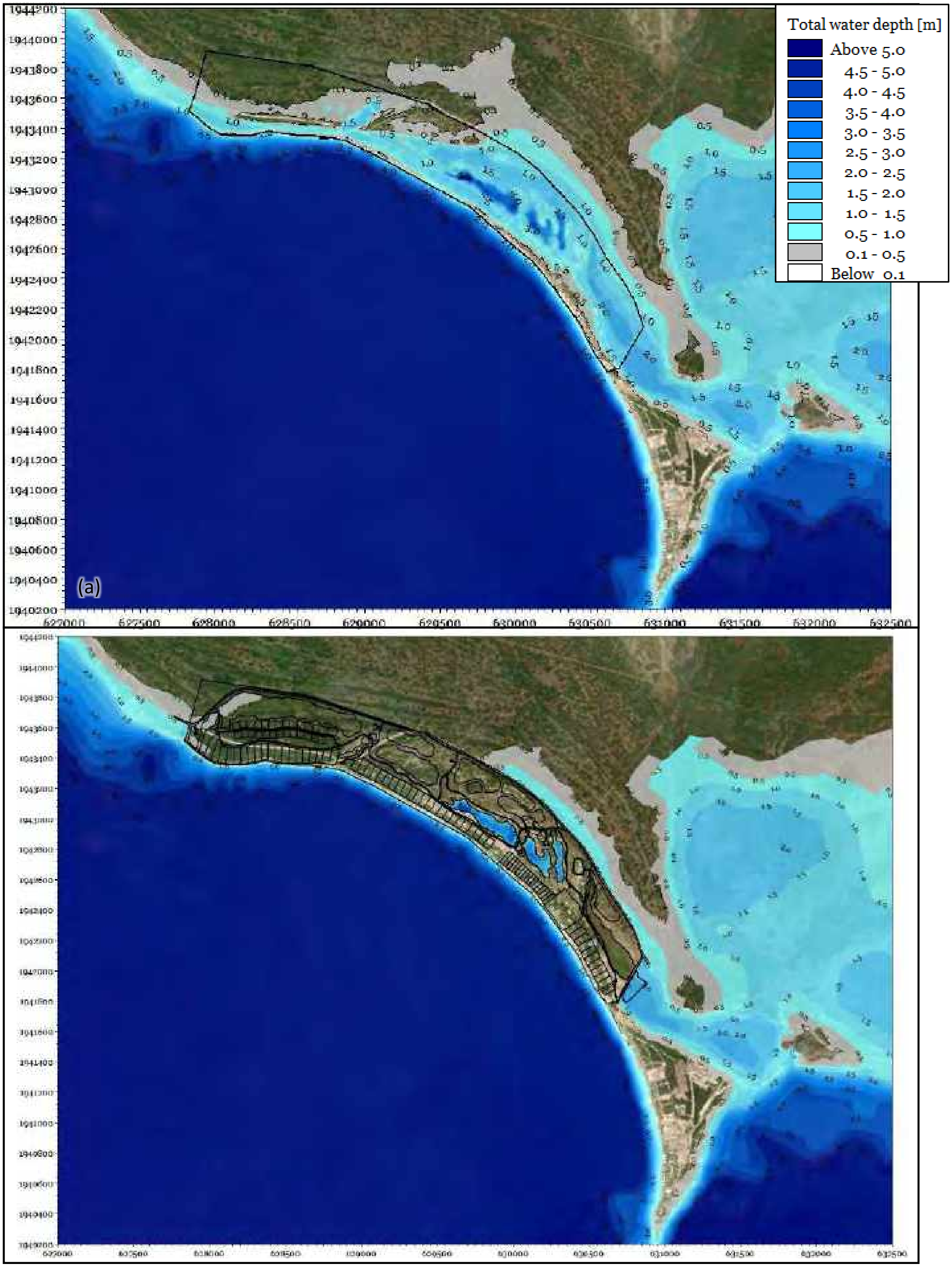

Figure 4.17 Storm surge comparison pre-development (top) and post-development (bottom) for the 50yr storm

Storm surge is experienced as inundation from the sea caused by storm events. During tropical storms and hurricanes, the sea level rises due to a number of interacting phenomena. These include: sea level raising because of the low-pressures experienced (and high velocities) under the central eye of the system where the winds are maximised; the high winds generate unusually high waves, which run up farther inland; as these large waves collapse, they further push up the water level. The combination of these phenomena contributes to what is known as storm surge.

The Paradise Found property, being relatively low and flat, is vulnerable to storm surge. The site is exposed to storm surge from two points: along the beach and from Gravenor Bay across the salt ponds. Anecdotal reports suggest that Hurricane Luis (1995), Hurricane Irma, and Hurricane Jose (both 2017) did not cause catastrophic storm surge at the beach. This provided an opportunity to validate the storm surge modelling assessment.

Assessing the vulnerability of the project to storm surge involved the following key steps:

- Historical assessment carried out for all tropical storms and hurricanes to have passed within 300km of the project site since 1852. The storm track data from the National Hurricane Centre was used within our in-house software, HURWave. This search criterion resulted in a total of 209 storms.

- The waves and water levels generated by each of these storms just offshore of the site were parametrically determined.

- The waves that would have a direct or near-direct approach to the Paradise Found site were filtered out from the larger database. The highest hurricane waves for Barbuda are from the east but the worst-case waves for the site are from the south. A statistical analysis was carried out on these wave and water level conditions. This produced the 25yr, 50yr and 100yr conditions.

- These hydrodynamic conditions were simulated in the model domain of MIKE21, which was set up for the south of Barbuda using collected bathymetry and topography as the baseline data for the model. The model provided the storm surge levels for the project site based on the selected input conditions. This process was completed for the existing site conditions, thereby providing storm surge plots for the 25yr, 50yr and 100yr storm conditions.

- Hurricane Irma (2017) was a large ferocious hurricane that hit the north of Barbuda. The damage to Codrington and its people is still being felt to this day. Hurricane Irma is locally considered the worst hurricane to have hit the island. It is to be noted however, that the project site is located to the south of the island. For that side, Hurricane Luis (1995) passed from the southeast as a Category 4 storm. To verify the model for the project site, the full track of Hurricane Luis (1995) was simulated in MIKE21 and an inundation map for the project site at the timestep where the worst inundation was observed, was recorded to evaluate if the predicted results validated the anecdotal reports of limited inundation from the sea for that event.

- The above simulations were repeated for all the storms for the scenario with the development in place and taking future projected sea level rise into consideration. The sea level rise considerations were incorporated by using the Inter-Governmental Panel on Climate Change (IPCC) projections for mean global sea level change. The IPCC RCP8.5 scenario was chosen as it represents the highest level of radiative forcing by the year 2100 (least responsive societal reaction to GHG emissions). The global mean increase in sea level is projected to be 0.69m. This additional water level was added to the model domain in the simulation of the 25yr, 50yr and 100yr conditions for the scenario with the development masterplan in place.

The simulations for the various return periods were done assuming the event happens during a high-tide situation. The simulations of Hurricane Luis and Hurricane Irma were done with the actual tide conditions that occurred during the storms. Based on the statistical analysis, the waves from Luis were found to be slightly higher than from the 25-year event, however the simulated water level (storm surge) was less. Luis therefore showed storm surge levels even less than the 25-year hurricane. The plots below show storm surge for Luis as well as the pre- and post-development scenarios for the modelled 25-year event.

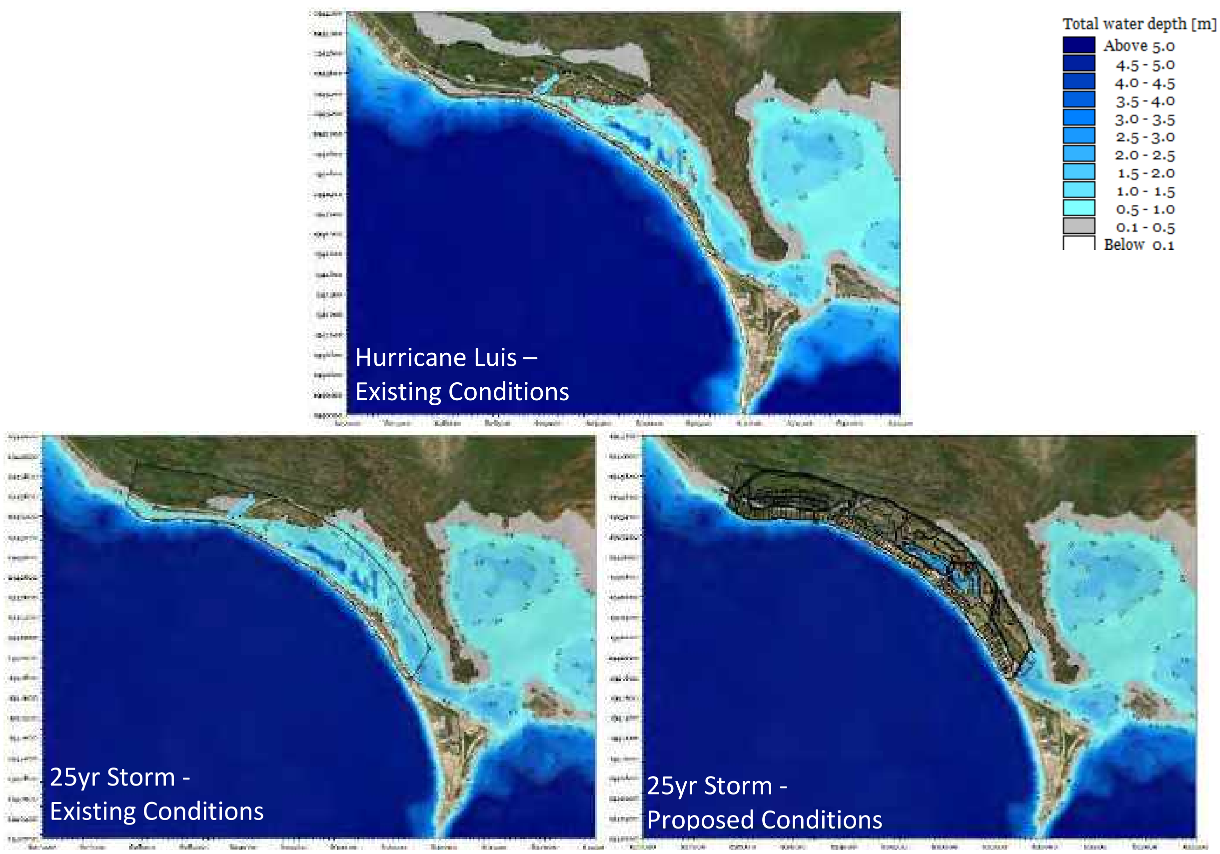

Figure 4.18 Storm surge comparison for Hurricane Luis (top) and 25-year event (pre-development (bottom-left) and post-development (bottom-right))

For the pre-development scenario, the water elevation is shown above existing ground level, whereas for the post-development case, it is shown as being above the proposed finished ground levels. The following are key observations from the analysis:

- Hurricane Luis did not produce significant inundation from the beach, and this finding concurs with the anecdotal reports. Rather, inundation was observed to come in from an influx of water from Gravenor Bay, which increased the height of the water in the salt ponds. The low-pressure center of the hurricane affected the height of the water in the ponds and the winds from the hurricane pushed the water, causing inundation of the low areas around the pond. These low areas typically flood in any case when there are heavy rainfall events.

- All simulated events caused some level of inundation along the shoreline as waves ran up across the beach and into the dune area. This inundation level carries farther inland for higher return periods. There is a single low area between Pond 3 and the beach where there is a consistent breach of waves causing additional inundation around this pond. The post-development scenario, however, raises the elevation of this area, thereby getting rid of this impact.

- Gravenor Bay represents the most significant path for inundation of the site. Waves breach this bay and carry water across the salt ponds and on to the property. A dyke built to an elevation of +3m is proposed along this eastern property boundary, which eliminates this impact for the post-development scenario.

- In the 100-year event, water levels are as high as 2.6m (approx. 8.5ft) above existing ground at the site shoreline. The 100-year event inundates most of the existing property. The high areas of the site where the K Club cottages were built and towards the raised areas at the north-western end of the property had lower depths of 0.1 - 0.3m.

- With the dyke along the eastern property boundary in place, low areas around the ponds raised, and the waterfront properties appropriately setback from the shoreline, the proposed development will not be at high risk from storm surge inundation for events up to the 100-year return period.

4.1.7 Surface Drainage

The natural existing drainage features and ponds on the Paradise Found site become inundated with flood water easily during moderate rainfall conditions. Further, the offsite drainage run-off has a significant impact by infiltrating the Paradise Found site. The existing flooding situation onsite demonstrates the need for an assessment of current drainage features and existing site conditions along with a need for the design of a new comprehensive drainage strategy and drainage system.

Despite efforts to elevate areas of the site and construct a golf course by previous developers, the site still floods quite easily and significantly as indicated in the hydrology models. The hydrology model (MIKE 21 Hydrodynamic) identifies the areas of concern that needs to be addressed. Low lying areas of the site will require significant filling and drainage works to provide flood management solutions. There are cost implications and, as a result, various solutions have been investigated and optimized.

MIKE21 has been validated multiple times as an accurate flow routine for overland flooding, infiltration and structure calculations (MIKE, 2012; Shrestha et al., n.d.; Teng et al., 2017). To ensure that the model was properly defined, previous validation tests using the 2-year rainfall statistics were done and compared to a recent rainfall event. After validation was achieved the 5yr, 10yr, 25yr, 50yr and 100yr rainfall events were run on the existing site. Flood modelling was done for all master plans previously submitted (September 2016, November 2016, and December 2016). However, only the recent master plan presented in November 2022 is examined in this report.

Figure 4.19 illustrates the existing and post development scenarios for the 10yr rainfall event. The master plan presented was the latest version at the time of this report and had been modified from previous versions to reduce fill and allow non-critical areas of the site to flood. These models aided in the design of smaller scale drainage features such as swales and French drains. The design of these is discussed in further sections of the report.

As shown, in the 10yr flood event there is a flow of rainwater from the north-east of the project site. This flow then diverts to form two arms of flow. One flows to the west around the high point to the north of the property. The other flows towards the south-east through most ponds. The lower elevation area in the centre of the property was quickly inundated with some flow towards the coast.

Under proposed conditions there was an increase in flow depths at the property roadway which is to be conveyed by a swale along the roadway. The salt ponds to the south had an additional 0.5m of water at the deepest parts, however there was not any increase in inundation predicted on the neighbouring properties. Within the property boundary there were some small areas of ponding which would be carried away by the proposed French drains or swales.

The results of all return period testing show that the aerial extent of flooding increases with greater return periods in those noncritical areas.

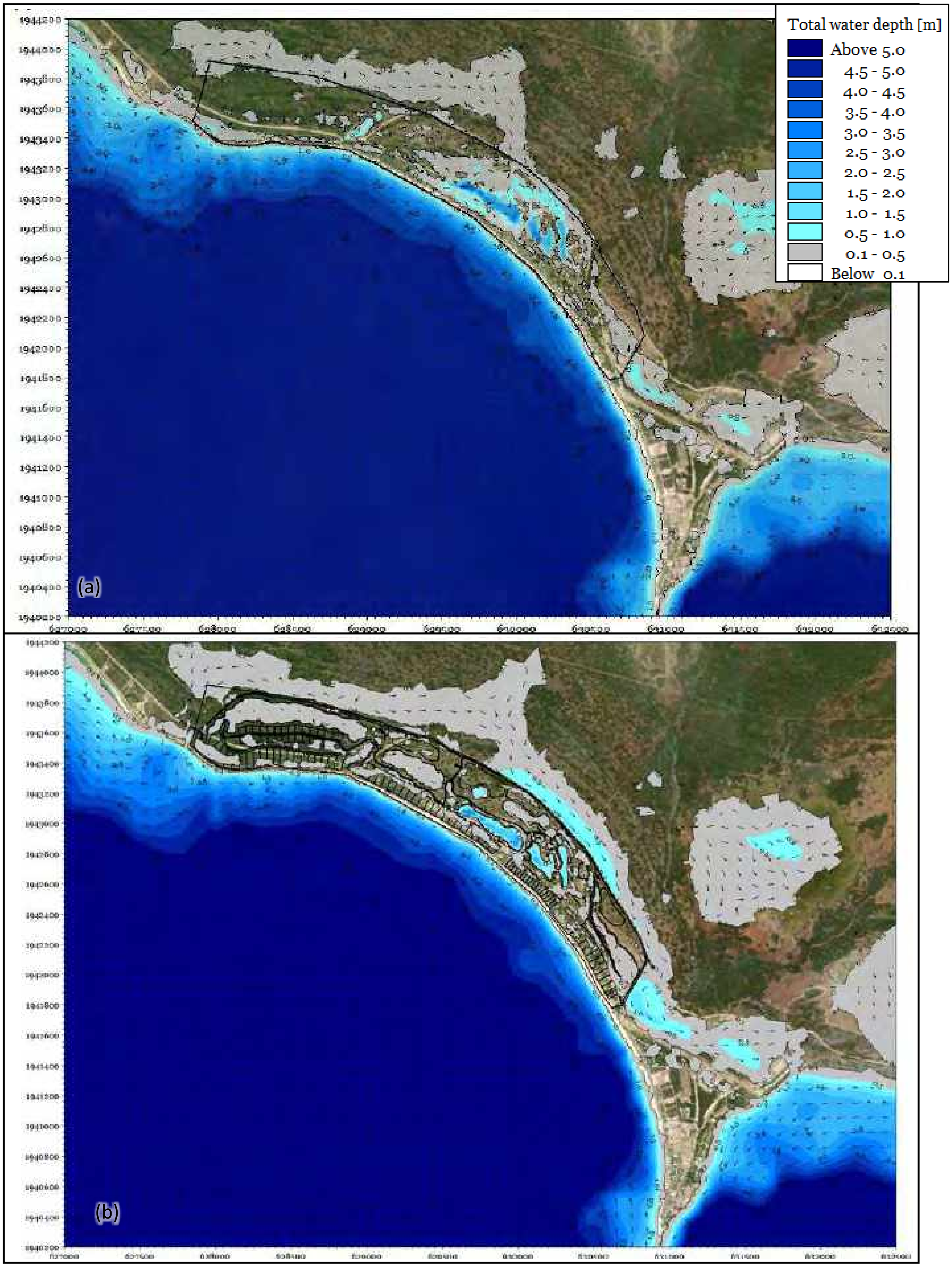

Figure 4.19 10yr flood map for existing and post-development scenarios

New ponds have been designed with regards to master planning requirements, aesthetics, drainage requirements, cut and fill requirements, as well as ecological considerations and geophysical requirements. A three-dimensional model has been set up and used to optimize the drainage system, the various drainage elements, and components of the preliminary design system. With this model, further iterations can be easily reviewed and investigated. A cost effective, balanced cut/fill solution has been achieved and can be improved upon in advancing towards a final design. As previously stated, the revised master plan allows areas to be flooded during events less frequent than 1 in 50yr to reduce cut and fill volumes. The developers accept the risks associated with flooding within their property boundaries and aim to not increase the flooding of nearby lots.

The site conditions have been effectively reviewed and a grading strategy has been developed with the team to optimize the grading levels around the ponds and low-lying zones resulting in a cost-effective approach to the fill and grading of the site. Most of the cut material extracted from the site can be used for effective filling material. However, some of the cut material will require treatment that will involve mixing and crushing. The geological report identified various soil components on the site and the new ponds provide a good source of reliable fill material.

The material volume calculations were executed for the Master Planning models. In the latest design, the cut and fill requirements reasonably match each other using onsite cut resources. Some material may need to be provided to increase the dune height and for late-stage grading. Volumes calculated for the main earthworks are shown below in Table 4-9.

Table 4-9 Cut and Fill volumes for the current Master Plan Layout

Zone	Cut Volume (m^3)	Fill Volume (m^3)
Grading Land	680,036	704,127
Sand Dune	-	38,462
Geotube	-	5,322

This is an important consideration, as imported material costs are twice as much as site sourced material. For a project of this magnitude, a sustainable and balanced approach to cut/fill volumes can offer significant savings. It is also to be noted that the possibility exists for ponds to be deepened by about 0.3m to provide more material for the earthworks, and this would potentially balance the cut and fill volumes.

For the site to have proper drainage it must have a clear definition of flow off the site. This is to be achieved by grading the land so that surface runoff does not stay in the development for long. The offsite discharge coming from the north must be diverted so that it does not interfere with infrastructure. Lastly, the ponds should add to the drainage storage capacity of the site by allowing for small retention in the ponds.

It must be clearly understood by the developers that this effort to reduce fill requirements can result in flooding of areas of the site for events exceeding the 1 in 50yr event. These areas include the private beachfront lots, northwest of the hotel cottages, the depression zones of the recreational and nursery areas, areas around the spa village and the restaurant village north of Pond 1.

Table 4-10 documents the various objectives of the drainage analysis and their anticipated outcomes and implications.

Table 4-10 Drainage Related Tasks with Anticipated Outcomes & Implications

Drainage Objectives	Proposed Outcomes & Implications for Drainage
Assess qualitatively the existing natural drainage and flooding characteristics of the site as well as the impact of offsite runoff.	The natural existing drainage features and ponds on the Paradise Found site become inundated with flood water fairly easily in moderate rainstorm conditions. Furthermore, the offsite drainage run off has a significant impact by infiltrating the Paradise Found site. The existing flooding situation onsite demonstrates the need for an assessment of current drainage features and existing site conditions along with a need for the design of a new comprehensive drainage strategy and drainage system.
Investigate the extent of site flood conditions via hydrology model	Despite efforts to elevate areas of the site and construct a golf course by the previous developers, the site still floods quite easily and quite significantly as indicated in the hydrology models. The hydrology model identifies the areas of concern that needs to be addressed. Low lying areas of the site will require significant filling and drainage works in order to provide flood management solutions. There are cost implications as a result, various solutions have been investigated and optimized.
Identify, quantify and delineate the Storm Water Catchment Areas which will help to define the site drainage requirements.	The current existing ponds are quite large in size relative to the catchment areas. The new ponds are also significant in size relative to their catchment zones. Therefore, there must be a reasonable link between catchment zones, ponds, and drainage features. Comprehensive site drainage requirements have been identified and optimized resulting in an effective preliminary design solution.
Design new retention ponds with respect to the required drainage capacity and within the natural ecological boundaries of the site.	New ponds have been designed with regards to master planning requirements, aesthetics, drainage requirements, cut and fill requirements, as well as ecological considerations and geophysical requirements.
Simulate storm conditions, analyze flood routing and runoff via the ponds and identify the overall storm water drainage system performance during storm conditions.	The simulation of storm conditions that analyzes the flood routing and runoff via the ponds has been executed in accordance with the suggested design criteria and site model. This simulation has assisted in successfully identifying an effective preliminary storm water drainage design system.

4.2 Biological Environment

The site footprint occurs at a derelict former development site, with manmade ponds, modified soils and elevations and hard structures. The site includes the original K Club resort footprint, inclusive of the golf course, which was abandoned in 2004. As such, the area is not an undeveloped site but one that had previously undergone extensive modification.

Several types of habitat / ecosystems were identified within the site and immediate surrounding study area. The main ecosystem types found at the Paradise Found site were mangroves, dry forest, ponds, sand dunes and rocky shore. The western end of the property is occupied by shrub/scrub type ecosystems with xerophytic vegetation. Various species of cacti dominate the area. Rocky shores exist along sections of the shoreline, sand dunes occur in the middle sections of the property and there are mangrove stands on the landward side, however, not to the easternmost limits. The eastern section of the property is characterised by dry limestone forest, with large areas occupied by invasive wild cotton species along the roadway. A large proportion of the site is bare soil.

To determine the dominance of species in the various floral assemblages on the site, a series of observation points were established across the site to make note of the dominant vegetation. The output of the surveys was an update of the list of species, descriptions of the ecological assemblages, habitats and overall ecosystems collated from the 2016 Baseline Report. This information is included in the October 2022 Baseline Report, attached as Appendix B.

A total of 30 species were encountered on the site across the various habitats identified. Four species were listed as endemic (Locustberry, Dagger Plant, Wild Frangipani and Lignum vitae); one species was listed as near threatened (Lignum vitae); and one species was listed as threatened (Black Mangrove) by the IUCN Red List of Threatened Species. All other species are listed as being of "least concern".

Fixed point bird counts were undertaken to describe the avifauna within the site. Based on factors such as access, vegetation type and cover, four bird count locations were established on the site, and these were recorded using a hand-held GPS unit. A total of 20 bird species were observed on the site either during the bird counts or opportunistically. Of these species, the West Indian Whistling Duck and Caribbean Coot are considered near threatened and the Barbuda Warbler is listed as vulnerable. All other species are listed as being of "least concern".

The red-footed tortoise (*Chelonoidis carbonaria*) is found in this ecosystem as they prefer places that help with their thermoregulation so are often found under shrubs and dry leaf litter. They are medium sized with dark-coloured, loaf-shaped carapaces (back shell) with a lighter patch in the middle of each scute (scales on the shell), with dark limbs with red scales (Figure 4.20). During the initial baseline studies in 2016, a male specimen measuring 24cm in length was found on site. The red-footed tortoise undergo aestivation (a period of dormancy similar to hibernation), by lowering their metabolic rate when the climatic conditions are unfavourable, i.e., high temperatures and arid conditions of the dry season. This makes them vulnerable to humans, their only predator on the island. The population on the site is unknown and none were seen on site during the October 2022 site surveys. The red-footed tortoise is classified in the (IUCN) RED List as a vulnerable species. This RED list classification is notable, and the vulnerability of this species must be considered when undertaking any large-scale development.

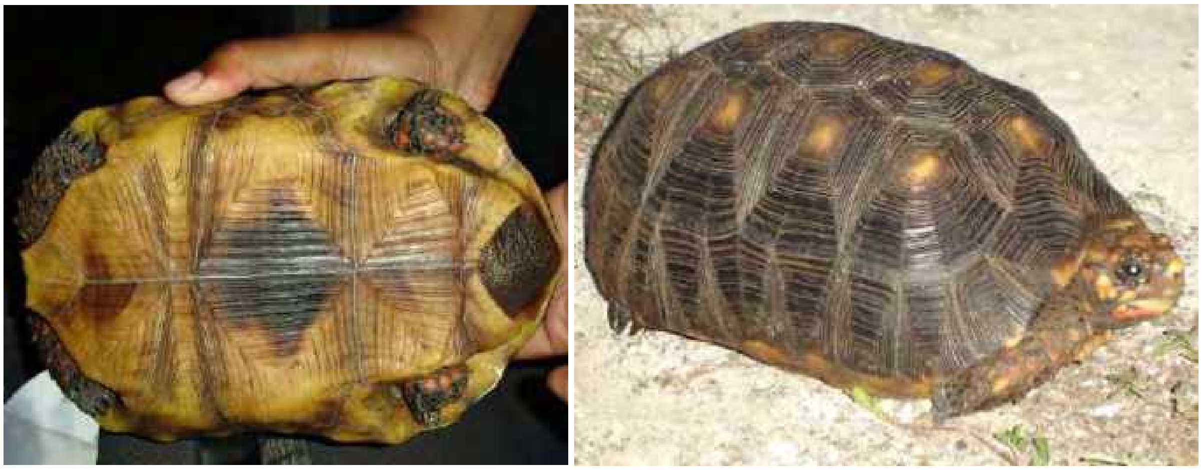

Figure 4.20 Red-footed tortoise (Chelonoidis carbonaria)

Other fauna, including donkeys and iguanas were observed but are listed as being of "least concern".

The shoreline at the site is sandy with a gentle beach. The seafloor has a mix of sand, silt, and seagrass substrate and the typical marine flora and fauna associated with this type of substrate and wave energy.

Four species of sea turtles are found in Antigua and Barbuda waters. These include Green Turtle (*Chelonia mydas)*, Hawksbill Turtle (*Eretmochelys imbricata)*, Loggerhead Turtle (*Caretta)* and Leatherback Turtle (*Dermochelys coriacea)*. Under the Environmental Protection and Management Act (EPMA) 2019 these sea turtles have been declared as "*protected wildlife*". In addition, these four turtles are listed on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species. The Leatherback and the Loggerhead are listed as "vulnerable", the Green Turtle is listed as "endangered", and the Hawksbill is listed as "critically endangered".

Information provided by the Department of Environment indicates that Princess Diana Beach, which borders the south-western boundary of the project site/ proposed Nobu Beach Inn is a nesting site for Leatherbacks, Hawksbills and Greens.

During the initial phase of the project (2016) a full benthic assessment was carried out. At that time the percentage of living substrate was found to be quite high at 70%. There were large swathes of healthy, well established seagrass beds (mostly *Thalassia sp*) mixed with patches of *Syringodium.* Corals present at that time were mostly small (<10cm) and were scattered in the nearshore area.

A resurvey of the marine benthos was not carried out as no part of the development plans involve encroachment on the seafloor. The project will therefore not have any direct impacts on the marine environment or, notably, to the Codrington Lagoon.

4.3 Social / Cultural Environment

4.3.1 Overview

This section of the report presents information that facilitates an understanding of the population and the potential social and economic impacts of the proposed project on the population. The issues of employment and livelihoods, health and well-being, and awareness of the population about the project activities, vulnerabilities of the aged, children, youth and those with differing abilities are explored and presented.

A gender analysis of the data collected is presented where possible.

The cultural norms, practices of the population, and assets that have potential for being affected, are also presented. The analyses seek to strengthen the investor's focus on the social components, especially in cases where the local communities affected may be dependent on the same natural resources as the investor.

The literature of this Social Impact Assessment (SIA) is situated around three main theoretical issues: The concept of the 'social licence'; the human rights-based approach; and the importance of the non-technical risks or the social risks.

The Social Licence to Operate, according to Vanclay *et al* (2015), refers to the level of acceptance or approval of the activities of an organization by its stakeholders, especially locally impacted communities. The theory contends that leading corporations accept that they need to meet more than just the regulatory requirements. It argues that corporations also need to consider, if not meet, the expectations of a wide range of stakeholders, including international NGOs and local communities. The consequences of ignoring the expectations of this wide array of stakeholders could put corporations at risk not only of their reputational position but also at the risk of being subject to negative action and the financial consequences of those actions.

Vanclay *et al* (2015) note that in some countries, 'social licence' has become an established element of the language of business, influencing and driving the business strategy of many companies. They conclude that a social licence has become part of the governance landscape.

The human rights-based approach refers to a conceptual and procedural framework which seeks to ensure the promotion and protection of human rights in policies, programs, plans and projects. Such an approach seeks to: (1) position human rights and its principles as the core element of actions; (2) demand accountability and transparency by duty-bearers towards rights-holders; (3) foster empowerment and capacity building of rights-holders to, *inter alia*, hold duty-bearers to account; (4) ensure that the meaningful participation of rights-holders in development processes and planned interventions is recognised as an intrinsic right, not simply as best practice; and (5) ensure the non-discriminatory engagement of rights-holders and the prioritization of especially-vulnerable or marginalized individuals or groups (e.g. women, elderly, children and youth, minorities and indigenous peoples).

Last but by no mease least is the notion of non-technical or social risks, which refers to those risks such as the managerial, legal, social, and political issues faced by a project, in contrast to the technical risks (i.e., the physical, structural, engineering, and environmental risks). Often due to the technocratic focus of many project staff, the technical risks are usually fully considered whereas the non-technical risks are under-considered or ignored altogether. The World Bank defines social risk as "the possibility that the intervention would create, reinforce or deepen inequity and/or social conflict, or that the attitudes and actions of key stakeholders may subvert the achievement of the development objective, or that the development objective, or means to achieve it, lack ownership among key stakeholders". For the World Bank, social risk is both a risk (threat) to the success of the project, and also risk (social issues) created by the project, which in turn becomes a threat to the project.

4.3.2 Methodology

The SIA uses a mixed applied research approach. The methodology includes desk review of relevant literature; community engagement of stakeholders, using an in-depth semi structured questionnaire; consultations with key policy makers; and collection and analysis, including a gender analysis, of data about the Directly Affected Community (DAC). Such an approach ensures a full understanding of the baseline conditions which the project encounters.

Stakeholder groups were identified as follows: elders who knew the history of the island well; fisherfolk; farmers; people who own and run guest houses; persons who transport tourists (tour guides); persons who are engaged in any way with the tourism industry (e.g., cooking food for tourists); and those in the health sector. In addition, policy makers were identified for in-depth interviews such as the Chair of the Barbuda Council, the Member of Parliament for Barbuda, the CEO (Ag) of the Barbuda Council, key officers in the Division of Statistics, Ministry of Finance, the Gender Affairs Department of the Ministry of Social Transformation, officials from the Ministry of Health, Wellness (both in Barbuda and Antigua) and the Climate Assessment and Information Officer, Department of Environment.

The key ethical issue that may arise in this assessment surrounds the question regarding for whom the SIA assessor works - the community or the project proponent? The report emphasizes to all parties that the assessment is being conducted to the highest ethical standards and it adopts an independent stance. Such a stance allows the SIA to make relevant community interests explicit in the assessment and should the assessor "perceive risks beyond those identified in the preliminary assessment conducted by the DOE, the assessor is obligated to investigate such".[5] Through such an approach the Assessor seeks to lay bare opportunities for building a balanced, just, and harmonious relation between community and project proponent.

The governance arrangements for the conduct of the SIA are derived from the Review of Plan Application #G10-2021 (Paradise Found), by the Director of the Department of Environment of the Ministry of Health, Wellness and Environment of the Government of Antigua and Barbuda. That review called for an EIA to be undertaken, which in Section Five (5) *inter alia,* requested a Socio Economic & Health Environment Baseline.

In section 5.5 the request noted that (the)

> "Baseline data should include the demography, nearest settlements, and existing infrastructure facilities in the proposed area. Present employment and livelihood of these populations and awareness of the population about the proposed activity should also be included. Vulnerable groups and gender analysis may also be included if applicable. If there are cultural practices or norms which may affect the environment or be affected by the environment it should also be mentioned".

This Report is situated within the conceptual understanding of the notions of livelihoods as defined by Chambers and Conway (1991). A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can

[5] DOE April 2021

cope with and recover from stress and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base.

To better understand how persons in the DAC of Barbuda, develop and maintain livelihoods, the Sustainable Livelihoods Framework (SLF) was applied[6]. This framework is an analysis tool, useful for understanding the many factors that affect a person's livelihood and how those factors interact with each other. The SLF views livelihoods as systems and provides a way to understand:

1. The assets people draw upon.
2. The strategies they develop to make a living.
3. The context within which a livelihood is developed.
4. Those factors that make a livelihood more or less vulnerable to shocks and stresses.

How people access and use these assets, within the social, economic, political, and environmental contexts, form a livelihood strategy. The range and diversity of livelihood strategies are enormous. The SLF acknowledges that an individual may take on several activities to meet his/her needs. One or many individuals may engage in activities that contribute to a collective livelihood strategy.

The diverse livelihood strategies of the DAC of Barbuda will be presented as part of the Community Profile.

One limitation of the applied methodology which the assessor encountered was data driven, as social statistics are not as current or readily available across the Caribbean, and the situation in Antigua and Barbuda was found to be no different. Another was that the COVID-19 pandemic acted as a constraint to consultations, as some people were unavailable because of the exigencies of the Pandemic.

Yet still another issue identified as a limitation of the Assessment, was the fact that multiple development projects are currently taking place on the island, with members of the DAC being unable to distinguish between which development and its impacts belong to which developer or project. This lack of clarity results in the social impact analysis having to consider all on-going effects and impacts. In the assessment methodology, such a situation is often referred to as a multiple hazard environment resulting in complex impacts and requiring solutions that engage enhanced application of the tools of integrated development planning. [7]

4.3.3 Community Profile and Social Baseline

Barbuda with a land area of 176 km^2, is located some 40 km north of Antigua and has a land mass size of approximately 39% that of Antigua and Barbuda, which together comprises some 456 km^2. Antigua, the bigger sister island, has a land area of 280 km^2. The estimated population in 2022 for Antigua and

[6] DFID's Sustainable Livelihoods Approach and its Framework. https://efaidnbmnnnibpcajpcglclefindmkaj/http://www.glopp.ch/B7/en/multimedia/B7_1_pdf2.pdf

[7] Integrated Development Planning is an approach to planning that involves the entire geographic area and its citizens in finding the best solutions to achieve good long-term development. https://www.etu.org.za/toolbox/docs/localgov/webidp.html

Barbuda was 100,722 and of those 52% are female and 48% male. Some 97% of the population resides in Antigua.

Barbuda has an estimated population of 1,935, of whom 52% are female and 47.8% male, with details being obtained from the Statistics Division.[8] Some 28 % of the population are 19 and under and 10% of the population comprise persons 65 to 80 and over.

Together, these islands comprise the state of Antigua and Barbuda and have similar characteristics of small island developing states (SIDS) in the Caribbean. Both islands are low-lying with 70% of the land in Antigua less than 30m above mean sea level and most of Barbuda only 3m above mean sea level. The country's economy is heavily dependent on natural resources, low-lying coastal zones, and favourable climate conditions to support the tourism sector, which accounts for about 80% of output gross domestic product (GDP), about 70% of direct and indirect employment and 85% of foreign exchange earnings. [9]

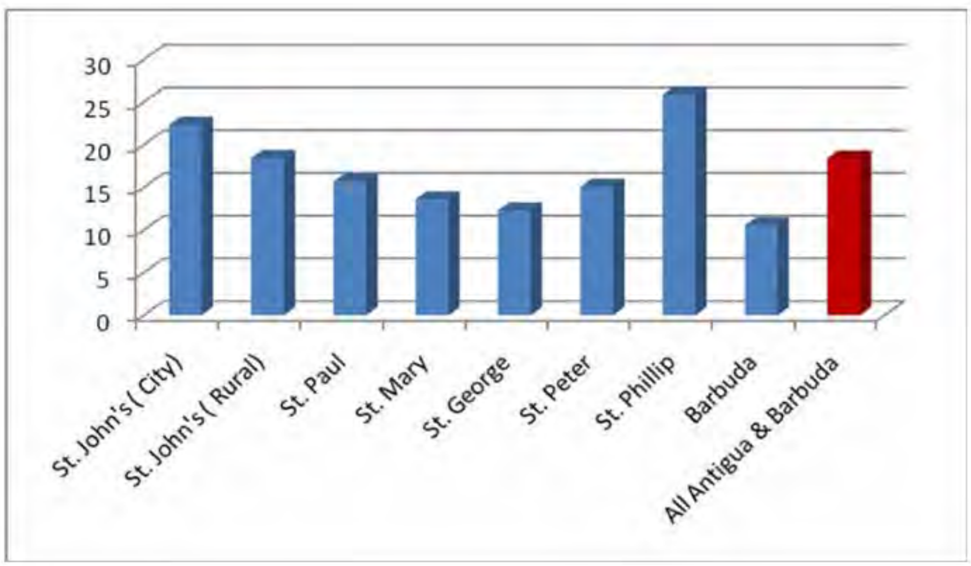

Figure 4.21 Proportion poor in Antigua and Barbuda by Parish
Source: 1. Survey of Living Conditions, Antigua and Barbuda: Poverty in a Services Economy in Transition 2007.

Despite a high-income ranking, according to the latest data available, approximately 18% of the total population falls below the national poverty line; 3.7% indigent (food poor); and 10% vulnerable to poverty in the event of a significant socio-economic shock or natural hazard. When considering the proportion of the population that is at risk of falling into poverty if there is a shock to the economy, the percentage rises to 28%.

[8] This estimate has been produced by the Statistics Division (as of July 2022) in support of this Assessment. It should be noted that all stakeholders have concerns about the accuracy of the projected population as numbers have been affected by the movement of people following the Hurricanes of 2017, the return of population groups, the arrival of workers from Antigua and wider Caribbean.
[9] Antigua and Barbuda Updated Nationally Determined Contribution, (NDC) for the period 2020 to 2030, communicated to the UNFCCC on 2nd September 2021. Government of Antigua and Barbuda, Department of Environment Ministry of Health, Wellness, and the Environment.

Interestingly Barbuda had the lowest proportion of poor (10.6%) when compared to other Parishes of Antigua and Barbuda.

Education Sector

There are two schools in Barbuda, the Holy Trinity Public Primary School, and the Sir Mc Chesney George Public Secondary School, which together provide education for the school age population, and which accounts for about 21% of the Barbuda population, or 409 children. Early Childhood Education centres include Toddlers' Paradise Day-care centre and the kindergarten, Cody Kelly Preschool, both of which, along with the Primary and Secondary school, suffered damage and required renovation and repair following the devastating hurricane season of 2017. Presently, most children can be seen walking to and from school.

Health

The health systems in Antigua and Barbuda are mainly financed and operated by Government. Health services are delivered at primary, secondary, and tertiary levels and at the primary level, there is a network of 25 public health clinics, with clinics located within 3.2 km of every major community. Secondary and tertiary health services are provided at the Mount St. John's Medical Centre, a 186-bed facility in Antigua, commissioned in 2009. There is one clinic and hospital in Barbuda, the Hanna Thomas Hospital, which was formally handed over to the Barbuda Council by the Government of Antigua and Barbuda, after its rehabilitation from the devastation in 2017.

The country is undergoing epidemiological transition with non- communicable diseases accounting for 85% of deaths, and most patient visits to primary health care facilities, and an ageing population (12% over 60 years, nationally and 15% in Barbuda). The three leading causes of death were cancer, heart disease, and diabetes. The government is implementing cost effective prevention activities focusing on obesity, exercise, and reduction in tobacco and alcohol use.

Communicable diseases, including HIV/AIDS, accidental and intentional injuries are among the ten leading causes of mortality.

About 70 % of infant deaths occur during the neonatal period, with main causes being birth asphyxia, prematurity, and injuries. Major focus is on reducing the neonatal deaths to meet the SDG's.

From 2011 to 2016 Antigua and Barbuda experienced increased cases of Vector borne diseases of Dengue, Chikungunya and Zika. Implementation is continuing of the integrated management strategy for control and prevention of vector-borne diseases.

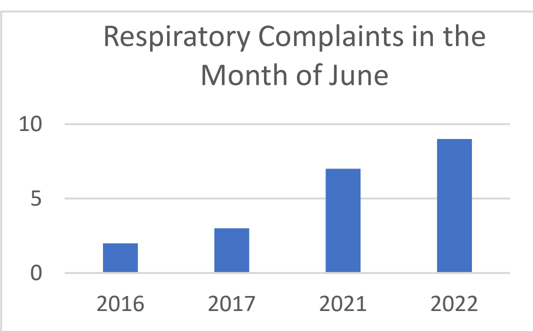

Figure 4.22 Number of children seen with respiratory complaints at the Hanna Thomas Hospital (June 2022)

In Barbuda, health concerns have been expressed by key informants and stakeholders emerging from the concentrated levels of dust, oil and diesel which have overtaken the environment of Codrington since development projects have gotten underway. Based on data collected by the Hanna Thomas Hospital (HTH), Dr. Deazle revealed that there has been an increase in the incidence of intense asthma due to dust. In addition, community members spoke of elders having to live like shut-ins to avoid the dust, children suffering from increased respiratory complaints and all residents of town experience the need to scamper off the roadways from oncoming trucks who use the roadways as well as pedestrians. There are few sidewalks to be found in Codrington. Measures will be implemented on this project to ensure that these problems are not exacerbated.

Two sets of data were collected at the Hanna Thomas Hospital to investigate the concerns of the DAC for children 18 and under, male and female. Data, as presented in Figure 4.22, was collected for the month of June for the years 2016 and 2017, before development projects got underway and before the devastation of the hurricanes of 2017. They were collected again for the same month in 2021 and 2022.

The data suggests a marked increase in the observed number of cases of respiratory illnesses ranging from difficulty breathing, to bronchitis, acute bronchitis, asthma, and acute asthma for the second period (June 2021 and June 2022) compared to the first period (June 2016 and June 2017).

Employment and Livelihoods

According to the Labour Force Survey (LFS) of 2017, the working age population of Barbuda comprises 1,341 persons or 69% of the population. The labour force participation rate was 70.9%. It was higher among men than among women. Of the working age male population, 73.9% participated in the labour force, compared with 68.5% of their female counterparts. There are two interesting facts about the LFS when the data for Barbuda and other Parishes in Antigua were compared. For one, the highest *labour force participation rate* was observed in the Parish of Barbuda, 88.9%, while the lowest was in the Parish of St. George, 72.3%.

The second was that the unemployment rate for Antigua and Barbuda stood at 13.7% based on the 2015 LFS. When the unemployment rate was examined by Parish, a significant amount of variation in unemployment rates was observed. Barbuda was found to have the lowest unemployment rate among the Parishes with only 7.4% of the labour force population being unemployed, while in the Parish of St Paul (in Antigua) the unemployment rate was reported at 20.6%, almost three times higher. Figure 4.23 below is taken from the preliminary release of the 2015 Labour Force Survey. It illustrates the variations in the unemployment rate by Parish and by Sex.

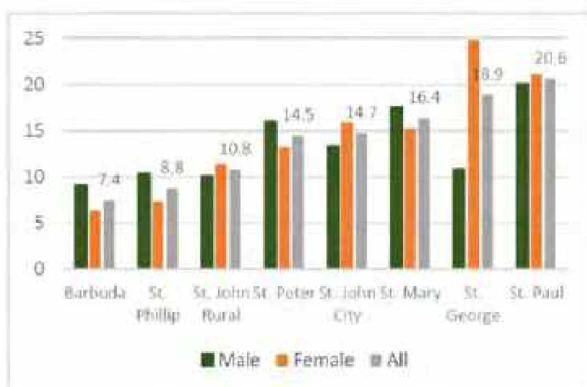

*Figure 4.23 Unemployment by Sex and Parish (*Source: 2 Preliminary LFS 2017)

The data suggests that a significant proportion of the active labour force in Barbuda is employed in various forms of income earning activity.[10]

Data gathered through consultations with stakeholders suggest that income earners in Barbuda are engaged in multiple livelihood activities which constitute their livelihood strategy. Livelihood strategies display a rich knowledge of the local environment and a strong commitment to sustainable development practices.[11] Barbudans work in the formal and

[10] See preliminary data from Labour force survey 2015 in Appendix

[11] There was a period when sand mining had been the main industry in Barbuda (2015 and 2016), but because of the potential impact on the environment, it was significantly curtailed. Currently there is a complete halt to sand mining on Barbuda. The last time that the Barbuda

informal sectors of the labour market. In the formal labour market, an examination of employment by occupation and sex indicate that the largest segment of the labour force is found among the elementary occupations, and these were predominantly women (Figure 4.24).

Skilled agricultural and fishery workers were all male, and craft and related trades workers were predominantly male, with females comprising approximately 22% of this occupation. Income earning activities in the informal sector include agricultural production on 'family grounds', fishing and free diving for lobster and conch when in season, 'picking salt' or salt mining, tour guides - providing day trips to tourists for snorkelling, bird watching and exploring caves and other attractions on the island such as the pink sand beaches and salt and freshwater ponds. Guest houses have been established for short stay visitors and many female micro entrepreneurs have established facilities that cater for meal preparation and sales across town to visitors and workers alike.

The unemployment rate for youths in Antigua and Barbuda according to the LFS 2015, aged 15 to 24 was 33.9%, more than three times the rate for adults aged 25 to 54. Unemployment was higher among young women (37.3%) than among young men (30.4%).[12]

	Male	Female	Total
Employment by occupational category (Main job)			
Armed Forces	-	-	-
Managers	-	-	-
Professionals	-	-	-
Technical and associate professionals	41	74	115
Clerical support workers	55	27	82
Service and sale workers	84	101	185
Skilled agricultural, forestry and fishery workers	20	-	20
Craft and related trades workers	50	14	64
Plant and machine operators, and assemblers	31	-	31
Elementary occupations	-	202	202
Total	**281**	**418**	**699**

Source: Statistics Division, Ministry of Finance and Corporate Governance
Date: 30th September, 2017

Figure 4.24 Barbuda: Employment by Occupation and Sex

Two examples should suffice to suggest that Barbudans are able to earn incomes that could support a good quality of life that would be significantly disrupted if development is not managed as key informants have cautioned.

The Lobster trade which is conducted from the Lagoon generates from about 9 to 11 thousand pounds of lobsters which are sold to exporters (many of whom are Antiguans and who conduct a brisk wholesale and retail business). The market price is $20 per pound and the open season is for approximately 10 months.[13] Fisher folk are extremely worried about pollution damage to the Lagoon by new developments, that would result in the destruction of the Lobster trade, and also the conch trade.

Another area of brisk earnings can be found in that of the tour guides operated both in the high and low season. Tour guides enjoyed a brisk trade taking 'day trippers' on whole day tours across Barbuda, including caves, frigate birds, lagoon, historical sites, etc. For such activity they were paid US100.00 per day, per person. Their costs included, fuel, boat maintenance and meals provided to tourists. Even at a conservative estimate of 200 workdays per year for ten tour guides who service 32 customers per day, income before expenses could be as high as US$640,000 per year.

Council had received revenues amounting to some $600,000.00 from sand mining was in the 2nd quarter of 2017.

[12] Antigua and Barbuda LFS 2015

[13] The Council receives a small fee of approximately $1,600 to $1,800 per month.

Stakeholders expressed concerns that developers were attempting to take control of the 'tour guide' trade by bringing in their own guides and boats to the exclusion of the Barbudan guides. In addition, there was the fear of Barbudans being excluded from access to certain areas such as the pink sand beaches.

Cultural Norms, Practices and Assets

The Antigua and Barbuda Medium-Term Development Strategy, 2016 to 2020 described Barbuda as, "a natural paradise with unique pink sand beaches, lagoons, salt ponds and unique flora and fauna species, including one of the world's largest bird sanctuaries." When asked about the cultural assets, a Barbudan replied," …it is traditional for us to hunt, it is traditional for us to fish, to farm and so forth, so that in itself is a cultural resource… The camp sites, that is a tradition that has been around for ages…now you are saying that all of these could be lost because you want to give it to someone else our cultural traditions don't matter?"

Although the planned development may be some 13.8 Kilometres away from Codrington, stakeholders expressed a sense of much intrusion and exclusion. Most stakeholders felt they had no information about developments taking place, could not distinguish between one developer and the other, and often thought that Paradise Found and PLH was one and the same development.

One stakeholder expressed it in this way, "I am not certain if they (Paradise Found) are associated with the PLH because the area where they supposed to develop now PLH is developing, so I am uncertain if there is a collaboration or anything of the sort".

Although many stated that they had not been consulted, it is to be noted that a Town Hall presentation was made and a community vote for the project was taken, which resulted in a vote (recorded 5th March 2015 by the Barbuda Local Government) approving the project.[14] Some community members do remember a very early consultation meeting in 2015 (or thereabouts) but nothing since. In general, there was interest as to how the people of Barbuda would benefit from the upcoming development.

There was much worry and consternation expressed about impending destruction of natural resources (draining of ponds, allowing chemicals to seep into the Lagoon, the mismanagement of human waste that could enter the waters, the destruction of near shore fishing areas, etc). Another stakeholder asked: "are we compromising our safety and the safety of our livelihoods for money? For persons to feel like, ok, we can make a few million dollars for a few years before all these (assets) gets destroyed and then we just find someplace else to go".

Community stakeholders took umbrage to the low-level jobs being offered to Barbudans and the exclusion of Barbudans to parts of the natural resources to which they have been accustomed.

Included among cultural assets are their access to the rich natural resources found on the island - from beaches to camp sites - which they frequent to pass on to the next generation, traditional knowledge about the value of the flora and fauna and indigenous animals. The Lagoon for Barbudans is a rich cultural asset, not only as it spawns the lobsters which forms part of their livelihoods but is part of their historic landscape.

[14] Barbudan Council Members were the key exception to this rule who noted that they had been spoken to by the Developers some time ago.

Among the cultural assets which the Barbudans hold dear is the social capital which supports their ability to "never lock a door or window". So strong is the social capital that fear of theft or assault does not exist.

Stakeholders expressed satisfaction and considered it a 'good turn of events" that some young people who previously had no jobs were getting jobs as labourers. But they want more for them, training, certification and opportunities for advancement.

5 Coastal and Overland Flooding

Newly collected data from external contractors were used to develop a new drainage master plan and coastal inundation defence for the property.

A major concern for this project is the potential for coastal and overland flooding, which was highlighted in the *Baseline Conditions Report – October 12, 2022* (attached as Appendix B). A summary of the findings from that analysis is presented in Figure 5.1. The baseline conditions show that coastal flooding is a threat from three low points on the property, the greatest of which is the low salt ponds to the south. These ponds act as an avenue for storm surge from the south-east to progress onto the project property. Statistically, wave conditions from this sector were higher than what would be experienced on the property's beach. These surge levels and extents were therefore used to guide the finished elevations of proposed roadways, beach dunes and property.

Computer model results showed that there are many low areas across the property where water pools during heavy rainfall. The locations of these areas were the focus of either filling or grading activities when developing the drainage master plan. Grading efforts will use the existing ponds as much as practical to hold storm water during heavy rainfall.

Figure 5.2 is a comparison of Google Earth images taken in 2016 and on the day after Hurricane Irma hit Barbuda. The dark areas in the lower image indicate flooding. These areas correspond with zones that were flooded in the hurricane simulations shown in Figure 5.1.

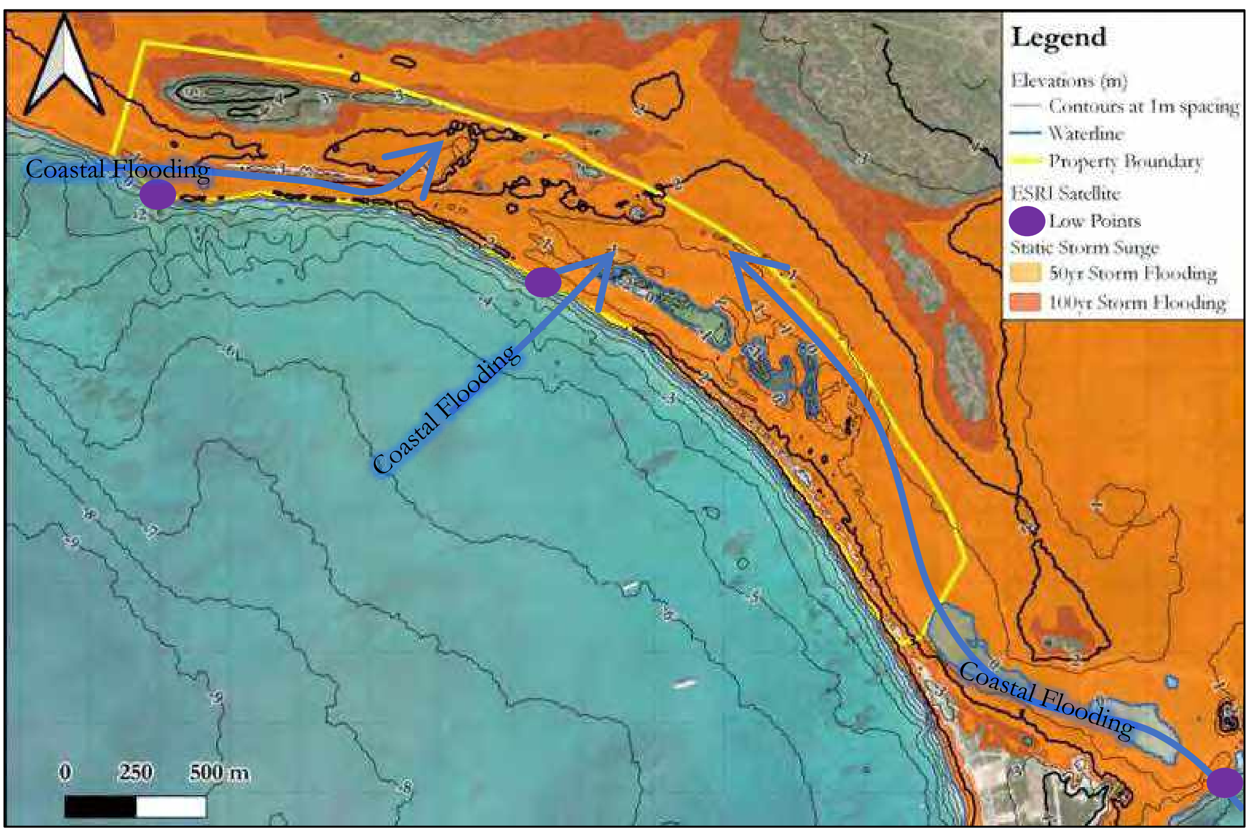

Figure 5.1 Main conclusions from the baseline study that guided coastal and drainage design

Figure 5.2 Satellite imagery of Barbuda in summer 2016 (top) & the day after Hurricane Irma 2017 (bottom)

5.1 Concept Development

Coastal intervention is typically either soft (such as beach nourishment) or hard (such as stone structures). The design philosophy on the property is guided by using what is readily available on the island. From early in the design phase the client indicated that the property should maintain its natural beauty with few imported obstructions. Therefore, the coastal defences were mainly soft. In this case two possible options were developed and compared to the do-nothing option.

From the topography collected and presented in the baseline conditions report, the south-eastern section of the property had a high sand dune that stopped the inundation of the land behind. This dune was used as a model for the lower beach sections to the north. Based on the 99th percentile waves and 100-year storm waves, dune plans and cross-sections were developed and are shown in Figure 5.4 and in Appendix D. The plan allows for overtopping onto the site while keeping the surge below the finished floor elevation proposed for the buildings (3.35m above MSL).

The dune construction is recommended to be an engineered core sand dune to limit the erosion potential during high energy events. These could be a core of smaller quarried armour stones wrapped in a geotextile fabric; or sand-filled coir envelopes, or geotubes. It is likely that the sand-filled coir envelopes, or the rock wrapped core, will be used for this application. A typical example of this is shown below in Figure 5.3.

The sand dune will be located along the phase-two private lots. Although it would be most desirable to have all coastal elements implemented at the same time, the nature of construction costs typically encourage the use of phasing. Since the lot will be developed in the second phase of the construction, it is anticipated that the bulk of the dune construction works will occur during the second development phase.

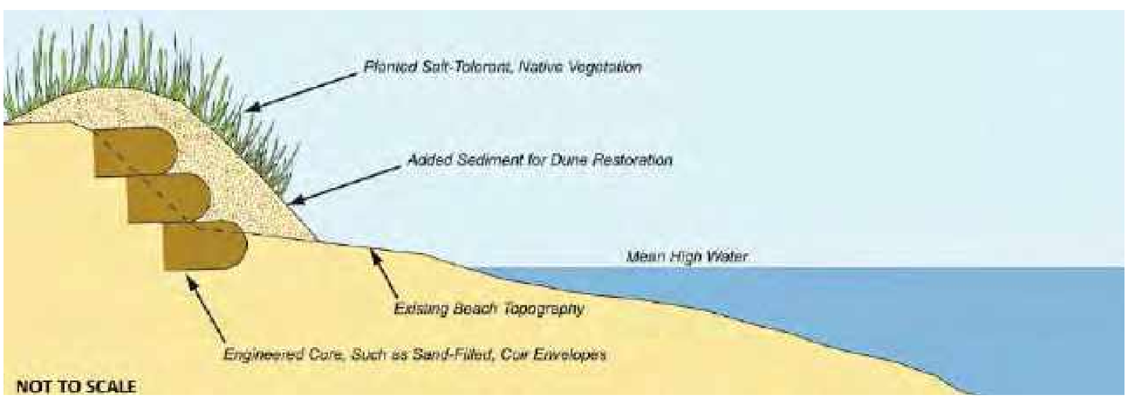

Figure 5.3 Engineered core dune[15]

[15] https://www.northeastoceancouncil.org/wp-content/uploads/2019/01/Living-Shoreline-Profile_Dune_Engineered-Core-1.pdf

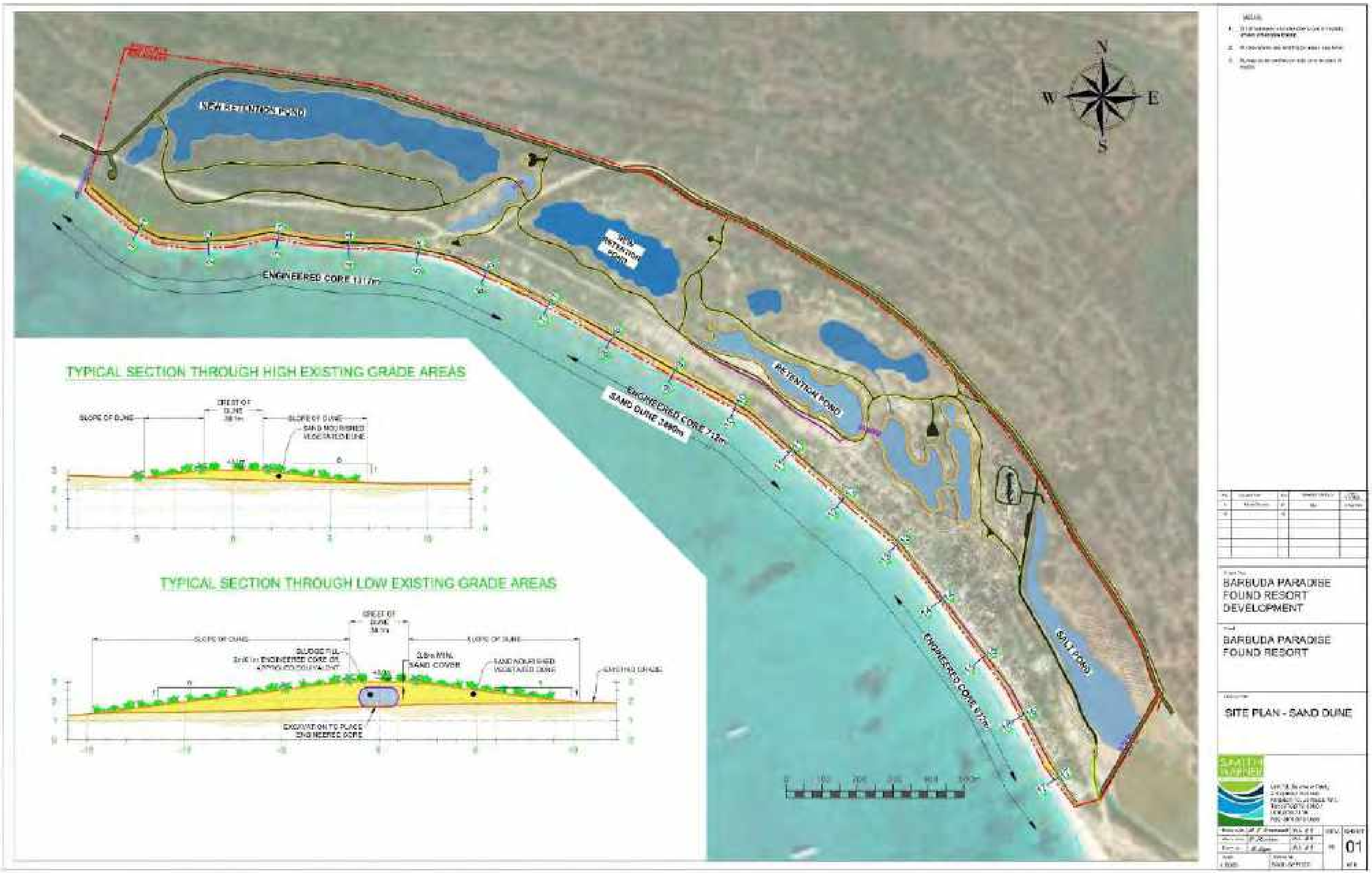

Figure 5.4 Plan and cross-sections of proposed vegetated sand dune (shown in plan in orange)

This section of the report presents considerations and calculations in the design of the structures. Boundary conditions used for the calculations are presented first, then nourishment specifications are shown.

5.1.1 Design Parameters

For the design of the structures, the maximum wave heights incident on each structure for a different wave forcing condition were extracted from the MIKE21 model. For this design, we must consider the wave conditions on the structures under:

1. Average daily wave conditions;
2. 99.86th percentile waves to represent a swell event; and
3. Hurricane conditions.

The use of a return period or design event such as the 1 in 50-year or 1 in 100-year essentially defines the kind of design conditions that will, on average, occur or be exceeded once every 50 years or every 100 years. It is important to understand risk and consider the chance of occurrence of a particular storm condition during the lifetime of a structure so that the associated risk of damage can be understood.

Table 5-1 gives the exposure risk (probability) over a project lifespan for different return period events. For example, a project lifespan of 50 years (Design Life = 50) has a 99% chance of a 1:10-year event occurring, a 64% chance of a 1:50-year event occurring and a 39% chance of a 1:100-year storm event occurring.

Table 5-1 ***Probability of occurrence for various return periods and design life***

Storm Event Return Period	Design Life (years)			
(years)	25	50	100	200
10	93%	99%	100%	100%
25	64%	87%	98%	100%
50	40%	64%	87%	98%
100	22%	39%	63%	87%
200	12%	22%	39%	63%
500	5%	10%	18%	33%

5.1.2 Design Overview

The proposed shoreline enhancement plan includes the extension of an existing dune to provide protection during swell events. To protect against a hurricane would require a dune with a crest elevation up to 3.5m above mean sea level, which would significantly increase the cost of the coastal works. To provide a more cost-effective design, the dune was lowered to +2.5m above MSL, which would protect lots against inundation in swell events. During the 50-year storm it is anticipated that the beach will be inundated, however the dune will reduce the depths of inundation further inland as highlighted in the following section.

The design features that will protect against coastal surge are:

1. *Beach nourishment*: The northern section of the shoreline is presently very low with elevations between 1m and 1.5m above MSL. Using the existing features as inspiration, the dune is to be extended to meet the northern boundary up to +3m above MSL. This would be an average increase in dune height of 1.5m. To further reduce the cost of the of dune, it is recommended

that an engineered core dune be used up to an elevation of approximately 2.7m above MSL and which would then be covered by 0.3m of sand. The dune is designed to be confined within the property boundary.

2. *Perimeter Road:* The property shoulders a main road for residents on the island which leads directly to some important facilities such as the seaport and airport. A critical component of the design was to have the road be accessible in a 50-year storm and to have it merge well with the existing marl road.

Updated Coastal Setback

A key outcome of the 2016 study was the prescription of coastal setback distances and elevations. These elevations were based on typical beach profiles at the southern shores. These levels included a consideration for hurricane surge levels. With the passage of the major storms that occurred in 2017, it was determined that the levels should be updated to include the hurricanes that passed in the time since the prior study. Additionally, climate change projections have changed since 2016, the Intergovernmental Panel on Climate Change (IPCC) Sixth Annual Report (AR6) was used to update the projected sea level rise. With these new formulations, the proposed setback and elevations were calculated (summarised in Table 5-2).

Table 5-2 Coastal setback and floor elevations calculated for dune areas

Design Scenario	Coastal Setback (m inland from high waterline)	Floor Elevations (m above mean sea level)
50-year storm	52	3.7
100-year storm	70	4.5

The final levels also include water increases related to high tide, sea level rise and a freeboard of 0.3m (1’). The freeboard was added to provide a buffer between possible surge and the base of structures.

The design narrative for this property shows that there is a focus on enhancing the property while being cognizant of typical building practices. On Barbuda, many homes are built atop stilts. This is expected to be utilized in the plan as it would reduce the amount of fill needed on the lots. The land will be graded the existing (and future) ponds to allow for proper drainage of the site.

Perimeter Road Elevation

A critical objective of the proposed concept was to reduce coastal flooding on the property and recommend safe elevations for an emergency roadway along the perimeter of the property boundary.

The elevation of this roadway was set based on the 50-year storm wave conditions. Once the static surge was computed, further investigations into the wind setup and wave runup were done to properly estimate a maximum elevation of water. Following this an allowance for the thickness of the road and freeboard were added. The final elevation was 3.0m above MSL. This road elevation is maintained from the southern boundary to the eastern boundary. The road elevation changes to meet existing grade at the northeast boundary where elevations are up to 6m.

Figure 5.5 shows the model results for a profile that runs through the road to determine if the road is overtopped. The results indicate that the elevation of the road would provide a satisfactory protection in a 50-year storm.

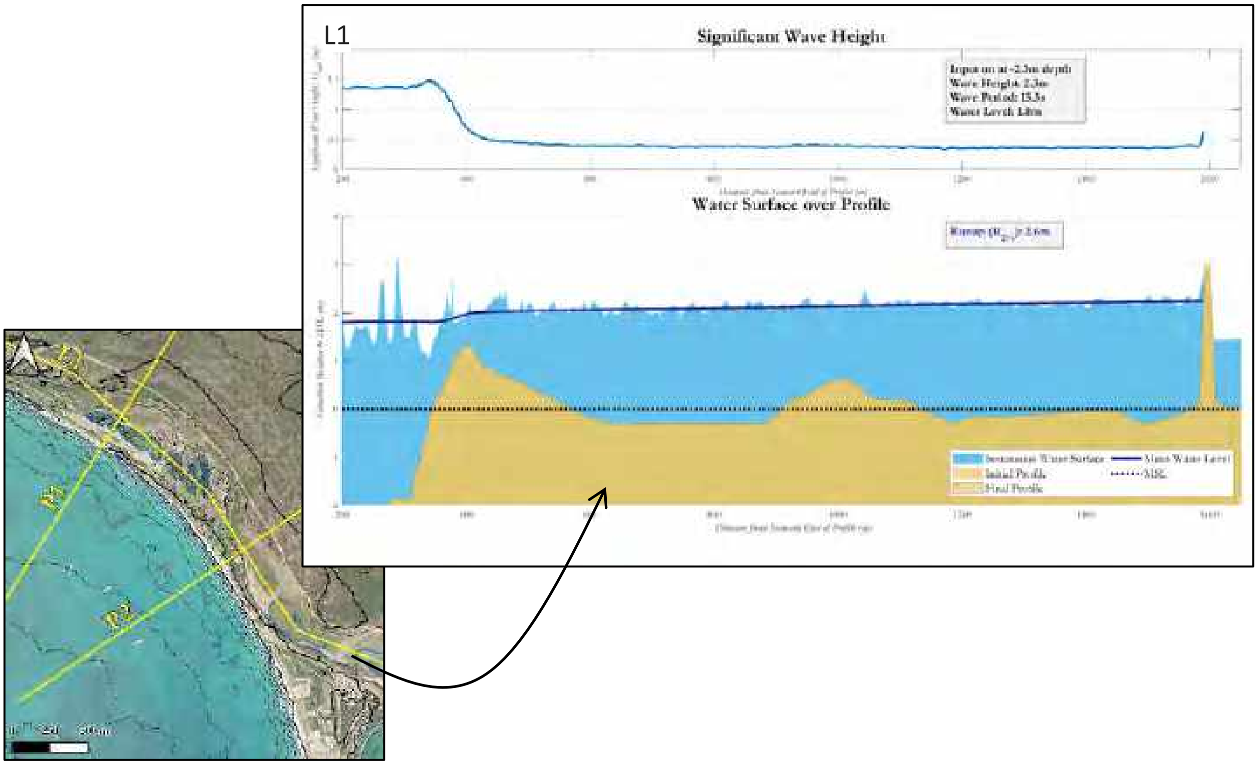

Figure 5.5 Model results for wave run-up and wind setup at the southern boundary with the concept in place

Sand Characteristics for Beach Nourishment

To further predict the behaviour of the beach with the extended dune in place, the formula developed by Ahrens and Hands[16] was used. Their research describes the use of nonlinear wave theory to predict cross-shore sediment movement under waves in shallow water. This synthesis of wave theory and sediment movement initiation criteria allows much of the present understanding of cross-shore sediment movement to be determined.

The beach stability is determined by looking at all the possible ranges of wave height and periods extracted along the proposed beach slope/toe and by varying the mean grain size diameter. The variation of parameters will cause the beach to either accrete, be transitional, or erode. Where the beach is in accretionary mode it can be concluded that the beach is adequately sheltered, and the grain size is ideal. Where the beach is in transitional mode it can be anticipated that the beach will fluctuate throughout the year and the shoreline may reshape. Where the beach is in erosion mode it would be recommended to adopt a coarser grain size for nourishment.

[16] Ahrens, J.P., Hands, E. B. (1998). Parameterizing Beach Erosion/Accretion Conditions. International Conference on Coastal Engineering 1998, Paper #75, Pages 2382 – 2394.

The wave parameters during swell events are represented by wave conditions exceeding 12 hours per year (99.86th percentile), and these were used to assess the stability of the beach. These wave conditions were up to a wave height of 0.75m and wave period of 15.0s at the toe of the beach nourishment. The tendency for the beach to accrete, erode, or be in a transitionary zone under the input conditions, is illustrated in Figure 5.6

The critical conditions show that the beach fluctuates naturally under existing conditions. The *in-situ* beach sediment is fine with a mean grain size of 0.25mm. Material that is used to nourish the beach should have a similar grain size distribution and have a low silt content (less than 0.5%). Higher silt content will result in cloudy water as the waves gradually clean the sand and can create a hardened surface over time. Other characteristics, such as carbonate content and colour are generally aesthetic, and are subject to preference. From tests done, the minimum grain size to keep the beach in at least a transient state is 0.15mm. If a fine sediment is placed on the beach, there is likely to be a high probability of erosion. In summary, a D50 grain size of 0.25mm is recommended to keep the beach in an accretionary zone.

		Beach Erosion / Accretion			
Parameters	Units	Max Daily Existing	Max Daily Proposed	Min Daily Existing	Min Daily Proposed
Hso	m	0.80	0.75	0.14	0.14
Tp	s	15.0	15.0	4.5	4.5
d50	mm	0.25	0.15	0.25	0.25
ρ sand	kg/m^3	1922	1922	1922	1922
ρ water	kg/m^3	1025	1025	1025	1025
rel pho		0.88	[illegible]	0.88	0.88
Lo	m	351	[illegible]	32	32
Hso/Lo		0.0023	[illegible]	0.0044	0.0043
Hb	m	2.02	[illegible]	0.29	0.29
db		2.6	[illegible]	0.4	0.4
Ns (Ahrens)		9240	[illegible]	1342	1308
Ns - Upper Transition		15330	[illegible]	8878	9144
Ns - Middle Transition		11469	[illegible]	6543	6841
Ns - Lower Transition		3689	[illegible]	3295	3393

Figure 5.6 Sediment erosion and accretion zones (Ahrens & Hands); spreadsheet in inset

5.2 Impacts on the Coast

The proposed shoreline concepts were developed from several model iterations to find the most environmentally and economically feasible solutions. Another objective was to ensure that the concepts proposed provided coastal defence against the design conditions of the 50-year storm and the 100-year storm. Most importantly, the proposed concept should not adversely impact the surrounding coastal areas. Fortunately, all of the proposed coastal interventions are land-based, which reduces the impact zone of the works.

To test possible changes in the wave climate in the area, conditions before and after the proposed concept were tested. Analyses were carried out primarily with the numerical modelling suite MIKE 21 which has been validated for surge modelling (MIKE, 2012). General beach response modelling was performed using various wave conditions and sediment sizes to determine the stability of the proposed sediment.

Further, MIKE 21 was used to evaluate the impacts of operational waves (both sea and swell) and hydrodynamics for both the existing condition ("do nothing" scenario) and the proposed dune concept described above. The modelling results were used to indicate what could happen in the short and long term if the proposed solution was implemented.

Short term impacts from erosion were simulated using the XBeach model in a profile mode. This model is well adapted for the modelling of beach and particularly dune changes in storms (Roelvink, 2009). The results of all tests are plotted side by side to easily compare the conditions for each test case. They are presented in the following sections.

5.2.1 Long-term Impacts on Operational Waves

The design philosophy for Paradise Found is in keeping with softer approaches to beach stability. Stability is related to the long-term patterns of erosion and accretion on a beach as determined by the operational wave climate. These waves generate currents which then move sediments towards or away from a beach. In the case of Paradise Found, the impact of the development was checked by comparing the wave climate with and without the concept in place.

The process of determining the operational waves along the project site were presented in prior reports. The main conclusions were that waves typically propagate from the south with a magnitude of 0.3m in the nearshore. The southern section of the property was more sheltered and thus had smaller wave heights of about 0.2m.

Figure 5.7 depicts a comparison of mean annual wave heights under existing and proposed conditions. Figure 5.8 shows the wave results for conditions exceeded 12 hours out of the year to represent a swell condition. Overall, the findings indicate that:

- There is no appreciable change in operational waves between the existing and proposed conditions. This is due to all works being confined on land within the property boundaries. Under operational conditions, the concept plan would provide an additional dune to the northern section of the property, which is more exposed to waves.
- In the more extreme condition of the 99.86th percentile waves, the wave heights range from 1m to 1.2m at the shoreline. As with the operational waves, the northern section of the beach is exposed to higher waves. These wave conditions may generate significant scour on the sandy beach, and this is addressed in the following section.

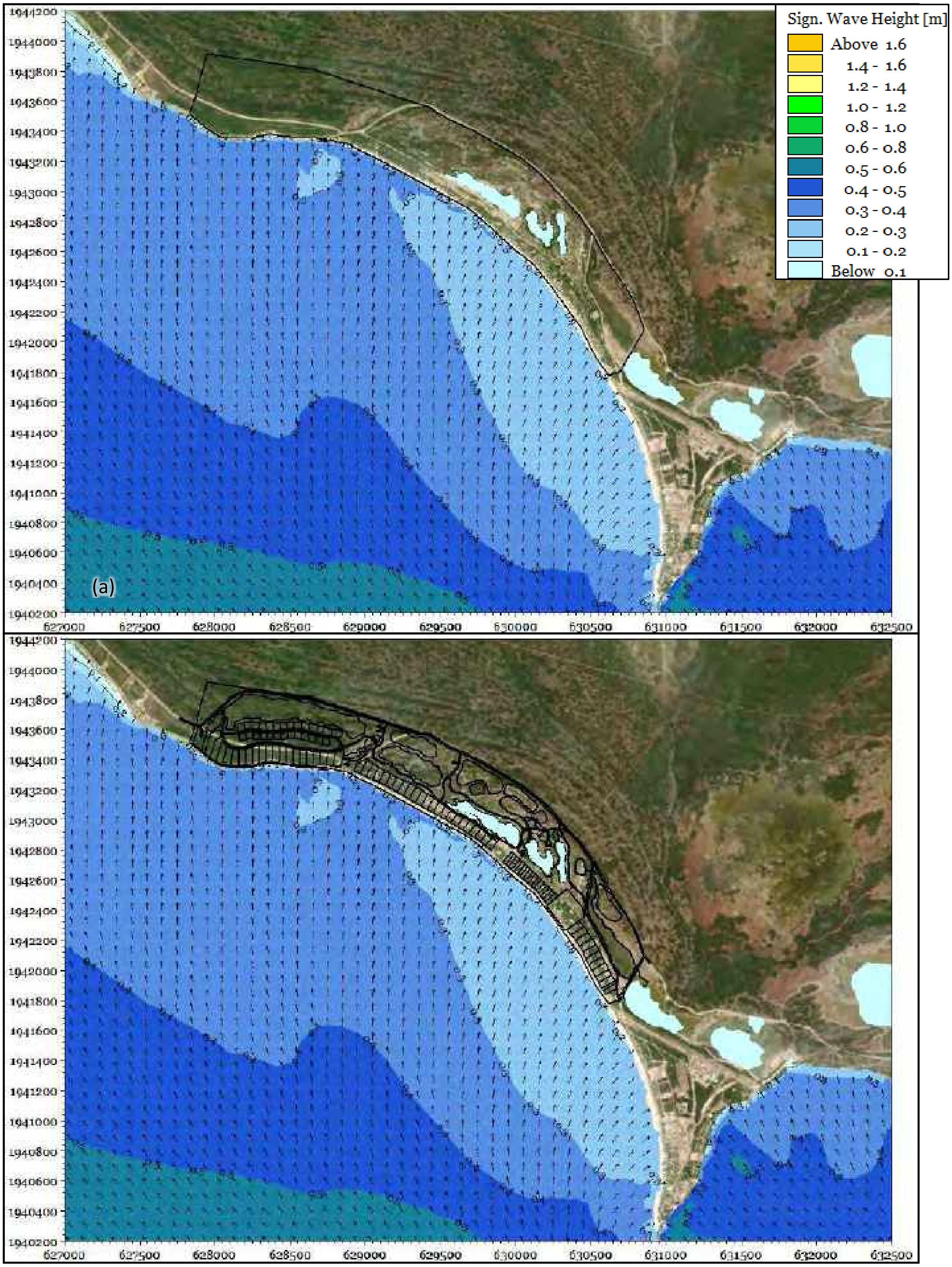

Figure 5.7 Comparison of mean annual waves results (a) under existing conditions and (b) with the plan in place

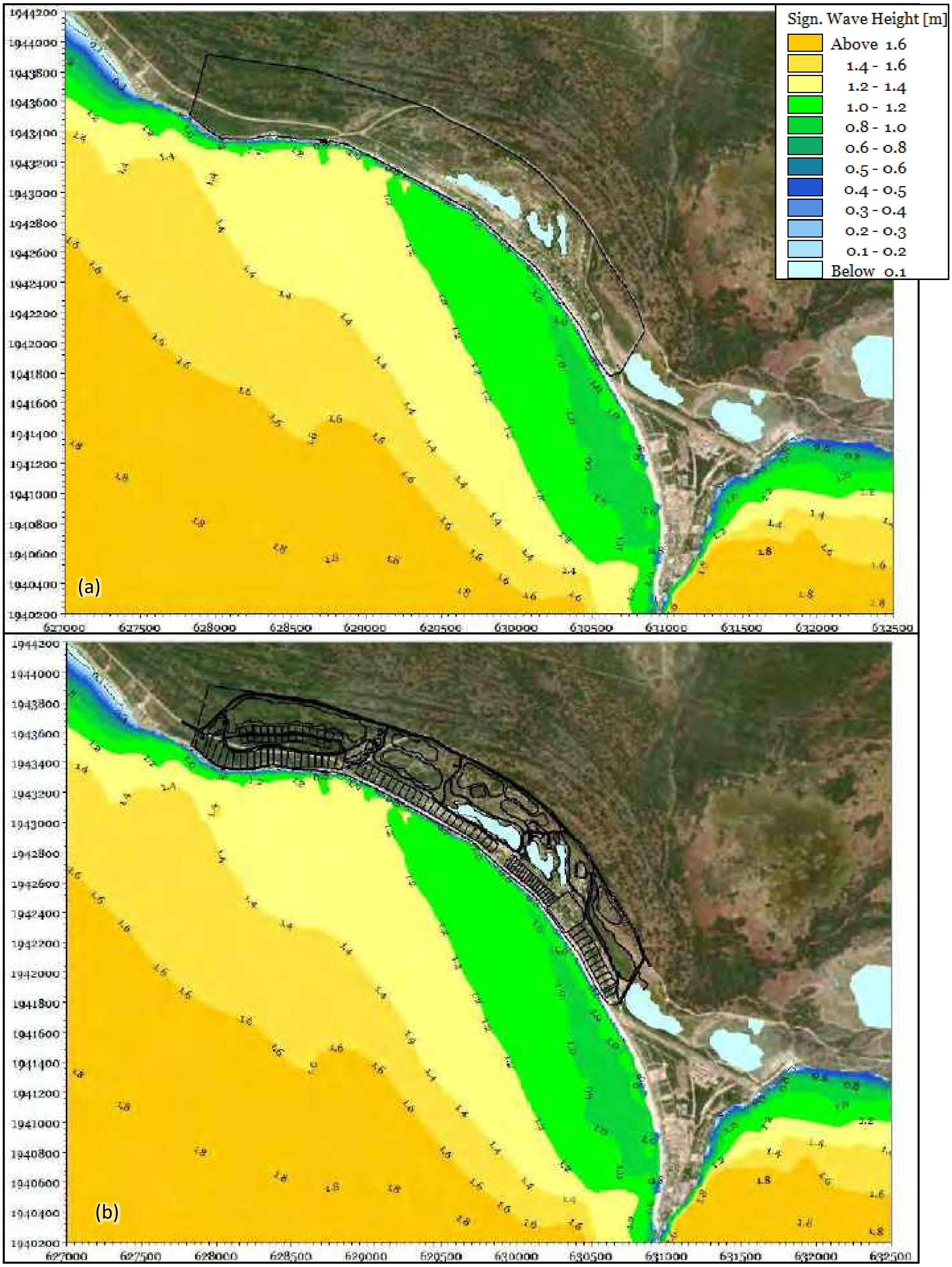

Figure 5.8 Comparison of wave heights statistically exceeded 12hrs per year (a) under existing and (b) proposed

5.2.2 Short-term Impacts from Swell Waves

High energy swell waves cause significant erosion on sandy shores. To capture the effects of a swell wave, forty-two years of wave data was assessed using exceedance statistics. A wave condition that is exceeded for only twelve hours per year was chosen and simulated at high tide. To account for possible climate change impacts, sea level rise was added to the simulation, and this was found to be 0.74m. Key results were plotted along a profile in the low vulnerable area to the north.

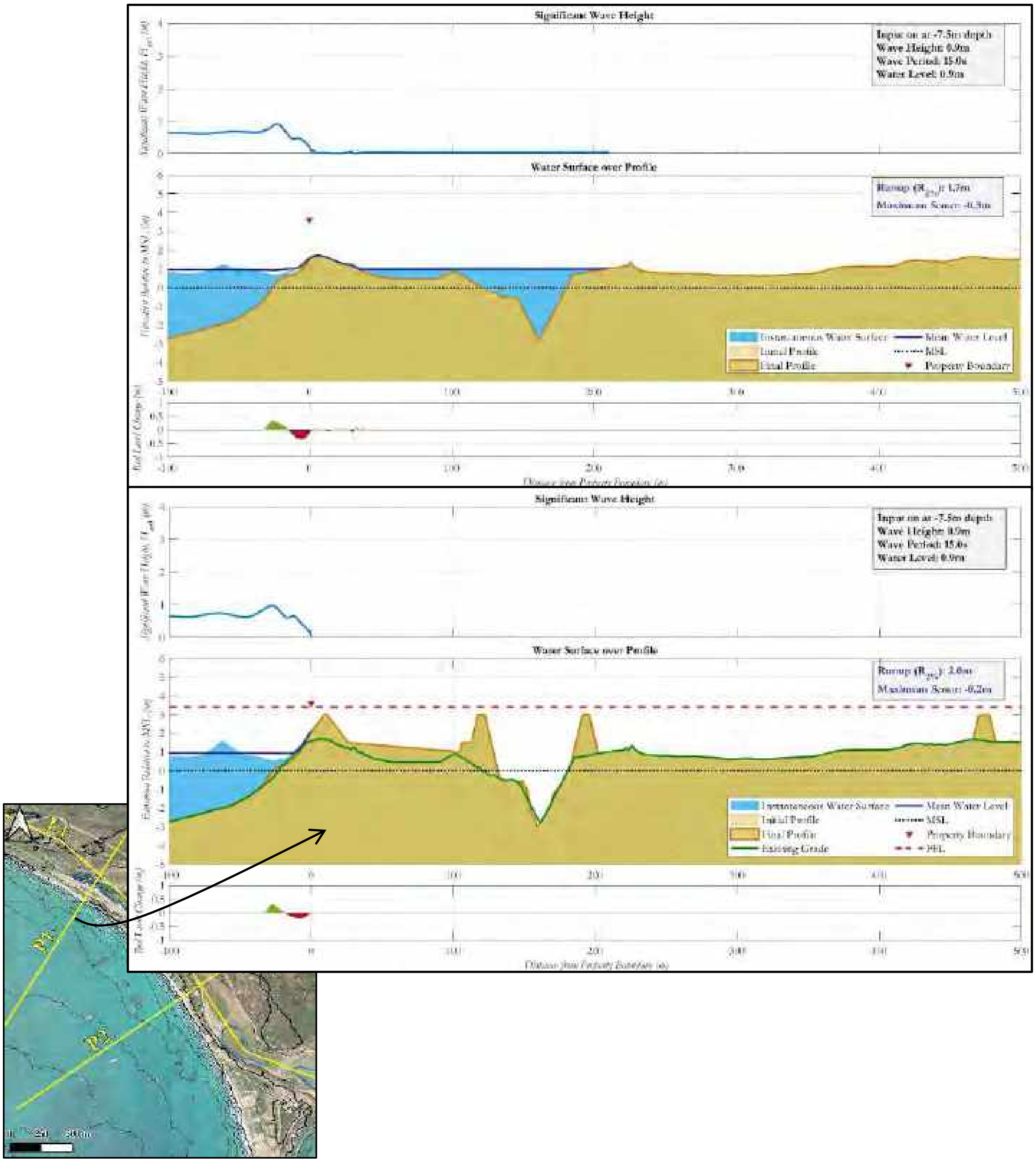

Figure 5.9 Comparison of erosion scour during 99.86th percentile wave conditions

In the existing case, there was up to 0.3m of scour along the beach profile (Figure 5.9). The face of the dune was eroded and deposited around the waterline, which led to a temporary widening of the beach. In proposed conditions, there was less scour of around 0.2m on the dune face. The eroded sediment from the dune was deposited by the waterline. Erosion/accretion zones were reduced for the proposed conditions from 75m to about 50m.

5.2.3 Short-term Impacts from Hurricane Waves

The island of Barbuda has experienced significant damage and loss of environment associated with the passage of hurricanes. As shown in prior reports, the combination of strong waves and high surges creates a major flooding issue for the low site. Under existing conditions, the land would be under 1-2m of water during the 50-year hurricane event. However, by extending the dune and raising the perimeter road (also to facilitate drainage) the development is protected from hurricane-related flooding as shown in Figure 5.10, Figure 5.12 and Figure 5.14.

Inundation results are shown in Figure 5.10 as water depths across the area. For the existing condition almost all areas slated for housing are shown to be inundated with up to 1.5m of water. In proposed conditions the surge is blocked by the extended dune and perimeter road. Inundation outside of the property is seen to be similar in both existing and proposed conditions. Properties to the south of Paradise found also did not see a significant change in coastal flooding as a result of the implemented works.

Storm surge extents and elevations are compared in Figure 5.12. As with the inundation mapping, the site was mostly not flooded by static storm surge under proposed conditions. Coastal flooding from the west was well handled with the extended dune in place. The static surge levels at the shoreline were computed to be up to 2.3m, which was higher than in existing conditions. These higher surge levels are related to the ground being elevated in the proposed concept. However, the higher surge levels did not produce higher inundation depths. A small area south of the perimeter road had a decrease of 0.1m in surge elevation which is likely linked to a reduced area for wind setup. Storm surge for areas outside of the property were not worsened by the perimeter structures.

Finally, the storm waves are plotted in Figure 5.14. Under existing conditions wave heights were an average of 0.4m on land with a maximum of 1m at the southeastern boundary. Under proposed conditions, small wave heights were simulated on the ponds of around 0.1m due to their large area. In the simulation, the rest of the property did not show any inundation and thus no wave heights. Outside of the property the wave heights were low (below 0.1m) like those in the existing scenario.

Climate change impacts have shown that in the near future 1 in 100-year events are likely to become more frequent thus reducing that return period to between a decadal and semi-centennial event by 2060 for some northern Caribbean islands (IPCC, 2022). This creates a situation in 35 years, in which the property will be exposed to flood potential more frequently than in the present day. The 100-year event was simulated to quantify the impacts on the project site and nearby properties. These results are shown in Figure 5.11, Figure 5.13 and Figure 5.15.

Inundation (Figure 5.11) covered almost all of the project site with water depths of around 2m in pond 1. Once again, the south-eastern surge breached the southern property boundary and propagated 3km further over land. There was inundation outside of the property of up to 1.5m of water depth. Most of the south-west coast was inundated with up to 2m of water. Only the high point to the northwest and the location of the current restaurant were not inundated by static surge.

In the proposed conditions there was far less inundation on the property. The easement to the north-west was breached and water flowed into the new pond and onto some lots. The water depth on the lots was predicted to be between 0.1m and 0.5m. Possible breaches along the property are to be expected for this 100-Year storm. It is recommended that the easement be outfitted with a gate to prevent surge from entering the property. Structures of that small a scale were not included in the storm surge modelling; however the flow patterns results will determine where they are to be most effectively placed.

Storm surge elevations relative to mean sea level are plotted in Figure 5.13 for the 100-year event. The existing result (top inset) shows surge levels up to 2.6m above mean sea level. The property and green areas to the northeast had surge levels between 2.3m and 2.5m above mean sea level. This result further shows that the surge and winds from the south-east heavily influence the surge levels on the property. An easy way to see this is to notice that the surge contours run parallel to the coastline in Gravenor's Bay.

The proposed conditions show how well the new road protects the property and the northeastern green areas. The surge on the property was reduced to a maximum level of 1.9m around the easement breach. All other areas that are to be developed had no significant static surge. Since the south-east surge was intercepted by the perimeter road, the maximum water elevation was reduced from 2.6m to 2.3m above mean sea level. Just outside of the perimeter road, the surge was slightly reduced to 2.2m from 2.3m. This is related to the reduced water surface area that wind blows over, which reduces the height and extent of the static surge.

Finally, Figure 5.15 shows the storm wave heights and directions for the 100-year event for existing and proposed conditions. Wave heights were quite low on the project site with an average wave height of 0.4m. Around the current hotel had wave heights below 0.1m and the high point also had wave heights below 0.1m. Surrounding areas to the north had wave heights that were lower than 0.1m. The inlet on Gravenor's Bay had wave heights between 0.4m and 0.6m.

Under proposed conditions wave heights were reduced with the property and to the north. The easement breach to the north had small waves below 0.1m. Wave heights outside of the property were still generally below 0.1m with some areas even showing a reduction in wave height. The wave heights just to the south of the property were between 0.1m and 0.4m. The reduction in wave heights is also related to a smaller wetted area for wave growth.

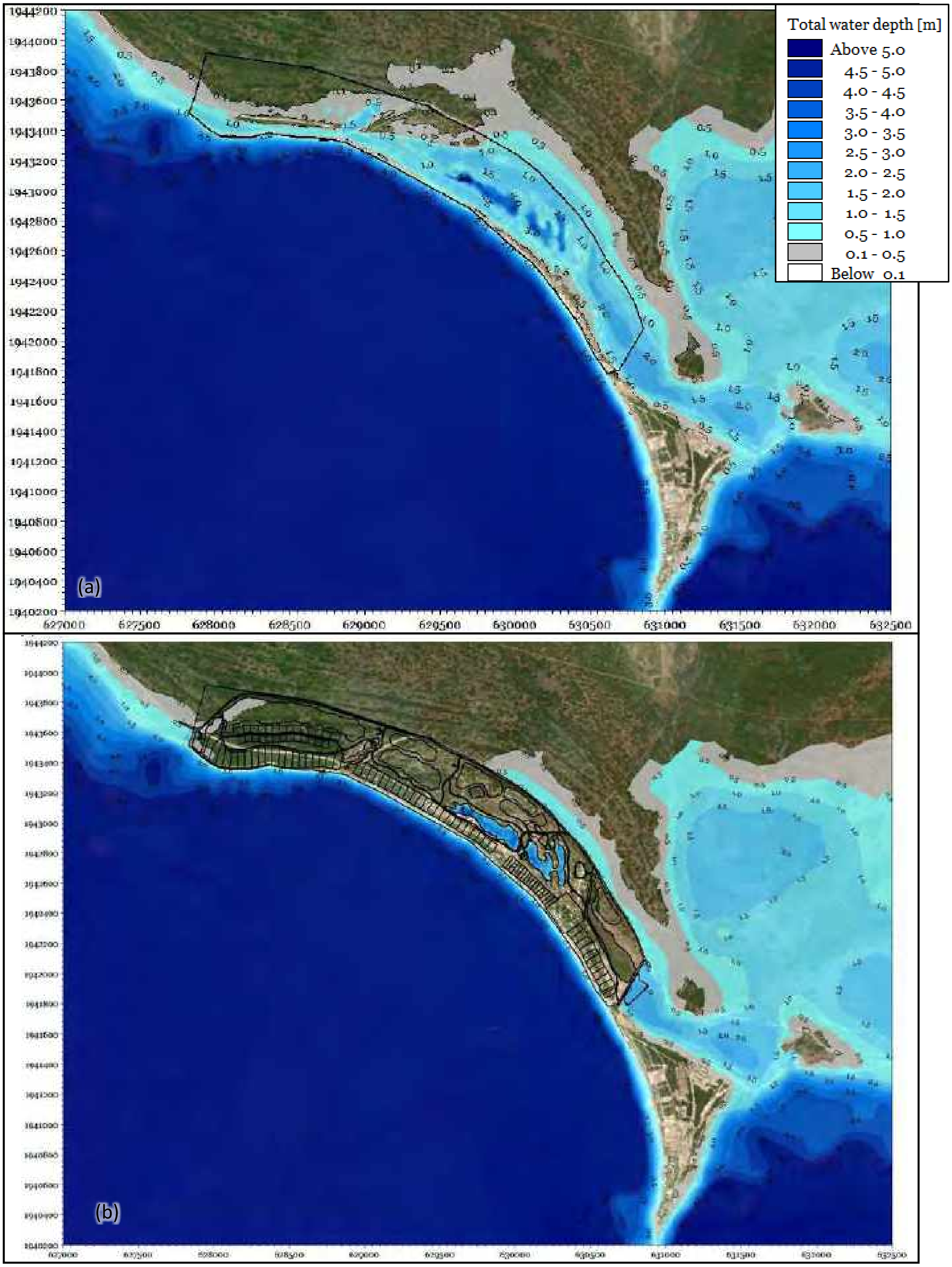

Figure 5.10 Comparison of 50-year storm simulation results for water depths (a) under existing and (b) proposed

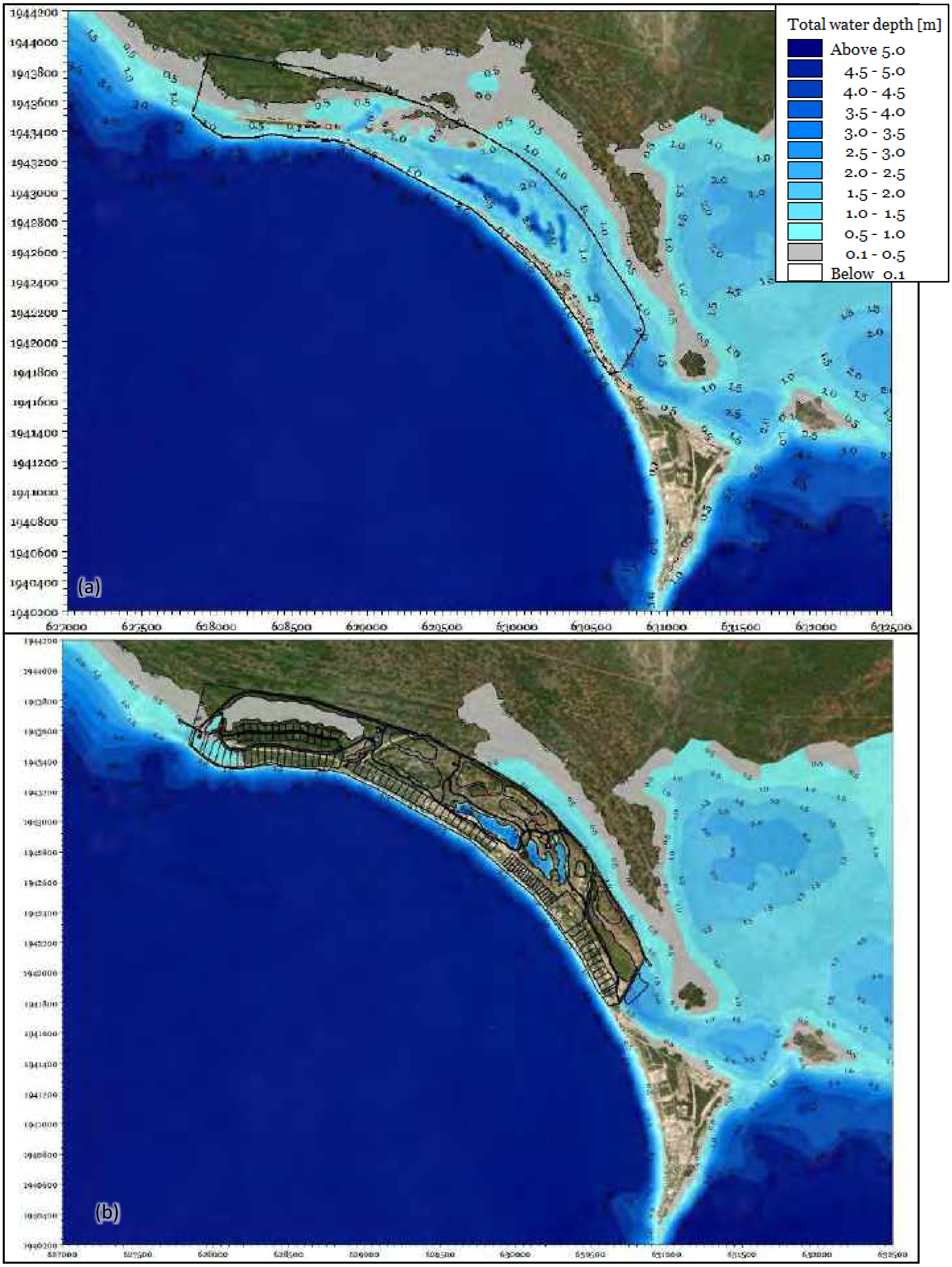

Figure 5.11 Comparison of 100-year storm simulation results for water depths (a) under existing and (b) proposed

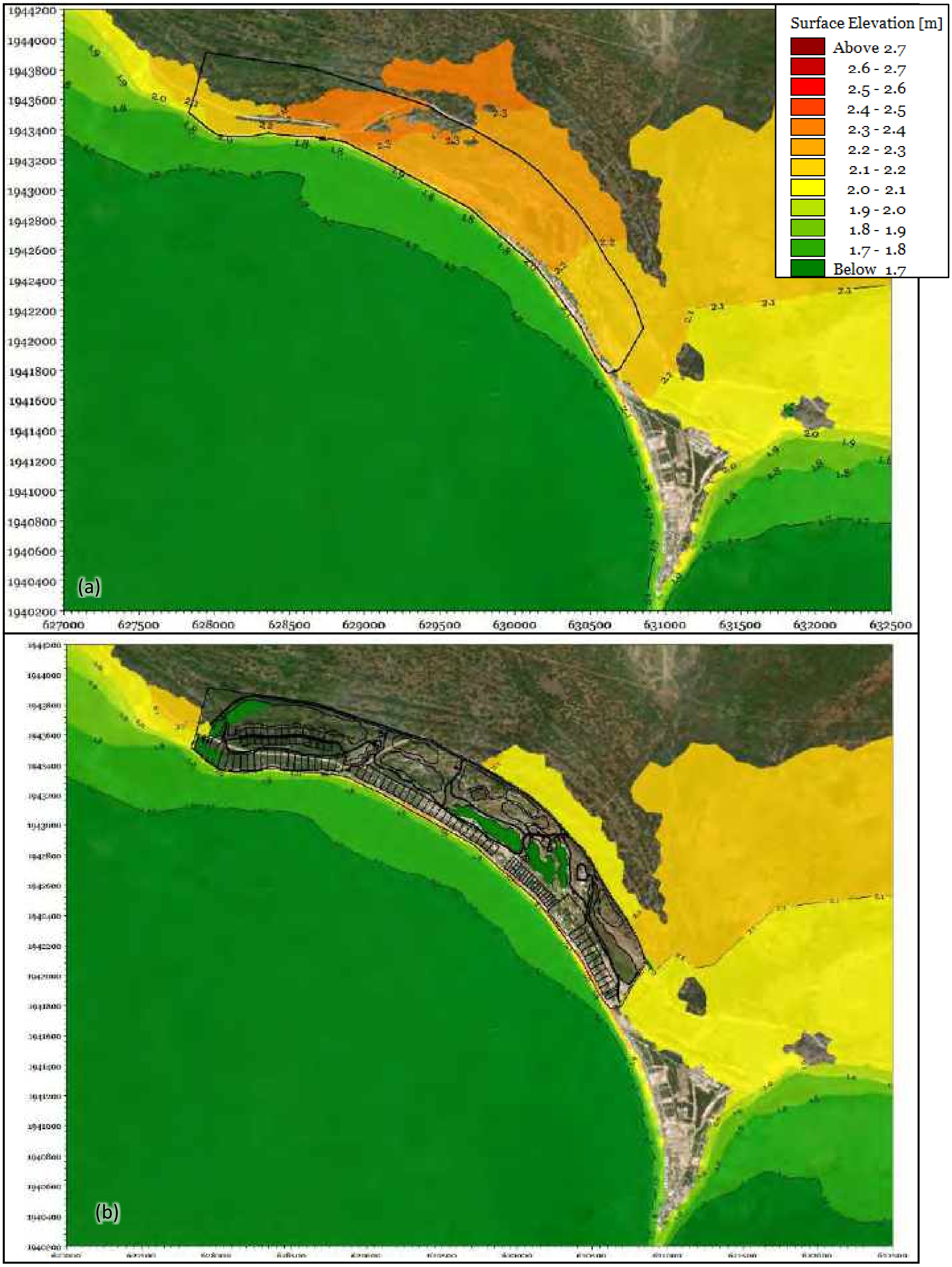

Figure 5.12 Comparison of 50-year storm simulation results for water elevations for (a) existing and (b) proposed

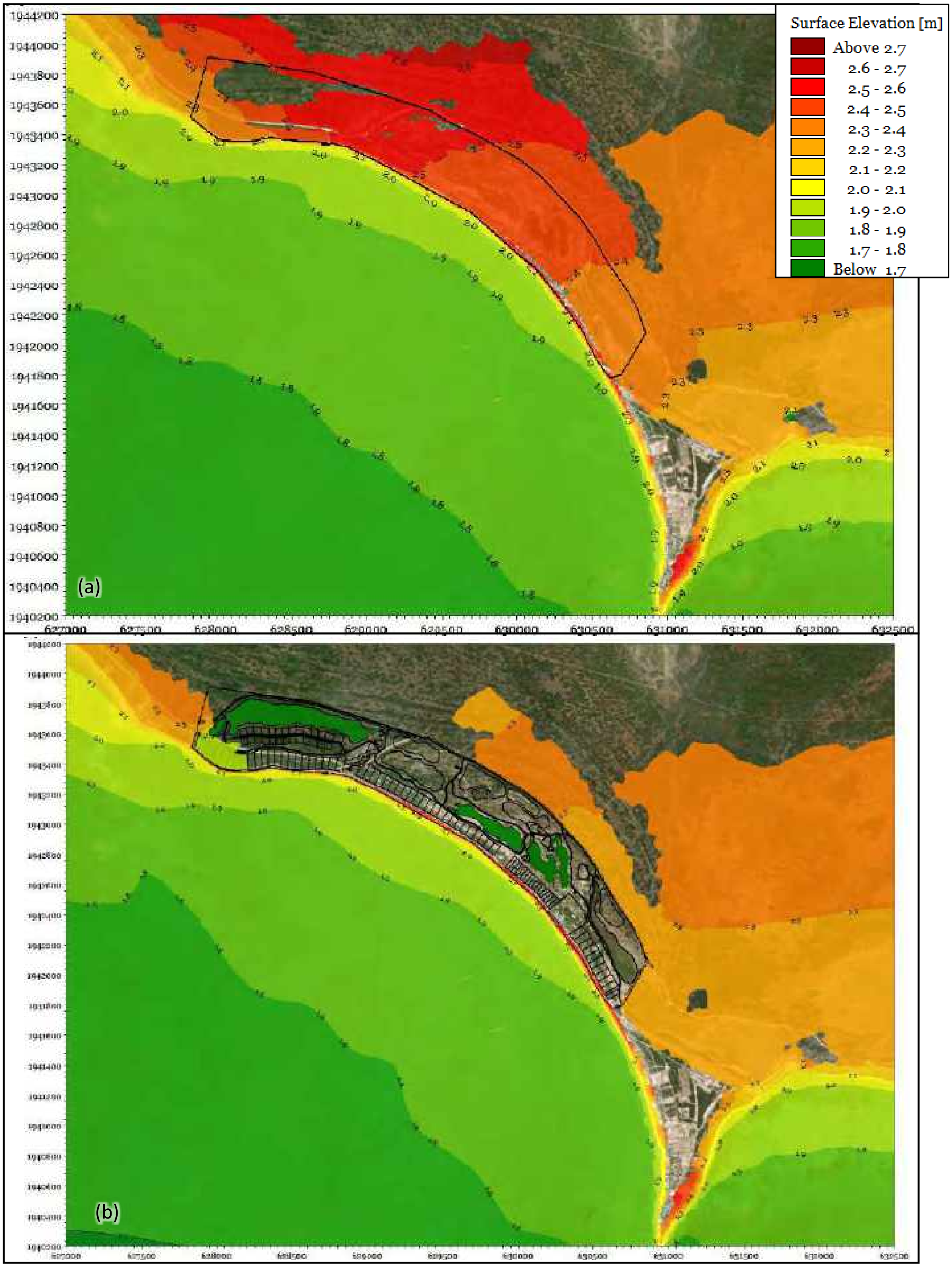

Figure 5.13 Comparison of 100-year storm simulation results for water elevations for (a) existing and (b) proposed

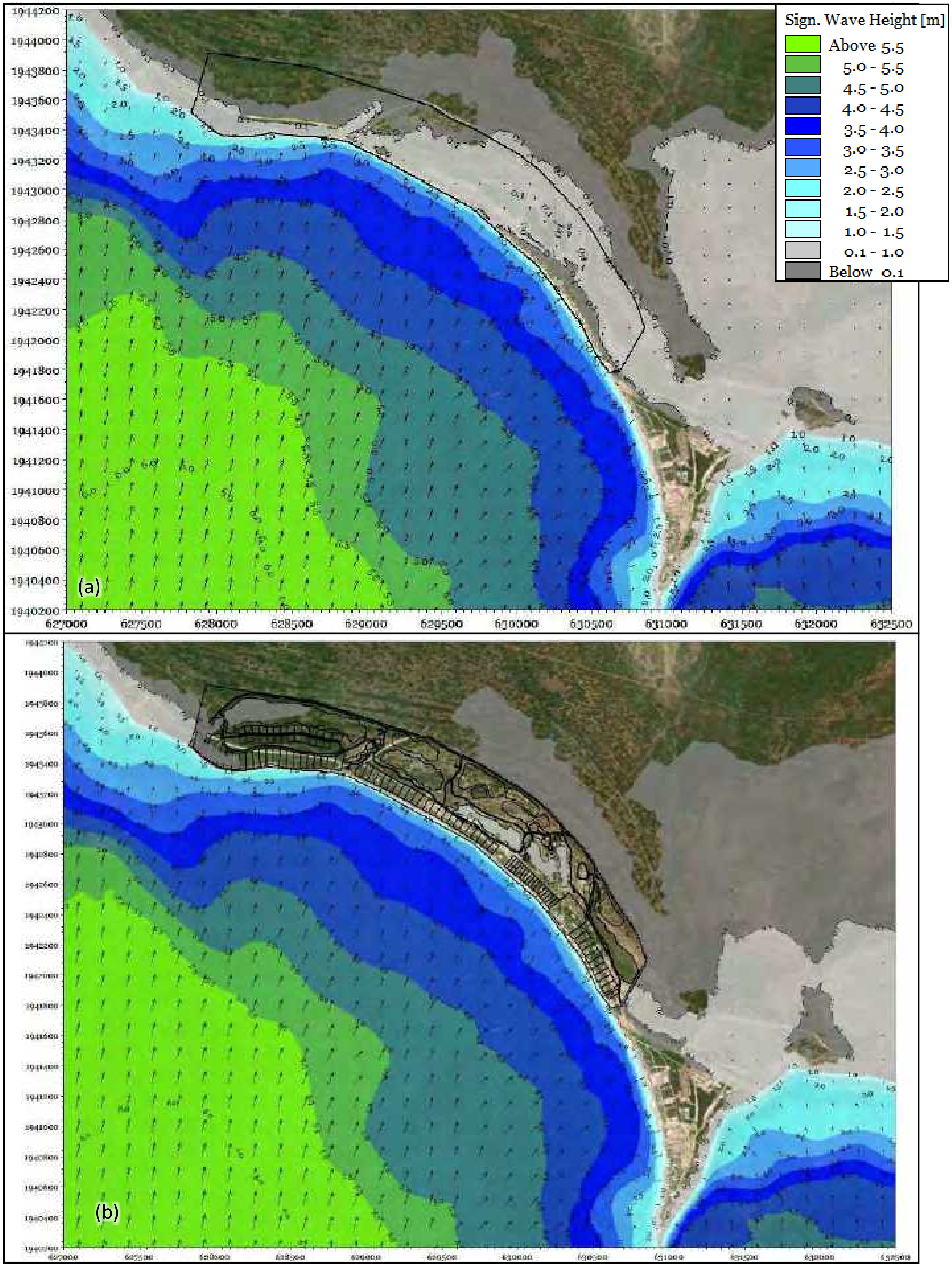

Figure 5.14 Comparison of 50-year storm simulation results for storm waves (a) existing and (b) proposed

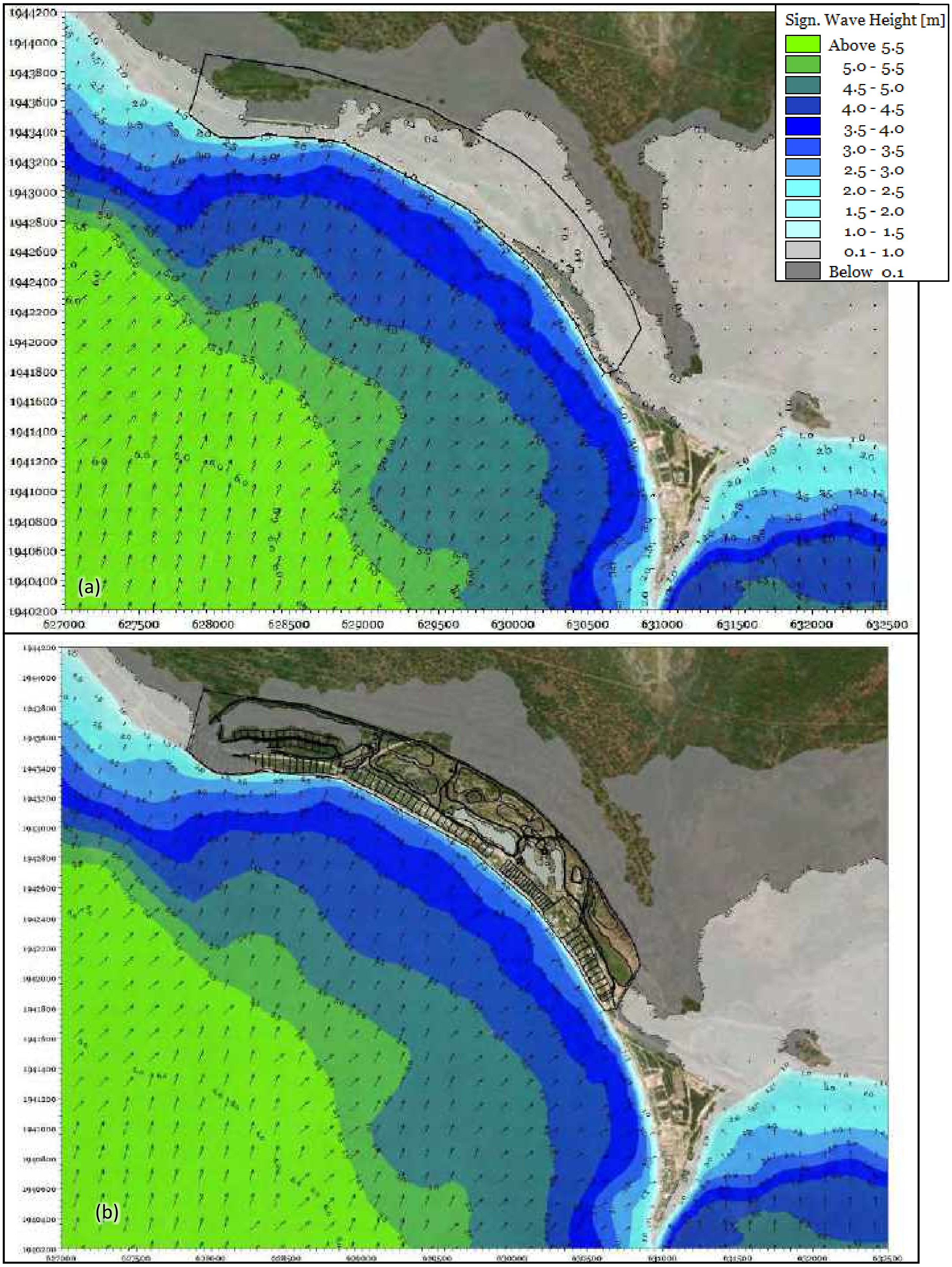

Figure 5.15 Comparison of 100-year storm simulation results for storm waves (a) existing and (b) proposed

Dynamic Storm Surge

The water levels associated with the hurricane wave climate analysis, as demonstrated previously, represent the static water levels occurring near the shoreline during a storm event. Nevertheless, waves often run up onto the beach at the shoreline, causing an additional increase in surge and flooding levels. This dynamic component of storm surge, known as wave run-up, combined with the static surge, results in the total inundation level.

Wave run-up transpires when a wave breaks, allowing a portion of its remaining energy to travel up the face of the beach. The elevation reached by the run-up depends on the characteristics of the "swash zone" – the area where the wave interacts with the beach. If this zone consists of a smooth, impermeable surface, a higher run-up is likely. In contrast, the presence of a rough, armoured stone slope or a vegetated surface can reduce the run-up.

Due to the localized variability of wave run-up and its dynamic nature, storm surge computations in numerical models typically do not incorporate wave run-up. However, it is calculated and employed in the design of coastal structures. Both the static and dynamic components of storm surge are combined to determine the final inundation levels, ensuring a comprehensive assessment of potential flooding risks.

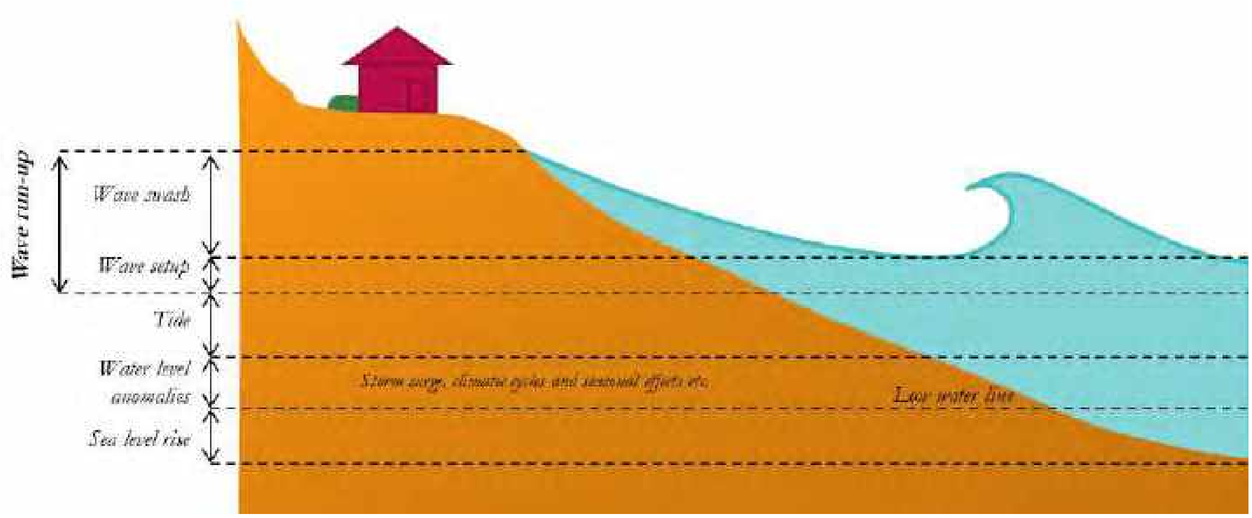

Figure 5.16 The water level components that contribute to coastal flooding

In this study, SWI applied XBeach (Roelvink, 2009) in a one-dimensional format to simulate the storm-induced water level changes for the design events outlined in the prior sections. To capture the water surface dynamics, the XBeach model was run in a non-hydrostatic mode, and sediment properties were described based on sediment samples as detailed in Section 5.1.2.

The study used profile 1 along the existing low areas in the centre of the property. The profile was extracted by using a simple routine in GIS software that merged lidar topographic data and bathymetry tracks. The data was interpolated to provide one-dimensional profiles that extended perpendicularly from the shoreline to about the 8m depth contour in the bay.

To properly capture the storm-induced water level changes, wave heights, wave periods, wind speeds, and water level set-up from the 100-year storm events were extracted at the seaward end of the profiles in the domain of the MIKE 21 results. This data was then input into the XBeach model with a direction perpendicular to the shore, representative of the worst-case scenario.

Overall, this approach provides a comprehensive methodology for storm surge modelling that considers wave run-up to define the total surge levels. The use of one-dimensional profiles derived from dense elevation data provides a detailed representation of the local topography, allowing for a more accurate simulation of storm-induced water level changes.

Wave runup levels are shown in Figure 5.17 for the 100-year event.

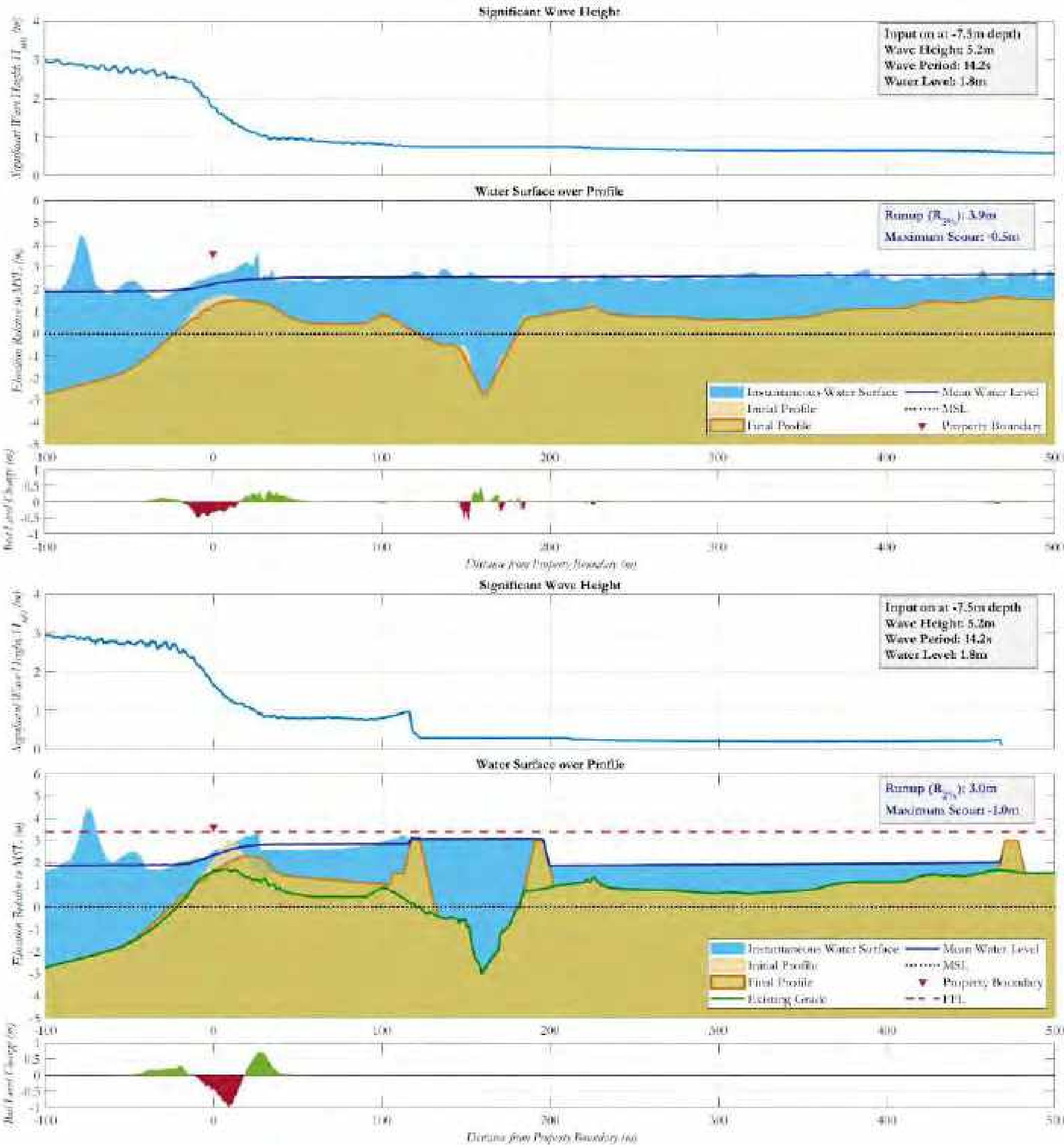

Figure 5.17 Wave runup results for the 100-year storm on the property for existing (top) and proposed (bottom)

Under the existing conditions the highest wave runup ($R_{2\%}$) was 3.9m which extended almost 1.6km from the (west) property boundary. Under proposed conditions, the flooding stops at the perimeter roadway and thus stops further inundation outside of the property. The maximum surge level under proposed conditions is 3m above MSL. There is a significant scour of the dune's face and crest of up to 1m. Depending on the section of dune this may be reduced by the presence of an engineered core. The finished floor elevation is therefore higher than the surge in proposed conditions which helps to protect property.

5.3 Hydrologic Analysis and Drainage Master Plan

This section of the report describes the existing drainage features and provides a master drainage plan that channels stormwater runoff from the upper catchment through the site that would tie-in to the beach design.

5.3.1 Methodology for Hydrologic Analysis

The methodology adopted was as follows:

1. Data collection to include:
    - Rainfall information
    - Soils information
    - Land use mapping
    - Topography of the catchment
    - Anecdotal data collection
2. Delineation of the catchments
3. Calculation of runoff for pre- and post-development
4. Proposed grading of site and driveways to ensure all runoff is captured.
5. Hydraulic analysis of the existing river, proposed drains, and drainage features.
6. Assess the impact of the development on the receiving drainage features.

Several International Guideline for preparing Hydrological and Hydraulic Design Reports for Drainage Systems was consulted to guide the designs. The following sizing criteria were used:

- The site drainage shall be sized to handle at minimum the 50-year return period flow.
- The main drains (U Drains and HDPE Pipes) will be sized to accommodate at minimum the 50-year return period flow.
- The major external drainage features (trapezoidal bioswale) will be sized to accommodate at minimum the 100-year return period flow.

The design strategy is to follow the existing slope of the land and channel surface runoff into the existing drainage features and to the eastern section of the property towards the existing river.

5.3.2 Hydrology

Precipitation Flooding versus Riverine Flooding

A distinction must be made between riverine flooding and what is called precipitation flooding. The major difference is that riverine floodplains have readily identifiable drainage paths, whether they are rivers, streams, ghauts, roadways or constructed channels. Riverine flooding is said to occur when the volume of stormwater runoff exceeds the volume provided by these drainage paths. Precipitation flooding on the other hand is the result of abnormalities in the topography of the land that are not easily identifiable, the overflow of which will cause flooding. A common form of precipitation flooding occurs when natural drainage paths are blocked, routing the runoff elsewhere and causing flooding; another example is in the case of sinkholes, which will pond an area during heavy precipitation.

The project site drainage catchment is particularly flat, which leads to significant ponding on the property after rainfall events. The island of Barbuda does not have any rivers, thus the identification of ponding areas and precipitation flooding will be important.

Catchment Delineation

Existing features of the property were detailed in the *Baseline Conditions Report* (SWI, October 2022). A field investigation and interviews were also carried out to collect additional information on low points and floodplains on the site. Additionally, the road alignment was noted as it would form a significant portion of the filling works on the property.

Detailed topography was provided by the client for the property. Contour lines for the whole island were extracted from the Post-Georges Disaster Mitigation database. These contours were very sparse and focused to the east where the highest point on the island is located. All the topography data was merged and used to delineate the catchment areas that interacted with the property.

The data for the island catchment area had several gaps and was not at a fine enough resolution to allow for processing in the model or further division into sub-catchments (Figure 5.18). This is a significant limitation in the hydraulic analysis, as flows can be dramatically altered based on the slope over which they move. Not having a detailed DEM creates gaps and inaccuracies over the catchment area and means the resulting flows can be taken as an estimate only.

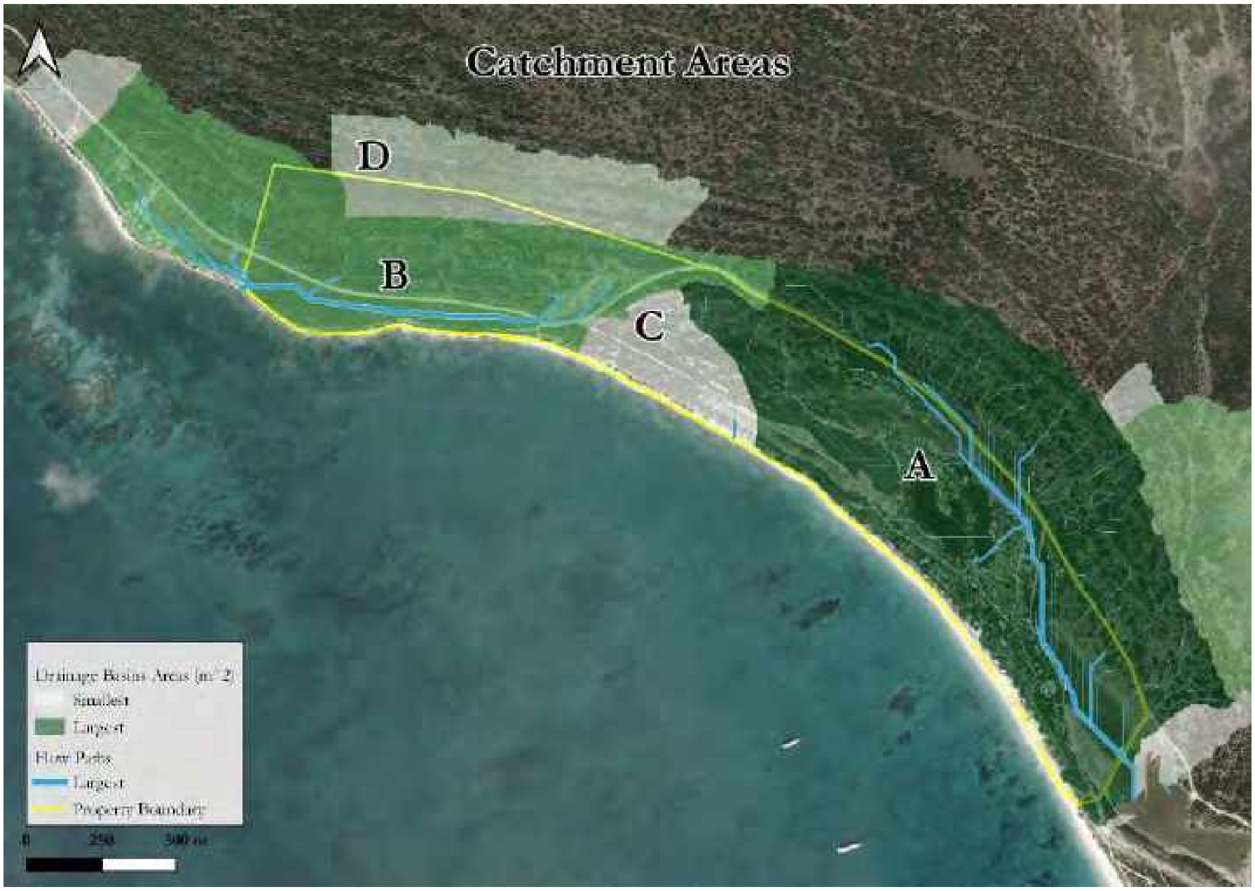

Figure 5.18 Catchment areas for the project site overlain on satellite imagery [© ESRI]

Based on the results of the catchment analysis, there are four catchment areas and drainage paths on the property. The largest catchment is Catchment A, which covers ponds 1, 2 and 3 and has an area of 1.4km^2. Pond 1 is the collection point for Catchment A and acts as the final point for discharge in this area. The northern half of the property drains to a low point near to the property boundary in Catchment B. This catchment has an area of 0.83km^2. Catchment C is located along the centre of the property's beach front. The catchment is smaller than the others with an area of 0.14km^2. This area drains towards the sea. The fourth catchment (D) has an area of 0.32km^2 which flows from the 6m ridge.

Soils

The soil types in the catchment are important determinants for how much water is retained in the soil and the resulting peak runoff possible. Significant borehole testing was done across the property to determine the soil and sub-soil layers in the area. This was presented in a lab report by CMT Technologies. It was determined that the land was mainly brown sand and sandy loam with pond areas having clayey sandy loam. The soil type has favourable internal drainage and infiltration properties.

Analysis of Extreme Rainfall

Extreme rainfall data was presented in the Baseline Conditions Report. The return periods used in the design were the 50-year rainfall (330 mm/day) and the 100-year rainfall (533 mm/day).

Runoff Estimation Using the Rational Method

The rational model is suitable for small urban catchments (less than 1.5km^2), which means that it is not applicable for the wider watershed but is ideal for calculating flow for the smaller catchments associated with the site. This method was developed primarily for estimating peak runoff according to the formula:

$$Q = CIA$$

Where,

C = runoff coefficient

I = rainfall intensity and

A = area of the catchment

Runoff coefficients were chosen based on the Urban Water Resources council 1992 recommended values.

Study Limitations

As previously discussed, there was a lack of accurate data for this analysis. Most notably the all-island contours were not available at a sufficiently detailed resolution, leading to major gaps and possible inaccuracies in the catchment delineation. Additionally, the soils and land-use data (which are used to determine the Curve Number) had to be averaged across the main catchment, which could in turn lead to over-estimating or under-estimating the flows.

5.3.3 Runoff Results

The calculation of surface runoff, based on a statistical depth of rainfall for a particular return period estimate and selected temporal distribution, was carried out for this project. The resulting peak discharges were calculated using the rational method for all catchments shown (Table 5-3). The generated flows ranged from a catchment minimum of 0.29m^3/s, to a catchment maximum of 4.27m^3/s for the 2 to 100-year event.

Table 5-3 Discharge volumes for catchments delineated

Catchment	Discharges (m^3/s)					
	2	*5*	*10*	*25*	*50*	*100*
A	1.09	1.46	1.72	1.85	2.54	4.10
B	1.14	1.52	1.79	1.92	2.65	4.27
C	0.29	0.39	0.46	0.49	0.68	1.10
D	1.12	1.50	1.76	1.90	2.61	4.21

As shown, the return periods considered vary from 2 years to 100 years, which is typical for a hydrological analysis. The choice of the actual drainage design return period to be used however depends on various factors, including the size of the drainage area, the risk of failure, the importance of the structure, and the desired degree of conservatism.

For the drainage area related to catchment zones A, B and D, a minimum of the 1 in 100-year design rainfall event was used for drainage sizing. This is in line with recommendations for flood protection works for minor drainage systems. This includes inlets, street and roadway gutters, roadside ditches, small channels and swales, and small underground pipe systems. These all collect storm water runoff and transport it to control facilities, previous areas and/or the major drainage system (i.e., natural waterways, large impoundments, gullies, rivers, etc.,).

5.3.4 Proposed Drainage Solutions

Design Criteria

The general site drainage for the project was designed according to specific guidelines set out in international drainage manuals and handbooks.

The following guidelines were adopted:

- Flood protection from rainfall will be designed against the 100-year return period event;
- Lot and building drainage will discharge surface flows to the existing ponds as best as is practical;
- Minimum and maximum velocities in storm drains shall be 1.0m/s and 3.5m/s, respectively;
- Tail water in receiving water bodies will be as follows:
    - Drains and culvert: normal depth for design flow;
    - Ponds, lakes, and rivers: Normal high-water depth; and
    - Sea and shoreline discharge: Mean High Water.

Drainage Design - Onsite Drainage

It is proposed that the natural slopes on the property be maintained to reduce the amount of cut and fill required. In housing/hotel lot groups (such as those in Phase B), the stormwater runoff will sheet flow across the property into the proposed drainage system. The low areas should be filled, and the site properly graded to improve the efficiency and effectiveness to facilitate proper drainage. It is recommended that suitable measures such as landscaped areas, grasscrete pavers and green spaces be maximized to reduce runoff.

Proposed Drainage Features

The objective of the drainage design is to successfully manage the surface flow and ponding on the site by reducing the potential for flooding, scour and poor water quality discharge along the shoreline or into the sea. The drainage master plan includes a combination of open bioswale channels along the proposed roadways inside the development, HDPE pipe connections and grading of the existing land to direct flows to the ponds. A berm with a finished elevation of +3m above mean sea level is proposed along the perimeter of the existing ponds. This combination of elements is proposed to handle the flows generated from the catchment associated with the proposed development. The proposed drainage master plan (shown in Figure 5.19) is as follows:

1. Grading of property towards proposed new ponds and bioswales where practical. For lots that have a natural drainage path away from the road, drains to exit points will be implemented.

2. In early phases, flows will be mainly handled by the existing ponds, with areas slated for pond creation being allowed to pond naturally.
3. News ponds will be dug to a level of mean sea level to maintain mangrove habitat in the ponds.
4. Existing ponds will have a berm of up to +3m above MSL crest elevation to allow for increased storage and to reduce breaching during rainfall events.
5. All drains and drainage features will require regular maintenance and clearing to work best.

The plan and cross-sections are included in Appendix D. It should be noted that at the extreme western end of the property the bioswale and a public access trail to the coastline will be provided within the limits of the Paradise Found property.

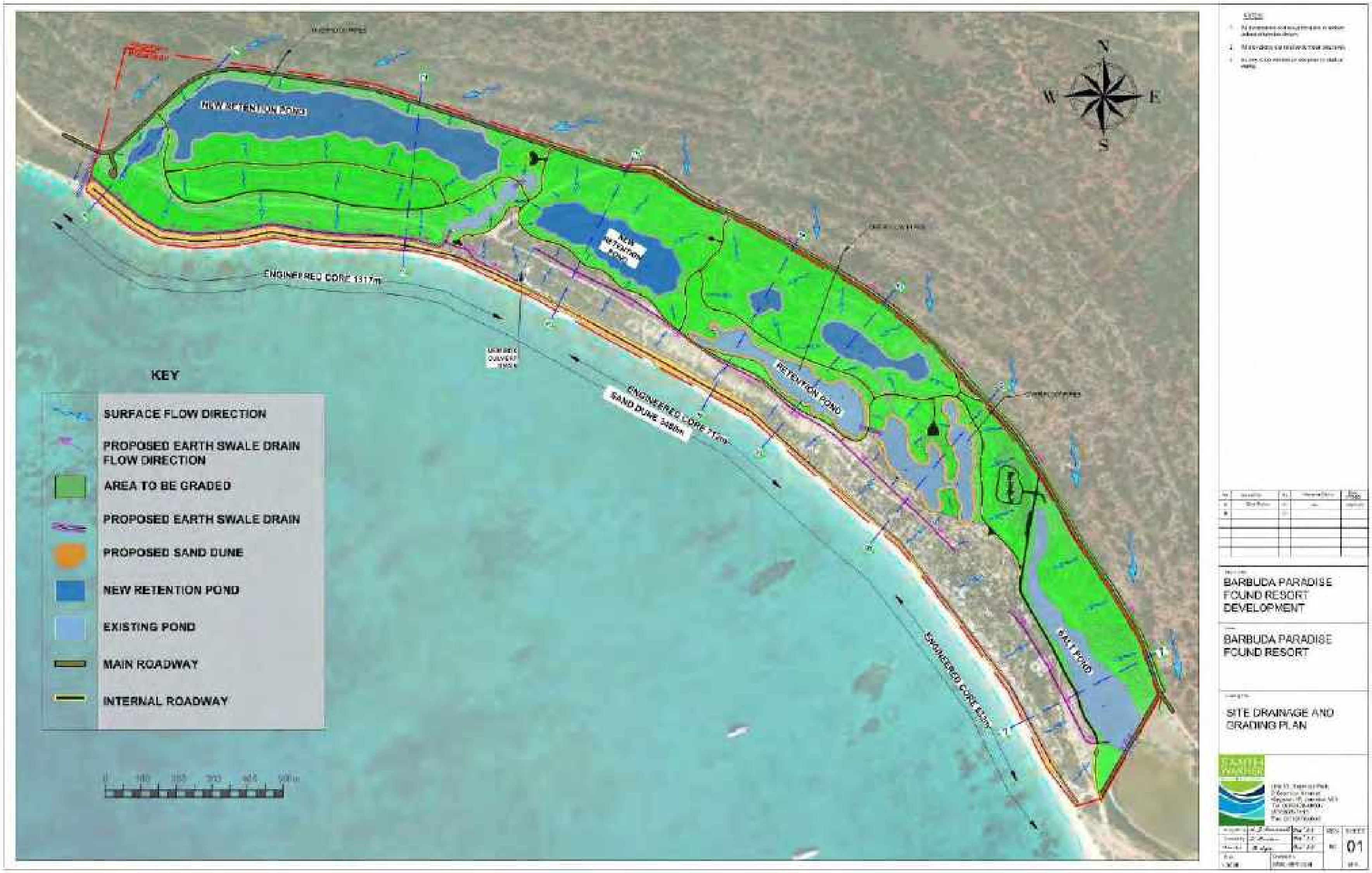

Figure 5.19 Proposed drainage plan

5.3.5 Hydraulics

Road Slopes

It is recommended that the internal roads do not have a gradient in excess of 15%. This will aid in reducing flow velocities off the roadways and reduce the erosion potential.

Drainage Design

The design of the drainage infrastructure was programmed using the Manning's Equation for the design for channels. The Manning's equation is one of the most used equations governing channel flows. It is an empirical equation that applies to uniform flow in channels and is a function of the channel velocity, flow area and channel slope. The drains were designed taking into the consideration recommended values of 1 to 3.5 m/s for velocities.

$Q = VA = \left(\frac{1.49}{n}\right) AR^{\frac{2}{3}} \sqrt{S} \quad [US]$ $Q = VA = \left(\frac{1.00}{n}\right) AR^{\frac{2}{3}} \sqrt{S} \quad [SI]$	Where: Q = Flow Rate, m^3/s (ft^3/s) v = Velocity, m/s (ft/s) A = Flow Area, m^2 (ft^2) n = Manning's Roughness Coefficient R = Hydraulic Radius, m (ft) S = Channel Slope, m/m (ft/ft)

Trapezoidal Channels and HDPE Pipes

Open trapezoidal channels are being proposed along the sides of roadways within the development. The perimeter road drain (A1) was designed to accommodate a minimum of $5.8m^3/s$ generated from the 1/100-year event. The north-western lots will have an open earth swale (B1) behind the dune that will be vegetated. This drain has a design flow of a minimum of $0.38m^3/s$ generated from the 1/100-year event. The central lots have an earth drain (A2) running along the internal road that was designed for a $0.50m^3/s$ flow. Finally, the southern drain (A3) behind the Phase A lots would require a flow capacity of $0.24m^3/s$.

All drainpipes were designed to accommodate the 1 in 100-year flow ranging from $0.24m^3/s$ to $5.8m^3/s$ to facilitate discharge into existing ponds and drainage features. All HDPE pipes are to be 900mm in diameter and have 3 pipes for each connection.

5.3.6 Drainage Maintenance

The entire drainage network consisting of trapezoidal channels and HDPE pipe culverts, will require regular maintenance and clearing to function properly. It is therefore essential that a maintenance program be developed and maintained to ensure regular cleaning of the drainage systems. The drainage infrastructure should be checked a minimum of once a week for regular maintenance (during the dry season) and after every rainfall event. Additionally, if advisories are issued for storms or heavy rainfall, the drains should be cleaned pre-emptively.

Some earth swales have flow rates lower than the 1m/s recommendation which may reduce their ability to self-clean. The drain cross sectional areas may be increased to provide a higher flow rate. It is strongly recommended that regular checks and cleaning of the earth swales be prioritised during the operation phase low flow rates.

5.3.7 Hydrodynamic Modelling of the Proposed Drainage Solution

The purpose of this exercise was to evaluate the effectiveness of the proposed internal drainage solution in handling the 50-year storm and the design flood (100-year return period rainfall), as well as to examine the levels of inundation (if any) experienced during the 100-year return period floods, and to propose minimum floor levels for the area surrounding the drainage pathway.

Possible impacts resulting from the discharge hydrodynamics associated with the flood events were evaluated using the two-dimensional MIKE 21 numerical model for both the existing conditions ("do nothing" scenario) and the proposed drainage solution described above. The modelling results were used to predict what would happen during the 24-hour flood event once the proposed solution is implemented.

Figure 5.20 shows the simulation results for a 50-year return period rainfall under existing and proposed conditions. The flow through the site is reduced with the proposed drainage plan in place. The focus of grading effort was to improve the overall drainage of the site by redirecting flows to the new ponds and drainage features. Water that will sheet flow across the site will be collected by earth swales that will carry the water to the existing ponds and drains. In this solution, the existing ponds will have a berm up to 3m above MSL. In the simulation, this berm stopped the ponds from breaching under a 50-year rainfall thus providing additional water storage during heavy rainfall events.

The 100-year rainfall event was also simulated (results in Figure 5.21) and acts as the design condition for the drains along the perimeter road and internal areas. During this severe event, there was flooding of most areas in the project area. Outside of the project area, there was an increase in flooding at the perimeter wall when compared to existing conditions. This is due to a shifting of the drainage path in the catchment area.

With the proposed conditions the flow shifted from through the site to around the site. Depths increased from 0.5m to 1m along some sections of the property's perimeter road. The inundation was increased mainly at the south-eastern end of the property. This inundation will be dealt with in two ways. There will be a drain along the south-eastern end of the property and there will be overflow pipes that will carry water over a 1.5m elevation into the ponds. The increased flow was localised to the salt pond areas. Neighbouring properties were found to not have a significant change in inundation depths for this event.

Overall, the proposed internal drainage plan can be deemed satisfactory as it performs well under both the 50-year and design 100-year return period flood event.

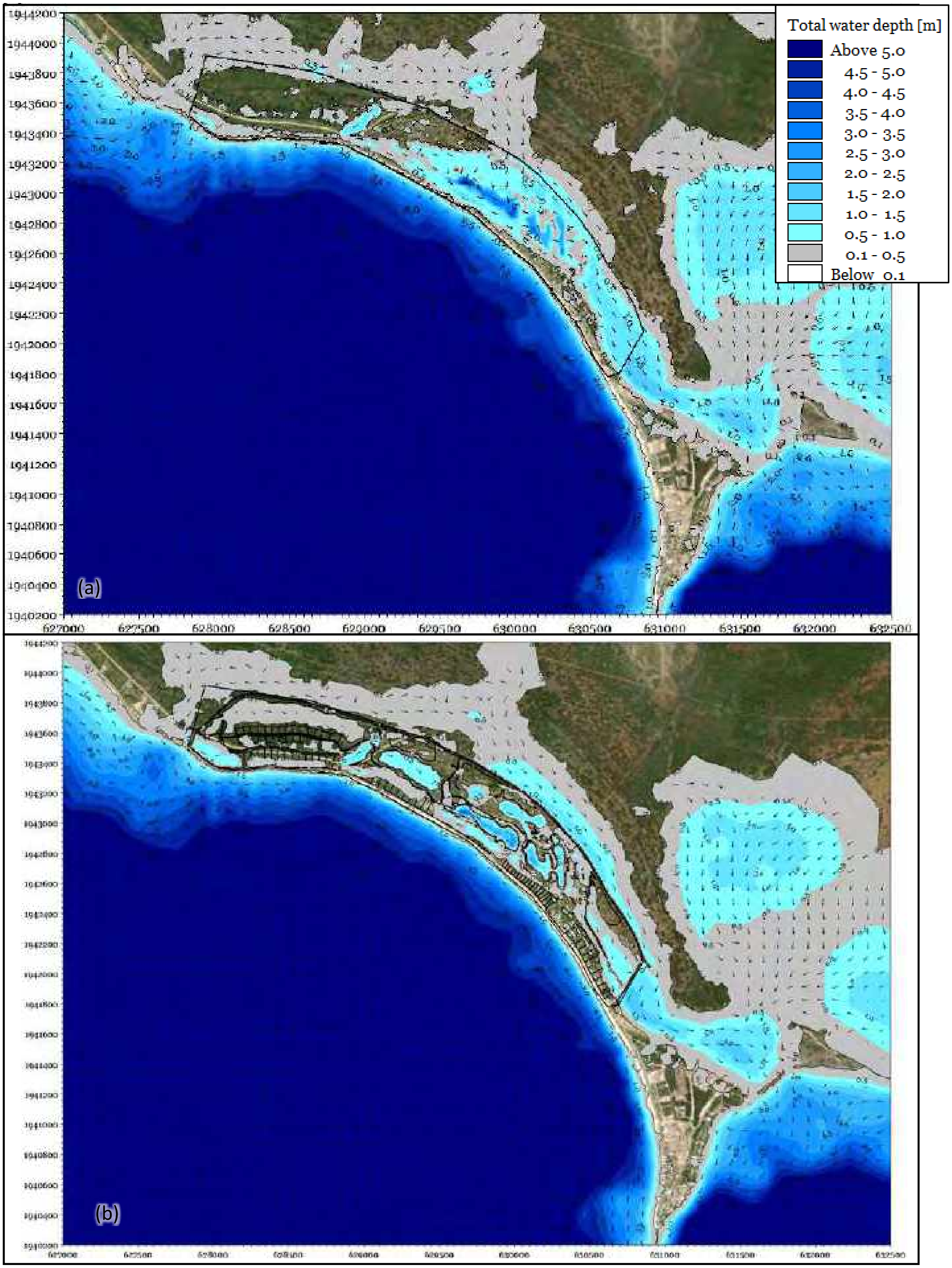

Figure 5.20 Comparison of existing and proposed drainage solutions subjected to a 50-year rainfall event

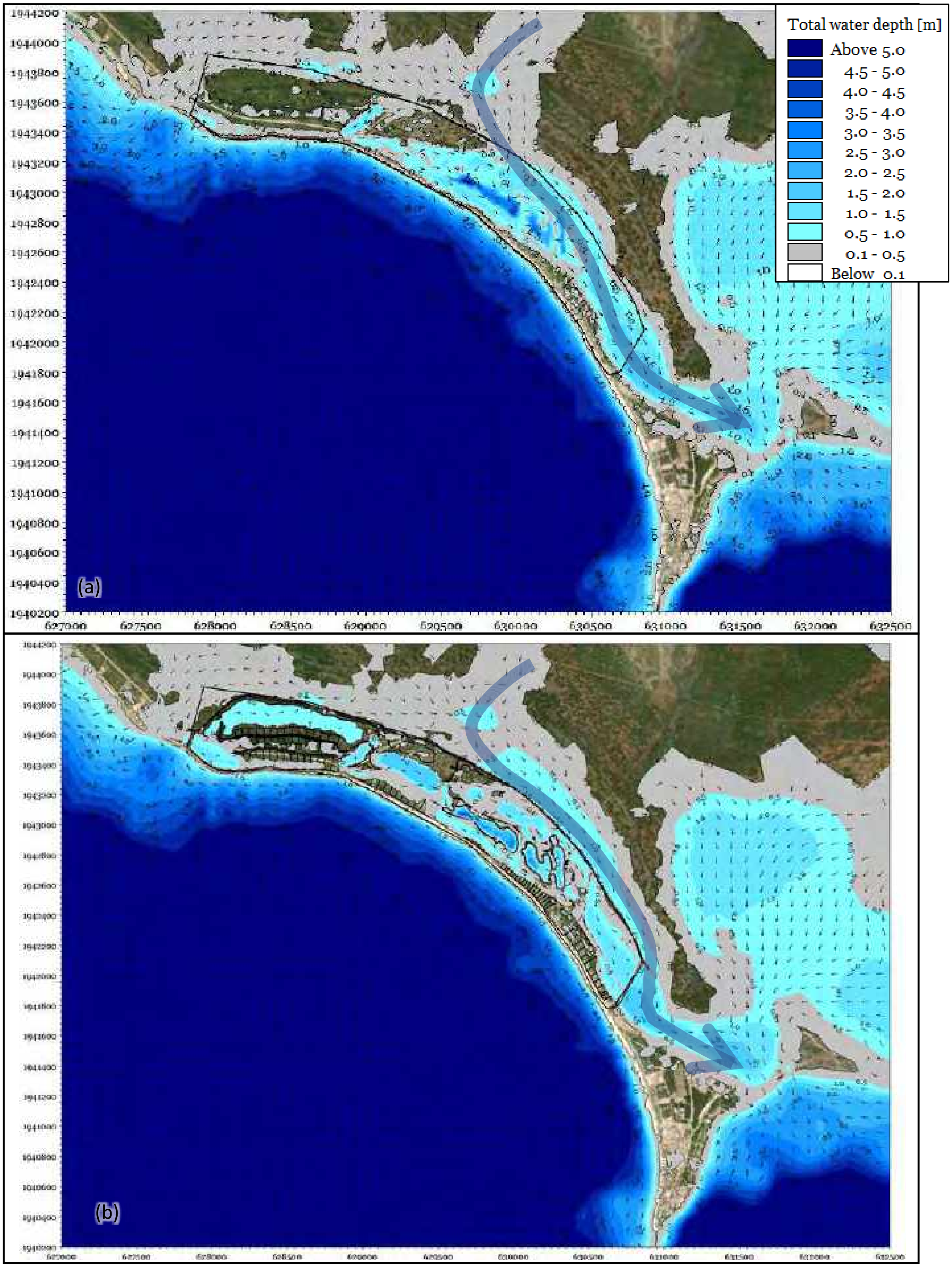

Figure 5.21 Comparison of existing and proposed drainage solutions subjected to a 100-year rainfall event

Earthen Swale Calculations

The earth swales were sized based on the rainfall runoff generated in the 100-year event. Calculations were done using the Rational Method to determine the flow from each catchment. The flow was then used to work backwards to find the appropriate sizing of the trapezoidal earth drains. The calculations for each drain are shown below in Table 5-4.

Table 5-4 Calculations for earth swale sizing

Parameters	Catchment ID			
	A1	A2	A3	B1
Drainage Runoff Calculations				
Drainage Area, A (m^2)	775,944.13	165,445.83	43,081.30	91,004.01
100-year event Rainfall Depth (mm)	533.00	533.00	533.00	533.00
Main stream length, L (m)	1776.00	1635.97	743.89	1292.89
Lower elevation (m)	0.76	1.40	0.00	0.91
Upper elevation (m)	2.74	3.00	1.67	3.20
Height differential, H (m)	1.98	1.60	1.67	2.29
Slope (-)	0.00	0.00	0.00	0.00
Runoff Coefficient, C (-)	0.04	0.04	0.04	0.04
Time of Concentration, min	84.94	83.82	33.15	55.67
Rainfall Intensity (mm/hr)	267.33	270.45	493.20	377.19
Peak Flow, Qp (m^3/s)	**2.32**	**0.50**	**0.24**	**0.38**
Trapezoidal Channel Dimensions				
Length (m)	2072.19	1635.97	697.15	929.45
Lower Elevation (m)	0.00	0.50	0.00	0.00
Upper Elevation (m)	2.74	2.50	1.80	2.00
Slope (%)	0.0013	0.0012	0.0026	0.0022
Mannings Coefficient (-)	0.025	0.025	0.025	0.025
Side Slope (cot α)	2.0	2.0	2.0	2.0
Width (m)	4.5	2.7	1.8	2.3
Flow Depth (m)	0.6	0.5	0.3	0.3
Depth with freeboard (m)	0.75	0.63	0.38	0.38
Channel Base Width (m)	1.50	0.20	0.30	0.80
Hydraulic Radius (m)	0.61	0.45	0.28	0.31
Wetted Perimeter (m)	3.66	2.00	1.38	1.88
Cross Sectional Area (m^2)	2.25	0.91	0.39	0.58
Velocity (m/s)	1.05	0.82	0.88	0.85
Flow Rate, Q (m^3/s)	**2.36**	**0.75**	**0.35**	**0.49**
Check	PASS	PASS	PASS	PASS

Overflow Pipes

A difference plot has been produced for the property to show how the flow changes from existing to proposed conditions (Figure 5.22). Positive values represent an increase (red tones) and negative values represent a decrease (blue and green tones). The project site had an average of 0.4m less water depth in the proposed conditions. The new ponds had higher water depths, which is to be expected as they were excavated to hold more water. Outside of the project site, the extents of the increased water depth could be clearly seen. This additional water will be directly addressed with two overflow pipes that connect to the ponds.

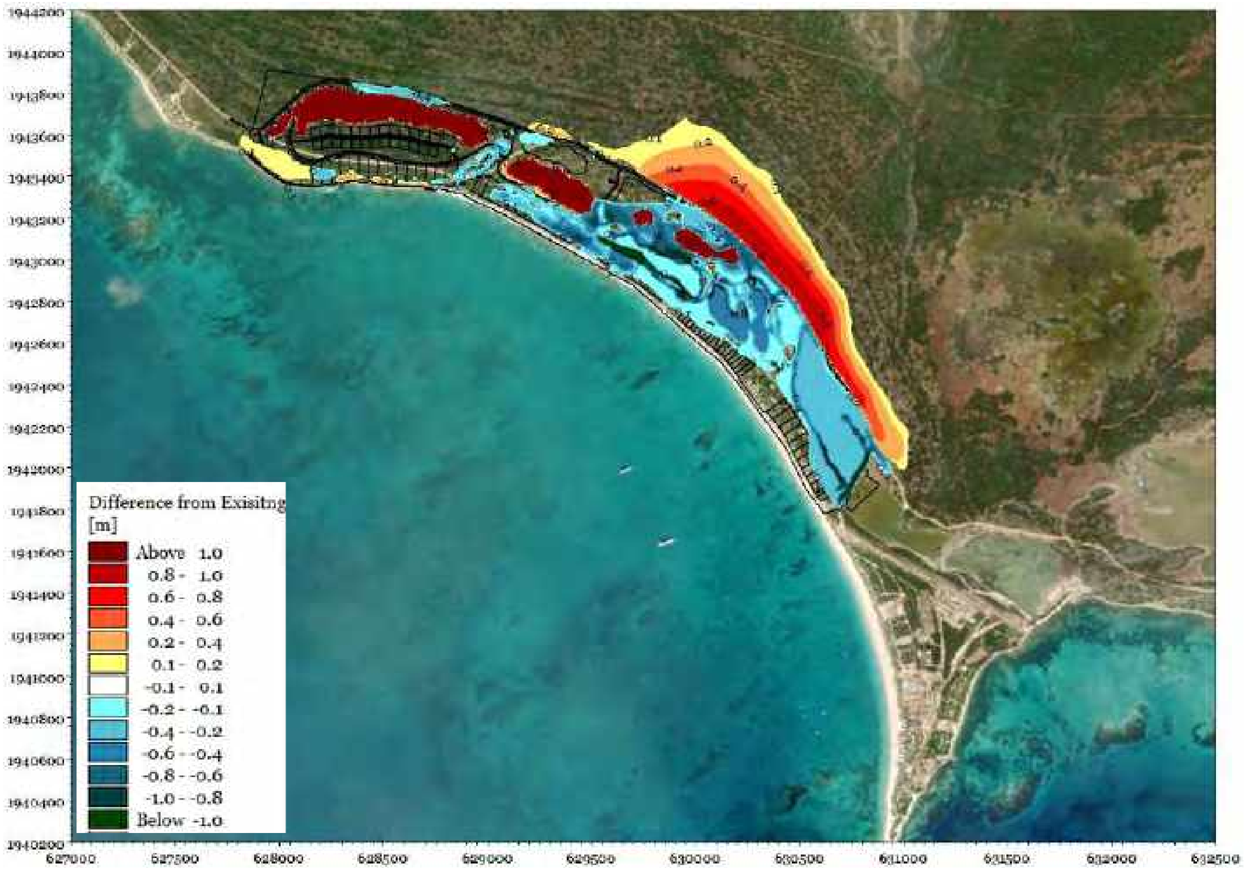

Figure 5.22 Total water depth difference plot for the 100-year event (proposed minus existing)

The total additional water volume outside of the property is 220,000m^3 which is less than the reduction of water volume through the property. Overflow pipes are proposed to reduce this volume by a minimum of 25%. The overflow pipes will be connected to the earth swale that runs along the perimeter road. The pipes will then run under the road and ground to the existing ponds (2 and 3). The pipes will be eight parallel HDPE pipes with a 0.3m diameter. The diameter was kept this small based on the available depth in the earth swale. The pipe inverts were based on the surface elevation of the water in the ponds and outside of the ponds.

These overflow pipes would remove about 73,000m^3 of water from the outside of the property and discharge them into the ponds. This volume is based on the building up of flow for 6 hours and then triggering the overflow pipes thereafter. The volume would correspond to an increase in water depth in the existing ponds of 1.1m. The calculations are shown below.

Table 5-5 Overflow pipe calculations

Parameters	OF1	OF2	OF3
	South	Centre	North
Overflow Pipe Calculations			
Length (m)	95.00	305.00	44.00
Lower Elevation (m)	0.90	0.90	0.60
Upper Elevation (m)	1.90	1.90	2.10
Slope (%)	0.011	0.003	0.034
Mannings Coefficient (-)	0.012	0.012	0.012
Pipe Diameter (in)	12.00	12.00	12.00
Pipe Diameter (mm)	304.8	304.8	304.8
Flow Depth, d/D (-)	0.75	0.75	0.75
Flow Fraction, Y (-)	228.6	228.6	228.6
Hydraulic Radius (m)	92.0	92.0	92.0
Wetted Perimeter (m)	638.4	638.4	638.4
Cross Sectional Area (mm^2)	58701.0	58701.0	58701.0
Velocity (m/s)	1.7	1.0	3.1
Flow Rate, Q (m^3/s)	0.10	0.06	0.18
Number of Pipes (no.)	8	8	4
Total Flow Rate, Q (m^3/s)	0.82	0.46	0.74
Duration (hrs)	16	16	16
Flow Volume (m^3)	47,115.43	26,295.11	42,394.96

6 Impact Assessment and Mitigation Measures

The following sections describe the potential impacts and proposed mitigation measures for the various activities associated with both the construction and operational phases of the Paradise Found resort. Cumulative impacts are also discussed. Cumulative impacts will result from the combined effects of this development and other development activities in the area undertaken by others. Under those circumstances, the developers of Paradise Found can only accept responsibility for mitigating adverse impacts that result from actions on their own project, but cannot accept responsibility for mitigating impacts that result from the actions of others.

6.1 Physical Environment

The following sections describe the potential impacts and proposed mitigation measures for the various activities associated with both the construction and operational phases of the Paradise Found resort.

6.1.1 Turbidity

Nature of Concern

During the placement of sand nourishment to the required the grade there is potential for turbidity and sedimentation of the area offshore the site.

Mitigation Measures

Turbidity barriers will be used around all works in the sea to minimize leakage of silty material to sensitive areas. Turbidity will also be monitored daily at two locations of each work area in the sea where there is construction in the sea. A further measure is to ensure that the sand used for nourishment has a low silt content (ideally less than 0.5%).

6.1.2 Oil Pollution

Nature of Concern

There is the potential for fuel leaks or spills from equipment used for the construction, excavation and/or sand nourishment during refuelling or operation. Refuelling of the boat and sea-based equipment should only be done at anchor out at sea if the sea conditions are calm, otherwise, all refuelling should be done when docked at land. Appropriate refuelling equipment (such as funnels) and techniques should always be used.

Mitigation Measures

Appropriate minor spill response equipment (for containment and clean-up) must be kept on site, including oil absorbent pads and disposal bags.

6.1.3 Dune Extension

Nature of Concern

Once the appropriate slope into the water has been attained through grading, the dune will be nourished with appropriately sized sediment. The sand will then be mechanically placed on the beach to match the lines and grades of the design and finally smoothed manually by labourers.

Mitigation Measures

Marine sand will be required for the beach nourishment exercise. The materials will be brought to the site from a certified/approved source. All acquired sediment will be placed on the proposed beach and shaped accordingly. The silt content should be low, ideally less than 0.5%, and great care should be taken when spreading to minimize loss of material.

6.1.4 Impaired Air Quality (Dust) during Construction Phase

Nature of Concern

Dust is the primary air quality concern arising from cleared areas, excavation works and the movement of construction vehicles and equipment and also from stockpiles of aggregate. The main sources of air emissions identified within the study area were:

- the road network (vehicular exhaust and the kick-up of dust from trucks transporting material); and
- dust from construction sites.

It is important to note that calculated 24-hour concentrations of $PM_{2.5}$ and PM_{10} at all four monitoring locations were less than the respective WHO Guidelines for a 24-hour averaging period.

Dust is released into the air from the contact of tires and working parts with the ground, particularly when equipment and vehicles travel over unpaved areas, thereby contributing to the 'kick-up' of dust into the air.

The developer at Paradise Found will have trucks in use on the project. The trucks will be used for the top loading of material, waste removal, concrete deliveries, and other construction-related tasks. Paradise Found does not own any trucks and is instead planning to use the services of local trucking operators in order to support the local economy.

There will be times when it will be necessary for the trucks to travel through Codrington, for example, to reach the local landfill or quarry site. Paradise Found anticipates that trucks will need to pass through Codrington 1 to 2 times per week, with a maximum of three trucks on each day. Figure 6.1 illustrates the route the trucks would take to the landfill.

Figure 6.1 Anticipated truck route during construction

Dust is a nuisance causing discomfort among persons affected and could also exacerbate illnesses such as asthma and bronchitis.

At high concentrations, dust can also affect plants by coating the leaves and impeding photosynthesis. The potential concern of dust on air quality is most pronounced in the dry season when winds are also highest.

Mitigation Measures

The following mitigation measures can be employed for the control of dust emissions during construction:

- Clear only the area needed for construction, leaving vegetation in other areas intact as far as practical, thereby reducing the area from which dust can be formed.
- Install dust screens close to sensitive receptors to reduce the amount of dust leaving the construction area.
- Designate a Community Relations Officer to deal with complaints from affected persons in the project area.
- Notify residents of schedule for significant truck movements.
- Vegetate or pave cleared areas as early as practical.
- Keep stockpiles to a minimum and use as soon as practical, thereby reducing a source of dust.

- Cover smaller stockpiles, or store fine aggregates in bins or silos. This prevents exposure of material to the wind.
- During earthworks (including excavation) implement dust control measures at source, including frequently wetting bare surfaces and access ways. Paradise Found has committed to using a water truck to provide dust control on the route when the construction trucks are in use in residential areas. Roads will be sprinkled through town and for 100m at either end of town on the days when trucks are being used at Paradise Found. Dust from trucks passing through town was an issue raised during the recent social impact study and Paradise Found is keen to mitigate this as best as possible.
- Cover the tray of all transport vehicles (with tarpaulins, etc.) while moving materials and fill to and from the site to prevent material/ fill flying up from the load into the air as dust.
- Implement a speed limit for trucks transporting materials to and from the construction site. This should be done in conjunction with the Police Service.

While this impact is expected to be temporary, it is expected to extend beyond the project area and have significant effects on social groups. Once the mitigation measures listed above are effectively implemented, this impact is expected to be medium intensity.

Cumulative Impact

Dust from the other construction projects ongoing in the vicinity of the Paradise Found project site will represent a cumulative impact with the dust generated from the Paradise Found development. This will result from the transport of material along the existing roadways. As previously noted, the impact of dust has already resulted in an increase in respiratory illnesses treated at the HTH. This cumulative impact is expected to be significant.

6.1.5 Impaired Air Quality (Exhaust Emissions) during Construction Phase

Nature of Concern

The main source of exhaust emissions in the study area are vehicles travelling along the roads. The engines of vehicles and powered equipment emit carbon monoxide, carbon dioxide, sulphur dioxide, nitrogen oxides, volatile organic compounds and soot (dust); all of which are harmful to people, animals and plants at sufficiently high concentrations. However, experience in other jurisdictions in the Caribbean suggests that such emissions dissipate to very low concentrations in a relatively small distance from source (typically less than 20 m). The impact of exhaust emissions is expected to be less significant than the impact of dust as discussed in Section 6.1.4, above.

Mitigation Measures

The following mitigation measures can be employed for the control of exhaust emissions during construction:

- Only use vehicles with a valid inspection certificate from the Transport Board.
- Properly service all vehicles and equipment to ensure that there are no visible sooty emissions.
- Remove defective vehicles from the fleet until they are repaired.
- Optimize trips bringing material and/or transporting waste from the site by ensuring that the use of part-filled trucks is minimized (to the extent practical).

- Designate a Community Relations Officer to deal with complaints from affected persons in the project area.
- Notify residents of schedule for significant truck movements.

Exhaust emissions from the passage and operation of vehicles and equipment is expected to be temporary, extend beyond the project site and have marked effects on individuals. Once the mitigation measures listed above are effectively implemented, this impact is expected to be low intensity.

Cumulative Impact

Exhaust emission from construction vehicles associated with the other construction projects ongoing in the vicinity of the Paradise Found project site will represent a cumulative impact with the emissions generated from the Paradise Found development. This will result from the transport of material along the existing roadways. This cumulative impact is expected to be moderate.

6.1.6 Impaired Air Quality (Emissions from Generators) during Operational Phase

Nature of Concern

As noted previously, due to a lack of existing infrastructure on the island, the electrical power demand will initially be met using diesel generators. To fuel these generators, diesel fuel will be stored on site in 9.1 m^3 volume (2.000 imperial gallons / 2,400 US gallons) tanks. Given the size and the need to continually use these generators, these emissions are expected to be significant.

Mitigation Measures

The following mitigation measures can be employed for the control of diesel emissions during operation:

- Phase out the reliance on generators in favor of more sustainable options, including photovoltaic systems and battery storage. The development will eventually seek to be energy self-sufficient from these sustainable energy sources, while maintaining generators on-site for redundancy.
- Site the generators downwind from the development (as far as practical) to reduce the impact of emissions on residents.
- Conduct regular maintenance of the generators to reduce the potential for excessive dark smoke.
- Include diesel generators with air pollution control devices. These can achieve considerable emissions reductions.

Once the mitigation measures listed above are effectively implemented, this impact is expected to be low intensity.

Cumulative Impact

Impaired air emissions from use of generators are not expected to be cumulative with other developments in the vicinity of Paradise Found.

6.1.7 Impaired Air Quality (Odours from the WWTPs) during Operational Phase

As no municipal wastewater treatment option is available on Barbuda, the Paradise Found development will construct a private WWTP to treat wastewater produced from the resort, while individual beachfront villas will be connected to their own WWTPs.

The proposed sewage treatment plants are of a type known not to emit foul odours during normal operation. Odour problems would develop only if there is a failure of the sewage treatment plants (see Risk Assessment). In order to minimize the incidence of such failures, preventative maintenance of the STP should be scheduled. Should a failure still occur, the appropriate mitigation measure would be to repair the system as quickly as possible. In this case, it would be in the interest of the Developer to do so, as the first persons to suffer from these odours would be guests and homeowners within the development. In addition, the location of the STP in an enclosed building within the services area should also help in mitigating odour.

Once the mitigation measures listed above are effectively implemented, this impact is expected to be low intensity.

Cumulative Impact

Odours from non-functioning WWTPs are not expected to be cumulative with other developments in the vicinity of Paradise Found.

6.1.8 Noise (Construction Phase)

Nature of Concern

Sources of noise at all monitored locations in the project vicinity included a combination of movement of trucks and birds chirping. Baseline noise measured on the site showed that equivalent continuous sound pressure levels (Leq) were generally higher during the daytime than the nighttime. Daytime Leq values recorded at the four monitoring locations were below the World Bank's daytime limit for commercial areas but at three locations the Leq were slightly above the daytime limit for residential areas.

In addition to vehicles traversing the area such as light motor vehicles and heavy motor vehicles, construction vehicles and equipment will also emit noise from their engines, exhaust, horns and alarms. Noise levels emitted by equipment will vary depending on factors such as the type of equipment used, the operation being performed and the condition of the equipment. Therefore, noise generated due to the project would be dependent upon the selected method of construction and the manner in which materials and equipment are moved within the project area (Society of Automotive Engineers, 1976). The equivalent sound level (Leq) of the construction or operation activity also depends on the fraction of time that the equipment is operated over the period. Construction noise can affect persons and structures in nearby communities at and around the project site.

Mitigation Measures

The following mitigation measures can be employed for the control of noise:

- Only use vehicles with a valid inspection certificate from the Transport Board.
- Ensure that noise-generating equipment are routinely maintained and inspected to reduce unnecessary increases in noise levels;

- Ensure that existing acoustic controls on all noise-generating equipment are functional.
- Designate a Community Relations Officer to deal with complaints from affected persons in the project area.
- Schedule construction activities for the period 7:00 am to 7:00 pm to the extent practical. If night work is necessary, inform the relevant authorities of the proposed schedule for this activity.
- Inform surrounding communities and other stakeholders of construction activities ahead of the start of works.

Noise generated by clearing, grading and other construction activity will be temporary, lasting for the duration of these activities. Noise is likely to be audible at the nearest residences but is expected to last only as long the construction phase lasts but may have significant effects on the functioning of social groups.

Once the mitigation measures listed above are effectively implemented, this impact is expected to be low intensity.

Cumulative Impact

Noise from the movement of existing construction vehicles will represent a cumulative impact with the noise generated from the Paradise Found development. This will result from the transport of material along the existing roadways. This cumulative impact is not expected to be significant in the immediate vicinity of the development but will have a more significant impact in Codrington where there are more residents.

6.1.9 Noise (Operational Phase)

Nature of Concern

The major source of noise during the operation phase is from the use of generators to power the diesel generators. Experience during a visit to the site to collect baseline data, is that the noise of the generator is very noticeable once outside.

Mitigation Measures

Measures to mitigate this impact include:

- Include noise levels specification when ordering new equipment.
- Place the generator in a plant room with thick walls, sound adsorption materials, sound-proof door and silencers for air inlets/outlets.
- Isolate the machine from the building structure by use of inertia blocks and vibration isolators.
- Provide flexible connectors between the machine and associated pipework to avoid structural vibration transmission.
- Use vibration isolators for attaching pipes to walls, ceilings or floors.
- Conduct regular maintenance, check alignment and quickly replace worn-out components.

Once the mitigation measures listed above are effectively implemented, this impact is expected to be low intensity.

Cumulative Impact

Noise from use of generators during the operation phase is not expected to result in a cumulative impact.

6.2 Biological Environment

6.2.1 Clearing of Vegetation (Loss of Habitat)

Nature of Concern

The habitats identified on the proposed project site include dry forest, ephemeral zones, xerophytic shrubland, salt pond and coastal fringe. In addition, there are brackish ponds that were created (Pond 1, Pond 2 and Pond 3) during the former development.

The clearing of vegetation during site preparation and construction works will result in loss of terrestrial habitat. Clearing of vegetation will be required to facilitate the construction of roads, drainage, utilities and facilities, and topsoil containing roots must also be removed (grubbing).

A total of 30 plant species were encountered on the site across the various habitats identified. Four species were listed as endemic (Locustberry, Dagger Plant, Wild Frangipani and Lignum vitae), one species was listed as near threatened (Lignum vitae) and one species was listed as threatened (Black Mangrove) by the IUCN Red List of Threatened Species. All other species are listed as least concern. Additionally, mangroves, native palms and cacti are protected species in Barbuda.

The removal of vegetation is associated with the loss of habitat for birds and other fauna supported by the system. It is expected that displaced fauna will be able to inhabit similar contiguous areas and their functioning may only be impaired for a short period until they re-establish themselves in adjacent suitable habitats.

Mitigation Measures

Although clearing of vegetation will be an unavoidable activity and impact during the construction phase, the following measures are also recommended to mitigate this impact:

- Minimize the areas to be cleared, to the extent practicable especially in areas where there are environmentally sensitive species such as the mangrove communities surrounding the ponds.
- If mangrove is to be cleared, approval will be required from the Fisheries Division and the Department of Environment.
- Allow for the re-vegetation of areas where possible, either naturally or by replanting, using same or like species, to the extent practical.
- Revegetating will be facilitated by use of the onsite nursery that already exists on site.

As noted above clearing of trees for the development will be a permanent and unavoidable impact of this development. A detailed *Mangrove Protection and Management Plan* is attached as Appendix C.

Cumulative Impact

Loss of habitat is expected to be cumulative impact since vegetation to be cleared for the Paradise Found development are representative of the same habitats cleared for the nearby PLH development. This cumulative impact is expected to be significant.

6.2.2 Disturbance to Terrestrial Species during Construction Phase

Nature of Concern

The construction of the Paradise Found development is expected to create noise and light conditions that have the potential to impact terrestrial fauna. This is separate from the concerns related to clearing of vegetation and loss of terrestrial habitat discussed above. Heavy transport vehicles and equipment used during the construction activities are expected to generate noise, which may result in mobile animals temporarily leaving the area during site clearing and construction activities. Artificial light may be required during the night to supplement existing lighting for site safety and security. Artificial lighting has the potential to impact the behaviour of nocturnal animals, which may include these animals avoiding areas with increased lighting. Additionally, the influx of workers in the area during site preparation and construction may result in unauthorized hunting of animals.

Twenty bird species were observed on the site. Of these, the West Indian Whistling Duck and Caribbean Coot are considered near threatened and the Barbuda Warbler is listed as vulnerable. All other species are listed as least concern.

Noise impacts on wildlife must be considered in two categories: impacts on wildlife on the site; and impacts on wildlife in adjacent areas. With regard to wildlife on site, noise is considered a significant concern because of the fragmented nature of the habitats on the site. Where possible the wildlife will leave the site due to the clearing of vegetation or take refuge in areas of the site which will not be cleared. Since it is not anticipated that perceptible noise increases will be experienced more than 200m from the site, noise impacts on wildlife in adjacent areas will be minimal. Noise impacts during site preparation and construction are expected to be transitory, lasting only while noise-intensive activities are in progress on the site.

The potential impacts associated with artificial lighting on nocturnal species will be of medium term duration as it may last beyond the construction phase into the operation phase but not by more than two years. Of the species observed on site, the West Indian Whistling Duck is considered nocturnal and would therefore be impacted by the introduction of artificial lights.

Mitigation Measures

In addition to the mitigation measures recommended for noise, the following mitigation measures are recommended to address this concern:

- Limit construction works to daylight hours to the extent practical;
- If night work is to occur, shield light from the vegetation and avoid use of bare and upturned bulbs;
- The minimum light intensity that can be used to ensure safety should be employed for night work; and
- Prohibit hunting or harassing of animals by workers on the construction site.

Noise impacts during site preparation and construction are expected to be transitory, lasting only while noise-intensive activities are in progress on the site. Similarly, the potential impacts associated with artificial lighting on nocturnal species will be of medium duration as it may last beyond the construction phase into the operation phase. Once the mitigation measures listed above are effectively implemented, this impact is expected to be of medium intensity.

Cumulative Impact

Noise and artificial light impacts to terrestrial species are not expected to be cumulative since construction noise and light from nearby projects will not extend to the Paradise Found site.

6.2.3 Impacts on Turtles

The main concerns to turtles arising from the proposed development are associated with the following:

- Artificial Light and Noise,
- Impaired Water Quality,
- Changes to Beach Morphology and
- Human Disturbance.

Artificial Light and Noise

Artificial lighting and noise from the construction and operation of Nobu Beach Inn can potentially affect nesting of land/sea turtles and their hatchlings. Artificial lighting on the beachfront may deter nesting sea turtles from coming ashore to lay eggs. Further, security lighting on buildings, and walkways can disorient hatchlings as well as nesting females thereby prohibiting them from finding the sea. Sea turtles orient towards the widest field of light, which is naturally in the direction of the sea towards the foam line of breaking waves on a dark beach. It should be noted that the brightness of artificial light needed to deter nesting or misorient hatchlings varies greatly with the level of ambient light (moonlight) and the availability of other visual cues.

In addition, noise generated during night time works during the construction phase and anthropogenic noise during operation of the resort may also deter turtles from nesting along Princess Diana Beach.

Impaired Water Quality

During the construction phase, there is potential for the entry of contaminants into the marine environment. For instance, barges will be used to transport construction material and equipment to the project site and any spills or leaks of oil or fuel from these vessels will impair water quality. This can directly impact sea turtles. Specifically, hydrocarbons significantly affect the skin, some aspects of blood chemistry, respiration, and salt gland function in juvenile sea turtles.

Furthermore, the improper disposal of solid waste, by workers during construction or by guests/tourists during the operation of the Nobu Beach Inn can also impair water quality. Solid waste, particularly plastics, is a major concern as they present a choking hazard to turtles since they are easily mistaken as food (jellyfish, sea sponges etc.). In addition, hatchlings and even adults can become entangled in solid waste, causing severe injury or death.

Changes in Beach Morphology

Extension of sand dunes along the northern section of the beach is proposed to protect against storm surges and coastal erosion. As such, a steeper slope towards the land will be established. These steep slopes can hinder nesting of sea turtles in this area as some turtles may not be capable of ascending the slope. For example, Hawksbills have been found to be sensitive to elevation when selecting nest, preferring to nest between 0.3 and 1.8 m (mean 1.1 m) above mean sea level (Horrocks and Scott 1991). It should be noted that the removal of beach vegetation will be required for grading and extension of the sand dunes. This will impact nesting of Hawksbills in particular as they prefer to nest in vegetation.

Human Disturbance

Besides artificial light, noise, impairment of water quality and alteration of the physical characteristics of the beach, turtles may be affected by the increased presence of people on the beach. Anthropogenic activity/disturbance along the beach may urge turtles to shift to other nesting beaches, delay egg laying, or select poor nesting sites. Heavy pedestrian and vehicular traffic compresses sand above nests, resulting in lower hatchling emergence success rates. Pedestrian tracks also interfere with the ability of hatchlings to reach the ocean. In addition, beach furniture left overnight on the nesting beach can obstruct adults and hatchlings as they make their way to and from the surf.

Mitigation Measures

- Where practical, schedule construction of shoreline features and buildings during non-nesting periods.
- Water dunes regularly to help establish vegetation quickly.
- Establish reasonable setbacks between the ocean and any permanent buildings.
- All exterior fixtures that produce light visible from the nesting beach should be shielded, directed only where light is needed, generally placed as low as practicable, and use long wavelength lamps (e.g., red/amber LEDs, low pressure sodium) and black baffles.
- Avoid bright white light, such as metal halide, halogen, fluorescent, mercury vapor, and incandescent lamps.
- Incorporate timers and motion sensitive lights to reduce beachfront lighting.
- Construction vehicles and equipment (including mufflers on this equipment) should be regularly inspected and maintained to ensure noise control systems (mufflers, etc.) are properly functioning.
- Design the drainage system to manage surface flow, eliminate sedimentation and improve water quality.
- Ensure that wastewater treatment systems are properly maintained.
- Use only low doses of landscape chemicals (fertilizers and weedicides).
- Collect all domestic garbage in secure receptacles for disposal at the landfill. No garbage should be left open or accessible to animals or allowed to litter the ground, beach or sea.

- Partner with local conservation groups to conduct beach clean-ups, especially just prior to the nesting season.
- During dune construction, ensure that the finished beach gradient considers the preferred elevations for sea turtles.
- Beach vegetation/ vegetation on sand dunes should be replanted immediately after the dunes are extended. This should include similar species to those removed.
- Beach furniture should be removed from the beach just after sunset, especially during nesting seasons.
- Consider an adopt-a-turtle program during the nesting season to allow tourists and residents to protect the turtles nesting at Princess Diana Beach.
- Prohibit hunting or harassing of all turtles and taking of eggs by workers and visitors on the beach.
- Prohibit entry of construction vehicles and machinery on the beach during the nesting season.
- Use of signage on the site to warn workers of restricted entry onto the beach.
- Use of barricades and fences along the construction site to prevent construction workers from easily accessing the beach.
- Use of signage on the site to alert tourists/visitors that the Princess Diana Beach is a turtle nesting site.
- Cleaning the beach of litter and debris should be done manually to avoid sand compaction and deep ruts in the sand.

It should be noted that the developer is committed to a turtle monitoring program including GPS mapping of nests and educational opportunities with local school children and guests.

6.2.1 Disturbance to Terrestrial Ecology during Operational Phase

Nature of Concern

During the operational phase there is the potential for impacts to the mangroves that fringe on site ponds as a result of a failure of one of the many WWTPs proposed for the site. This can lead to the release of untreated or poorly treated sewage into surface drains that discharge into the salt ponds on site leading to eutrophication. Eutrophication describes the process by which excessive plant and algal growth occurs due to the increased availability of one or more limiting growth factors needed for photosynthesis, such as nutrient fertilizers. Untreated sewage is rich in nitrogen and phosphorus, and so it is a contributor to eutrophication. Eutrophication creates dense blooms of noxious, foul-smelling phytoplankton that reduce water clarity, limiting light penetration, reducing growth and causing die-offs of plants. Although mangroves will initially benefit from the enhanced nutrient availability. Nutrient enrichment favours growth of shoots relative to roots, thus enhancing growth rates but increasing vulnerability to environmental stresses (Lovelock CE, Ball MC, Martin KC, C. Feller I, 2009).

Mitigation Measures

Measures that can be implemented to mitigate these impacts are as follows:

- Select wastewater treatment systems that are adequately sized to receive the combination of toilet waste and grey water from the hotel, villas and houses;

- Carefully choose the types of chemicals used in toilets, sinks and bathrooms and for laundering at the hotel, villas and houses so that they are not incompatible with the aeration of aerobic wastewater treatment systems.
- Maintain and repair all of the wastewater treatment systems in strict accordance with the manufacturer's recommendations.
- Educate residents on the most appropriate types of chemicals that can be used in toilets, sinks and bathrooms and for laundering.

Once the mitigation measures listed above are effectively implemented, this impact is expected to be low intensity.

Cumulative Impact

There is no cumulative impact on terrestrial ecology as a result of a failure of onsite WWTPs.

6.2.2 Impacts of Artificial Light on Fauna during Operational Phase

Nature of Concern

During the operational phase, lights from artificial sources will be used for various purposes including, lighting paths, security, etc. Since some of the site is expected to remain under vegetative cover and there will be replanting of areas cleared for construction, there is the potential for impacts to fauna in these habitats.

Mitigation Measures

- The lighting design must incorporate light levels that match usage, zone, time, and traffic.
- Lights should be shielded from the vegetation and the use of bare and upturned bulbs should be avoided.
- The minimum light intensity that can be used to ensure safety should be employed.

Once the mitigation measures listed above are effectively implemented, this impact is expected to be low intensity.

Cumulative Impact

There is no cumulative impact associated with artificial light.

6.2.3 Impacts of Brine Disposal During Operational Phase

At a distance of 232m (764 ft) apart, and less than 0.3m (1 ft) change in water level elevation at the Source Water Well (drawdown of 0.18m or 0.6 ft) and the Brine Disposal Well (recharge rise of 0.21m or 0.7 ft), it is not expected that the radius of influence of either well will extend to affect the other i.e., there should be no direct hydraulic mutual interference effect.

Neither is it likely that the brine disposed of in the brine disposal well will impact the water quality of the source water well given (a) the distance between the wells – 232m; (b) the injection of the brine at a depth of 31m (102 ft) below ground level (bgl), some 5.8m (19 ft) below the depth of the bottom of the source water well, (c) the density of the brine (i.e., 8.3 to 19 lbs/gal) is much higher than that of seawater (i.e., 4.7 lbs/gal), so the brine will sink when placed in the seawater in the well. It is useful to note that the source water well is likely to obtain most of its water from the conduit flow permeability encountered at a depth of 22.5m (73 ft) bgl (or -20.7m msl), whereas the movement of brine out of the brine disposal well is most likely to occur via the conduit flow permeability encountered at a depth of 37.2m (122 ft) bgl (-36.3m/-119 ft msl), increasing the depth separation to about 15.5m (51ft).

Impact on Nearby Wells

The nearest existing production well is the APUA Source Water Well located some 5.6km (3.5 miles) to the northwest of the Paradise Found wells. This well is too far away to envisage impact by the Paradise Found wells. The Palmetto Point wells are even farther away.

Impact on Fresh Groundwater

No impact on the fresh groundwater in the water table section of the Highlands limestone Aquifer is possible given its location far away, in the northeast of the island.

Impact on Marine Environment

The injection of brine via the Brine Disposal Well is designed to occur generally between a depth of 30-40.8m (099 - 134 ft) below msl (i.e., the open uncased section of the well). The brine can be expected to exit the well primarily via conduit flow permeability at -36.3m (-119 ft) msl, directly into the karstic Highlands Limestone Aquifer, well below the seafloor (i.e., not in open sea). In this underground cavern system, there is not expected to be any significant throughflow, such movement as occurs being driven primarily by tidal fluctuations. Therefore, the brine can be expected to develop into a plume, mix with the much larger volumes of the native seawater, while being slowly diluted to assimilation at its outer edges.

There is not expected to be any significant marine life within the Highland Limestone Aquifer that could be impacted negatively by the brine plume. Neither is the brine plume expected to enter open seawater and is therefore not expected to represent a threat to marine life in the coastal waters to the south and west of Barbuda.

6.3 Social and Cultural Environment

6.3.1 Methodology of the Social Impact Assessment

The social impact assessment (SIA) has a specific objective, which is to identify, analyse and assess the negative, positive, or neutral social impacts of a project. Such a process enables the management and monitoring of the direct and indirect impacts that affect the well-being of the people and their communities at all stages of the project's lifecycle.

To ascertain the extent of influence which the project may have on these factors, the methodology involves:

- The collection and analysis of a socio-economic baseline to establish existing characteristics of the directly affected community (DAC);
- An assessment of the potential positive and negative impacts that could result from implementation of the Project, and
- Propose measures to mitigate and monitor any potential negative impacts.

The SIA methodology has been completed in accordance with both national and international requirements.

The key aspects considered in detail in this SIA have been determined from the Terms of Reference and the outcome of the Baseline Conditions Report. As a result, the following issues are considered in this SIA:

- Impact on the demographics, social fabric, and social capital
- Impact on the health and well-being of children
- Impact on the elderly
- Impact on young women
- Impact on young men
- Impact on livelihoods
- Impact on cultural assets, norms, and practices

These have been examined during both the construction and operational phases of the project.

6.3.2 Identification of Impacts

The social impact assessment predicts and assesses the likely positive, negative, or neutral impacts of the project. Each impact is also subject to a gender assessment to make clear the differential impact on males and females. The assessment is based on the examination of scenarios with stakeholder consultation. Scenarios have been defined as "logical-imaginations based on construction of hypothetical futures" (UN Centre for Good Governance, 2006), regarding the assumptions about the SIA variables in question. Such consultations, which include local experts, local authorities, and knowledgeable citizens, allows local knowledge to play a part in determining the likely impacts. This allows the assessor to better rank the impacts in order of priority.

The significance determination, or the magnitude criteria for Socio-Economic Impact Assessment is then based upon social norms or values, professional judgement, and is dependent on the social factors under consideration. An impact significance assessment is an analysis of the extent to which potentially impacted communities and stakeholders may be affected, whether positively or negatively. Considerations are to be given to the probability, duration, scale, and intensity of the impact, as well as the characteristics of the community or stakeholders which may be affected. Where a potential impact is found to be significant, a residual significance assessment (extent of impact after management measures have been applied) is also undertaken (Queensland Government, 2018).

There are two orders of impacts to be considered, direct and indirect impacts. Direct impacts arise out of the effect of a social factor, while an indirect impact is a consequence of a direct impact.

The generic criteria for the definition of magnitude of impacts is summarised in the section following.

6.3.3 Impact Magnitude Criteria

The social assessment of impact magnitude is undertaken by first categorising identified impacts of the project as 'beneficial' or 'adverse'. Then impacts are categorised as 'major', 'moderate', 'minor' or 'negligible' based on consideration of parameters such as:

- **Duration** of the impact – ranging from beyond the life of the project to very short lived.

- **Spatial extent** of the impact – for instance, within the site boundary, within the region or nationally.
- **Social spread of the impact** – ranging from among a few workers or community persons to a broad cross section of the population/ local benefit sharing.
- **Reversibility** – ranging from 'permanent thus requiring significant intervention to return to baseline' to 'no change'.
- **Likelihood** – ranging from highly likely to potentially.

Table 6-1 presents generic criteria for determining impact magnitude (for adverse impacts). Each detailed assessment will define impact magnitude in relation to its environmental or social aspect.

Table 6-1 Criteria for determining social and gender impacts

Magnitude (beneficial or adverse)	Definition (considers likelihood, duration, number of people affected, spatial extent and local benefit sharing)
Major Adverse	A highly likely impact that would have implications beyond the Project's life. It would negatively affect the wellbeing of many people across a broad cross-section of the population. The affects would be felt across various segments of the local communities, or workers and increase their susceptibility to the negative effects of climate change.
Moderate	A likely impact that continues throughout the Project's life. It would affect the wellbeing of specific groups of people and specific segments of the local communities, or workers and increase their susceptibility to the negative effects of climate change.
Minor	A potential impact that occurs periodically or over the short term throughout the life of the Project. It would affect the wellbeing of a small number of people with little effect on the local communities, or workers. There would be little change to the susceptibility to the negative effects of climate change by those affected.
Negligible	A potential impact that is very short lived so that the socio-economic baseline remains relatively unchanged and there is no detectable effect on the wellbeing of people or the local communities or workers, or on their resilience to the negative effects of climate change.
Beneficial	A highly likely impact that would have potential benefits during and beyond the life of the project to the wellbeing of a section of the population and affecting various segments of the local community or workers. It should build resilience to the negative effects of climate change.
Highly Beneficial	A highly likely impact that would have potential benefits during and beyond the life of the project. It would affect positively the wellbeing of many people across a broad cross section of the population. It would affect positively various segments of the local community or workers and strengthen their resilience to the ill effects of climate change.

Source: Dominica Geothermal Development – Environmental and Social Impact Assessment. NZ Ministry of Foreign Affairs and Trade.

The duration of the impact has also been considered as this will play a key role in how the impact affects the community on a social level. The impacts were considered to either be short-term, medium- or long-term impacts, as defined by Table 6-2.

Table 6-2 Definition of duration of impacts

Duration of Impact	Definition
Short	Impacts restricted to the duration of the construction phase of the works
Medium	Impacts expected to terminate, or become negligible, within six months of the construction completion date
Long	Impacts expected to remain significant for a period greater than six months after the construction completion date.

The level of significance is then determined using the matrix presented in Table 6-3. The sensitivity of potential receptors is assumed to be of medium sensitivity for all social impacts. If the impact is negative then the effect is adverse, if the impact is positive then the effect is beneficial.

Table 6-3 Levels of significance

Magnitude of Impact	Sensitivity of Receptors			
	Negligible	**Low**	**Medium**	**High**
Negligible	Insignificant	Insignificant	Insignificant	Insignificant
Minor	Insignificant	Insignificant	Minor	Minor
Moderate	Insignificant	Minor	Moderate	Moderate
Major	Insignificant	Minor	Moderate	Major

6.3.4 Mitigation

Mitigation measures are actions that if taken can lessen or limit the adverse social impacts of an event. The mitigation hierarchy suggests that measures should involve avoidance, reduction, repair, in kind compensation and/or compensation by any other means. Mitigation measures have been identified and will be implemented to reduce significance impacts to an acceptable level.

6.3.5 Monitoring

Monitoring allows for the measuring of the effectiveness of mitigation measures. Monitoring and follow-up actions should be completed to:

- Continue the collection of data throughout the construction and operation phases.
- Evaluate the success of mitigation measures, or compliance with project standards or requirements.
- Assess whether there are impacts occurring that were not previously predicted.
- Where it is appropriate, involve local communities in monitoring efforts through participatory monitoring. In all cases, the collection of monitoring data and the dissemination of monitoring results should be transparent and made available to interested project stakeholders.

6.3.6 Residual and Cumulative Impacts

Those impacts that remain once the measures to address mitigation have been put in place are described as residual impacts. Those that occur as a combination of multiple impacts are considered cumulative impacts.

Both residual and cumulative impacts are to be assessed as part of the SIA.

6.3.7 Assessment Details – Introduction

There are potential positive and negative social impacts related to both the construction activities and the future operation/use of the new development.

A significant number of the potential negative impacts relate to construction works. As such, it is important to understand these before construction and to manage those construction activities to reduce or mitigate any negative impacts on the community. Upon completion, the project is expected to have both potential positive and negative impacts on the community. Interventions are to be considered to mitigate the negative impacts and to support or amplify the beneficial impacts.

The social impacts have been categorised under five headings: Socio Demographic; Employment; Livelihoods; Health and Well-being; and Cultural Heritage and access to cultural assets. The impacts are presented in two areas – construction impacts and operational impacts.

The impacts are felt both in Codrington but also in the island of Barbuda as a whole, particularly with regard to cultural heritage assets, norms, and cultural practices.

Construction Phase

6.3.8 Socio-Demographic

There is concern of impacts to the general population of the Barbudan Community, which is a delicate, micro community consisting of just under 2,000 persons. There is concern that during the construction phase, with many new workers seeking opportunities on the island, the population will expand. This may, however, be for a short period. Issues of changing personal safety, cultural practices and disruption of the norms and practices, resulting in a reduced quality of life usually enjoyed by the residents of Codrington, is of concern as new **short-term** workers arrive. This impact is considered to be potentially **adverse**.

6.3.9 Employment

The development of the Paradise Found Resort is expected to increase employment opportunities for young men from Codrington. The probability of this impact occurring is high and will occur in the **short term** and is not expected to last after the construction phase has been completed. It is expected to have **a beneficial impact,** which is expected to be of a medium **significance** as it's not anticipated to go beyond the construction phase of the project. There is little expectation that young men will receive long term jobs at the Resort.

6.3.10 Livelihoods

The construction phase is expected to have a beneficial impact on the livelihoods of some groups and an adverse effect on the livelihoods of others. Women who prepare food for tourists and workers have the potential to experience a **beneficial effect** during the construction phase as a brisk trade in their services should take place. The impact on the fishing and lobster trade is expected to be **negligible** during the construction period, as there may only be minor impact on the lagoon or coastal areas. The impact on tour guides and boat and tour operators who provide tour services to 'day trippers' who disembark from cruise ships and stay over tourists from Antigua is expected to be of **minimal** effect. There is also the impact on those who engage in salt mining who may be excluded from those areas during the construction phase. This group may suffer an **adverse impact**.

6.3.11 Health and Well-Being

A potential **adverse** effect on the health and well-being of children from the town of Codrington is expected during the construction phase. There is an increase in dust from the trucks working on the construction site and moving through the town of Codrington, leaving clouds of dust everywhere. The impact is **significant** and although the cause may cease at the end of the construction (that is the movement of trucks through the town during the construction phase), the impact **may have long term** consequences on the respiratory condition of the children.

There is the potential for an **adverse impact** on the elderly because of noise and air pollution during the construction phase. Trucks traverse the town roads, drivers can be seen undertaking servicing of their vehicles on the roadside, leaving oil and diesel residue. Trucks move at a very high speed through the town where the elderly walk to carry out their routine leisure and business activities. Sidewalks are nearly non-existent in Codrington.

6.3.12 Cultural Heritage Assets, Norms and Practices

There is the potential **adverse impact** to the population and their special relationship to the island involving their norms and cultural practices and the cultural assets which they share. The probability of this occurring is medium to high due to the possibility of exclusion from salt mining ponds, traditional camping sites, traditional fishing, and farming sites, etc., during the construction phase.

Table 6-4 following presents the impact assessment summary during the construction phase of the project.

Table 6-4 Impacts during construction phase

Theme	Area Impact	Impact	Probability of this Impact to occur	Type (Beneficial or Adverse)	Intensity	Magnitude	Impact Significance	Direct/Indirect	Duration (Short, Medium or Long Term)	Avoidable?	Reversible?
Employment	Codrington Village	Increase in employment opportunities for young men	High	Beneficial	High	Medium	Medium	Direct	Short to Medium		
Impact on Livelihoods	Island of barbuda	Impact on Tour Guides;	Medium	Adverse	High	Moderate	Moderate	Indirect	Short	No	Yes
	Codrington Village	Impact on women who cook for touists and workmen	Medium	Adverse	High	Moderate	Moderate	Indirect	Short	No	Yes
	Island of barbuda	Impact on boat and tour operators	Medium	Adverse	High	Moderate	Moderate	Indirect	Short	No	Yes
	Island of barbuda	Impact on fishing and lobster trade	Low	Negligible	low	low	low	direct	short		
Impact on Health and Well being of Children	Codrington Village	Increase in air and noise pollution from construction plant and transport	High	Adverse	High	High	High	Direct	Short		Yes
Impact on the elderly	Codrington Village	Increase in air and noise pollution from construction plant and transport	High	Adverse	High	High	High	Direct	Short		Yes
Impact on young women	Codrington Village	Potential to develop behaviours that reduce chance to fulfil true potential	High	Adverse	High	High		Direct/Indirect	Short/Long term	Yes	
Impact on Cultural Heritage assets, norms and practices	Island of Barbuda	Disruption of villagers way of life (fishing, salt mining, camping, hunting)	High	Adverse	Medium	Moderate	Moderate	Indirect	Short	Yes	Yes
Impact on Socio Demographic	Island of Barbuda	Potential for increase in the population from residents at the Resort	High	Adverse	Medium	Moderate	Moderate	Direct	Short	No	Yes

Operational Phase

6.3.13 Socio-Demographic

During the operational phase of the project, there is expected to be a population increase of possibly a longer duration, from those who purchase homes or are involved in long term rentals. The residents of Codrington are not clear what that population increase will look like, and they are concerned about what new practices will come for which they are not prepared. They perceive the impact to be **adverse** as they do not wish to be viewed or treated as second class citizens in their own homeland.

6.3.14 Employment

Only a small proportion of Barbudan male youth are unemployed. During the operational phase of the Resort, there is the potential for an **adverse impact** on employment if young Barbudans are put to work at purely elementary levels of work on the resort.

6.3.15 Livelihoods

There is the potential for **adverse impact** on livelihoods in Barbuda for a number of reasons: (a) if the Lagoon suffers from pollution or careless management of waste disposal. The impact on the Lobster trade would be significant; (b) if the tour boat operators are not allowed to continue their trade in preference to resort operators; (c) if local tour guides are unable to ply their trade over foreign tour guides; (d) if resorts become exclusive areas and tourists do not come to receive the services of women who cook in Codrington.

6.3.16 Health and Well Being

Tourism has the potential to involve young girls in behaviours that reduce their chances at fulfilling their true potential. There is a chance that young girls may be tempted to participate in the less positive aspects of the tourism sector, resulting in an **adverse impact** on the young women of Codrington.

6.3.17 Cultural Heritage, Assets, Norms and Practices

The development has the potential to exclude Barbudans from the cultural assets found in their environment to which they have enjoyed the use traditionally. Should the residents find themselves excluded from ponds, fishing grounds, and salt ponds, camp sites and improper waste disposal technologies result in the destruction of the lagoon which supports the lobster trade, the impact would be **adverse** and have long term implications. The significance level would be high, and information suggests that such action would **not be easily reversible**.

Table 6-5 presents the potential impact during the operational phase of the project.

Table 6-5 Operational impacts

Theme	Area Impact	Impact	Probability of this Impact to occur	Type (Beneficial or Adverse)	Sensitivity	Magnitude	Impact Significance	Direct/Indirect	Duration (Short, Medium or Long Term)	Avoidable?	Reversible?
Employment	Resort	Small number of persons may be hired at the elementary level to work at the Resort; no evidence of consideration of local technical staff	High	Adverse	High	high	high	Direct/indire	Medium	Yes	Yes
Impact on Livelihoods	Island barbuda	Impact on Tour Guides;	High	Adverse	High	high	high	Indirect	Long term	Yes	Yes
	Codrington Village	Impact on women who cook for touists	Medium	Adverse	Medium	Medium	Medium	Indirect	Long term	Yes	Yes
	Codrington Village	Impact on boat and tour operators	High	Adverse	High	high	high	Indirect	Long term	Yes	Yes
	Island of Barbuda	Impact on fishing and lobster trade	High	Adverse	High	high	high	Indirect	Long term	Yes	no
Impact on young women	Codrington Village	Tourists culture may seek to involve young girls in inappropriate behaviour that dampens personal development	Medium	Adverse	High	Medium	Medium	indrect	Long term	yes	yes
Impact on Cultural Heritage assets, norms and practices	Island of Barbuda	Exclusion from cultural assests; camp sites; ponds, fishing sites;damage to lobster breed grounds - the lagoon	high	adverse	High	high	high	direct/indirect	Long term	yes	no
Socio Demographic	Codrington village	Influx of new persons into the village for work or on the island as residents on the resort may change the culture of the population	Medium	Adverse	Medium	High	High	Indirect	Long Term	Yes	No

6.3.18 Mitigation Measures and Monitoring

Table 6-6 presents the mitigation measures recommended to address the potential impacts both for the construction and operational phases of the project. Many of the mitigation measures required during the construction phase of operation can be undertaken by simple setting of policy guidelines and ensuring regulations are adhered to. These can be supported by the Ministry of the Environment and the Barbuda Council. Other measures require information sharing with the Directly Affected Communities (DAC) so as to reduce the spread of misinformation and increase understanding regarding the actual work of the project. These should emanate from the project proponents and be disseminated with the support of the Barbuda Council. Measures that address training should be undertaken in conjunction with the Ministries of Labour and Education (and where women are the special target group, the Department of Gender Affairs) by the project proponents.

With regard to monitoring, it is important to measure all likely impacts and any issues that may be of concern to the various stakeholders and the DAC over time. This is done through the monitoring process.

Based on the data provided in the baseline conditions report, appropriate indicators can be selected that will allow the potential impacts to be tracked and monitored, such as the number of young men trained and employed on the job site.

In addition to the tracking of the implementation of the mitigation measures, the concerns of the various vulnerable groups such as the children, the elderly and young women should be monitored.

Having a mechanism to monitor for the unexpected is also needed. By regular monitoring of the effectiveness of the proposed mitigation measures, corrective action can be taken if necessary. Also, where any unanticipated issues arise, they can be addressed quickly.

Indicators also need to be considered to measure potential cumulative impacts.

The Project proponent, the Ministry of the Environment, Ministry of labour, the Department of Gender Affairs and the Barbuda Council all have their part to play in the monitoring activities.

Table 6-6 Proposed mitigation measures

Theme	Area Impact	Impact on Construction phase	Mitigation interventions	Impact during operation	Mitigation interventions
Employment	Codrington Village	Increase in employment opportunities for young men	Ensure that job oportunities are advertised where young men can be reached: recreation centres and sporting grounds; eating places and pubs; Develop a programme of on-the-job training that offers practical skills training and work with certification as an end product.	Small number of persons may be hired at the elementary level to work at the Resort; no evidence of consideration of local technical staff	Offer upskilling and retraining programmes including apprenticeship programmes with possibility for certification a the end of the planned programme.
Impact on Livelihoods	Island of Barbuda	Impact on Tour Guides;	Develop a policy that ensures local tour guides are used unless local guides are unavailable	Impact on Tour Guides;	Enusre that local tour guides receive a fair trading opportunity at services to be provided
	Codrington Village	Impact on women who cook for touists and workmen	n/a	Impact on women who cook for touists	Ensure that tourists have the option and are offerred the opportunity to vist the villages and participated in the loal food
	Island of Barbuda	Impact on boat and tour operators	Develop a policy that ensures local tour guides are used unless local guides are unavailable	Impact on boat and tour operators	Enusre that local boat operators and tour guides receive a fair trading opportunity at services to be provided
	Island of barbuda	Impact on fishing and lobster trade	n/a	Impact on fishing and lobster trade	Safeguard the Lagoon
Impact on Health and Well being of Children	Codrington Village	Increase in air and noise pollution from construction plant and transport	Regulate truck use &/or wet roads of transit; this reduces dust affecting the elderly; assign an area for parking outside of town where service operations can take place.	Neutral impact expected	none required
Impact on the elderly	Codrington Village	Increase in air and noise pollution from construction plant and transport	Regulate truck use &/or wet roads of transit; this reduces dust affecting the elderly; assign an area for parking outside of town where service operations can take place.	Neutral impact expected	none required
Impact on young women	Codrington Village	Potential to develop behaviours that reduce chance to fulfil true potential	Increase job training opporotunities for young women theus reducing their susceptibility to the groom prospects of male workers. Provide sexual harrassment in the workplace traing for young male construction and transport workers on site.	Tourists culture may seek to involve young girls in inappropriate behaviour that dampens personal development	Ensure opportunities exist on island for furthering education and skills development for young women
Impact on Cultural Heritage assets, norms and practices	Island of Barbuda	Disruption of villagers way of life (fishing, salt mining, camping, hunting)	Share information explaining the short term nature of the disruptions and work through methods with the DAC as to how to limit and mitigate the disruptions during the construction period	Exclusion from cultural assests; camp sites; ponds, fishing sites;damage to lobster breed grounds - the lagoon	Share information widely on the development proposals with the DAC ; allow locals to share views; arrive at concensus
Impact on Socio Demographic	Island of Barbuda	Potential for increase in the population from residents at the Resort		Influx of new persons into the village for work or on the island as residents on the resort may change the culture of the population	Encourage orientation sessions for resort owners to learn something of the history and culture of the island

7 Comparison of Alternatives

Figure 7.1 shows the current plans, which are less dense than originally planned (see Table 2-1 above for a listing of project elements originally, versus presently).

Based on this revised, reduced density layout the following improvements have been achieved:

- Reduced demand on the water supply
- Better control of dust on site
- Reduced dust/impacts on roads because of the need for fewer trucks
- Improvements to the ponds including increased mangrove habitat
- Improved drainage and reduced potential for flooding
- Less construction activity overall

In light of the Memorandum of Agreement between Paradise Found LLC and the Government of Antigua and Barbuda dated 28 November 2014, the "No Action Alternative" which is normally addressed under the Comparison of Alternatives is not considered applicable on this project.

Figure 7.1 Revised Master Plan (2022)

8 Management Plans

Two management plans have been prepared to guide the implementation of this project: a Mangrove Protection and Management Plan and a Disaster Management Plan. These documents were prepared by Ecoengineering Consultants Limited as Health, Safety and Environment (HSE) Subconsultant to Smith Warner International on this assignment.

8.1 Mangrove Protection and Management Plan

As discussed in section 6.2, clearing of trees for the development will be a permanent and unavoidable impact of this development. A detailed *Mangrove Protection and Management Plan* has therefore been prepared and is attached as Appendix C.

8.2 Disaster Management Plan

The Disaster Management Plan, attached as Appendix E, identifies credible risk scenarios associated with the construction and operation of the development, and sets out procedures for responding to those risks.

The Plan consists of five chapters and an appendix. The document defines an emergency and indicates levels of emergency, describes the proposed Paradise Found Development, addresses emergency preparedness, sets out steps to be taken when managing a risk incident, and presents emergency response procedures for each of the credible risk incidents.

Appendix A Hydrogeology Reports

PROJECT OF THE PARADISE FOUND DEVELOPMENT, BARBUDA
ENVIRONMENTAL IMPACT ASSESSMENT

Report on
SOURCE & BRINE DISPOSAL WELLS
(PARADISE FOUND DESALINATION PLANT)

2023 April

prepared by

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Project File #225

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1 INTRODUCTION

1.1 Background

The Paradise Found Development is a major tourism development proposed for the island of Barbuda. The Antigua and Barbuda Department of the Environment (A&B-DoE) requires the preparation of an Environmental Impact Assessment (EIA) of the project, as part of the planning approval process. **SMITH WARNER INTERNATIONAL Limited (SWIL)** has been contracted by the developers to undertake the EIA. SWIL has in turn retained the services of **Hydrology Consultants Limited (HydroConsult)** to provide the hydrogeological services needed to implement the water resources component of the EIA.

The Paradise Found Development proposes to obtain the freshwater needed for construction (and subsequent operation of the development facility) by desalination/reverse osmosis. SWIL was required, inter alia, to consider and evaluate a suitable source water for the desalination plant, and an appropriate brine disposal facility, both with minimum negative environmental impacts. This aspect of the assignment was entrusted to HydroConsult.

HydroConsult carried out a Reconnaissance Water Resources Study of Barbuda in Jul/Aug 2022 the results of which were presented in a report[1] that defined the baseline hydrogeological conditions on the island, particularly as it affected the proposed Paradise Found Development. The Report recommended that the source water be obtained from and the brine effluent be disposed of, via tube wells in a karstic limestone aquifer underlying the Paradise Found property at acceptable depth, and that exploratory wells be established to demonstrate viability and minimum environmental impact.

These recommendations were accepted by Paradise Found and they entered into a well contract with Walker Wells Limited (Walkerwells) to establish the wells. Walkerwells had been successfully constructing such well for a number of years in Barbuda, under similar hydrogeological conditions as obtained at the Paradise Found property. A source well and a brine disposal well were proved by WalkerWells on Paradise Found property in Mar/Apr 2023. HydroConsult monitored the well construction and directed yield testing of the wells.

This report describes the construction and yield testing of the source water and brine disposal wells, evaluate their suitability for purpose, and describe their minimum impact on the water resources (including marine) environment of Barbuda in general, and the Paradise Found property (and its environs) in particular.

1.2 Objectives & Scope

This second (and final) phase of the water resources component of the assignment had as its primary objectives (a) the proving of a source water well with a capacity of 375 USgpm to support the production of 150 USgpm of freshwater from a desalination plant; (b) the establishment of a disposal well that allowed the injection of 225 USgpm of brine effluent from the desalination plant, and (c) determination of the impact of the operation of these wells on the water resources (including marine) environment within the Paradise Found property and its environs.

[1] **HYDROLOGY CONSULTANTS LIMITED (2022):** Report on the Baseline Hydrogeological Conditions, Barbuda. Unpublished report of the Paradise Found Development dated 2022 August.

Secondarily, the drilling of the wells was necessary to confirm the hydro-stratigraphic sequence underlying the Paradise Found property to better understand the hydraulic relationships between the hydro-stratigraphic units encountered, and to evaluate the movement of groundwater into the source water well and brine out of the disposal well, as well as the likely impact on the subsurface terrestrial and marine environments.

1.3 Approach & Methodology

A zoom meeting on Mar 2023 involving Paradise Found, SWIL, HydroConsult and Walkerwell agreed, inter alia, the period of the construction and yield testing of the wells - Mar to Apr, and availability of HydroConsult to monitor the drilling operations and obtain the hydrogeological data that was required. The construction and yield testing of the source water and the brine disposal wells took place between 20 Mar and 07 April, and was monitored by HydroConsult.

1.3.1 Well Construction

The respective sites of the Source Water/Production Well and the Brine Disposal Well were identified in the field for the Well Contractor by Paradise Found. Their locations are given in **Figure 1-1**, below.

Figure 1-1: **LOCATION OF SOURCE WATER & DISPOSAL WELLS, PARADISE FOUND, BARBUDA**

The wells were constructed using a Rotary Drill Rig (normal circulation). The 10 in ID x 83 ft deep - Source Water Well took 9-days to construct and yield test, and the 8/6 in ID x 137 ft deep - Brine Disposal Well was completed in 10-days. The use of drilling mud prevented the monitoring of the water level in the wells during construction. Circulation drilling samples were collected at 5 ft intervals and provided to HydroConsult for lithologic logging. HydroConsult monitored well construction and prepared lithologic logs of the formation samples collected by the Well Contractor.

1.3.2 Yield Development & Testing

On completion of the construction of each well, the respective drill holes were cleaned of drilling mud and their yield developed (i.e., drilling mud and/or drill cuttings removed from the limestone formation) by air-lift pumping, until their well discharges were clear.

The Yield Testing (i.e., Constant Rate Tests) were carried out using a submersible pump with pump suction placed at 20 ft bgl. in both wells. The test rates were 286 USgpm for the Source Water Well and 315 USgpm for the Brine Disposal Well - the upper limits of the pump capacity. The duration of each Test was 6-hours. The rates of pump discharge were monitored using a water meter installed within the discharge line. The test discharges were disposed of in nearby surface ponds.

Depth to water level in the respective wells was measured using a Graduated Electric Dip Probe. Ground Surface elevations at the head of each well were provided by SWIL. They also provided sea-level tidal fluctuations for Barbuda for the duration of the yield testing.

HydroConsult observed the Yield Development pumping, designed the Yield Tests in consultation with the Well Contractor, monitored/recorded well discharge rates, and non-pumping and pumping well water levels.

1.3.3 Water Quality Monitoring

The Electrical Conductivity and Temperature of the various groundwaters in wells and the test discharge from the Source Water and Brine Disposal wells were monitored in the field by HydroConsult, using a Solinst TLC Meter (Model 107MK3). Unfortunately, the Meter malfunction prior to the completion of the Brine Disposal Well.

1.3.4 Reporting

On return to Jamaica, HydroConsult completed the necessary hydrogeological analysis/interpretation and prepared this project report. There were regular consultations with SWIL during the field work in Barbuda and the hydrogeological analysis/interpretation in Jamaica.

1.4 Acknowledgements

The assistance and/or cooperation of the staff of the following institutions, in the implementation of this phase of the assignment, are hereby gratefully acknowledged:-

Walker Wells Limited
Paradise Found Development
Smith Warner International Limited

2. RESULTS OF BASELINE HYDROGEOLOGICAL INVESTIGATION

The Phase I hydrogeological investigations had concluded as follows: -

(i) The hydro-stratigraphic units of Barbuda, their stratigraphic sequence, subsurface relationships, and hydraulic character described by previous investigators, were examined in the field, and found to be generally accurate. However, wells recently drilled through the Palmetto Sand Aquifer in the Palmetto Point headland in the south west end of Barbuda, indicated that the Central Plains Limestone Aquiclude was absent, requiring a re-interpretation of the stratigraphic sequence in that area, and the depositional history of Barbuda.

(ii) Field determinations of Specific Conductance (i.e., Electrical Conductivity) allowed characterisation of the water quality in the water table sections of the Highland Limestone Aquifer, Central Plains Limestone Aquiclude and the Palmetto Sand Aquifer. The fresh groundwater in the Palmetto Sand Aquifer reported by previous investigators up to 1992, no longer existed, but was now moderately saline, believed to result from the extensive mining of the sand and the exposure of the water table to direct evaporation.

(iii) Brine disposal options employed on Barbuda included beach disposal and well injection, the latter being the preferred option, given its potential for minimum environmental impact.

(iv) The proposed disposal of the brine into the Highland Limestone Aquifer at Paradise Found - at a depth of 100 ft bmsl and confined by the physical barrier formed by the low permeability overlying Central Plains Limestone Aquiclude, has the potential to isolate the brine-plume to complete dilution/dissipation, with no impact on marine life. In the absence of the Central Plains Limestone Aquiclude, the dilution/dissipation would begin within the Highland Limestone Aquifer and be completed in the open seawater, at depths in excess of 100 ft bmsl.

(v) It was proposed that an exploratory brine disposal well be established at Paradise Found, to obtain hydrogeological information needed to better understand the subsurface conditions that control brine disposal, and to demonstrate that disposal wells can be successfully developed at Paradise Found.

Of particular note was the uncertainty concerning the presence (or absence) of the Central Plains Limestone Aquiclude in-between the surface Palmetto Sands and the underlying Highlands Limestone, in the Paradise Found area. The proposed drilling of the exploratory brine disposal well was expected to resolve this uncertainty, in addition to evaluating the feasibility of brine disposal into the Highlands Limestone Aquifer.

If present, the Central Plains Limestone Aquiclude would form a subsurface hydraulic barrier, preventing the subsurface movement of seawater (and/or brine) from the underlying Highlands Limestone Aquifer into the overlying surface Palmetto Sands Aquifer.

However, if absent - as occurs to the north-east in the Palmetto Point headlands, the lower salinity (EC- 10,000 µS/cm) groundwater in the Palmetto Sand Aquifer, would be in direct hydraulic continuity with the underlying high salinity (EC-23000 to 54,000 µS/cm) Highlands Limestone Aquifer. In this event, particular care would need to be exercised to ensure the disposal of the brine at depths in the Highland Limestone Aquifer, well below the geological contact between the Palmetto Sands and the Highland Limestone, to minimise potential negative impact on the groundwater in the Palmetto Sand Aquifer.

3. SOURCE WATER WELL

3.1 Hydro-stratigraphic Sequence – Source Water Well

The Lithologic Log of the formation samples collected by the Well Contractor from the Source Water Well is set out in **Figure 3-1**, below.

Figure 3-1: **LITHOLOGIC LOG – SOURCE WATER WELL**

Site Location:	Paradise Found Production Well
Coordinates:	17° 33' 56.5" N; 61° 46' 16.2" W
Drilling Method:	Rotary - Normal Circulation
Sampling Method:	Circulation
Sampling Frequency:	5 ft intervals

Depth (ft)	Thickness (ft)	Lithologic Description	Formation
0 to 32	32	SAND - beige coloured, calcareous, sub-rounded, fine to medium grained, with major coral fragments and minor shell fractions.	PALMETTO SANDS
32 to 35	3	CLAY - brown, stiff	BASAL CLAY
35 to 62	27	LIMESTONE - beige coloured, dense, coral limestone, with no evidence of permeability	HIGHLAND LIMESTONE
62 to 73	13	LIMESTONE - beige/grey coloured, dense, limestone	
73 to 83		Loss of drilling fluid circulation, no samples recovered	

The following observations are worthy of note: -

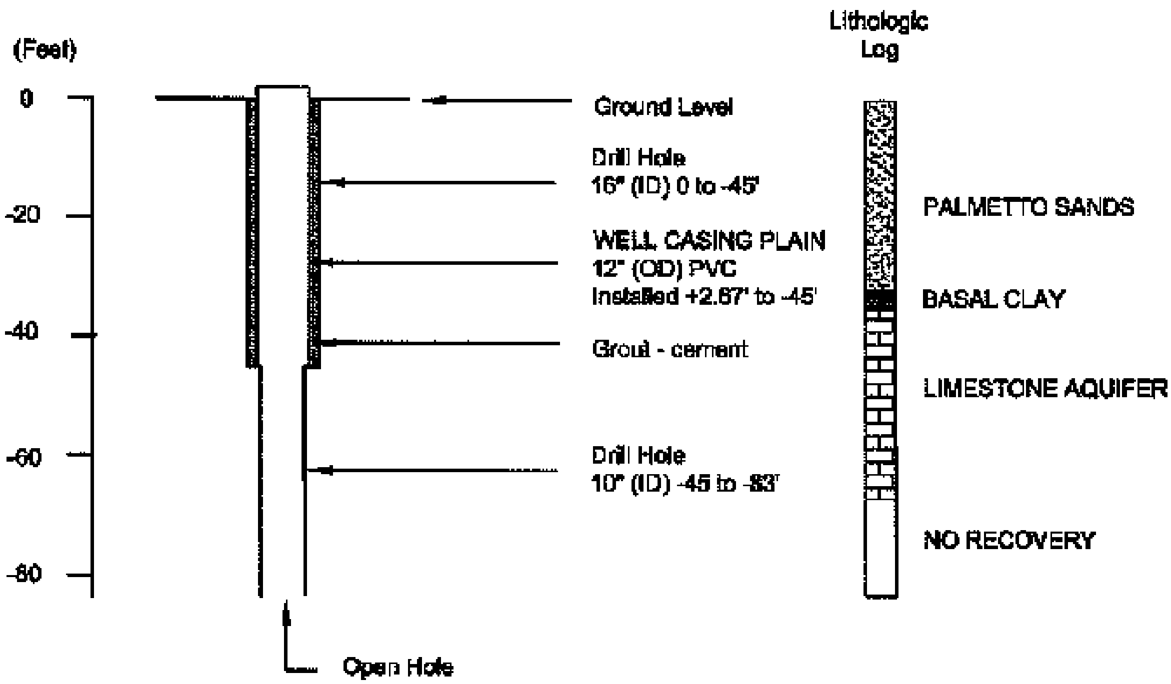
(i) The Basal Clay appears to be a localised feature, as it was not encountered in the Brine Disposal Well, Some 1,000 ft to the north, and

(ii) The loss of circulation at a depth of 73 ft bgl, indicated the interception of significant conduit flow permeability, typical of a cavern in karstic limestone.

3.2 As-built Design – Source Water Well

The main elements of the As-built Design of the Source Water Well for the Paradise Found Development is given as **Figure 3-2**, below.

Figure 3-2: **SCHEMATIC AS-BUILT DESIGN – SOURCE WATER WELL**



Not Drawn To Scale

The following observations are worthy of note: -

(i) The annular space between the wall of the 16" ID Drill Hole and the 12" OD PVC Casing was grouted with cement down to a depth of 45 ft bgl, some 13 ft below the bottom of the Palmetto Sands Formation, to prevent the seepage of sand into the underlying Highlands Limestone Formation, and

(ii) The presence of the 3 ft thickness of Clay at the base of the Palmetto Sand Formation, although believed to be localised, can be expected to form an additional seal against the movement of sand into the Highland limestone Formation.

(iii) The bottom 38 ft of the 10" ID Drill Hole (i.e., 45 to 83 ft bgl) was left uncased/open, to allow for maximum hydraulic connectivity between the well and the aquifer.

3.3 Source Water Well Productivity

Evaluation of the yield productivity of the Source Water Well was based on the results of a Constant Rate Test. This Test involved the pumping of the well at a continuous constant rate of 286 USgpm, for a period of 6-hours, after measuring its initial non-pumping water level and monitoring the pumping water level at regular intervals. On the cessation of pumping, the recovery of the water level was monitored for 1-hour. A summary of the Constant Rate Test results is included in **Table 3-1**, below.

Table 3-1: **SUMMARY RESULTS – CONSTANT RATE TEST**

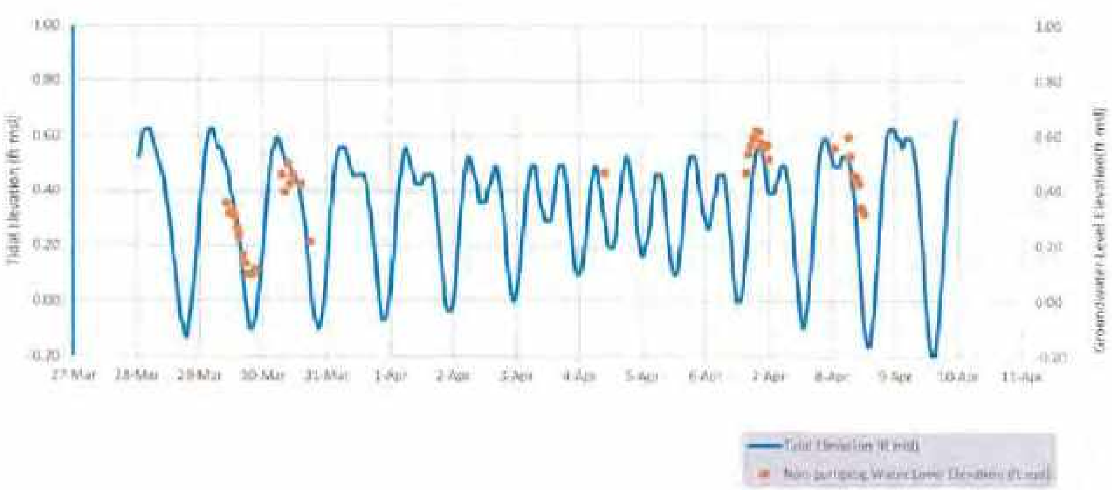
Hour	Elapse Time (min)	Depth to Water (ft)	Water Level Elevation (ft msl)	Drawdown (Recovery) (ft)	Tide Elevation (ft msl)	Change in Tide Elevation (ft msl)	Discharge Rate (Usgpm)	Remarks
1009		7.58	0.42				0	Non-pumping Water Level
1013	0	7.58	0.42	0.00	0.38		0	Started pumping
1613	360	8.51	-0.51	0.93	-0.09	0.47	286	Stopped pumping
1713	420	8.00	0.00	-0.51	0.00	0.09	0	

1 - Reference Point for water level measurements 3.33 ft agl (top of Stilling Tube)
2 - Ground Level Elevation: 4.67 ft amsl

The following observations are worthy of note: -

(i) The non-pumping water level in the Source Water Well fluctuated in sync with Tidal fluctuations, indicating that the Highland Limestone Aquifer is in direct hydraulic continuity with the Sea. This is illustrated in **Figure 3-3**, below.

Figure 3-3: **TIDAL & WELL WATER LEVEL FLUCTUATIONS**



(ii) However, the Tidal fluctuations complicate the well water level response under pumping conditions. Pumping during a period of declining Tide causes an increase in drawdown in excess of that which would have occurred if there was no tidal influence, as occurred during the Constant Rate Test of the Source Water Well on 28 Mar. As listed in **Table 3-1**, above, the Drawdown (i.e., the difference between the non-pumping water level just prior to the start of pumping and the pumping water level at the cessation of pumping) was 0.93 ft, and the Change in the Elevation of the Tide for the same time period was 0.47 ft, indicating that the actual Drawdown was 0.46 ft i.e., 0.93 less 0.47.

(iii) The Specific Capacity (or yield) of the Source Water Well was determined to be 622 USgpm/ft i.e., discharge of 286 USgpm/drawdown of 0.46 ft. At the design discharge of 375 USgpm the associated Drawdown can be expected to be about 0.7 ft.

(iv) This relatively high well yield for the Source Water Well no doubt reflects the interception of conduit flow permeability at a depth of 73 ft bgl, indicated by the loss of drilling circulation at that depth.

3.4 Salinity Profile – Source Water Well

The Salinity Profile of the Source Water Well was determined from a Depth Conductivity Traverse conducted after the yield development pumping but before the Constant Rate Test. The results are given in **Table 3-2**, below.

Table 3-2: **SALINITY PROFILE – SOURCE WATER WELL**

Depth below Measurement Point (ft)	Elevation at Depth (ft msl)	Electrical Conductivity (μS/cm)	Temperature (°C)	Hydro-stratigraphic Unit
7.4	0.44	23,400	30.0	PALMETTO SAND AQUIFER
10.0	-2.16	43,900	30.8	
15.0	-7.16	44,400	30.9	
20.0	-12.16	44,900	31.3	
25.0	-17.16	46,000	31.4	
30.0	-22.16	46,100	31.4	
35.0	-27.16	46,100	31.4	
40.0	-32.16	46,800	31.4	HIGHLAND LIMESTONE AQUIFER
45.0	-37.16	51,400	30.2	
50.0	-42.16	52,500	29.4	
55.0	-47.16	53,300	29.1	
60.0	-52.16	53,400	28.8	
65.0	-57.16	53,900	28.7	
70.0	-62.16	53,900	28.7	
75.0	-67.16	54,200	28.5	
80.0	-72.16	54,100	28.5	

Elevation of Measurement Point	:	7.84 ft msl
Measurement Point	:	3.17 ft agl
Ground Surface Elevation	:	4.67 ft amsl

The following observations are worthy of note: -

(i) Very saline groundwater occupied the entire water column in the well, indicating that the lower salinity groundwater of the Palmetto Sands Aquifer had been successfully excluded by the Cement Grout used to fill the annular space between the well casing and the Drill Hole, down to a depth of 45 ft bgl. The Phase 1 Investigations had determined the background salinity in the Palmetto Sand Aquifer to have Electrical Conductivity of 10,000 to 12,000 µS/cm.

(ii) Given that the Electrical Conductivity of Seawater is about 50,000 µS/cm, Seawater was encountered in the Source water Well at a depth elevation of -45 ft msl. In this event, water production from this well can be expected to conform to seawater quality.

4. BRINE DISPOSAL WELL

4.1 Hydro-stratigraphic Sequence – Brine Disposal Well

The Lithologic Log of the formation samples collected by the Well Contractor from the Brine Disposal Well is set out in **Figure 4-1**, below.

Figure 3-1: **LITHOLOGIC LOG – BRINE DISPOSAL WELL**

Site Location:	Paradise Found Disposal Well
Coordinates:	17° 34' 05.5" N; 61° 46' 16.1" W
Drilling Method:	Rotary Normal Circulation
Sampling Method:	Circulation
Sampling Frequency:	5 ft intervals

Depth (ft)	Thickness (ft)	Lithologic Description	Formation
0 to 45	45	SAND - beige coloured, calcareous, sub-rounded, fine to medium grained, with major coral fragments and minor shell fractions.	PALMETTO SANDS
45 to 110	65	LIMESTONE - beige coloured, dense, coral limestone with evidence of iron staining at 75 to 90 ft. depth	HIGHLAND LIMESTONE
110 - 122	12	LIMESTONE - predominantly, light brown coral fragments with beige coloured, dense, beige coloured limestone Nodules of grey clay present between 119 to 122 ft depth	
122 to 137	15	Loss of drilling fluid circulation, no samples recovered	

The following observations are worthy of note: -

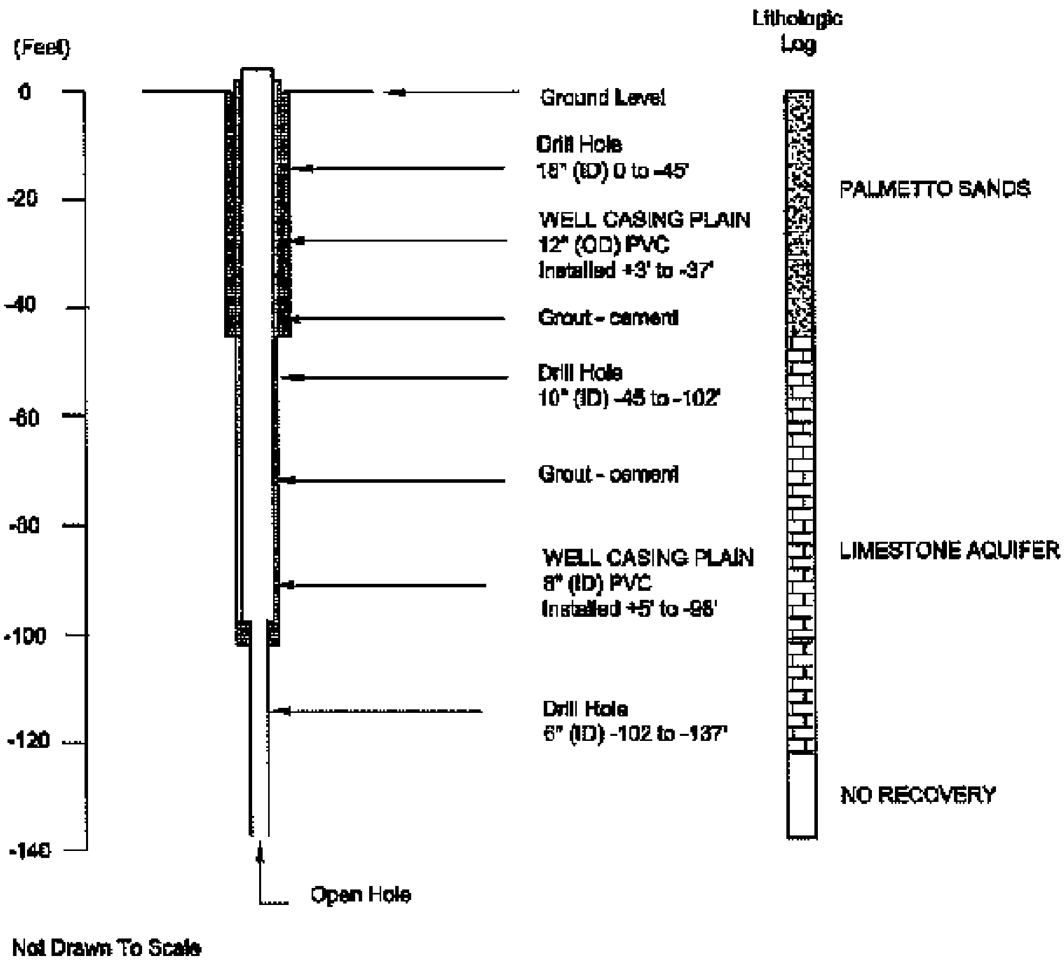
(i) The Basal Clay strata encountered at the base of the Palmetto Sands in the Source Water Well, was missing from the hydro-stratigraphic sequence in the Brine Disposal Well, so that the Palmetto Sands rests directly on top of the Highland Limestone.

(ii) The loss of circulation at a depth of 122 ft bgl (-119 ft msl), indicated the interception of significant conduit permeability, typical of a cavern in karstic limestone.

4.2 As-built Design – Brine Disposal Well

The main elements of the As-built Design of the Brine Disposal Well for the Paradise Found Development is given as **Figure 4-2**, below.

Figure 4-2: **SCHEMATIC AS-BUILT DESIGN – BRINE DISPOSAL WELL**



The following observations are worthy of note: -

(i) The annular space between the wall of the Drill Hole and the PVC Well Casing was grouted with cement down to a depth of 98 ft bgl; some 61 ft below the bottom of the Palmetto Sands Formation, to prevent the seepage of sand into the underlying Highlands Limestone Formation, and 15 ft below the depth of the bottom of the Source Water Well to avoid the recirculation of the brine effluent.

(ii) The bottom 35 ft of the 6" ID Drill Hole (i.e., 102 to 137 ft bgl) was left uncased/open, to allow for maximum hydraulic connectivity between the well and the aquifer.

4.3 Brine Disposal Well Productivity

The productivity of the Brine Disposal Well relates to the rate at which it accepts injected brine effluent. An actual injection test with brine was not carried out because of the unavailability of brine.

Given that the Cone of Depression associated with the pumping of a well at a particular rate is equivalent to the recharge cone associated with injection of water into the well at the same rate, the results of a Constant Rate Test were considered sufficient to evaluate the productivity of the Paradise Found Brine Disposal Well.

A Constant Rate Test was conducted on the Brine Disposal Well on 7 Apr 2023. The Test involved the pumping of the well at a continuous constant rate of 315 USgpm, for a period of 6-hours, after measuring its initial non-pumping water level and monitoring the pumping water level at regular intervals. On the cessation of pumping, the recovery of the water level was monitored for 1-hour. A summary of the Constant Rate Test results is included in **Table 4-1**, below.

Table 4-1: **SUMMARY RESULTS – CONSTANT RATE TEST**

Hour	Elapse Time (min)	Depth to Water (ft)	Water Level Elevation (ft msl)	Drawdown (Recovery) (ft)	Tide Elevation (ft msl)	Change in Tide Elevation (ft)	Discharge Rate (Usgpm)	Remarks
1240		5.52					0	Non-pumping Water Level
1244	0	5.52	0.23	0.00	-0.08		0	Start pumping
1844	360	5.91	-0.16	0.39	0.54	0.62	314	Stop pumping
1944	420	5.15	0.60	(-0.76)	0.69	0.15	0	

1 - Reference Point for water level measurements: 3.00 ft agl (top of Stilling Tube)
2 - Ground Level Elevation: 2.75 ft msl

The following observations are worthy of note: -

(i) The non-pumping water level in the Brine Disposal Well fluctuated in sync with Tidal fluctuations, indicating that the Highland Limestone Aquifer is in direct hydraulic continuity with the Sea, as shown in **Figure 3-3**, above.

(ii) However, the Tidal fluctuations complicate the well water level response under pumping conditions. Pumping during a period of increasing Tide causes a decrease in drawdown to values lower that which would have occurred if there was no tidal influence, as occurred during the Constant Rate Test of the Brine Disposal Well on 07 Apr. As listed in **Table 4-1**, above, the Drawdown (i.e., the difference between the non-pumping water level just prior to the start of pumping and the pumping water level at the cessation of pumping) was 0.39 ft, and the Change in the Elevation of the Tide for the same time period was 0.62 ft, indicating that the actual Drawdown was 1.01 ft i.e., 0.39 plus 0.62.

(iii) The Specific Capacity (or yield) of the Brine Disposal Well was determined to be 312 USgpm/ft i.e., discharge of 315 USgpm/drawdown of 1.01 ft. At the design injection rate of of 225 USgpm the associated increase in water level can be expected to be about 0.7 ft.

(iv) This relatively high productivity of the Brine Disposal Well no doubt reflects the interception of conduit flow permeability at a depth of 122 ft bgl (-119 ft msl), indicated by the loss of drilling circulation at that depth.

4.4 Salinity Profile – Brine Disposal Well

A Salinity Profile for the Brine Disposal Well was not determined because of the malfunctioning of the Conductivity Meter. However, a result similar to that obtained for the Source Water Well is likely for the Brine Disposal Well.

5. POTENTIAL IMPACT OF PARADISE FOUND WELLS

5.1 Mutual Interference Effect

At a distance of 764 ft apart, and < 1 ft change in water level elevation at the Source Water Well (drawdown of 0.6 ft) and the Brine Disposal Well (recharge rise of 0.7 ft), it is not expected that the radius of influence of either well will extend to affect the other i.e., there should be no direct hydraulic mutual interference effect. Besides, the amplitude and continuous change in the tidal fluctuations would make such a determination impractical.

Neither is it likely that the brine disposed of in the Brine Disposal Well will impact the water quality of the Source Water Well given (a) the distance between the wells – 764 ft; (b) the injection of the brine at a depth of 102 ft bgl, some 19 ft below the depth of the bottom of the Source Water Well, (c) the density of the brine (i.e., 8.3 to 19 lbs/gal) is much higher than that of Seawater (i.e., 4.7 lbs/gal), so the brine will sink when placed in the Seawater in the well. It is useful to note that the Source Water Well is likely to obtain most of its water from the conduit flow permeability encountered at a depth of 73 ft bgl (-68 ft msl), whereas the movement of brine out of the Brine Disposal Well is most likely to occur via the conduit flow permeability encountered at a depth of 122 ft bgl (-119 ft msl), increasing the depth separation to about 51 ft.

5.2 Impact on Nearby Wells

The nearest production well is the APUA Source Water Well located some 3.5 miles to the northwest of the Paradise Found wells. This well is too far away to envisage impact by the Paradise Found wells. The Palmetto Point wells are even farther away.

5.3 Impact on Fresh Groundwater

No impact on the fresh groundwater in the water table section of the Highlands limestone Aquifer is possible given its location far away, in the northeast of the island.

5.4 Impact on Marine Environment

The injection of brine via the Brine Disposal Well is designed to occur generally between a depth of -99 to -134 ft msl i.e., the open uncased section of the well. The brine can be expected to exit the well primarily via conduit flow permeability at -119 ft msl, directly into the karstic Highlands Limestone Aquifer, well below the seafloor i.e., not in open sea. In this underground cavern system, there is not expected to be any significant throughflow, such movement as occurs being driven primarily by tidal fluctuations . Therefore, the brine can be expected to develop into a plume, mix with the much larger volumes of the native seawater, while being slowly diluted to assimilation at its outer edges.

There is not expected to be any significant marine life within the Highland Limestone Aquifer that could be impacted negatively by the brine plume. Neither is the brine plume expected to enter open seawater and is therefore not expected to represent a threat to marine life in the coastal waters to the south and west of Barbuda.

6. SUMMARY OF RESULTS

The following have been achieved during Phase 2 of the water resources component of the EIA for the proposed Paradise Found Development in Barbuda: -

(i) **Source Water Well** - A 10 in ID x 83 ft deep well, with a reliable yield of 375 USgpm has been successfully constructed and yield tested, to serve as the water source for the Paradise Found desalination plant.

(ii) **Brine Disposal Well** – A 8/6 in ID x 137 ft deep well, with an injection productivity >225 USgpm has been successfully constructed and yield tested, to dispose of the brine effluent from the Paradise Found desalination plant.

(iii) **Minimal Environmental Impact** -The Source Water Well and/or the Brine Disposal Well were assessed as not having any mutual interference one with the other; were too far away to impact nearby wells; were too far away to impact fresh groundwater resources in the north of the island, and the brine plume is likely to be largely contained within the Highland Limestone Aquifer, below the seafloor, posing little if any threat to coastal marine life along the southwest coastline of Barbuda.

End of Report

Appendix B Baseline Study (October 2022)

Environmental Impact Assessment for the Paradise Found Development, Barbuda

BASELINE CONDITIONS REPORT

Submitted to: Mr Darren Flanagan

12 OCTOBER 2022

Submitted by: Smith Warner International Limited
Unit 13, Seymour Park, 2 Seymour Avenue
Kingston 10, Jamaica, WI

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Appendix 1 Description of monitoring equipment and air/noise monitoring results

Appendix 2 Species Notes

Appendix 3 Hydrogeological Study

Appendix 4 Maps and data for socioeconomic study

1 Project Understanding and Background

The proponents of the Paradise Found Resort development submitted a Plan Application (#G10-2021) to the Department of Environment (DoE), Antigua. The DoE responded with a letter (dated April 28, 2021) outlining their concerns regarding some aspects of the submission and advising that an Environmental Impact Assessment (EIA) would need to be done. The letter outlined the main areas of concern that must be addressed, which included:

- Hydrological and drainage;
- Pollution of wetlands;
- Desalination and reverse osmosis; and
- Climate change impacts.

The objective of this assignment is to carry out a full environmental impact assessment that addresses the DoE concerns, troubleshoots areas of potential conflict in advance, and allows the project to move forward.

In June 2016, Smith Warner International (SWI) carried out a baseline study and drainage plan for the beachfront development of almost 400 acres. The focus at that time was on recommending appropriate coastal setbacks considering climate change. Brisbane Consultants Ltd were responsible for the drainage aspects and Maya Blue was brought in to assess the hydrogeology of the property. Over the project's life several master plans were developed with varying pond sizes and locations, and work was undertaken to assess the site in all its complexity and dynamism. In December 2016, the compiled study was handed over to the client. The findings from that investigation are summarized below:

- The hydrogeology studies indicated that an increase in the right type of natural endemic vegetation cover across the site, such as neem (*Azadirachta indica*) will enhance the ecological framework of the site. Strategic landscaping may also lead to a reduction in the ambient air temperature across the site. Hardy vegetation, such as mangroves, should also be used to further enhance drainage and pond stability.
- The storage capacity of the ponds was a major concern, which led to recommendations of berms being built around the ponds to increase their water storage capacity. A cut/fill plan was developed with this in mind to balance the soil excavation volumes.

After completing the first phase of the project at the end of 2016, the next steps were to seek additional funding for the project and acquire planning and regulatory permits. However, in September 2017 a major hurricane (Hurricane Irma) hit the island and left it in ruins, essentially requiring that the property would need treatment before development. Since that time, the project has been on hold while the government of Antigua and Barbuda engage in recovery activities from the natural disaster.

It is our understanding that the master plan has been revised to a smaller scale, with a focus on the southern portion of the property. An image of the revised and updated Master Plan of the development is shown in Figure 1.1.

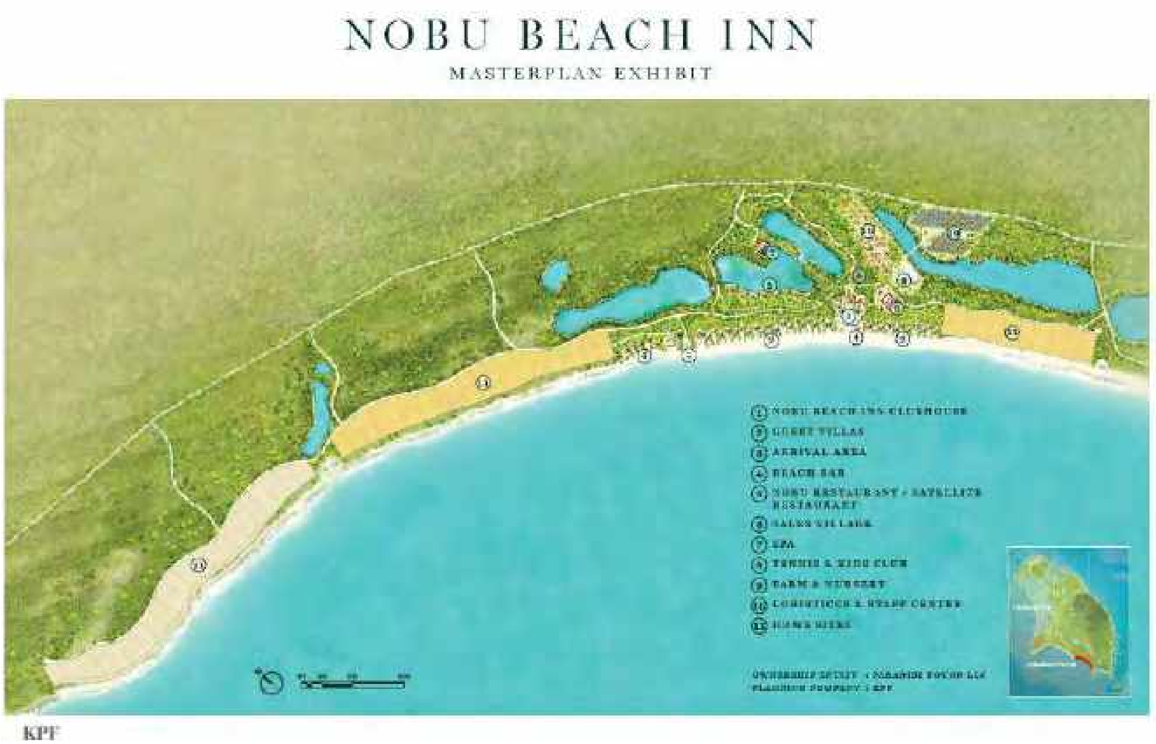

Figure 1.1 Masterplan for project site

2 Description of Project

The Project Application number and name are given as G10-2021 Paradise Found Resort Development in Barbuda. The site identified for the resort development is contained within approximately 391 acres, which have been (long-) leased to the developer to facilitate hotel and villa development. The application describes the project as a resort mixed-use property.[1]

The development is to be located at the site of the former K Club Development on the southeast coast of Barbuda (Figure 2.1 and Figure 2.2). The terrain of the area is characteristic of Barbuda. The site is low-lying and many wetland ecosystems and hydraulic features are present. The Development is within an area zoned for Tourism Development.

The Plan application submitted for the development is for 39 individual guest villas (each with a private pool) staggered along the beachfront, as well as a signature Nobu Restaurant, beach club and bar, spa and wellness centre, tennis pavilion and kids club. The resort property will also have a small farm and plant nursery, private homes and back of house area with housing and amenities for staff.

[1] Review of Plan Application #G10-2021 (Paradise Found), Department of the Environment April 28, 2021. Department of the Environment, Ministry of Health Wellness and the Environment

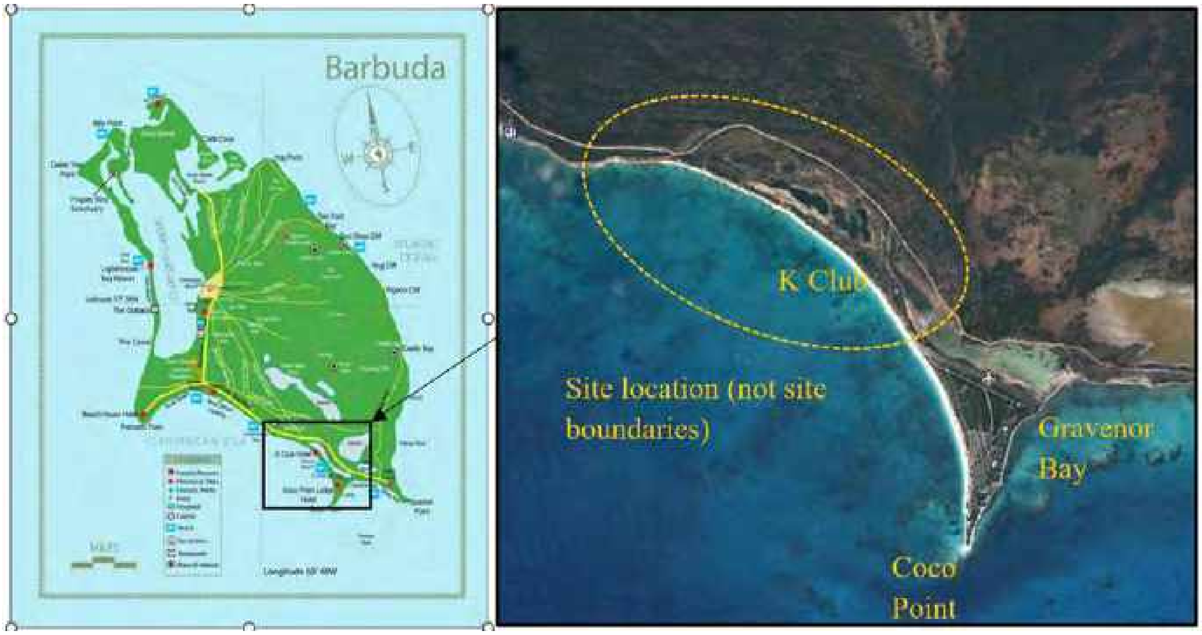

Figure 2.1 Map of Barbuda (left) with inset showing project location

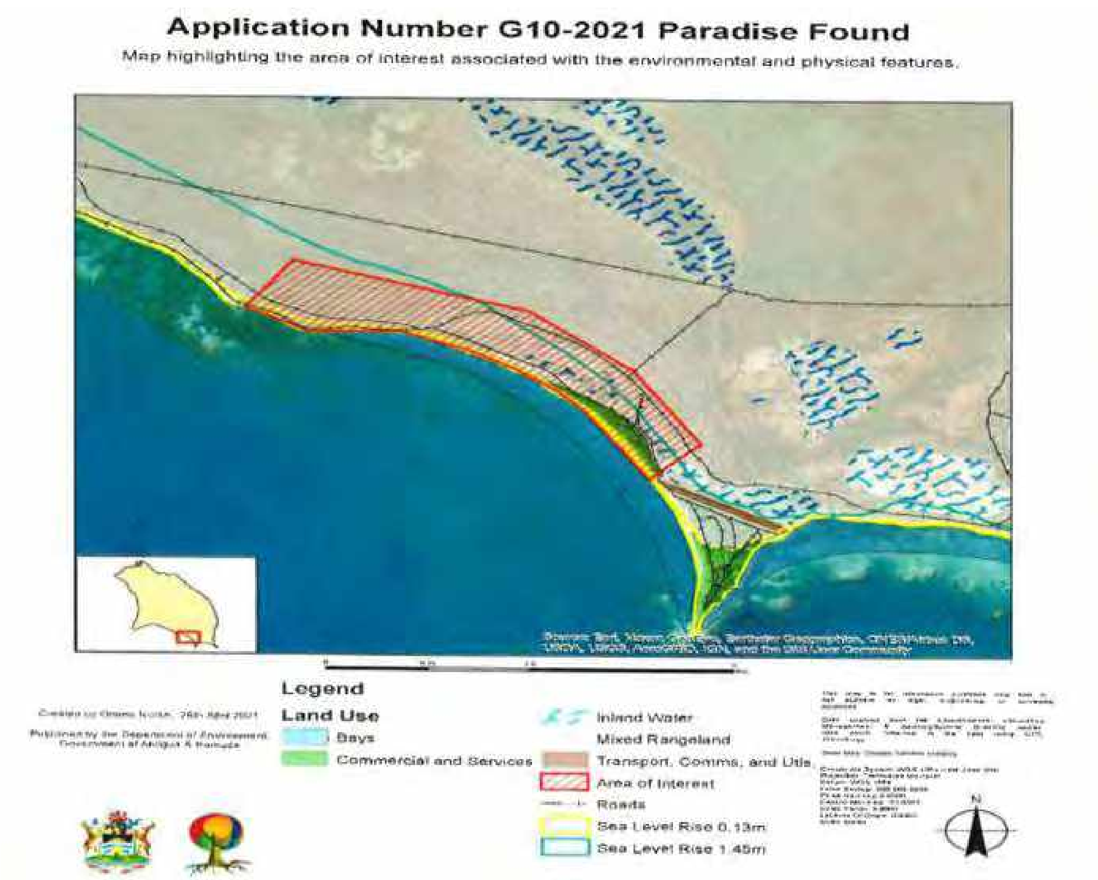

Figure 2.2 Paradise Found development property (in red hatch)

3 Regulatory Framework

There are several pieces of legislation, new and existing regulations and guidelines (local, regional and international), which together present a framework that situates the social impact assessment and its outcomes on the island of Barbuda in the State of Antigua and Barbuda. The following discussion seeks to present the most relevant documents and the succinct points within each.

Antigua and Barbuda Act No. 6 of 2003

An Act to make provision for the orderly and progressive development of land 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 the land; for the regulation of the construction of buildings and other related matters; to confer additional powers in respect of the acquisition and development of land for planning; and for purposes connected with the matters aforesaid.

Additionally, the Director of the Department of Environment may also require, in consultation with the Chief Town and Country Planner that any matter that is likely to cause any serious social impact or harm to the environment or to human health to be subject to an environmental impact assessment (EIA). The third schedule of the Act (Section 23) notes matters for which environmental impact assessment shall be required includes (number 10) “a hotel or resort complex”.

As a general rule any proposed developments, undertakings and other activities that are likely to cause an adverse impact on human health, society or the environment should be subject to the EIA process, including *inter alia:*

- Proposals that could harm or destroy important cultural resources including archaeological sites, cemeteries, historic sites and landmarks; and
- Proposals that would challenge or contravene customary controls over the use of environmental resources.

Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean (Escazu Agreement 2018)

Article 1 sets out the Objective of the Agreement as being to guarantee the full and effective implementation in Latin America and the Caribbean of the rights of access to environmental information, public participation in the environmental decision-making process and access to justice in environmental matters, and the creation and strengthening of capacities and cooperation, contributing to the protection of the right of every person of present and future generations to live in a healthy environment and to sustainable development.

Article 6 discusses the generation and dissemination of environmental information and notes that “Each Party shall promote access to environmental information contained in concessions, contracts, agreements or authorizations granted, which involve the use of public goods, services or resources, in accordance with domestic legislation.

Article 7 indicates that “Each Party shall ensure the public’s right to participation and, for that purpose, commits to implement open and inclusive participation in environmental decision-making processes based on domestic and international normative frameworks.”

The Government of Antigua and Barbuda is a signatory to this Agreement.

Medium-Term Development Strategy 2016 to 2020

The Medium-Term Development Strategy (MTDS) represents a set of strategies and actions to be undertaken by Antigua and Barbuda over the Medium-Term (2016 to 2020) in moving the country towards its long-term goals. Within such a framework, Antigua and Barbuda will strive to become a developed country within 15-20 years, guided by the vision of "A harmonious, prosperous and modern Antigua and Barbuda founded on the principles of sustainability and inclusive growth; where equality of opportunity, peace, and justice prevail for all citizens and residents". The attainment of this vision must be guided by a sustainable development approach in which we treat our public sector machinery as a single system working towards a singular, overarching goal, which is "To improve the quality of life for all Antiguans and Barbudans and their posterity".

Flagship Priority Three: Transform Barbuda into a Green, Low Density, High-End Tourism Destination. Barbuda is a natural paradise with unique pink sand beaches, lagoons, salt ponds and unique flora and fauna species, including one of the world's largest bird sanctuaries. Barbuda is virtually untouched with significant growth potential which, if exploited in a sustainable manner, can substantially transform the way of life for Barbudans while at the same time, protecting and preserving its natural beauty.

IUCN Environmental and Social management System (ESM) Standard on Cultural Heritage (Version 2.1 – December 2019)[2]

The purpose of the Standard on Cultural Heritage is to assure that projects:

i. Anticipate and avoid negative impacts on cultural resources or, if avoidance is not possible, minimise and compensate for impacts;
ii. Avoid restrictions of people's ability to legitimately use and/or access cultural resources;
iii. Assure a fair and equitable sharing of benefits if existing and new uses of cultural resources generate economic, cultural, and social benefits.

For this Standard cultural heritage refers to:

i. A tangible, moveable or immovable cultural resource or site with paleontological, archaeological, historical, cultural, artistic, religious, spiritual, or symbolic value for a nation, people or community; or
ii. A natural feature or resource with cultural, religious, spiritual, or symbolic significance for a nation, people or community associated with that feature.

Examples of the first category are burial sites, monuments, buildings, groups of buildings, urban areas, and cultural landscapes. Examples of the second are sacred mountains, forests, trees, or landscapes.

For the People of Barbuda their island has historic, cultural, spiritual and symbolic value for its people.

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[2] This standard is consistent with internationally accepted social safeguard standards related to cultural heritage, notably International Finance Corporation's Performance Standard 8 on Cultural Heritage and the World Bank's Operational Manual section on Physical Cultural Resources, among others.

4 Field Investigations and Data Collection

4.1 Topography and Bathymetry

A boat-based bathymetric survey with echo-sounder and GPS was conducted to map the nearshore area as well as within Pond 2 and Pond 3 in July 2016 (Figure 4.1). The methodology consisted of using the boat to traverse the nearshore zone, making a series of tracks from deep water (approximately 10m) towards the shoreline. Horizontal positioning was measured using GPS equipment, and an ODOM EchoTrac CV100 single beam echo sounder provided the water depth information along the tracks. The raw data from this survey was referenced to the UTM 20N system and elevations set relative to the mean sea level (MSL) datum for continuity of data.

The topography of the land was quantified by producing a Digital Elevation Model (DEM) from drone topography of areas with low vegetation coverage combined with the surveyor's topographic data (Figure 4.2). Data from the bathymetric survey and topographic DEM were both referenced to MSL for continuity of data. The bathymetry and topography will be used in a computer model to simulate wave propagation up to the shoreline and inundation of the property and surrounding areas.

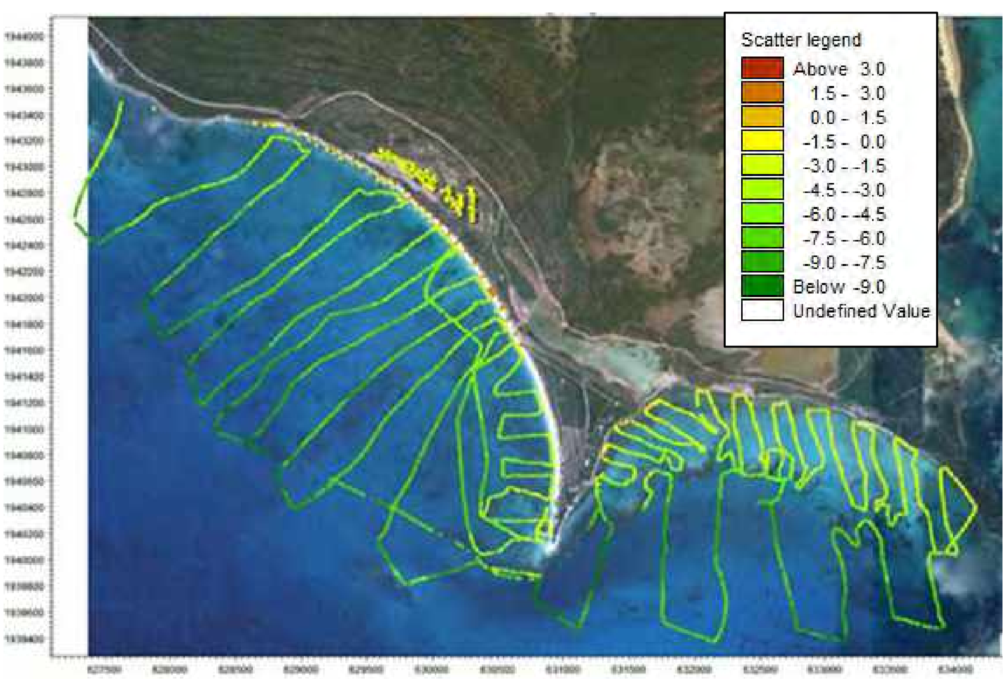

Figure 4.1 Bathymetric data points from the boat-based bathymetry survey

Figure 4.2 Topographic data points from the DEM of the site and nearshore

Contour maps are then created to show the contours of the nearshore area and the ponds. The maximum depth recorded was -4.1m in Pond 3, while Pond 2 recorded depths of 2m below sea level. The bathymetric and topographic contours, along with water depth in the ponds, are shown in Figure 4.3 and Figure 4.4.

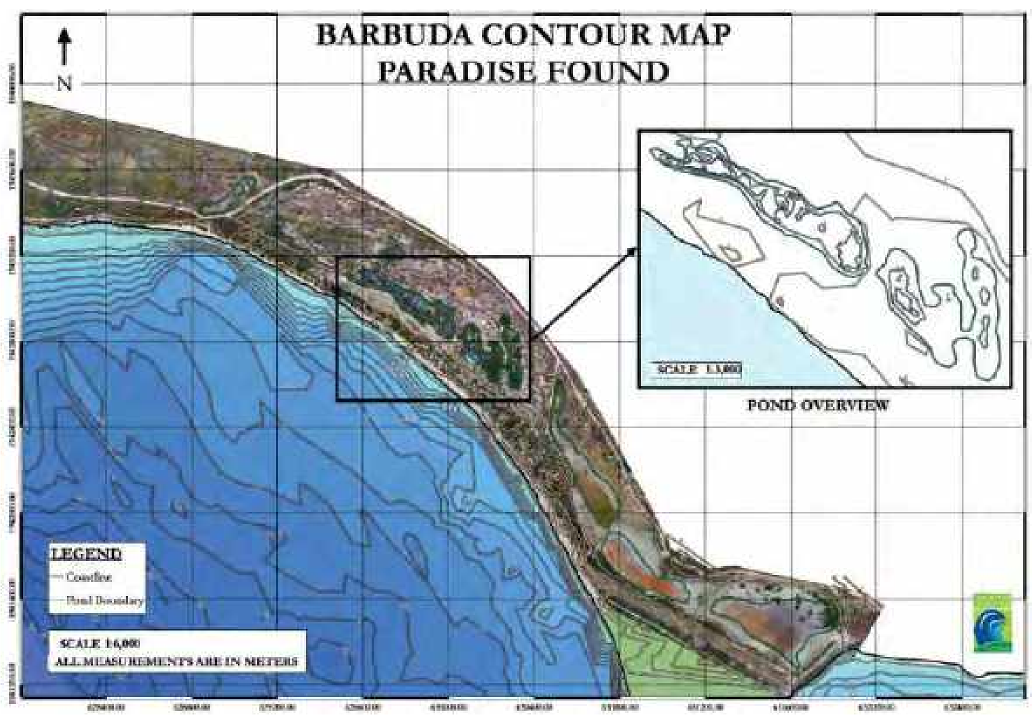

Figure 4.3 Contour Map showing bathymetry and topography of site

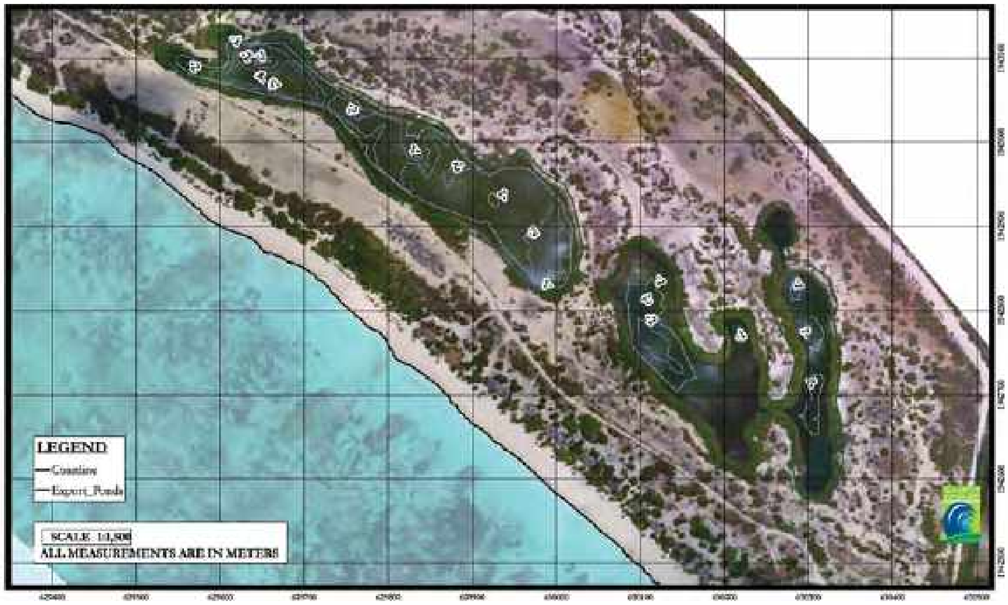

Figure 4.4 Contour Map showing bathymetry of Pond 2 and Pond 3

Barbuda is connected to Antigua by an underwater plateau. The water depths south and southwest of the island are very shallow, with the maximum depth being approximately 33m below mean sea level. To the east the sea floor quickly reaches depths of 1000m below mean sea level as is common around other islands. Closer to the shoreline of the Paradise Found site, the water becomes 4m deep within the first 200m from shore. Beyond this, the gradient is very gentle, reaching 10m depths over 2,000m. The bathymetry explains the calm wave climate around the project site.

4.2 Baseline Coastal Conditions

4.2.1 Currents and Tides

Generally, the currents in this area are slow (below 0.05m/s), which is to be expected because of the gentle bathymetry and low wave energy along this section of shoreline. Stronger currents at this site flow parallel to the shoreline and have an average speed of 0.09m/s. Along the southern shore of the project area there is a north-westerly flowing current, while along its northern shore there is a south-easterly flowing current. These currents meet at the centre of the site and the shear resulting from their interaction gives rise to a small gyre (Figure 4.5). This gyre has the potential to generate two areas of possible rip currents.

Additionally, there are stronger currents over two shallow features in the center of the bay. Thus, the main gyre is affected by these shallow features, which creates smaller, less organised gyres in the nearshore.

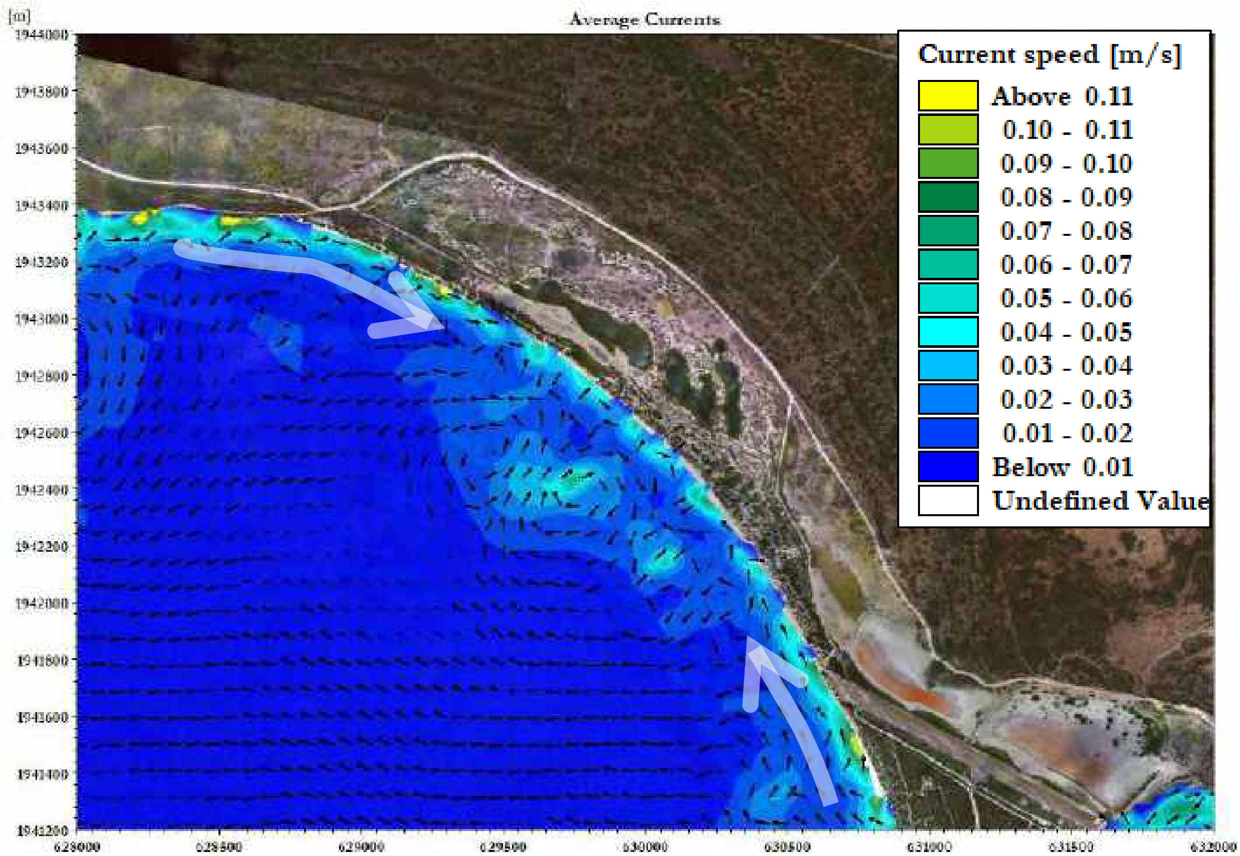

Figure 4.5 Current speeds and directions at the project site

4.2.2 Oceanic Surface Currents

The Guiana Current sweeps north-westerly offshore South America and splits into (i) the Caribbean Current, which enters the Caribbean Sea and (ii) the Antilles Current, which moves on the outside of the Lesser Antilles Island arc, up past the Lucayan Peninsula where it joins the Gulf Stream (Figure 4.6). It is the Antilles Current, as an oceanic driver, that would have the most influence on the shorelines of Barbuda. Further, it is likely, but not shown at a suitable scale in the figures below, that the Antilles Current will result in smaller gyres through its interactions with the islands in the Lesser Antilles.

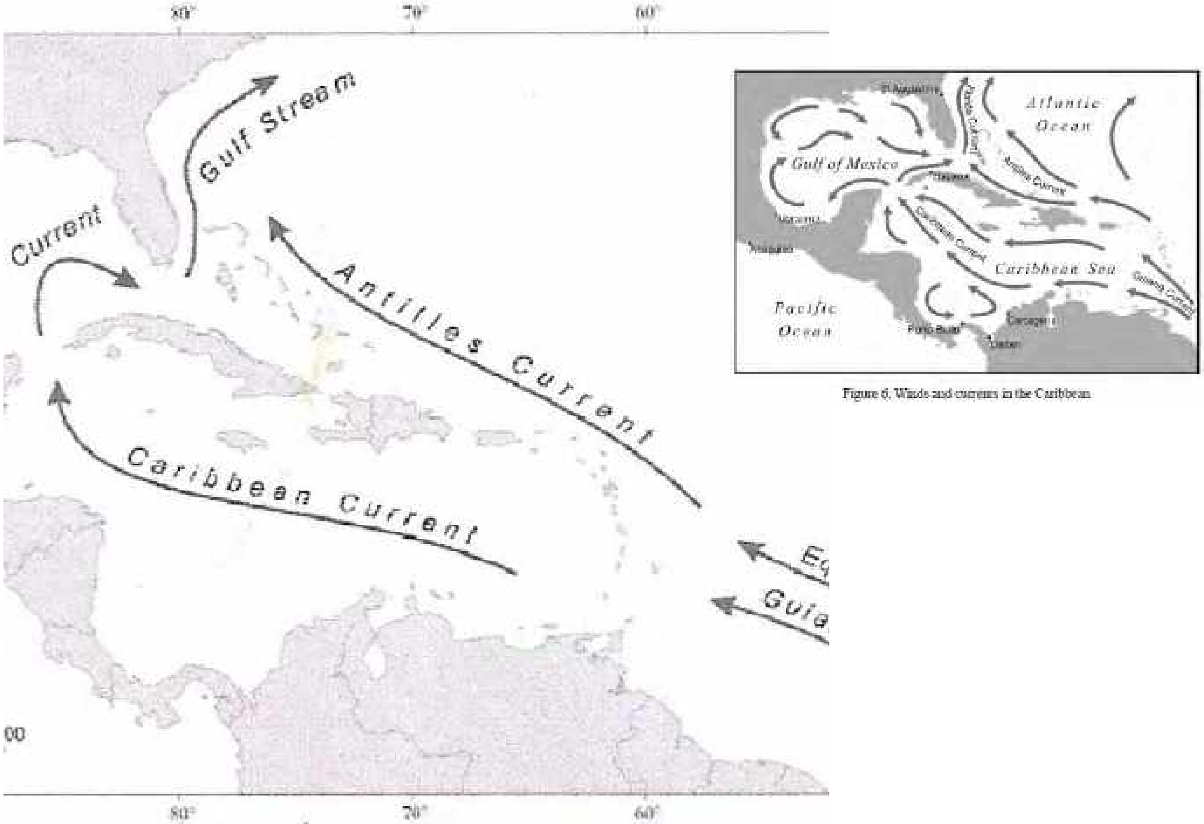

Figure 4.6 Oceanic surface currents affecting the Caribbean

4.2.3 Operational Wave Climate

MIKE21, a coupled wave-hydrodynamic-sediment model developed by the Danish Hydraulic Institute, was set up for this project area. The model was used to transform wind and wave fields from deep water to the nearshore at the project site and to determine both operational wave conditions and hurricane wave conditions, including storm surge and inundation. Figure 4.7 shows the MIKE21 flexible mesh representing the seabed that was used for this modeling.

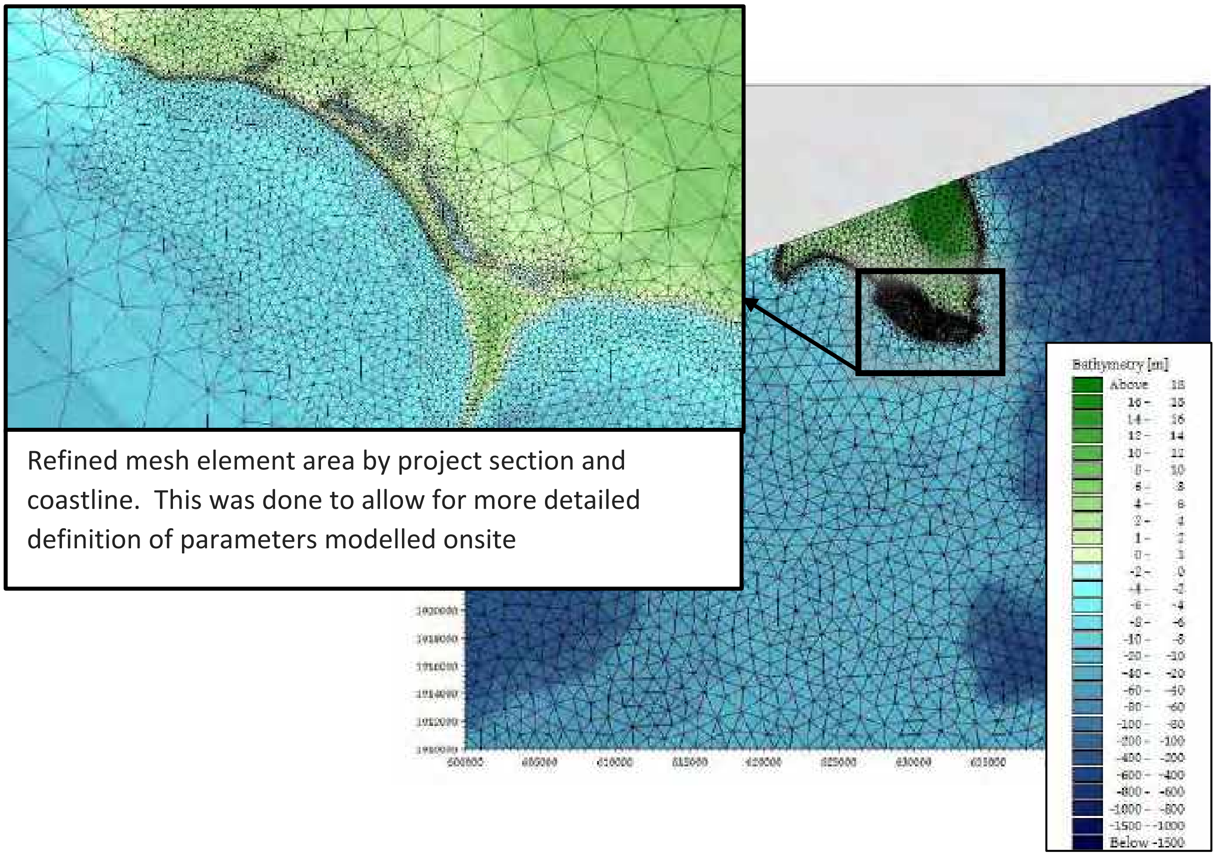

Figure 4.7 Numerical model domain - Flexible mesh used when modelling the existing conditions on the site

Offshore Wave Climate

The operational wave climate at the project site is characterized by (a) day-to-day, relatively calm conditions and (b) seasonal winter swells (December to May). The day-to-day conditions are created by the north-east Trade Winds. The north and east coasts of Barbuda are especially vulnerable to these wave conditions because of their location. The swells, on the other hand, are generated by north Atlantic cold fronts and these waves can approach from the north to north-west sector.

The deep-water operational wave climate describing the day-to-day wave conditions was obtained in 2016 from the global wave model Wave Watch 3(WW3) developed by the US National Oceanic and Atmospheric Administration (NOAA). The WW3 model archives wave parameters including wave height, period, and direction as well as the wind speed and direction. Data was available for every three hours from July 1999 to April 2015, giving a total of over 46,000 data points per parameter and covering almost 16 years. Day-to-day waves were extracted from the NOAA Wave Watch 3 model at a location close to the island.

Figure 4.8 below shows the distribution of wave directions observed in deep water around Barbuda. As expected, most of the wave's approach from easterly directions, generated by the Trade Winds that dominate the wind climate of the Caribbean Sea. The Paradise Found property is on the lee side of the island and is largely sheltered from these waves. The waves having secondary dominance approach from the northwest. These occur in the winter months when North American cold fronts generate waves that reach the Caribbean as seasonal northwesterly swells. Paradise Found beach, although partially protected from direct impact of these waves by Palmetto Point, would be impacted by these waves more so than from the easterly waves. These distinct wave climates would cause significant seasonal variations in beach slopes, as shown in Figure 4.9 where there are sometimes beach cliffs of more than 2m in height on the shoreline. The beach typically has gentler slopes in the summer months, while in the winter months the swells result in steeper gradients on the beach.

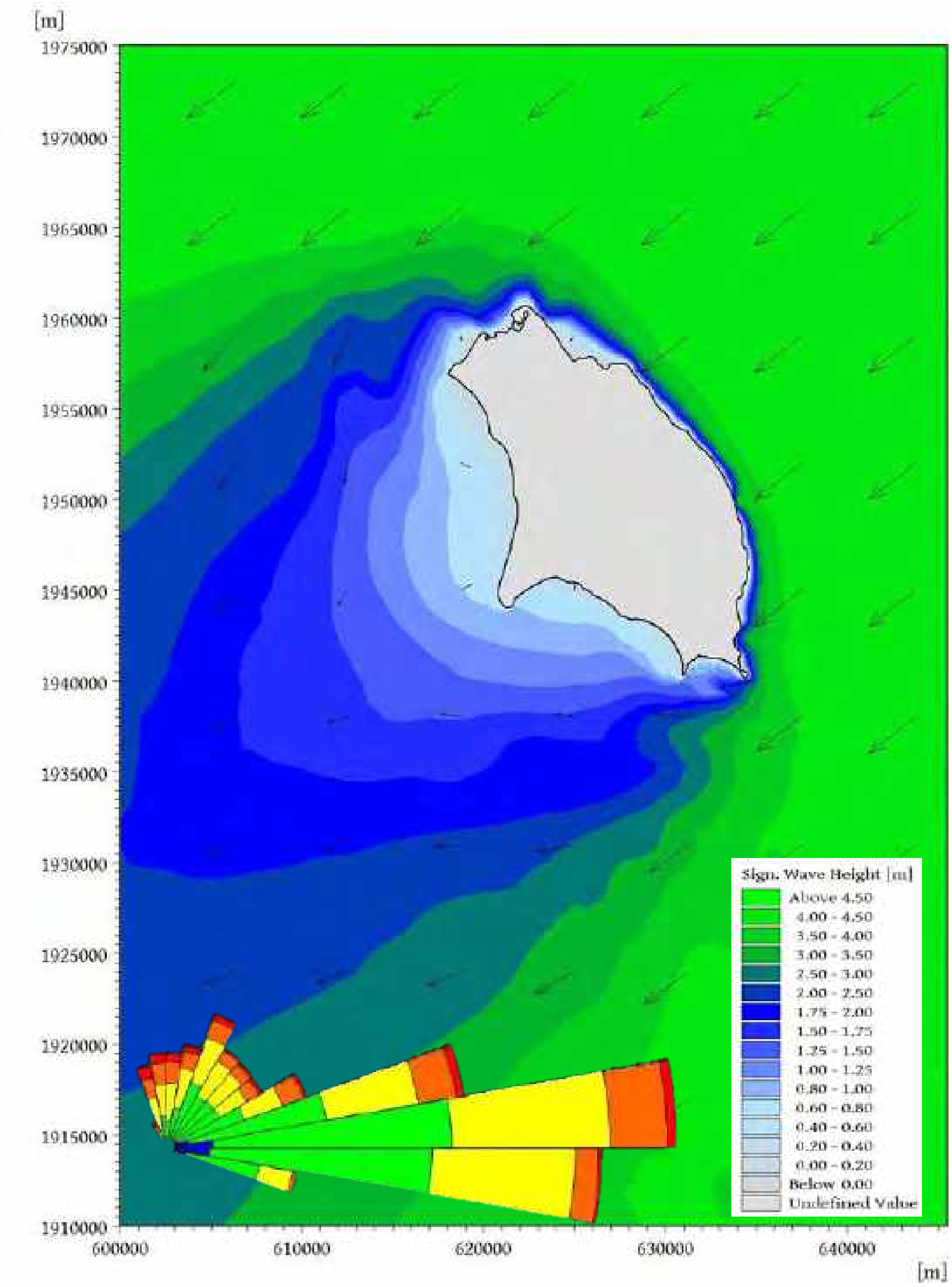

Figure 4.8 Mean annual wave climate around Barbuda and wave rose showing the distribution of wave directions

Figure 4.9 Beach profile change

Nearshore Wave Climate

The WW3 model used by the NOAA is usually applied on spatial scales (grid increments) larger than 1-10km and outside the surf zone. As a result, the model is not at a sufficiently detailed scale to provide accurate nearshore wave data. The nearshore wave climate for this project was therefore developed using a spectral wave model MIKE21 SW to simulate waves as they approach the nearshore of the project site. The basic starting point of the model is the creation of a computational mesh where waves and currents are determined at each simulation time step. The MIKE21 model uses a flexible mesh that represents the seabed using a series of connected triangular and/or quadrangular elements. The bathymetric data is then interpolated on the flexible mesh to create the model domain. As shown in Figure 4.10, the model domain extends out to water depths of at least 1000m and captures the changing contours, which tend to run parallel to the shoreline.

We used 20 years of wave data to predict the conditions at the site and found that over the past 20 years the average wave heights within the bay were less than 0.20m. Low wave heights are expected since the site is sheltered from the dominant wave direction (north-east). Fortunately, these wave heights are suitable for comfortable wading/swimming and other recreational activities in the area, yet sufficiently energetic so as to not result in stagnant water conditions.

Along the Ironshore to the north, higher waves were indicated. This section of the shoreline is less sheltered as is it out of the shadow zone of Coco Point. Waves to the north were about 0.2m at the shoreline. In contrast, the remainder of the site had small ripples at the shoreline (~5cm). These results are in keeping with Barbuda's bathymetry and the local wave regimes.

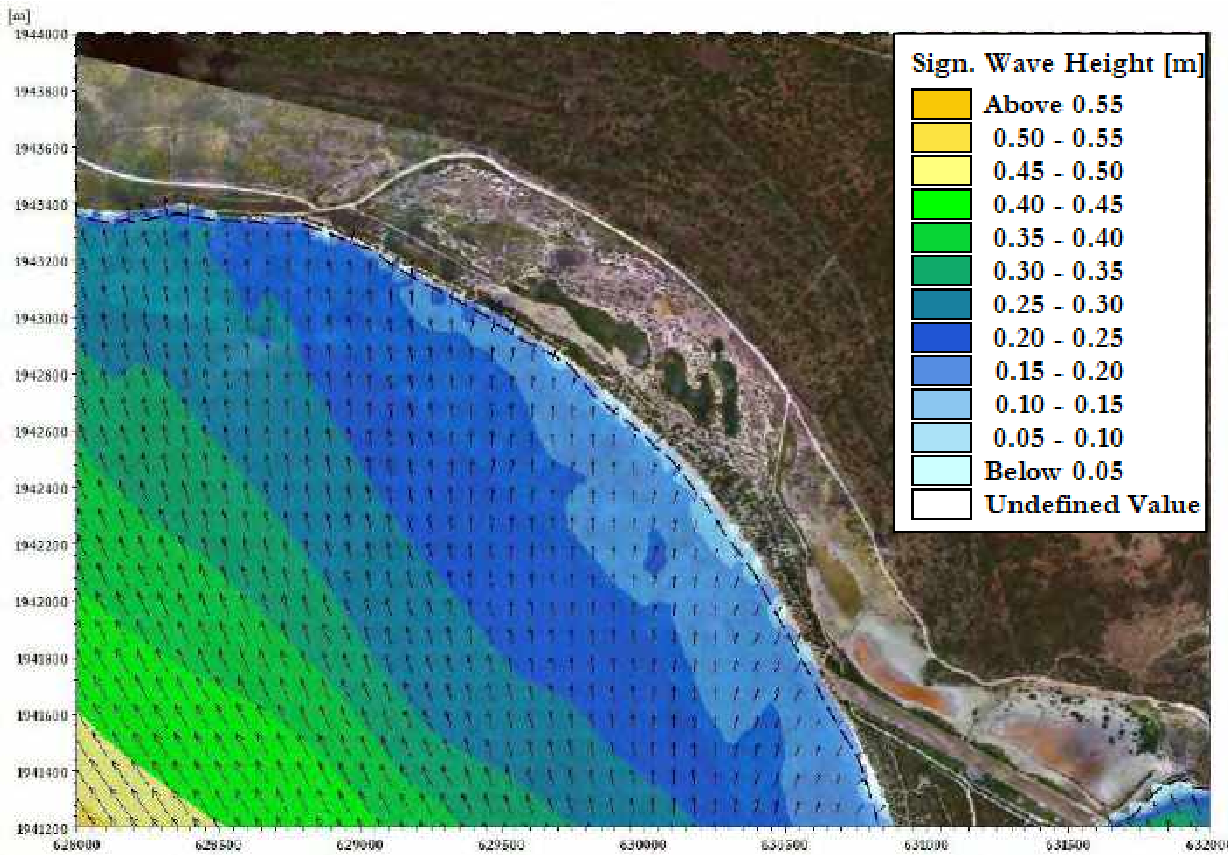

Figure 4.10   20-year mean wave heights and directions

4.2.4 Extreme (Hurricane) Wave Climate and Storm Surge

The Caribbean region is vulnerable to tropical storms and hurricanes each year from June to November. Dramatic and abrupt changes to the coastline can occur because of these storms. Extreme waves occur infrequently, and ideally, decades of data must be explored to adequately describe the statistics associated with these events.

For the Atlantic Ocean, detailed information on tropical cyclones, including all hurricanes, has been collected by the US National Oceanic and Atmospheric Administration (NOAA) at the National Hurricane Center (NHC). This database of storm tracks and other parameters is the main source of information describing individual storms. Hurricane tracks in the North Atlantic basin can often be characterized by a parabolic sweep. These typically form between latitudes 5°N and 25°N off the west coast of Africa and then track across the Atlantic Ocean. Those formed at the lower latitudes are usually pushed on a westerly track by the north-east Trade Winds, whereas those of the higher latitudes track more to the north and north-west.

A tropical cyclone is classified as a hurricane only after it has attained one-minute maximum sustained near-surface (10m above ground level) winds of 33m/s or more. Below this, these cyclones are referred to as tropical storms. The Saffir-Simpson Scale is commonly used to classify hurricanes into five different ranges based on the maximum wind speed attained.

Storm Occurrence

Using HurWAVE (Banton 2002), an in-house storm hindcasting program, we determined that a total of 209 hurricanes and tropical storms have passed within a 300km radius of the Paradise Found property since 1852. This search radius was selected as it provides a good balance between storm size and wave generating capabilities. The number of occurrences within each storm category (per the Saffir-Simpson scale) is shown in Figure 4.11. Seventy-nine (79) of these were hurricanes per the Saffir Simpson scale. The data shows that on average one hurricane (Cat 1 to Cat 5) passes this location every 2 to 3 years and one intense hurricane (Cat 3 to Cat 5) passes every 5 to 6 years (Figure 4.12). The bar chart shows that many of the storms that pass the project area are weaker than a Category 3 cyclone. Only 14.1% percent of the recorded storms were Category 3 or stronger. The graph shows that the study area was more frequently hit by tropical storms and was rarely affected by major hurricanes.

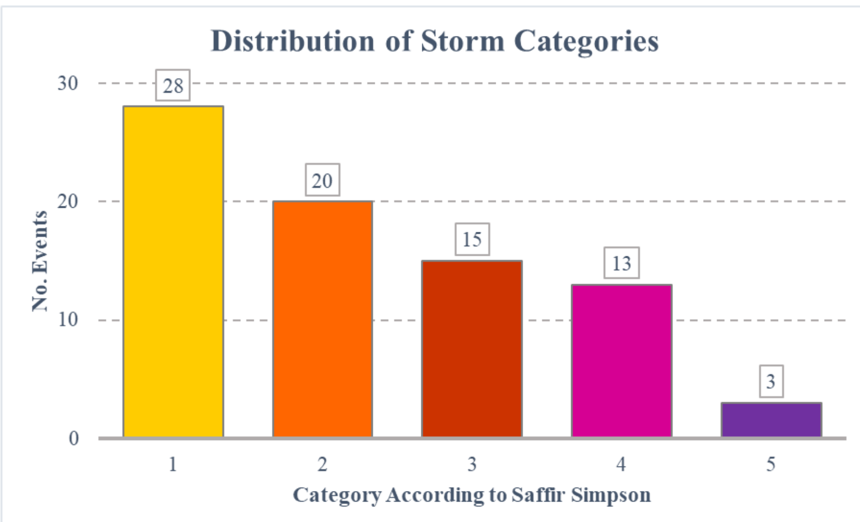

Figure 4.11 Distribution of storms according to the Saffir Simpson scale

Hurricanes typically pass the island in a north westerly direction going either south or north of the island (Figure 4.13). There has been a maximum of three storms affecting Barbuda in a single hurricane season: in 1995 Hurricane Luis, Hurricane Marilyn and Tropical Storm Iris caused significant damage in Antigua and Barbuda. More recently, the island was affected by Hurricane Irma (Category 5) and Hurricane Jose (Category 4) in 2017. While these hurricanes created havoc over the island it should be noted that they passed to the north of the Paradise Found site and limited impact of storm surges from the sea was reported.

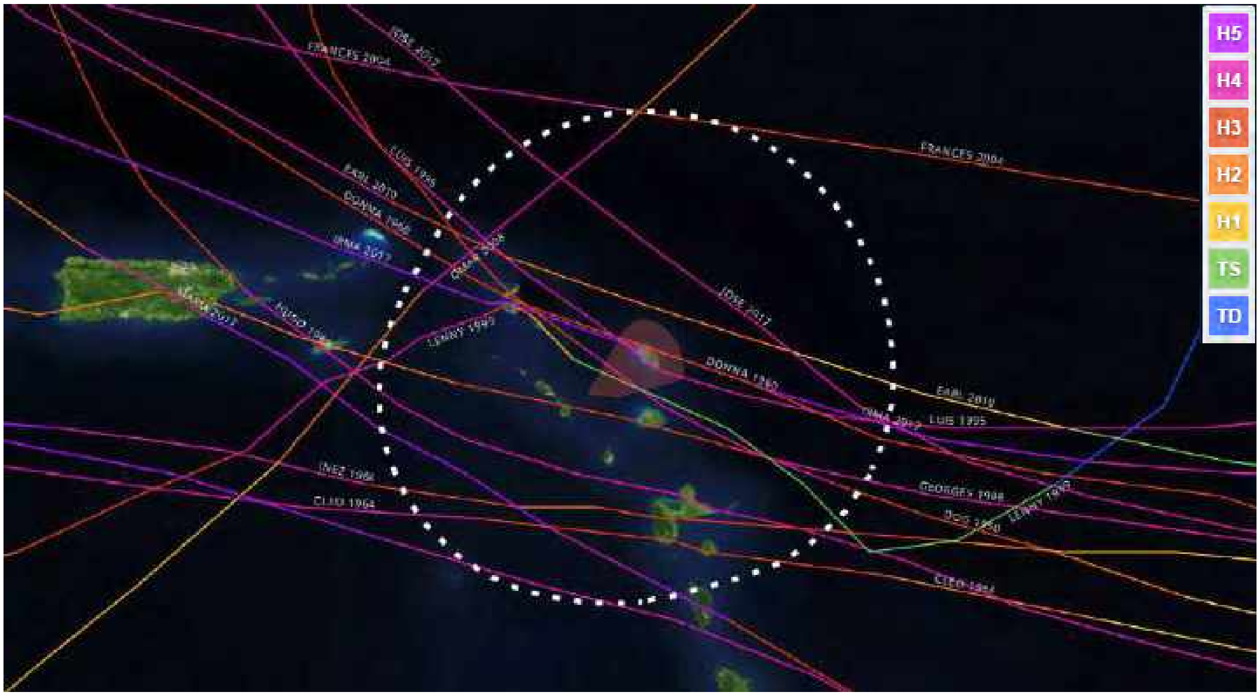

Figure 4.12 Named Category 3-5 Hurricanes passing within a 300km radius of the site

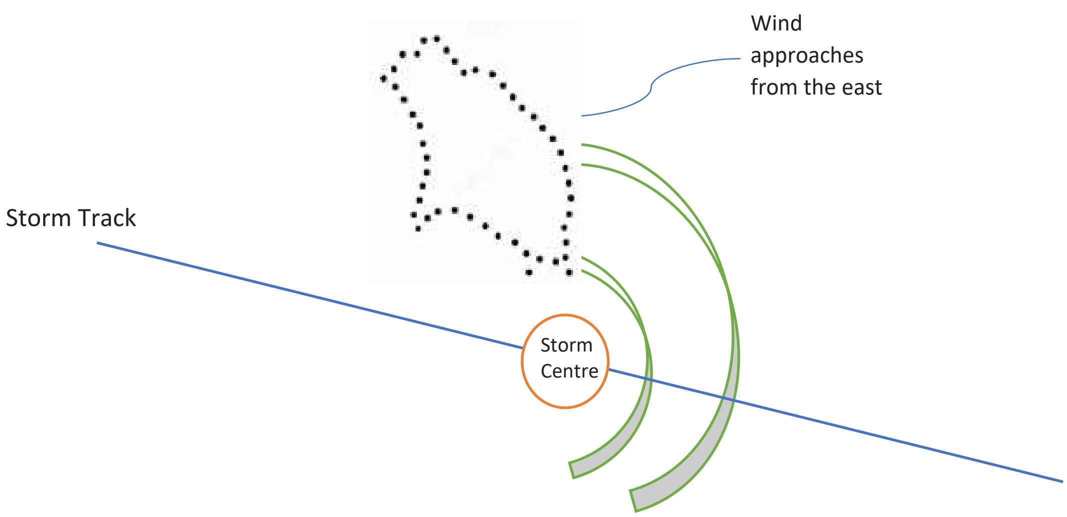

Figure 4.13 Schematic diagram of wind & wave directions from hurricane conditions

The impact on the project property would have depended not just on the intensity of the hurricane but also on the direction of approach, speed of approach and proximity. The location of Paradise Found on the southwestern (lee) side of the island means that it is less vulnerable than other more exposed parts of the island. However, the low site topography and the opening to the sea provided by the salt ponds to Gravenor Bay makes the site vulnerable to hurricane surge. This is particularly the case for hurricanes that track from the south: the anticlockwise rotating winds in a hurricane could churn up significant surge at Paradise Found. Tropical storm Iris (1995) was one such hurricane that came from the south.

Hurricane Waves and Storm Surge Levels

Hurricanes have two immediate coastal hazards: (1) high energy waves and (2) extreme water levels. These extreme conditions can be calculated using the MIKE21 Spectral Wave (SW)/Hydrodynamic (HD) models.

Input conditions for the models typically include the highest deep-water wave and water level conditions, which the models use to simulate the transformation of waves from deep-water to the shallow water location of the site. For worst-case wave conditions, the values are selected through the process of hindcasting where design conditions are calculated for a past event at a given time and location. Water levels are obtained by assessing possible extreme tides and the sea level rise conditions that take place under hurricane conditions. The process is described briefly in the following paragraphs.

Deep water wave parameters were calculated for each selected tropical cyclone using parametric hurricane models (Cooper 1988; Young and Burchell 1996). The resulting wave conditions were divided into directional sectors and each set was fit to a statistical function (Weibell) describing their exceedance probability. The wave parameter values for the 50 and 100-year return periods were determined from the best-fit statistical distribution. The deep-water wave parameters corresponding to the 50 and 100-year return periods were computed for five directional sectors of incidence. These return periods were calculated using the probability of wave height exceedance. The 1-in-25, 1-in-50 and 1-in-100-year events have, respectively, a 4%, 2% and 1% chance of occurring (Figure 4.14). The event with the 1% chance of occurrence is typically the design condition used for protecting critical infrastructure. Table 4-1 shows the wave heights, wind speeds, and periods for the directional sectors investigated. These wave parameters will be used in MIKE21 SW with the inclusion of the static storm surge levels to obtain design wave heights in the nearshore of the selected areas.

The elevated water levels that accompany hurricanes and can create flooding and cause damage to coastal infrastructure is known as storm surge. Storm surge is the rise in water surface elevation of the sea above its mean level. Storm surge is made up of two major components:

i. Static surge, which includes:
   - Highest Astronomical Tide (HAT)
   - Inverse Barometric Rise (IBR) (caused by low pressure under the eye of the hurricane)
   - Global Sea Level Rise (GSLR)
ii. Dynamic surge, which includes:
   - Wind Set-up (when winds push water up onto the land),
   - Wave Set-up (increase in mean sea level caused by wave breaking)

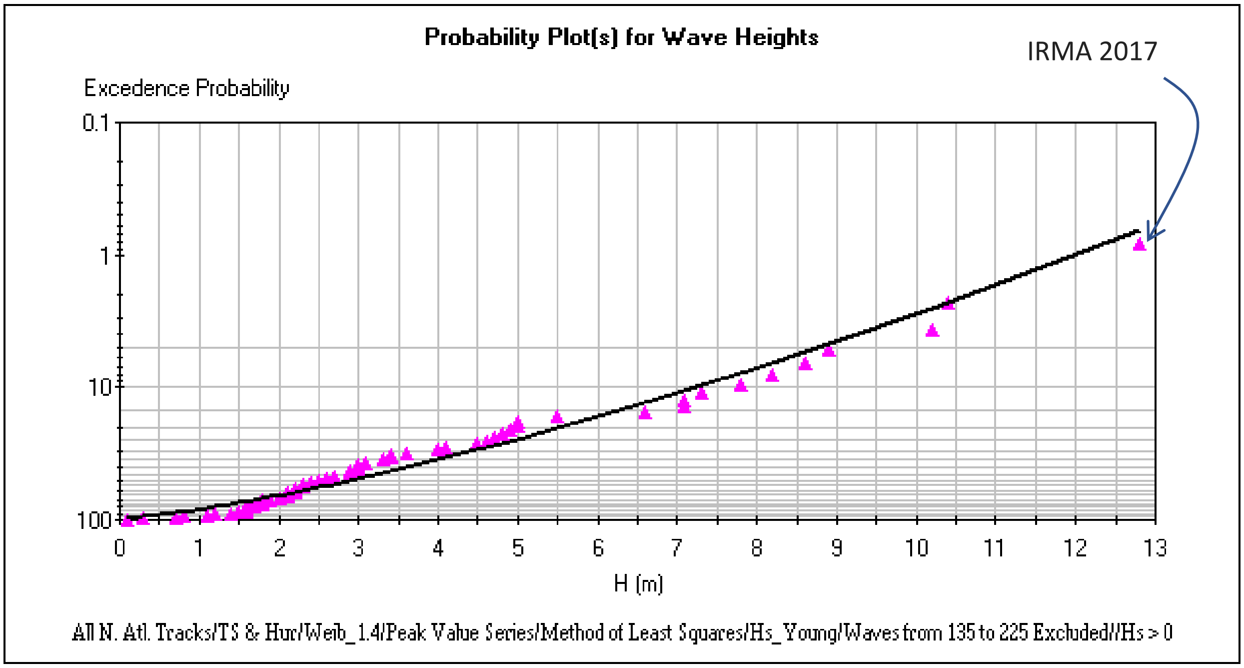

Figure 4.14 Probability of exceedance plots for significant wave heights for past hurricane waves approaching from the south

Table 4-1 Deep water hurricane wave parameters (significant wave height (H_s), peak period (T_p) and wind speed (V_m) resulting from the 25, 50 and 100-year return periods for the most impactful sector

Directional Sector	*Parameters*	*Return Period*		
		25	50	100
South	Hs (m)	8.0	9.2	10.36
	Tp (s)	12.19	13.4	14.4
	Vm (m/s)	26.0	30.8	35.5

To compute the total static storm surge level in deep water, global sea level rise (GSLR) for the projected year and the highest astronomical tide were added to the IBR values. The results for the 50, 100 and 200-year water surface level values are listed in Table 4-2. Results were further used as input boundary conditions to the MIKE21 Spectral Wave (SW) model.

Table 4-2 Calculation of water levels for 25, 50 and 20 – year hurricane return periods

Parameter	Return Period (years)			Notes
	25	50	100	
IBR (m)	0.40	0.48	0.55	Determined through statistical hind-casting analysis
Highest Astronomical Tide (m)	0.12			Determined through historical analysis
Rate of Sea Level Rise (mm/year)	10.5			RCP8.6 Scenario value from IPCC AR6 report (IPCC 2021)
Design Time Horizon (years)	50	100	200	Design life of the structure
Design Deep Water Surface Level **without Climate Change (m)**	0.52	0.60	0.67	Sum of IBR, Highest Astronomical Tide
Design Deep Water Surface Level **with Climate Change (m)**	0.78	1.12	1.72	Sum of IBR, Highest Astronomical Tide, and Sea Level Rise for 50, 100 and 200 years.

Hurricane Irma (September 2017) was a devastating hurricane that made a direct hit on Barbuda. In addition to the effects of sustained high winds (for over 3 hours), there are reports of extreme levels of storm surge, of between 1.5m – 3.3m. The images below show the landscape around the historical Martello Tower, which is located at the shoreline to the north-west of Paradise Found. The extensive flooding around the tower is evident.

Figure 4.15 Flooding from Hurricane Irma at the Martello Tower

4.3 Ambient Air Quality

The objectives of the ambient air quality monitoring exercise were to:

- Establish baseline air quality conditions within the study area for the proposed Paradise Found Development and

- Compare baseline air quality results with air quality guidelines developed by the World Health Organization/ World Bank.

The air quality parameter monitored for this exercise was Particulate Matter, which refers to a mixture of solid particles and liquid droplets found in the air including:

- **PM_{10}**: particles with diameters that are generally 10 micrometers and smaller and
- **$PM_{2.5}$**: particles, with diameters that are generally 2.5 micrometers and smaller.

These particles are so small that they can be inhaled and cause serious health issues such as aggravated asthma, lung disease and heart complications. Particulate matter as dust can also be a nuisance. At high concentrations, dust can also affect plants by coating the leaves and impeding photosynthesis. PM_{10} and $PM_{2.5}$ are emitted directly from a source such as unpaved roads or construction sites. Therefore, since this is a construction project, these parameters were monitored at strategic locations within the study area to establish the baseline.

4.3.1 Methodology

Locations and Schedule

Ambient air quality monitoring was conducted at four locations within the study area on the 15th and 16th of July 2022 (Table 4-3 and Photograph 4-1 to 4-4). These locations were selected based on the site boundaries and activities within the area. A&N 1 and A&N 4 respectively are representative of the northern and southern boundaries of the site and A&N 2 is representative of the nearest sensitive receptor, which in this case was a house with occupants who could be affected by particulate matter. A&N 3 was chosen as construction works were on-going in the vicinity of this area.

Table 4-3 Monitoring Locations and Schedule

Monitoring Location	*GPS Coordinates (WGS 84)*		*Date*	*Time*
	Easting	*Northing*		
A&N 1	0630675	1941808	15 July, 2022	8:25 a.m. to 10:40 a.m.
A&N 2	0629987	1942698		11:20a.m. to 2:40 p.m.
A&N 3	0629515	1943084	16 July, 2022	8:55 a.m. to 11:15 a.m.
A&N 4	0628987	1943382		11:25 a.m. to 1:40 p.m.

Figure 4.16 Air monitoring locations

Photograph 4-1 A&N Location 1

Photograph 4-2 A&N Location 2

Photograph 4-3   A&N Location 3

Photograph 4-4   A&N Location 4

On both days of ambient air quality monitoring, the weather conditions were noted to be mostly sunny with gentle winds. However, a slight drizzle was experienced during monitoring at A&N Location 3.

A DustTrak II aerosol monitor (Model 8530) was used to measure Particulate matter ($PM_{2.5}$ and PM_{10}) at each of the four monitoring locations. A description of the equipment is included in Appendix 1. For each monitoring event, the DustTrak II was zero calibrated, placed in an enclosure (to protect from rainfall) and mounted onto a surveyor's tripod. Each parameter was monitored at all locations for a 1-hour period and at a one (1) minute logging interval. Subsequent to field monitoring, data was downloaded on a laptop and 24-hour concentrations of $PM_{2.5}$ and PM_{10} at each location were calculated using the following formula:

$$\frac{Cx}{Cp} = \left(\frac{tp}{tx}\right)^n$$

Where:

n= 0.2 (index);

Cx= 24 hour Concentration;

Cp= 8 hour Concentration;

tp= 8 hour time in minutes and

tx= 24 hour time in minutes.

The estimated 24-hour concentrations were then compared to World Bank Air Quality Guidelines.

Instrumentation

DustTrak II Aerosol Monitors are battery-operated, data-logging, light-scattering laser photometers that provide real-time aerosol mass readings. They use a sheath air system that isolates the aerosol in the optics chamber to keep the optics clean for improved reliability and low maintenance. The DustTrak II monitor measures aerosol contaminants such as dust, smoke, fumes, and mists.

Limitations

No limitations were encountered during the air quality monitoring exercise.

Photograph 4-5 DustTrak II Enclosure mounted on Tripod

Photograph 4-6 Calibration of DustTrak II

4.3.2 Regulatory Framework

In the absence of national laws for air quality, World Health Organization (WHO) and World Bank Guidelines were used for comparison purposes.

The WHO guidelines present recommended limits for health harmful concentrations of key air pollutants both outdoors and inside buildings based on global scientific evidence. Relevant parameters and their respective WHO Guidelines are presented in Table 4-4.

Table 4-4 WHO Air Quality Guidelines

Parameter		Averaging Period	Guideline ($\mu g/m^3$)
Particulate Matter	PM_{10}	24-hour	50
	$PM_{2.5}$	24-hour	25

4.3.3 Results and Discussion

The main sources of air emissions identified within the study area were (i) the road network (vehicular exhaust and the kick-up of dust from trucks transporting material); and (ii) dust from construction sites.

Photograph 4-7 Dump truck transporting material to construction site near A&N1

Photograph 4-8 Vehicles traversing roadway

Photograph 4-9 Dusty Roadway

Photograph 4-10 Crane traversing roadway near A&N4

Table 4-5 and Table 4-6 summarize the results of the air quality monitoring exercise undertaken on 15-16 July 2022 at four locations within the study area (see Appendix 1 for full data reports). Since monitoring of each parameter was only conducted for 1 hour at each location, the Time Weighted Average (TWA) was used to calculate estimated concentrations of $PM_{2.5}$ and PM_{10} for a 24-hour period at each location (see Table 4-7 and Table 4-8).

Table 4-5 Average PM 2.5 Concentrations for 1 Hour Monitoring Period

Monitoring Location	PM 2.5			
	Avg.		TWA (8hr)	
	mg/m^3	$\mu g/m^3$	mg/m^3	$\mu g/m^3$
A&N 1	0.084	84	0.010	10
A&N 2	0.018	18	0.002	2
A&N 3	0.013	13	0.002	2
A&N 4	0.018	18	0.002	2

Table 4-6 PM 10 Concentrations for 1 Hour Monitoring Period

Monitoring Location	PM 10			
	Avg.		TWA (8hr)	
	mg/m^3	$\mu g/m^3$	mg/m^3	$\mu g/m^3$
A&N 1	0.077	77	0.010	10
A&N 2	0.027	27	0.003	3
A&N 3	0.066	66	0.008	8
A&N 4	0.030	30	0.004	4

Table 4-7 Estimated PM 2.5 Concentrations for 24-hour Period

Monitoring Location	Concentration		WHO Guideline ($\mu g/m^3$)
	mg/m^3	$\mu g/m^3$	
A&N 1	0.0080	8.0	25
A&N 2	0.0016	1.6	
A&N 3	0.0016	1.6	
A&N 4	0.0016	1.6	

Table 4-8 Estimated PM 10 Concentrations for 24-hour Period

Monitoring Location	Concentration		WHO Guideline ($\mu g/m^3$)
	mg/m^3	$\mu g/m^3$	
A&N 1	0.0080	8.0	50
A&N 2	0.0024	2.4	
A&N 3	0.0064	6.4	
A&N 4	0.0032	3.2	

$PM_{2.5}$

Estimated 24-hour concentrations of $PM_{2.5}$ ranged from 1.6 µg/m³ to 8.0 µg/m³ at the four air quality monitoring locations (Table 4-7). The highest concentration of $PM_{2.5}$ was recorded at A&N 1.

Figure 4.17 indicates that estimated 24-hour concentrations of $PM_{2.5}$ at all four monitoring locations were significantly less than WHO Guideline of 25 µg/m³ for a 24-hour averaging period.

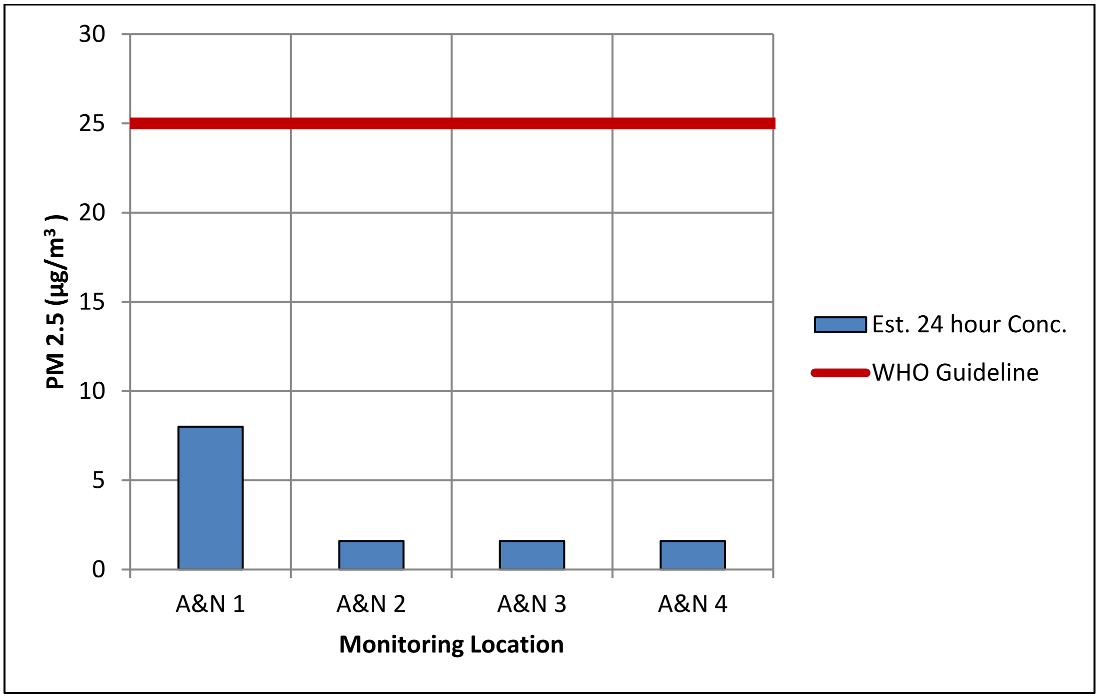

Figure 4.17 Estimated 24 Hour Concentrations of PM 2.5

PM_{10}

Estimated 24 hour-concentrations of PM_{10} ranged from 2.4 µg/m³ to 8.0 µg/m³ at the four air quality monitoring locations (Table 4-8). The highest concentration of PM_{10} was recorded at A&N 1.

Figure 4.18 indicates that estimated 24-hour concentrations of PM_{10} at all four monitoring locations were significantly less than WHO Guideline of 50 µg/m³ for a 24-hour averaging period.

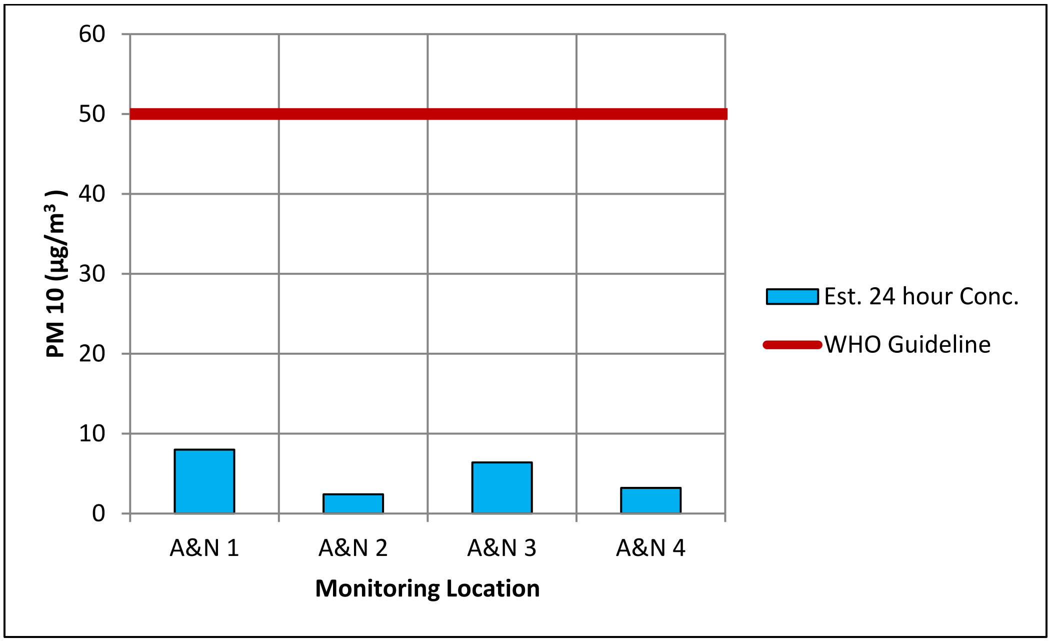

Figure 4.18 Estimated 24 Hour Concentrations of PM 10

4.3.4 Conclusion

Based on the results, the following was determined:

- The main sources of air emissions identified within the study area were from the road network (vehicular exhaust and the kick-up of dust from trucks transporting material); and dust from construction sites.
- Concentrations of both $PM_{2.5}$ and PM_{10} were highest at A&N1.
- However, estimated 24-hour concentrations of $PM_{2.5}$ and PM_{10} at all four monitoring locations were less than the respective WHO Guidelines for a 24-hour averaging period.
- None of the sources of air emissions identified appear to significantly impact the ambient concentrations of $PM_{2.5}$ and PM_{10} within the study area.
- Given that the proposed project site is situated on the coast and vegetation is sparsely distributed, the site experiences good dispersion characteristics.

4.4 Ambient Noise

The objectives of the noise monitoring exercise were to:

- Establish baseline noise conditions within the study area for the proposed Paradise Found Development and
- Compare baseline noise results with noise guidelines developed by the World Health Organization/ World Bank Group.

4.4.1 Methodology

Locations and Schedule

Noise monitoring was conducted for one (1) hour during the daytime and one (1) hour during the nighttime at four (4) locations within the study area on the 15th and 16th of July 2022 (Table 4-9 and Figure 4.19). These locations were selected based on the site boundaries and activities within the area. A&N 1 and A&N 4 respectively are representative of the northern and southern boundaries of the site and A&N 2 is representative of the nearest sensitive receptor. A&N 3 was chosen as construction works for a new helipad were on-going in the vicinity of this area.

Table 4-9 Noise monitoring locations and schedule

Monitoring Location	*GPS Coordinates*		*Date*	*Time*
	Easting	*Northing*		
A&N 1	0630675	1941808	15 July, 2022	Daytime- 8:35 a.m. to 9:35 a.m. Nighttime- 1.04 p.m. to 11:04 p.m.
A&N 2	0629987	1942698		Daytime- 11:30 a.m. to 12:3 p.m. Nighttime- 11.22 p.m. to 12:22 p.m.
A&N 3	0629515	1943084	16 July, 2022	Daytime- 10:11 a.m. to 11:11 a.m. Nighttime- 11.15 p.m. to 12:15 p.m.
A&N 4	0628987	1943382		Daytime- 11:34 a.m. to 12:34 a.m. Nighttime- 10.05 p.m. to 11:05 p.m.

Figure 4.19 Noise monitoring locations

Photograph 4-11   A&N 1

Photograph 4-12 A&N 2 at Night

Photograph 4-13   A&N 3

Photograph 4-14   A&N 4 at Night

A SoundPro sound meter manufactured by Quest Technologies (DL Series) was used to monitor noise levels for one (1) hour during the daytime and one (1) hour during the nighttime at each of the four monitoring locations. For each monitoring event, the sound meter was calibrated, mounted onto a tripod and set to record equivalent continuous sound pressure level (Leq) for a one (1) hour period at one (1) minute logging interval.

After field monitoring, data was downloaded onto a laptop and compared to the World Bank Group's Environmental Noise Management Guidelines.

Instrumentation

The Quest Technologies SoundPro DL is a Type 2 precision integrating instrument designed for use in noise surveys for commercial, industrial and environmental situations. This instrument meets or exceeds the requirements of the following standards:

- ANSI S1.4-1993, Type 2;
- IEC 651-1978; and
- IEC 804-1985, Type 2.

This instrument has a total measurement range between 20 and 140 dB. It has selectable response characteristics (slow, fast, peak and impulse), 3 weighting options ("A", "C" and "Linear") and offer output to serial devices (computers and/or printers) through an RS-232C interface. Additionally, this meter allows the user to select which parameters are to be logged and the exchange rates (3, 4, 5 or 6 dB) at which integrations are performed.

For this monitoring exercise equivalent continuous sound pressure level (Leq) was determined with the meters set on the "Fast" response and "A-weighted" frequency. The instantaneous unweighted peak sound pressure level (Lpeak) was determined with the meter set on the "Peak" response and "Linear" frequency.

Limitations

No limitations were encountered during the noise monitoring exercise.

4.4.2 Regulatory Framework

In the absence of national laws for noise, limits listed in the World bank Group-Environmental Health and Safety Guidelines-Environmental Noise Management Guidelines were used for comparison purposes. The EHS Guidelines state that noise impacts should not exceed the levels presented in Table 4-10 below or result in a maximum increase in background levels of 3 dB at the nearest receptor location off-site.

Table 4-10 World Bank Group Noise Guidelines

Receptor	*One (1) hour L_{eq} (dBA)*	
	Daytime (7:00 a.m.-22:00 p.m.)	*Nighttime (22:00 p.m.-7:00 a.m.)*
Residential; Institutional; Educational	55	45
Industrial; Commercial	70	70

The study area has been zoned for Tourism, but currently commercial activity throughout the region is sparse. Furthermore, residential homes are few and far between. However, it should be noted that the nearest sensitive receptor was a house located at A&N 2.

Given the presence of both residential and commercial buildings within the study area, the results of this noise monitoring exercise were compared to the guidelines for Commercial Areas as well as Residential Areas.

4.4.3 Results and Discussion

Table 4-11 lists the sources of noise identified at each monitoring location.

Table 4-11 Sources of Noise Within the Study Area

Monitoring Location	Sources of Noise	
	Daytime	Nighttime
A&N1	• Vehicles traversing roadway (mainly trucks) • Wind • Birds Chirping	• Vehicles traversing roadway • Insects • Crab catchers
A&N2	• Birds Chirping • Vehicles • Persons Chatting • Heavy Equipment working in the distance	• Vehicle • Wind
A&N3	• Music • Construction work (on Helipad) • Birds Chirping	• Music in the distance • Vehicle
A&N4	• Vehicles traversing roadway • Truck horns • Wind • Birds chirping	• Music in the distance • Vehicles traversing roadway

Photograph 4-15 Dump Truck Transporting Material to Construction Site near A&N1

Photograph 4-16 Bananaquit on Tree at A&N 2

Photograph 4-17 Vehicles traversing roadway near A&N 4

Photograph 4-18 Crane

Table 4-12 and Table 4-13 summarize the results of the noise monitoring exercise undertaken on 15 and 16 July 2022 at four locations within the study area (see Appendix 1 for full data reports).

Table 4-12 Summary of daytime noise monitoring results

Monitoring Location	Daytime			
	L_{eq} (dB)	Lmin (dB)	Lmax (dB)	L_{pk} (dB)
A&N1	58.3	40.3	89.0	120.6
A&N2	49.7	42.1	82.6	109.3
A&N3	55.2	37.4	76.5	104.9
A&N4	60.9	37.4	96.7	111.3

Table 4-13 Summary of nighttime noise monitoring results

Monitoring Location	Nighttime			
	L_{eq} (dB)	Lmin (dB)	Lmax (dB)	L_{pk} (dB)
A&N1	52.8	37.8	76.1	104.6
A&N2	55.3	45.5	78.1	100.6
A&N3	44.9	35.7	63.7	82.7
A&N4	48.8	35.5	69.1	93.8

Figure 4.20 indicates that equivalent continuous sound pressure levels (Leq) were higher during the daytime than the nighttime at all monitoring locations except A&N2.

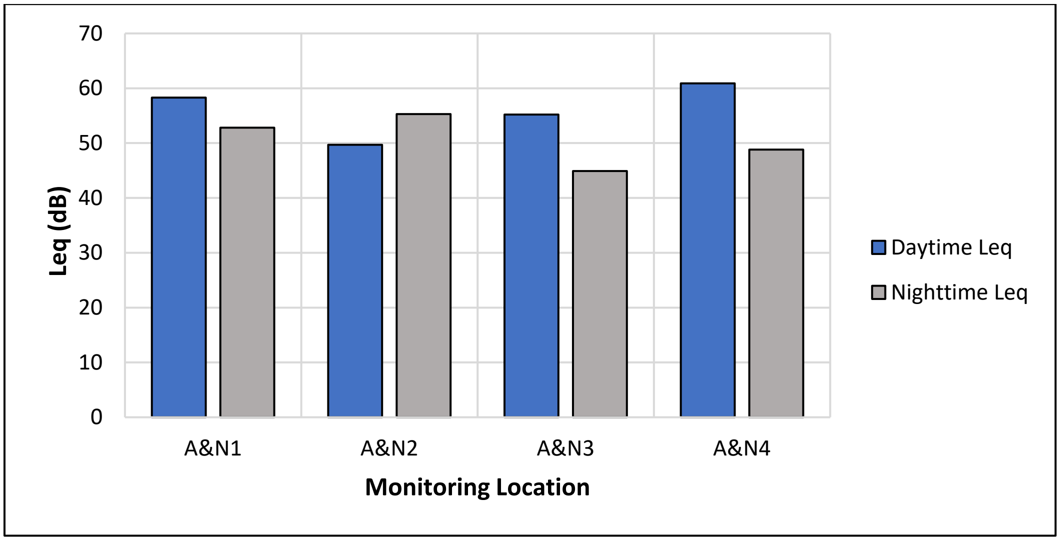

Figure 4.20 Comparison of Daytime Leq and Nighttime Leq

Daytime

Daytime Leq values at the four noise monitoring locations ranged between 49.7 dB and 60.9 dB. The highest daytime Leq was recorded at A&N4 while the lowest daytime Leq was recorded at A&N2 (see Table 4-12).

Figure 4.21 compares the daytime Leq values recorded at each monitoring location to the World Bank Group's Noise Guidelines. The chart indicates that daytime Leq values recorded at the four monitoring locations were below the daytime limit for commercial areas. However, Leq values recorded at A&N1, A&N3 and A&N4 were at, or slightly above, the daytime limit for residential areas.

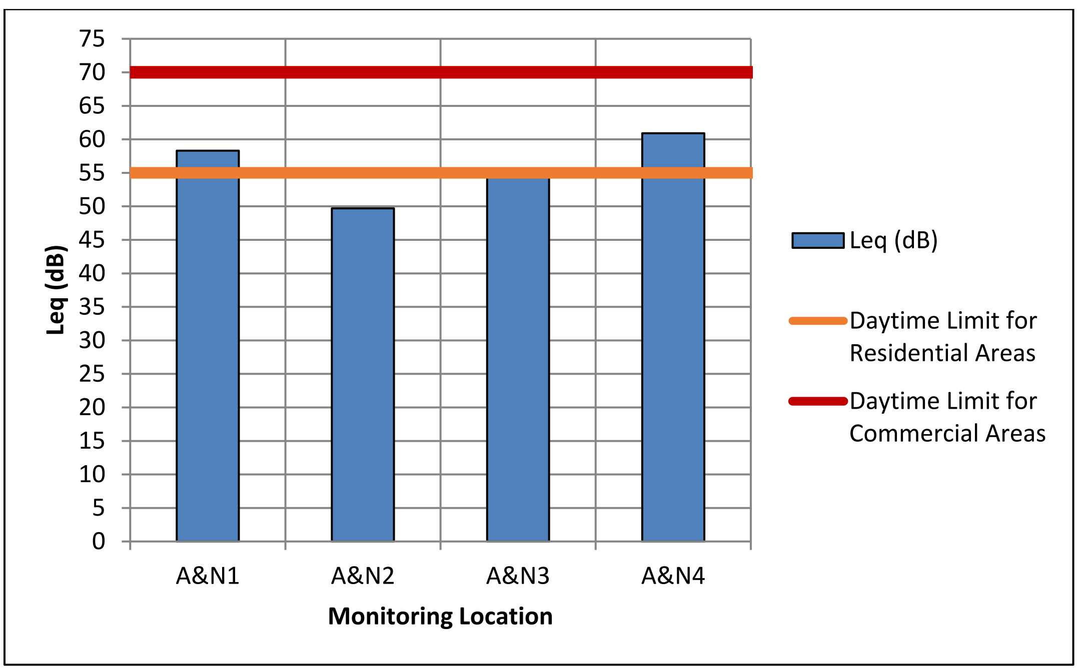

Figure 4.21 Daytime Leq in Comparison to World Bank Noise Guidelines

Nighttime

Nighttime Leq values at the four noise monitoring locations ranged between 44.9 dB and 55.3 dB. The highest daytime Leq was recorded at A&N2 while the lowest daytime Leq was recorded at A&N3.

Figure 4.22 compares the nighttime Leq values recorded at each monitoring location to the World Bank Group's Noise Guidelines. Similar to the daytime, nighttime Leq values recorded at all four monitoring locations were also below the limit for commercial areas. However, Leq values recorded at A&N1, A&N2 and A&N4 were slightly above the daytime limit for residential areas.

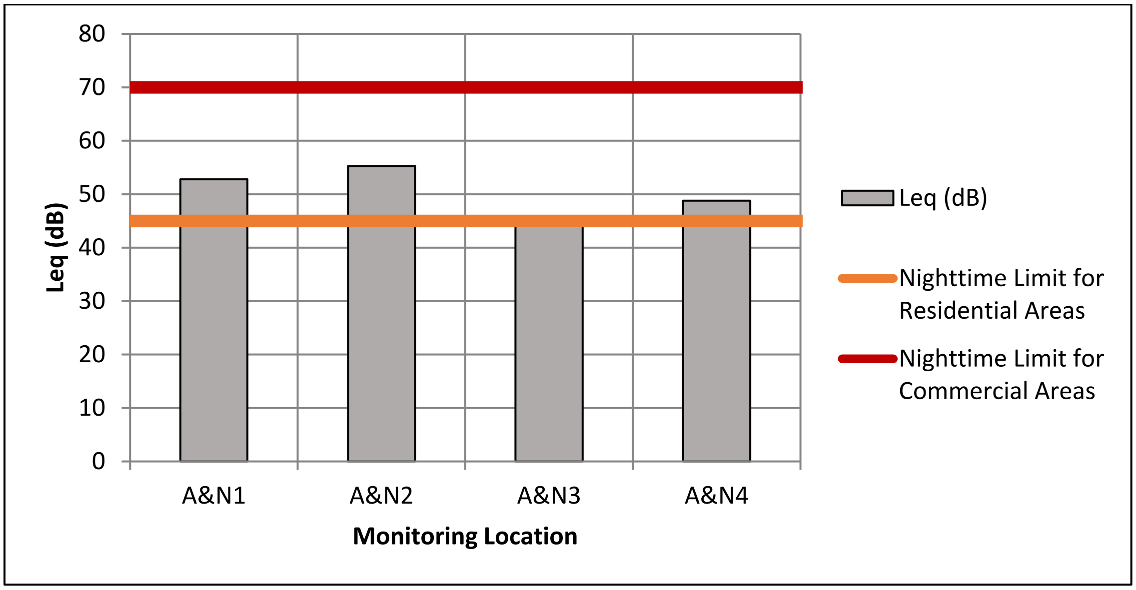

Figure 4.22 Nighttime Leq in Comparison to World Bank Noise Guidelines

4.4.4 Conclusion

Based on the results of the noise monitoring exercise, the following was determined:

- Equivalent continuous sound pressure levels (Leq) were higher during the daytime than the nighttime at all monitoring locations except A&N2.
- Daytime Leq values recorded at the four monitoring locations were below the daytime limit for commercial areas. However, Leq values recorded at A&N1, A&N3 and A&N4 were slightly above the daytime limit for residential areas.
- Similar to the daytime, nighttime Leq values recorded at all four monitoring locations were also below the limit for commercial areas. However, Leq values recorded at A&N1, A&N2 and A&N4 were slightly above the daytime limit for residential areas.
- These results provide an envelope of noise ranges during the day and night, which will be used to assess the impacts of the proposed development on the noise regime.

5 Ecological Surveys

The site footprint occurs at a derelict former development site, with manmade ponds, modified soils and elevations and hard structures. The site includes the original K Club resort footprint, inclusive of the golf course, which was abandoned in 2004. As such, the area is not an undeveloped site but one which had previously undergone extensive modification. Since the abandonment of the K Club development, the only major development has been the opening of the Nobu Restaurant in 2021. However, the entire island of Barbuda, including the Paradise Found site, was severely impacted by the passage of Hurricanes Irma and Maria in 2017.

The habitats identified during previous surveys in 2016 as well as a review of literature include dry forest, ephemeral zones, xerophytic shrubland, salt pond and coastal fringe (Figure 5.1). In addition, there are brackish ponds that were created for the former development.

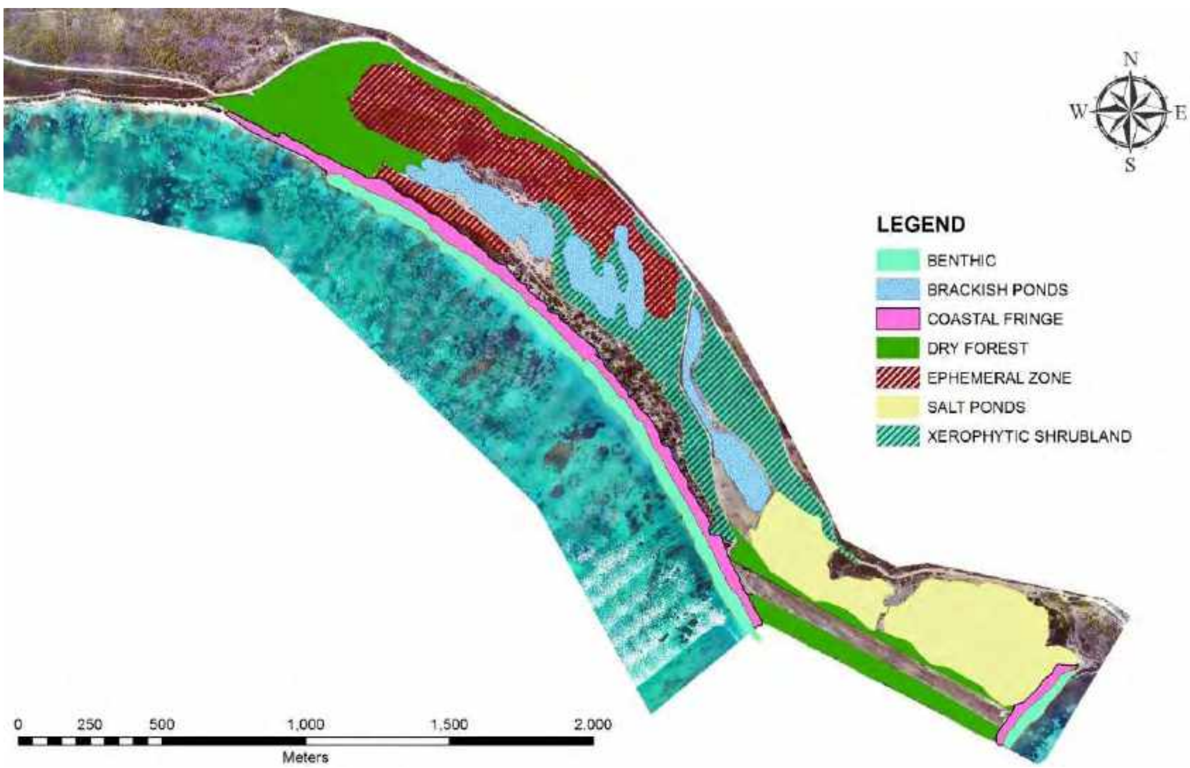

Figure 5.1 Habitat types at the site

5.1 Terrestrial Flora

To determine the dominance of species in the various floral assemblages on the site, a series of observation points were established across the site to make note of the dominant vegetation (Table 5-1 and Figure 5.2). At each observation point, trees and shrub species within a 20m radius with a circumference at breast height (CBH) of ≥ 63 cm were identified. This was used to gauge the dominance of mature tree species. Additionally, plants (smaller trees, saplings, and seedlings) with a CBH of < 63cm were also noted to determine the dominance of the upcoming generation. A handheld GPS unit was used to note each observation point and a digital camera was used to help document the field observations. Rare threatened and endangered species were also noted. The output of the surveys was an update of the list of species, description of the ecological assemblages, habitats and overall ecosystems collated from the 2016 report. Species notes are provided in Appendix 2.

Table 5-1 GPS coordinates of vegetation observation points

Observation Point	Easting	Northing
1	630675	1941808
2	630501	1942650
3	629991	1942721
4	630614	1941967
5	630615	1941956
6	630314	1942965
7	629347	1943576
8	628876	1943405
9	627839	1943509
10	627839	1943510
11	627870	1943627
12	629551	1943110
13	630031	1942891
14	630156	1942779
15	630274	1942872
16	630221	1942408
17	629856	1943027
18	629644	1943051
19	629119	1943317
20	629204	1943445
21	628979	1943382
22	628842	1943379

Figure 5.2 Vegetation observation points

Table 5-2 contains a list of the species encountered. A total of 30 species were encountered on the site across the various habitats identified. Four species were listed as endemic (Locustberry, Dagger Plant, Wild Frangipani and Lignum vitae); one species was listed as near threatened (Lignum vitae); and one species was listed as threatened (Black Mangrove) by the IUCN Red List of Threatened Species. All other species are listed as being of “least concern”.

Table 5-2 List of plant species recorded during vegetation survey 2022

Common name	Scientific name	Status*
Locustberry	*Byrsonima lucida*	Endemic
Wild Tamarind	*Leucaena leucocephala*	Least Concern
Sweet Acacia	*Vachellia farnesiana*	Least Concern
Button Mangrove	*Conocarpus erectus*	Least Concern
Lignum vitae	*Guaiacum officinale*	Near Threatened
Wild Cinnamon	*Canella winterana*	Least Concern
Hogwood	*Comocladia dodonaea*	Least Concern
Loblolly	*Pisonia subcordata*	Least Concern
Strangler Fig	*Ficus citrifolia*	Least Concern
Ram Goat Cherry	*Malphigia linearis*	Least Concern
Bahama Strongbark	*Bourreria succulenta*	Least Concern
Sage	*Lantana involucrata*	Least Concern
Canker Berry	*Solanum racemosum*	Least Concern
Pink Trumpet	*Tabebuia heterophylla*	Least Concern
Giant Airplant	*Tillandsia utriculata*	Least Concern
Christmas Bush / Hog Bush	*Comocladia dodonaea*	Least Concern
Goat Bush	*Castela erecta*	Least Concern
Dagger Plant	*Agave karatto*	Endemic
Cacti (duldul)	*Pilosocereus royenni*	Least Concern
Creeping Bentgrass	*Agrostis palustris (var. Penncross*	Least Concern
Logwood	*Haematoxylon campechianum*	Least Concern
Wild Frangipani	*Pulmeria alba*	Endemic
White Mangrove	*Laguncularia racemosa*	Least Concern
Black Mangrove	*Avivenia germinans*	Threatened
Red Mangrove	*Rhizophora mangle*	Least Concern
Shoreline Purslane	*Sesuvium portulacastrum*	Least Concern
Beach Morning Glory	*Ipomoea pes-caprae*	Least Concern
Seagrape	*Cocoloba uvifera*	Endemic
Seaside Mahoe	*Thespesia populnea*	Least Concern
Coconut Palms	*Cocos nucifera*	Least Concern

*Status based on IUCN Red List of Threatened Species.

5.2 Terrestrial Fauna

5.2.1 Avifauna

Fixed point bird counts were undertaken to describe the avifauna within the site. Based on factors such as access, vegetation type and cover, four bird count locations were established on the site, and these were recorded using a hand-held GPS unit (Table 5-3 and Figure 5.3). All birds seen or heard within a 10-minute period at each point count location were recorded. Fixed point counts were undertaken twice at each location: a morning and an afternoon count. Species lists were prepared at the end of the survey and cross referenced against designated rare, threatened, endangered and endemic species. Other fauna species were observed opportunistically while doing the vegetation survey and the bird counts.

Table 5-3 GPS coordinates of bird count locations

Location	Easting	Northing
BC1	629929	1942864
BC2	630028	1942936
BC3	629923	1942693
BC4	629552	1943119

Figure 5.3 Bird count locations

Species observed at these locations are shown in Table 5-4. Species notes are included in Appendix 2. A total of twenty bird species were observed on the site either during the bird counts or opportunistically. Of these species, the West Indian Whistling Duck and Caribbean Coot are considered near threatened and the Barbuda Warbler is listed as vulnerable. All other species are listed as being of "least concern".

Table 5-4 Bird species observed

Common name	Scientific name	Bird count location				Status
		1	2	3	4	
Barbuda Warbler	*Dendroica subita*		x		x	Vulnerable
Helmeted Guineafowl**	*Numida meleagris*					Least Concern
Ground doves	*Columbina passerina*	x	x		x	Least Concern
White-winged Dove	*Zenaida asiatica*		x			Least Concern
Turtle Dove	*Zenaida aurita*	x				Least Concern
Black-winged Stilt	*Himantopus himantopu*	x		x		Least Concern
West Indian Whistling-duck**	*Dendrocygna arborea*					Near Threatened
Brown Pelican	*Pelecanus occidentalus*			x		Least Concern
Cattle Egret	*Bubulcus ibis*	x				Least Concern
Scaly breasted Thrasher	*Margarops fuscus*		x			Least Concern
Osprey	*Pandion haliaetus*	x				Least Concern
Antillean Crested Hummingbird**	*Orthorhyncus cristatus*					Least Concern
Least Tern	*Sterna antillarum*	x	x	x	x	Least Concern
Black-Faced Grassquit	*Tiaris bicolour*		x			Least Concern
Little Stilt	*Calidris minuta*		x			Least Concern
Carib Grackle	*Quiscalus lugubris*	x				Least Concern
Wilson's Plover	*Charadrius wilsonia*		x			Least Concern
Bananaquit**	*Coereba flaveola*					Least Concern
Lesser Antillean Bullfinch**	*Loxigilla noctis*					Least Concern
*Caribbean coot	*Fulica caribaea*					Near Threatened

Note: Status based on IUCN Red List of Threatened Species
* Species observed during 2016 survey only
** Species observed opportunistically

5.2.2 Other Fauna

Table 5-5 lists the other faunal species observed on the site. Species notes are included in Appendix 2. The only vulnerable species listed was the Red-footed Tortoise. All other species are listed as being of "least concern".

Table 5-5 Other faunal species observed

Common name	Scientific name	Status*
Donkey	*Equus africanus asinus*	Least Concern
European Fallow Deer	*Dama dama*	Least Concern
Iguana	*Iguana iguana*	Least Concern
Red-footed Tortoise	*Chelonoidis carbonaria*	Vulnerable
Mongoose	*Herpestes auropunctatus*	Least Concern
Hermit crab	*Paguroidea sp)*	Least Concern
Fiddler crab	*Uca sp*	Least Concern
Caribbean Duppy Crab	*Cardisoma guanhumi*	Least Concern

**Status based on IUCN Red List of Threatened Species*

5.3 Habitats / Ecosystems Within the Site

Based on site investigations, ecological surveys and literature review, several types of habitat / ecosystems were identified within the site and immediate surrounding study area. The main ecosystem types found at the Paradise Found site were mangroves, dry forest, ponds, sand dunes and rocky shore. The western end of the property is occupied by shrub/scrub type ecosystems with xerophytic vegetation. Various species of cacti dominate the area. Rocky shores exist along sections of the shoreline, sand dunes occur in the middle sections of the property and there are mangrove stands on the landward side, however, not to the easternmost limits. The eastern section of the property is characterised by dry limestone forest, with large areas occupied by invasive wild cotton species along the roadway. A large proportion of the site is bare soil (Figure 5.4 and Figure 5.5). The major ecosystems are described in the following sections.

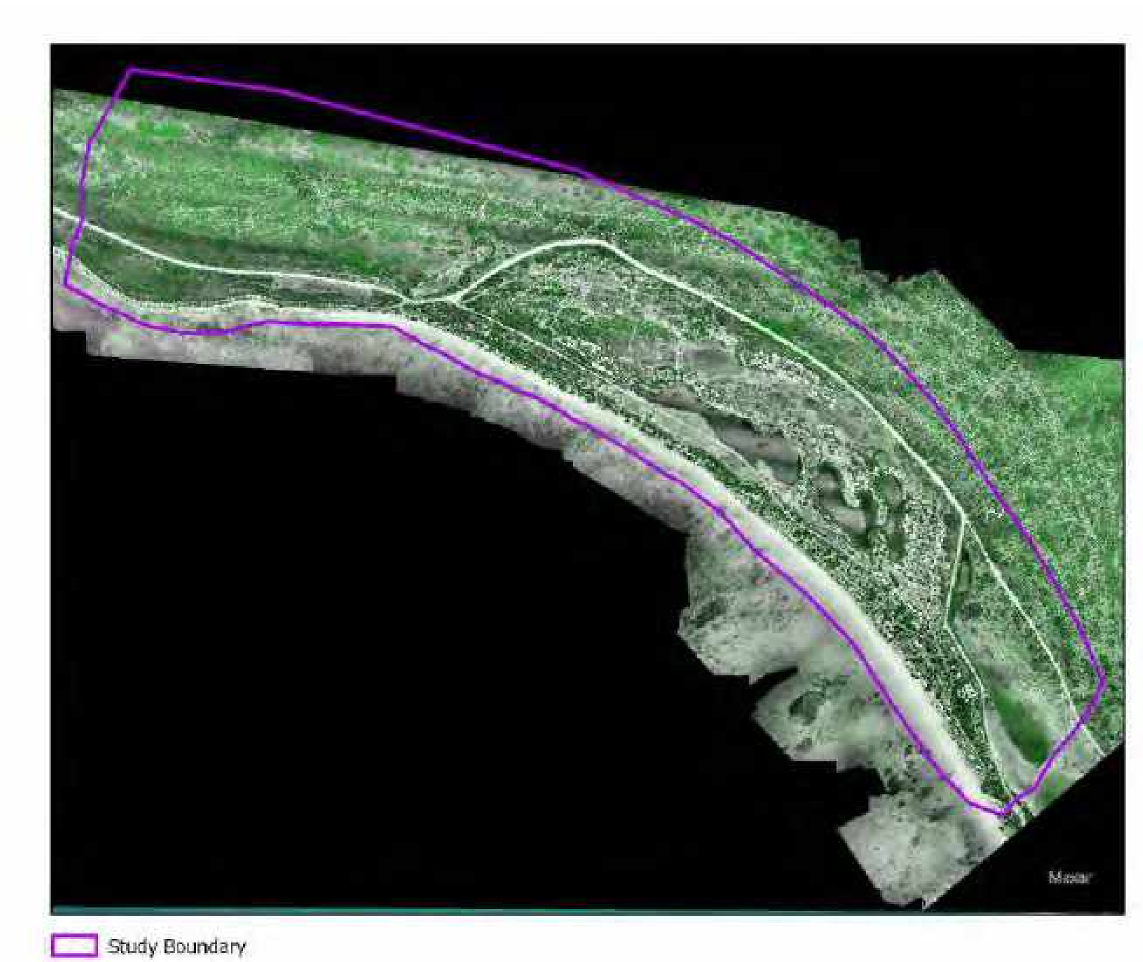

Figure 5.4 A false colour remotely sensed image showing the distribution of vegetation throughout the site. Green areas are vegetation while white areas are bare soil and built structures. Note there are several open bare areas, especially along the ephemeral zone.

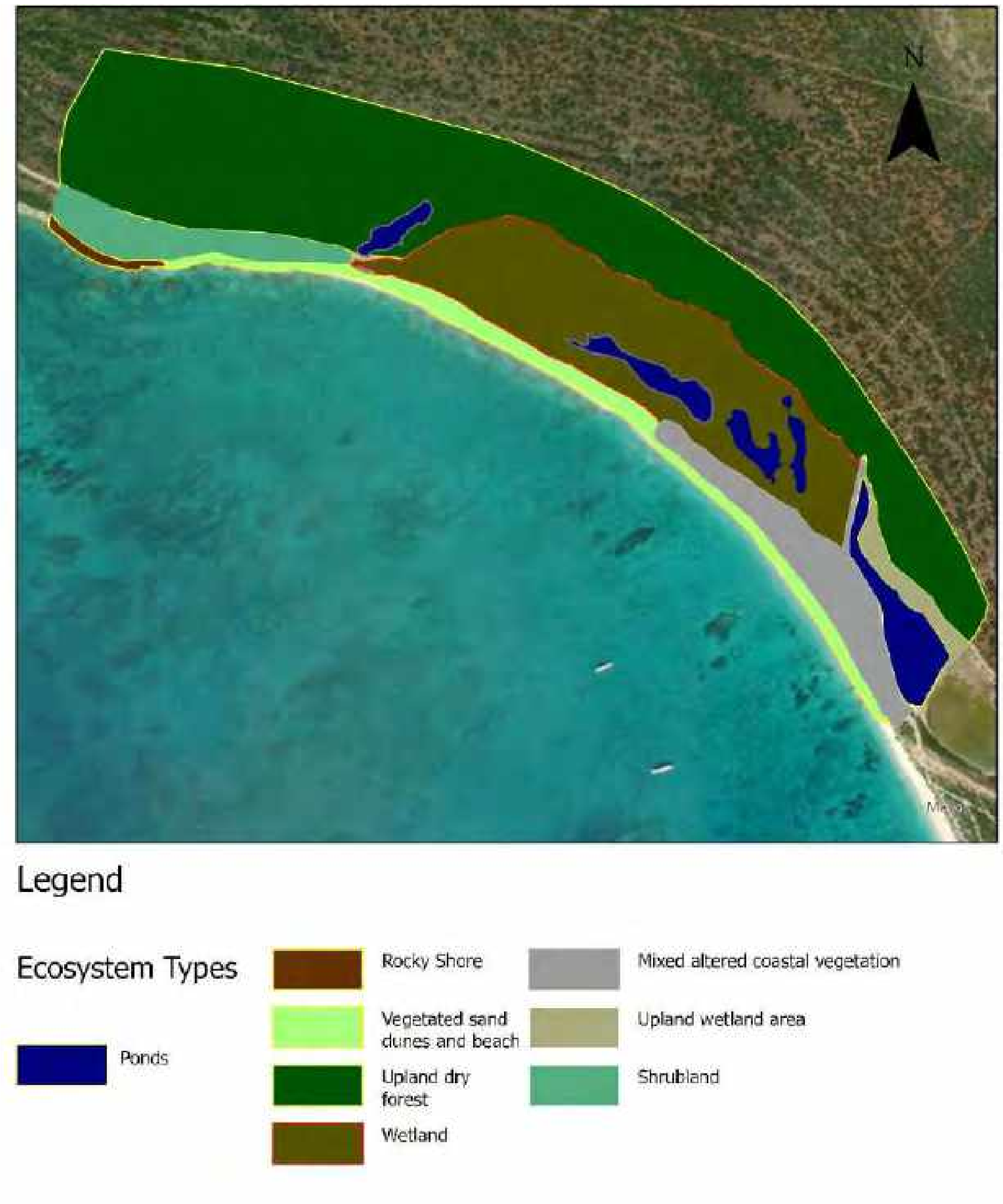

Figure 5.5 Map of the different ecosystem types observed across the proposed development site

5.3.1 Dry Forest

This ecosystem is located to the west, southwest and northwest of the site and is defined by its dense patches of broad-leaved evergreen sclerophyllous tree types such as locustberry (*Byrsonima lucida*), wild tamarind (*Leucaena leucocephala*) sweet acacia (*Vachellia farnesiana*), button mangrove (*Conocarpus erectus*), lignum vitae (*Guaiacum officinale*), wild cinnamon (*Canella winterana*), hogwood (*Comocladia dodonaea*), loblolly (*Pisonia subcordata*), strangler fig (*Ficus citrifolia*), ram goat cherry (*Malphigia linearis*), Bahama strongbark (*Bourreria succulenta*), sage (*Lantana involucrata*), canker berry (*Solanum racemosum*) and pink trumpet (poui) tree (*Tabebuia heterophylla*).

Shrubs in this habitat include the Christmas bush (*Comocladia dodonaea*) which causes a rash similar to poison ivy when touched, and goat bush (*Castela erecta*). The habitat also includes native agaves such as the National plant of Barbuda, the dagger plant (*Agave karatto*) and cacti (see photos below).

Photograph 5-1 Typical dry forest (2016)

Photograph 5-2 Typical dry forest (2022)

Photograph 5-3 Dagger plants

Photograph 5-4 Christmas bush

Photograph 5-5 Candelabra cactus

The undergrowth is dominated by the grass Agrostis palustris (*var. Penncross*) a non-native species known to be used extensively on golf greens throughout the Caribbean and may be a relic of the abandoned golf course.

Several donkeys (*Equus africanus asinus*) were observed roaming freely and grazing on both grass and shrubs in this ecosystem(see photo below). While the European fallow deer (*Dama dama*) was not observed on site in this habitat during the 2022 survey, they were observed during the 2016 survey.

Photograph 5-6 Donkey observed during 2022 surveys

Iguanas (*Iguana iguana*) were also observed within this habitat and are common on the island. The iguana is also non-native and anecdotal evidence designates the appearance of this species after Hurricane Louis, thought to have come over on debris by sea from neighbouring Guadeloupe (SWI, 2016).

The red-footed tortoise (*Chelonoidis carbonaria*) is found in this ecosystem as they prefer places that help with their thermoregulation so are often found under shrubs and dry leaf litter. While not observed during the 2022 survey, they were identified during the 2016 survey.

5.3.2 Xerophytic Shrubland

This zone is extremely dry with thin soil cover dominated by limestone outcrops. It comprises stunted sclerophyllous (scrub) vegetation with a dominance of several *Acacia sp*, logwood (*Haematoxylon campechianum*), and wild tamarind (*Leucaena leucocephala*) which were noted to be stunted (less than 3m). Wild frangipani (*Pulmeria alba*), dagger plant (*Agave karatto*), and cacti such as duldul (*Pilosocereus royenni*) were also in abundance, all less that 3m in height (see Photographs 5-7 and 5-8). The undergrowth was notably sparse or non-existent with vegetation established on thin soil lenses.

Photograph 5-7 Example of xerophytic shrubland

Photograph 5-8 Example of xerophytic shrubland

The Barbuda Warbler (*Dendroica subita*) which is endemic to Barbuda was observed at several sites within this habitat and is one of the country's four globally threatened birds. The helmeted guineafowl, (*Numida meleagris*), an introduced species, was also observed in this habitat. Other bird species included ground doves (*Columbina passerina*), white-winged doves (*Zenaida asiatica*) and turtle doves, (*Zenaida aurita*).

Ground lizards (*Ameiva griswoldi*) and several Anoli species were prevalent in this habitat living amongst the leaf litter.

5.3.3 Ephemeral zone

Ephemeral zones are habitats that have developed in response to extremes of drought and temporary flooding, forming shallow ponds. This ecosystem was identified in two areas of the site; to the north and to the south along the road into the site. The zones comprise clumps of stunted mangrove with vast expanses of non-vegetated areas in between.

Northern Ephemeral Zone

The vegetation forms isolated clusters separated by large expanses of clay loam soil with sporadic outcrops of hard limestone. During the wet season, these areas become saturated. These ephemeral ponds to the north were observed to be more short-lived. In periods of high precipitation there is evidence that this area can become quite extensive, as observed during the 2016 investigation of this habitat. The plant clusters noted in the north central of the site are predominantly buttonwood mangrove (*Conocarpus erectus*) a dense multiple-trunked mangrove plant known for its ability to withstand harsh environments with salty and dry soils and its tolerance of temporal flooding and extended periods of drought as found in this habitat. The plant clusters are between 1–4m with shorter plants dominating in the middle of the habitat. Buttonwood mangroves can grow to substantial heights in areas with a more stable soil moisture content.

Traversing from west to east across this habitat, the dominant plant type changes to the white mangrove (*Laguncularia racemosa*) another inland mangrove species, which can be seen in the foreground and midground forming a fringe in front of the button mangrove stand. Usually quite tall, in this habitat the white mangrove varied from 1-3m. It can develop both pneumatophores or silted roots and, in this habitat, only stilted roots were observed.

To the northeast of this habitat, above the easternmost water body on the site, the dominant vegetation transitions to the more salt tolerant black mangrove (*Avivenia germinans*). The black mangrove is also able to tolerate anaerobic soil conditions, where it develops pneumatophores or breathing roots which emerge as pipes from the ground. The black mangrove does not form dense clusters as found with the button mangrove but in solitary stands.

Southern Ephemeral zone

The southern ephemeral zone is well established and differs from the comparable habitat to the north in that the water is retained for longer and forms a shallow seasonal pond used by a diversity of wading birds and coastal birds. It has very little vegetation within the pond itself but its northern and southern fringe are framed with clumps of white mangrove (*Laguncularia racemosa*).

The pond is bordered to the south by dense mangrove fringe. The water table is very high in this region and may explain the long retention time of this ephemeral pond. The pond is fairly clear with fine marl muds lining its base (see photographs 5-9 and 5-10).

Photograph 5-9 Southern ephemeral zone

Photograph 5-10 Southern ephemeral zone

Donkeys were prevalent in this habitat and were observed feeding on the button mangrove plants. The dominant wading bird was the black-winged stilt (*Himantopus himantopus*) often accompanied by the Caribbean coot (*Fulica caribaea*), and other wading and sea birds such as the vulnerable West Indian Whistling-duck (*Dendrocygna arborea*).

Occasional hermit crabs *(Paguroidea sp*) were noted in the mangrove fringe as well as the fiddler crab (*Uca sp*.) and the Caribbean duppy crab (*Cardisoma guanhumi*), inhabiting burrows near the shoreline.

5.3.4 Mangroves

The mangrove forest ecosystem occurs as a sparse open forest, in patches and thin stands along the ephemeral zone and along the fringes of the brackish ponds. The white mangrove was found to be distributed throughout the site; their stature improving with greater freshwater supply. Very few red mangroves were seen at the edges of the salt pond within the property boundary (the western pond) in some areas. Some patches were still showing the effects of the hurricane winds with many trees toppled over and dead. The mangrove stands that appeared healthiest were those along the fringes of the ponds, particularly at Pond #2, which showed signs of algal mats. Other stands were seen along the transition zone between the sand dunes and the flatter upland areas. The substrate was a sandy loam in the upper reaches, upgradient of the brackish ponds, while down-gradient of the ponds it was a moist sandy clay. Nearer to the shore, the soil type was a loose sand. Overall, the mangrove forest was found to be degraded. There was significant distance between stands and several different species of trees, including the invasive wild cotton, was observed between stands and therefore competing for the resources. Moreover, several of the mangrove stands appeared either dead or undergoing die-back.

Figure 5.6 Mangrove trees along the fringes of an artificial pond created along the western limits of the site. These mangroves receive some fresh water from a spring north of the pond. The trees at the location were of a better stature than those within the ephemeral zones and along the fringes of the salt pond.

Figure 5.7 Mangroves within a section of the ephemeral zone near pond 2. These trees are significantly shorter, and some are dead.

Figure 5.8 Dead mangrove stands, reportedly damaged during Hurricane Irma and never recovered

5.3.5 Coastal fringe

Nearest the sea, plants such as the succulent shoreline purslane (*Sesuvium portulacastrum*) were observed alongside the sand runner, beach morning glory (*Ipomoea pes-caprae*) (Photograph 5-11), and coastal grasses that trap sand to form small dunes. However, most of the dunes along the shoreline of the K-club were removed to accommodate the development (Photograph 5-12). Further to the west small sand dunes were noted. The coastal fringe exhibits vegetation succession landward from vines and shrubs to coastal trees, such as seagrape (*Cocoloba uvifera*), seaside mahoe (*Thespesia populnea*), and coconut palms (*Cocos nucifera*) further inland.

Photograph 5-11 Coastal fringe vegetation

Photograph 5-12 Beach gradient with coconut trees in the background

Bird species observed included the Brown Pelican and Least Tern.

5.4 Wetland/Ponds

5.4.1 Brackish Ponds

The site has three prominent and permanent ponds of varying sizes located at the southern half of the site (Figure 5.9). One pond is natural in origin, the other two are man-made, constructed during the development and landscaping of the former golf course. The topography is flat with groundwater located a few metres below ground surface. The ponds are brackish and contribute to a particular type of habitat.

Figure 5.9 Pond locations

Pond 3

Located to the centre of the site, Pond 3 is a manmade pond created from former excavations to provide fill material to raise the site for the former golf course (Photographs 5-13 and 5-14). It is the deepest pond on site dropping to 5m to the west. It has two eyots, or small islands, located within the eastern and western lobes.

The eastern eyot is comprised predominantly of a dense white mangrove cluster and the western eyot is developed on Codrington Limestone colonized by white mangrove (Photographs 5-15 and 5-16). It is important to note that white mangrove is a pioneer species and establishes and stabilizes when favourable conditions prevail. This encourages the further colonization by other mangrove species and the habitat matures. The fringe of the pond is dominated by this species with other dry forest vegetation occurring towards the west. The vegetation in this area also showed the impacts of the passage of the two hurricanes in 2017.

Photograph 5-13 Pond 3

Photograph 5-14 Pond 3

Photograph 5-15 Eyot in pond 3

Photograph 5-16 Mangrove fringe pond 3

Pond 2

Pond 2, located to the east of Pond 3, was noted to be an ecologically balanced pond with sufficient water clarity, green algae hornwort (*Ceratophyllum demersum*) and an abundance of fish and wading birds. Pond 2 is comprised of two lobes located to the east and west and surrounded by white, red and button mangrove (Photographs 5-17 and 5-18). The pond is on average 2m deep.

The only fish species observed was the sleeper goby (*Gobiomorus dormitor*), which is native to marine, fresh and brackish waters and is diadromous (migrates between freshwater and saltwater). Both lobes showed evidence of green algae (Photographs 5-19 and 5-20). Anecdotal evidence is that Tarpon (*Megalops atlanticus*) can also be found in the ponds.

Photograph 5-17 Pond 2 vegetation

Photograph 5-18 Pond 2 vegetation

Photograph 5-19 Pond 2 algae

Photograph 5-20 Pond 2 algae

Pond 1

Pond 1, located to the east of the site is a lenticular pond of two lobes, the second being wider and close to the salt pond, a prominent feature to the east of the site footprint. For this study the two lobes were designated as Pond 1 West and Pond 1 East. Pond 1 West is surrounded by red mangrove and is known for having large tarpon and carp. Pond 1 East is a shallow broad pond sparsely vegetated along its fringe with xerophytic vegetation as well as the more salt tolerant white mangrove.

5.4.2 Salt Ponds

The salt ponds are located to the east of the site footprint, and for this study both lobes, east and west, have been treated as one habitat. The salt ponds provide important ecosystem services including attenuation of freshwater runoff to the sea, erosion control, and retention of nutrients and sediments. They also, along with the mangrove footprint, provide critical habitat and food resources for resident and migratory birds.

The salt ponds on the site footprint are surrounded by xerophytic vegetation and when mangrove plant species were observed these were predominantly white mangrove (*Laguncularia racemosa*), which exists in environments that have seasonal fluctuations in salinity (Photograph 5-21). They rarely survive over 50ppt. The plants observed within the salt pond were predominantly dead or dormant plants due to the high salinity (95ppt).

Aesthetically, the salt ponds are known to vary in colour and this is due to different assemblages of algae, which respond to the varying salinity of the salt pond throughout the year. During the wet or raining season, the water levels are higher and the salinity decreases. Brown algae predominate and lend their colour to the salt ponds creating an orange-brown hue. During drier periods, the colour dramatically changes to bright pink due to the then dominant halobacteria (*Archaea sp*).

Photograph 5-21 Salt pond

6 Status of the Ponds

From satellite imagery (Figure 6.1), four ponds can be observed within the limits of the project site. Anecdotal information from the residents is that three of these ponds are artificial; namely Ponds 2, 3 and 4. The westernmost pond (Pond 4) is reportedly the most recently created. It is reported to have been created (anecdotal evidence) as a result of freshwater exploration, as there is a spring just to the north of it. The depths within the ponds range typically from very shallow at their edges to depths in excess of 10m in the middle sections. From the water quality analyses, all the ponds have high levels of salts. The sample results discussed later in this chapter show salt levels even higher than the ambient marine environment (sea water) for pond #1, while the others are brackish. Details on water quality are provided in the following pages.

Figure 6.1 Ponds within the property boundary

6.1 Description of the Ponds

Pond # 1

Pond one is an elongated pond to the east of the property. A raised marl road separates this pond from the salt pond to the east. During a site visit it was observed that the road elevation was not much higher than the pond's water level. This pond's water chemistry should therefore indicate high salt content from exchange between the two systems during the rainy season when there is hydrologic connectivity. Along the periphery of the eastern section of the pond, there was very sparse vegetation, an indication of saline water conditions. Only a few stands of vegetation could be observed along its eastern limits. At the upper northwest end, however, there were thicker stands of vegetation along the banks of the pond. This is likely due to more tolerable conditions as a result of freshwater input from overland flows originating at higher elevations.

Figure 6.2 A view of pond #1, looking east. The pond is dry in some areas (even walkable) and in other areas there is typically 0.25m and deeper water

Pond # 2

Pond 2 is the horseshoe shaped pond with two lobes (Figure 8.3). Pond 2 has distinctively denser fringing vegetation that appears to be healthy. There is evidence of marl being dumped along sections of the pond's edges and single mangrove trees were observed to be growing within the limestone type soil. Noteworthy was the green colour of the water body and the presence of thick algal mats along its edges. This indicates a source of nutrients entering the pond, which has implications for dissolved oxygen levels and therefore biological health in the pond. A water sample was taken for analysis to quantify these observations. This pond's water chemistry is expected to indicate high salt content from exchange between the two systems during the rainy season when there is hydrologic connectivity. Along the periphery of the eastern section of the pond there was very sparse vegetation, an indication of saline water conditions. Only a few stands of vegetation could be observed along its eastern limits. At the upper northwest end, however, there were thicker stands of vegetation along the banks of the pond. This is likely due to more tolerable conditions from freshwater input coming from overland flows from the higher elevations.

Figure 8.3 Pond#2 showing the green discolouration and algal mats observed at the pond's edges. Note the vegetation along the pond appears healthy

Pond 3

The structure of Pond 3 was noted to be degrading as the embankments appeared eroded. There was also fresh marl material dumped around the pond's back and front bays. The water in the pond appeared to have good clarity however, and wildlife could be seen wading in the water. The pond is reportedly known to house a variety of large fishes such as tarpon, mullet, barracuda and mangrove snapper. Fringing vegetation along the pond's periphery comprised mainly of white mangrove. The mangroves along the pond's embankment had diminutive stature and open canopy and appeared dead in some areas and dying (dead trees within stands) in others. Anecdotal information from residents indicate that the mangroves were impacted during Hurricane Irma and never recovered.

Figure 6.4 Pond 3

Pond 4

Pond #4 is located at the north-west corner of the property (Figure 6.5). Its existence is due to the property owners exploring the possibility of freshwater resource development from groundwater in the area as well as for marl material. It was reported that there is a spring north of the pond, which feeds freshwater into it. Anecdotal information provided is that the pond only has significant volumes of water when it rains heavily and runoff from the surrounding catchment contributes to its volume. The beach area elevation is also higher than the area of the pond, hence, flood waters are stored within it. The pond had white mangroves within and along its periphery. The stands were of substantially greater stature compared to those fringing ponds 2 and 3. Landcover around the pond was a mix of trees and shrubs, with no immediate land use in the vicinity except for a few isolated cabins on the southern section of the roadway (on the seaward side).

Figure 6.5 A panoramic view of pond#4. Only the lower elevations are inundated as it had not rained for a long time in Barbuda

6.2 Water Quality in the Ponds

The ponds were assessed for their baseline water quality, to give a picture of what conditions are prior to the development. From field observations, all except pond #2 seemed to show generally good water quality conditions (Figure 6.6). Circulation within the upper regions of the water column was evident from the ripples on the water surface, and wildlife could be observed foraging in and around the ponds. There was also no unusual smell detected from the edges of the ponds. Pond #2, however, showed signs of nutrient accumulation, in that there were significant algal masses along the inner edges of the ponds and the surface showed a distinct green discolouration. This was reportedly observed following the last hurricane (Irma).

Figure 6.6 A comparison of the water clarity between Pond 2 (left) and Pond 3 (right)

On the contrary, the physico-chemical analysis of the samples showed that neither nitrate nor phosphate levels were high in the pond. This may require further investigations to determine the cause of the green discolouration in that specific pond. Samples were taken at the locations shown in Figure 6.7. An excerpt of the water quality analysis report is presented in Figure 6.8.

It is worth noting that according to the analyses, salinity levels in the ponds (samples 1-4 and control) are higher than that of the ambient marine (seawater). Based on the salinity readings from the samples analysed, pond #1 can be described as hypersaline (its salinity level is significantly greater than seawater). Nitrate and phosphate levels are well within the standards, even for pond #2, suggesting that the green discolouration observed may be a result of something other than the introduction of nutrients into the system.

Biological Oxygen Demand (BOD) is a measure of the amount of oxygen required to remove waste organic matter from water in the process of decomposition by aerobic bacteria. Higher BOD indicates more oxygen is required, i.e., there is less for oxygen-demanding species to feed on, and signifies lower water quality. Low BOD means less oxygen is being removed from water, so it is generally purer.

The results of the water quality analysis show that BOD levels are higher in the ponds than in the marine environment, which is reasonable given that their salt and turbidity levels (an indication of suspended sediments) are also higher. Both the ponds and the sea environment are within satisfactory ambient standards for Antigua and Barbuda (the US EPA standards) and are in keeping with ambient standards for recreational purposes.

Figure 6.7 Locations of sampling for water quality testing

Sample ID	Sample Description	Faecal coliform (<200) cfu/100ml	Escherichia coli[1] (126)	pH	Turbidity NTU	Salinity ppm	Nitrate ppm	Phosphate[2] ppm	BOD Ppm
S#1	Brackish pond	ND	ND	8.44	3.65	67000	0.02	0.47	11.3
S#2	Brackish pond	ND	ND	8.04	5.52	47940	<0.02	0.22	11.3
S#3	Brackish pond	ND	ND	8.05	8.55	47950	<0.02	0.20	8.4
S#4	Brackish pond	ND	ND	8.30	106	44420	<0.02	0.11	5.6
S#5	Marine	ND	ND	8.26	1.27	33050	<0.02	0.06	5.0
S#6	Marine	ND	ND	8.51	1.97	33160	<0.02	0.15	5.0
S#7	Marine	ND	ND	8.38	1.28	33130	<0.02	0.44	<5.0
Control	Control	ND	ND	8.04	8.36	48550	<0.02	0.12	5.0

Figure 6.8 An excerpt of the water quality analyses report by the Department of Analytical Services, Antigua. Ministry of Agriculture

6.3 Site Water Levels

At the time of the inspection, no above-ground surface water was observed. The ephemeral zones up-gradient and down-gradient of the brackish ponds were saturated in some sections and moist in others, but no water could be seen above the ground's surface. The ephemeral zones, as the name suggests, are often inundated after heavy showers, since the area landward of the site is at a higher elevation and so too is the beach area, due to the sand dunes on the backshore. Therefore, all runoff ends up ponding in these zones.

Water level rods were marked and erected at several locations throughout the site, along the periphery of the brackish ponds and within the ephemeral zones, to measure water depths above the surface in the event that the area experiences heavy or prolonged rainfall in the months to come (Figure 6.9 and Figure 6.10 and Table 6-1). The readings would be recorded and measured against an established datum, determined by the topographic land surveyor.

Figure 6.9 The distribution of the water levels monitoring points across the site, established for baseline and post development monitoring

Figure 6.10 Water level monitoring point

Table 6-1 Water monitoring location and description

WL Name	Water level pole map ID	Location Description	GPS coordinates
WL#2	458	Between Pond 2 lobes	17.56795 N 61.77338W
WL #3	459	Back yard of Pond 3 centre	17.56994N 61.77635W
WL# 4	460	Front yard of Pond 3 bottom	17.56776N 61.775W
WL # 5	461	Ephemeral Zone along roadway	17.56967N 61.77829W
WL#1	463	Mad-made pond -Western Boundary	17.57341N 61.78556W
WL# 6	465	Low Lying area behind Pond 3 head	17.57166N 61.77873W
WL# 7	466	Behind guest cottages	17.56652N 61.7709W

7 Land Use and Landcover (LULC)

Landcover over the site is a mixture of mangrove stands, dry forest, shrubland and open water bodies. There are ponds that were created (the brackish ponds) and naturally occurring salt ponds. The main land uses are residential and resort development and associated amenities. Land development is minimal and mostly restricted to coastline areas. A comparison of historical imagery using Google Earth shows that land cover and land use have not changed much over the last nearly two decades (Figure 7.1). The upper reaches in the watershed are predominantly shrubland and dry forest, while the lower regions have minimal human development.

Figure 7.1 Google Earth imagery showing land use from 2005 to 2020

8 Watershed Characterisation

The Paradise Found project site is shown in Figure 8.1 at the south-western section of the island shoreline. Elevations over the project area range from sea level (0m MSL) to about 10m above mean sea level, and these elevation changes occur gradually. The watershed drains toward the south, towards the Caribbean Sea. Note that no rivers were detected during the site reconnaissance, hence the flow paths are apparently generated from natural gradients in the topography of the site, where water drains during and immediately after significant rain events, and hence are ephemeral. The drainage density of these flow paths can be described as very sparse, contributing to a short residence time of water within the site's catchment. The geology is limestone, hence infiltration rates are high in the catchment except in the lowest regions where fluvial deposits occur.

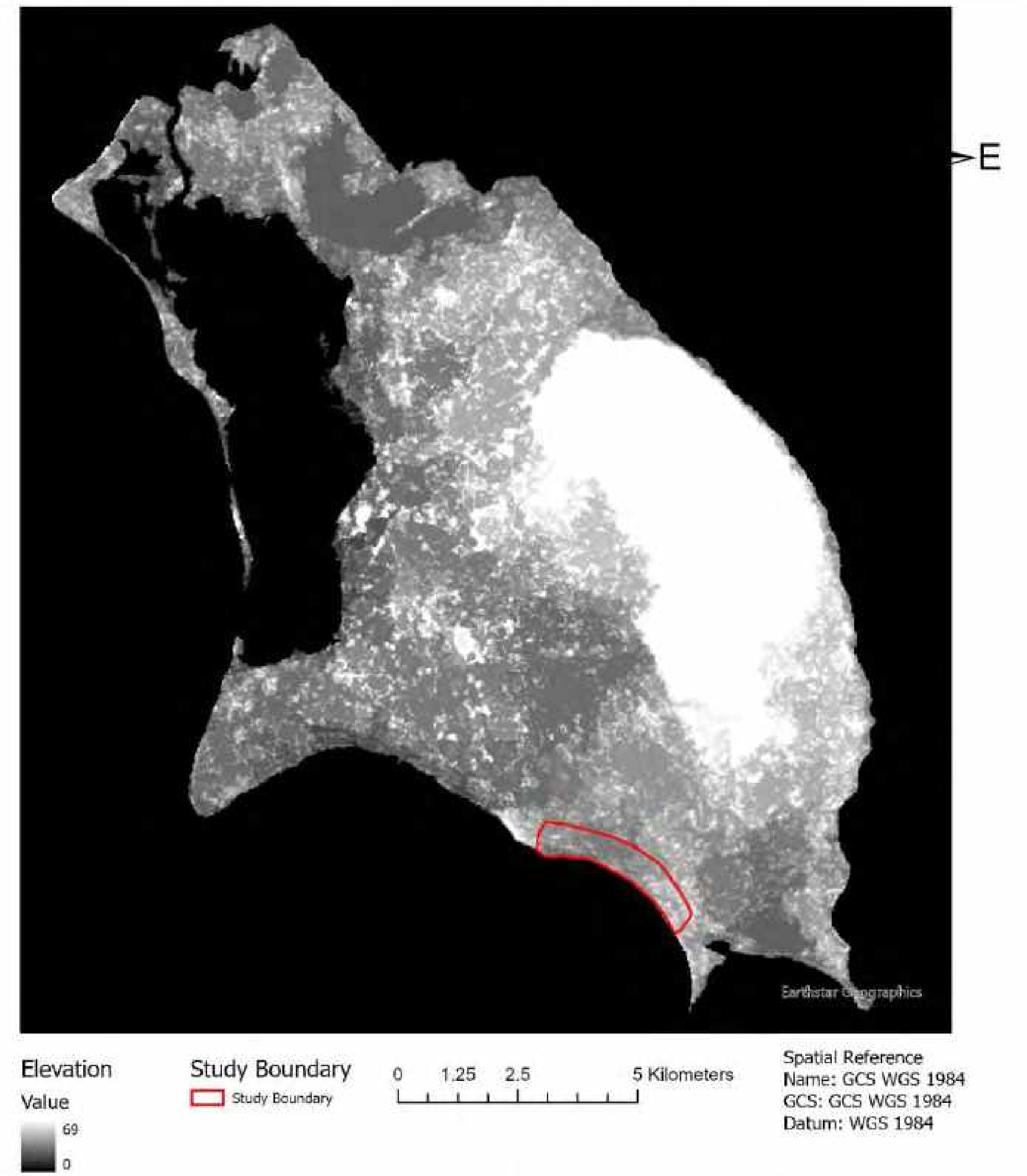

Figure 8.1 Barbuda elevations

9 Rainfall and Drainage

9.1 Rainfall and Flooding

Barbuda has a tropical marine climate and maintains a generally dry environment. Forty years of historical rainfall data show that Barbuda has low rainfall frequency with most months registering under 100mm of rainfall. Climate change projections state that Barbuda will experience longer dry periods, with January to March slated to be the driest. Extreme rainfall events such as those that occur during tropical storms and hurricanes are likely to become more intense, with larger peak wind speeds and heavier precipitation.

Ponding is a common aspect of Barbuda's natural drainage system. The project site is low-lying with salt ponds and manmade ponds. Sections that mainly experience flooding are north of Pond 3, Pond 1 and its outlet towards Gravenor's Bay.

The Post Georges Disaster Mitigation Task Force that was formed after the devastating effects of Hurricane Georges (1998) produced various guidelines and indicative diagrams on the vulnerability of Antigua, Barbuda and St. Kitts and Nevis. These diagrams were compared with model results for validation, in addition to comparison with recent rainfall events. The Antigua and Barbuda's Second National Communication on Climate Change to the UFCC document assessed the existing conditions and presented insight on the projections that are applicable to the islands.

Rainfall and flooding characteristics were assessed to ensure that the drainage system would be able to support the stormwater discharge from defined rainfall events. The parameters that are immediately affected include the sizing of the ponds and necessary grades on the site to prevent unwanted water retention.

9.2 Methodology and Approach

The methodology adopted was as follows:

1. Data collection to include:
    - Rainfall information,
    - Soils information,
    - Land use mapping,
    - Topography of the catchment, and
    - Anecdotal data collection.
2. Delineation of the catchments
3. Calculation of runoff for pre and post development
4. Propose grading plan to ensure all runoff is captured

9.3 Site Characteristics

The site is low-lying and generally floods with small amounts of rainfall. Areas that are quickly inundated are highlighted in Figure 9.1. These areas are generally located around the existing ponds, the spring and along the coastline. The land is gently sloping towards the coastline.

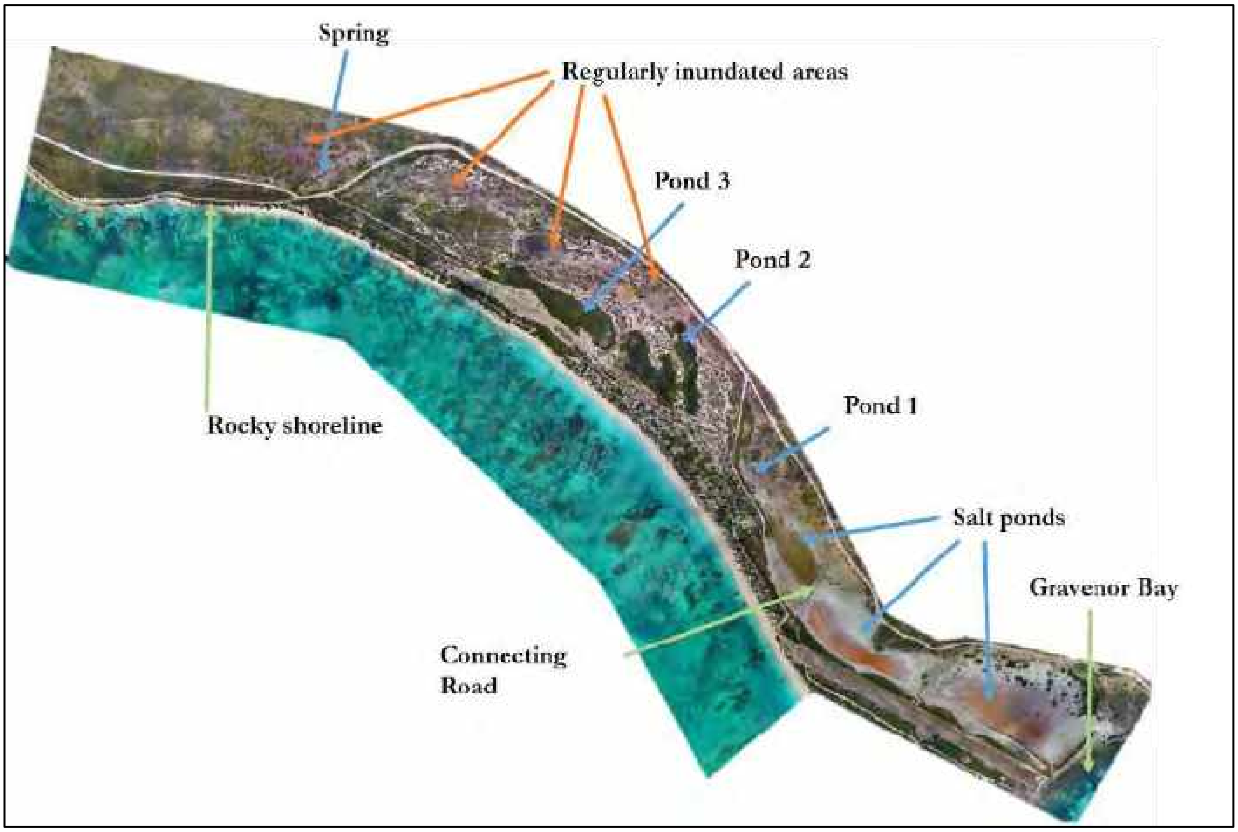

Figure 9.1 Paradise found site characteristics

Figure 9.2 images of low-lying/flood prone areas on Paradise Found property

9.4 Data Collection

Data collection began with a review of existing studies on Barbuda, which included rainfall station reports and climate reports from PGDM and the Department of Environment (DOE). Soil type and basic topography were qualitatively assessed to fine-tune further investigations. The topography of the site was quantified by producing a Digital Elevation Model based on LiDAR data received from the client.

It was important to delineate the catchment associated with the site to calculate the expected runoff within the project area. Preliminary site discharge values were calculated by producing a catchment plan and calculated precipitation levels for specified return periods. The Meteorological Service, Government of Antigua and Barbuda, provided 41 years of monthly rainfall data at the Coco Point, Barbuda station. Statistical operations were performed on the data to arrive at the rainfall levels for the 2, 5, 10, 25, 50 and 100-year events. The SCS-Type III Rainfall Distribution curve was used to arrive at daily precipitation values. SCS-Type III was recommended by the Antigua and Barbuda SNC to the UFCC.

Watershed delineations were not consistent across the previous studies. As a result, a watershed plan was delineated using the Shuttle Radar Topography Mission (SRTM) model that had 30m grid spacing point elevation data as recommended by the Antigua Meteorological services. The modified Rational Method was used to calculate the stormwater discharge for each watershed.

Sub Catchment 1: located to the south of Pond 1, and slopes northward towards Pond 1 from a maximum level of +2.1m to a minimum level of +1.4m at the north embankment. Note that the south embankment is lower at +0.9m because the master plan drainage strategy as suggested by the architects is to allow the village south land zone to flood if required. This strategy provides for savings in fill material.

Sub Catchment 2: surrounds Pond 2, and slopes towards it with a gradient of 1% to a minimum level of +1.1m at the pond embankment.

Sub Catchment 3: surrounds Pond 3 and has a varying topography. The delineation and average slope of this sub catchment are approximated for the purpose of drainage modeling. The portion of the sub catchment that drains into Pond 3 is modeled with a gradient of 1% to a minimum level of +1.1m at the pond embankment.

Sub Catchment 4: surrounds the recreational Pond R4 and has a varying topography. The delineation and average slope of this sub catchment are approximated for the purpose of drainage modeling. The portion of the sub catchment which drains into Pond R4 is modeled with a gradient of 0.5% to a minimum level of +1.4m at the pond embankment.

Sub Catchment 5: surrounds retention pond R5 and has an average slope of 0.8 % to a minimum level of +1.4m at the pond embankment.

Sub Catchment 6: surrounds retention pond R6 has a varying topography. This sub catchment is modeled with a gradient of 4% to a minimum level of +1.4m at the pond embankment.

Sub Catchment7: drains partially into Pond P1 and partially into Pond R7 with a slope of 1.6 % and a minimum level of +1.4m at the embankments of both ponds.

Sub Catchment 8: located north of Pond P1 and slopes southward towards Pond P1 with a gradient of 0.8%. Its minimum level is +1.4m at the pond embankment.

Sub Catchment 9: located offsite and borders the project site at the north-west corner. It has been approximated at 90 acres in size with an average slope of less than 1%. This sub catchment is the only one in the system that includes channel flow because an open channel is to be created within the sub catchment using a levee wall. This sub catchment discharges into the proposed off-site detention Pond D8, and indirectly affects Ponds R4 and R5 peak levels.

9.5 Rainfall Trends

Rainfall trend graphs were plotted using available precipitation data as shown in Figure 9.3 and Figure 9.4. Barbuda has a dry season from January to April and a primary wet season from August through to November. The wet season coincides with peak tropical storm activity. The largest recorded value for the Coco Point station was in November 1999 where 483mm of rainfall was recorded. This was due to Hurricane Lenny passing south of the island.

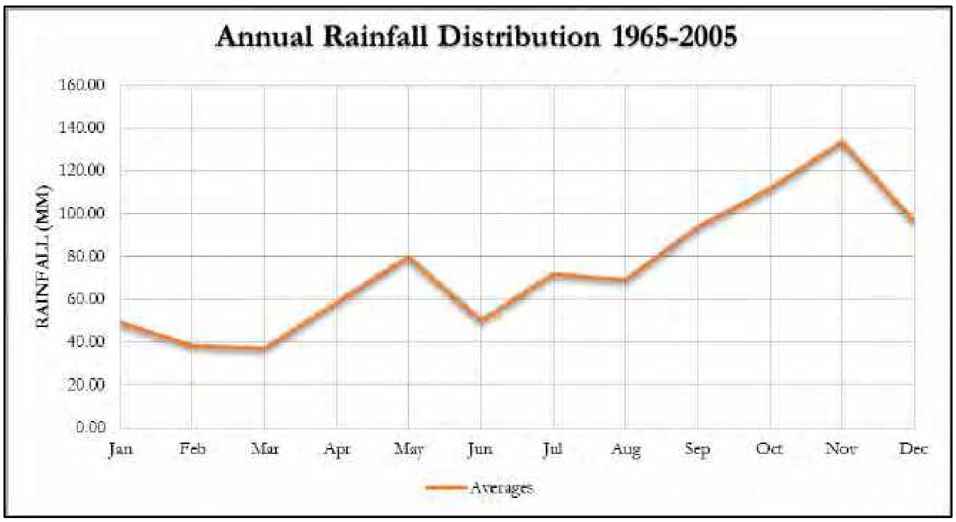

Figure 9.3 Annual rainfall distribution for the period 1965-2005

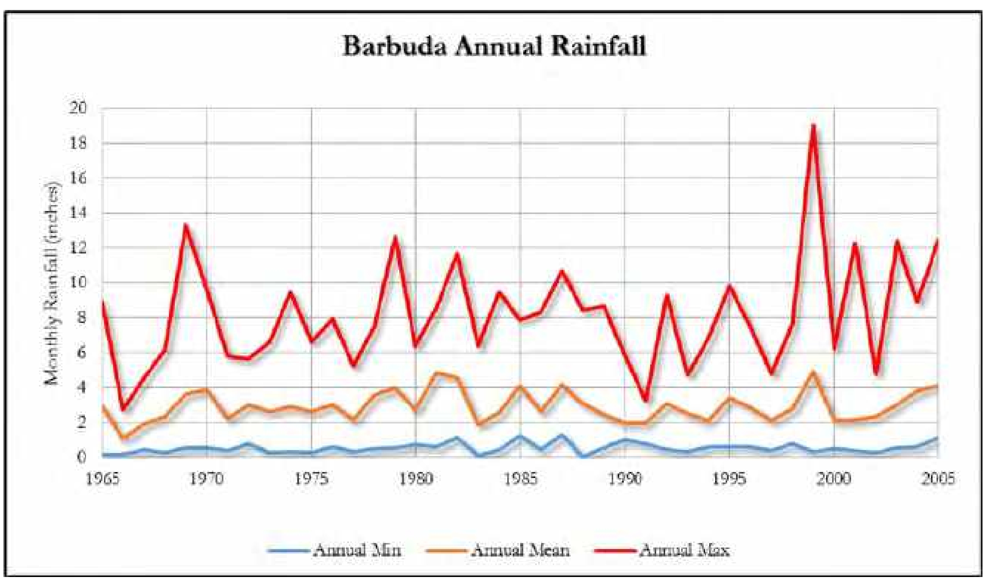

Figure 9.4 Annual minimum, mean and maximum for the period 1965 to 2005

9.6 Flood Modelling and Mapping

Flood modelling was done using the hydrodynamics module of the MIKE 21 software suite (DHI). The bathymetric data mesh, precipitation rates and stormwater discharge values were used as input for inundation plots. Model simulations incorporated rainfall over the entire island for 24 hours to properly assess discharge flows. Soil saturation was assumed by allowing no infiltration on the site.

To ensure that the model was properly defined, validation tests using the 2-year rainfall statistics were done and compared to a recent rainfall event. After validation was achieved the 5yr, 10yr, 25yr, 50yr and 100yr rainfall events were run on the existing site. Flood modelling was done for all master plans submitted (September 2016, November 2016 and December 2016). The proposed elevations for each layout were converted into a flexible mesh and the rainfall events were modelled with the new elevations to quantify the changes.

The main parameters used in the analysis of the rainfall data were the total water depth and surface elevation of discharge. They were plotted and overlain on the site image. Total water depth showed areas of inundation while surface elevation was used to assess the flow of discharge across the site.

9.7 Key Findings

Barbuda does not experience high rainfall, but rather many droughts. As a result, rainfall values are much lower than for other Caribbean nations. Rainfall values for each return period are shown in Table 9-1.

Table 9-1 Rainfall levels for each return period

Return Period (years)	Rainfall	
	(mm)	(in)
T2	142	5.6
T5	19	7.6
T10	223	8.8
T25	240	9.4
T50	330	13
T100	533	21

The flow of discharge begins in the highlands (offsite) at an elevation of approximately +42m. The drainage path flows between the major ponds to the east of the proposed site and towards Codrington Lagoon. There is a low ridge at +8m that acts as a barrier for Ponds 1, 2 and 3. East of the bend in the roadway was the main inlet for offsite discharge. That offsite discharge contributed to the overflow of Pond 2 and 3. During all rainfall event simulations Pond 3 overflowed and the depression west of the roadway was inundated. Discharge from Pond 3 flowed to the sea through a break in the berm which had an elevation of less than +1m.

Existing site plots show that main flows enter northeast of Pond 4 and east of Pond 1. A small depression east of the main road by Pond 4 was inundated quickly along with the main outlet by Coco

Point. Validation was achieved since what was seen in the simulation was mirrored on the site and in previous reports.

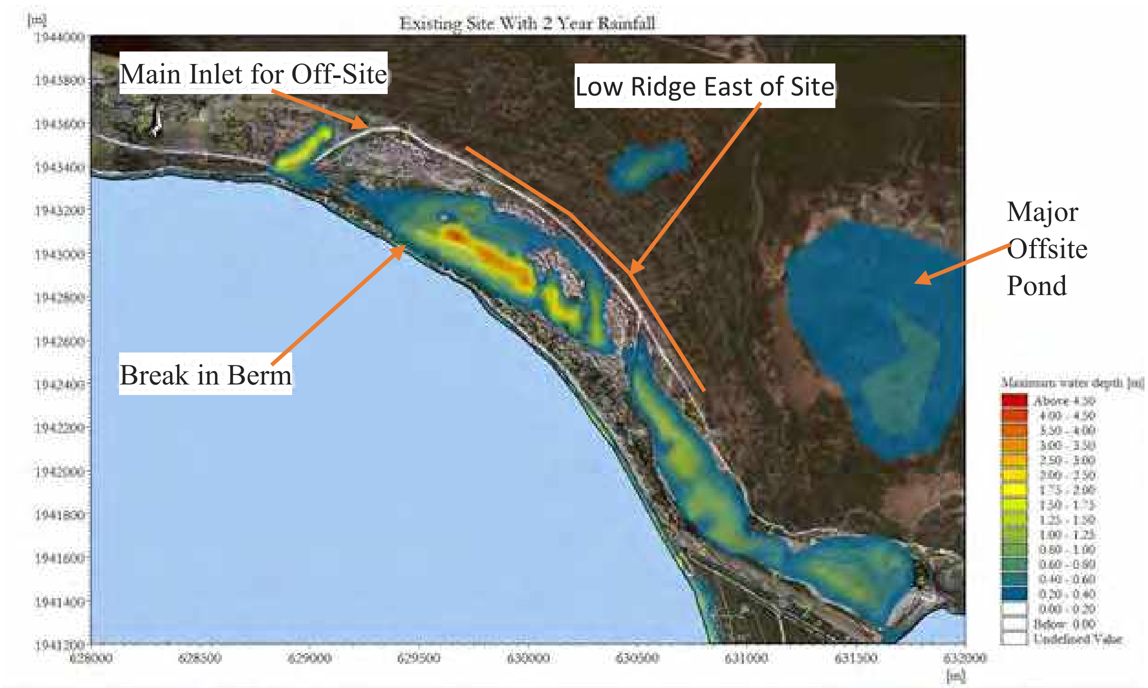

Figure 9.5 Main observations from simulations using existing site with 2yr rainfall plot

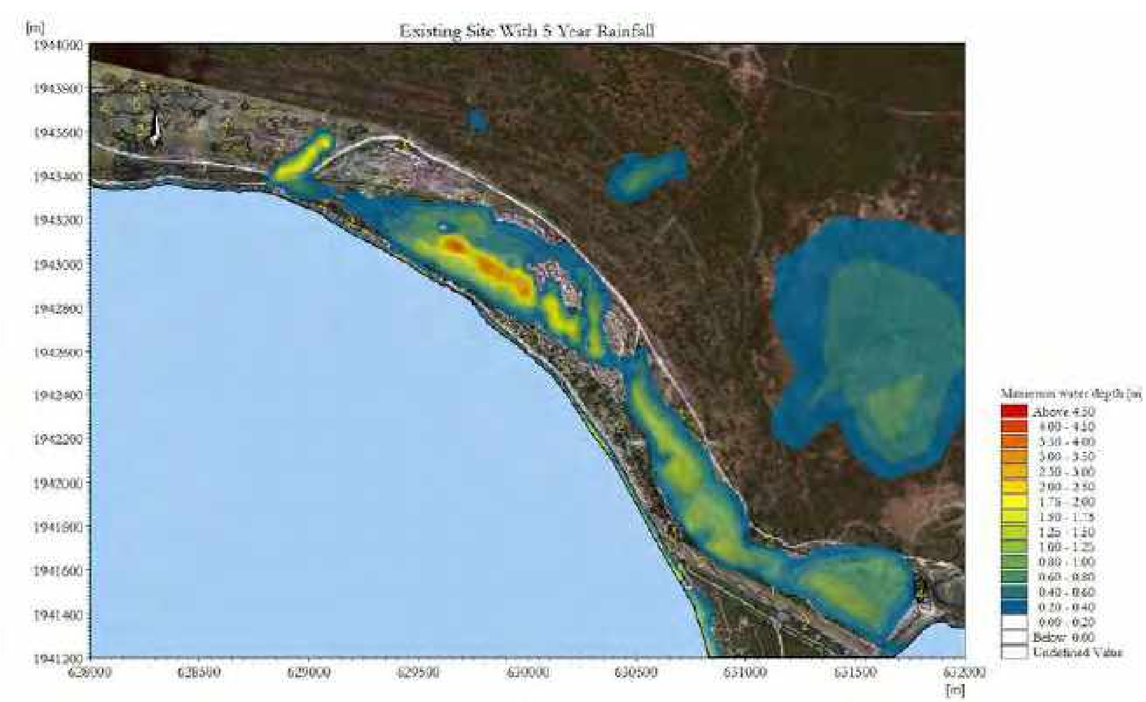

Figure 9.6 simulations using existing site with 5yr rainfall plot

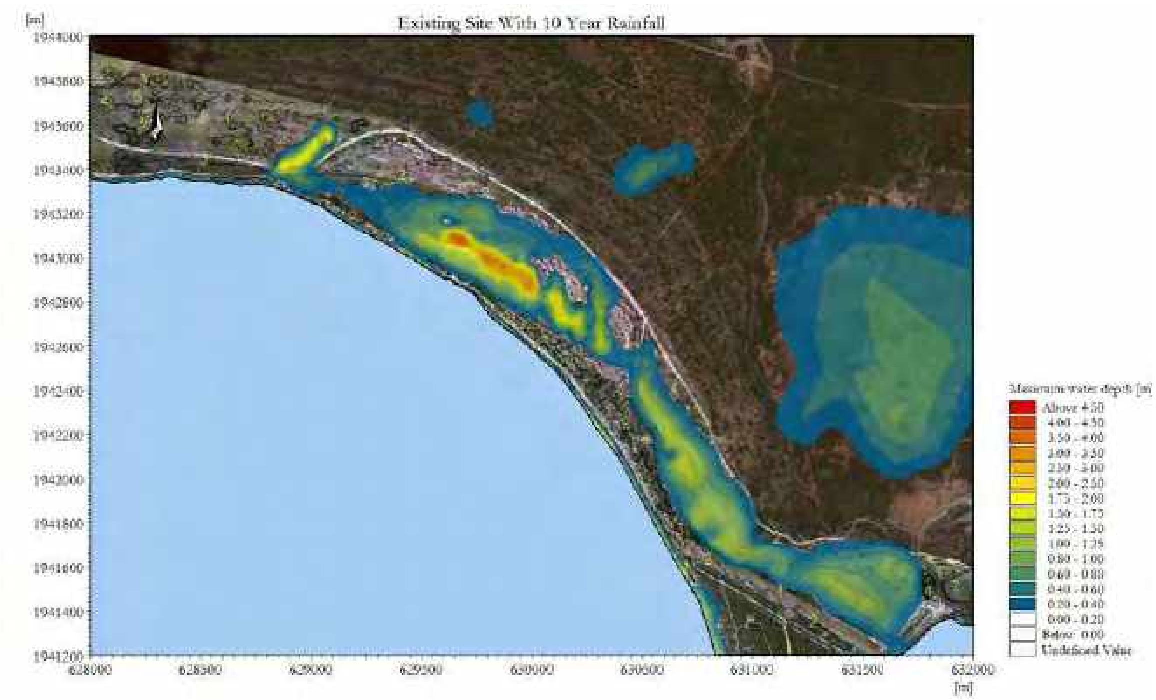

Figure 9.7 simulations using existing site with 10yr rainfall plot

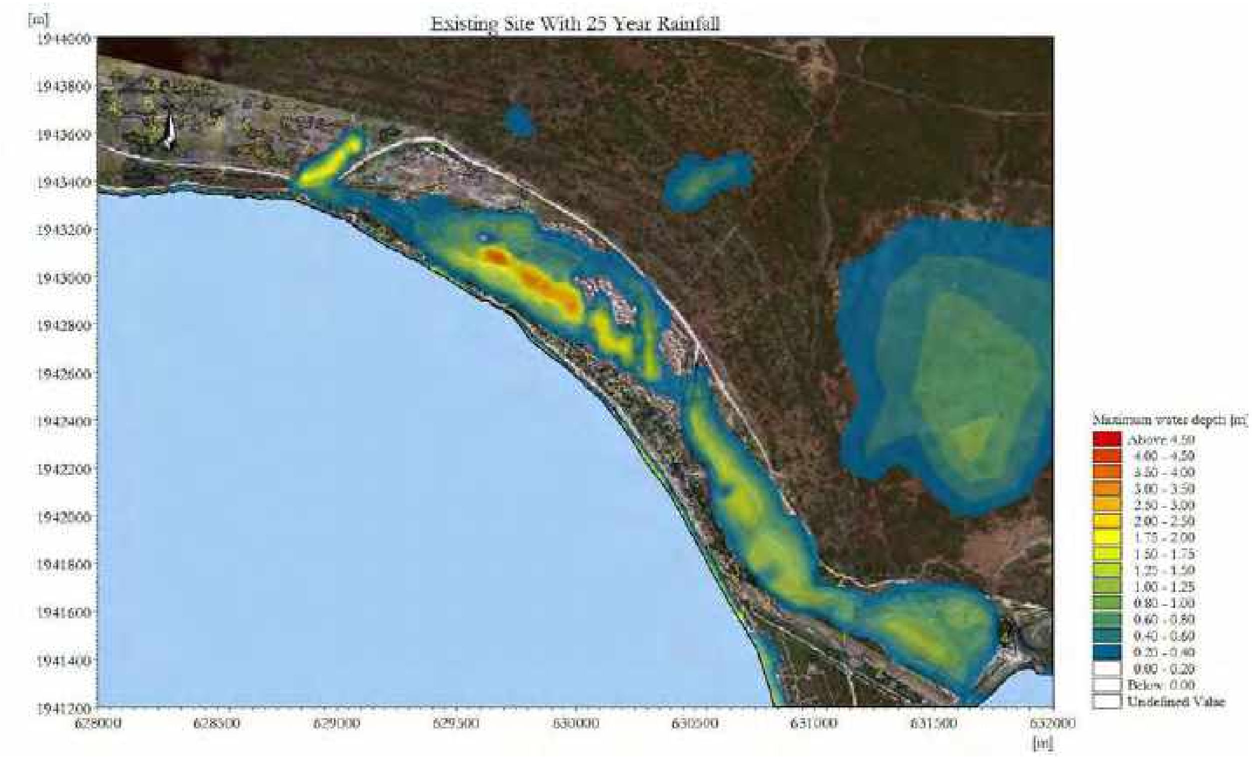

Figure 9.8 simulations using existing site with 25yr rainfall plot

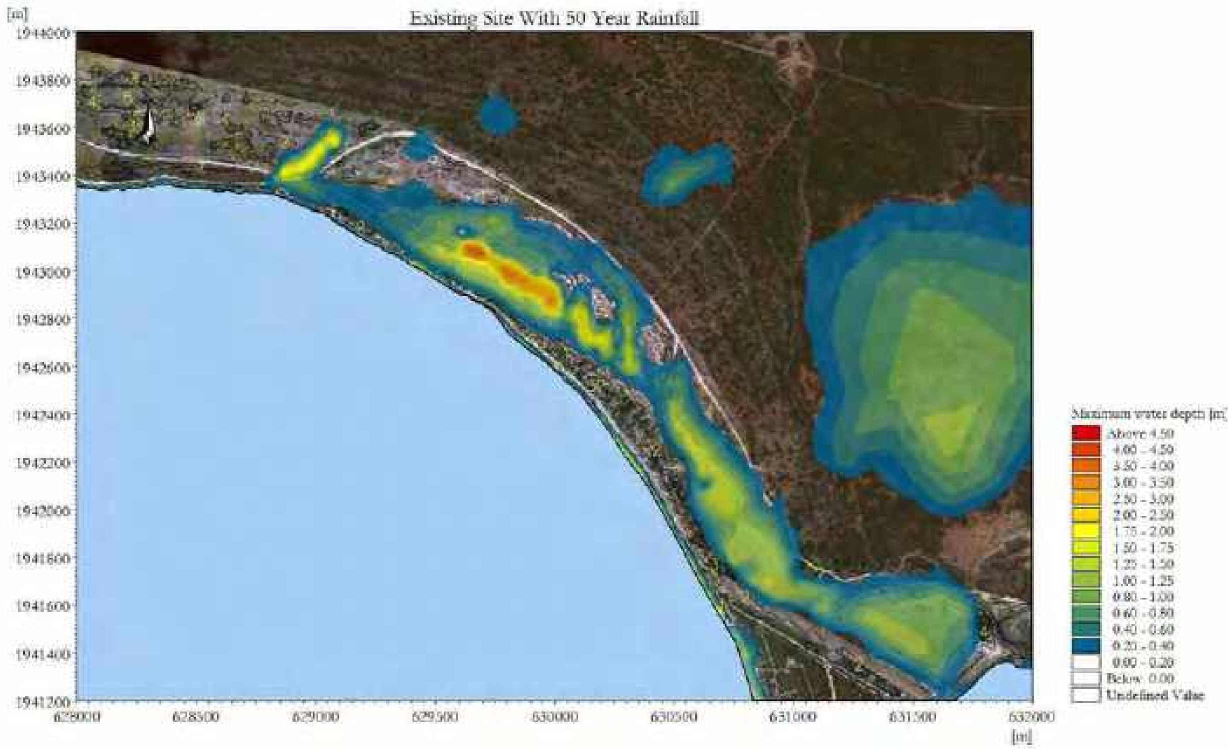

Figure 9.9 simulations using existing site with 50yr rainfall plot

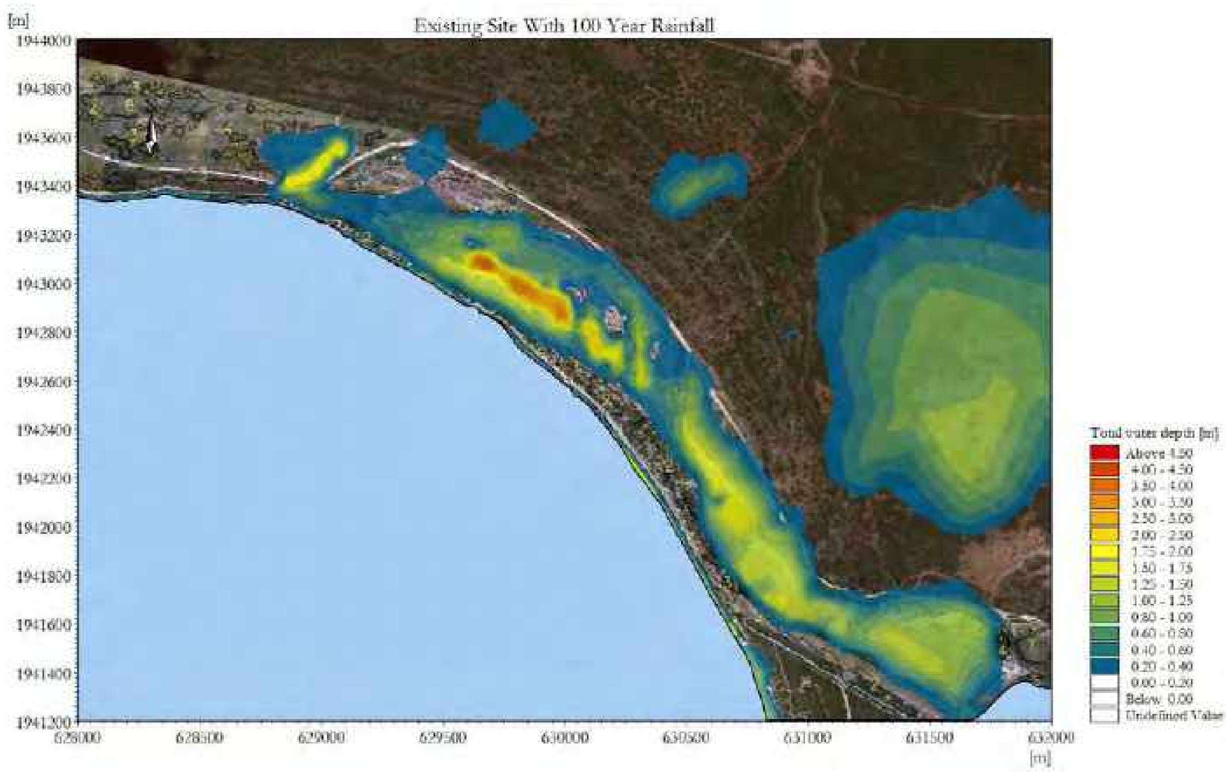

Figure 9.10 simulations using existing site with 100yr rainfall plot

The September 2016 master plan greatly improved flow and reduced inundation across the site. Better definitions of flow across the project site were established and unwanted ponding was reduced, however there were areas of concern west of Pond 1 and north of proposed Pond 2 where depths of 0.25m-1.0m were seen for the 100-year event. Other berms had no inundation after all rainfall events. The initial master plan involved large volumes of fill, which would prove to be a costly venture. Subsequent plans involved lowering the berms to optimise the cut and fill ratio.

The December 2016 master plan improved drainage in the areas around the main hotel and included lowered berms east of pond 2 and west of pond 1. The reduction in berm height led to larger levels of inundation in these areas. Using the 50-year event as an example; the initial master plan had only small ponds with maximum depths of 0.25m south of the drainage ponds and by pond 1. However, the latest master plan had ponds with larger surface areas and depths of 0.75-1.0m in those areas. The plots for the 50-year event are shown in Figure 9.11

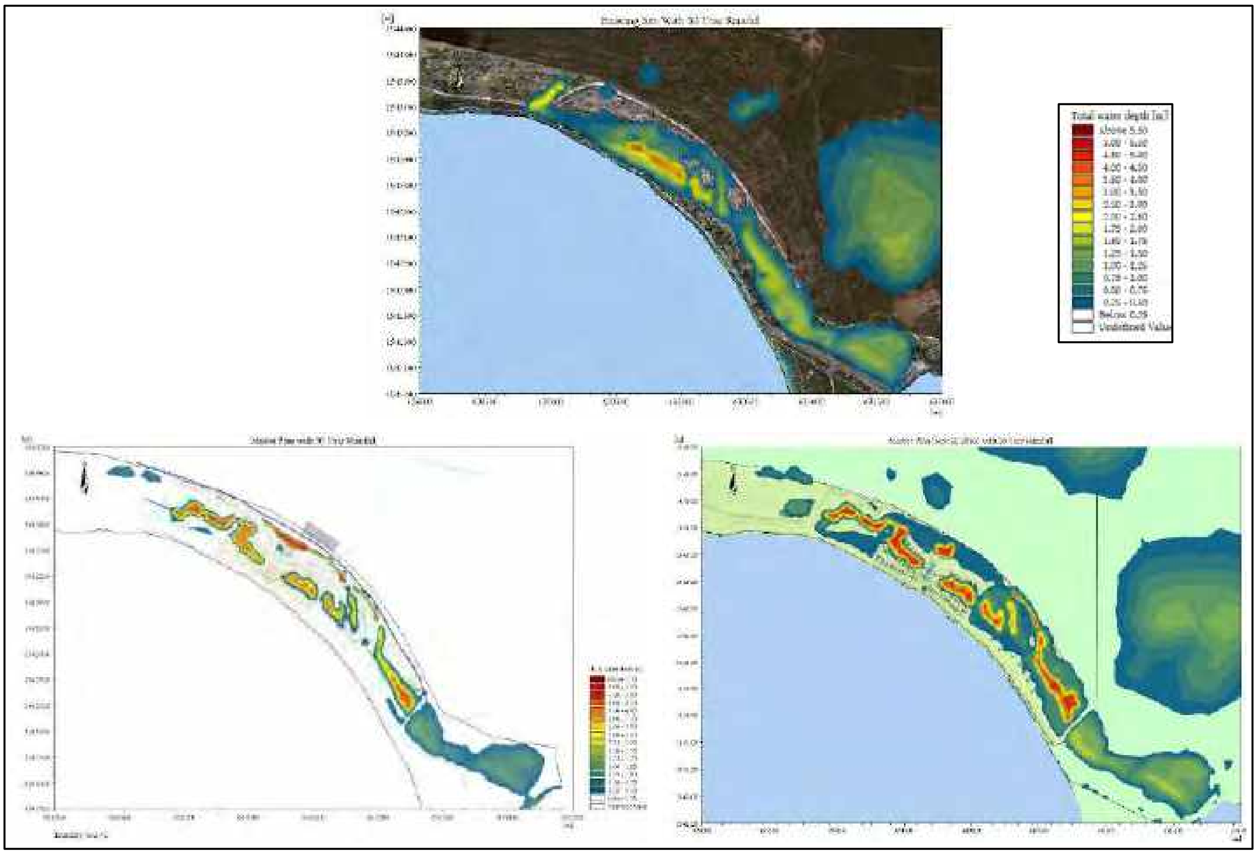

Figure 9.11 50 year event for existing conditions (top), the September Master Plan (bottom-left) and the December Master Plan (bottom-right)

10 Hydrogeological Assessment

A detailed hydrogeological assessment is underway and a summary of the findings are presented in the following pages. The full report is attached as Appendix 3.

The hydro-stratigraphic units of Barbuda, their stratigraphic sequence, subsurface relationships, and hydraulic character described by previous investigators, were examined in the field, and found to be generally accurate. However, wells recently drilled through the Palmetto Sand Aquifer in the Palmetto Point headland in the southwest end of Barbuda, indicated that the Central Plains Limestone Aquiclude was absent, requiring a re-interpretation of the stratigraphic sequence in that area, and the depositional history of Barbuda.

The determination of well head elevations for data points in the Highland Limestone Aquifer, the Central Plains Limestone Aquiclude and the Palmetto Sand Aquifer will allow computation of the water table elevation in the respective hydro-stratigraphic units and a better understanding of the hydraulic relations between them.

Field determinations of Specific Conductance (i.e., Electrical Conductivity) allowed characterisation of the water quality in the water table sections of the Highland Limestone Aquifer, Central Plains Limestone Aquiclude and the Palmetto Sand Aquifer. The fresh groundwater in the Palmetto Sand Aquifer reported by previous investigators up to 1992, no longer existed but was now moderately saline, believed to result from the extensive mining of the sand and the exposure of the water table to direct evaporation.

11 Social Impact Assessment

This analysis presents a body of information that allows the reader to understand the characteristics of the population and the potential social and economic impacts of the proposed project on the population. Issues of employment and livelihoods, health and well-being, and awareness of the population about the project activities, vulnerabilities of the aged, children, youth and those with differing abilities are explored and presented in this baseline conditions report. Where possible, gender analyses are also presented.

The cultural norms, practices of the population, and assets that have the potential to be affected are also presented. And lastly, the analysis seeks to be sufficiently broad to cover major impacts but also practical, relevant, and efficient by focusing on key potential areas of concern. It seeks to strengthen the investor's focus on the social components, especially in cases where the local communities affected may be dependent on the same natural resources as the investor. [3]

The analysis is situated within the literature of the social impact assessment around three main theoretical issues: that which address the concept of the 'social license'; the human rights-based approach; and that of the importance of the non-technical risks or the social risks.

The Social License to Operate, according to Vanclay et al (2015), refers to the level of acceptance or approval of the activities of an organization by its stakeholders, especially locally impacted communities. The theory contends that leading corporations accept that they need to meet more than just the regulatory requirements. It argues that corporations also need to consider, if not meet, the expectations

[3] The World Bank . RAI-KN 14 Environmental and Social Impact assessments.

of a wide range of stakeholders, including international NGOs and local communities. The consequences for ignoring the expectation of this wide array of stakeholders could put corporations at risk not only of their reputational position but also the risk of being subject to negative action and the financial consequences of those actions.[4]

Vanclay et al (2015) notes that in some countries, 'social licence' has become an established element of the language of business, influencing and driving the business strategy of many companies. They conclude that a social licence has become part of the governance landscape.

The human rights-based approach refers to a conceptual and procedural framework which seeks to ensure the promotion and protection of human rights in policies, programs, plans and projects. Such an approach seeks to: (1) position human rights and its principles as the core element of actions; (2) demands accountability and transparency by duty-bearers towards rights-holders; (3) fosters empowerment and capacity building of rights-holders to, inter alia, hold duty-bearers to account; (4) ensures that the meaningful participation of rights-holders in development processes and planned interventions is recognised as an intrinsic right, not simply as best practice; and (5) ensures the non-discriminatory engagement of rights-holders and the prioritization of especially-vulnerable or marginalized individuals or groups (e.g. women, elderly, children and youth, minorities and Indigenous peoples).

Last but by no means least is the notion of non-technical or social risks, which refers to those risks such as the managerial, legal, social and political issues faced by a project, in contrast to the technical risks (i.e. the physical, structural, engineering and environmental risks). Often due to the technocratic focus of many project staff the technical risks are usually fully considered, whereas the non-technical risks are under-considered or ignored altogether. The World Bank defines social risk as "the possibility that the intervention would create, reinforce or deepen inequity and/or social conflict, or that the attitudes and actions of key stakeholders may subvert the achievement of the development objective, or that the development objective, or means to achieve it, lack ownership among key stakeholders".[5] For the World Bank, social risk is both risk (threats) to the success of the project, but also risk (social issues) created by the project, which in turn become threats to the project.

11.1 Methodology

The Social Impact Assessment (SIA) uses a mixed applied research approach. The methodology includes desk review of relevant literature; community engagement of stakeholders, utilizing an in- depth semi structured questionnaire; consultations with key policy makers; and collection and analysis, including a gender analysis of data about the Directly Affected Community (DAC). Such an approach ensures a full understanding of the baseline conditions the project encounters.

Stakeholder groups were identified as follows: elders who knew the history of the island well; fisherfolk; farmers; people who own and run guest houses; persons who transport tourists (tour guides); persons who are engaged in any way with the tourism industry (e.g., cooking food for tourists); and those in the

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[4] Impact Assessment & Project Appraisal 32(4), 263-272. http://dx.doi.org/10.1080/14615517.2014.941141

[5] Vanclay, et al (2015). Social Impact Assessment: Guidance for Assessing and Managing the Social Impacts of Projects (IAIA:Fargo)

health sector. In addition, policy makers were identified for in-depth interviews. These included the Chair of the Barbuda Council, the Member of Parliament for Barbuda, the CEO (Ag.) of the Barbuda Council, key Officers in the Division of Statistics, Ministry of Finance, the Gender Affairs Department of the Ministry of Social Transformation, Officials from the Ministry of Health, Wellness (both in Barbuda and Antigua) and the Climate Assessment and Information Officer, Department of Environment.

The key ethical issue that may arise in this assessment surrounds the question regarding for whom the SIA assessor works - the community or the project proponent? The report emphasizes to all parties that the assessment is being conducted to the highest ethical standards and will adopt an independent stance. Such a stance allows the SIA to make relevant community interests explicit in the assessment and should the assessor "perceive risks beyond those identified in the preliminary assessment conducted by the DOE, the assessor is obligated to investigate such".[6] Through such an approach the Assessor seeks to lay bare opportunities for building a balanced, just and harmonious relation between community and project proponent.

The governance arrangements for the conduct of the SIA are derived from the Review of Plan Application #G10-2021 (Paradise Found), by the Director of the Department of Environment of the Ministry of Health, Wellness and Environment of the Government of Antigua and Barbuda. That review called for an EIA to be undertaken, which in Section five (5) *inter alia* requested a Socio Economic & Health Environment Baseline.

In section 5.5 the request noted that (the)

" Baseline data should include the demography, nearest settlements, and existing infrastructure facilities in the proposed area. Present employment and livelihood of these populations and awareness of the population about the proposed activity should also be included. Vulnerable groups and gender analysis may also be included if applicable. If there are cultural practices or norms which may affect the environment or be affected by the environment it should also be mentioned".

This Report is situated within the conceptual understanding of the notions of livelihoods as defined by Chambers and Conway (1991). *A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stress and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base.*

To better understand how persons in the directly affected community (DAC) of Barbuda, i.e., those living in Codrington Village, develop and maintain livelihoods, the Sustainable Livelihoods Framework (SLF) was applied[7]. This framework is an analysis tool, useful for understanding the many factors that affect a person's livelihood and how those factors interact with each other. The SLF views livelihoods as systems and provides a way to understand:

1. the assets people draw upon;

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[6] DOE April 2021

[7] DFID's Sustainable Livelihoods Approach and its Framework. https://efaidnbmnnnibpcajpcglclefindmkaj/http://www.glopp.ch/B7/en/multimedia/B7_1_pdf2.pdf

2. the strategies they develop to make a living;
3. the context within which a livelihood is developed; and
4. and those factors that make a livelihood more or less vulnerable to shocks and stresses.

How people access and use these assets, within the social, economic, political, and environmental contexts, form a livelihood strategy. The range and diversity of livelihood strategies are enormous. The SLF acknowledges that an individual may take on several activities to meet his/her needs. One or many individuals may engage in activities that contribute to a collective livelihood strategy.

The diverse livelihood strategies of the DAC of Barbuda will be presented as part of the Community Profile.

One limitation of the applied methodology the assessor encountered was data driven, as social statistics are not as current or readily available across the Caribbean, and the situation in Antigua and Barbuda was found to be no different. Another was that the COVID-19 pandemic acted as a constraint to consultations as some people were unavailable because of the exigencies of the Pandemic.

Yet still another issue identified as a limitation of the Assessment was the multiple development projects that are currently taking place on the island, with members of the DAC being unable to distinguish between what development and its impacts belong to which developer or project. This lack of clarity results in the social impact analysis having to take into account all ongoing effects and impacts. In the assessment methodology, such a situation is often referred to as a multiple hazard environment resulting in complex impacts and requiring solutions that engage enhanced application of the tools of integrated development planning.[8]

11.2 Community Profile and Social Baseline

Barbuda has a land area of 176km^2, is located some 40 km north of Antigua and has a land mass size of approximately 39% that of Antigua and Barbuda, which together comprises some 456km. Antigua the bigger sister island has a land area of 280 km^2. The estimated population in 2022 for Antigua and Barbuda is 100,722 and of those 52% are female and 48% male. Some 97% of the population resides in Antigua.

Barbuda has an estimated population of 1,935, of whom 52% are female and 47.8% male, details are presented in Appendix 4.[9] Some 28% of the population are 19 and under and 10% of the population comprise persons 65 to 80 and over.

Together, these islands comprise the state of Antigua and Barbuda and have similar characteristics of small island developing states (SIDS) in the Caribbean Sea. Both islands are low-lying, with 70% of the land in Antigua less than 30m above mean sea level and most of Barbuda only 3m above mean sea level.

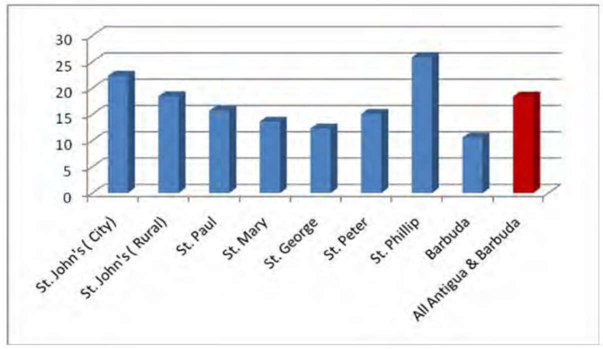
[8] Integrated Development Planning is an approach to planning that involves the entire geographic area and its citizens in finding the best solutions to achieve good long-term development. https://www.etu.org.za/toolbox/docs/localgov/webidp.html

[9] This estimate has been produced by the Statistics Division (as of July 2022) in support of this Assessment. It should be noted that all stakeholders have concerns about the accuracy of the projected population as numbers have been affected by the movement of people following the Hurricanes of 2017, the return of population groups, the arrival of workers from Antigua and wider Caribbean.

The country's economy is heavily dependent on natural resources, low-lying coastal zones, and favourable climate conditions that support the tourism sector, which accounts for about 80% of output gross domestic product (GDP), about 70% of direct and indirect employment and 85% of foreign exchange earnings.[10]

Despite a high-income ranking, according to the latest data available, approximately 18% of the total population falls below the national poverty line; 3.7% indigent (food poor); and 10% vulnerable to poverty in the event of a significant socio-economic shock or natural hazard. When considering the proportion of the population that is at risk of falling into poverty if there is a shock to the economy, the percentage rises to 28%.

Interestingly Barbuda had the lowest proportion of poor (10.6%) compared to other Parishes of Antigua and Barbuda (Figure 11.1).



Source: 1. Survey of Living Conditions, Antigua and Barbuda: Poverty in a Services Economy in Transition 2007

Figure 11.1. Proportion Poor in Antigua and Barbuda by Parish

11.2.1 Education

There are two schools in Barbuda, the Holy Trinity Public Primary School and the Sir McChesney George Public Secondary School, which together provide education for the school age population, and which in turn accounts for about 21% of the Barbuda population, or 409 children. Early Childhood Education centres include Toddlers' Paradise Day-care centre and the kindergarten, Cody Kelly Preschool, both of which along with the primary and secondary school suffered damage and required renovation and repair following the devastating Hurricane season of 2017. Most children can be seen walking to and from school.

11.2.2 Health

The health systems in Antigua and Barbuda are mainly financed and operated by Government. Health services are delivered at primary, secondary, and tertiary levels and at the primary level there is a network of 25 public health clinics with clinics located within 3.2 km of every major community. Secondary and tertiary health services are provided at the Mount St. John's Medical Centre, a 186-bed facility in Antigua, commissioned in 2009. There is one clinic and hospital in Barbuda, the Hannah Thomas Hospital, which was formally handed over to the Barbuda Council by the Government of Antigua and Barbuda, after its rehabilitation from the devastation in 2017.

The country is undergoing epidemiological transition with non-communicable diseases accounting for 85% of deaths, and most patient visits to primary health care facilities, and an ageing population (12% over 60 years, nationally and 15% in Barbuda). The three leading causes of death were cancer, heart

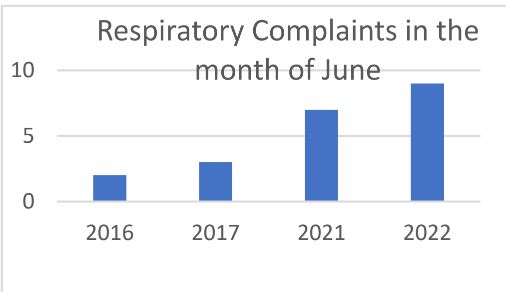
[10] Antigua and Barbuda Updated Nationally Determined Contribution, (NDC) for the period 2020 to 2030, Communicated to the UNFCCC on 2nd September 2021. Government of Antigua and Barbuda, Department of Environment Ministry of Health, Wellness, and the Environment.

disease, and diabetes. The government is implementing cost effective prevention activities focusing on obesity, exercise, and reduction in tobacco and alcohol use.

Communicable diseases, including HIV/AIDS, accidental and intentional injuries are among the ten leading causes of mortality.

About 70% of infant deaths occur during the neonatal period with main causes being birth asphyxia, prematurity, and injuries. Major focus is on reducing the neonatal deaths to meet the SDGs.

From 2011 to 2016 Antigua and Barbuda experienced increased cases of vector borne diseases of dengue, chikungunya and Zika. Implementation is continuing of the integrated management strategy for control and prevention of these vector-borne diseases.



Source: 1. Hanna Thomas Hospital data collected by the Assessor with permission of the Hospital Director

Figure 11.2. Number of children seen with respiratory complaints at the Hanna Thomas Hospital for two periods

In Barbuda health concerns have been expressed by key informants and stakeholders emerging from the concentrated levels of dust, oil and diesel that have overtaken the environment of Codrington Village since development projects have gotten underway. Community members speak of elders having to live like shut-ins to avoid the dust, children suffering from increased respiratory complaints and all villagers experience the need to scamper off the roadways from oncoming trucks who use the roadways as well as pedestrians. There are very few sidewalks to be found in Codrington.

Two sets of data were collected at the Hanna Thomas Hospital to investigate the concerns of the DAC for children 18 and under, male and female. Data, as presented in Figure 11.2, was collected for the month of June for the years 2016 and 2017, before development projects got underway and before the devastation of the hurricanes of 2017 and for the same month in 2021 and 2022.

The data suggested a marked increase in observed numbers of cases of respiratory illnesses ranging from difficulty breathing, to bronchitis, acute bronchitis, asthma, and acute asthma for the second period (June 2021 and June 2022) over the first period (June 2016 and June 2017).

11.2.3 Employment and livelihoods

According to the Labour Force Survey (LFS) of 2017, the working age population of Barbuda comprise 1,341 persons or 69% of the population. The labour force participation rate was 70.9%. It was higher among men than among women. Of the working age male population, 73.9% participated in the labour force, compared with 68.5% of their female counterparts. There are two interesting facts about the LFS when the data for Barbuda and other parishes in Antigua were compared. For one, the highest *labour force participation rate* was observed in Barbuda, 88.9%, while the lowest was in the Parish of St. George, 72.3%.

The second was that the unemployment rate for Antigua and Barbuda stood at 13.7% based on the 2015 LFS. When the unemployment rate was examined by parish, a significant amount of variation in unemployment rates was observed. Barbuda was found to have the lowest unemployment rate among the parishes with only 7.4% of the labour force population being unemployed, while in the parish of St Paul (in Antigua) the unemployment rate was reported at 20.6%, almost three times higher. Figure 11.3 below is taken from the preliminary release of the 2015 Labour Force Survey. It illustrates the variations in the unemployment rate by Parish and Sex.

The data suggests that a significant proportion of the active labour force in Barbuda is employed in various forms of income earning activity.[11]

Source: 2 Preliminary LFS 2017

Figure 11.3 Unemployment by Sex and Parish

Data gathered through consultations with stakeholders suggest that income earners in Barbuda are engaged in multiple livelihood activities which constitute their livelihood strategy. Livelihood strategies display a rich knowledge of the local environment and a strong commitment to sustainable development practices.[12] Barbudans work in the formal and informal sectors of the labour market. In the formal labour market, an examination of employment by occupation and sex indicates that the largest segment of the labour force is found among the elementary occupations, and these were mostly women (Figure 11.4)

	Male	Female	Total
Employment by occupational category (Main job)			
Armed Forces	-	-	-
Managers	-	-	-
Professionals	-	-	-
Technical and associate professionals	41	74	115
Clerical support workers	55	27	82
Service and sale workers	84	101	185
Skilled agricultural, forestry and fishery workers	20	-	20
Craft and related trades workers	50	14	64
Plant and machine operators, and assemblers	31	-	31
Elementary occupations	-	202	202
Total	**281**	**418**	**699**

Source: Statistics Division, Ministry of Finance and Corporate Governance
Date: 30th September, 2017

Figure 11.4 Barbuda Employment by Occupation and Sex

Skilled agricultural and fishery workers were all male, and craft and related trades workers were predominantly male, with females comprising approximately 22% of this occupation. Income earning activities in the informal sector include agricultural production on 'family grounds', fishing and free diving for lobster and conch when in season, 'picking salt' or salt mining, tour guides (providing day trips to tourists for snorkeling, bird watching and exploring caves and other attractions on the island such as the pink sand beaches and salt and freshwater ponds). Guest houses have

[11] See preliminary data from Labour force survey 2015 in Appendix
[12] There was a period when sand mining had been the main industry in Barbuda (2015 and 2016), but because of the potential impact on the environment, it was significantly curtailed. Currently there is a complete halt to sand mining on Barbuda. The last time that the Barbuda Council had received revenues amounting to some $600,000.00 from sand mining was in the 2nd quarter of 2017.

been established for short stay visitors and many female micro entrepreneurs have established facilities that cater for meal preparation and sales across the Village to visitors and workers alike.

The unemployment rate for youths in Antigua and Barbuda according to the LFS 2015, aged 15 to 24, was 33.9%, more than three times the rate for adults aged 25 to 54. Unemployment was higher among young women (37.3%) than among young men (30.4%).[13]

Two examples, described below, suggest that Barbudans are able to earn incomes that could support a good quality of life that would be significantly disrupted if development is not managed as key informants have warned.

1. The Lobster trade which is conducted from the Lagoon generates from about 9,000 to 11,000 pounds of lobsters being sold to exporters (many of whom are Antiguans who conduct a brisk wholesale and retail business). The market price is $20 per pound and the open season is for approximately 10 months.[14] Fisher folk are extremely worried about pollution damage to the Lagoon by new developments, which would result in the destruction of the Lobster trade and the conch trade.
2. Another area of brisk earnings can be found in that of the tour guides operated both in the high and low seasons. Tour guides enjoyed a brisk trade taking 'day trippers' on whole day tours across Barbuda, including caves, frigate birds, lagoon, historical sites, etc. For such activity they were paid US100 per day, per person. Their costs included fuel, boat maintenance and meals provided to tourists. Even at a conservative estimate of 200 workdays per year for ten tour guides who service 32 customers per day, income before expenses could be as high as US$640,000 per year.

   Stakeholders expressed concerns that developers were attempting to take control of the 'tour guide' trade by bringing in their own guides and boats to the exclusion of the Barbudan guides. In addition, there was the fear of Barbudans being excluded from access to certain areas such as the pink sand beaches.

11.2.4 Cultural Norms, Practices and Assets

The Antigua and Barbuda Medium-Term Development Strategy, 2016 to 2020 described Barbuda as "a natural paradise with unique pink sand beaches, lagoons, salt ponds and unique flora and fauna species, including one of the world's largest bird sanctuaries." When asked about the cultural assets, a Barbudan replied, "…it is traditional for us to hunt, it is traditional for us to fish, to farm and so forth, so that in itself is a cultural resource… The camp sites, that is a tradition that has been around for ages… now you are saying that all of these could be lost because you want to give it to someone else… Our cultural traditions don't matter?"

Although the planned development may be some 13.8 km away from the Codrington Village, stakeholders expressed a sense of much intrusion and exclusion. Most stakeholders felt they had no

[13] Antigua and Barbuda LFS 2015
[14] The Council receives a small fee of approximately $1,600 to $1,800 per month.

information about developments taking place, could not distinguish between one developer and the other, thought that Paradise Found and PLH was one and the same development.

One stakeholder expressed it in this way: “I am not certain if they (Paradise Found) are associated with the PLH because the area where they supposed to develop now PLH is developing, so I am uncertain if there is a collaboration or anything of the sort”.

Most reiterated that they had not been consulted.[15] Some community members do remember a very early consultation meeting in 2015 (or thereabouts) but nothing since then and no news as to any new or changed plans and no idea how they, the people of Barbuda, would benefit from the observed development.

There was much worry and consternation expressed about impending destruction of natural resources (draining of ponds, allowing chemicals to seep into the Lagoon, the mismanagement of human waste that could enter the waters, the destruction of nearshore fishing areas, etc.). Another stakeholder asked: “Are we compromising our safety and the safety of our livelihoods for money? For persons to feel like, ok, we can make a few million dollars for a few years before all these (assets) gets destroyed and then we just find someplace else to go”… “you see the same company that left Abaco is the same company that is here doing the exact same thing”.

Community stakeholders took umbrage to the low-level jobs being offered to Barbudans and the exclusion of Barbudans to parts of the natural resources to which they have been accustomed.

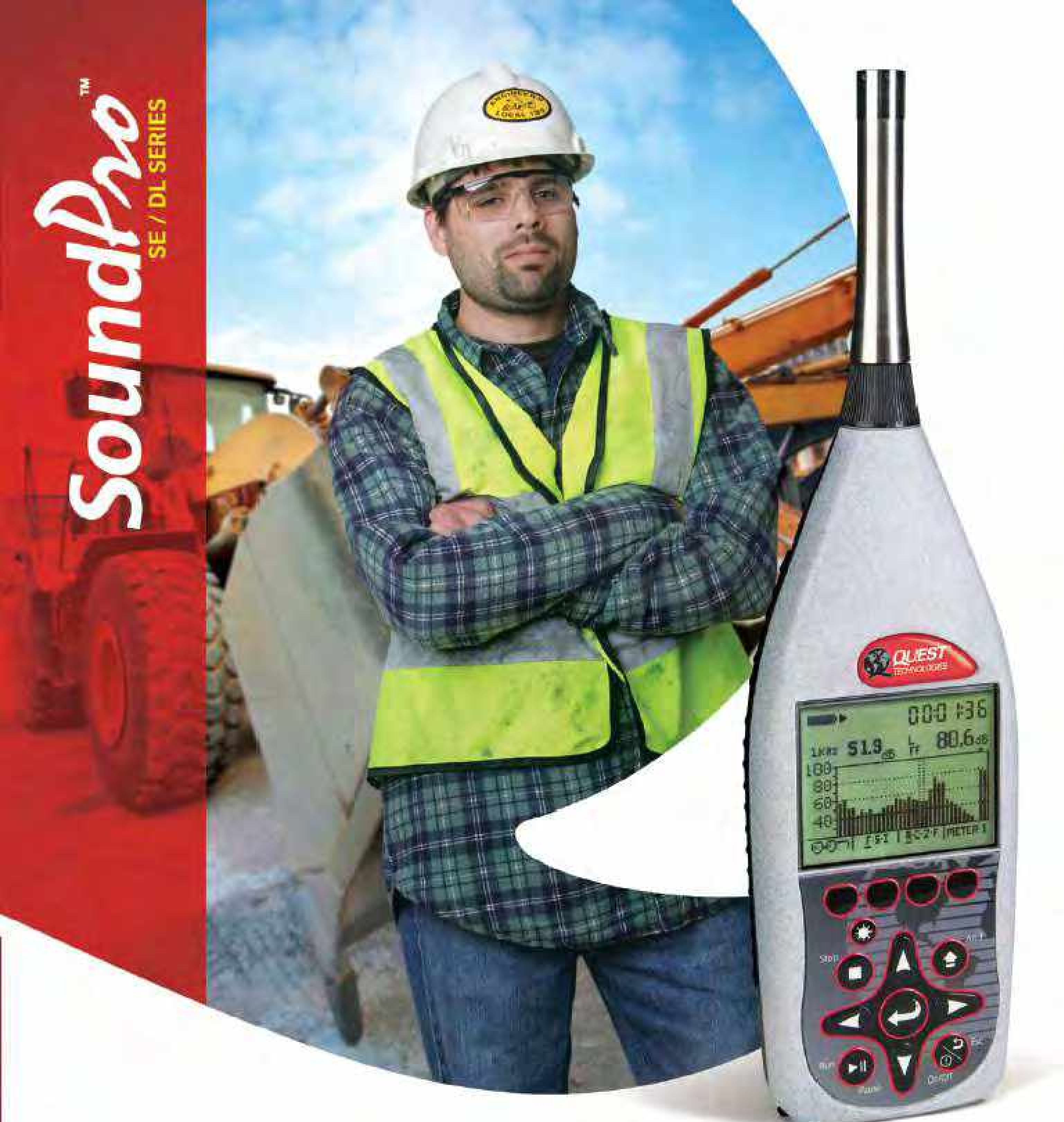
Included among cultural assets are their access to the rich natural resources found on the island - from beaches to camp sites - which they frequent to pass on to the next generation, traditional knowledge about the value of the flora and fauna and indigenous animals. The Lagoon for Barbudans is a rich cultural asset not only as it spawns the lobsters that form part of their livelihoods but is part of their historic landscape.

Among the cultural assets the Barbudans hold dear is the social capital that supports their ability to “never lock a door or window”. So strong is the social capital that fear of theft or assault does not exist. The new workforce on the development sites brings new people into the village with new behaviours, including the use of drugs and sexual grooming of young girls.

Stakeholders expressed satisfaction and considered a ‘good turn of events” that some young people who had no jobs are getting jobs as labourers, but they want more for them, training, certification and opportunities for advancement.

[15] Barbudan Council Members were the key exception to this rule who noted that they had been spoken to by the Developers some time ago.

Appendix 1 Description of monitoring equipment and air/noise monitoring results



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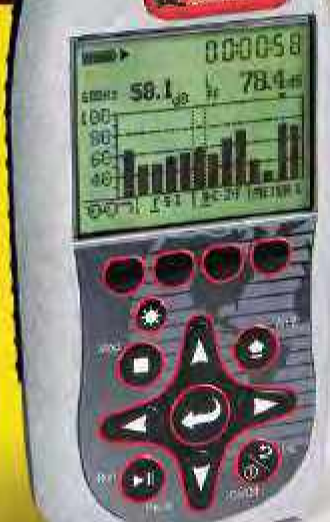
The SoundPro SE/DL series of sound level meters represent latest technology development and innovative features in a simple to use instrument that is ideal for:

Occupational Noise Evaluations, Hearing Protector Selection Measurements, Environmental Noise Assessments, Noise Ordinance Enforcement and Legal Metrology, General Sound and Frequency Analysis Measurements.



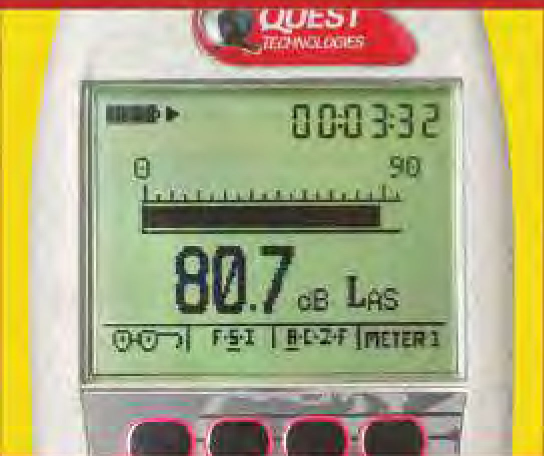
Typical User Applications include documentation of workplace noise by exposure data and real-time frequency analysis in 1/1 and 1/3 octave bands. This documentation is used to ensure regulatory compliance and provide the foundation data for hearing conservation programs. Other common applications include general environmental measurements, vehicle noise evaluations, quality control and process measurements, building acoustics, and military noise studies including heavy weapons, warfighter exposures, shipboard measurements, and mobile equipment evaluations.

Key Features of the SoundPro SE/DL series include:

1) Precision Class 1 and General Purpose Class 2 Models
2) Full compliance with latest U.S. and international standards
3) Proven friendly menu driven user interface
4) High Speed Digital Signal Processor with fast data transfer rate
5) Removable SD Memory Card for file storage
6) Powerful feature sets and options such as Acoustic Spectral Curves and Speech Intelligibility functions

Features Common to All SoundPro SE/DL Models:

- ANSI & IEC Standards Compliant
- Available in Class 1 Precision or Class 2 Models
- Two "virtual" Sound Level Meters Running Simultaneously
- Concurrent A-weighted and C-Weighted Measurements
- Programmable & Level Triggered Start and Stop
- A, C, and Z (Flat) Frequency Weighting
- Fast, Slow, and IEC Impulse Time Response
- Selectable Thresholds 10 dB – 140 dB
- 3, 4, 5, 6 dB Exchange Rates
- Luminescent Keypad and Backlit Display
- SD Memory Card Slot
- USB Communications Port & Serial RS-232 Output
- Multilingual Display (English, German, Spanish, French, Italian, & Portuguese)
- Time History Data Logging with 1 second to 60 minute intervals
- Back Erase Function
- Noise Dose Calculation / Dosimetry Function



SPL DISPLAY
Quasi-Analogue and Numerical

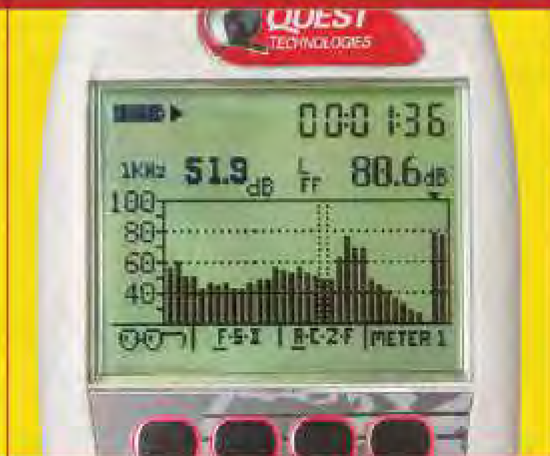
Analogue Display View

Displays the current Sound Pressure Level (SPL) with selected time response and filter weightings. The amplitude of the displayed measurement is shown both graphically by the length of the bar and numerically below the bar. The bar appears if the measured value is above the minimum value for the selected measurement range.

1/1 OCTAVE
Band Bar Chart Measurement Screen

Broadband Bar Chart View

Displays 1/1 octave analysis measurements in filter band and broadband values for both meters 1 and 2. This screen contains 13 bars with 11 filter bands and 2 for broadband. Bars appear if the value for the measurement is above the minimum value for the selected range.



1/3 OCTAVE
Band Bar Chart Measurement Screen

Broadband Bar Chart View

Displays 1/3 octave-band analysis measurements in filter band and broadband values for both meters 1 and 2. This screen contains 35 bars with 33 filter bands and 2 for broadband. Bars appear if the value for the bar is above the minimum value for the selected measurement range.

Optional Features and Expanded Capabilities:

- Full (1/1) Octave Band Real-Time Analysis
- Third (1/3) Octave Band Real-Time Analysis
- Acoustic Spectral Curves Option
- Speech Intelligibility Option
- Outdoor Weatherproof Measuring System Option
- Audiometric Calibration Kit Configurations
- GPS Data Incorporation (Using compatible GPS Receiver)
- Optional Microphones in ¼", ½", and 1" sizes

SoundPro
Outdoor Measuring System (OMS)

The SoundPro Outdoor Measuring System is a tool used to protect your instrumentation from exposure to wind, rain, snow, chemicals, particulates, animals, tampering, vandalism and theft. It is also used for extended battery life with up to one week of continuous monitoring (two weeks with optional second battery). The weatherproof case holds the meter and battery pack with room for accessories and storage of the system components while not in use.

Exposed components are made of stainless steel, ABS and engineered polymers. The kit contains all necessary masts, windscreens, cables, battery packs and adapters required for use with the SoundPro SE and DL instruments. Provisions exist in the case design to allow customer-supplied padlocks and cables to be used to lock the case and secure it to a stationary object.

SPECIFICATIONS FOR THE SOUNDPRO SE/DL

GENERAL	
DISPLAY LANGUAGES:	English, Spanish, French, German, Italian, Portuguese
USER INTERFACE:	10 Pushbuttons and 4 Soft keys, Menu Driven
DISPLAY TYPE:	Transflective 128 X 64 Dot Matrix LCD with additional fiber optic backlighting
STANDARDS	
EN/IEC 61672, ANSI S1.4, ANSI S1.43, EN/IEC 61260, ANSI S1.11, CISPR 16-1, IEC 6100-4-2, IEC 6100-6-2 (also meets requirements of former standards IEC 60651 and 60804)	
CE Marked	
MEASUREMENTS	
PARAMETERS:	SPL, LMAX, LMIN, Peak, LEQ, LAVG, SEL, LN (selectable L1 to L99), TWA, Taktm, Dose, PDose, Exposure (PA2H), LDN, CNEL
RANGES:	120 dB+ (A-weighted) total dynamic measurement range over 8 individual ranges of 90 dB (A-weighted) each (with filters - 80 dB ranges); Overall measurement range 0 dB to 140 dB
PEAK RANGE:	Up to 143 dB using standard BK4936 microphone; higher with optional microphones and preamps
FREQUENCY WEIGHTING:	A, C, Z and F (Flat)
RESPONSE TIME:	Fast, Slow, IEC Impulse
EXCHANGE RATES:	3, 4, 5, and 6 dB
CRITERION LEVEL:	40 to 100 dB
UPPER LIMIT TIME LOGGING:	10 to 140 dB selectable
RUN MODES:	Level Triggered Run/Pause, Clock/Date Triggered Power On and Run for Programmed Duration, External Logic Input Run/Pause, and Keypad initiated Run/Pause for Programmed Duration
MEASUREMENT REFERENCES:	SPL: 114 dB Frequency: 1 kHz Direction: 0 Degrees using free field response microphone
OCTAVE AND THIRD OCTAVE FILTERS (OPTIONAL)	
FULL OCTAVE FILTERS:	11 bands with center frequencies from 16 Hz to 16 kHz
THIRD OCTAVE FILTERS:	33 bands with center frequencies from 12.5 Hz to 20 kHz
CALIBRATION	
HISTORY:	Complete Calibration History with post study verification logged with calibration history
DATALOGGING OPTION	
DL MODELS:	Include standard removable secure digital (SD) memory card. This card is required to store multiple sessions/studies and for setup storage. QuestSuite® Professional II required to interpret data files.
SUMMARY DATA & TIME HISTORY DATA LOGGED:	Max, Min, Peak, LN, LEQ (LAVG if using 5 dB exchange rate)
LOGGING INTERVALS:	User selectable from among 11 settings ranging from 1 second to 60 minutes
MEMORY:	Accepts 128 mb to 2 GB SD Memory Cards
SPECIAL FUNCTIONS	
BACK ERASE:	Selectable 1 second to 20 seconds removal of measurement data (data removed by back erasing retained in session file)
SECURITY:	4 digit code protection for Runs and Setups available
OPTIONAL ACOUSTIC SPECTRAL CURVES:	Noise Criterion (NC) Curves, Preferred Noise Criterion (PNC) Curves, Room Criterion (RC) Curves, Balanced Noise Criterion (NCB) Curves, Noise Rating (NR) Curves, Audiometric Room Curves (per ANSI S3.1), and Audiometric Room Curves (per OSHA Hearing Conservation Amendment)
OPTIONAL SPEECH INTELLIGIBILITY FUNCTION:	Firmware can be installed in the SoundPro® series to allow the testing and evaluation of intelligibility of human speech, particularly through public address (PA), fire alarm and mass notification systems (MNS) based on the Speech Transmission Index (STI) and the STI-PA method in accordance with IEC 60268-16 and NFPA 72 National Fire Alarm Code

*Specifications continued on next page

SPECIFICATIONS FOR THE SOUNDPRO SE/DL *(CONTINUED)*

PORTS AND CONNECTIONS	
POWER JACK:	External power supply 9-16 VDC
AC/DC OUTPUT:	3.5 mm stereo (tip-AC, Ring-DC, Ring2-Ground)
10 PIN AUXILIARY CONNECTOR:	RS-232, 3 digital outputs, 1 digital input
USB:	Conforms to USB 2.0, Mini B Connector
ELECTRICAL CHARACTERISTICS	
BATTERIES:	4 disposable AA Alkaline Cells, typically >10 hours continuous use without backlight (SLM only without filters activated); Optional Nickel Metal Hydride (NiMH) Cells, typically 10+ hours (SLM only)
EXTERNAL DC POWER INPUT:	100 – 240 VAC, 47-63 Hz transformed to 9 VDC
STANDARD MICROPHONES:	Class/Type 1 Precision – BK4936; Class/Type 2 General Purpose – QE7052; other optional types and sizes available from ¼" to 1" prepolarized or standard condenser types
MICROPHONE POLARIZATION:	Selectable 0 volts or 200 volts
MICROPHONE SENSITIVITY:	Selectable nominal values in decibels relevant to 1 Volt/Pa
METER INPUT:	50 KOhm nominal input impedance
PREAMPLIFIER:	Removable Preamp directly accepts ½" (0.52" or 13.2 mm) microphone; other sizes require adapter
REMOTE CABLE:	Will drive up to 15 meters of cable with negligible signal loss
INPUT IMPEDANCE:	20 kΩ in series with 11 µF capacitance, with 100 pF capacitance to ground
PHYSICAL CHARACTERISTICS	
SIZE:	3.1"W X 11.1"H X 1.6" thick (with preamp & microphone); 7.9 cm X 28.2 cm X 4.1 cm
WEIGHT:	0.54 kg or 1.2 lbs. (including batteries)
HOUSING:	Stainless fiber filled ABS Polycarbonate with additional internal EM/RFI shielding
TRIPOD MOUNT:	Standard photographic mount on rear accepts ¼"- 20 screw threads
ENVIRONMENTAL	
TEMPERATURE:	Operating -10^0 to $+ 50^0$ C. (<± 0.5 dB effect); Storage -25^0 C to $+ 70^0$ C
HUMIDITY:	10% to 90% RH, non-condensing
EXTERNAL FIELDS:	Electric – 10 V/meter, 1 kHz modulated, 30 MHz – 1 GHz, <55 dBC; Magnetic – 80 A/m, 50/60 Hz, no significant effect

*All Specifications Subject to Change

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Certificate of Calibration

Certificate No: 968252 BGG110027

Submitted By: ENGINEERING, APPLIED SCIENCE & TECHNOLOGY LTD (EAST)
62 EASTERN MAIN ROAD
ST. AUGUSTINE, TRINIDAD

Serial Number:	BGG110027	**Date Received:**	9/15/2021
Customer ID:	E.A.S.T.	**Date Issued:**	9/24/2021
Model:	SOUNDPRO DL-2 SLM	**Valid Until:**	9/24/2022

Test Conditions:

Temperature: 18°C to 29°C
Humidity: 20% to 80%
Barometric Pressure: 890 mbar to 1050 mbar

Model Conditions:

As Found: IN TOLERANCE
As Left: IN TOLERANCE

SubAssemblies:

Description:	Serial Number:
TYPE 2 PREAMP	1207 1451
MICROPHONE QE 7052 1/2 IN. ELECTRET	30708

Calibrated per Procedure: 53V899

Reference Standard(s):

I.D. Number	Device	Last Calibration	Date Calibration Due
EF000176	QUEST-CAL	12/6/2020	12/6/2021
ET0000556	B&K ENSEMBLE	1/22/2020	1/22/2022

Measurement Uncertainty:

ACOUSTIC +/- 0.19DB
Estimated at 95% Confidence Level (k=2)

Calibrated By: Brian L Bayer 9/24/2021
BRIAN BAYER Service Technician

This report certifies that all calibration equipment used in the test is traceable to NIST, and applies only to the unit identified under equipment above. This report must not be reproduced except in its entirety without the written approval of TSI Incorporated.

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Certificate of Calibration

Certificate No: 968252 QIG110126

Submitted By: ENGINEERING,APPLIED SCIENCE & TECHNOLOGY LTD(EAST)
62 EASTERN MAIN ROAD
ST. AUGUSTINE, TRINIDAD

Serial Number:	QIG110126	**Date Received:**	9/15/2021
Customer ID:	E.A.S.T.	**Date Issued:**	9/24/2021
Model:	QC-10 CALIBRATOR	**Valid Until:**	9/24/2022

Test Conditions:

Temperature: 18°C to 29°C
Humidity: 20% to 80%
Barometric Pressure: 890 mbar to 1050 mbar

Model Conditions:

As Found: IN TOLERANCE
As Left: IN TOLERANCE

SubAssemblies:

Description: **Serial Number:**

Calibrated per Procedure: 56V981

Reference Standard(s):

I.D. Number	Device	Last Calibration	Date Calibration Due
ET0000556	B&K ENSEMBLE	1/22/2020	1/22/2022
T00230	FLUKE 45 MULTIMETER	2/17/2020	2/17/2022

Measurement Uncertainty:

ACOUSTIC +/- 0.19DB AC VOLTAGE +/- 1.4% FREQUENCY +/- 0.058%
Estimated at 95% Confidence Level (k=2)

Calibrated By: Brian L Bayer 9/24/2021
BRIAN BAYER **Service Technician**

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DATA REPORTS

Barbuda - Location 1 (Day)

7/15/2022

Information Panel

Name	S003_BGG110027_15072022_093805
Start Time	15/07/2022 08:34:21 AM
Stop Time	15/07/2022 09:34:21 AM
Device Name	BGG110027
Model Type	SoundPro DL
Device Firmware Rev	R.13H
Comments	

Summary Data Panel

Description	Meter	Value	Description	Meter	Value
Leq	1	58.3 dB	Lmax	1	89 dB
Lmin	1	40.3 dB	Lpk	1	102.6 dB
Rtime	1	01:00:00			
Exchange Rate	1	3 dB	Weighting	1	A
Response	1	FAST	Bandwidth	1	OFF
Exchange Rate	2	3 dB	Weighting	2	C
Response	2	FAST			

Logged Data Table

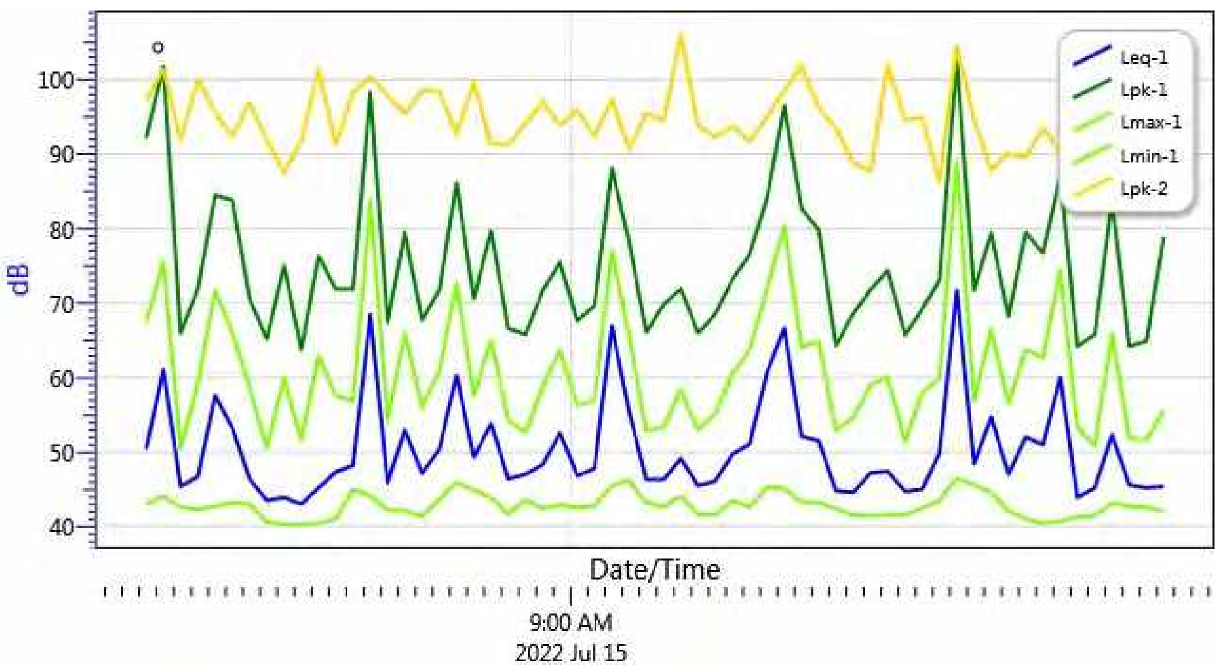
Date/Time	Leq-1	Lmax-1	Lmin-1	Lpk-1
15/07/2022 08:35:21 AM	50.4	67.4	43	92.2
08:36:21 AM	61	75.5	44.1	101.8
08:37:21 AM	45.4	50.5	42.6	66
08:38:21 AM	46.7	59.2	42.3	71.9
08:39:21 AM	57.6	71.7	42.7	84.5
08:40:21 AM	53.2	66	43.2	83.8
08:41:21 AM	46.4	58.7	43	70.6
08:42:21 AM	43.5	50.5	40.6	65.2
08:43:21 AM	43.9	59.9	40.3	75
08:44:21 AM	43	51.6	40.3	63.8
08:45:21 AM	45.2	62.9	40.4	76.3
08:46:21 AM	47.3	57.6	41	71.9

08:47:21 AM	48.2	56.8	45	71.9
08:48:21 AM	68.5	83.7	44.1	98.3
08:49:21 AM	45.9	54.2	42.2	67.5
08:50:21 AM	53	66.1	42.2	79.5
08:51:21 AM	47.1	56	41.3	67.7
08:52:21 AM	50.4	60.9	43.7	71.8
08:53:21 AM	60.3	72.6	45.9	86.1
08:54:21 AM	49.3	57.6	44.9	70.6
08:55:21 AM	53.8	65	43.9	79.7
08:56:21 AM	46.4	54.3	41.7	66.6
08:57:21 AM	47	52.6	43.6	65.8
08:58:21 AM	48.3	58.8	42.4	71.7
08:59:21 AM	52.6	63.7	43	75.5
09:00:21 AM	46.8	56.2	42.5	67.6
09:01:21 AM	47.8	57	42.8	69.7
09:02:21 AM	66.9	77	45.5	88.1
09:03:21 AM	55.4	65.6	46.2	78.2
09:04:21 AM	46.3	52.9	43.2	66.1
09:05:21 AM	46.3	53.3	42.7	69.8
09:06:21 AM	49.1	58.3	44.1	71.9
09:07:21 AM	45.5	53	41.6	66
09:08:21 AM	46.1	55.1	41.6	68.5
09:09:21 AM	49.7	60.6	43.5	73.2
09:10:21 AM	51.1	63.7	42.6	76.6
09:11:21 AM	60.7	71.9	45.3	84.1
09:12:21 AM	66.6	80.4	45.1	96.5
09:13:21 AM	52.1	64.1	43.3	82.7
09:14:21 AM	51.5	64.8	43.2	79.8
09:15:21 AM	44.8	52.9	42.4	64.3
09:16:21 AM	44.6	54.6	41.5	68.6
09:17:21 AM	47.2	59	41.5	71.8
09:18:21 AM	47.4	60.1	41.5	74.4
09:19:21 AM	44.7	51.3	41.6	65.7
09:20:21 AM	45	58	42.5	69.2
09:21:21 AM	49.9	59.9	43.5	73.1
09:22:21 AM	71.7	89	46.5	102.6
09:23:21 AM	48.4	56.8	45.6	71.7

09:24:21 AM	54.7	66.4	44.6	79.4
09:25:21 AM	47	56.5	42.1	68.2
09:26:21 AM	52	63.8	41	79.5
09:27:21 AM	51	62.6	40.4	76.7
09:28:21 AM	60	74.4	40.7	87
09:29:21 AM	43.9	53.4	41.3	64.2
09:30:21 AM	45.2	50.8	41.4	65.8
09:31:21 AM	52.3	66	43.2	83.8
09:32:21 AM	45.6	51.8	42.7	64.2
09:33:21 AM	45.2	51.6	42.6	64.9
09:34:21 AM	45.4	55.6	42	78.9

Logged Data Chart

S003_BGG110027_15072022_093805: Logged Data Chart



Barbuda - Location 2 (Day)

7/15/2022

Information Panel

Name	S004_BGG110027_15072022_122717
Start Time	15/07/2022 11:27:03 AM
Stop Time	15/07/2022 12:27:03 PM
Device Name	BGG110027
Model Type	SoundPro DL
Device Firmware Rev	R.13H
Comments	

Summary Data Panel

Description	Meter	Value	Description	Meter	Value
Leq	1	49.7 dB	Lmax	1	82.6 dB
Lmin	1	42.1 dB	Lpk	1	109.3 dB
Rtime	1	01:00:00			
Exchange Rate	1	3 dB	Weighting	1	A
Response	1	FAST	Bandwidth	1	OFF
Exchange Rate	2	3 dB	Weighting	2	C
Response	2	FAST			

Logged Data Table

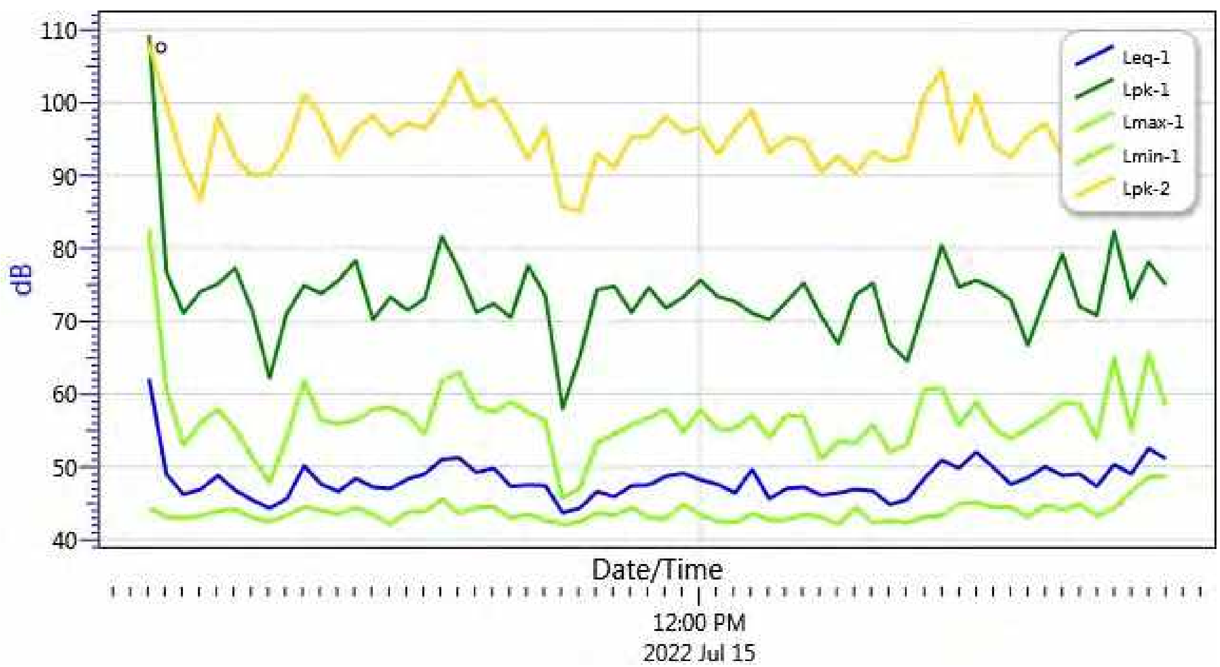
Date/Time	Leq-1	Lmax-1	Lmin-1	Lpk-1
15/07/2022 11:28:03 AM	62.1	82.6	44.4	109.3
11:29:03 AM	49	60.7	43.1	76.8
11:30:03 AM	46.2	53	42.9	71.1
11:31:03 AM	46.9	56	43.3	74.1
11:32:03 AM	48.8	57.9	43.9	75.1
11:33:03 AM	46.8	55.1	44.2	77.3
11:34:03 AM	45.4	51.3	43	71.4
11:35:03 AM	44.3	47.8	42.5	62.2
11:36:03 AM	45.6	54	43.3	71.1
11:37:03 AM	50.1	61.8	44.5	74.9
11:38:03 AM	47.6	56.4	44	73.8
11:39:03 AM	46.6	55.9	43.5	75.6

11:40:03 AM	48.4	56.4	44.4	78.3
11:41:03 AM	47.2	57.9	43.4	70.2
11:42:03 AM	47	58.1	42.1	73.3
11:43:03 AM	48.3	57.1	43.8	71.5
11:44:03 AM	49	54.5	43.8	73.1
11:45:03 AM	51	61.8	45.6	81.6
11:46:03 AM	51.2	62.9	43.6	77
11:47:03 AM	49.2	58.3	44.4	71.2
11:48:03 AM	49.8	57.5	44.5	72.4
11:49:03 AM	47.3	58.9	42.9	70.5
11:50:03 AM	47.5	57.5	43.5	77.6
11:51:03 AM	47.4	56.3	42.6	73.5
11:52:03 AM	43.7	45.7	42.1	58
11:53:03 AM	44.3	47.1	42.4	65.1
11:54:03 AM	46.6	53.3	43.7	74.3
11:55:03 AM	45.9	54.5	43.3	74.8
11:56:03 AM	47.4	55.8	44.4	71.2
11:57:03 AM	47.5	56.7	43	74.6
11:58:03 AM	48.7	57.9	42.8	71.8
11:59:03 AM	49.1	54.8	44.9	73.3
12:00:03 PM	48.2	57.8	43.4	75.6
12:01:03 PM	47.6	55.2	42.5	73.4
12:02:03 PM	46.4	55.2	42.3	72.7
12:03:03 PM	49.6	57.1	43.6	71.1
12:04:03 PM	45.6	54	42.7	70.2
12:05:03 PM	47	57.1	42.7	72.7
12:06:03 PM	47.2	56.9	43.5	75.2
12:07:03 PM	46.1	51.1	43.1	70.7
12:08:03 PM	46.4	53.5	42.1	66.9
12:09:03 PM	46.9	53.2	44.4	73.6
12:10:03 PM	46.7	55.8	42.3	75.2
12:11:03 PM	44.8	52	42.6	66.9
12:12:03 PM	45.5	53.1	42.3	64.5
12:13:03 PM	48.4	60.6	43.1	72.3
12:14:03 PM	50.9	60.8	43.3	80.4
12:15:03 PM	49.8	55.7	44.9	74.7
12:16:03 PM	52	58.8	45.1	75.6

12:17:03 PM	49.9	55.4	44.4	74.6
12:18:03 PM	47.6	53.8	44.5	72.9
12:19:03 PM	48.5	55.3	43.1	66.7
12:20:03 PM	50	56.7	44.8	73.2
12:21:03 PM	48.8	58.7	44	79.2
12:22:03 PM	49	58.6	44.9	72
12:23:03 PM	47.3	53.9	43.2	70.8
12:24:03 PM	50.3	65	44.3	82.3
12:25:03 PM	49	55.1	46.6	73
12:26:03 PM	52.5	65.6	48.6	78.1
12:27:03 PM	51.1	58.3	48.7	75

Logged Data Chart

S004_BGG110027_15072022_122717: Logged Data Chart



Barbuda - Location 3 (Day)

7/16/2022

Information Panel

Name	S007_BGG110027_16072022_111141
Start Time	16/07/2022 10:11:11 AM
Stop Time	16/07/2022 11:11:11 AM
Device Name	BGG110027
Model Type	SoundPro DL
Device Firmware Rev	R.13H
Comments	

Summary Data Panel

Description	Meter	Value	Description	Meter	Value
Leq	1	55.2 dB	Lmax	1	76.5 dB
Lmin	1	37.4 dB	Lpk	1	104.9 dB
Rtime	1	01:00:00			
Exchange Rate	1	3 dB	Weighting	1	A
Response	1	FAST	Bandwidth	1	OFF
Exchange Rate	2	3 dB	Weighting	2	C
Response	2	FAST			

Logged Data Table

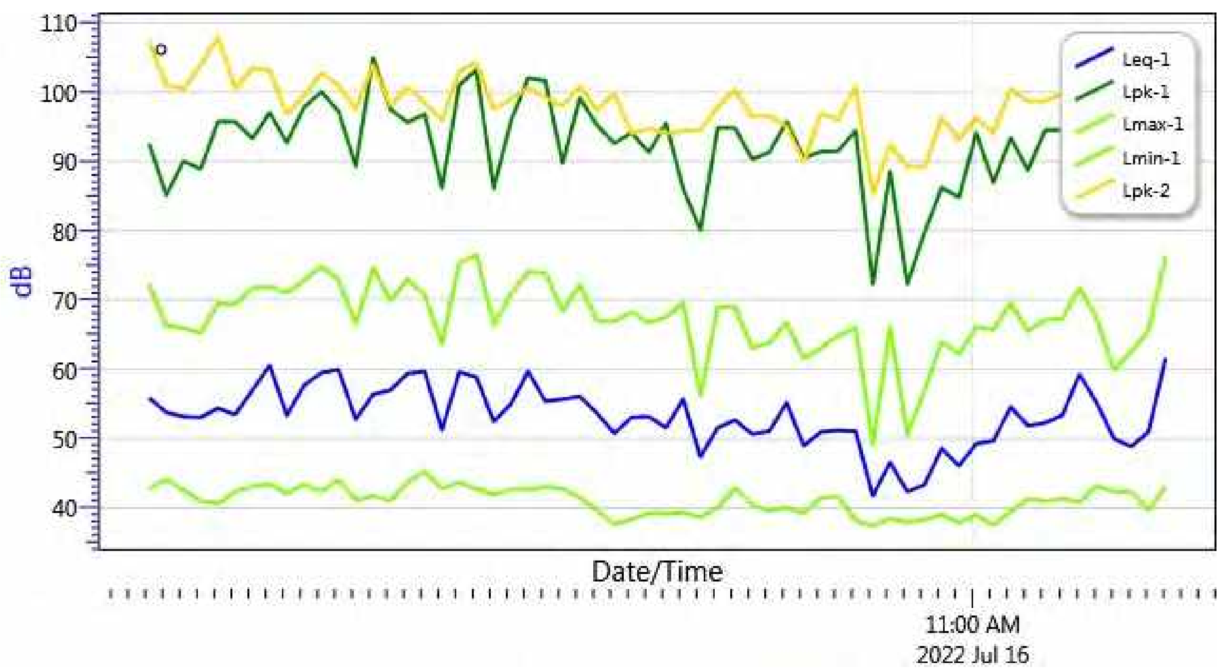
Date/Time	Leq-1	Lmax-1	Lmin-1	Lpk-1
16/07/2022 10:12:11 AM	55.9	72.2	42.8	92.6
10:13:11 AM	53.8	66.3	44.2	85.1
10:14:11 AM	53.2	65.9	42.6	90
10:15:11 AM	53.1	65.3	41.1	88.9
10:16:11 AM	54.4	69.5	40.7	95.7
10:17:11 AM	53.5	69.4	42.4	95.7
10:18:11 AM	57	71.7	43.1	93.3
10:19:11 AM	60.6	71.9	43.5	97
10:20:11 AM	53.4	71	42.2	92.7
10:21:11 AM	57.7	72.9	43.4	97.8
10:22:11 AM	59.5	74.8	42.4	100
10:23:11 AM	60	73	44.1	97.2

10:24:11 AM	52.8	66.5	41.1	89.3
10:25:11 AM	56.4	74.6	41.8	104.9
10:26:11 AM	57	69.9	41	97.5
10:27:11 AM	59.4	73	43.7	95.6
10:28:11 AM	59.7	70.7	45.3	96.8
10:29:11 AM	51.3	63.6	42.8	86.2
10:30:11 AM	59.6	75.3	43.7	101
10:31:11 AM	58.9	76.5	42.8	103.2
10:32:11 AM	52.5	66.4	42	86.1
10:33:11 AM	55	70.9	42.7	95.8
10:34:11 AM	59.7	74.1	42.7	102
10:35:11 AM	55.4	73.9	43.1	101.6
10:36:11 AM	55.7	68.4	42.8	89.7
10:37:11 AM	56.1	72.2	41.5	99.1
10:38:11 AM	53.7	67	39.8	95.2
10:39:11 AM	50.8	66.9	37.7	92.6
10:40:11 AM	53.1	68.3	38.4	94.1
10:41:11 AM	53.2	66.7	39.3	91.3
10:42:11 AM	51.6	67.5	39.2	95.5
10:43:11 AM	55.7	69.6	39.4	86
10:44:11 AM	47.4	56.2	38.7	80.1
10:45:11 AM	51.6	69	40.1	94.8
10:46:11 AM	52.7	69	43	94.8
10:47:11 AM	50.7	63.1	40.5	90.3
10:48:11 AM	51.1	63.8	39.6	91.3
10:49:11 AM	55.2	66.7	40.1	95.7
10:50:11 AM	49	61.6	39.3	90.5
10:51:11 AM	51	63.1	41.5	91.4
10:52:11 AM	51.2	64.9	41.7	91.5
10:53:11 AM	51.1	66	38.2	94.4
10:54:11 AM	41.8	49.1	37.4	72.3
10:55:11 AM	46.6	66.1	38.5	88.5
10:56:11 AM	42.4	50.6	38	72.3
10:57:11 AM	43.4	56.9	38.3	79.7
10:58:11 AM	48.6	64	39.1	86.2
10:59:11 AM	46.1	62.2	37.9	84.8
11:00:11 AM	49.3	66.1	39.1	94.1

11:01:11 AM	49.7	65.7	37.5	86.9
11:02:11 AM	54.6	69.5	39.5	93.4
11:03:11 AM	51.9	65.5	41.4	88.7
11:04:11 AM	52.3	67.2	41	94.5
11:05:11 AM	53.4	67.3	41.4	94.5
11:06:11 AM	59.3	71.8	40.9	95.4
11:07:11 AM	55.1	67.3	43.2	95
11:08:11 AM	50	59.9	42.4	82.4
11:09:11 AM	48.9	62.6	42.4	89.3
11:10:11 AM	51	65.6	39.7	88.8
11:11:11 AM	61.7	76.3	43.2	98.6

Logged Data Chart

S007_BGG110027_16072022_111141: Logged Data Chart



Barbuda - Location 4 (Day)

7/16/2022

Information Panel

Name	S008_BGG110027_16072022_124016
Start Time	16/07/2022 11:34:45 AM
Stop Time	16/07/2022 12:34:45 PM
Device Name	BGG110027
Model Type	SoundPro DL
Device Firmware Rev	R.13H
Comments	

Summary Data Panel

Description	Meter	Value	Description	Meter	Value
Leq	1	60.9 dB	Lmax	1	96.7 dB
Lmin	1	37.4 dB	Lpk	1	111.3 dB
Rtime	1	01:00:00			
Exchange Rate	1	3 dB	Weighting	1	A
Response	1	FAST	Bandwidth	1	OFF
Exchange Rate	2	3 dB	Weighting	2	C
Response	2	FAST			

Logged Data Table

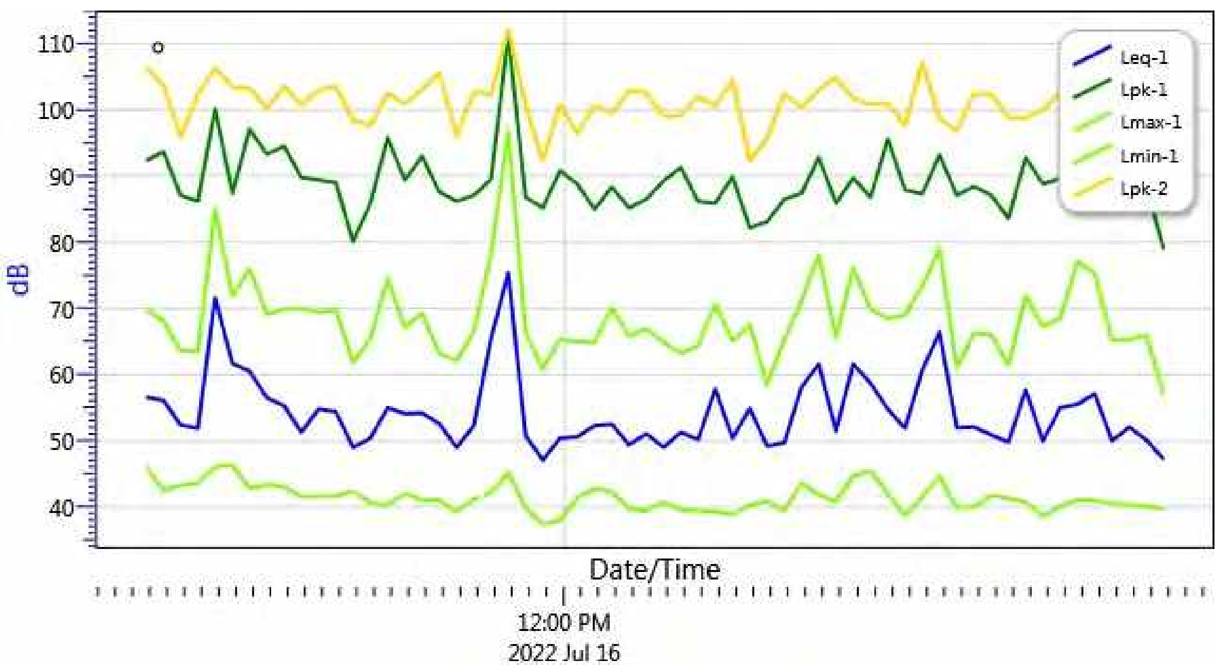
Date/Time	Leq-1	Lmax-1	Lmin-1	Lpk-1
16/07/2022 11:35:45 AM	56.6	69.9	46	92.3
11:36:45 AM	56.1	68	42.5	93.7
11:37:45 AM	52.4	63.6	43.3	87.1
11:38:45 AM	51.9	63.5	43.6	86.2
11:39:45 AM	71.6	85	46.1	100.1
11:40:45 AM	61.7	71.9	46.3	87.4
11:41:45 AM	60.5	76	42.8	97.1
11:42:45 AM	56.5	69.1	43.4	93.3
11:43:45 AM	55.3	69.9	43.1	94.5
11:44:45 AM	51.3	70	41.5	89.8
11:45:45 AM	54.8	69.4	41.6	89.4
11:46:45 AM	54.4	69.8	41.7	89

11:47:45 AM	49	61.8	42.4	80.1
11:48:45 AM	50.4	65.4	40.6	85.9
11:49:45 AM	55	74.5	40.3	95.8
11:50:45 AM	54.1	67.1	42.1	89.4
11:51:45 AM	54.2	69.3	41	93
11:52:45 AM	52.6	63.2	41.1	87.6
11:53:45 AM	49	62.1	39.3	86.2
11:54:45 AM	52.3	66.5	41.2	87.1
11:55:45 AM	65.5	78.3	42.2	89.5
11:56:45 AM	75.4	96.7	45.2	111.3
11:57:45 AM	50.8	66.4	40	86.8
11:58:45 AM	47.1	60.9	37.4	85.2
11:59:45 AM	50.4	65.3	38	90.8
12:00:45 PM	50.6	65	41.4	88.8
12:01:45 PM	52.3	64.9	42.8	85
12:02:45 PM	52.5	70	42.3	88.3
12:03:45 PM	49.4	65.8	39.8	85.2
12:04:45 PM	51.1	66.9	39.4	86.5
12:05:45 PM	49	64.9	40.8	89.3
12:06:45 PM	51.3	63.2	39.6	91.3
12:07:45 PM	50.2	64.4	39.4	86.2
12:08:45 PM	57.8	70.7	39.3	85.9
12:09:45 PM	50.4	65.1	38.9	89.9
12:10:45 PM	54.9	67.6	40.3	82.2
12:11:45 PM	49.2	58.5	40.9	83.1
12:12:45 PM	49.7	65.3	39.5	86.5
12:13:45 PM	58.1	71.1	43.6	87.4
12:14:45 PM	61.6	78.1	41.9	92.8
12:15:45 PM	51.5	65.6	40.8	85.9
12:16:45 PM	61.6	76.1	44.7	89.7
12:17:45 PM	58.7	69.9	45.4	86.8
12:18:45 PM	54.8	68.5	42.1	95.6
12:19:45 PM	51.9	69	38.7	87.9
12:20:45 PM	60.7	73.4	41.5	87.3
12:21:45 PM	66.4	79.1	44.7	93.2
12:22:45 PM	52	61.1	39.8	87.1
12:23:45 PM	52.1	66.2	40	88.4

12:24:45 PM	50.9	66.1	41.8	87.1
12:25:45 PM	49.8	61.4	41.3	83.6
12:26:45 PM	57.7	71.9	40.8	92.8
12:27:45 PM	50	67.3	38.6	88.8
12:28:45 PM	55	68.5	40.1	89.6
12:29:45 PM	55.5	77.1	41.1	102.9
12:30:45 PM	57.1	75.3	41	95
12:31:45 PM	50	65.2	40.5	86.2
12:32:45 PM	52.1	65.3	40.4	85
12:33:45 PM	50.1	66	40.1	88.5
12:34:45 PM	47.2	57	39.7	78.9

Logged Data Chart

S008_BGG110027_16072022_124016: Logged Data Chart



Barbuda - Location 1 (Night)

7/16/2022

Information Panel

Name	S005_BGG110027_16072022_003429
Start Time	15/07/2022 10:04:22 PM
Stop Time	15/07/2022 11:04:22 PM
Device Name	BGG110027
Model Type	SoundPro DL
Device Firmware Rev	R.13H
Comments	

Summary Data Panel

Description	Meter	Value	Description	Meter	Value
Leq	1	52.8 dB	Lmax	1	76.1 dB
Lmin	1	37.8 dB	Lpk	1	104.6 dB
Rtime	1	01:00:00			
Exchange Rate	1	3 dB	Weighting	1	A
Response	1	FAST	Bandwidth	1	OFF
Exchange Rate	2	3 dB	Weighting	2	C
Response	2	FAST			

Logged Data Table

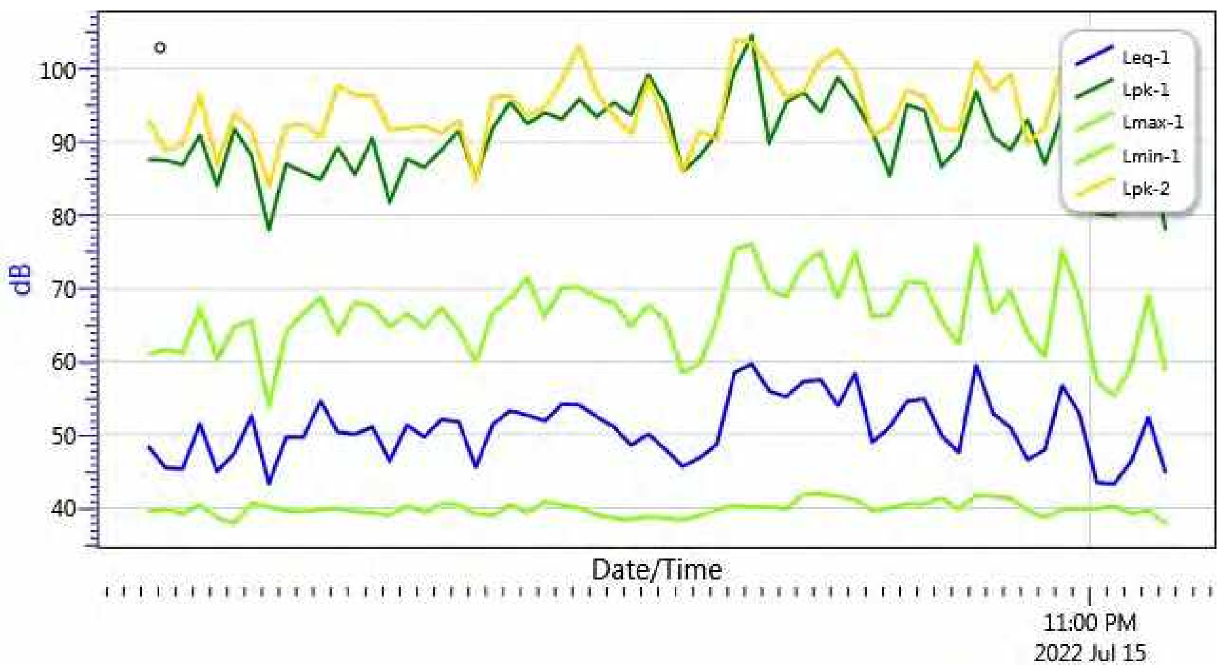
Date/Time	Leq-1	Lmax-1	Lmin-1	Lpk-1
15/07/2022 10:05:22 PM	48.5	61	39.5	87.6
10:06:22 PM	45.5	61.6	39.9	87.5
10:07:22 PM	45.4	61.2	39.2	86.9
10:08:22 PM	51.5	67.5	40.5	90.9
10:09:22 PM	45	60.4	38.7	84
10:10:22 PM	47.5	64.7	37.9	91.8
10:11:22 PM	52.6	65.6	40.7	88.1
10:12:22 PM	43.3	53.8	40.2	78
10:13:22 PM	49.7	64.1	39.6	87
10:14:22 PM	49.7	66.6	39.5	85.9
10:15:22 PM	54.6	68.8	39.8	84.9
10:16:22 PM	50.4	63.9	40	89.2

10:17:22 PM	50.1	68.1	39.5	85.6
10:18:22 PM	51.1	67.5	39.4	90.5
10:19:22 PM	46.4	64.7	39	81.7
10:20:22 PM	51.4	66.6	40.4	87.7
10:21:22 PM	49.7	64.6	39.4	86.5
10:22:22 PM	52.1	67.3	40.6	88.9
10:23:22 PM	51.8	64.4	40.5	91.5
10:24:22 PM	45.6	60	39.2	85.1
10:25:22 PM	51.5	66.7	39	92
10:26:22 PM	53.3	68.7	40.5	95.4
10:27:22 PM	52.7	71.4	39.4	92.5
10:28:22 PM	51.9	66.2	40.9	94
10:29:22 PM	54.2	70.1	40.4	93.1
10:30:22 PM	54.1	70.2	40	95.9
10:31:22 PM	52.5	68.8	39.1	93.4
10:32:22 PM	51.1	68	38.6	95.4
10:33:22 PM	48.6	64.9	38.4	93.7
10:34:22 PM	50.1	67.8	38.9	99.2
10:35:22 PM	48	65.5	38.6	95.2
10:36:22 PM	45.7	58.5	38.4	86
10:37:22 PM	46.9	59.8	39	88.1
10:38:22 PM	48.8	65.7	39.8	91.3
10:39:22 PM	58.5	75.3	40.3	99.6
10:40:22 PM	59.7	76.1	40.1	104.6
10:41:22 PM	56	69.9	40.2	89.8
10:42:22 PM	55.2	68.9	39.9	95.4
10:43:22 PM	57.3	73.3	41.9	96.8
10:44:22 PM	57.5	75	42	94.1
10:45:22 PM	54	68.7	41.6	98.8
10:46:22 PM	58.4	74.9	41.2	95.5
10:47:22 PM	49	66.2	39.6	91.3
10:48:22 PM	51.1	66.4	40	85.4
10:49:22 PM	54.6	70.9	40.6	95.1
10:50:22 PM	54.9	70.7	40.5	94.3
10:51:22 PM	49.9	65.6	41.5	86.6
10:52:22 PM	47.6	62.4	39.8	89.3
10:53:22 PM	59.5	75.8	41.8	96.9

10:54:22 PM	52.9	66.5	41.6	90.7
10:55:22 PM	51	69.5	41.4	88.9
10:56:22 PM	46.6	63.8	39.7	93
10:57:22 PM	48	60.7	38.7	87
10:58:22 PM	56.7	75.2	39.8	94
10:59:22 PM	52.9	68.9	39.9	91.2
11:00:22 PM	43.5	57.4	39.9	80.2
11:01:22 PM	43.3	55.3	40.3	80
11:02:22 PM	46.4	59.4	39.3	85.6
11:03:22 PM	52.4	69	39.7	89.9
11:04:22 PM	44.8	58.7	37.8	77.9

Logged Data Chart

S005_BGG110027_16072022_003429: Logged Data Chart



Barbuda - Location 2 (Night)

7/16/2022

Information Panel

Name	S006_BGG110027_16072022_003452
Start Time	15/07/2022 11:22:12 PM
Stop Time	16/07/2022 12:22:12 AM
Device Name	BGG110027
Model Type	SoundPro DL
Device Firmware Rev	R.13H
Comments	

Summary Data Panel

Description	Meter	Value	Description	Meter	Value
Leq	1	55.3 dB	Lmax	1	78.1 dB
Lmin	1	45.5 dB	Lpk	1	100.6 dB
Rtime	1	01:00:00			
Exchange Rate	1	3 dB	Weighting	1	A
Response	1	FAST	Bandwidth	1	OFF
Exchange Rate	2	3 dB	Weighting	2	C
Response	2	FAST			

Logged Data Table

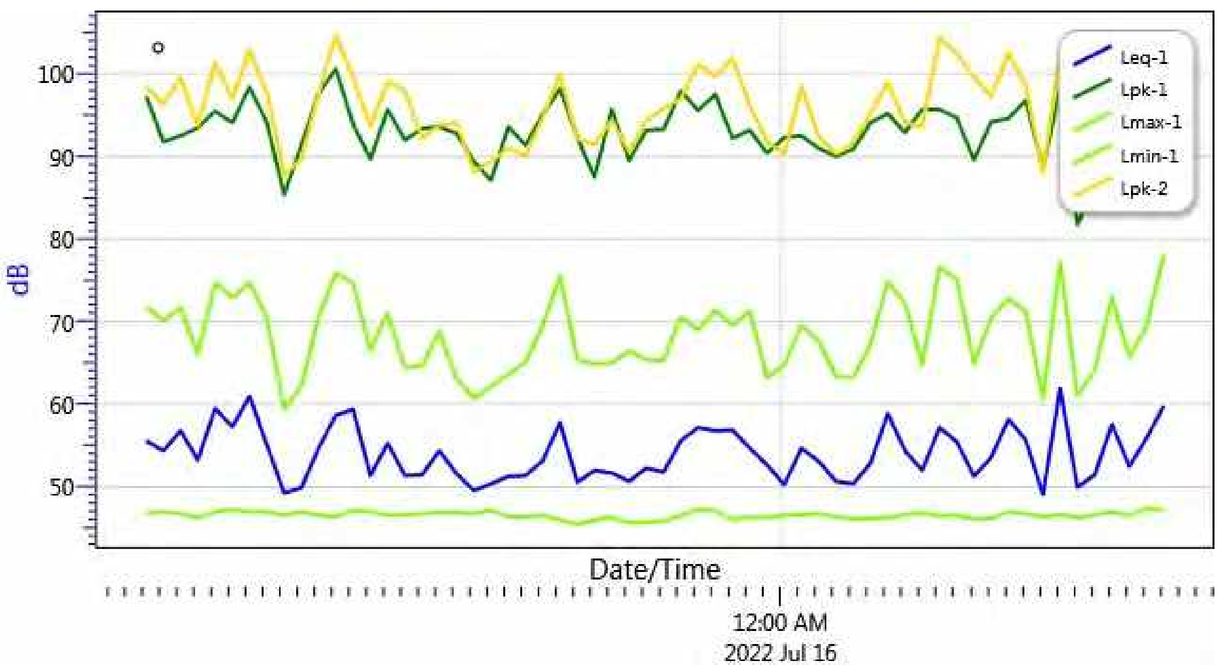
Date/Time	Leq-1	Lmax-1	Lmin-1	Lpk-1
15/07/2022 11:23:12 PM	55.6	71.8	46.9	97.3
11:24:12 PM	54.4	70.1	47	91.8
11:25:12 PM	56.8	71.8	46.8	92.5
11:26:12 PM	53.3	66	46.3	93.5
11:27:12 PM	59.5	74.7	47	95.5
11:28:12 PM	57.3	72.9	47.3	94.1
11:29:12 PM	61	74.8	47	98.4
11:30:12 PM	55.1	70.5	47	94.1
11:31:12 PM	49.3	59.4	46.6	85.4
11:32:12 PM	49.9	62.2	47	91.4
11:33:12 PM	54.7	70.6	46.6	97.6
11:34:12 PM	58.7	75.9	46.4	100.6

11:35:12 PM	59.4	74.7	47.2	93.9
11:36:12 PM	51.4	66.6	47	89.7
11:37:12 PM	55.3	71	46.6	95.7
11:38:12 PM	51.4	64.4	46.6	92
11:39:12 PM	51.5	64.7	46.8	93.4
11:40:12 PM	54.4	68.8	46.9	93.6
11:41:12 PM	51.6	63.1	46.9	92.8
11:42:12 PM	49.6	60.7	46.8	89.4
11:43:12 PM	50.4	62.2	47.2	87.1
11:44:12 PM	51.3	63.7	46.4	93.6
11:45:12 PM	51.4	65.1	46.4	91.4
11:46:12 PM	53.2	69.5	46.6	95.1
11:47:12 PM	57.8	75.6	46	98.2
11:48:12 PM	50.6	65.4	45.5	92.3
11:49:12 PM	52	64.9	46	87.5
11:50:12 PM	51.7	65	46.3	95.7
11:51:12 PM	50.7	66.5	45.7	89.5
11:52:12 PM	52.3	65.4	45.7	93.2
11:53:12 PM	51.8	65.3	45.9	93.3
11:54:12 PM	55.6	70.6	46.5	97.9
11:55:12 PM	57.2	69	47.3	95.6
11:56:12 PM	56.8	71.4	47.2	97.5
11:57:12 PM	56.9	69.6	46	92.2
11:58:12 PM	54.7	71.3	46.4	93.2
11:59:12 PM	52.7	63.2	46.3	90.4
16/07/2022 12:00:12 AM	50.3	64.8	46.6	92.3
12:01:12 AM	54.7	69.6	46.6	92.5
12:02:12 AM	53.1	67.7	46.8	91
12:03:12 AM	50.7	63.4	46.4	90
12:04:12 AM	50.4	63.3	46.1	90.9
12:05:12 AM	52.9	67.3	46.2	94.1
12:06:12 AM	58.9	74.9	46.3	95.2
12:07:12 AM	54.4	72.2	46.7	92.9
12:08:12 AM	52	64.8	46.9	95.7
12:09:12 AM	57.2	76.6	46.5	95.7
12:10:12 AM	55.5	75.2	46.6	94.7
12:11:12 AM	51.3	65	46.1	89.6

12:12:12 AM	53.6	70.5	46.2	94.2
12:13:12 AM	58.2	72.8	47	94.6
12:14:12 AM	55.7	71.3	46.8	96.8
12:15:12 AM	49.1	60.7	46.4	88.6
12:16:12 AM	61.9	77.2	46.7	98.4
12:17:12 AM	50	61.1	46.3	81.8
12:18:12 AM	51.5	64.1	46.6	86.3
12:19:12 AM	57.6	73	47	92.2
12:20:12 AM	52.5	65.8	46.5	93.5
12:21:12 AM	55.9	69.4	47.5	91.5
12:22:12 AM	59.8	78.1	47.1	98.7

Logged Data Chart

S006_BGG110027_16072022_003452: Logged Data Chart



Barbuda - Location 3 (Night)

7/17/2022

Information Panel

Name	S010_BGG110027_17072022_001716
Start Time	16/07/2022 11:15:57 PM
Stop Time	17/07/2022 12:15:57 AM
Device Name	BGG110027
Model Type	SoundPro DL
Device Firmware Rev	R.13H
Comments	

Summary Data Panel

Description	Meter	Value	Description	Meter	Value
Leq	1	44.9 dB	Lmax	1	63.7 dB
Lmin	1	35.7 dB	Lpk	1	82.7 dB
Rtime	1	01:00:00			
Exchange Rate	1	3 dB	Weighting	1	A
Response	1	FAST	Bandwidth	1	OFF
Exchange Rate	2	3 dB	Weighting	2	C
Response	2	FAST			

Logged Data Table

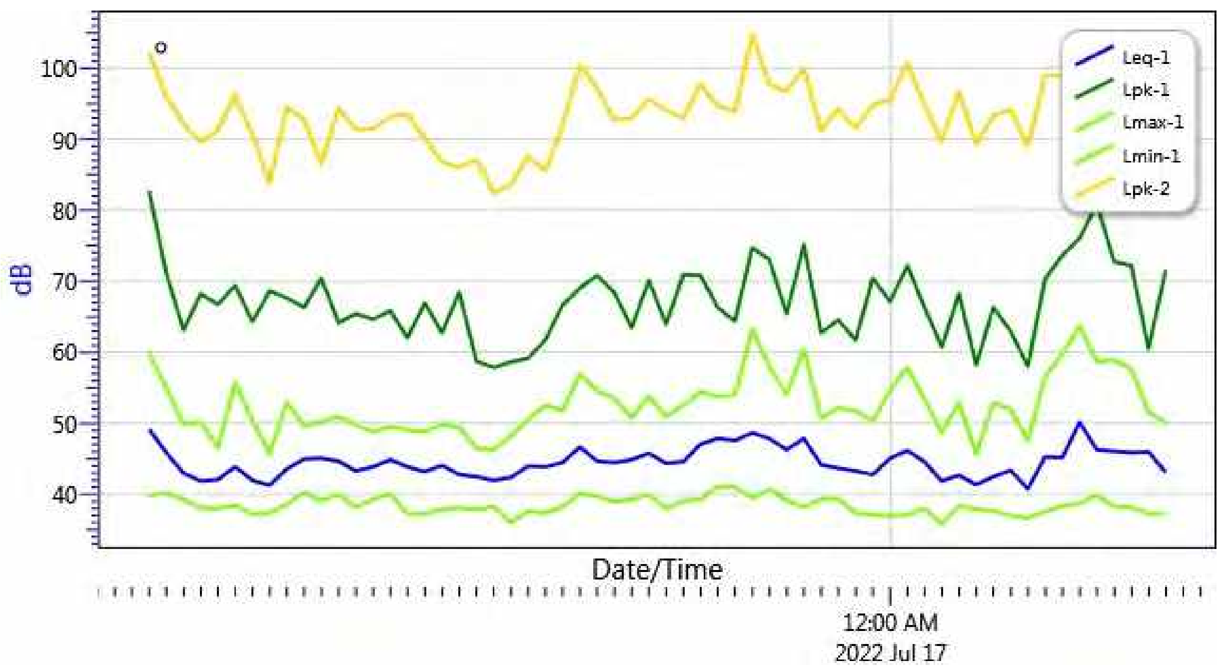
Date/Time	Leq-1	Lmax-1	Lmin-1	Lpk-1
16/07/2022 11:16:57 PM	49.1	59.8	39.7	82.7
11:17:57 PM	45.8	54.9	40.1	71.1
11:18:57 PM	42.9	49.8	39.2	63.1
11:19:57 PM	41.8	50.1	38	68.2
11:20:57 PM	42	46.5	37.9	66.7
11:21:57 PM	43.8	55.7	38.4	69.4
11:22:57 PM	41.9	50.4	37.1	64.3
11:23:57 PM	41.2	45.7	37.3	68.6
11:24:57 PM	43.5	52.9	38.5	67.6
11:25:57 PM	44.9	49.6	40.2	66.3
11:26:57 PM	45	50.1	39	70.4
11:27:57 PM	44.6	50.9	39.9	64.1

11:28:57 PM	43.2	49.8	38.1	65.4
11:29:57 PM	43.8	48.7	39.2	64.6
11:30:57 PM	44.8	49.5	40	65.8
11:31:57 PM	43.8	49	37.1	62
11:32:57 PM	43.1	48.7	37.2	66.9
11:33:57 PM	44	49.8	37.8	62.7
11:34:57 PM	42.7	49.4	38	68.4
11:35:57 PM	42.4	46.4	37.8	58.7
11:36:57 PM	41.9	46.2	38.2	57.8
11:37:57 PM	42.3	48.2	35.9	58.6
11:38:57 PM	43.9	50.5	37.6	59.1
11:39:57 PM	43.8	52.5	37.3	61.7
11:40:57 PM	44.4	51.7	38.1	66.6
11:41:57 PM	46.6	56.9	40.1	69
11:42:57 PM	44.6	54.5	39.6	70.8
11:43:57 PM	44.4	53.5	38.9	68.4
11:44:57 PM	44.8	50.7	39.2	63.4
11:45:57 PM	45.7	53.8	39.9	70.1
11:46:57 PM	44.3	50.9	37.9	63.9
11:47:57 PM	44.5	52.5	39	70.9
11:48:57 PM	47	54.4	39.2	70.8
11:49:57 PM	47.8	53.7	41	66.3
11:50:57 PM	47.5	53.9	41	64.3
11:51:57 PM	48.6	63.2	39.3	74.7
11:52:57 PM	47.8	57.9	40.7	73
11:53:57 PM	46.2	54	39.1	65.4
11:54:57 PM	47.8	60.4	38.1	75.1
11:55:57 PM	44.1	50.7	39.3	62.7
11:56:57 PM	43.6	52.1	39.3	64.5
11:57:57 PM	43.2	51.7	37.3	61.7
11:58:57 PM	42.7	50.3	37	70.4
11:59:57 PM	45	54.6	36.9	67.1
17/07/2022 12:00:57 AM	46.1	57.8	37	72.2
12:01:57 AM	44.5	53.3	38	66.3
12:02:57 AM	41.8	48.7	35.7	60.7
12:03:57 AM	42.6	52.9	38.3	68.2
12:04:57 AM	41.3	45.6	37.8	58.2

12:05:57 AM	42.4	52.8	37.6	66.3
12:06:57 AM	43.3	51.9	36.9	62.9
12:07:57 AM	40.7	47.5	36.6	58
12:08:57 AM	45.2	56.5	37.5	70.3
12:09:57 AM	45.1	59.7	38.3	73.6
12:10:57 AM	50.1	63.7	38.6	76
12:11:57 AM	46.2	58.6	39.8	80.9
12:12:57 AM	46	58.9	38.2	72.7
12:13:57 AM	45.8	57.6	38.1	72.2
12:14:57 AM	45.9	51.5	37.2	60.5
12:15:57 AM	43	50	37.1	71.6

Logged Data Chart

S010_BGG110027_17072022_001716: Logged Data Chart



Barbuda ζ Location 4 (Night)

7/17/2022

Information Panel

Name	S009_BGG110027_16072022_230454
Start Time	16/07/2022 10:05:31 PM
Stop Time	16/07/2022 11:05:31 PM
Device Name	BGG110027
Model Type	SoundPro DL
Device Firmware Rev	R.13H
Comments	

Summary Data Panel

Description	Meter	Value	Description	Meter	Value
Leq	1	48.8 dB	Lmax	1	69.1 dB
Lmin	1	35.5 dB	Lpk	1	93.8 dB
Rtime	1	01:00:00			
Exchange Rate	1	3 dB	Weighting	1	A
Response	1	FAST	Bandwidth	1	OFF
Exchange Rate	2	3 dB	Weighting	2	C
Response	2	FAST			

Logged Data Table

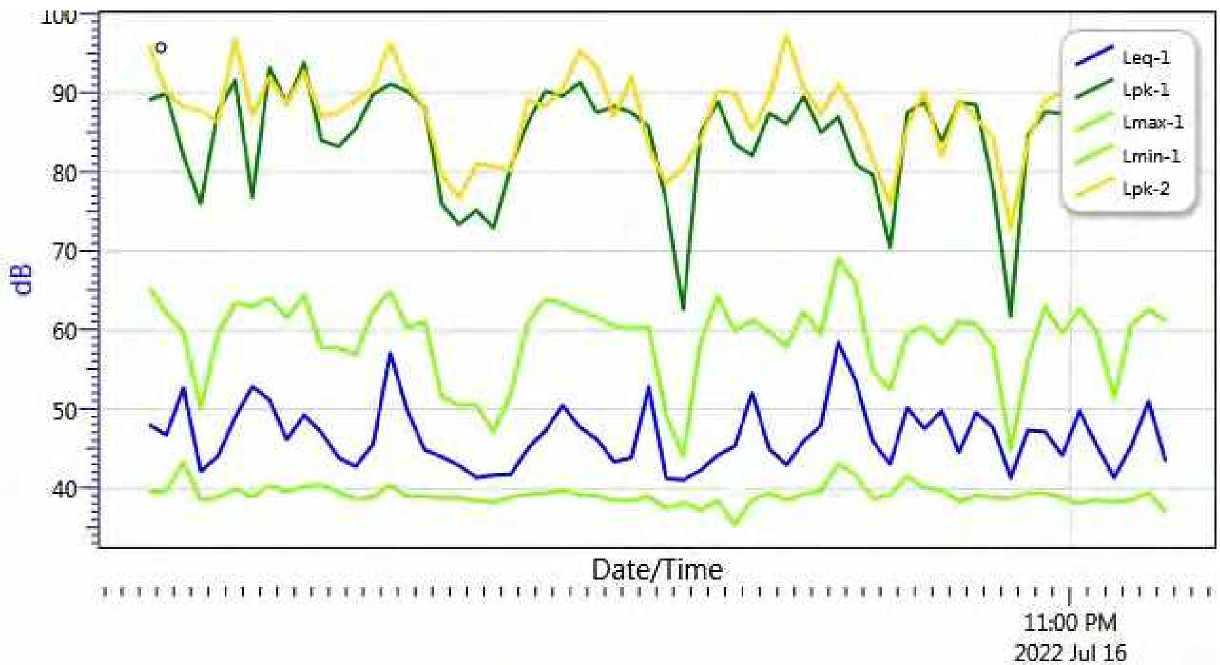
Date/Time	Leq-1	Lmax-1	Lmin-1	Lpk-1
16/07/2022 10:06:31 PM	48.1	65.4	39.6	89.1
10:07:31 PM	46.8	62.3	39.7	89.9
10:08:31 PM	52.7	59.6	43.4	82
10:09:31 PM	42.2	50.2	38.6	76
10:10:31 PM	44.1	59.5	38.9	87.6
10:11:31 PM	49	63.5	40	91.6
10:12:31 PM	52.9	63	38.9	76.8
10:13:31 PM	51.2	64.1	40.4	93.2
10:14:31 PM	46.2	61.6	39.6	88.6
10:15:31 PM	49.3	64.5	40.3	93.8
10:16:31 PM	47.1	57.8	40.5	84
10:17:31 PM	43.9	57.8	39.6	83.2

10:18:31 PM	42.8	56.9	38.7	85.5
10:19:31 PM	45.6	62.4	38.9	89.8
10:20:31 PM	57.1	64.9	40.5	91.1
10:21:31 PM	49.8	60.3	39	90.2
10:22:31 PM	44.9	61.1	39	88.1
10:23:31 PM	44	51.6	38.9	75.9
10:24:31 PM	42.9	50.5	38.8	73.4
10:25:31 PM	41.4	50.6	38.5	75.2
10:26:31 PM	41.7	47.1	38.3	72.9
10:27:31 PM	41.8	52	38.9	80.7
10:28:31 PM	45.1	61.1	39.3	86.4
10:29:31 PM	47.3	63.9	39.4	90.2
10:30:31 PM	50.5	63.4	39.8	89.6
10:31:31 PM	47.8	62.4	39.2	91.3
10:32:31 PM	46.2	61.6	39.1	87.5
10:33:31 PM	43.4	60.5	38.6	88.3
10:34:31 PM	43.9	60.2	38.5	87.5
10:35:31 PM	52.9	60.4	39	85.7
10:36:31 PM	41.3	49.3	37.5	76.3
10:37:31 PM	41.1	44.1	38.2	62.6
10:38:31 PM	42.3	58.5	37.3	85
10:39:31 PM	44.2	64.3	38.5	88.9
10:40:31 PM	45.4	59.9	35.5	83.5
10:41:31 PM	52.1	61.3	38.6	82.1
10:42:31 PM	45	59.8	39.4	87.4
10:43:31 PM	43	58	38.6	86.1
10:44:31 PM	46	62.3	39.3	89.5
10:45:31 PM	48	59.5	39.7	85
10:46:31 PM	58.5	69.1	43.2	87
10:47:31 PM	53.6	65.8	41.7	81
10:48:31 PM	46	55	38.7	79.6
10:49:31 PM	43.1	52.5	39.2	70.5
10:50:31 PM	50.2	59.5	41.6	87.5
10:51:31 PM	47.6	60.5	40.1	88.8
10:52:31 PM	49.8	58.3	39.8	83.9
10:53:31 PM	44.6	61.1	38.4	88.8
10:54:31 PM	49.6	60.8	39.1	88.5

10:55:31 PM	47.7	57.8	38.9	77.9
10:56:31 PM	41.3	44.8	38.8	61.7
10:57:31 PM	47.4	56.2	39.4	84.6
10:58:31 PM	47.2	63	39.4	87.6
10:59:31 PM	44.2	59.6	38.9	87.4
11:00:31 PM	49.8	62.7	38.1	90
11:01:31 PM	45.4	59.8	38.6	85.2
11:02:31 PM	41.4	51.4	38.3	77.2
11:03:31 PM	45.4	60.7	38.6	85.9
11:04:31 PM	51	62.6	39.5	90
11:05:31 PM	43.4	61.2	37	91.4

Logged Data Chart

S009_BGG110027_16072022_230454: Logged Data Chart



DUSTTRAK™ II
AEROSOL MONITORS
MODELS 8530, 8530EP AND 8532

DESKTOP OR HANDHELD UNITS FOR ANY ENVIRONMENT, ANY APPLICATION

DustTrak™ II Aerosol Monitors are battery-operated, data-logging, light-scattering laser photometers that give you real-time aerosol mass readings. They use a sheath air system that isolates the aerosol in the optics chamber to keep the optics clean for improved reliability and low maintenance. From desktop and desktop with external pump models to a handheld model, the DustTrak II offers a suitable solution for harsh industrial workplaces, construction and environmental sites and other outdoor applications, as well as clean office settings. The DustTrak II monitors measure aerosol contaminants such as dust, smoke, fumes and mists.

Features and Benefits

All Models

+ Real-time mass concentration readings and data-logging allow for data analysis during and after sampling
+ Measure aerosol concentrations corresponding to PM1, PM2.5, Respirable, and PM10 size fractions, using a variety of inlet conditioners
+ Easy-to-use graphical user interface with color touch-screen for effortless operation

Handheld Model (8532)

+ Long life internal pump for continuous sampling
+ Single-point data collection for walk through surveys
+ Lightweight design with ergonomic handle for portable applications

Desktop Models (8530 and 8530EP)

+ Energy-efficient, long lasting external pump for continuous, unattended, 24/7, outdoor monitoring applications (Model 8530EP only)
+ Long life internal pump for shorter work-shift or IAQ sampling applications (Model 8530)
+ Gravimetric reference sampling capability for custom reference calibrations
+ Automatic zeroing (with optional zero module) to minimize the effect of zero drift
+ STEL alarm setpoint for tracking 15-minute average mass concentrations
+ Environmental protected and tamper-proof secure (with an optional environmental enclosure)
+ Inlet sample conditioning (with optional heated inlet sample conditioner) to reduce the effect of humidity on photometric mass measurements (for use with an environmental enclosure)
+ Cloud Data Management System as hosted by Netronix™

Desktop Models: Ideal for Long-Term Surveys and Remote Monitoring Applications

The DustTrak II is offered as a standard desktop (Model 8530), as well as a desktop with external pump (Model 8530EP.) Both models have manual and programmable data logging functions, making them ideal for unattended applications. The standard desktop model is most suitable for indoor, continuous monitoring, while the desktop with external pump is designed for 24/7 unattended, remote monitoring outdoors.

The DustTrak II desktop models come with USB (device and host), Ethernet, and analog and alarm outputs allowing remote access to data. User adjustable alarm setpoints for instantaneous or 15-minute short-term excursion limit (STEL) are also available on desktop models. The alarm output with user-defined setpoint alerts you when upset or changing conditions occur.

The DustTrak II desktop monitors have several unique features:

+ Measure aerosols in high concentrations up to 400 mg/m3.
+ External pump (Model 8530EP) with low power consumption for continuous, unattended monitoring in remote outdoor locations.
+ Gravimetric sampling capability using a 37-mm filter cassette which can be inserted in-line with the aerosol stream allowing you to perform an integral gravimetric analysis for custom reference calibrations.
+ Zeros automatically using the external zeroing module. This optional accessory is used when sampling over extended periods of time. By zeroing the monitor during sampling, the effect of zero drift is minimized.
+ STEL alarm feature for tracking 15-minute average mass concentrations when alarm setpoint has been reached for applications like monitoring fugitive emissions at hazardous waste sites.
+ Provide for environmental protection and tamper-proof security using an environmental enclosure. This optional accessory encloses the instrument within a waterproof, lockable, custom-designed case.
+ Condition the sample air stream before entering the instrument optics using a heated inlet sample conditioner (designed for use with an environmental enclosure.) This optional accessory is used in humid environments. By conditioning the sample, the humidity and water vapor are minimized, reducing elevated measurements.

Handheld Models: Perfect for Walk-Through Surveys and Single-Point Data Collection Applications

The DustTrak II Handheld Model 8532 is lightweight and portable. It is perfect for industrial hygiene surveys, point source location monitoring, indoor air quality investigations, engineering control evaluations/validation, and for baseline trending and screening. Like the desktop models, it has manual and programmable data logging functions. In addition, the handheld model also has a single-point data logging capability. Single-point data collection is used for walk-through industrial hygiene surveys and indoor air quality investigations.

Applications	Desktop	Handheld
Aerosol research studies	+	+
Baseline trending and screening	+	+
Engineering control evaluations		+
Engineering studies		+
Epidemiology studies	+	+
Indoor air quality investigations	+	+
Industrial/occupational hygiene surveys	+	+
Point source monitoring		+
Outdoor environmental monitoring	+	
Process monitoring	+	+
Remote monitoring	+	
Battery Performance		
Models 8530 and 8530EP (Typical) 6600 mAH Li-Ion Battery Pack (P/N 801680)	1 Battery	2 Batteries
Battery runtime (hours)	Up to 6	Up to 12
Charge time* (hours) in DustTrak	4	8
Charge time* (hours) in external battery charger (P/N 801685)	4	8

Model 8532 (Typical) 3600 mAH Li-Ion Battery Pack (P/N 801681)	Battery
Battery runtime (hours)	Up to 6
Charge time* (hours) in DustTrak	4
Charge time* (hours) in external battery charger (P/N 801686)	4

* Of a fully depleted battery

Cloud Data Management System for 24/7 remote dust monitoring

DustTrak II Aerosol Monitor Features

All Models

+ Li-Ion rechargeable batteries
+ Internal and external battery charging capabilities
+ Outlet port for isokinetic sampling applications
+ User serviceable sheath flow and pump filters
+ Logged test pause and restart feature
+ Logged test programming
  + Color touch screen–either manual mode or program mode
  + TrakPro™ Data Analysis Software via a PC
+ User adjustable custom calibration settings
+ Instantaneous alarm settings with visual and audible warnings
+ Real-time graph display
+ View statistical information during and after sampling
+ On-screen instrument status indicators: FLOW, LASER and FILTER
+ Filter service indicator for user preventative maintenance

Desktop Models (8530 and 8530EP)

+ Long life external pump (8530EP)
+ Internal pump (8530)
+ Hot swappable batteries
+ Gravimetric reference sample capability
+ STEL alarm setpoint

Optional Accessories

+ Auto zeroing module
+ Protective environmental enclosure (8535 and 8537)
+ Heated inlet sample conditioner (for use with an environmental enclosure)
+ Cloud Data Management System as hosted by Netronix™

Handheld Model (8532)

+ Long life internal pump
+ Single-point data collection for walk through surveys

Desktop Monitor with
External Pump, Model 8530EP

Easy to Program and Operate

The graphical user interface with color touch-screen puts everything at your fingertips. The easy-to-read display shows real-time mass concentration and graphical data, as well as other statistical information along with instrument pump, laser and flow status, and much more. Perform quick walk-through surveys or program the instrument's advanced logging modes for long-term sampling investigations. Program start times, total sampling times, logging intervals, alarm setpoints and many other parameters. You can even set up the instrument for continuous unattended operation.

TrakPro™ Software Makes Monitoring Easier than Ever

TrakPro™ Data Analysis Software allows you to set up and program directly from a PC. It even features the ability for remote programming and data acquisition from your PC via wireless communication options or over an Ethernet network. As always, you can print graphs, raw data tables, and statistical and comprehensive reports for record keeping purposes.

SPECIFICATIONS

DUSTTRAK™ II AEROSOL MONITORS
MODELS 8530, 8530EP AND 8532

Sensor Type
90° light scattering

Particle Size Range
0.1 to 10 µm

Aerosol Concentration Range

8530 Desktop	0.001 to 400 mg/m³
8530EP Desktop with External Pump	0.001 to 400 mg/m³
8532 Handheld	0.001 to 150 mg/m³

Resolution
±0.1% of reading or 0.001 mg/m³, whichever is greater

Zero Stability
±0.002 mg/m³ per 24 hours at 10 sec time constant

Flow Rate
3.0 L/min set at factory, 1.40 to 3.0 L/min, user adjustable

Flow Accuracy
±5% of factory set point, internal flow controlled

Temperature Coefficient
+0.001 mg/m³ per °C

Operational Temp
32 to 120°F (0 to 50°C)

Storage Temp
-4 to 140°F (-20 to 60°C)

Operational Humidity
0 to 95% RH, non-condensing

Time Constant
User adjustable, 1 to 60 seconds

Data Logging
5 MB of on-board memory (>60,000 data points)
45 days at 1 minute logging interval

Log Interval
User adjustable, 1 second to 1 hour

Physical Size (H x W x D)

Handheld	4.9 x 4.8 x 12.5 in. (12.5 x 12.1 x 31.6 cm)
Desktop	5.3 x 8.5 x 8.8 in. (13.5 x 21.6 x 22.4 cm)
External Pump	4.0 x 7.0 x 3.5 in. (10.0 x 18.0 x 9.0 cm)

Weight

Handheld	2.9 lb (1.3 kg), 3.3 lb (1.5 kg) with battery
Desktop	3.5 lb (1.6 kg), 4.5 lb (2.0 kg)-1 battery, 5.5 lb (2.5 kg)-2 batteries
External Pump	3.0 lb (1.4 kg)

Communications

8530	USB (host and device) and Ethernet. Stored data accessible using flash memory drive
8530EP	USB (host and device) and Ethernet. Stored data accessible using flash memory drive plus, cable assembly for external pump
8532	USB (Hose and device). Stored data accessible using flash memory drive

Power-AC
Switching AC power adapter with universal line cord included, 115-240 VAC

Analog Out

8530/8530EP	User selectable output, 0 to 5 V or 4 to 20 mA. User selectable scaling range

Alarm Out

8530/8530EP	Relay or audible buzzer Relay Non-latching MOSFET switch + User selectable set point + -5% deadband + Connector 4-pin, Mini-DIN connectors
8532	Audible buzzer

Screen

8530	5.7 in. VGA color touchscreen
8532	3.5 in. VGA color touchscreen

Gravimetric Sampling

8530/8530EP	Removable 37 mm cartridge (user supplied)

CE Rating

Immunity	EN61236-1:2006
Emissions	EN61236-1:2006

Specifications are subject to change without notice.

UNDERSTANDING, ACCELERATED

TSI Incorporated - Visit our website **www.tsi.com** for more information.

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France	**Tel:** +33 4 91 11 87 64	**Singapore**	**Tel:** +65 6595 6388
Germany	**Tel:** +49 241 523030		

  Printed in U.S.A.

R.O.S.E ENVIRONMENTAL LTD.

FORM # HSE-F-066-TC

ISSUE DATE: 6th May, 11

TEST CERTIFICATE
21187

Date: 12th July 2022

Client: Ecoengineering Consultants Limited

Your ref.: Rental **Our ref.:** DN 025366/BL/IK/LAJ

Type of Equipment: TSI DustTrak

TEST DATE	EQUIPMENT DESCRIPTION	SERIAL #	SERVICE PROVIDED
12th July 2022	TSI DustTrak II	8530084312	Verification

NOTE:

1. Zero verification was completed using a TSI HEPA filter.
2. Unit's flow rate verified at 3.029 L/min.

Service Technician

Physically Verified By

Authorized By

Loc 1 - PM2.5

Instrument		Data Properties	
Model	DustTrak II	Start Date	15/07/2022
Instrument S/N	8530084312	Start Time	09:35:09
		Stop Date	15/07/2022
		Stop Time	10:35:09
		Total Time	0:01:00:00
		Logging Interval	60 seconds

Statistics	
	AEROSOL
Avg	0.084 mg/m^3
Max	0.302 mg/m^3
Max Date	15/07/2022
Max Time	09:36:09
Min	0.077 mg/m^3
Min Date	15/07/2022
Min Time	09:38:09
TWA (8 hr)	0.010
TWA Start Date	15/07/2022
TWA Start Time	09:35:09
TWA End Time	10:35:09

Test Data			
Data Point	**Date**	**Time**	**AEROSOL mg/m^3**
1	15/07/2022	09:36:09	0.302
2	15/07/2022	09:37:09	0.078
3	15/07/2022	09:38:09	0.077
4	15/07/2022	09:39:09	0.077
5	15/07/2022	09:40:09	0.077
6	15/07/2022	09:41:09	0.083
7	15/07/2022	09:42:09	0.078
8	15/07/2022	09:43:09	0.077
9	15/07/2022	09:44:09	0.078
10	15/07/2022	09:45:09	0.077
11	15/07/2022	09:46:09	0.080
12	15/07/2022	09:47:09	0.088
13	15/07/2022	09:48:09	0.077
14	15/07/2022	09:49:09	0.079
15	15/07/2022	09:50:09	0.077
16	15/07/2022	09:51:09	0.078
17	15/07/2022	09:52:09	0.078
18	15/07/2022	09:53:09	0.079
19	15/07/2022	09:54:09	0.078
20	15/07/2022	09:55:09	0.078
21	15/07/2022	09:56:09	0.097

Test Data			
Data Point	**Date**	**Time**	**AEROSOL mg/m^3**
22	15/07/2022	09:57:09	0.079
23	15/07/2022	09:58:09	0.079
24	15/07/2022	09:59:09	0.079
25	15/07/2022	10:00:09	0.079
26	15/07/2022	10:01:09	0.080
27	15/07/2022	10:02:09	0.079
28	15/07/2022	10:03:09	0.079
29	15/07/2022	10:04:09	0.079
30	15/07/2022	10:05:09	0.081
31	15/07/2022	10:06:09	0.079
32	15/07/2022	10:07:09	0.079
33	15/07/2022	10:08:09	0.079
34	15/07/2022	10:09:09	0.079
35	15/07/2022	10:10:09	0.080
36	15/07/2022	10:11:09	0.079
37	15/07/2022	10:12:09	0.079
38	15/07/2022	10:13:09	0.079
39	15/07/2022	10:14:09	0.079
40	15/07/2022	10:15:09	0.080
41	15/07/2022	10:16:09	0.079
42	15/07/2022	10:17:09	0.079
43	15/07/2022	10:18:09	0.079
44	15/07/2022	10:19:09	0.079
45	15/07/2022	10:20:09	0.080
46	15/07/2022	10:21:09	0.080
47	15/07/2022	10:22:09	0.079
48	15/07/2022	10:23:09	0.079
49	15/07/2022	10:24:09	0.079
50	15/07/2022	10:25:09	0.081
51	15/07/2022	10:26:09	0.080
52	15/07/2022	10:27:09	0.080
53	15/07/2022	10:28:09	0.102
54	15/07/2022	10:29:09	0.080
55	15/07/2022	10:30:09	0.080
56	15/07/2022	10:31:09	0.081
57	15/07/2022	10:32:09	0.080
58	15/07/2022	10:33:09	0.081
59	15/07/2022	10:34:09	0.081
60	15/07/2022	10:35:09	0.080

Loc 2 - PM2.5

Instrument		Data Properties	
Model	DustTrak II	Start Date	15/07/2022
Instrument S/N	8530084312	Start Time	13:32:15
		Stop Date	15/07/2022
		Stop Time	14:32:15
		Total Time	0:01:00:00
		Logging Interval	60 seconds

Statistics	
	AEROSOL
Avg	0.018 mg/m^3
Max	0.099 mg/m^3
Max Date	15/07/2022
Max Time	13:33:15
Min	0.001 mg/m^3
Min Date	15/07/2022
Min Time	13:39:15
TWA (8 hr)	0.002
TWA Start Date	15/07/2022
TWA Start Time	13:32:15
TWA End Time	14:32:15

Test Data

Data Point	Date	Time	AEROSOL mg/m^3
1	15/07/2022	13:33:15	0.099
2	15/07/2022	13:34:15	0.031
3	15/07/2022	13:35:15	0.010
4	15/07/2022	13:36:15	0.007
5	15/07/2022	13:37:15	0.003
6	15/07/2022	13:38:15	0.004
7	15/07/2022	13:39:15	0.001
8	15/07/2022	13:40:15	0.001
9	15/07/2022	13:41:15	0.001
10	15/07/2022	13:42:15	0.001
11	15/07/2022	13:43:15	0.001
12	15/07/2022	13:44:15	0.005
13	15/07/2022	13:45:15	0.001
14	15/07/2022	13:46:15	0.002
15	15/07/2022	13:47:15	0.001
16	15/07/2022	13:48:15	0.004
17	15/07/2022	13:49:15	0.018
18	15/07/2022	13:50:15	0.018
19	15/07/2022	13:51:15	0.019
20	15/07/2022	13:52:15	0.019
21	15/07/2022	13:53:15	0.019

Test Data			
Data Point	**Date**	**Time**	**AEROSOL mg/m^3**
22	15/07/2022	13:54:15	0.019
23	15/07/2022	13:55:15	0.019
24	15/07/2022	13:56:15	0.019
25	15/07/2022	13:57:15	0.019
26	15/07/2022	13:58:15	0.019
27	15/07/2022	13:59:15	0.019
28	15/07/2022	14:00:15	0.019
29	15/07/2022	14:01:15	0.019
30	15/07/2022	14:02:15	0.020
31	15/07/2022	14:03:15	0.019
32	15/07/2022	14:04:15	0.019
33	15/07/2022	14:05:15	0.019
34	15/07/2022	14:06:15	0.019
35	15/07/2022	14:07:15	0.020
36	15/07/2022	14:08:15	0.020
37	15/07/2022	14:09:15	0.020
38	15/07/2022	14:10:15	0.021
39	15/07/2022	14:11:15	0.021
40	15/07/2022	14:12:15	0.020
41	15/07/2022	14:13:15	0.020
42	15/07/2022	14:14:15	0.020
43	15/07/2022	14:15:15	0.021
44	15/07/2022	14:16:15	0.021
45	15/07/2022	14:17:15	0.021
46	15/07/2022	14:18:15	0.021
47	15/07/2022	14:19:15	0.021
48	15/07/2022	14:20:15	0.021
49	15/07/2022	14:21:15	0.021
50	15/07/2022	14:22:15	0.021
51	15/07/2022	14:23:15	0.022
52	15/07/2022	14:24:15	0.021
53	15/07/2022	14:25:15	0.022
54	15/07/2022	14:26:15	0.022
55	15/07/2022	14:27:15	0.021
56	15/07/2022	14:28:15	0.022
57	15/07/2022	14:29:15	0.022
58	15/07/2022	14:30:15	0.021
59	15/07/2022	14:31:15	0.021
60	15/07/2022	14:32:15	0.022

Loc 3 - PM2.5

Instrument		Data Properties	
Model	DustTrak II	Start Date	16/07/2022
Instrument S/N	8530084312	Start Time	10:13:49
		Stop Date	16/07/2022
		Stop Time	11:13:49
		Total Time	0:01:00:00
		Logging Interval	60 seconds

Statistics	
	AEROSOL
Avg	0.013 mg/m^3
Max	0.021 mg/m^3
Max Date	16/07/2022
Max Time	11:12:49
Min	0.008 mg/m^3
Min Date	16/07/2022
Min Time	10:14:49
TWA (8 hr)	0.002
TWA Start Date	16/07/2022
TWA Start Time	10:13:49
TWA End Time	11:13:49

Test Data

Data Point	Date	Time	AEROSOL mg/m^3
1	16/07/2022	10:14:49	0.008
2	16/07/2022	10:15:49	0.009
3	16/07/2022	10:16:49	0.009
4	16/07/2022	10:17:49	0.009
5	16/07/2022	10:18:49	0.009
6	16/07/2022	10:19:49	0.009
7	16/07/2022	10:20:49	0.010
8	16/07/2022	10:21:49	0.010
9	16/07/2022	10:22:49	0.010
10	16/07/2022	10:23:49	0.010
11	16/07/2022	10:24:49	0.010
12	16/07/2022	10:25:49	0.010
13	16/07/2022	10:26:49	0.010
14	16/07/2022	10:27:49	0.009
15	16/07/2022	10:28:49	0.009
16	16/07/2022	10:29:49	0.010
17	16/07/2022	10:30:49	0.010
18	16/07/2022	10:31:49	0.010
19	16/07/2022	10:32:49	0.010
20	16/07/2022	10:33:49	0.010
21	16/07/2022	10:34:49	0.011

Test Data			
Data Point	**Date**	**Time**	**AEROSOL mg/m^3**
22	16/07/2022	10:35:49	0.011
23	16/07/2022	10:36:49	0.011
24	16/07/2022	10:37:49	0.011
25	16/07/2022	10:38:49	0.011
26	16/07/2022	10:39:49	0.011
27	16/07/2022	10:40:49	0.011
28	16/07/2022	10:41:49	0.011
29	16/07/2022	10:42:49	0.011
30	16/07/2022	10:43:49	0.012
31	16/07/2022	10:44:49	0.012
32	16/07/2022	10:45:49	0.012
33	16/07/2022	10:46:49	0.012
34	16/07/2022	10:47:49	0.013
35	16/07/2022	10:48:49	0.012
36	16/07/2022	10:49:49	0.013
37	16/07/2022	10:50:49	0.013
38	16/07/2022	10:51:49	0.012
39	16/07/2022	10:52:49	0.012
40	16/07/2022	10:53:49	0.012
41	16/07/2022	10:54:49	0.012
42	16/07/2022	10:55:49	0.012
43	16/07/2022	10:56:49	0.013
44	16/07/2022	10:57:49	0.013
45	16/07/2022	10:58:49	0.013
46	16/07/2022	10:59:49	0.013
47	16/07/2022	11:00:49	0.014
48	16/07/2022	11:01:49	0.015
49	16/07/2022	11:02:49	0.015
50	16/07/2022	11:03:49	0.016
51	16/07/2022	11:04:49	0.018
52	16/07/2022	11:05:49	0.018
53	16/07/2022	11:06:49	0.018
54	16/07/2022	11:07:49	0.019
55	16/07/2022	11:08:49	0.019
56	16/07/2022	11:09:49	0.020
57	16/07/2022	11:10:49	0.020
58	16/07/2022	11:11:49	0.020
59	16/07/2022	11:12:49	0.021
60	16/07/2022	11:13:49	0.021

Loc 4 - PM2.5

Instrument		Data Properties	
Model	DustTrak II	Start Date	16/07/2022
Instrument S/N	8530084312	Start Time	12:35:42
		Stop Date	16/07/2022
		Stop Time	13:35:42
		Total Time	0:01:00:00
		Logging Interval	60 seconds

Statistics	
	AEROSOL
Avg	0.018 mg/m^3
Max	0.027 mg/m^3
Max Date	16/07/2022
Max Time	12:36:42
Min	0.017 mg/m^3
Min Date	16/07/2022
Min Time	13:02:42
TWA (8 hr)	0.002
TWA Start Date	16/07/2022
TWA Start Time	12:35:42
TWA End Time	13:35:42

Test Data

Data Point	Date	Time	AEROSOL mg/m^3
1	16/07/2022	12:36:42	0.027
2	16/07/2022	12:37:42	0.019
3	16/07/2022	12:38:42	0.018
4	16/07/2022	12:39:42	0.018
5	16/07/2022	12:40:42	0.018
6	16/07/2022	12:41:42	0.020
7	16/07/2022	12:42:42	0.018
8	16/07/2022	12:43:42	0.018
9	16/07/2022	12:44:42	0.018
10	16/07/2022	12:45:42	0.018
11	16/07/2022	12:46:42	0.018
12	16/07/2022	12:47:42	0.019
13	16/07/2022	12:48:42	0.019
14	16/07/2022	12:49:42	0.026
15	16/07/2022	12:50:42	0.021
16	16/07/2022	12:51:42	0.018
17	16/07/2022	12:52:42	0.018
18	16/07/2022	12:53:42	0.018
19	16/07/2022	12:54:42	0.019
20	16/07/2022	12:55:42	0.018
21	16/07/2022	12:56:42	0.019

Test Data			
Data Point	**Date**	**Time**	**AEROSOL mg/m^3**
22	16/07/2022	12:57:42	0.018
23	16/07/2022	12:58:42	0.018
24	16/07/2022	12:59:42	0.018
25	16/07/2022	13:00:42	0.018
26	16/07/2022	13:01:42	0.018
27	16/07/2022	13:02:42	0.017
28	16/07/2022	13:03:42	0.017
29	16/07/2022	13:04:42	0.017
30	16/07/2022	13:05:42	0.018
31	16/07/2022	13:06:42	0.018
32	16/07/2022	13:07:42	0.019
33	16/07/2022	13:08:42	0.017
34	16/07/2022	13:09:42	0.017
35	16/07/2022	13:10:42	0.017
36	16/07/2022	13:11:42	0.018
37	16/07/2022	13:12:42	0.017
38	16/07/2022	13:13:42	0.017
39	16/07/2022	13:14:42	0.017
40	16/07/2022	13:15:42	0.018
41	16/07/2022	13:16:42	0.017
42	16/07/2022	13:17:42	0.017
43	16/07/2022	13:18:42	0.018
44	16/07/2022	13:19:42	0.017
45	16/07/2022	13:20:42	0.018
46	16/07/2022	13:21:42	0.018
47	16/07/2022	13:22:42	0.018
48	16/07/2022	13:23:42	0.017
49	16/07/2022	13:24:42	0.018
50	16/07/2022	13:25:42	0.018
51	16/07/2022	13:26:42	0.019
52	16/07/2022	13:27:42	0.018
53	16/07/2022	13:28:42	0.018
54	16/07/2022	13:29:42	0.018
55	16/07/2022	13:30:42	0.017
56	16/07/2022	13:31:42	0.018
57	16/07/2022	13:32:42	0.017
58	16/07/2022	13:33:42	0.021
59	16/07/2022	13:34:42	0.018
60	16/07/2022	13:35:42	0.018

Loc 1 - PM10

Instrument		Data Properties	
Model	DustTrak II	Start Date	15/07/2022
Instrument S/N	8530084312	Start Time	08:32:18
		Stop Date	15/07/2022
		Stop Time	09:32:18
		Total Time	0:01:00:00
		Logging Interval	60 seconds

Statistics	
	AEROSOL
Avg	0.077 mg/m^3
Max	0.092 mg/m^3
Max Date	15/07/2022
Max Time	09:20:18
Min	0.052 mg/m^3
Min Date	15/07/2022
Min Time	08:33:18
TWA (8 hr)	0.010
TWA Start Date	15/07/2022
TWA Start Time	08:32:18
TWA End Time	09:32:18

Test Data			
Data Point	**Date**	**Time**	**AEROSOL mg/m^3**
1	15/07/2022	08:33:18	0.052
2	15/07/2022	08:34:18	0.052
3	15/07/2022	08:35:18	0.053
4	15/07/2022	08:36:18	0.055
5	15/07/2022	08:37:18	0.057
6	15/07/2022	08:38:18	0.060
7	15/07/2022	08:39:18	0.062
8	15/07/2022	08:40:18	0.064
9	15/07/2022	08:41:18	0.067
10	15/07/2022	08:42:18	0.069
11	15/07/2022	08:43:18	0.071
12	15/07/2022	08:44:18	0.072
13	15/07/2022	08:45:18	0.074
14	15/07/2022	08:46:18	0.077
15	15/07/2022	08:47:18	0.077
16	15/07/2022	08:48:18	0.078
17	15/07/2022	08:49:18	0.078
18	15/07/2022	08:50:18	0.079
19	15/07/2022	08:51:18	0.079
20	15/07/2022	08:52:18	0.079
21	15/07/2022	08:53:18	0.080

Test Data			
Data Point	**Date**	**Time**	**AEROSOL mg/m^3**
22	15/07/2022	08:54:18	0.080
23	15/07/2022	08:55:18	0.080
24	15/07/2022	08:56:18	0.080
25	15/07/2022	08:57:18	0.079
26	15/07/2022	08:58:18	0.079
27	15/07/2022	08:59:18	0.079
28	15/07/2022	09:00:18	0.079
29	15/07/2022	09:01:18	0.080
30	15/07/2022	09:02:18	0.080
31	15/07/2022	09:03:18	0.080
32	15/07/2022	09:04:18	0.080
33	15/07/2022	09:05:18	0.080
34	15/07/2022	09:06:18	0.080
35	15/07/2022	09:07:18	0.080
36	15/07/2022	09:08:18	0.081
37	15/07/2022	09:09:18	0.081
38	15/07/2022	09:10:18	0.090
39	15/07/2022	09:11:18	0.082
40	15/07/2022	09:12:18	0.081
41	15/07/2022	09:13:18	0.081
42	15/07/2022	09:14:18	0.082
43	15/07/2022	09:15:18	0.082
44	15/07/2022	09:16:18	0.082
45	15/07/2022	09:17:18	0.082
46	15/07/2022	09:18:18	0.083
47	15/07/2022	09:19:18	0.082
48	15/07/2022	09:20:18	0.092
49	15/07/2022	09:21:18	0.084
50	15/07/2022	09:22:18	0.082
51	15/07/2022	09:23:18	0.083
52	15/07/2022	09:24:18	0.083
53	15/07/2022	09:25:18	0.083
54	15/07/2022	09:26:18	0.084
55	15/07/2022	09:27:18	0.084
56	15/07/2022	09:28:18	0.083
57	15/07/2022	09:29:18	0.084
58	15/07/2022	09:30:18	0.083
59	15/07/2022	09:31:18	0.084
60	15/07/2022	09:32:18	0.083

Loc 2 - PM10

Instrument		Data Properties	
Model	DustTrak II	Start Date	15/07/2022
Instrument S/N	8530084312	Start Time	11:24:51
		Stop Date	15/07/2022
		Stop Time	12:24:51
		Total Time	0:01:00:00
		Logging Interval	60 seconds

Statistics	
	AEROSOL
Avg	0.021 mg/m^3
Max	0.027 mg/m^3
Max Date	15/07/2022
Max Time	11:25:51
Min	0.018 mg/m^3
Min Date	15/07/2022
Min Time	11:38:51
TWA (8 hr)	0.003
TWA Start Date	15/07/2022
TWA Start Time	11:24:51
TWA End Time	12:24:51

Test Data			
Data Point	**Date**	**Time**	**AEROSOL mg/m^3**
1	15/07/2022	11:25:51	0.027
2	15/07/2022	11:26:51	0.019
3	15/07/2022	11:27:51	0.019
4	15/07/2022	11:28:51	0.019
5	15/07/2022	11:29:51	0.020
6	15/07/2022	11:30:51	0.020
7	15/07/2022	11:31:51	0.019
8	15/07/2022	11:32:51	0.020
9	15/07/2022	11:33:51	0.019
10	15/07/2022	11:34:51	0.019
11	15/07/2022	11:35:51	0.019
12	15/07/2022	11:36:51	0.019
13	15/07/2022	11:37:51	0.019
14	15/07/2022	11:38:51	0.018
15	15/07/2022	11:39:51	0.018
16	15/07/2022	11:40:51	0.019
17	15/07/2022	11:41:51	0.019
18	15/07/2022	11:42:51	0.019
19	15/07/2022	11:43:51	0.019
20	15/07/2022	11:44:51	0.019
21	15/07/2022	11:45:51	0.018

Test Data			
Data Point	**Date**	**Time**	**AEROSOL mg/m^3**
22	15/07/2022	11:46:51	0.018
23	15/07/2022	11:47:51	0.019
24	15/07/2022	11:48:51	0.019
25	15/07/2022	11:49:51	0.019
26	15/07/2022	11:50:51	0.019
27	15/07/2022	11:51:51	0.020
28	15/07/2022	11:52:51	0.021
29	15/07/2022	11:53:51	0.021
30	15/07/2022	11:54:51	0.021
31	15/07/2022	11:55:51	0.021
32	15/07/2022	11:56:51	0.020
33	15/07/2022	11:57:51	0.021
34	15/07/2022	11:58:51	0.023
35	15/07/2022	11:59:51	0.022
36	15/07/2022	12:00:51	0.022
37	15/07/2022	12:01:51	0.022
38	15/07/2022	12:02:51	0.022
39	15/07/2022	12:03:51	0.023
40	15/07/2022	12:04:51	0.023
41	15/07/2022	12:05:51	0.023
42	15/07/2022	12:06:51	0.024
43	15/07/2022	12:07:51	0.023
44	15/07/2022	12:08:51	0.023
45	15/07/2022	12:09:51	0.024
46	15/07/2022	12:10:51	0.024
47	15/07/2022	12:11:51	0.024
48	15/07/2022	12:12:51	0.024
49	15/07/2022	12:13:51	0.024
50	15/07/2022	12:14:51	0.024
51	15/07/2022	12:15:51	0.024
52	15/07/2022	12:16:51	0.024
53	15/07/2022	12:17:51	0.024
54	15/07/2022	12:18:51	0.024
55	15/07/2022	12:19:51	0.024
56	15/07/2022	12:20:51	0.024
57	15/07/2022	12:21:51	0.025
58	15/07/2022	12:22:51	0.024
59	15/07/2022	12:23:51	0.027
60	15/07/2022	12:24:51	0.025

Loc 3 - PM10

Instrument		Data Properties	
Model	DustTrak II	Start Date	16/07/2022
Instrument S/N	8530084312	Start Time	09:04:53
		Stop Date	16/07/2022
		Stop Time	10:04:53
		Total Time	0:01:00:00
		Logging Interval	60 seconds

Statistics	
	AEROSOL
Avg	0.066 mg/m^3
Max	0.120 mg/m^3
Max Date	16/07/2022
Max Time	09:05:53
Min	0.018 mg/m^3
Min Date	16/07/2022
Min Time	09:06:53
TWA (8 hr)	0.008
TWA Start Date	16/07/2022
TWA Start Time	09:04:53
TWA End Time	10:04:53

Test Data			
Data Point	**Date**	**Time**	**AEROSOL mg/m^3**
1	16/07/2022	09:05:53	0.120
2	16/07/2022	09:06:53	0.018
3	16/07/2022	09:07:53	0.019
4	16/07/2022	09:08:53	0.021
5	16/07/2022	09:09:53	0.026
6	16/07/2022	09:10:53	0.031
7	16/07/2022	09:11:53	0.033
8	16/07/2022	09:12:53	0.037
9	16/07/2022	09:13:53	0.040
10	16/07/2022	09:14:53	0.043
11	16/07/2022	09:15:53	0.048
12	16/07/2022	09:16:53	0.050
13	16/07/2022	09:17:53	0.052
14	16/07/2022	09:18:53	0.057
15	16/07/2022	09:19:53	0.060
16	16/07/2022	09:20:53	0.061
17	16/07/2022	09:21:53	0.063
18	16/07/2022	09:22:53	0.064
19	16/07/2022	09:23:53	0.065
20	16/07/2022	09:24:53	0.065
21	16/07/2022	09:25:53	0.066

Test Data			
Data Point	**Date**	**Time**	**AEROSOL mg/m^3**
22	16/07/2022	09:26:53	0.067
23	16/07/2022	09:27:53	0.066
24	16/07/2022	09:28:53	0.067
25	16/07/2022	09:29:53	0.069
26	16/07/2022	09:30:53	0.068
27	16/07/2022	09:31:53	0.068
28	16/07/2022	09:32:53	0.068
29	16/07/2022	09:33:53	0.071
30	16/07/2022	09:34:53	0.072
31	16/07/2022	09:35:53	0.073
32	16/07/2022	09:36:53	0.074
33	16/07/2022	09:37:53	0.076
34	16/07/2022	09:38:53	0.077
35	16/07/2022	09:39:53	0.076
36	16/07/2022	09:40:53	0.076
37	16/07/2022	09:41:53	0.077
38	16/07/2022	09:42:53	0.077
39	16/07/2022	09:43:53	0.078
40	16/07/2022	09:44:53	0.078
41	16/07/2022	09:45:53	0.078
42	16/07/2022	09:46:53	0.078
43	16/07/2022	09:47:53	0.078
44	16/07/2022	09:48:53	0.078
45	16/07/2022	09:49:53	0.078
46	16/07/2022	09:50:53	0.077
47	16/07/2022	09:51:53	0.077
48	16/07/2022	09:52:53	0.078
49	16/07/2022	09:53:53	0.078
50	16/07/2022	09:54:53	0.078
51	16/07/2022	09:55:53	0.078
52	16/07/2022	09:56:53	0.077
53	16/07/2022	09:57:53	0.077
54	16/07/2022	09:58:53	0.077
55	16/07/2022	09:59:53	0.076
56	16/07/2022	10:00:53	0.077
57	16/07/2022	10:01:53	0.077
58	16/07/2022	10:02:53	0.078
59	16/07/2022	10:03:53	0.077
60	16/07/2022	10:04:53	0.078

Loc 4 - PM10

Instrument		Data Properties	
Model	DustTrak II	Start Date	16/07/2022
Instrument S/N	8530084312	Start Time	11:31:15
		Stop Date	16/07/2022
		Stop Time	12:31:15
		Total Time	0:01:00:00
		Logging Interval	60 seconds

Statistics	
	AEROSOL
Avg	0.030 mg/m^3
Max	0.039 mg/m^3
Max Date	16/07/2022
Max Time	11:54:15
Min	0.026 mg/m^3
Min Date	16/07/2022
Min Time	12:02:15
TWA (8 hr)	0.004
TWA Start Date	16/07/2022
TWA Start Time	11:31:15
TWA End Time	12:31:15

Test Data			
Data Point	**Date**	**Time**	**AEROSOL mg/m^3**
1	16/07/2022	11:32:15	0.028
2	16/07/2022	11:33:15	0.031
3	16/07/2022	11:34:15	0.030
4	16/07/2022	11:35:15	0.030
5	16/07/2022	11:36:15	0.029
6	16/07/2022	11:37:15	0.031
7	16/07/2022	11:38:15	0.031
8	16/07/2022	11:39:15	0.029
9	16/07/2022	11:40:15	0.031
10	16/07/2022	11:41:15	0.030
11	16/07/2022	11:42:15	0.028
12	16/07/2022	11:43:15	0.028
13	16/07/2022	11:44:15	0.029
14	16/07/2022	11:45:15	0.029
15	16/07/2022	11:46:15	0.028
16	16/07/2022	11:47:15	0.028
17	16/07/2022	11:48:15	0.028
18	16/07/2022	11:49:15	0.029
19	16/07/2022	11:50:15	0.029
20	16/07/2022	11:51:15	0.028
21	16/07/2022	11:52:15	0.030

Test Data			
Data Point	**Date**	**Time**	**AEROSOL mg/m^3**
22	16/07/2022	11:53:15	0.029
23	16/07/2022	11:54:15	0.039
24	16/07/2022	11:55:15	0.036
25	16/07/2022	11:56:15	0.035
26	16/07/2022	11:57:15	0.033
27	16/07/2022	11:58:15	0.027
28	16/07/2022	11:59:15	0.027
29	16/07/2022	12:00:15	0.034
30	16/07/2022	12:01:15	0.028
31	16/07/2022	12:02:15	0.026
32	16/07/2022	12:03:15	0.026
33	16/07/2022	12:04:15	0.026
34	16/07/2022	12:05:15	0.026
35	16/07/2022	12:06:15	0.027
36	16/07/2022	12:07:15	0.027
37	16/07/2022	12:08:15	0.028
38	16/07/2022	12:09:15	0.031
39	16/07/2022	12:10:15	0.026
40	16/07/2022	12:11:15	0.027
41	16/07/2022	12:12:15	0.026
42	16/07/2022	12:13:15	0.028
43	16/07/2022	12:14:15	0.028
44	16/07/2022	12:15:15	0.030
45	16/07/2022	12:16:15	0.029
46	16/07/2022	12:17:15	0.027
47	16/07/2022	12:18:15	0.032
48	16/07/2022	12:19:15	0.031
49	16/07/2022	12:20:15	0.036
50	16/07/2022	12:21:15	0.030
51	16/07/2022	12:22:15	0.033
52	16/07/2022	12:23:15	0.030
53	16/07/2022	12:24:15	0.029
54	16/07/2022	12:25:15	0.030
55	16/07/2022	12:26:15	0.030
56	16/07/2022	12:27:15	0.029
57	16/07/2022	12:28:15	0.030
58	16/07/2022	12:29:15	0.029
59	16/07/2022	12:30:15	0.033
60	16/07/2022	12:31:15	0.030

Appendix 2 Species Notes

ENVIRONMENTAL IMPACT ASSESSMENT
FOR THE PARADISE FOUND DEVELOPMENT, BARBUDA
BASELINE CONDITIONS REPORT

TERRESTRIAL ECOLOGY

ATTACHMENT 1: SPECIES NOTES

This Annex presents Species Notes for the Flora, Avifauna and Fauna species noted on the study area in July 2022.

FLORA

Byrsonima lucida **(Locustberry)** is endemic to the US State of Florida as well as islands of the Caribbean. It is a shrub or a small tree that produces pink flowers. Its natural habitat is hammocks in dry limestone rocklands, and in sandy pine-palm woods.

Leucaena leucocephala **(Wild Tamarind)** is native to Southern Mexico and Northern Central America, and also now naturalized throughout the tropics. It is a small to medium-sized mimosoid tree, with a single trunk, and is commonly found in dry lowland habitats. It is a weed of open often coastal habitats, semi-natural, disturbed, degraded habitats and occasionally agricultural land where it has been planted as a shade tree.

Vachellia farnesiana **(Sweet Acacia)** is native from Southern California to Southern Florida, Mexico and Central America. It is a 15-20ft, multi-trunked tree or shrub that bears finely divided leaves on spiny branches. The bipinnately compound foliage is light-green and ferny. There are small, fragrant, orange-yellow flowers and reddish-brown woody pods that are long, rounded and tapered at both ends.

Conocarpus erectus **(Button Mangrove)** is native to sandy, coastal shores, landward of the tidal mangrove zone. It is also found within South and Central Florida. It is an evergreen spreading shrub to low-branching tree with a narrow-rounded crown and green leaves. There are purplish-green, cone-like fruits that are 1/2 in in diameter. They are preceded by clusters of whitish flowers.

Guaiacum officinale **(Lignum Vitae)** is native to the Caribbean and the Northern coast of South America. It is a small tree that is very slow growing, reaching approximately 10m in height with a trunk diameter of 60cm. The tree is evergreen throughout most of its native range with compound leaves and blue flowers. The flowers have five petals that yield a bright-orange fruit with red flesh and black seeds.

Canella winterana **(Wild Cinnamon)** is native to North America, particularly Florida. It is usually found in coastal thickets and hammocks, often on limestone or calcareous soils. The wood of Canella is very heavy, hard and close grained. It is dark red-brown and the thick sapwood consists of 25 to 30 layers of annual growth which is light brown or yellow in colour.

Comocladia dodonaea **(Hogwood)** is native to the islands of the Caribbean. It is a species of tree within the cashew family. In the sap of the plant and on the surface of the leaves is an urishiol poison similar to that of poison ivy.

***Pisonia subcordata* (Loblolly)** is native to the islands of the Caribbean, mainly the Leeward Islands. It is a deciduous tree with a rounded crown of stout branches, which can grow 12-15m tall. The wood is sometimes harvested from the wild for local use.

***Ficus citrifolia* (Strangler Fig)** is a species of banyan native to Southern Florida, the Caribbean, Mexico, Central America and Northern South America south to Paraguay. These trees typically grow 15m tall, and may also cover a wide area due to their ability to drop aerial roots from branches and spread horizontally. There are small flowers enclosed in open ended fruit which appears on the ends of long stalks from the lead axils.

***Malphigia linearis* (Ram Goat Chery)** is native to Cuba, Puerto Rico and the Lesser Antilles. It is a shrub with red berries.

***Bourreria succulenta* (Bahama Strongbark)** is native to the islands of the Caribbean, The Bahamas, Southern North America and Florida. It is an evergreen shrub or small tree with spreading or drooping branches that can grow 3.5-7.5m tall. The tree is occasionally harvested from the wild for local use and source of fuel.

***Lantana involucrate* (Sage)** is native to South Florida to South America. It is usually found in coastal shell ridges. It is a heavily branched, unarmed shrub, growing to about 3ft. It has downy oval leaves with toothed edges. The flowers are white to lavender, small, and arranged in clusters. These blossoms are followed by purple fruit.

***Solanum racemosum* (Canker Berry)** is native to Florida and is usually found in coastal dunes and hammocks.

***Tabebuia heterophylla* (Pink Trumpet)** is a species of tree that is native to the islands of the Caribbean, and is also cultivated. These trees grow up to 20-30ft tall. The leaves are opposite and palmately compound with five or fewer leaflets. The fruit is a seedpod, which splits along two lines to shed the numerous tin light brown seeds. This tree is also valuable for its timber production.

***Tilandsia utriculata* (Giant airplant)** is native to islands of the Caribbean, Florida, Central and South America. It is a tank epiphyte that may be able to grow terrestrially, with large light-green to grey-green leaves with a wide base and scales.

***Castela erecta* (Goat Bush)** is native to chaparral and brush countries, prairies, plains, meadows, pastures, savannas, hillsides and slopes. It is a thicket forming, spiny shrub with bitter bark. The branchlets are lightly coloured, terminating in stout spines bearing lateral ones. The leaves are firm textured, with a pointed or rounded tip and smooth, turned down margins with the upper surface being shiny. The flowers are small, red-orange, occurring in small groups or singly.

***Agave karatto* (The Dagger Plant)** is the national flower of Antigua and Barbuda. It is a succulent plant that forms rosettes of dagger-like, medium green leaves with a sharp tip and small teeth along the edges. The rosettes grow up to 3m in diameter whilst the leaves grow up to 1m long. The yellow flowers appear on up to 5.5m spikes branched near the top. After blooming, numerous bulbils appear near the spent flowers, forming new plants which shortly drop to the ground.

***Pilosocereus royenni* (Cacti)** is native to the islands of the Caribbean It is composed of multiple long, tubular shaped branches, each ribbed with multiple sections and sharp spines.

***Agrostis palustris* (Creeping Bentgrass)** is a low-growing, fine-bladed perennial grassy weed. It has a creeping growth habit that spreads by long, vigorous stolons. This lawn weed has a tall, rounded ligule and narrow blades that are flat, veined and rough along the edges.
***Haematoxylon campechianum* (Logwood)** is native to Central America and the islands of the Caribbean. It is a species of flowering tree in the legume family. The wood is heavy and extremely hard, and grows 9-15m tall. It has a short, crooked trunk and the leaves are pinnately compound with oval or heart-shaped leaflets. There are also yellow flowers that grow in clusters from the leaf axil and produce long flattened pods that are pointed at both ends.

***Pulmeria alba* (Wild Frangipani)** is endemic to Mexico, Central America and the islands of the Carribean. These are deciduous shrubs or small trees with flowers that are most fragrant at night.

***Laguncularia racemosa* (White Mangrove)** is native to the coasts of Western Africa, The Bahamas, the islands of the Caribbean, and on the Pacific Coast of the Americas. It is a mangrove tree, approximately 12-18m tall. The bark is grey-brown or reddish, and rough and fissured. Prop roots are present, depending upon environmental conditions. The leaves are opposite, elliptical, 12-18cm long, and 2.5-5.0cm broad. They are also rounded at both ends, smooth, leathery in texture and yellow-green in colour.

***Avivenia germinans* (Black Mangrove)** is usually found in sandy and muddy shores where seawater reaches. It is a shrub or small tree growing up to 12m. The seeds are encased in a fruit, which reveals the germinated seedling when it falls into the water. This mangrove does not grow on prop roots, but possesses pneumatophores that allows its roots to breathe even when submerged. The name black mangrove refers to the colour of the trunk and heartwood.

***Rhizophora mangle* (Red Mangrove)** is distributed in estuarine ecosystems throughout the tropics. These grow on aerial prop roots, which arch above the water level, giving stands of this tree the characteristic “mangrove” appearance. Its seeds are actually called propagules as they grow into fully mature plants before dropping off the parent tree. These are dispersed by water until eventually embedding in the shallows.

***Sesuvium portulacastrum* (Shoreline Purslane)** is a sprawling perennial herb up to 30cm high that grows in coastal areas throughout much of the world. It has thick, smooth stems up to 1m long with smooth, fleshy, glossy green leaves that are linear. The flowers are pink or purple.

***Ipomoea pes-caprae* (Beach Morning Glory)** is a common pantropical creeping vine which grows on the upper parts of beaches and is able to endure salted air. Its seeds float and are unaffected by salt water. It can be found on the sandy shores of the tropical Atlantic, Pacific, and Indian Oceans.

***Cocoloba uvifera* (Seagrape)** is native to coastal beaches throughout tropical America and the islands of the Caribbean. It bears green fruit which gradually ripens to a purplish colour. Each fruit contains a large pit that constitutes most of the volume of the fruit.

***Thespesia populnea* (Seaside Mahoe)** is commonly found on tropical coastlines. It is adapted for oceanic dispersal and growth in island environments. This species reaches a height of 6-10m and its trunk can measure up to 20-30cm in diameter. It is able to grow in the wide range of soil types that may be present in coastal environments.

***Cocos nucifera* (Coconut Palms)** is a large palm, growing up to 30m, with pinnate leaves 4-6m long. Old leaves are able to break away cleanly, leaving the trunk smooth. This tree does not have taproots nor root hairs, but a fibrous root system which consists of thin roots.

Avifauna

***Dendroica subita* (Barbuda Warbler)** is endemic to the island of Barbuda. It is usually found in tropical dry shrubland near wetlands. It is approximately 12-13.5cm long and weighs 5-8g. It has a yellow below with grey upperparts, and a grey eyering. It feeds mainly on insects.

***Numida meleagris* (Helmeted Guineafowl)** is a large, approximately 53-58cm bird with a round body and a small head. It is commonly found in Barbuda. It weighs approximately 1.3kg. The body plumage is grey-black spangled with white. Similar to other guineafowls, this species has an unfeathered head, which is decorated with a dull yellow or reddish bony knob, and bare skin with red, blue, or black hues. The wings are short and rounded, and the tail is short. They breed in warm, fairly dry and open habitats with scattered shrubs and trees such as savanna. Its diet consists of seeds, fruits, greens, snails, spiders, worms and insects.

***Columbina passerina* (Ground Dove)** is a small bird that inhabits the Southern United States, the islands of the Caribbean and Northern South America. It is a common resident of Barbuda.This species ranges from 15-18cm in length, spans 27cm across the wings and weighs 26-40g. It has a yellow beak with a black tip and the feathers surrounding the beak are pink. They live in open areas that have trees and bushes, and they are also found in forests with sandy areas, farmlands and savannas. Its diet consists mostly of seeds from grasses or weeds. It also occasionally eats fruits and berries.

***Zenaida asiatica* (White-Winged Dove)** is native to the United States and the islands of the Caribbean. It is a common resident of Barbuda. They have a distinctive white edge on their wings, with a blue eyering and red eyes. The plumage is brownish-grey to grey. They inhabit deserts, scrubs and urban areas. Its diet consists mostly of grains, but will also occasionally include pollen and nectar.

***Zenaida aurita* (Turtle Dove)** is the national bird of Anguilla, therefore it is fairly common in Barbuda. It is approximately 28-30cm in length. It has a short, rounded tail that is darkly coloured. There is also white on the trailing edge of its wings while in flight. Its diet consists mainly of grains and seeds, and sometimes insects.

Himantopus *himantopu* (Black-Winged Stilt) is a common resident of Barbuda. It is 33-36cm long with long pink legs and a long thin black bull. They are blackish above and white below, with a white head and neck. Males tend to have a black back, often with greenish gloss. Females' backs have a brown hue contrasting with the black. They are usually found in marshes, shallow lakes and ponds. Its diet consists mainly of insects and crustaceans.

***Dendrocygna arborea* (West-Indian Whistling Duck)** is found within the islands of the Caribbean. It is a common resident of Barbuda. It is approximately 48-58cm and 760-1320g. It has a long black bill, long head and longish legs. It has a pale foreneck and light brown face. Its diet consists of plant food including the fruit of the royal palm.

***Pelecanus occidentalus* (Brown Pelican)** is found in the United States. It is a fairly uncommon resident of Barbuda. It has a white head with a yellowish wash on the crown while the nape and neck are dark maroon-brown. The upper sides of the neck have white lines along the base of the gular pouch and the lower foreneck has a pale yellowish patch. Its diet consists mainly of fish, but occasionally amphibians, crustaceans and the eggs and nestlings of birds.

***Bubulcus ibis* (Cattle Egret)** is a fairly common resident of Barbuda. It is a white bird adorned with buff plumes. It has a short, thick neck and a sturdy bill, with a hunched posture. Its feeding habitats include grasslands, and pastures. It often also accompanies cattle, catching insects disturbed by these animals.

***Margarops fuscus* (Scaly Breasted Thrasher)** is native to the Lesser Antilles. It is approximately 23cm long and weighs 53-98g. It has a short and slightly decurved bill. Their tail is a darker brownish black and its outer feathers have white tips. Its diet consists of arthropods, fruits and berries.

***Pandion haliaetus* (Osprey)** is found in temperate and tropical regions, therefore it is a fairly common resident of Barbuda. It is a large raptor reaching more than 60cm in length and 180cm across the wings. It is brown on the upperparts and predominantly greyish on the head and underparts. Its diet consists almost exclusively of fish.

***Orthorhyncus cristatus* (Antillean Crested Hummingbird)** is found across the islands of the Caribbean, therefore it is a fairly common resident of Barbuda. Males have a short straight black bill, head with a green crest, tipped metallic green to bright blue green with a black, rounded tail. Females do not have a crest and the underparts are light grey. Its natural habitats are subtropical or tropical moist lowland forests.

***Sterna antillarum* (Least Tern)** is found mainly in North and South America. It is a fairly uncommon resident of Barbuda. It is a small tern, approximately 22-24cm long with a wingspan of 50cm. The upper parts are a fairly uniform pale grey and the underparts white. It hunts primarily in shallow estuaries and lagoons, where smaller fishes are abundant.

***Tiaris bicolour* (Black-Faced Grassquit)** is a fairly common resident of Barbuda. It is around 10cm long and weights 10g. It has a short conical black bill, a black head and breast with an olive green back. Its diet consists mainly of seeds, especially from grasses and weeds.

***Calidris minuta* (Little Stilt)** is a common resident of Barbuda. It is small with a fine dark bill and dark legs. Its diet consists mainly of small invertebrates in the mud.

***Quiscalus lugubris* (Carib Grackle)** is a common resident of Barbuda. It is 27cm long with a long wedge-shaped tail. Its plumage is entirely black with a violet iridescence. Its eyes are yellow and it has a strong dark bill. Its diet consists mainly of insects, other invertebrates, small fish, frogs and lozards.

***Charadrius wilsonia* (Wilson's Plover)** is a common resident of Barbuda. The breeding male has a black breast band, lores and forecrown and a rufous mask, whilst the females have a similar plumage but a brown rufous. Its diet consists mainly of food from beaches, mainly crabs.

***Coereba flaveola* (Bananaquit)** is a common resident of Barbuda. It is a small bird with dark grey upperparts, a black crown and sides of the head. Its diet consists mainly of nectar from flowers.

***Loxigilla noctis* (Lesser Antillean Bullfinch)** is a common resident of Barbuda. It is usually found in subtropical or tropical dry forest or moist lowland forest. Its diet consists mainly of seeds from grasses and weeds.

Fulica caribaea (Caribbean coot) is a large waterbird of the family Rallidae, which is a resident breeder in the Caribbean and parts of Venezuela. The breeding habitat is freshwater lakes and marshes. They are omnivores, eating plant material, insects, fish, and other aquatic animals.

<u>Other Faunal</u>

***Equus africanus asinus* (Donkey)** is found in the desert and other arid areas of the world. Its diet consists mainly of grasses, bark and leaves.

***Dama Dama* (European Fallow Deer)** had been introduced to Barbuda. Its diet consists mainly of grasses, mast, herbs, dwarf shrubs, leaves, buds, shoots and bark.

***Iguana Iguana* (Iguana)** is found in a variety of habitats, including deserts, rocky regions, swamps, rainforests and lowlands. Its diet consists of only plants, and some fruits and flowers.

***Chelonoidis carbonaria* (Red-Footed Tortoise)** is found on several Caribbean Islands, although it is not clear if they are native or brought by humans. The preferred habitat of this species varies by region, but includes fairly consistent seasonal temperatures. Its diet consists mainly of slow-moving invertebrates such as slugs and snails.

***Herpestes auropunctatus* (Mongoose)** is native to South Asia and has been introduced to islands of the Caribbean for control of rats and snakes. Its diet consists mainly of vertebrates and plant matter.

***Paguroidea sp* (Hermit Crabs)** is usually found in forests and marshes near the ocean. Its diet consists mainly of vegetables and non-citrus fruits.

***Uca sp* (Fiddler Crab)** is found along sea beaches and brackish intertidal mud flats, lagoons and swamps. Its diet mainly consists of pellet food, supplemented with vegetables and fruit.

***Cardisoma guanhumi* (Caribbean Duppy Crab)** is usually found throughout estuarine and other coastal regions of the Caribbean. Its diet mainly consists of leaves and fruits and occasionally, insects.

Appendix 3 Hydrogeological Study

PROJECT OF THE PARADISE FOUND DEVELOPMENT, BARBUDA
ENVIRONMENTAL IMPACT ASSESMENT

Report on
BASELINE HYDROGEOLOGICAL CONDITIONS

2022 August

prepared by

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CONTENTS

1. INTRODUCTION

1.1 Background

The Paradise Found Development is a major tourism development proposed for the south-central coastal area of the island of Barbuda. The Antigua & Barbuda Department of the Environment (A&B-DoE) requires the preparation of an Environmental Impact Assessment (EIA) of the project, as a part of its planning approval process. **SMITH WARNER INTERNATIONAL Limited (SWIL)** has been entrusted by the Developers with the preparation of the EIA.

The freshwater for the construction and operation of the Paradise Found Development is to be sourced from the desalination of seawater. It is envisaged that the source water for the desal plant will be obtained from deep wells, and that the disposal of the brine effluent from the desal plant will also be via deep wells, located within the Paradise Found Development's property boundary and drilled into an aquifer at depths of 60 to 120 feet below mean sea level (bmsl). **HYDROLOGY CONSULTANTS Limited (HydroConsult)** has been contracted by SWIL to satisfy the requirements of the A&B-DoE with respect to the seawater source well(s) and the brine disposal well(s).

1.2 Objectives & Scope

HydroConsult is required to (a) propose a methodology for the disposal of the brine effluent from a desalination plant that is environmentally acceptable i.e., has no significant negative impact on the natural environment and/or existing water supply systems, and (b) contribute hydrogeological input to the tasks of other Team Members, as may be required.

The Sub-Consultancy Agreement (SWIL/HydroConsult) specifies contributions to the following project deliverables:-
D1: Baseline Conditions Report – through data collection and literature review;
D2: Hydrogeological Impact Report (Leading);
D3: Draft Environmental Impact Report, and
D4: Final Environmental Impact Assessment Report.

HydroConsult in its implementation of the assignment was to be guided by the overall project Work Plan and Schedule.

1.3 Approach & Methodology

HydroConsult proposes to implement the assignment in three distinct phases, as follows: -

1.3.1 Phase 1: Reconnaissance Study

(i) Collation and review of existing data, maps, and reports on the hydrogeology of Barbuda. The primary source was a report entitled "A Hydrogeological Evaluation of the Impact of Sand Mining on the Palmetto Sand Aquifer, Barbuda" prepared in 1992 June by HydroConsult, for the Barbuda Council. Descriptions of the physiography and hydrogeology of Barbuda included therein proved particularly useful. Personal communication with Antigua Public Utilities Authority (APUA) personnel in Antigua - Veronica Yearwood (Hydrology Technician), Ms. Williams (Office of the Manager of the Water Department), and in Barbuda – Leonard DeSouza (Supervisor Water Supply) failed to unearth any additional report on the hydrogeology of Barbuda.

(ii) Field Reconnaissance in Barbuda – June 20/22, 2022, involving the following; -

- Field examination of outcrops of the hydro-stratigraphic sequence – Highland Limestone Aquifer, Central Plains Limestone Aquiclude and the Palmetto Sands Aquifer, including field determination of groundwater Electrical Conductivity, Temperature, and measurements of depth to the respective water tables. Relevant features of the respective hydro-stratigraphic units were photographed.
- Visited seawater source wells operated by APUA and PLH, brine disposal wells operated by PLH and beach brine disposal by the APUA. PLH is a developer of a tourism development in the Palmetto Point area.
- Personal Communication with Denroy Alexander (Drilling Supervisor, Walkerwells Ltd) the Well Contractor that had established the existing seawater source wells and brine disposal wells at Palmetto Point for PLH. Contracted confidentiality clauses prevented the sharing of the detailed results of the drilling but he was able to provide general information on drilling conditions, subsurface geology, successful well designs, Walkerwells drilling capability and work schedule in Barbuda.

(iii) A Preliminary Well Design, Draft Well Specifications and a Draft Bill of Quantities for a Brine Disposal Well, to guide discussions with Walkerwells on a Well Contract, were prepared and sent to Monty Walker, CEO of Walkerwells Ltd in Trinidad, on 08 July 2022. It is expected that the Well Contract will be entered into with Paradise Found Development and Engineering Supervision provided by HydroConsult.

(iv) Presentation of the results of the Reconnaissance Study in this report on the Baseline Hydrogeological Conditions in Barbuda in general, and the Paradise Found Development area in particular

1.3.2 Phase 2: Field Determination of Impact

(i) Construction and Yield Testing of an Exploratory Brine Disposal Well at a site to be agreed with Paradise Found Development, to prove the viability of the proposed brine disposal methodology. It is anticipated that drilling samples retrieved will allow confirmation of the subsurface hydro-stratigraphy; Multiple and Constant Rate Pumping Tests to confirm aquifer permeability, well yield and well water quality; Slug Test to confirm injection rates; depth conductivity traverse to confirm water quality stratification, and downhole camera inspection/video recording to indicate limestone lithology and the occurrence of conduit permeability. The results of these exercises will be presented in a Well Completion Report.

(ii) Field Monitoring of groundwater elevation and water quality in nearby wells within the Highland Limestone Aquifer the Central Plains Limestone Aquiclude and the Palmetto Sand Aquifer, prior, during and after the yield and slug tests of the well – to identify impact, if any. The A&B-DoE will be invited to observe the well testing and water resources monitoring to ensure confidence in the results obtained.

(iii) Analysis, interpretation, and presentation of the results of the investigations – conclusions and recommendations, in a Hydrogeological Impact Report.

1.4 Acknowledgements

The assistance and/or co-operation of the Staff in the implementation of this Assignment, of the following institutions, are hereby gratefully acknowledged: -

Antigua Public Utilities Authority
Barbuda Council
Paradise Found Development
Smith Warner International Ltd

2. HYDROLOGICAL SETTING

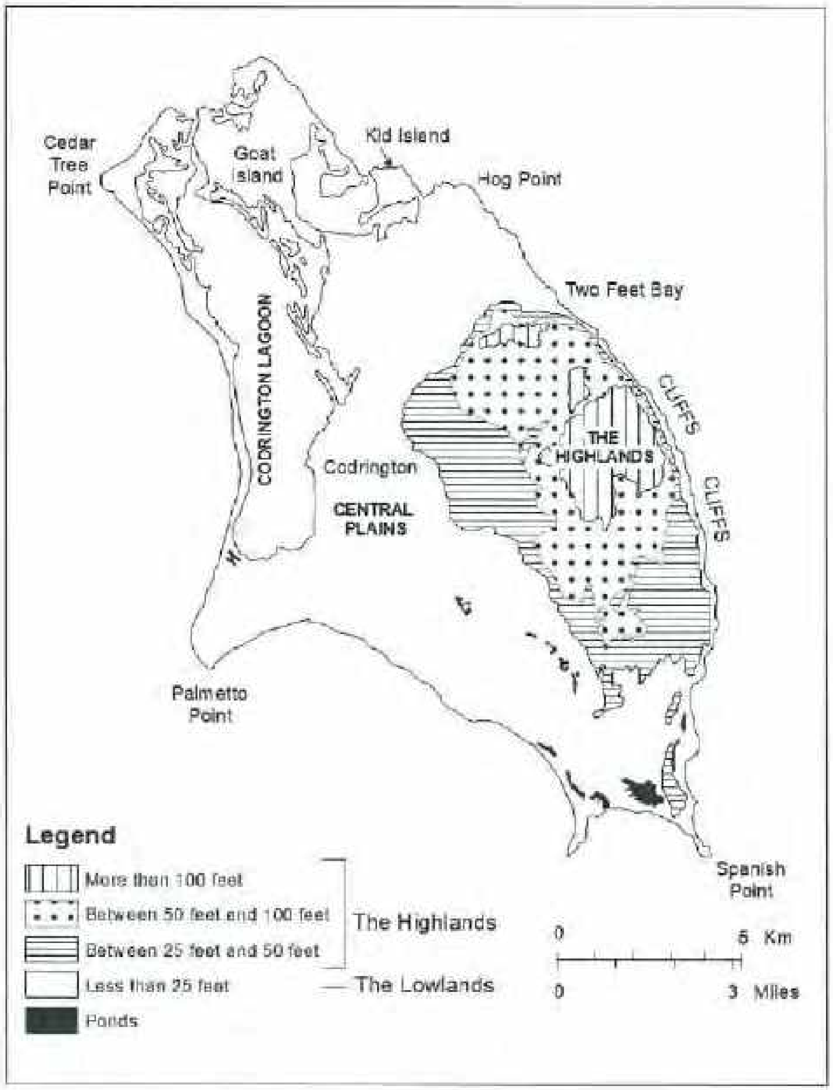
2.1 Physiography

Barbuda is an island located in the northeastern section of the Caribbean Sea, about 25-miles north of Antigua. It is 60 square miles in area, roughly oval in shape - 12 x 5 miles, and aligned in a NW-SE direction.

Barbuda may be subdivided into three distinct physical regions, as listed, and shown in **Figure 2-1**, below.

- The Highlands;
- The Lowlands, and
- The Codrington Lagoon

Figure 2-1: **PHYSIOGRAPHIC SUBDIVISIONS OF BARBUDA**



The Highlands is an area of limestone upland located in the eastern and central sections of Barbuda, occupying about 30% of the island. Surface elevations range from about 25 to just over 100 ft above mean sea level (amsl)

The Lowlands occur to the south, west, and north of the Highlands, forming a relatively featureless plain, with surface elevations < 25-ft amsl.

The Codrington Lagoon occupies a 6 x 1.5 mile, N-S aligned depression, located west of the central and northern Lowlands, paralleling most of the western coast of the island. The Lagoon is bordered on the south, west and north by beach sands, with surface elevations generally < 10 ft amsl, but dune ridges particularly in the south may rise to 25 ft amsl. However, extensive sand mining for in excess of 30-year in the south, such as at Palmetto Point, may have significantly reduced the surface elevations.

2.2 Surfacewater Hydrology

There is no perennial or seasonal surface stream on the island.

Rainfall infiltrates rapidly into the karstic limestone uplands of the Highlands, with drainage being primarily subsurface (i.e., submarine underflow) into the sea and Codrington Lagoon.

Rainfall over the Lowlands, runoff primarily as sheet overland flow during heavy rainfall events, a result of its flat featureless topography and the relatively low infiltration capacity of the Central Plains Limestone Aquiclude, which forms most of the Lowlands.

The unconsolidated windblown sands that fringe the Lowlands in the south and at Palmetto Point in the southwest, exhibit a high infiltration capacity, such that there is no overland flow, but pooling in mined-out depressions before infiltrating into the subsurface.

The Codrington Lagoon is in direct contact with the sea via a narrow opening at its northern end, a feature primarily responsible for it being occupied by seawater, although seepage from the sea through the coastal sands can be expected to contribute to its salinity. Personal communication with Fisherfolk that use the Lagoon, reported the presence of freshwater submarine springs issuing from the floor of the Lagoon.

Three saline surface ponds and three other flooded mangrove swamp forests occupy what appears to be a shallow, downfaulted, linear, surface depression within the Lowlands, positioned to the south and southwest of the Highlands and aligned in a SE-NW direction. The water level in these ponds appear to be related, if not controlled, by tidal sea level changes but have no surface opening to the sea i.e., thought to be indirectly linked through groundwater in the Central Plains Limestone Aquiclude.

2.3 Groundwater Hydrology

Three hydro-stratigraphic units are recognised by Yearwood & Barrage-Bigot (1988), as follows: -

- Highland Limestone Aquifer;
- Central Plains Limestone Aquiclude, and
- Palmetto Sand Aquifer.

Their outcrops are given in **Figure 2-2** (Brasier & Mather, 1975) and geological sections included as **Figure 2-3**, to illustrate their subsurface relationships as interpreted by HydroConsult (1992) and revised this Study.

Figure 2-2: **HYDRO-STRATIGRAPHIC MAP OF BARBUDA**

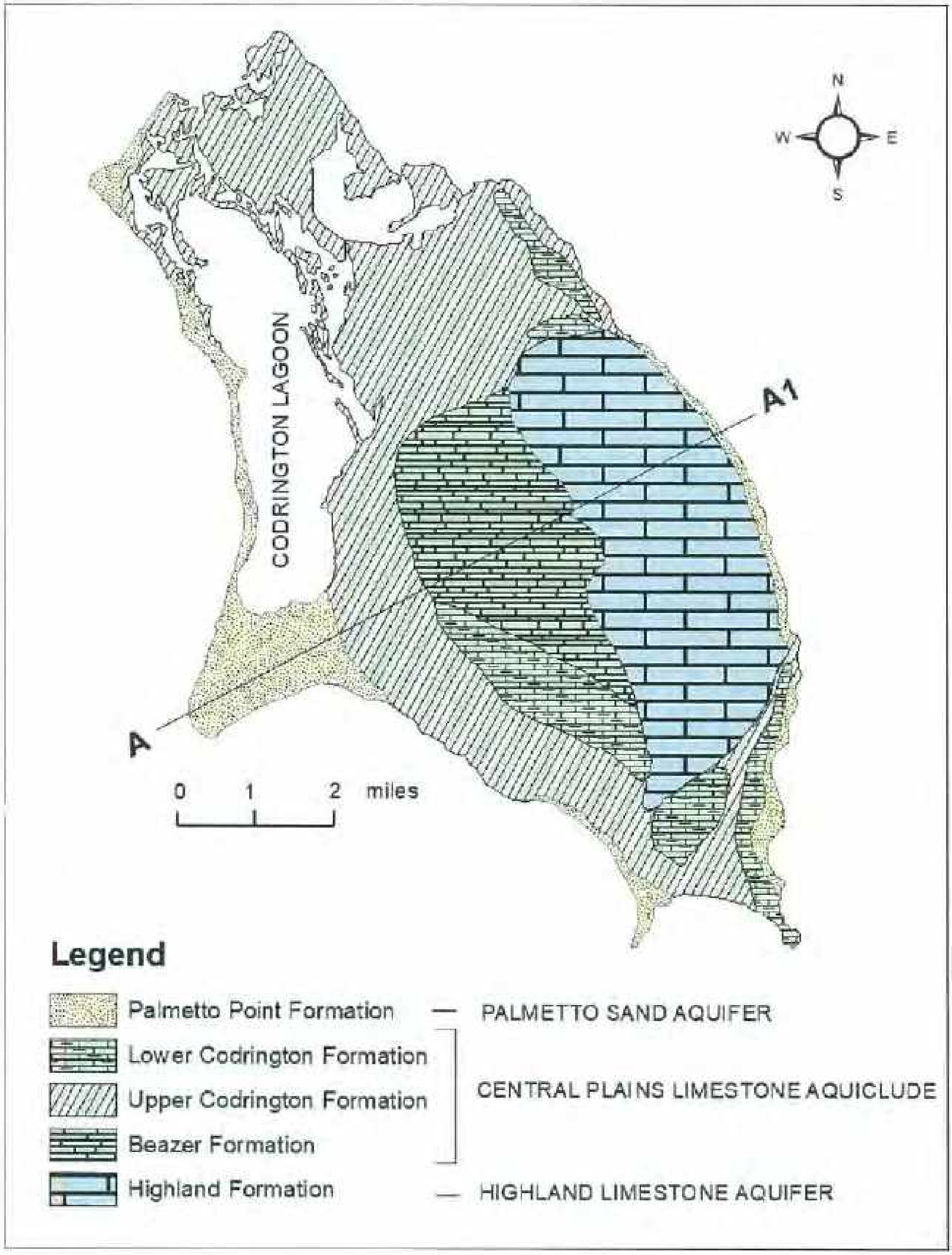
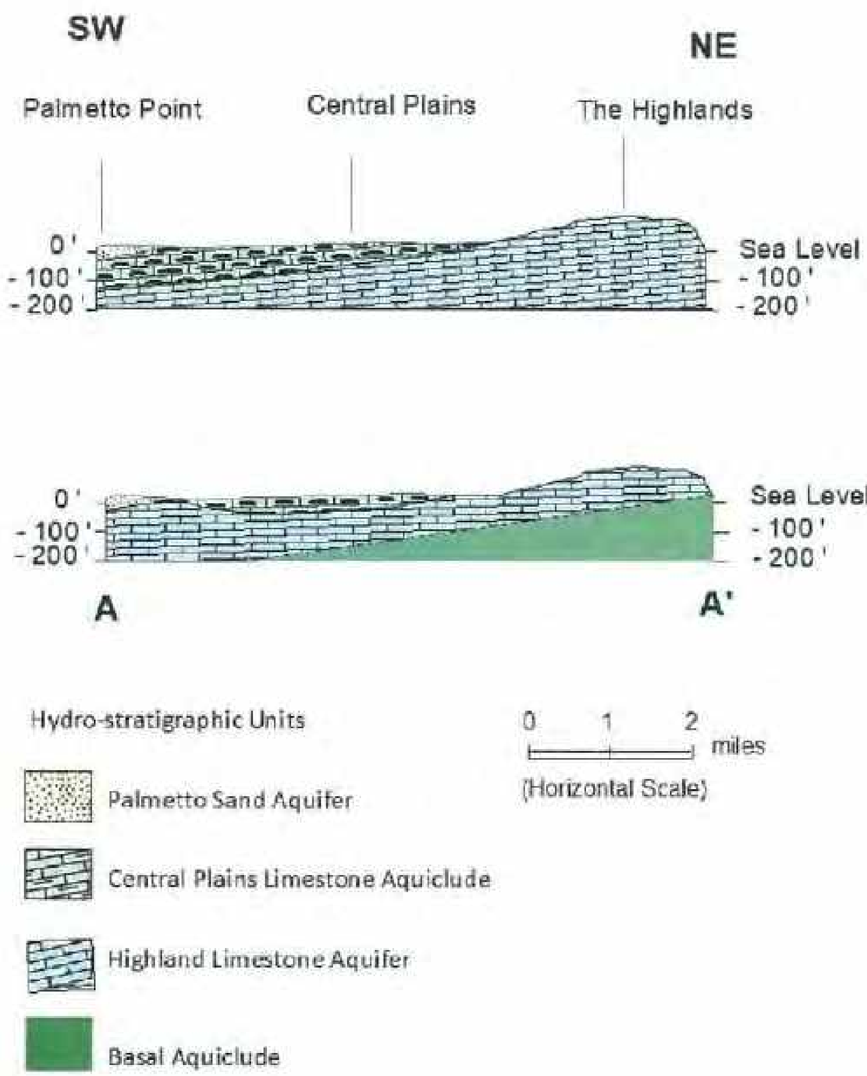


Figure 2-3: **HYDRO-STRATIGRAPHIC SECTIONS THROUGH BARBUDA**



2.3.1 Basal Aquiclude

The geological foundation of Barbuda is believed to be formed by island arc volcanics and volcaniclastic, as exists throughout the Caribbean Islands.

Its existence, not previously reported, was indicated this Study by the presence of fresh groundwater in a collapsed cavern located a few hundred feet from the northeast coast, shown in **Figure 2-4**, below. This is a clear indication that the Highland Limestone Aquifer was not in hydraulic continuity with the sea at its eastern geological boundary and must therefore be physically separated from the sea by impervious strata, which function as a basal aquiclude.

Figure 2-4: **LOCATION OF SELECT FEATURES VISITED THIS STUDY**

2.3.2 Highland Limestone Aquifer

Brasier & Mather (1975) described the lithology of the Highland Limestone Aquifer as a massive, compact and extensively recrystallised, bioclastic reef deposit. It is believed to have a gentle dip to the southwest, underlying the Central Plains Limestone Aquiclude. The thickness of the Highlands Limestone is uncertain, but it was interpreted by the geological section to exceed 100 ft.

Since being uplifted, the Highland Limestone has been subjected to karstification by percolating rainwater recharge i.e., the dissolution of the calcium carbonate rich limestone along lines of weakness such as primary porosity, joints, fractures - by mildly acidic rainwater, to create linked conduits in the subsurface, ranging in diameter from inches to feet. Brasier & Mather (1975) reported the presence of sinkholes and caverns throughout the limestone outcrop in the Highlands. The Walkerwells Driller reported that wells drilled at Palmetto Point into the Highland Limestone Aquifer intercepted caverns several feet in height, between depths of 60 and 120 ft below ground level (bgl), proving the presence of major conduit flow permeability in the Highland Limestone Aquifer along the south coast of Barbuda. The collapsed roof of a cavern called 'Cave' in the northern area of the outcrop was visited this Study. Its location is shown in **Figure 2-5**, below.

Figure 2-5:

The Cave – roof collapse of cavern to expose the water table in the Highland Limestone Aquifer. Being used as a sources of domestic water by a nearby guest house - Frangipani

The Highland Limestone Aquifer in the Highlands supports a water table i.e., top of the groundwater saturated aquifer exposed to atmospheric pressure. Where the Highland Limestone Aquifer dips under the Central Plains Limestone Aquiclude within the Lowlands, it is confined under pressures higher than atmospheric. Wallace Evans (1974) reported an artesian rise of 24 ft in an exploratory borehole drilled through the Central Plains Limestone Aquiclude into the top of the underlying Highland Limestone Aquifer, at a location east of Codrington. The nature of the groundwater surface in the limestone aquifer in the Palmetto Point area in southwestern Barbuda is uncertain, as the Central Plains Limestone Aquiclude is absent and the limestone is overlain by 30 to 40 ft of the Palmetto Sand Aquifer i.e., there is no confining layer, and as a result there may be hydraulic continuity between the underlying Highland Limestone Aquifer and the Palmetto Sands Aquifer.

The very high permeability (and associated high Transmissivity) of the karstified Highlands Limestone Aquifer and the absence of a subsurface barrier to pond groundwater within it, together, imply a relatively flat and low elevation for the water table within the limestone aquifer. The single data point within the Highland Limestone Aquifer at "the Cave", is insufficient to allow the preparation of a water table contour map for the aquifer. The depth to the water table in "the Cave" was measured at 10.5 ft bgl this Study, so a subsequent determination of the ground surface elevation would allow computation of the water table elevation.

The major groundwater movement within the Highland Limestone Aquifer is to the southwest, down dip towards the sea and Codrington Lagoon. The freshwater springs that rise from the floor of the Codrington Lagoon represent submarine discharge from the Highlands Limestone Aquifer. The absence of springs at the geological boundary with the Central Plains Limestone Aquiclude and/or along the coast, indicates direct submarine discharge from the limestone aquifer into the sea, evidence that the aquifer is in hydraulic continuity with the sea.

The groundwater within the Highlands Limestone Aquifer in the Highlands is fresh groundwater. Wallace Evans (1974) reported relatively low salinities for Borehole #7, which was drilled into the Highlands Limestone Aquifer east of Codrington i.e., Chloride of 142 to 601 mg/l. The groundwater in "the Cave" was determined this Study to have a Specific Conductance of 992 µS/cm and a temperature of 29.4°C. A Specific Conductance of <1000 µS/cm is indicative of freshwater.

The quality of the groundwater within the Highland Limestone Aquifer beneath the Central Plains Limestone Aquiclude i.e., below the Lowlands, is less certain. It depends on the position of the Ghyben Herzberg (GH) Interface i.e., the position/location of the interface between fresh groundwater and saline groundwater (seawater). The position of the GH Interface within the limestone aquifer could be (a) inland of the coast if fresh groundwater recharge is low; (b) in the vicinity of the coast if recharge is moderately high and (c) seaward of the coast when the aquifer recharge is high. The Ghyben-Herzberg Relationship describes the relationship between fresh and saline groundwater i.e., for every 1 ft of fresh groundwater above mean sea level (amsl) there is 40 ft of fresh ground water below mean sea level (bmsl). Determination of the elevation of the water table within the limestone aquifer would allow estimation of the extent of fresh and/or saline groundwater within the Highland Limestone Aquifer. Such an understanding would assist in estimating the pre-development salinities in the Highland Limestone Aquifer at depth under the Paradise Found Development area.

2.3.3 Central Plains Limestone Aquiclude

Brasier & Mather (1975) grouped the Beazer and Codrington Formations into the Central Plains Limestone Aquiclude because of their common stratigraphic position above the Highland Limestone Aquifer. Their lithologies range from patchily recrystallised reef limestone to calcarenites. Wallace Evans (1974) described the Codrington Limestone exposed in shallow, large diameter, hand dug wells as being"….a dense fine grained limestone, bedded in thin layers and well consolidated, with limited fissures and solution cavities." i.e., no evidence of karstification.

The Central Plains Limestone Aquiclude appears to be relatively thin, as indicated by a thickness of 32 ft proved by Borehole #6, located just east of Codrington (Wallace Evans, 1974). It appears to be absent from the stratigraphic sequence in wells drilled in the Palmetto Point area in southwestern Barbuda, indicating likely deposition in a laterally restricted depression, characteristic of back-reef environments.

The Central Plains Limestone Aquiclude exhibit overall low permeability (and Transmissivity), hence its characterisation as an aquiclude. The equipping of the dug wells with low capacity (i.e., <10 igpm) hand pumps or small electric pumps is evidence of this low permeability. These dug wells are commonly used as household sources of water for non-potable uses. A Municipal Dug well is shown in **Figure 2.6**, below.

Figure 2.6: **JAM HAND DUG MUNICIPAL WELL – CODRINGTON, BARBUDA**

Groundwater levels in the Central Plains Limestone Aquiclude are unconfined i.e., it is a water table aquiclude. The water table is believed to be at or just amsl (Wallace Evans, 1974). Depth to Water Level measurements were taken in 3 No. of the hand-dug wells, with the expectation that subsequent survey determination of well head elevations will allow the computation of water table elevations.

The groundwater quality in the Central Plains Limestone Aquiclude is dominated by medium high salinities. Wallace Evans (1974) reported salinities >1000 mg/l Chloride. Field measurements of Specific Conductance taken this Study, indicated a range between 3,680 µS/cm at the Jam Well and 5,480 µS/cm at the Desouza's Meadows Well. Their locations are given in **Figure 2-4**, above. This relatively high salinity is consistent with the incomplete flushing by rainwater recharge of seawater trapped within the porosity of the rock, during its deposition under coastal marine conditions.

2.3.4 Palmetto Sand Aquifer

The Palmetto Sand deposits fringe the southern and western leeward coasts of Barbuda and is most extensive in the Palmetto Point headland in the southwest, as shown in **Figure 2-2**, above. The Palmetto Sand Aquifer is an unconsolidated, fine to medium grained, calcareous sand, with abundant coral and molluscs shell fragments. A maximum thickness of 40 ft have been reported for wells drilled through the Palmetto Sand Aquifer into the underlying Highland Limestone Aquifer, indicating that the Central Plain Limestone Aquiclude is absent from the stratigraphic sequence, in the Palmetto Point area..

The sand deposits in the Palmetto Point headland constitute the Palmetto Sands Aquifer. These beach sands have been fashioned by the wind into dunes, ridges, and swales. The 1970 topographic map showed two main ridges paralleling the southern shoreline at Palmetto, attaining an elevation of 25 ft amsl. However, sand mining for in excess of 30-years is expected to have significantly reduced the height of the Palmetto Sands.

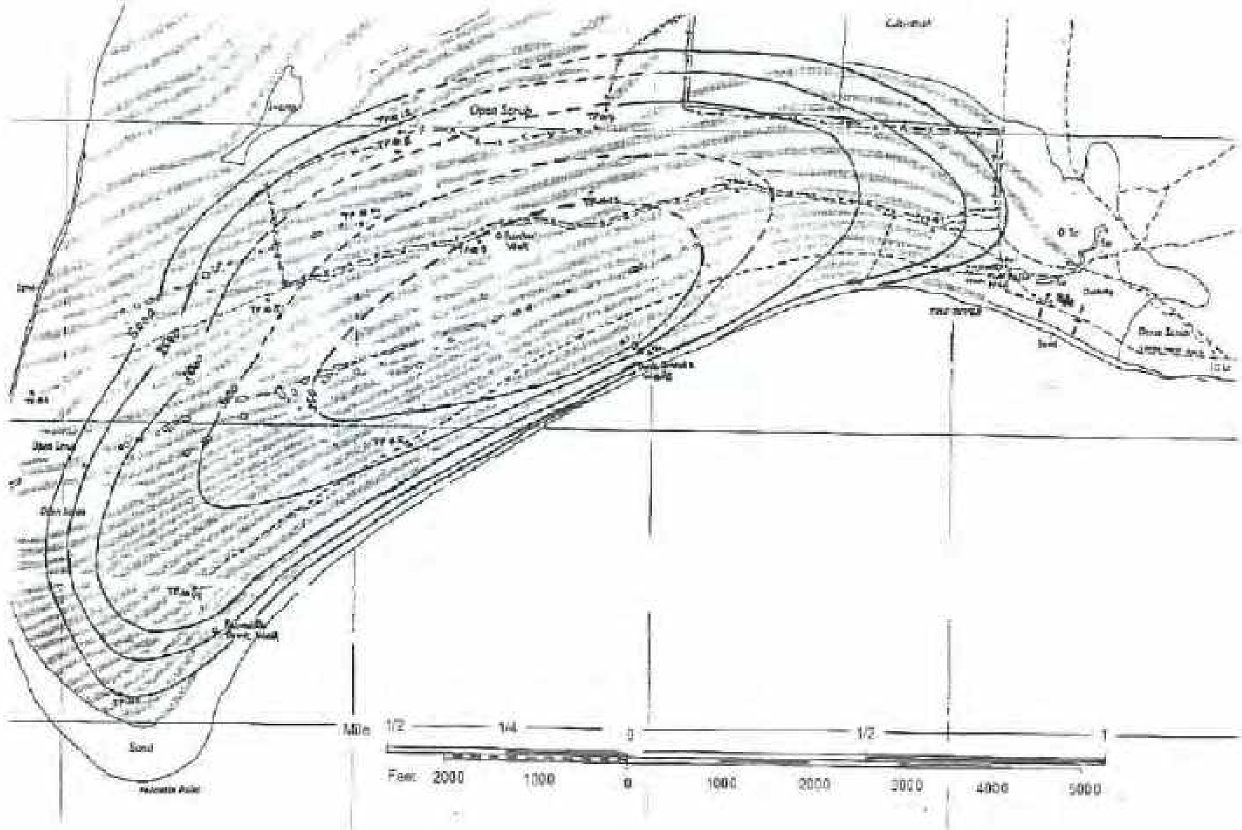
This aquifer is recharged by rainfall. Mather (1971) reported that rainwater rapidly infiltrated into the subsurface so that there is no surface ponding or surface runoff, even after heavy rains.

Prior to the sand mining, groundwater in the Palmetto Sand Aquifer occurred as a freshwater lens centered on the main ridge and elongated along an ENE – SSW axis, as shown in **Figure 2-6,** below (HydroConsult, 1992).

The area within the 1000 micromhos/cm (or µS/cm) constituted fresh groundwater, suitable for use as a source of domestic water supply. The central thickness of the freshwater lens was about 40 ft as indicated by a Chloride value of 400 mg/l at a depth of 30 ft in a boring drilled into the sand aquifer (Mather 1971). This was consistent with lens thicknesses in the Cayman Islands (Lloyd, 1980) and Hellshire Limestone in Jamaica (HydroConsult, 1982). The location of the Mather (1971) boring is not known. Groundwater flow within the Palmetto Sands Aquifer is intergranular and was radially towards the lens edge.

The sand mining has created a number of mined out pits where excavation has extended down to the water table, exposing the groundwater to the direct effects of evaporation, creating pools with Specific Conductance of 10,400 to 12,500 µS/cm. The lens structure is still believed to exist within the Palmetto Sand Aquifer, although near totally occupied by brackish groundwater – 10,000 to 12,500 µS/cm i.e., no fresh groundwater.

Figure 2-7: **PRE-MINING FRESHWATER LENS IN THE PALMETTO SAND AQUIFER, BARBUDA**



3. BRINE DISPOSAL OPTIONS

3.1 International Brine Disposal Options

Internationally, seawater desalination is increasingly being used as a source of freshwater in water deficient countries, primarily for domestic/municipal supply but also for irrigation. A variety of disposal methods are used to dispose of the resulting brine effluent, as listed below: -

- Beach Disposal;
- Marine Outfall;
- Deep-well Injection;
- Evaporation Ponds, and
- Land Application.

The Evaporation Pond and Land Application options were not considered suitable for a small island like Barbuda, because of the need for relatively large tracts of land, and the potential sterilization of the land for other uses. The use of Marine Outfalls is associated with technologically challenging bio-fouling and severe negative environmental impacts on seawater quality and marine life. Beach and Deepwell disposal are currently practiced on Barbuda.

3.2 Current Disposal Practices on Barbuda

3.2.1 Beach Brine Disposal

The Antigua Public Utilities Authority (APUA) operates a desalination plant located about miles along the main road southeast of the Martello Tower, and sited <100 ft from the shoreline. The plant has a rated capacity of about 100 imperial gallons per minute (igpm) of freshwater – personal communication with Leonard Desouza, Barbuda Manager. The brine effluent from the plant is discharged via a 4" ID PVC pipeline directly onto the beach, the brine flowing over and through a rocky shoreline into the sea, as shown below in **Figure 3-1**, below. The APUA Manager for Barbuda, was not aware of any environmental monitoring of the impact of the brine in the vicinity of the entry of the brine into the sea. This Study observed an absence of fish and/or molluscs in the immediate vicinity of the outfall.

Figure 3-1: **BEACH DISPOSAL OF BRINE BY APUA DESALINATION PLANT, BARBUDA**

The hotel at Cocoa Point is also believed to practice beach brine disposal, but access to the property was denied, this Study.

The beach disposal option is an obvious low cost option that avoids the bio-fouling that is associated with a marine outfall and employs the surface wave energy in rapidly diluting/dissipating the brine effluent. However, it can be expected to create negative environmental conditions for coastal marine life – flora and fauna, by creating coastal waters with much higher salinities than promotes life and growth. The density of the brine is at least 4 times higher than seawater, so the brine will occur as a super saline plume that sinks to the coastal sea-floor and move downgradient or spreading out, until it is fully diluted/dissipated by the receiving seawater. The higher the rate of brine disposal the more significant the negative impacts.

3.2.2 Deepwell Brine Disposal

The PLH desalination plant (s) at Palmetto Point dispose of the brine effluent produced via 2 No. deepwells. Each well is 16" OD, reported to be 120 ft in depth, with disposal via the lower uncased section (i.e., open hole) of the wells. Information on the capacity of the desal plants, the rate brine production, and the rate of brine disposal, were not available to this Study. Brine Disposal #2 Well was visited and observed to be adequately disposing of the effluent fed into it. A photograph of the PHL Brine Disposal #2 Well is included below as **Figure 3-2**.

Figure 3-2: **PLH BRINE DISPOSAL #2 WELL – PALMETTO POINT, BARBUDA**

Neither was there information on the existence of environmental monitoring of the impact of the source wells and/or the brine disposal wells.

The Brine Disposal wells at Palmetto Point inject the brine into the karstified Highland Limestone Aquifer at depths reported to be between 60 and 120 ft bmsl i.e., not directly into the sea. The brine can be expected to plume within the limestone aquifer and be subject to dilution/dissipation primarily by physical mixing with the native seawater at its edges, such that the brine plume is near, if not fully, assimilated by the time it reaches the open seawater. In this event, the impact on marine life would be negligible, if any.

However, the presence of conduit flow permeability within the limestone aquifer i.e., caverns, could cause a short-circuiting that subjects the brine-plume to varying levels of dilution/dissipation, before entering the open seawater. In the worst case scenario, where the brine-plume enters the open seawater with minimum attenuation, its relatively small volume in relation to that of the open seawater, can be expected to be rapidly diluted/dissipated the brine-plume to background seawater quality, with minimum impact on marine life, at seawater depths of 60 to 120 ft. bmsl.

Although not present in the Palmetto Point headlands, it is likely that the Central Plains Limestone Aquiclude will be present in the hydro-stratigraphic sequence at Paradise Found. In this event, the Central Plains Limestone Aquiclude would tend to function as a physical barrier between the Highland Limestone Aquifer and the open seawater, causing the brine-plume to be trapped within the underlying Highland Limestone Aquifer below the limestone aquiclude, with no direct impact on the physical conditions and/or water quality of the open seawater above the limestone aquiclude.

The higher capital and operational costs associated with the deepwell brine disposal option is readily justified by its far superior environmentally friendly character.

3.3 PREFERRED BRINE DISPOSAL OPTION

The deepwell brine disposal option is the more environmentally acceptable option and is recommended for use by the Paradise Found Development.

4. POTENTIAL IMPACT OF PARADISE FOUND BRINE DISPOSAL WELL(S)

4.1 Brine Chemistry and Production

4.1.1 Brine Chemistry

The chemistry of brine from desalination plants is determined by the chemistry of the source water and the technology used in the desalination process. The range in the major chemical constituents of brine effluent from RO seawater desalination plants in the Persian/Arabian Gulf, are reported by **Omerspahic et al (2022).** The Specific Conductance (or Electrical Conductivity) was the most relevant parameter to this Study, given its ease of field determination. The range given for Emirates RO was 10,850 to 81,100 μS/cm.

4.1.2 Brine Density

The density of freshwater is 4.5 lbs/gal, that of seawater is 4.7 lbs/gal, and for brine it ranges from 8.3 to 19 lbs/gal. Being significantly heavier, brine sinks when placed/discharged into freshwater or seawater bodies.

4.1.3 Brine Temperature

The Reverse Osmosis desalination process does not result in a temperature change in the conversion of the source water to brine.

4.1.4 Brine Production

The conversion of source water to brine depends on the quality of the source water, the type of desalination technology employed and its efficiency. The conversion ratio ranges from 1.5 to 0.5 i.e., 40% to 0.50% freshwater for each unit of source water. The freshwater demand of the Paradise Found Development is not yet known to the Study, so the production of brine cannot be estimated at this time.

4.2 Exploratory Brine Disposal Well

It is proposed that an exploratory well be constructed at a site on the Paradise Found Development property, yet to be decided, to achieve the following: -

(i) Confirm the hydro-stratigraphic sequence at Paradise Found, in particular the presence of the Central Plains Limestone Aquiclude, to allow determination of the likely disposition of the brine-plume;

(ii) Examination of the lithology of the Highland Limestone Aquifer, in particular the presence of cavities, to allow an evaluation of their potential to short-circuit the movement of the brine-plume to the open seawater;

(iii) Conduct yield tests – Multiple Rate, Constant Rate, and a Slug Test to determine aquifer characteristics and well performance, and

(iv) Prove that a brine-disposal well can be successfully developed at Paradise Found;

Walkerwells Limited has successfully completed source and brine-disposal wells for PLH within the Palmetto Point area and is expected to complete their existing well contracts on the island by early August 2022. In an attempt to have Walkerwells complete the Paradise Found Brine Disposal Well before they leave the island, to avoid the expense of remobilizing from offshore, contact was made with their CEO – Monty Walker (Port of Spain, Trinidad), who was advised of the intent to have the exploratory well constructed and tested. A draft well design, well specifications and Bill of Quantities were sent on 8th July 2022 to Walkerwells to guide negotiation of a Well Contract with Paradise Found Development. Walkerwells acknowledge receipt of the documents but has yet to respond. A copy of the email to Walkerwells is included as **Appendix 1**.

4.3 Impact on Water Resources

4.3.1 Impact on the Highlands Limestone Aquifer

(a) Fresh Groundwater

The only natural source of fresh groundwater in Barbuda is contained within the Highland Limestone Aquifer, centered on the Highlands, located some 6 miles to the northeast of the Paradise Found coastline, the likely location of the Paradise Found brine disposal wells. Given this distance away and that the water table is upgradient, it is very unlikely that the brine-plume will extend to impact the fresh groundwater reserves in the Highland Limestone Aquifer in the Highlands.

Nevertheless, the single access to the water table in the Highland Limestone Aquifer at the "Cave" (known to this Study) will be monitored during yield testing of the Paradise Found exploratory brine disposal well.

(b) Saline Groundwater

The Highland Limestone Aquifer under the Paradise Found coastal area, the top of which occurs at a depth of about 40 ft. bgl, is believed to be saline, as indicated by Specific Conductance of 28,400 µS/cm (measured this Study) in the PLH source wells (for their desalination plant) drilled into the Highland Limestone Aquifer at Palmetto Point, some 4 miles to the east of Paradise Found. Seawater has a Specific Conductance of about 35,000 µS/cm. It is proposed that the Paradise Found Exploratory Brine Disposal Well (and future wells) be also finished in the Highland Limestone Aquifer, believed to be occupied by a very brackish groundwater or seawater.

The Central Plains Limestone Aquiclude is believed to overlie the Highland Limestone Aquifer at Paradise Found, forming a physical low permeability barrier, preventing the movement of the saline groundwater (and/or brine-plume), from the Highland Limestone Aquifer into the open seawater above the limestone aquiclude. When injected into the well, the brine can be expected to rapidly sink to the bottom of the well and move laterally and vertically into the aquifer. On entering the aquifer, the brine-plume should move primarily down dip to increasing depth and an increasing distance from the well (and coastline), until it is diluted/dissipated to background salinity levels. This process of dilution/dissipation will begin as soon as the brine enters the aquifer and continue throughout its movement within the aquifer.

The brine-plume will be confined within the Highland Limestone Aquifer. There is not expected to be any marine life within the aquifer and so this method of brine disposal is/should be environmentally acceptable.

Alternatively, in the absence of the Central Plains Limestone Aquiclude, the Highland Limestone Aquifer will be in direct hydraulic continuity with the open seawater. Injection of the brine into the aquifer at depths >100ft bmsl, may be followed by movement via caverns i.e., conduit permeability, into the open seawater, short-circuiting (i.e., shortening) the dilution/dissipation process/path within the aquifer, with completion in the open seawater. In this event, the partially dissipated brine-plume will extend into and create hostile environmental conditions for marine life in and around the exit of the cave. The impact on the open seawater will depend on the rate of brine injection, the size of the cavern, the length of the flow patch through the aquifer, and the turbulence within the seawater, none of which can be objectively estimated.

This movement/dissipation of the injected brine-plume will take place at depths >100 ft bmsl, under conditions that cannot be monitored by standard hydrological techniques, as there will be no other direct access to the Highland Limestone Aquifer at those depths.

4.3.2 Impact on the Palmetto Sand Aquifer

At the Paradise Found coast, the Palmetto Sand Aquifer extends from ground surface to a depth of about 20 ft bgl and is underlain by the Central Plains Limestone Aquiclude. The Paradise Found Exploratory Brine Disposal Well will be drilled through the Palmetto Sand Aquifer and the Central Plains Limestone Aquiclude, and into the Highland Limestone Aquifer. The Well will be designed/constructed to prevent the movement of brine from the well into the Palmetto Sand Aquifer and/or the Central Plains Limestone Aquiclude, by the use of blank well casing and by grouting the annular space between the outer wall of the well casing and the respective formations. Therefore, there should be no direct impact of the brine-plume on the Palmetto Sand Aquifer and/or the Central Plains Limestone Aquiclude.

The brine will be injected into the Highland Limestone Aquifer at a depth of 100 ft bmsl, at least 80ft below the base of the Palmetto Sand Aquifer. Given that the brine is much denser than the saline groundwater in the Highland Limestone Aquifer, the brine is expected to sink and move farther away from the Palmetto Sand Aquifer, with little, if any potential to indirectly impact the Palmetto Sand Aquifer.

Nevertheless, the Specific Conductance of the Martello Tower Well, which is located at the northeast end of the Palmetto Sand Aquifer, and the nearest sand well to Paradise Found, will be monitored.

5. SUMMARY OF RESULTS

5.1 Conclusions

Hydrogeology

(i) The hydro-stratigraphic units of Barbuda, their stratigraphic sequence, subsurface relationships, and hydraulic character described by previous investigators, were examined in the field, and found to be generally accurate. However, wells recently drilled through the Palmetto Sand Aquifer in the Palmetto Point headland in the south west end of Barbuda, indicated that the Central Plains Limestone Aquiclude was absent, requiring a re-interpretation of the stratigraphic sequence in that area, and the depositional history of Barbuda, as presented in Section 2.3, above.

(ii) The determination of well head elevations for data points in the Highland Limestone Aquifer, the Central Plains Limestone Aquiclude and the Palmetto Sand Aquifer will allow computation of the water table elevation in the respective hydro-stratigraphic units and a better understanding of the hydraulic relations between them.

(iii) Field determinations of Specific Conductance (i.e., Electrical Conductivity) allowed characterisation of the water quality in the water table sections of the Highland Limestone Aquifer, Central Plains Limestone Aquiclude and the Palmetto Sand Aquifer. The fresh groundwater in the Palmetto Sand Aquifer reported by previous investigators up to 1992, no longer existed but was now moderately saline, believed to result from the extensive mining of the sand and the exposure of the water table to direct evaporation.

Brine Disposal Options

(iv) Brine disposal options employed on Barbuda included beach disposal and well injection, the latter being the preferred option, given its potential for minimum environmental impact.

(v) The proposed disposal of the brine into the Highland Limestone Aquifer at Paradise Found - at a depth of 100 ft bmsl and confined by the physical barrier formed by the low permeability overlying Central Plains Limestone Aquiclude, has the potential to isolate the brine-plume to complete dilution/dissipation, with no impact on marine life. In the absence of the Central Plains Limestone Aquiclude, the dilution/dissipation would begin within the Highland Limestone Aquifer and be completed in the open seawater, at depths in excess of 100 ft bmsl.

(v) It is proposed that an exploratory brine disposal well be established at Paradise Found, to obtain hydrogeological information needed to better understand the subsurface conditions that control brine disposal, and to demonstrate that disposal wells can be successfully developed at Paradise Found.

(vi) Draft - well design, well specifications and bill of quantities have been provided to the current Well Contractor on Barbuda to guide negotiation of a Well Contract with Paradise Found Development.

5.2 Recommendations

The following recommendations are proposed for implementation: -

(i) Establish an exploratory brine disposal well at Paradise Found to obtain hydrogeological information needed to better understand the conditions that control the movement on the brine in the subsurface, and to demonstrate that disposal wells can be successfully developed at Paradise Found.

(ii) Determine by survey measurement the Well Head Elevations at select wells, to allow determination of the water table elevation in the respective hydro-stratigraphic units, and the nature of the hydraulic relations between them.

End of Report.

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APPENDIX I

Email sent to Walkerwells Ltd - 08 Jul 2022
(including Well Design, Well Specifications and Bill of Quantities)

Subject: PARADISE FOUND DEVELOPMENT, BARBUDA - Exploratory Brine Disposal Well

From: hydroconsult@flowja.com

To: sales@landwengineering.com

Cc: duvaughn@smithwarner.com, natalie.ferguson@dairyspring.com, ivan.lowe@dairyspring.com

Date: Friday, 08/07/2022 10:03 AM

3 attachments: 225-Barbuda.DisposalWellDeisgn.2022.07.07.pdf 57 KB, 225-Barbuda.DisposalWellSpecifications.2022.07.08.pdf 625 KB, 225-Barbuda.ExploratoryDisposalWell.BQ.2022.07.06.xlsx 54 KB

Good Day Monty,

I have been engaged as a sub-consultant to Smith Warner international, who have been contracted to conduct an EIA on a proposed major tourism development in the south of Barbuda. I am responsible for proving an acceptable design/methodology for disposal of the brine from a desalination plant - to the satisfaction of the Antigua & Barbuda Department of the Environment.

I am likely to propose deep well disposal into the Highland Limestone Aquifer that underlies the development site. This aquifer is karstic and characterised by conduit permeability and very high well yields. I am aware that Walkerwells ltd has been constructing source and disposal wells into this same aquifer for PLH at Palmetto Point and would like to explore the possibility of Walkerwells proving source and disposal wells for Paradise Found, on completion of your other contracts on Barbuda.

The following are provided to guide our discussions: -

1. Draft Schematic Well Design;
2. Draft Well Contract Specifications,
3. Draft Bill of Quantities.

As you are aware, I was recently in Barbuda (June20/22) and benefited from discussions with your Drilling Supervisor - Denroy Alexander. Please note the following likely differences to your present operations in Barbuda; -

(i) The use of temporary mild steel construction casing to keep the Drill Hole open down to the limestone;

(ii) Formation sampling at 5 ft intervals for lithologic analysis of the hydro-stratigraphic formations encountered;

(iii) Use of screw coupling for the PVC well casing and reducer;

(iv) Downhole Camera Inspection to allow an insitu inspection of the limestone aquifer, just prior to installation of the permanent well casing column;

(v) Downhole Conductivity Traverse/Measurement.to confirm salinities in the formations encounter, to be done just prior to the installation of the permanent well casing;

(vi) Plumbness and Alignment Tests to confirm acceptability to accommodate a well pump/column, and

(vii) Installation of Well Casing Anchor at the well head.

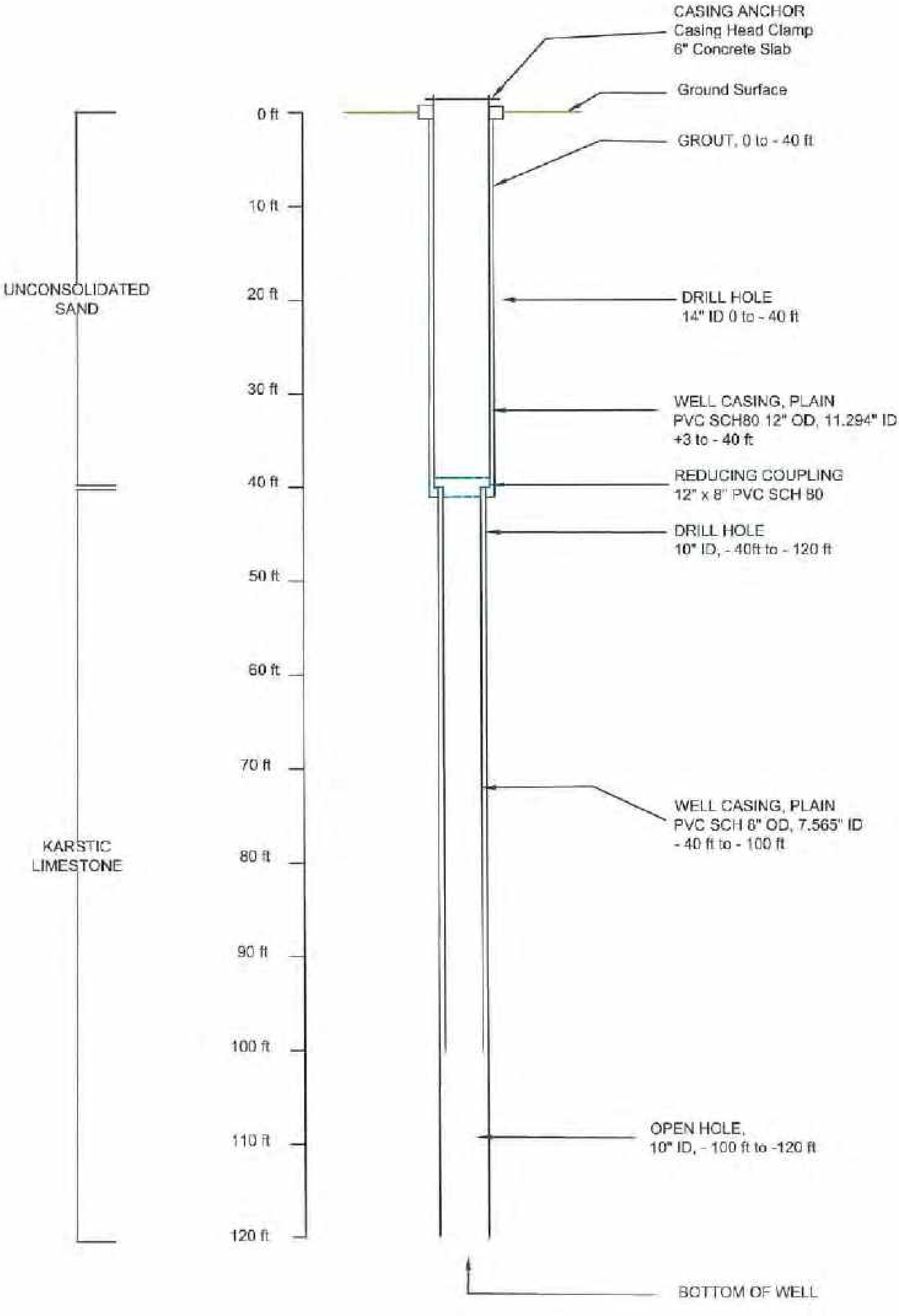
The location and number of wells have not yet been determined, but I am likely to recommend at least 4No. to the Client i.e., 2No. Source wells and 2No. Disposal wells (1No. Duty and !No. Standby, Source and Disposal well), including the proposed exploratory well.

WhatsApp me when you are ready for our discussions

Regards
Michael

Michael White

Managing Director/ Hydrogeologist
Hydrology Consultants Limited
1b Easton Avenue, Cottage #1
Kingston 5
Tel: +1 (876) 978-0214, +1 (876) 978-4102
Mobile: +1 (876) 382-6381



NOT DRAWN BY SCALE

PROJECT OF THE PARADISE FOUND DEVELOPMENT, BARBUDA
ENVIRONMENTAL IMPACT ASSESMENT

Exploratory Brine Disposal Well
WELL SPECIFICATIONS

2022 July

prepared by

HYDROLOGY CONSULTANTS LIMITED
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For

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CONTENTS

1. GENERAL DESCRIPTION OF THE WORKS

The works consist of the construction, yield development and pump testing of a brine disposal well at Paradise Found in Barbuda. The brine is to be disposed of in the Highland Limestone Aquifer.

2. LOCATION

The well is to be constructed at the spot identified by the Engineer. The approximate location is shown in **Figure 1**.

Figure 1: **LOCATION OF THE PROPOSED PARADISE FOUND, BARBUDA DISPOSAL WELL**

3. DRILLING METHOD

The Contractor shall use a Cable Toll Rig to construct the well or any other method that shall allow proper execution of the drilling and sampling programmes, to the satisfaction of the Engineer.

4. DRILLER'S LOG AND REPORT

4.1 Driller's Log

During the construction of the well, the contractor shall prepare and keep on the site for the inspection of the Engineer, a complete log setting forth the following: -

(a) The reference point for all depth measurements;

(b) The depth at which each change of formation occurs;

(c) The thickness of each stratum;

(d) Identification of the material of which each stratum is composed;

(e) The depth interval at which each sample was taken;

(f) The depth at which the hole diameter changes;

(g) The depth at which water was first encountered;

(h) The depth to static water level and changes in static water level with depth;

(i) Total depth of completed well;

(j) Depth of any lost drilling material and/or tool;

(k) The depth and description of the casing used in the drilling and to construct the well;

(l) Any and all other pertinent information, including that which may be present by the Engineer.

4.2 Daily Driller's Report

During the drilling of the well a detailed Daily Driller's Report shall be maintained and delivered upon request to the Engineer. The report shall give a complete description of all formation material encountered, number of feet drilled, number of hours on the job, time log showing actual penetration time required to drill each foot of hole, type of bit, shutdown due to breakdown, the water level in the well at the beginning and end of each shift, water level at each change of formation, meters of casing set, and such other pertinent information as may be requested by the Engineer.

4.3 Completion Report

Within fourteen (14) days of completion of construction of the well, the Contractor shall submit a Completion Report to the Engineer, setting out a suitably dated Driller's Log, "as constructed" drawings of the well and any other pertinent information.

5. FORMATION SAMPLING

5.1 Sampling Method

Samples of the formation material shall be taken by the Contractor using the bailer method or method suited to the drilling method used, as may be approved by the Engineer.

5.2 Sampling Interval

Formation samples shall be taken at 5 ft intervals.

5.3 Sample Size

Two (2 No.) 4 lbs representative sample shall be obtained by the Contractor from each sampling interval. In most instances more cuttings will be removed than required. The total volume of the cuttings shall be thoroughly mixed and quartered until the number and volumes of samples required are obtained as a residual.

5.4 Sample Identification and Storage

Immediately after retrieval, formation samples shall be placed in containers approved by the Engineer, securely closed to avoid spillage and contamination, and clearly labeled with the following information:

(a) Location of well;
(b) Name and number of well;
(c) Depth interval represented by sample;
(d) Date sample collected

The label shall be placed either directly on the container or on a tag attached thereto, using ink, indelible pencil or other medium that is resistant to moisture and sunlight.

The Contractor shall be responsible for the safe storage of the samples until such time as the Engineer accepts them.

6. WELL CONSTRUCTION

6.1 Drill Hole

The Contractor shall construct the Drill Hole straight and plumb, to the dimensions set out below:

Depth (below ground level)		Diameter (internal)	
m	ft	mm	ins
0 - 12 12 - 37	0 - 40 40 - 120	406 254	16 10

The 16" ID Drill Hole shall be kept open as it passes through the Palmetto Sands Aquifer by the installation of temporary 16" OD mild steel construction casing, down to the Highland Limestone Aquifer. The 10" ID Drill Hole in the Highland Limestone is expected to be sufficiently competent to not require the installation of construction casing to stay open.

6.2 Well Casing

(i) The casing to be supplied shall be of PVC, Schedule 80 ASTM D-1785, threaded to the dimensions set out below:

Description	Upper Casing		Lower Casing	
	metric	imperial	metric	imperial
Pipe Size	305 mm	12.00 in	203 mm	8.00 in
External diameter	324 mm	12.75 in	207 mm	8.63 in
Internal Diameter	288.95 mm	11.46 in	181.86	7.16 in
Wall Thickness	17.45 mm	0.687 in	12.70 mm	0.500 in
Weight	7.58 kg	16.70 lbs	3.710 kg	8.18 lbs
Ends				
Collapse Strength	1586 kPa	230 psi	1724 kPa	250 psi

(ii) The well casing shall be installed as follows: -

Diameter (mm)	Depth		Type
	metre	feet	
305	+0.91 to - 12.19	+3 to - 40	Plain
203	-12.19 to - 30.48	- 40 to - 100	Plain

(iii) The casing lengths shall be joined water-tight using threaded couplings to the standards of the American Society for Testing and Materials (ASTM). The resulting join shall be straight and have the same structural integrity as the casings themselves.

(iv) The casing column (i.e., the 43' length of 12" OD and 80' length of 8"ID casing linked by a 12' x 8' Reducer) shall be installed after the construction of the entire Drill Hole has been completed i.e., down to the design depth of 120 feet bgl.

(v) The casing shall be installed by lowering or some other method approved by the Engineer. Driving of the casing shall be avoided. The installation of the casing shall be witnessed by the Engineer.

(vi) The bottom of the casing column shall not be sealed.

6.3 Well Plumbness and Alignment

(i) The well shall be constructed and the casing set round, plumb and true to line, as defined herein.

(ii) To demonstrate the compliance of the work with the requirements the Contractor shall furnish all labour, tools and equipment to perform the tests described in Specifications 6.3 (iii) and (iv) below. The tests for plumbness and alignment shall be made following construction of the well and before the test pumping equipment is installed. These tests shall be witnessed by the Engineer.

(iii) Plumbness shall be tested by lowering a plumb ring or plummet, into the well from a pulley fitted to a tripod and located 10 ft above the top and over the centre of the well. The plumb ring or plummet shall have an outside diameter 0.5 inch smaller than the internal diameter of the casing being tested. Plumbness shall be such that the plumb ring or plummet does not vary from the vertical in excess of 0.13 in/ft down to a depth of 40 ft.

(iv) Alignment shall be tested by lowering into the well to a depth of 40 ft a section of pipe 40 ft long or a dummy of the same length. The outer diameter of the pipe or dummy shall not be more than 0.9 inches less than the internal diameter of the 8 inch diameter casing being tested. The dummy when lowered into the well shall pass freely down to a depth of 40 ft.

(v) The Employer and/or the Engineer shall refuse to accept the well if the test proves faulty plumbness. In this Event, the Contractor shall correct the fault or abandon the well and plug the hole and drill another well, at his own expense.

(vi) Records of the test results and all other information pertinent to well plumbness and alignment shall be kept and submitted as part of the Completion Report. Where necessary these records shall also be submitted in support of Claims for payment.

6.4 Grouting

(i) The Contractor shall seal the annular space between the inner wall of the drill and the outer wall of the well casing down to a depth of 45 ft using a 1: 1.5: 3 nominal mix of cement, sand and gravel as grout, to protect the well against the entry of unwanted water from the surface.

(ii) A Formation Packer shall be clamped onto the 8-inch OD casing at a depth of 45 ft, using stainless steel straps, to trap and hold the grout in place within the annular space.

(iii) Prior to grouting, the annular space shall be flushed to ensure that the space is open and ready to receive the sealing material. Grouting shall be done in one continuous operation in which the annular space is filled.

(iv) The emplacement of the grout shall be witnessed by the Engineer and shall be certified by him to be of satisfactory construction.

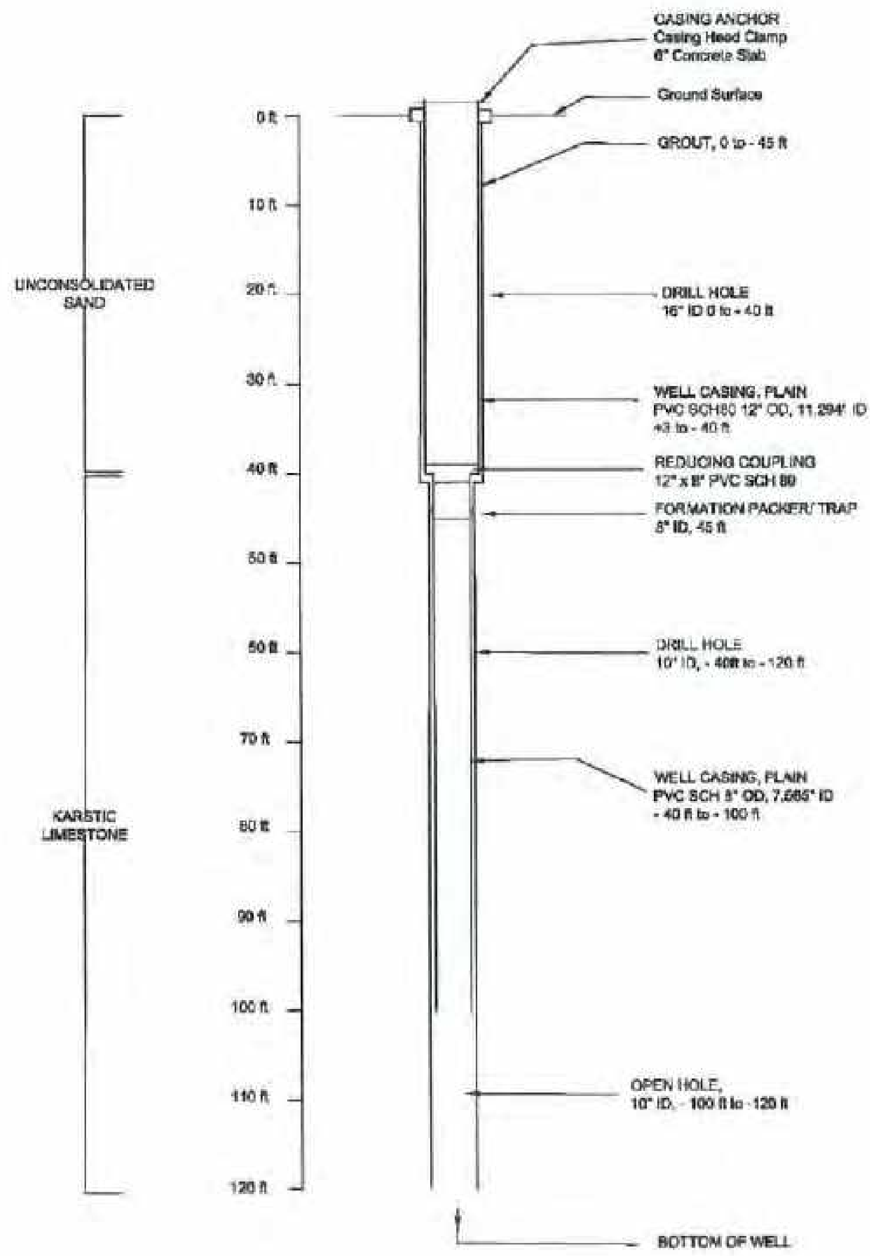
6.5 Well Head Foundation

The casing column shall be supported at ground level by a 6-inch, thick re-enforced concrete slab, with the casing anchored in the concrete by means of a clamp.

6.6 Summary - Well Design

A schematic summary of the design of the Paradise Found Disposal well is presented as **Figure 2**, below.

Figure 2: **SCHEMATIC WELL DESIGN – PARADISE FOUND EXPLORATORY DISPOSAL WELL**



7. WELL DEVELOPMENT AND YIELD TESTING

7.1 Plant and Equipment

(i) Pumping Plant: The Contractor shall furnish, install, and remove a test pumping plant capable of production rates of up to 700 igpm. The pump suction shall be set at a minimum depth of 35 feet and the pumping plant capable of the aforementioned production rates while pumping from a depth of 35 feet. The pumping plant shall be complete with a prime mover of ample power, controls, and appurtenances, and be capable of being operated without interruption for a minimum 48-hour period at the aforementioned rates of production and pumping lifts.

(ii) Measurement of Well Discharge: The Contractor shall have fitted to the pump a discharge pipe of 8-inch diameter and shall provide suitable orifice plates and the necessary coupling to fix an orifice to the end of the discharge pipe. A manometer consisting of a nipple and a 6 ft length of small diameter plastic tubing, shall be fitted to the pipe 2 ft upstream of the orifice and along the centre line of the side of the horizontal discharge pipe. No elbows, valves or other fittings shall be closer than 4 ft upstream from the manometer.

(iii) Measurement of Water Level: A stilling tube of 1 in diameter shall be installed in the well, alongside the pump column, securely fastened at the top of the well and extending down to pump suction. The stilling tube shall be of PVC.

(iv) Disposal of Test Discharge: Discharge water shall be conducted from the pump to the nearest storm sewer or ditch, or some other point as shall be approved by the Engineer.

7.2 Well Development

(i) The Contractor shall undertake development of the well for a maximum period of 48 hours, or as directed by the Engineer. The development process must be witnessed by the Engineer.

(ii) The well shall be developed by pump surging i.e. interrupted pumping. The pumping shall be carried out in at least four steps, at pumping rates of up to 700 igpm, at an interval as determined by the Engineer, with each step for a minimum 6-hour duration, or as may be directed by the Engineer. The Contractor shall measure and record the depth to water at the beginning and at the end of each step of the interrupted pumping at the associated rates of discharge.

7.3 Well Performance Test

(i) The performance of the well shall be tested by pumping continuously at four successively higher discharge rates, each rate to be for a six-hour duration, or as directed by the Engineer.

(ii) The start of the Well Performance Test shall be not less than 24 hours after the termination of development exercises and shall be as directed by the Engineer.

(iii) The Contractor shall be responsible for ensuring continuous operation of the pumping plant and other test equipment as directed by the Engineer.

(iv) The Engineer shall instruct the Contractor as to the required rates of production and shall monitor changes in water level and well discharge throughout the test.

(v) The failure of the pump operations for a period greater than one percent of the elapsed time shall require suspension of the test until the water level in the pumped well has recovered to its original level. For the purposes of these specifications, recovery shall be considered complete after the well has been allowed to rest for a period at least equal to the elapsed pumping time for the aborted test - except that if any three consecutive water level measurements spaced 20 minutes apart show no further rise in the water level in the well, the test shall be resumed immediately. The Engineer shall be the sole judge as to whether the latter condition exists.

7.4 Constant Rate Test

(i) The long term effect of pumping on the aquifer shall be approximated by the continuous pumping of the well for at least 24 hours at the recommended rate of production.

(ii) The Constant Rate Test shall be started no less than 24 hours after the termination of the Well Performance Test.

(iii) The Contractor shall be responsible for ensuring continuous operation of the pumping plant and other test equipment as directed by the Engineer.

(iv) The Engineer shall instruct the Contractor as to the rate of production and shall monitor changes in water level and well discharge and collect water samples for water quality analyses.

(v) The failure of the pump operations for a period greater than one percent of the elapsed time shall require suspension of the test until the water level in the pumped well has recovered to its original level. For the purposes of these specifications, recovery shall be considered complete after the well has been allowed to rest for a period at least equal to the elapsed pumping time for the aborted test - except that if any three consecutive water level measurements spaced 20 minutes apart show no further rise in the water level in the well, the test shall be resumed immediately. The Engineer shall be the sole judge as to whether the latter condition exists.

7.5 Slug Test

(i) The long-term effect of injection on the aquifer shall be approximated by the addition of a volume of water to be determined by the Engineer over a period of 6 hours.

(ii) The Slug Test shall be started no less than 24 hours after the termination of the Constant Rate Test.

(iii) The Contractor shall be responsible for ensuring continuous operation of the test equipment as directed by the Engineer.

(iv) The Engineer shall instruct the Contractor as to the rate of injection of water to be added to the well and shall monitor changes in water levels.

(v) The failure of the operations for a period greater than one percent of the elapsed time shall require suspension of the test until the water level in the well has recovered to its original level. For the purposes of these specifications, recovery shall be considered complete after the well has been allowed to return to the static water level as confirmed by the Engineer. The Engineer shall be the sole judge as to whether the conditions for resumption of the test exists.

8. WATER SAMPLES AND ANALYSES

(i) The Engineer shall be responsible for the collection of water samples for chemical and bacteriological analyses. The samples shall be of the discharge from the pumping well.

(ii) Analyses of the water samples shall be carried out by the Engineer.

9. COMPLETION OF WELL

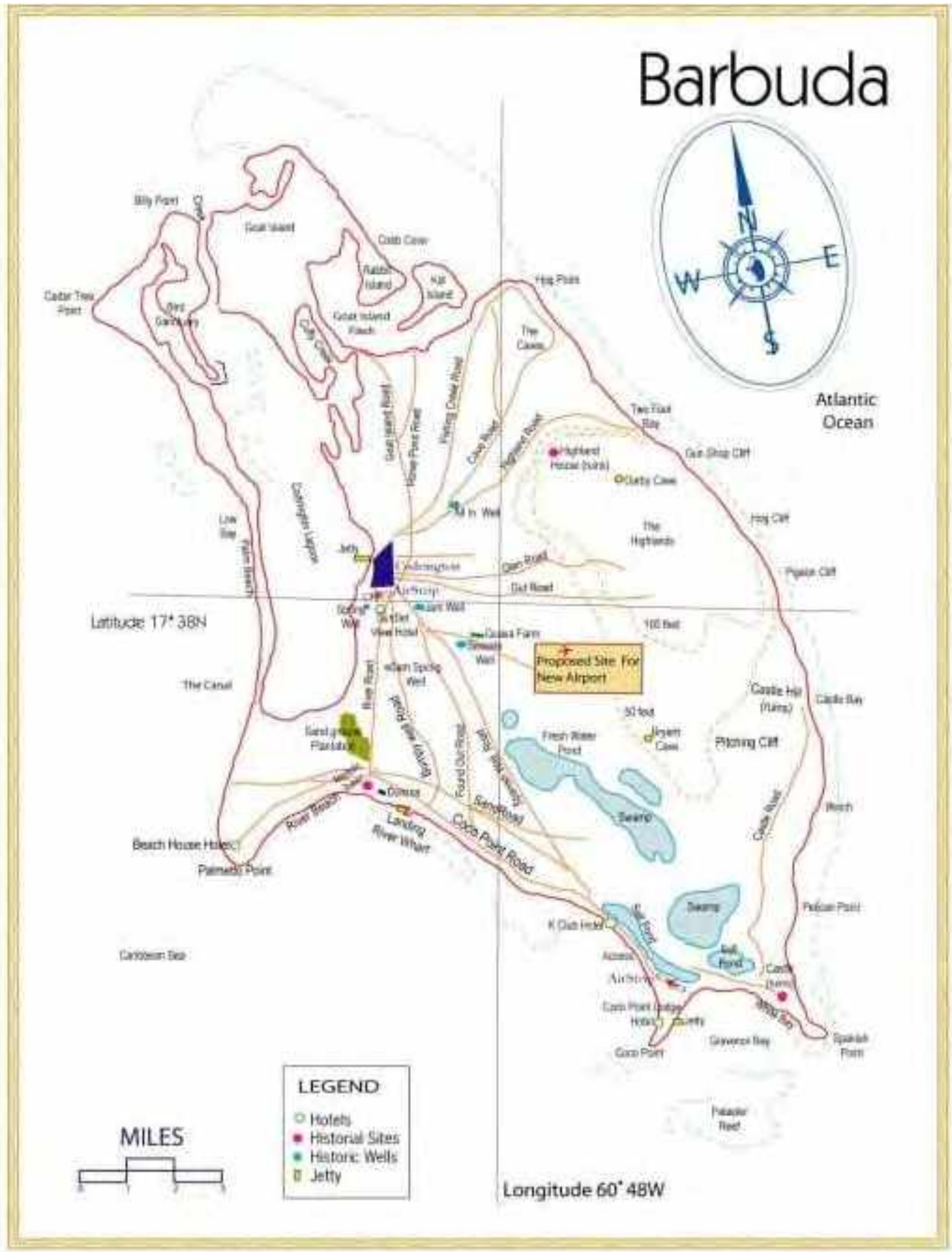
The well shall be capped with a threaded PVC Cap.

PARADISE FOUND DEVELOPMENT, BARBUDA
Exploratory Brine Disposal Well
Bill of Quantities

Item	Description	Quantity	Unit	Rate	Amount
	BILL #1 - PRELIMINARIES				
1.1	Sanitary & Welfare Facilities	4	weeks		
1.2	Watching & Security	4	weeks		
1.3	Utilities for Works	4	weeks		
1.4	Performance Bond	All			
1.5	Insurance Risk	All			
	Total Bill #1				
	BILL #2 - WELL CONSTRUCTION				
2.1	Mobilisation	Item			
2.2	Site preparation	ALL			
2.3	Construct drill hole -120'				
	(a) 14" ID, 0 to - 40 ft	40	feet		
	(b) 8" ID, - 40 to -120 ft	80	feet		
2.4	Provide formation samples @ 5 ft. intervals	24	No.		
2.5	Construction Casing - mild steel				
	(a) 14" OD - supply/install/withdraw	40	feet		
2.6	Supply PVC Sch 80 well casing/reducer				
	(a) Plain Casing 12" OD	43	feet		
	(b) Plain Casing 8" OD	60	feet		
	(c) PVC Sch 80 12" x 8" Reducer	1	No.		
2.7	Install PVC Sch 80 casing column				
	(a) 12" OD - supply/install	43	feet		
	(b) 8" OD - supplly/install	60	feet		
	(c) PVC Sch 80 12" x 6" Reducer - install				
2.8	Perform Tests				
	(a) Plumbness Test	1	No.		
	(b) Alignment Test	1	No.		
2.90	Grouting, 0 to - 45 ft (in annular space between permanent well casing and drill hole)	42	feet		
2.10	Construct well head foundation - reinforced concrete 4'x4'x6"	Item			
2.11	Provide/install PVC screw cap	Item			
2.12	Conduct/Record Downhole Camera Inspection	Item			
2.13	Demobilization	Item	day		
	Total Bill #2				
	BILL #3 - PUMP TESTING				
3.1	Test Pumping Plant				
	(a) Supply - 700 igpm	Item			
	(b) Install/withdraw	60	feet		
3.2	Discharge measurement assembly	Item			
3.3	Stilling Tube	60	feet		
3.4	Yield development pumping	48	hour		
3.5	Yield Testing - Multiple Rate Test				
	(a) </= 350 igpm	24	hours		
	(b) 351 to 700 igp	6	hours		
3.6	Yield Testing - Constant Rate Test	24	hours		
3.7	Slug Test - 500 igpm	6	hours		
3.8	Sample collection/Laboratory analysis by Client	9	samples		
3.9	Provisional for disposal of yield test discharge	Item	sum		
	Total Bill #3				
	Total All Bills				
	Contingency - 10%				
	TOTAL WELL CONTRACT				

Appendix 4 Maps and data for socioeconomic study

Planning Map of Barbuda



Education facilities in Barbuda

B4 Map of the Location of Primary and Secondary Schools in Antigua and Barbuda

Figure B1: Map for Barbuda

Table 4.8 Headcount, Poverty Gap and Poverty Severity by District 2005/06

District	Head count	Poverty Gap	Poverty Severity
St. John's City	22.29	9.33	5.84
St. John's Rural	18.41	6.63	3.64
St. Paul	15.63	5.62	2.80
St. Mary	13.57	2.63	1.11
St. George	12.28	2.75	1.06
St. Peter	15.03	6.05	3.72
St. Philip	25.85	7.47	3.23
Barbuda	10.53	3.31	1.15
All Antigua & Barbuda	18.36	6.63	3.75

Appendix C Mangrove Protection and Management Plan

EIA FOR PARADISE FOUND RESORT DEVELOPMENT

MANGROVE PROTECTION AND MANAGEMENT PLAN

ECO REPORT No. 08/2023

April 18, 2023

PREPARED BY

ECOENGINEERING CONSULTANTS LIMITED

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TABLE OF CONTENTS

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Eco Report No. 08/2023 **April 18, 2023**

EIA FOR PARADISE FOUND RESORT DEVELOPMENT

MANGROVE PROTECTION AND MANAGEMENT PLAN

1 INTRODUCTION

1.1 Authorization and Layout of Work Plan

1.1.1 Authorization

This Mangrove Protection and Management Plan (MPMP) was prepared by Ecoengineering Consultants Limited for Smith Warner International (SWI) in response to comments made by the Department of the Environment. Those comments deal specifically with issues relating to ecosystem impacts and habitat loss.

1.1.2 Layout

This MPMP consists of seven chapters and an appendix. This introductory chapter provides a background of the project and indicates the purpose and scope of this MPMP. Chapter 2 outlines the relevant legislation that governs this Plan. Chapter 3 provides a brief project description, while Chapter 4 describes the existing environment. Chapter 5 discusses the impacts and recommends mitigation measures, while Chapter 6 provides the management plan to ensure that the recommended mitigation measures are effectively implemented. Finally, Chapter 7 provides a summary of the monitoring requirements.

1.2 Background

The Paradise Found project is a proposed 391-acre development on the leeward side of Barbuda (see Figure 1). The project comprises a hotel with 17 units, 10 villas, and 53 hotel estates, in addition to 27 inland lots and 43 custom beach lots. Individual guest villas will also have private pools, and there will be a Nobu restaurant, beach club and bar, spa and wellness centre, tennis pavilion and kids club, as well as a small farm and plant nursery (see Figure 2). A Back of House facility (BOH) will support the project. The development incorporates the former and now derelict K Club. The development plan was submitted as application number G10-2021 to the Development Control Authority (DCA). A Draft ESIA report was submitted to the Department of Environment (DoE) in response to that Application, following which comments were received. This MPMP has been prepared in response to specific comments to the Draft ESIA, provided by the DoE.

1.3 Project Objectives

The objectives of this Plan are as follows:

- Identify the extent of mangroves to be cleared for the infrastructure works;
- Propose a mangrove replanting strategy in accordance with 'no net loss' policy;
- Identify potential impacts to the remaining mangroves from the construction works; and
- Recommend measures to mitigate these impacts.

FIGURE 1: LOCATION MAP

2 RELEVANT LEGISLATION

This chapter documents the relevant legal framework that will guide the measures described in this MPMP under the following headings:

- Environmental Protection and Management Act, 2019, and
- Forestry Act.

2.1 Environmental Protection and Management Act, 2019

This act was established to provide for sustainable environmental protection and management of natural resources, to allocate responsibility for the management of environmental matters, to give effect to Antigua and Barbuda's treaty obligations with respect to the environment and to provide framework financial mechanisms to satisfy the requirements of the Act.

2.1.1 Protected Areas, 2019

Under the Environmental Protection and Management Act, 2019, there are provisions for the designation of "protected areas". According to this listing, the DoE may designate any area as being a protected area. To date, designated protected areas include strict nature reserves, wilderness areas, national parks, natural monuments, habitat or species management area, protected landscape or seascape and managed resource protected areas. There are no protected areas within the vicinity of the proposed development.

2.1.2 Protected Wildlife and Plants, 2019

Under the Environmental Protection and Management Act, 2019, there are provisions for the designation of protected wildlife and plants. According to this listing, the DoE may designate an animal or plant as being protected. Based on the species observed on site, the following plants are listed as protected under the Act:

Black Mangrove	*Avicennia germinans*
Black Mangrove	*Avicennia schaueriana*
Button Mangrove	*Conocarpus erectus*
White Mangrove	*Laguncularia racemosa*
Red Mangrove	*Rhizophora mangle*

2.2 Forestry Act

This act provides legislation related to forest management and the protection of forest areas. The following is considered relevant to this proposed development:

- No person shall clear any land for cultivation, pasturage reserve or other purpose, or cut, or fell any timber; without having first obtained a permit in writing from the Chief Forest Officer.

- The Minister may declare that any estate or part thereof shall be subject to the Part III including the need for reforestation of the estate.

3 PROJECT DESCRIPTION

As shown in Figure 2, the Development Plan, this development will include the following facilities:

1) Nobu Beach Inn Clubhouse,
2) Guest Villas,
3) Arrival Area,
4) Beach Bar,
5) Nobu Restaurant / Satellite Restaurant,
6) Sales Village,
7) Spa,
8) Tennis and Kids Club,
9) Farm and Nursery,
10) Logistics and Staff Centre, and
11) Home Sites.

Due to the remote location of the project and the current lack of infrastructure on the island of Barbuda, the project must develop much of its own infrastructure and support facilities. The ambition of the project is that it should ultimately be as independent as possible in supplying its own food, water, and energy. The development will therefore include a road network, a drainage system, water supply, electricity supply and a wastewater treatment plant.

Based on the Development Plan, the activities most likely to result in loss of mangroves include, road construction and drainage infrastructure including, in particular, the installation of new ponds.

FIGURE 2: DEVELOPMENT PLAN

3.1 Road Network

Roads will be constructed within the site to service the various elements of the development. The Client has indicated that most of the roads will be left in a natural state, with select areas only being paved (approximately 80% left in a natural state and 20% paved). In addition, in their Land Lease, Paradise Found was granted the right to re-route the existing boundary road that runs through this property. The road realignment project will be completed in two phases (see Figure 3). Phase 1 of the road project will involve re-routing the road towards the perimeter of the property at the north end of the property boundary (adjacent to Barbuda Cottages) and following the perimeter boundary to the location at the centre of the property where the existing road crosses to the outside of the property line. The rest of the road location (which is existing and currently in use) would stay the same and follow the outside boundary fence until it reaches the old salt pond road at the south end of the property.

Phase 2 of the road realignment will involve improving and rehabilitating the old existing road that crosses the salt pond at the south end of the property. The road in this area has existing pipes and culverts underneath that have been damaged because the pipes were uncovered and rendered vulnerable to the elements. Paradise Found intends to re-establish the road, add littoral shelves alongside it for planting mangroves, and install sufficient culverts to assist with the flow of water in and out of the salt pond to prevent ponding and stagnation of water.

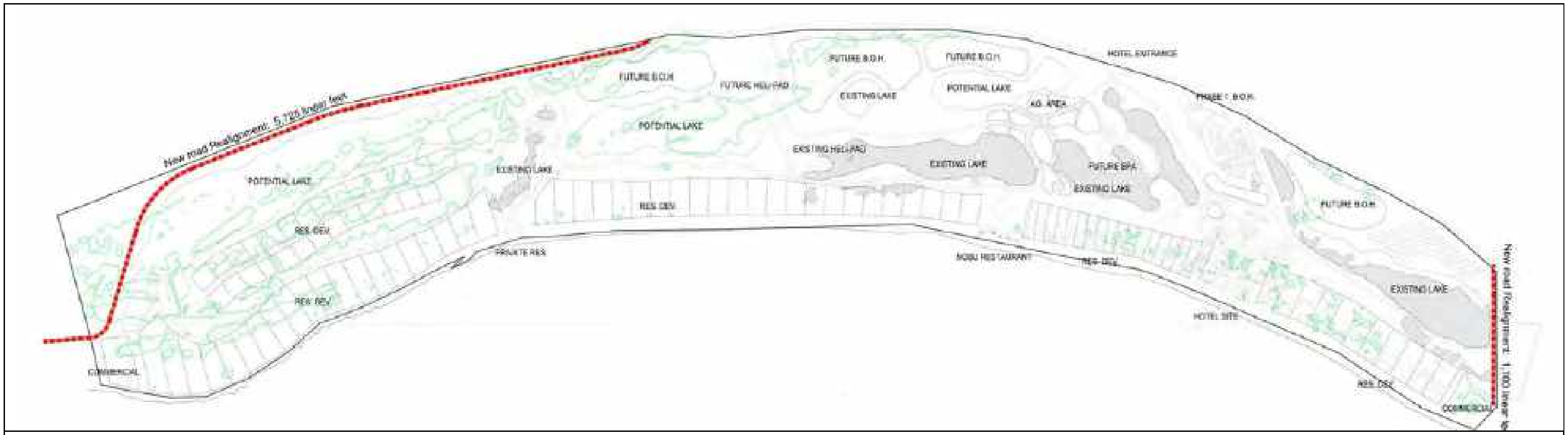

FIGURE 3: ROAD REALIGNMENTS PHASE 1 AND PHASE 2

3.2 Drainage System

As the Development is constructed, consideration will be given to sizing catchment zones in each phase, collection of water, transportation or delivery of water, and disposal of water for both surface runoff and closed gravity pipe networks. Using the Rational Method of design to assess overland flow, the use of closed pipe networks will be minimized as much as possible and reserved only for situations where the disposal of water is rapidly required or where built infrastructure prohibits the construction of natural drains, such as in and around buildings and associated hard-standing areas, decks, pathways, and parking zones. The collected water will be conveyed in closed pipes or open channel systems to a point of disposal such as a bio-swale, soakaways, detention ponds, or disposal well.

The remaining areas of the development site will be addressed in a more holistic and non-disruptive way. Rainfall will be handled more naturally, incorporating surface runoff and subsurface runoff, and taking into account the fact that the existing natural ground offers good percolation, which facilitates subsurface runoff that conveys the water to the existing ponds and low-lying areas, filtering water as it travels. Rainwater harvesting systems can also be employed in this development, which would also assist in the management of stormwater runoff.

The Development intends to use structural, vegetative, and managerial solutions to treat, prevent, and reduce water pollution caused by stormwater runoff. These primary drainage solutions will consider areas of potential contamination such as petrochemical or grease deposits, and interceptors will be located as necessary. Erosion of sediment issues are not considered to be significant, as hydraulic gradients will likely be small. Still, any final grading or drainage solution will carefully look at that potential and adopt soil stabilization solutions if required. Protecting the existing pond ecology will be paramount in any final storm drainage management solution. Additionally, for the created ponds, groundwater cover conditions experienced in the existing ponds will be replicated.

Hurricane Irma in 2017 caused significant damage to the salt pond at the southern end of the property. Paradise Found intends to bolster the strength and health of the mangroves surrounding the salt pond area to protect the pond and the adjacent regions from future intense storms. Paradise Found intends to transplant mangrove plants where possible and restore the mangrove's health by ensuring that its tidal and freshwater hydrology is functioning normally so that the mangrove can repair itself over time.

3.3 Clearing and Grubbing

Clearing of vegetation will be required to facilitate the construction of roads, drainage, utilities and facilities, and topsoil containing roots must also be removed (grubbing). This will likely be done using the following methods:

- Mangrove trees will be cut using chain saws only after necessary approvals have been obtained from the relevant divisions of the Ministry of Agriculture, Lands, Fisheries and Barbuda.
- Smaller bushes and grass will either be cut manually or removed using bulldozers.

- Cleared vegetation will be removed from the site in dump trucks to a location where they can be composted, or to the landfill for disposal.
- Grubbing will be done using bulldozers. Grubbed topsoil will be temporarily stockpiled on site for use in landscaping.

3.4 Earthworks

Earthworks will be required in areas where the existing ground elevation must be adjusted upward or downward to facilitate construction work (see Figure 4), likely using the following methods:

- Excavation to lower the existing ground elevation will likely be done using bulldozers or road graders. Surplus material from such excavation will either be reused on site or removed from site for beneficial reuse elsewhere.

- It is preferable to balance excavation and filling in the design so that all fill material will come from the site itself. If this is not possible, fill material will have to be brought from offsite in dump trucks.

- Regardless of source, fill material will be spread in layers using bulldozers, road graders or front-end loaders and compacted using sheepsfoot rollers or smooth face rollers to achieve the required density. Successive layers will then be spread and compacted until the target elevation is reached.

3.5 Construction of Roads

The cross-section of a typical road is shown in Figure 5. To construct this, the roadbed must be compacted using sheepsfoot or smooth rollers until the required density is achieved. Gravel will be brought to the site in dump trucks and spread and compacted in layers as described for filling in Section 3.3. If the road is to be paved with asphalt, this will be brought to the site in dump trucks, spread using asphalt spreaders and compacted using smooth face rollers. If the road is to be paved with concrete, the likely method will be as described below.

For concrete works, formwork and reinforcing steel will be brought to the site in flatbed trucks. Reinforcing steel will be cut and bent to the required lengths and shapes. Formwork will be installed to receive the concrete and reinforcing steel placed within the formwork. Concrete will then be placed into the formwork and compacted using vibrators.

Where premixed concrete is used, this will be mixed offsite at a batch plant and brought to the site in mixer trucks. Where concrete is to be mixed on site, the mixers must be brought to site on flatbed trucks and assembled at the selected locations. Sand and gravel will be brought to the site in dump trucks and water brought to the site in tankers. Cement will be imported to the island in ships, most likely in shipping containers. These containers will then be brought to the site by road. Concrete can then be batched on site in the mixers using these materials.

3.6 Construction of Drainage System

For earthen drains the alignment will be prepared by clearing and grubbing (see Section 3.3) and excavation or filling (see Section 3.4). The drain itself will then be trenched using a backhoe or an excavator. Paved drains will be prepared and trenched as for earthen drains, and then lined with concrete using methods as described in Section 3.5. Alternatively, precast concrete drain sections may be brought to site on flatbed trucks and lowered into the trenches using hayab units on the trucks or by hand.

Self-loading/unloading truck (hayab)

For buried pipe drains, the precast concrete or PVC pipes must be imported to the site by ship and brought to the site on flatbed trucks. Trenches will be dug along the design alignments using backhoes or excavators, and the pipes lowered into the trenches using hayab units (for concrete pipes) or by hand (PVC pipes). Backfill will then be placed to the sides and over the pipes in layers, with each layer being compacted to the required density using whackers.

Culverts will be constructed of precast concrete pipes and installed using the same methods as just described for buried pipe drains. In addition, a head wall with wing walls and apron will be constructed at each end of each culvert using methods to be described in Section 3.5.

New ponds on site will be excavated using bulldozers or excavators to the dimensions as shown in the drawings in Appendix D with edge treatment as shown in Figure 6.

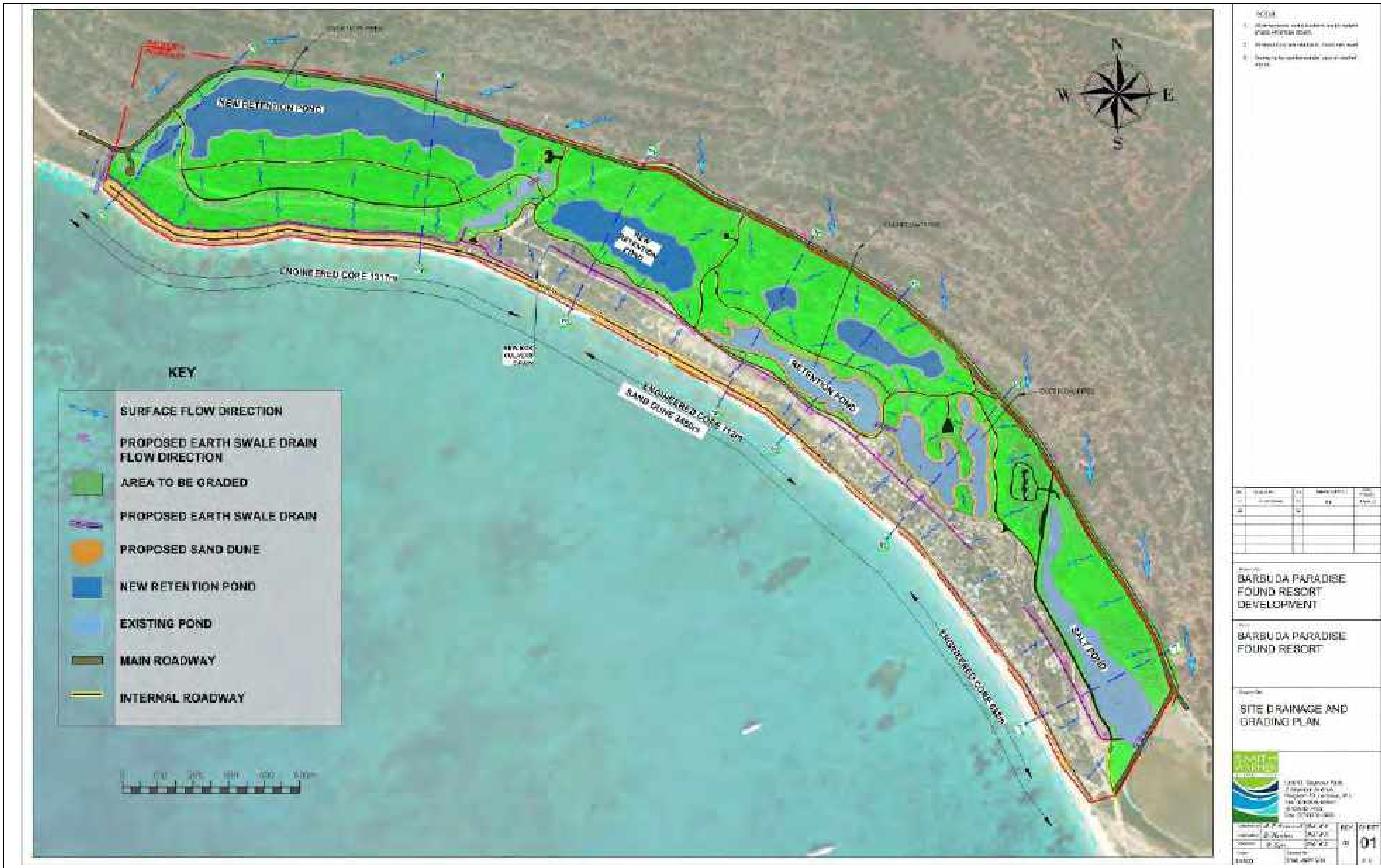

FIGURE 4: PARADISE FOUND GRADING AND DRAINAGE CONCEPT PLAN

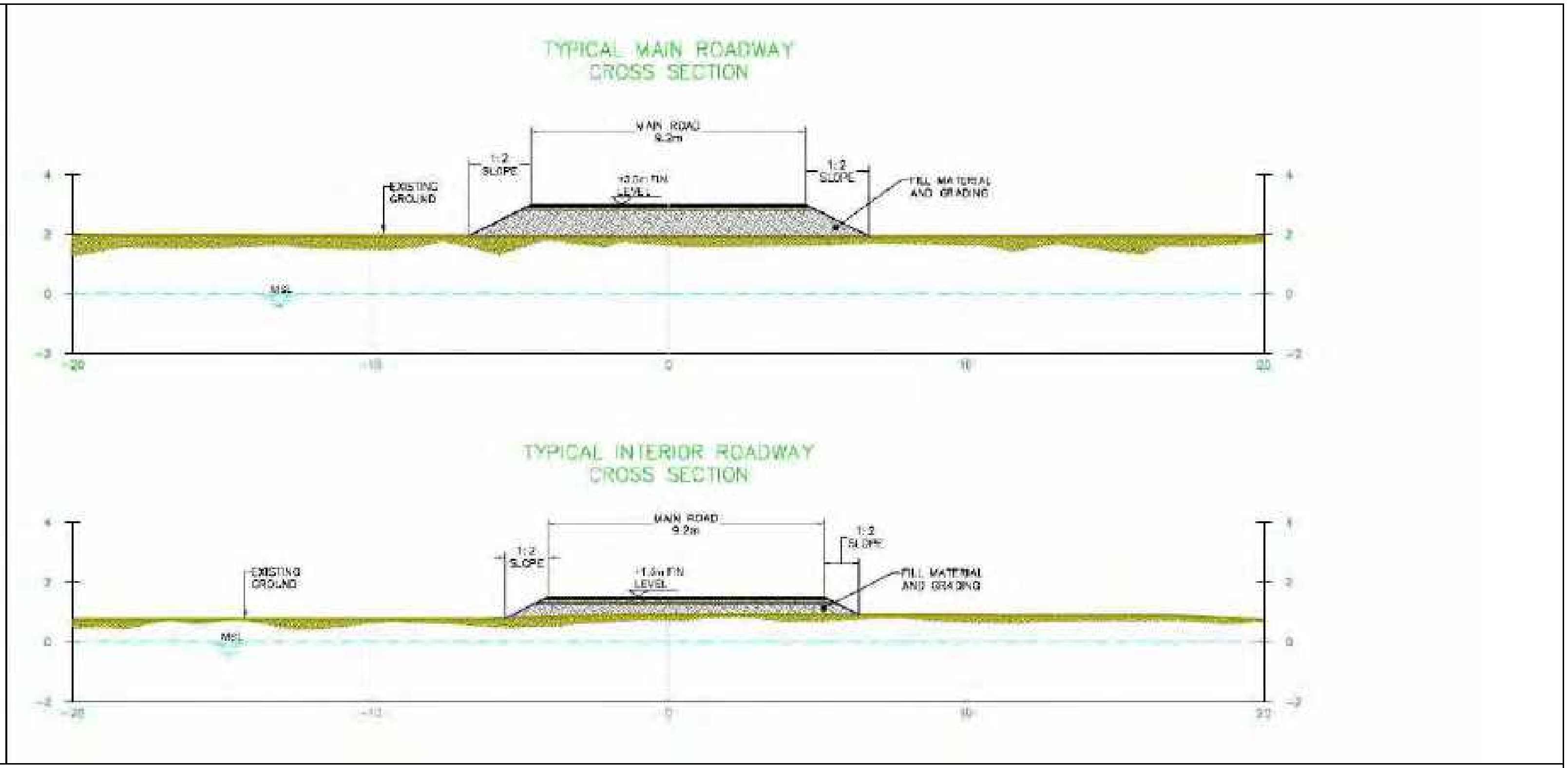

FIGURE 5: CROSS-SECTIONS OF TYPICAL MAIN ROAD AND INTERIOR ROAD

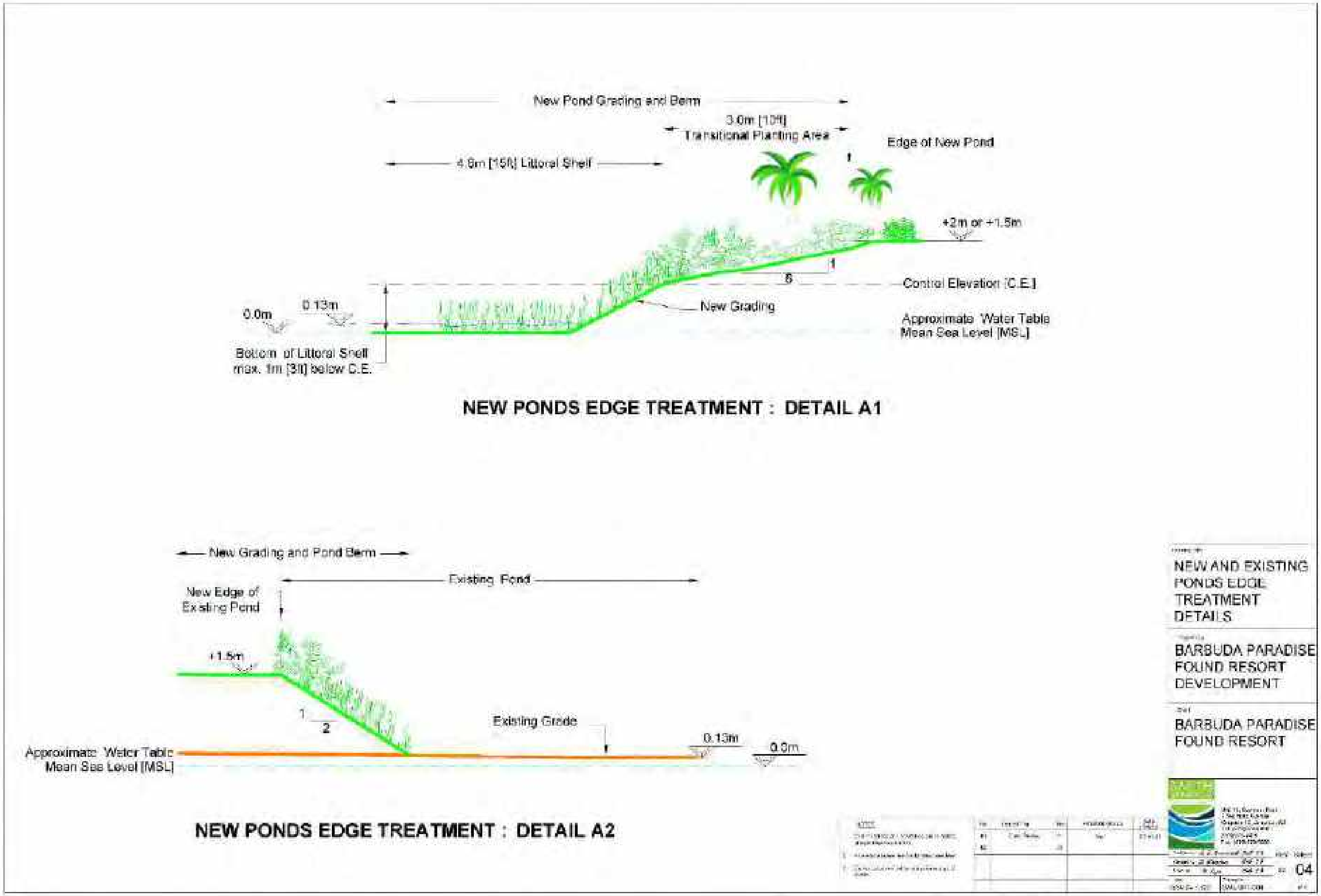

FIGURE 6: EDGE TREATMENT FOR NEW PONDS

4 EXISTING ENVIRONMENT

A vegetation survey was conducted within the boundaries of the project area to document the vegetation present on site.

4.1 Approach

To determine the dominance of species in the various floral assemblages on the site, a series of observation points was established across the site to make note of the dominant vegetation. At each observation point, trees and shrub species within a 20m radius with a circumference at breast height (CBH) of ≥ 63 m, were identified. This was used to gauge the dominance of mature tree species. Additionally, plants (smaller trees, saplings, and seedlings) with a CBH of < 63cm were also noted to determine the dominance of the upcoming generation. A handheld GPS unit was used to note each observation point and a digital camera was used to help document the field observations. Rare threatened and endangered species were also noted.

4.2 Findings

A total of 30 species were encountered on the site across the various habitats identified (see Figure 7). Four species were listed as endemic (Locustberry, Dagger Plant, Wild Frangipani and Lignum vitae), one species was listed as near threatened (Lignum vitae) and one species was listed as threatened (Black Mangrove) by the IUCN Red List of Threatened Species. All other species are listed as least concern. However, as noted in Section 2.1.2, mangroves are considered protected species in Barbuda.

Mangroves were generally found on the site as follows:

Northern Ephemeral Zone	Black Mangrove Black Mangrove Button Mangrove White Mangrove	*Avicennia germinans* *Avicennia schaueriana* *Conocarpus erectus* *Laguncularia racemosa*
Southern Ephemeral Zone	White Mangrove	*Laguncularia racemosa*
Brackish Pond 1	White Mangrove Red Mangrove	*Laguncularia racemosa* *Rhizophora mangle*
Brackish Pond 2	Button Mangrove White Mangrove Red Mangrove	*Conocarpus erectus* *Laguncularia racemosa* *Rhizophora mangle*
Brackish Pond 3	White Mangrove	*Laguncularia racemosa*
Salt Pond	White Mangrove	*Laguncularia racemosa*

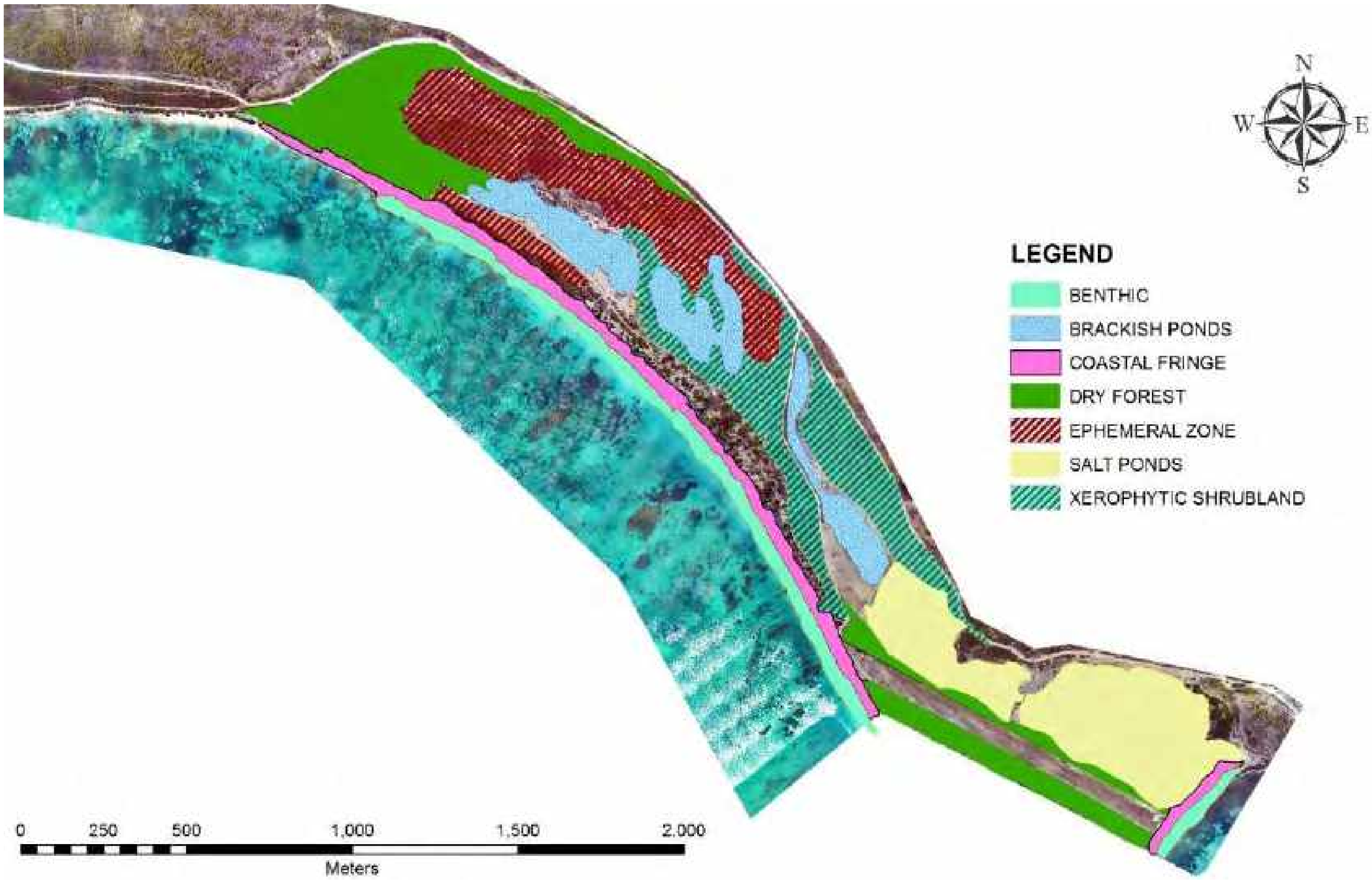

FIGURE 7: SITE HABITATS

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5 IMPACTS AND MITIGATION MEASURES

The potential impacts of the proposed works were identified from the likely construction methods to be employed as described in Chapter 3, from general guidance documents, and Ecoengineering's experience on similar projects. These include:

- Direct habitat loss;
- Altered drainage;
- Sedimentation;
- Impaired water quality; and
- Improper solid waste disposal.

5.1 Direct Habitat Loss

5.1.1 Nature of Impact

As noted in Section 4.2, four mangrove species are found within the area of the proposed works, namely Black Mangrove (*Avicennia germinans*), White Mangrove (*Laguncularia racemosa*), Red Mangrove (*Rhizophora mangle*) and Button Mangrove (*Conocarpus erectus*). Mangroves were found within the north and south ephemeral zones and the fringes of the brackish and saltwater ponds (see Figure 7).

The proposed works will result in the direct loss of mangroves for the construction of the home sites in the southern ephemeral zone as well as potential loss of mangrove trees associated with the construction of a 2.5m berm with a finished elevation of +2.5m above mean sea level around the perimeter of the ponds. This equates to a potential direct loss of approximately 7.28 ha of mangrove vegetation.

The loss of mangrove vegetation may impact upon the fisheries and ecosystem services provided by the mangroves and this impact is expected to be moderate before mitigation.

5.1.2 Mitigation Measures

The clearing of mangrove trees and loss of terrestrial habitat is a permanent and unavoidable impact of this project. Notwithstanding, the following mitigation measures are recommended to minimize this concern:

- Avoid clearing vegetation in areas not required for construction works
- Burning of cleared vegetation to be prohibited.
- Use of herbicides in vegetation clearance to be prohibited.
- All necessary permits relating to the felling of trees to be obtained; and
- Finally, Paradise Found is committed to employ the “no net loss” policy on this project by replanting mangrove plants around the existing ponds as well as the new ponds to be installed on site.

Successful replanting of mangrove species relies on the following:

- Understanding the ecology of the individual mangrove species at the site (namely black, white and red mangrove); in particular, the patterns of reproduction, propagule distribution, and successful seedling establishment.
- Understanding the normal hydrologic patterns that control the distribution and successful establishment and growth of these mangrove species.
- Only plant propagules, collected seedlings, or cultivated seedlings.

The process of replanting mangrove trees in accordance with the “no net loss” policy will involve the following steps:

Site Selection

- The site selected must show signs of secondary growth or sparse vegetation with a few mangrove species growing.
- The site chosen must be the appropriate zonation for the particular species to be planted.
- The site should be sheltered with limited or no exposure to strong waves, currents, and winds. The site should also not be undergoing active erosion.
- Since mangroves are already found on the edges of the ponds as well as the ephemeral zones, it is expected that mangrove replanting in these areas will be successful.

Nursery

- The site has an existing nursery where seedlings are available for replanting throughout the site. Mangrove seedlings will therefore be cultivated for replanting throughout the site as described above.

Planting

- Two-year old seedlings or older (18 inches tall) have proven to be best for successful out planting. The greater the root mass the greater the chance of successful out planting.

5.2 Altered Drainage

5.2.1 Nature of Concern

Some areas of mangrove on the site may experience altered drainage as a result of construction activities. At present, the natural existing drainage features and ponds on the Paradise Found site become inundated with flood water easily during moderate rainfall conditions. Further, the offsite drainage run-off has a significant impact by infiltrating the Paradise Found site. The existing flooding situation onsite demonstrates the need for an assessment of current drainage features and existing site conditions along with a need for the design of a new comprehensive drainage strategy and drainage system.

Hydrological regimes are considered the key factor influencing mangrove species growth, distribution, structure and individual tree growth. Hydrologic alterations as a result of construction works can redirect natural water flow, decrease the degree of inundation, and create habitat fragmentation (Milbrandt et al. 2006). These modifications of local hydrographic patterns affect mangrove propagule dispersal, seedling establishment, and growth (Ellison and Farnsworth 1996; Duke et al. 1998; Milbrandt and Tinsley 2006), while drainage and entrained water stress decrease mangrove litter fall and productivity (Carter et al. 1973). Without mitigation this impact is major.

5.2.2 Mitigation Measures

For the site to have proper drainage it must have a clear definition of flow off the site. The main mitigation measure to address this impact will be the provision of culverts and other drainage structures (as much as practicable) to maintain adequate drainage. The key aspects of the drainage system as designed for the site includes:

- Earthen drains,
- Paved drains,
- Culverts,
- Ponds.

The following guidelines will be adopted:

- Perimeter drainage will be designed to accommodate the 100-year return period event, to minimise impacts on adjacent lands.
- On-site drainage will be designed to accommodate the 50-year return period event;
- Flood protection from rainfall will be designed against the 50-year return period event;
- Lot and building drainage will discharge surface flows to the existing ponds as best as is practical;
- Minimum and maximum velocities in storm drains according to design standards shall be 1.0m/s and 3.5m/s, respectively;
- Tail water in receiving water bodies will be as follows:
    - Drains and culvert: normal depth for design flow;
    - Ponds, lakes, and rivers: Normal high-water depth; and
    - Sea and shoreline discharge: Mean High Water.

The proposed drainage master plan (shown in Figure 4) is as follows:

- Grading of property towards proposed roadways where practical. For lots that have a natural drainage path away from the road, drains to exit points will be implemented.
- Flows will be mainly handled by drains to the existing ponds, with areas slated for pond creation being allowed to pond naturally.
- Existing ponds will have a berm of up to 2.5m above MSL crest elevation to allow for increased storage and to reduce breaching during rainfall events.
- All drains and drainage features will require regular maintenance and clearing to work best.

5.3 Sedimentation

5.3.1 Nature of Concern

Increased sedimentation as a result of increased surface runoff associated with changes in site topography and drainage pathways can lead to burial of mangrove roots and pneumatophores, causing dieback. In fact, data collected in the field indicates that mangrove trees and new propagules suffer during sedimentation events, because of root burial (Ellison, 1999).

5.3.2 Mitigation Measures

The development intends to use structural, vegetative, and managerial solutions to treat, prevent, and reduce water pollution caused by stormwater runoff. The following specific measures are recommended to reduce the impact of soil erosion and therefore siltation / sedimentation:

- Undertake a phased approach to clearing and grading.
- Erosion issues are not considered to be significant as hydraulic gradients will likely be small. Still, any final grading or drainage solution will carefully look at that potential and adopt soil stabilization solutions if required. Conversely, gradients will be examined to ensure that siltation or scouring issues do not become problematic. Consideration must be given to using gravel working pads, cross ditching, soil stabilization or synthetic geotextiles to maintain stable subgrade conditions. Monitor exposed areas for signs of erosion.
- Natural vegetative cover and canopy cover should be maintained as far as practical. Areas not required for construction works should not be cleared.
- Re-vegetate or otherwise cover cleared areas as early as practical.
- Design runoff control features to minimize soil erosion.
- Keep material stored on site to a practical minimum. Where aggregate is to be stored on site, it should be stored at least 30m away from major watercourses and drains and confined using wooden cribs or covered with tarpaulins.
- Where appropriate, construct bale dikes, silt fences, diversion berms or swales along the top of the riverbank to prevent loose dirt and debris from entering the watercourse.
- Consider using land-based silt barriers to reduce the migration of silt into the ponds.

5.4 Impaired Water Quality

There is no "effluent" anticipated from the proposed infrastructure works. However, impaired water quality may arise as a result of:

- Siltation/ sedimentation,
- Hydrocarbon spills and leaks,
- Improper sewage disposal, and
- Concrete washings.

The impact of increased sedimentation was discussed in Section 5.3 above.

5.4.1 Hydrocarbon Spills and Leaks

5.4.1.1 Nature of Concern

This impact relates to contamination of surface water and nearshore marine water from lubricants and other hydrocarbons that may occur during site preparation and construction from fuel spills and leaks, and improper disposal of spent lubricants. Hydrocarbons and chemicals at high concentrations can result in the die-off of plants.

5.4.1.2 Mitigation Measures

Mitigation measures available to address this concern during the construction phase include:

- Both primary drainage solutions (open channels and/or closed pipe networks) will consider areas of potential contamination such as petrochemical or grease deposits, and interceptors will be located as necessary.
- Fuel should be stored in bunded areas (secondary containment) to ensure that any spills or leaks are contained and not allowed to runoff into the receiving environment. The floors of the bunded areas should be either clay-lined, or concrete-lined.
- Prohibit fuelling or servicing of vehicles on-site (to the extent practical) or designate a specific area for fuelling and servicing of vehicles and surround this area with dykes and provide it with a paved flooring.
- Keep spill kits with absorbent pads on site to respond to spills, rather than “washing-down” the area.
- Use appropriate pumps, hoses and nozzles for refuelling and place disconnected hoses in containers after refuelling to prevent spills of residual fuel.
- Vehicles and construction machinery should be routinely serviced to ensure that there is no leakage from equipment.
- Transport collected spent lubricants off-site to a facility capable of treating and/or disposing of waste of this kind.

The effective implementation of these mitigation measures is expected to effectively control the impact of hydrocarbon contamination of adjacent watercourses and the nearshore area.

5.4.2 Improper Sewage Disposal

This concern arises from improper disposal of faecal matter, which can reduce water quality by increasing the quantities of faecal coliform bacteria within water bodies. Untreated sewage contains bacteria and viruses that can endanger human health and harm aquatic organisms. This can lead to an increase in pathogenic diseases (among downstream users), as well as a reduction in dissolved oxygen levels. Although mangrove trees are adapted to survive low oxygen environments, fauna inhabiting the mangrove areas will be adversely impacted by very low oxygen levels.

It is common practice that during construction activities for portable toilets or other appropriate toilet facilities be provided on-site for workers and they should be instructed to make use of these. Portable units should be regularly removed from site for emptying and cleaning, and the waste disposed of at an approved facility. It is expected that if this course of action is implemented, concerns associated with discharge of improperly treated sewage will effectively be eliminated.

5.4.3 Concrete Washings

5.4.3.1 Nature of Concern

Concrete washings arise mainly from the rinsing of concrete trucks after they have dispensed their load at the site. The offloading chute and the drum of the truck are normally sprayed with fresh water to prevent concrete from accumulating and hardening on these parts. The chemical content of cement and concrete slurry - especially lime - can be lethal to fish, insects and plants. Concrete washings can have a high pH (of 12– 13) and so causes alkali burns. This high pH also renders dilution of concrete washings impractical, and a single bucket of concrete washings could result in a fish kill. Water quality impairment impacts associated with concrete washings will arise from drainage construction and culvert construction.

5.4.3.2 Mitigation Measures

Impacts relating to impaired water quality from concrete washings can be managed with the following measures:

- Prohibit the discharge from concrete washings into any watercourses or in surface drains.
- Establish a well-identified earthen pit on the site into which concrete washings will be allowed to enter. This pit should be lined with plastic to avoid groundwater contamination. After evaporation of the water, the hardened material should be regularly removed and sent for disposal at an approved landfill.
- All tools and equipment that come into contact with concrete or cement must also be washed such that the wash water flows into the pit, or they must be washed in a designated area where the wash water can similarly be allowed to evaporate, and the hardened material sent for disposal at an approved landfill.

The effective implementation of these mitigation measures are expected to effectively control the impact of concrete washings of adjacent watercourses and the nearshore area.

5.5 Improper Disposal of Solid Wastes

5.5.1 Nature of Concern

During the proposed infrastructure works, the primary waste to be generated will include felled vegetation and topsoil. There will also be non-hazardous material such as crates, wrappers, packaging material and domestic garbage from workers.

Improper disposal of these wastes is a cause for concern since they can be blown or washed off the site. This can directly cause blockage of drains and adjacent watercourses, creating flooding in upstream areas and stagnation (leading to mosquito infestations). With respect to mangroves, solid wastes and particularly plastic wastes can result in a stress response leading to increased pneumatophore growth and then eventual die off.

5.5.2 Mitigation Measures

The following may be implemented to mitigate against improper waste disposal:

- Require that the Contractor develop a comprehensive Waste Management Plan utilizing the re-use, reduce and recycle approach.
- Avoid the burning of waste on site (packaging material, construction scraps or felled vegetation), as burning will produce unacceptable air emissions and also poses the danger of bush and forest fires.
- Encourage the sorting of recyclable material (such as glass and plastics containers) for later collection and disposal by an approved recycling company.
- Encourage the composting of biodegradable material (e.g. felled vegetation) on site. Suitable areas can be set aside for composting.
- Secure excavated material well away from roadside drains, adjacent watercourses and nearshore areas, so as to minimize the possibility of siltation or blockage.
- Collect all domestic garbage in secure receptacles for disposal at an approved landfill. No garbage will be left open or accessible to animals or allowed to litter the ground or drains.

6 MANAGEMENT PLAN

6.1 Approach

The preparation of this Management Plan chapter involved the following steps:

- Adverse environmental impacts of the proposed works were identified and assessed (see Chapter 5).
- Appropriate mitigation measures were prescribed for each adverse environmental impact (see Chapter 5).
- The party responsible for carrying out the mitigation actions was identified in the context of the institutional arrangements for the proposed project. The timing for each action was defined, along with specialized equipment or material required.
- The direct cost of implementing each mitigation action was estimated. It should be noted, however, that in many cases the cost of implementing mitigation actions is a part of the normal overall cost, and therefore not shown as a separate cost.
- Monitoring requirements were also recommended for each adverse environmental impact.
- The party responsible for monitoring was identified in the context of the institutional arrangements for the proposed project.
- The timing and location for monitoring events were described, along with specialized equipment or material required.
- The direct environmental cost of monitoring was estimated.

An assessment report will be prepared supported by relevant monitoring results during the infrastructure works and the MPMP will be revised (if necessary) to ensure continued effective pollution control and protection of the mangrove system.

6.2 Management Structure

The following is a brief description of roles and responsibilities of different entities during the construction of the Paradise Found Development. Figure 8 shows the organization structure for the management of the construction phase. Key functions on this chart are assigned to:

- Paradise Found LLC;
    - Project Manager;
    - Landscape Manager;
- Development Control Authority (Planning Authority)
- Department of Environment (Environmental Regulator);
- Forestry Unit,
- Fisheries Division,
- Smith Warner International (the Prime Consultant); and
- Ecoengineering Consultants Limited (the Environmental Subconsultant).

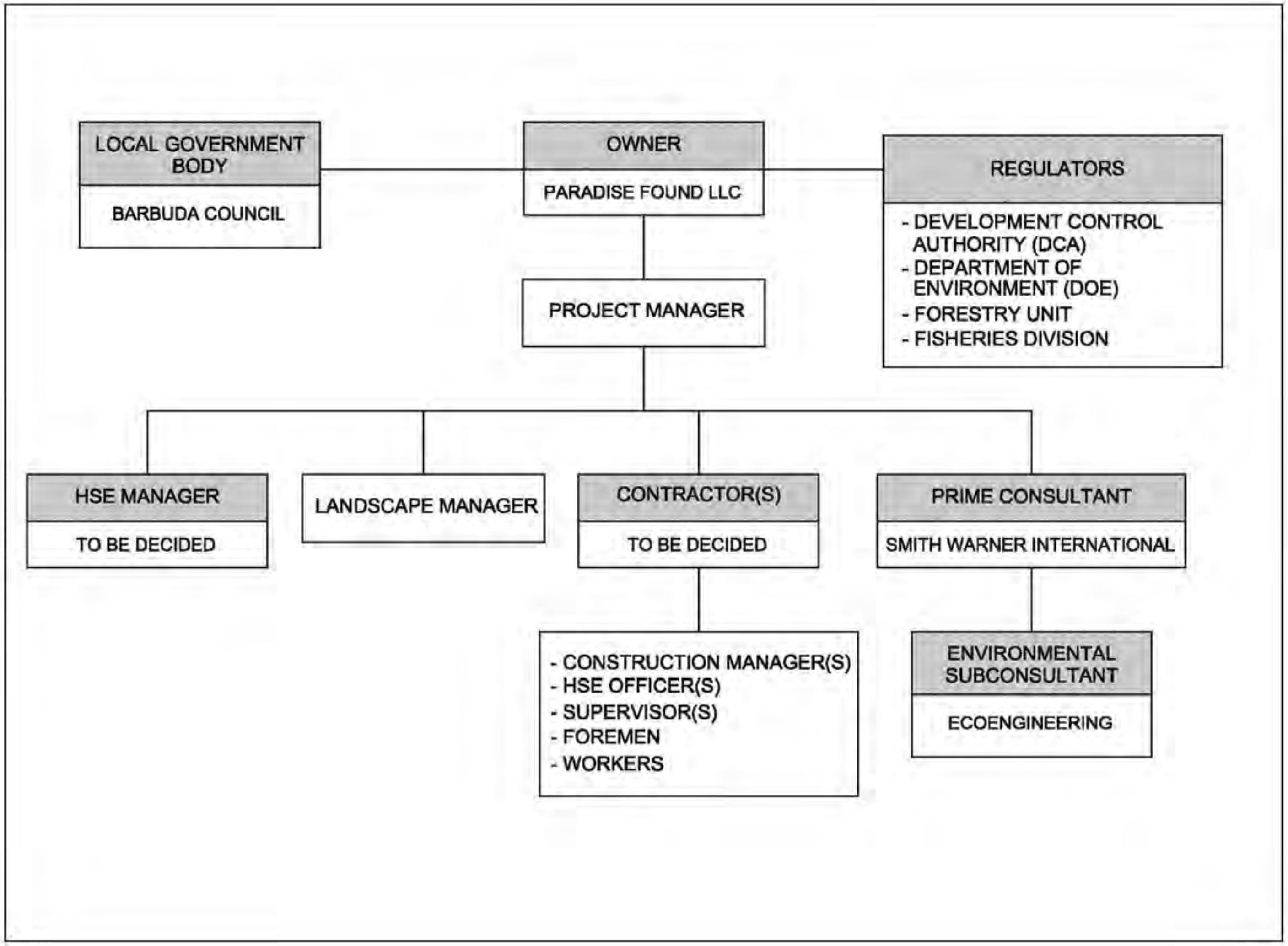

FIGURE 8: ORGANIZATION STRUCTURE FOR CONSTRUCTION PHASE

6.2.1 Paradise Found LLC

Paradise Found LLC is the implementing agency and will function as the Owner/Developer, responsible for funding all works on this project and for overseeing the overall execution of the project during infrastructure development. Specific roles and responsibilities covered by the Paradise Found LLC team will likely be undertaken by a Project Manager and a Landscape Manager.

The Project Manager will represent Paradise Found LLC in the day-to-day oversight of the construction works. She or he will be supported by Engineers and Technicians in verifying that the Contractors are undertaking the works in accordance with the design drawing and specifications.

The Landscape Manager will be responsible for ensuring that the Landscape Plan and the Mangrove Protection and Management Plan is implemented. The Landscape Manager will also be responsible for maintaining the on-site nursery.

The Prime Consultant (see Section 6.2.5) and the Environmental Subconsultant (see Section 6.2.5) will also support the work of Paradise Found LLC

6.2.2 Department of Environment

The DoE's overall mission is to provide technical advice and implement projects and programs on behalf of the Government and the people of Antigua and Barbuda. The DoE is also responsible for maintaining an up-to-date national environmental policy, engaging the public in environmental awareness and coordinating the process of conducting Environmental Impact Assessments (EIAs) for all applicable developments.

This MPMP has been prepared in response to comments on the draft ESIA provided by the DoE. The DoE will review this report and recommend amendments where necessary. The DCA will include conditions in the Development Approval including those specific to the MPMP for implementation by Paradise Found LLC.

6.2.3 Forestry Unit, Ministry of Agriculture, Lands, Fisheries and Barbuda

The Forestry Unit of the Ministry of Agriculture, Lands, Fisheries and Barbuda is responsible for the conservation and management of the nation's terrestrial biological diversity. The Unit will be responsible for permitting before any trees are cut.

6.2.4 Fisheries Division, Ministry of Agriculture, Lands, Fisheries and Barbuda

The Fisheries Division is responsible for management of fisheries and aquaculture activities in Antigua and Barbuda. The Division also has particular responsibility to ensure the conservation of the fish resources and the ecosystems to which they belong. Since mangroves provide habitats for fisheries, they are therefore afforded some protection under the Fisheries Act No. 22 of 2006.

6.2.5 The Prime Consultant

Smith Warner International, as Prime Consultant, will assist Paradise Found LLC in managing the work of the contractor(s) as well as the work of the Environmental Subconsultant (see Section 6.2.6, below).

6.2.6 The Environmental Subconsultant

Ecoengineering will assist Paradise Found LLC in ensuring that this project is implemented to suitable environmental standards. They will provide monitoring services to address environmental conditions of the Development Approval as required.

6.3 Record Keeping

During the construction works, a variety of records will have to be maintained onsite by the Project Manager or appropriate delegate. These include:

- A register for public complaints.
- A register for documenting how frequently garbage bins are emptied, including the haulage and disposal records.
- A register of spills and leaks of hydrocarbons.
- A register documenting the maintenance of vehicles and equipment.
- Inspection Checklists for instances where features being constructed are verified for compliance with the design and monitoring is undertaken.
- A register for other types of waste disposal and or remediation (hazardous wastes, remediation, etc.).

In addition, the Project Manager will have to maintain a manifest of all inspections undertaken by her/him and any other Contractor personnel. Non-compliance observations or complaints, accidents, incidents will require reporting (see Section 6.4 below) so that such issues can be addressed.

6.4 Reporting

The reporting will be as follows, unless otherwise stated:

- The Health, Safety & Environment (HSE) Officer will relay any observation of non-compliance to the Project Manager immediately through verbal communication followed by a written report (including proposed solutions to address the non-compliance) within 48 hours of the observance of the non-compliance.

- The Landscape Manager will relay any observation of non-compliance in implementation of the MPMP to the Project Manager.

- The Environmental Subconsultant will prepare inspection reports to be forwarded to the Project Manager.

- Where environmental monitoring reports are to be prepared, the Environmental Subconsultant will prepare monitoring reports within 5 days of receipt of results from the sampling and submit to the Project Manager for his attention.

6.5 Mitigation and Monitoring

Impacts include:

- Direct habitat loss;
- Altered drainage;
- Sedimentation;
- Impaired water quality; and
- Improper solid waste disposal.

6.5.1 Direct Habitat Loss

Table 6.1	POTENTIAL IMPACT	CLEARING OF VEGETATION (LOSS OF TERRESTRIAL HABITAT)
MITIGATION MEASURES		• Avoid clearing vegetation in areas not required for construction works. • Prohibit burning of cleared vegetation. • Prohibit use of herbicides in vegetation clearance. • Obtain all necessary permits relating to the felling of trees. • Finally, Paradise Found is committed to employ the “no net loss” policy on this project by replanting mangrove plants around the existing ponds as well as the new ponds to be installed on site.
ACTION BY		• Landscape Manager to obtain necessary permits for the removal of trees. • Environmental Subconsultant to oversee the replanting of mangrove plants in accordance with MPMP. • Project Manager to implement all other mitigation measures.
TIMING		• Obtain necessary permits prior to clearing activities (felling and transport of trees). • Implement all other measures after clearing and grading.
SPECIALIZED EQUIPMENT OR MATERIAL		None required

Table 6.1	POTENTIAL IMPACT	CLEARING OF VEGETATION (LOSS OF TERRESTRIAL HABITAT)
MONITORING / VERIFICATION		

HOW / BY WHOM/ WHAT / WHERE/ FREQUENCY		• The Project Manager to verify that permits to fell and haul trees (where necessary) has been acquired.
		• The Construction Manager to oversee the extent and/or phasing of site clearing activities.
		• HSE Officer to record any complaints of removal of vegetation (outside of designated areas) and or burning.
		• HSE Manager to verify that only areas designated for clearing are cleared and that no burning of vegetation or use of herbicides occurs on site.
		• Environmental subconsultant to undertake the following:
		  • Aerial photography (drone survey) and field surveys to map the distribution and coverage of mangrove on the project site. This will be done on completion of clearing and repeated on completion of infrastructure works.
		  • Mangrove health surveys to consist of:
		    o regular visual assessments to determine mangrove condition; and
		    o detailed mangrove health surveys upon completion of clearing, after six months (following commencement of construction) and on completion of infrastructure works. It is recommended that three or four monitoring sites be established, including a reference site. This should include species, number of adults, number of saplings, number of seedlings, stem diameters.

SPECIALIZED EQUIPMENT OR MATERIAL		• Complaints Register • Permits
RECORD KEEPING		See Section 6.3
REPORTING		See Section 6.4

6.5.2 Altered Drainage

Table 6.2	POTENTIAL IMPACT	TEMPORARY IMPEDED DRAINAGE
MITIGATION MEASURES		• Perimeter drainage will be designed to accommodate the 100-year return period event, so as to minimise impacts on adjacent lands. • On-site drainage will be designed to accommodate the 50-year return period event; • Flood protection from rainfall will be designed against the 50-year return period event; • Lot and building drainage will discharge surface flows to the existing ponds as best as is practical; • Minimum and maximum velocities in storm drains shall be 1.0m/s and 3.5 m/s, respectively; • Grading of property towards proposed roadways where practical. For lots that have a natural drainage path away from the road, drains to exit points will be implemented. • Flows will be mainly handled by drains to the existing ponds, with areas slated for pond creation being allowed to pond naturally. • Existing ponds will have a berm of up to 2.5m above MSL crest elevation to allow for increased storage and to reduce breaching during rainfall events. • All drains and drainage features will require regular maintenance and clearing to work best.
ACTION BY		• Project Manager to ensure that drains and culverts are adequately sized. • Project Manager to implement all other mitigation measures.
TIMING		• Design and analysis to be conducted prior to the start of construction works. • Implement all other mitigation measures throughout the construction phase.
SPECIALIZED EQUIPMENT OR MATERIAL		None required
MONITORING / VERIFICATION		
HOW / BY WHOM/ WHAT / WHERE/ FREQUENCY		• HSE Manager to verify (via daily inspections) that the on-site drainage is constructed according to design specifications. • The HSE Officers to inspect the condition of drains weekly to ensure that they are free from debris and other obstructions. • The HSE Officers to conduct weekly inspections of the site to ensure that mitigation measures are being implemented.

Table 6.2	POTENTIAL IMPACT	TEMPORARY IMPEDED DRAINAGE
SPECIALIZED EQUIPMENT OR MATERIAL		Inspection Checklist
RECORD KEEPING		See Section 6.3.
REPORTING		See Section 6.4

6.5.3 Sedimentation

Table 6.3	POTENTIAL IMPACT	ONSITE EROSION AND SEDIMENT MIGRATION
MITIGATION MEASURES		• Undertake a phased approach to clearing and grading. • Erosion issues are not considered to be significant as hydraulic gradients will likely be small. Still, any final grading or drainage solution will carefully look at that potential and adopt soil stabilization solutions if required. Conversely, gradients will be examined to ensure that siltation or scouring issues do not become problematic. Consideration must be given to using gravel working pads, cross ditching, soil stabilization or synthetic geotextiles to maintain stable subgrade conditions. Monitor exposed areas for signs of erosion. • Natural vegetative cover and canopy cover should be maintained as far as practical. Areas not required for construction works should not be cleared. • Re-vegetate or otherwise cover cleared areas as early as practical. • Design runoff control features to minimize soil erosion. • Keep material stored on site to a practical minimum. Where aggregate is to be stored on site, it should be stored at least 30m away from major watercourses and drains and confined using wooden cribs or covered with tarpaulins. • Where appropriate, construct bale dikes, silt fences, diversion berms or swales along the top of the riverbank to prevent loose dirt and debris from entering the watercourse. • Consider using land-based silt barriers to reduce the migration of silt into the ponds.
ACTION BY		• Project Manager to schedule phased construction works. • Construction Manager to implement all other mitigation measures.
TIMING		• Design of structures and schedule of clearing to be conducted prior to the start of construction. • All other works to be implemented throughout the construction phase.

Table 6.3	POTENTIAL IMPACT	ONSITE EROSION AND SEDIMENT MIGRATION
SPECIALIZED EQUIPMENT OR MATERIAL		• Geotextiles • Tarpaulins or plastic • Silt Fences
MONITORING / VERIFICATION		
HOW / BY WHOM/ WHAT / WHERE/ FREQUENCY		• HSE Manager will verify (via daily inspections) that erosion control measures are constructed according to design specifications and that they are adequately located. • The Landscape Manager to: • oversee the extent and/or phasing of site clearing, • inspect erosion control measures for functionality and effectiveness (weekly). • The HSE Officers to: • monitor exposed areas for signs of erosion on a weekly basis and/or following rainfall events. • Inspect drains and channels for visible turbidity and solid deposits. • The HSE Officers to conduct weekly inspections of the site (or within 24 hours of significant rainfall events) to ensure that mitigation measures are being implemented.
SPECIALIZED EQUIPMENT OR MATERIAL		Inspection Checklist
RECORD KEEPING		See Section 6.3
REPORTING		See Section 6.4

6.5.4 Impaired Water Quality

6.5.4.1 Hydrocarbon Spills and Leaks

Table 6.4	POTENTIAL IMPACT	IMPAIRED SURFACE WATER (HYDROCARBON SPILLS AND LEAKS)
MITIGATION MEASURES		• Both primary drainage solutions (open channels and/or closed pipe networks) will consider areas of potential contamination such as petrochemical or grease deposits, and interceptors will be located as necessary. • Fuel should be stored in bunded areas (secondary containment) to ensure that any spills or leaks are contained and not allowed to runoff into the receiving environment. The floors of the bunded areas should be either clay-lined, or concrete-lined. • Prohibit fuelling or servicing of vehicles on-site (to the extent practical) or designate a specific area for fuelling and servicing of vehicles and surround this area with dykes and provide it with a paved flooring.

Table 6.4	POTENTIAL IMPACT	IMPAIRED SURFACE WATER (HYDROCARBON SPILLS AND LEAKS)
		• Keep spill kits with absorbent pads on site to respond to spills, rather than "washing-down" the area. • Use appropriate pumps, hoses and nozzles for refuelling and place disconnected hoses in containers after refuelling to prevent spills of residual fuel. • Vehicles and construction machinery should be routinely serviced to ensure that there is no leakage from equipment. • Transport collected spent lubricants off-site to a facility capable of treating and/or disposing of waste of this kind.
ACTION BY		• Project Manager to implement all mitigation measures.
TIMING		• Area for re-fuelling should be designated prior to the start of construction works. • Other measures to be implemented throughout the construction phase.
SPECIALIZED EQUIPMENT OR MATERIAL		• Appropriately sized and sealed containers for the storage of spent lubricants • Spill kits
MONITORING / VERIFICATION		
HOW / BY WHOM/ WHAT / WHERE/ FREQUENCY		• The HSE Manager to conduct weekly inspections to ensure that all mitigation measures are being implemented and that they are effective. • The Environmental Subcontractor to monitor TPH in the neighbouring watercourses, drains and in the nearshore area monthly during the construction phase. • HSE Officers to conduct daily visual inspections on vehicles and equipment for evidence of spills and leaks in the terrestrial and aquatic environment.
SPECIALIZED EQUIPMENT OR MATERIAL		• Inspection checklists • Bomb sampler for retrieving samples • Sealed, sterilized sample bottles • Cooler for storing samples
RECORD KEEPING		See Section 6.3
REPORTING		See Section 6.4

6.5.4.2 Concrete Washings

Table 6.5	POTENTIAL IMPACT	IMPAIRED SURFACE WATER (CONCRETE WASHINGS)
MITIGATION MEASURES		• Prohibit the discharge from concrete washings into any watercourses or in surface drains. • Establish a well-identified earthen pit on the site into which concrete washings will be allowed to enter. This pit should be lined with plastic to avoid groundwater contamination. After evaporation of the water, the hardened material

Table 6.5	POTENTIAL IMPACT	IMPAIRED SURFACE WATER (CONCRETE WASHINGS)
		should be regularly removed and sent for disposal at an approved landfill. • All tools and equipment that came into contact with concrete or cement must also be washed such that the wash water flows into the pit, or they must be washed in a designated area where the wash water can similarly be allowed to evaporate, and the hardened material sent for disposal at an approved landfill.
ACTION BY		• Project Manager to designate an area for concrete washings to enter. • HSE Manager to implement other mitigation measures.
TIMING		• Designate and establish concrete washings pit prior to the start of construction works. • Implement all other mitigation measures throughout the construction phase.
SPECIALIZED EQUIPMENT OR MATERIAL		None required
MONITORING / VERIFICATION		
HOW / BY WHOM/ WHAT / WHERE/ FREQUENCY		• The HSE Manager to verify that the concrete wash pit is adequately located, sized and of impermeable layer. • The HSE Officers to ensure the proper implementation of mitigation measures, monitor the activities of workers and check for signs of improper disposal of concrete washings (daily during concrete works).
SPECIALIZED EQUIPMENT OR MATERIAL		Checklist
RECORD KEEPING		See Section 6.3
REPORTING		See Section 6.4

6.5.5 Improper Disposal of Solid Waste

Table 6.6	POTENTIAL IMPACT	IMPROPER SOLID WASTE DISPOSAL
MITIGATION MEASURES		• Require that the Contractor(s) develop comprehensive Waste Management Plan(s) utilizing the re-use, reduce and recycle approach. • Avoid the burning of waste on site (packaging material, construction scraps or felled vegetation), as burning will produce unacceptable air emissions and poses the danger of bush and forest fires.

Table 6.6	POTENTIAL IMPACT	IMPROPER SOLID WASTE DISPOSAL
		• Encourage the sorting of recyclable material (such as glass and plastics containers) for later collection and disposal by an approved recycling company. • Encourage the composting of biodegradable material (e.g. felled vegetation) on site. Suitable areas can be set aside for composting. • Secure excavated material well away from roadside drains, adjacent watercourses and nearshore areas, so as to minimize the possibility of siltation or blockage; • Collect all domestic garbage in secure receptacles for disposal at an approved landfill. No garbage will be left open or accessible to animals or allowed to litter the ground or drains.
ACTION BY		• Construction Manager and HSE Manager to prepare the Waste Management Plan. • Construction Supervisor and HSE Officer to implement all other measures.
TIMING		• Develop the Waste Management Plan prior to the start of construction works. • Implement all other mitigation measures (including the Waste Management Plan) throughout the construction phase.
SPECIALIZED EQUIPMENT OR MATERIAL		None required
MONITORING / VERIFICATION		
HOW / BY WHOM/ WHAT / WHERE/ FREQUENCY		• Project Manager to verify that the Waste Management Plan has been approved by the DOE. • HSE Manager to maintain a logbook of all disposal certificates. • HSE Manager to maintain complaints register relating to the improper disposal of wastes. • The HSE Officers to undertake daily inspections on the site and note any instances of improper waste disposal. • The HSE Manager will also review disposal certificates and complaints register.
SPECIALIZED EQUIPMENT OR MATERIAL		• Complaints Register • Logbook
RECORD KEEPING		See Section 6.3
REPORTING		See Section 6.4

7 SUMMARY OF MONITORING REQUIREMENTS

Table 7-1 provides a summary of monitoring required to determine the effectiveness of mitigation measures and the overall environmental performance of the project.

TABLE 7-1: SUMMARY OF MONITORING

IMPACT	MONITORING	RESPONSIBLE PARTY	FREQUENCY
Clearing of Vegetation / Loss of Terrestrial Habitat	Verify that permits to fell and haul trees (where necessary) has been acquired.	Project Manager	Prior to construction
	Oversee the extent and/or phasing of site clearing activities.	The Construction Manager	Weekly during construction
	Record any complaints of removal of vegetation (outside of designated areas) and or burning.	HSE Manager	Continuous during construction
	Verify that only areas designated for clearing are cleared and that no burning of vegetation or use of herbicides occurs on site.	HSE Officers	Continuous during construction
	Undertake the following: • Aerial photography (drone survey) and field surveys to map the distribution and coverage of mangrove on the project site as a repeat of the baseline surveys. • Mangrove health surveys to consist of:	Environmental subconsultant	This will be done on completion of clearing and repeated on completion of infrastructure works.

IMPACT	MONITORING	RESPONSIBLE PARTY	FREQUENCY
	• regular visual assessments to determine mangrove condition; and • detailed mangrove health surveys It is recommended that three or four monitoring sites be established, including a reference site. This should include species, number of adults, number of saplings, number of seedlings, stem diameters.		upon completion of clearing, after six months (following commencement of construction) and on completion of infrastructure works.
Altered Drainage	Verify that the on-site drainage is constructed according to design specifications.	HSE Manager	Daily inspections)
	Inspect the condition of drains to ensure that they are free from debris and other obstructions.	HSE Officers	Daily
	Conduct inspections of the site to ensure that mitigation measures are being implemented.	HSE Manager	Weekly
Sedimentation	• Verify that erosion control measures are constructed according to design specifications and that they are adequately located.	HSE Manager	Weekly

IMPACT	MONITORING	RESPONSIBLE PARTY	FREQUENCY
	• oversee the extent and/or phasing of site clearing, • inspect erosion control measures for functionality and effectiveness.	Landscape Manager	Weekly
	• monitor exposed areas for signs of erosion. • inspect drains and channels for visible turbidity and solid deposit	HSE Officers	Weekly and / or following rainfall events
	• Conduct inspections of the site to ensure that mitigation measures are being implemented.	HSE Manager	Weekly (or within 24 hours of significant rainfall events)
Impaired Water Quality – Hydrocarbon Spills and Leaks	Conduct inspections to ensure that all mitigation measures are being implemented and that they are effective.	HSE Manager	Weekly
	Monitor TPH in the neighbouring watercourses, drains and in the nearshore area.	Environmental Subconsultant	Monthly
	Conduct visual inspections on vehicles and equipment for evidence of spills and leaks in the terrestrial and aquatic environment.	HSE Officer	Daily
Impaired Water Quality – Concrete Washings	Verify that the concrete wash pit is adequately located, sized and of impermeable layer.	HSE Manager	Once at the beginning of concrete works

IMPACT	MONITORING	RESPONSIBLE PARTY	FREQUENCY
	Ensure the proper implementation of mitigation measures, monitor the activities of workers and check for signs of improper disposal of concrete washings.	HSE Officers	daily during concrete works
Improper Disposal of Solid Waste	Verify that the Waste Management Plan has been approved by the DOE.	Project Manager	Prior to construction phase
	Maintain a logbook of all disposal certificates.	HSE Manager	Continuous throughout the construction phase
	Maintain complaints register relating to the improper disposal of wastes.	HSE Manager	Continuous throughout the construction phase
	Undertake inspections on the site and note any instances of improper waste disposal.	HSE Officers	Daily
	Review disposal certificates and complaints register.	HSE Manager	Continuous throughout the construction phase

8 LIST OF REFERENCES

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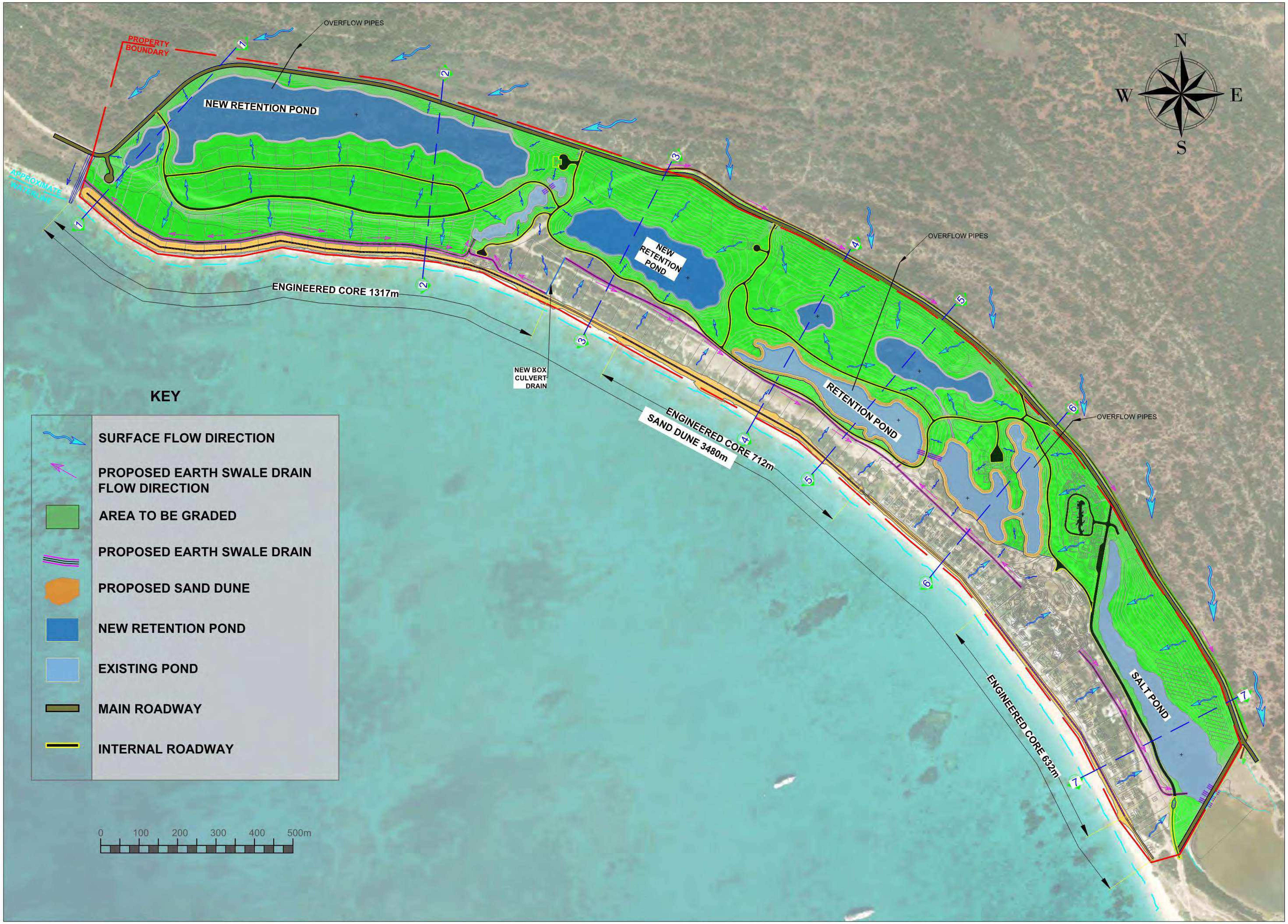
Appendix D Drawings



NOTES:

1. All dimensions and elevations are in meters unless otherwise shown.
2. All elevations are relative to mean sea level.
3. Survey to be verified on site prior to start of works.

No.	Issued For:	No.	Revision (REV.)	Date YY/M/D
01	Client Review	01	N/a	3-April-23
02		02		

Project Title

BARBUDA PARADISE FOUND RESORT DEVELOPMENT

Client

BARBUDA PARADISE FOUND RESORT

Drawing Title

SITE DRAINAGE AND GRADING PLAN

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			REV.	SHEET
Designed by:	A. J. Grennell	Feb' 23	00	01
Checked by:	D. Henlon	Feb' 23		
Drawn by:	R. Lyn	Feb' 23		
Scale: 1:5000	Drawing No.: SWIL-BPFG04			of 4

CROSS SECTION 1-1

CROSS SECTION 2-2

KEY

- PROPOSED LINE GRADE
- EXISTING GRADE TO REMAIN
- EXISTING GRADE TO BE REMOVE
- EXISTING WATERLINE

CROSS SECTION 3-3

NOTES:

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Drawing Title: SITE DRAINAGE AND GRADING CROSS SECTIONS

Project Title: BARBUDA PARADISE FOUND RESORT DEVELOPMENT

Client: BARBUDA PARADISE FOUND RESORT

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Drawing No.: SWIL-BPF-G02

REV. 00

SHEET 02 of 4

KEY

	PROPOSED LINE GRADE
	EXISTING GRADE TO REMAIN
	EXISTING GRADE TO BE REMOVE
	EXISTING WATERLINE

NOTES:

1. All dimensions and elevations are in meters unless otherwise shown.
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01	Client Review	01	N/a	3-April-23
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Drawing Title: SITE DRAINAGE AND GRADING CROSS SECTIONS

Project Title: BARBUDA PARADISE FOUND RESORT DEVELOPMENT

Client: BARBUDA PARADISE FOUND RESORT

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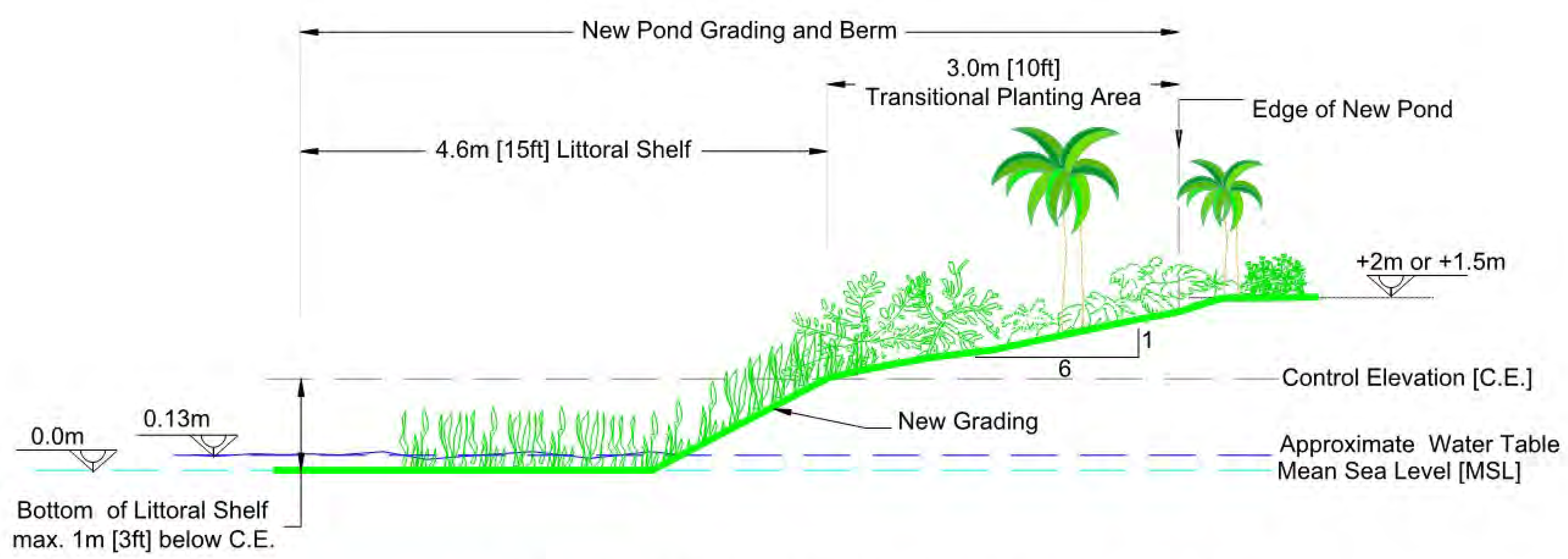
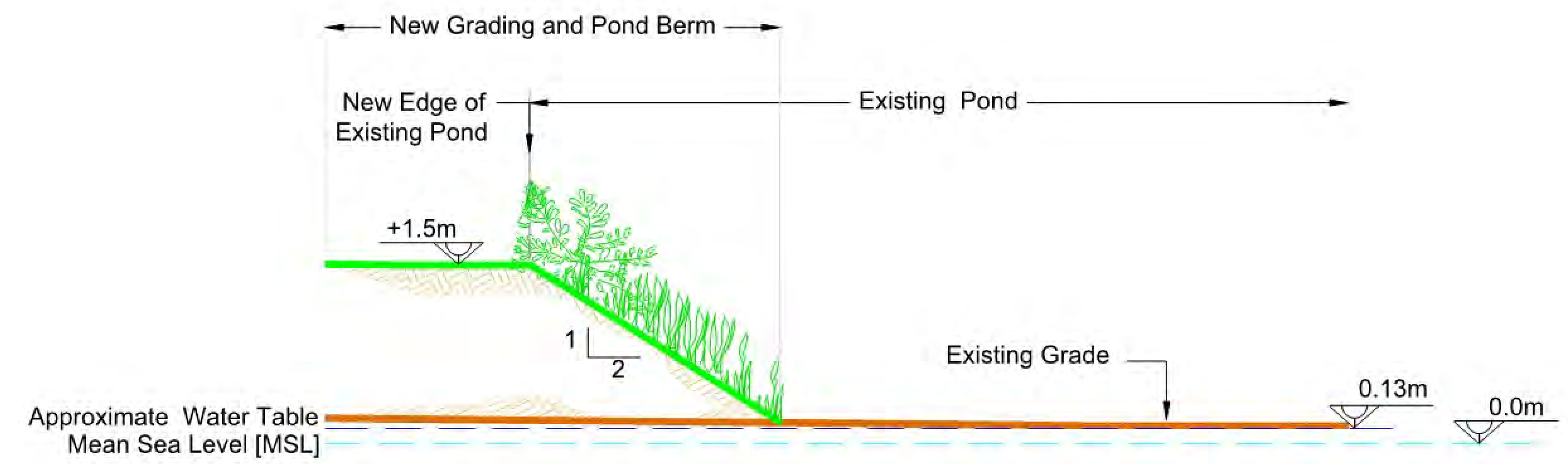
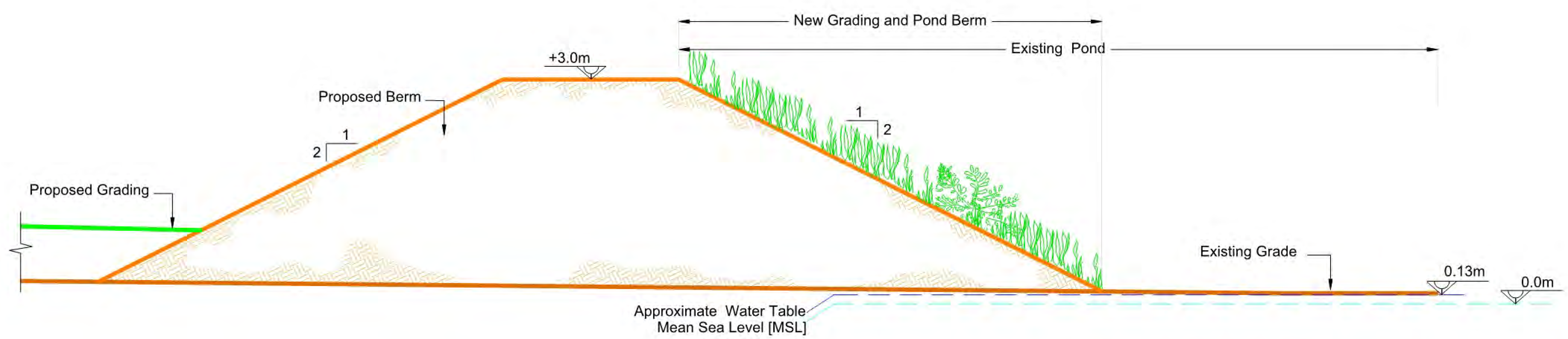
Drawn by: R. Lyn Feb' 23
Scale: SCALE= 1:375
Drawing No.: SWIL-BPF-G03
REV. 00
SHEET 03 of 4



NEW PONDS EDGE TREATMENT : DETAIL A1



EXISTING PONDS EDGE TREATMENT : DETAIL A2



EXISTING PONDS EDGE TREATMENT : DETAIL A3

Drawing Title

NEW AND EXISTING PONDS EDGE TREATMENT DETAILS

Project Title

BARBUDA PARADISE FOUND RESORT DEVELOPMENT

Client

BARBUDA PARADISE FOUND RESORT

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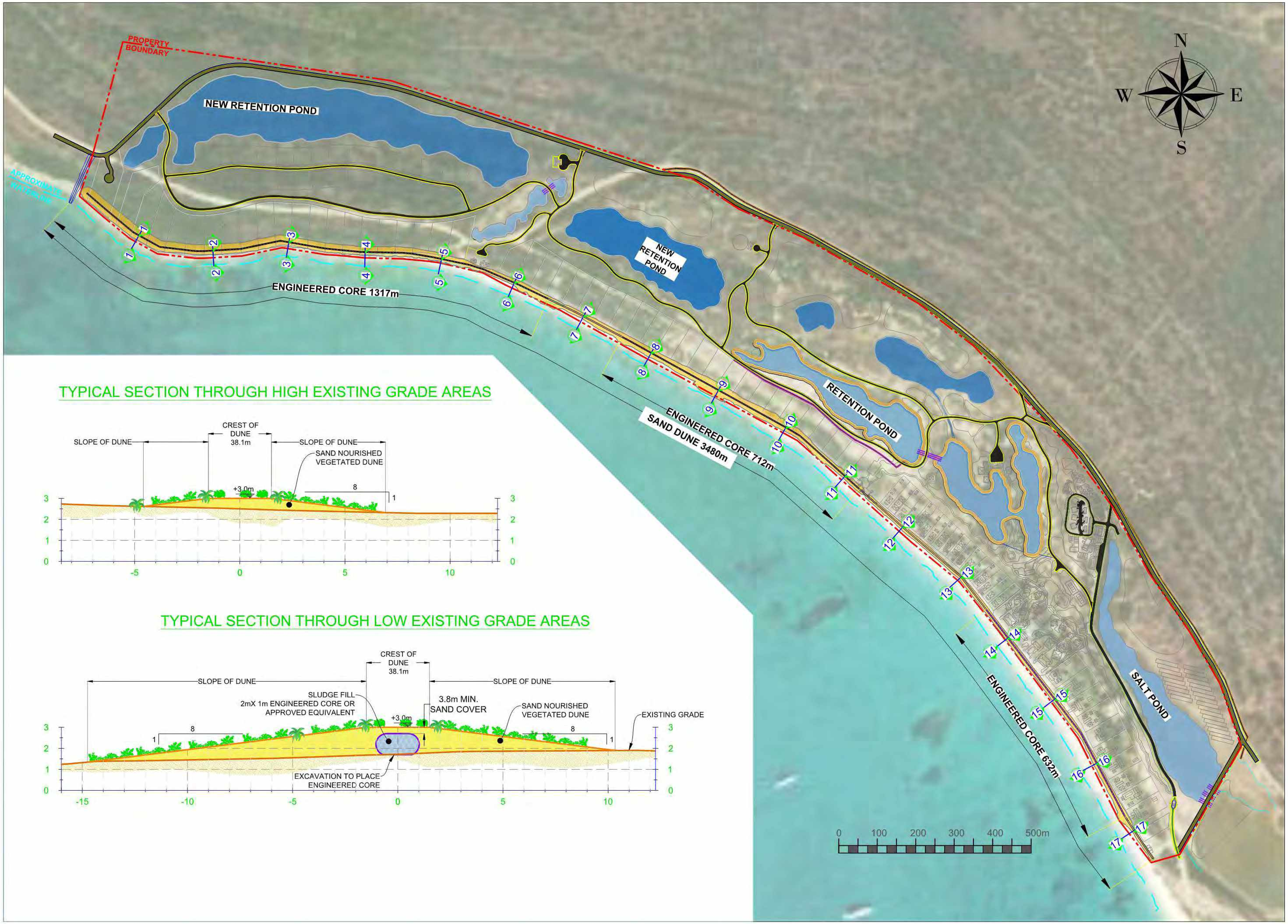
Drawing No.: SWIL-BPF-G04

REV. 00

SHEET 04 of 4



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01	Client Review	01	N/a	3-April-23
02		02		

Project Title

BARBUDA PARADISE FOUND RESORT DEVELOPMENT

Client

BARBUDA PARADISE FOUND RESORT

Drawing Title

SITE PLAN - SAND DUNE

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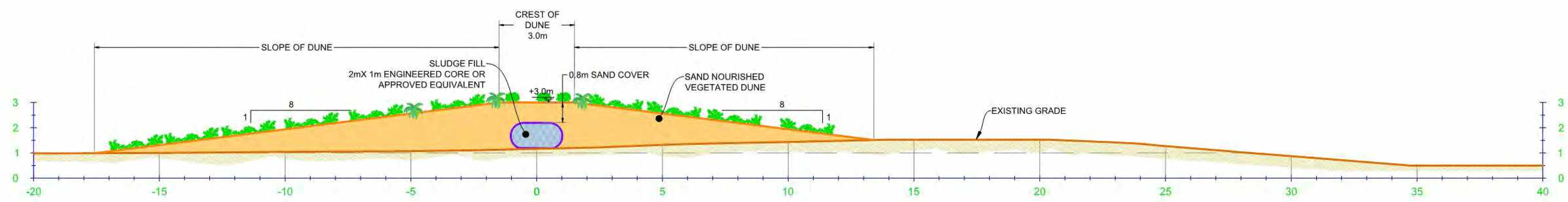
Scale: 1:5000	Drawing No.: SWIL-BPFG01			of 6

CROSS SECTION 1-1



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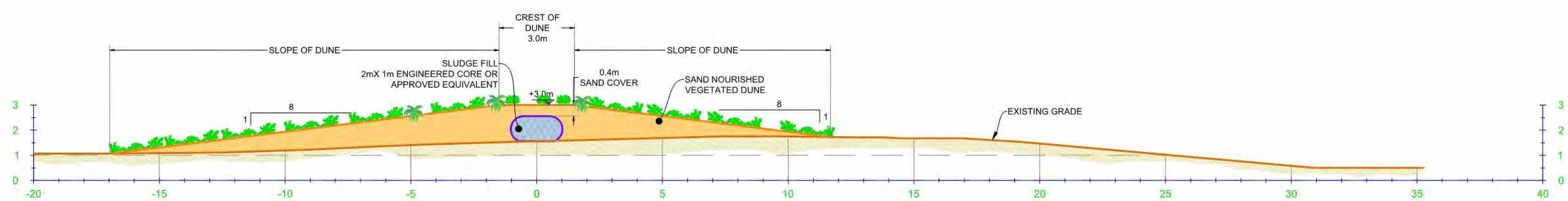

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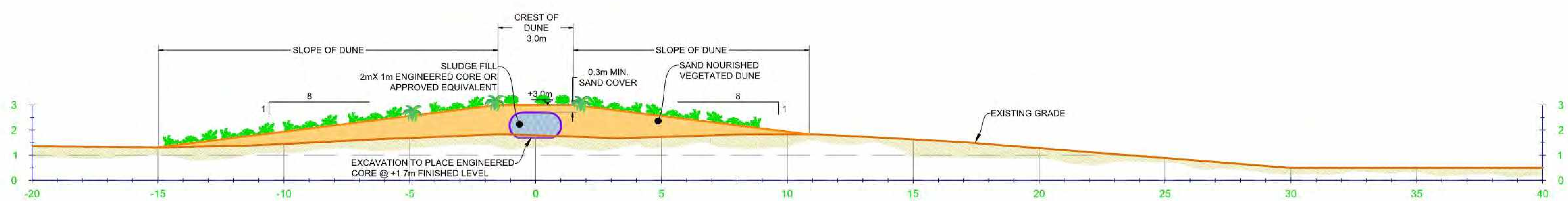

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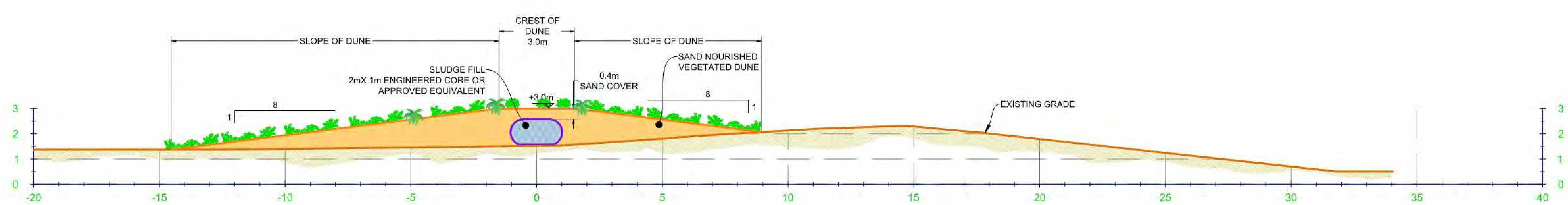

NOTES:

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3. Survey to be verified on site prior to start of works.

No.	Issued For:	No.	Revision (REV.)	Date YY/M/D
01	Client Review	01	N/a	3-April-23
02		02		

Project Title

BARBUDA PARADISE FOUND RESORT DEVELOPMENT

Client

BARBUDA PARADISE FOUND RESORT

Drawing Title

SAND DUNE SECTIONS

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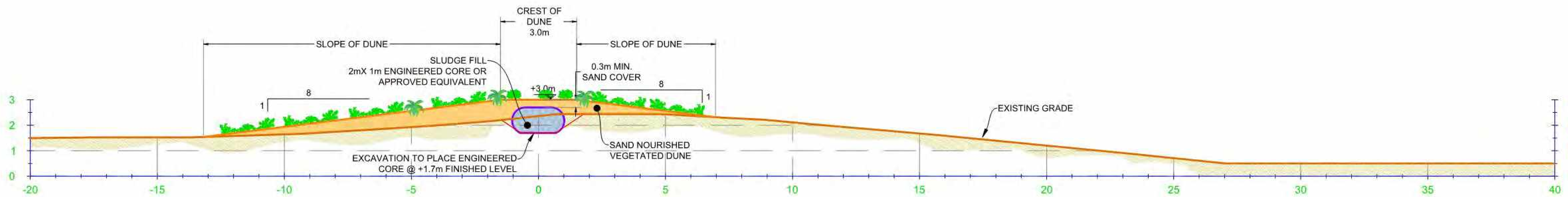
CROSS SECTION 5-5



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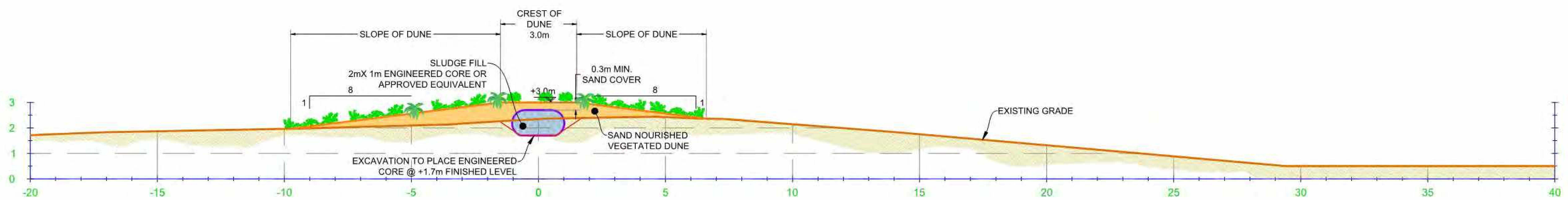

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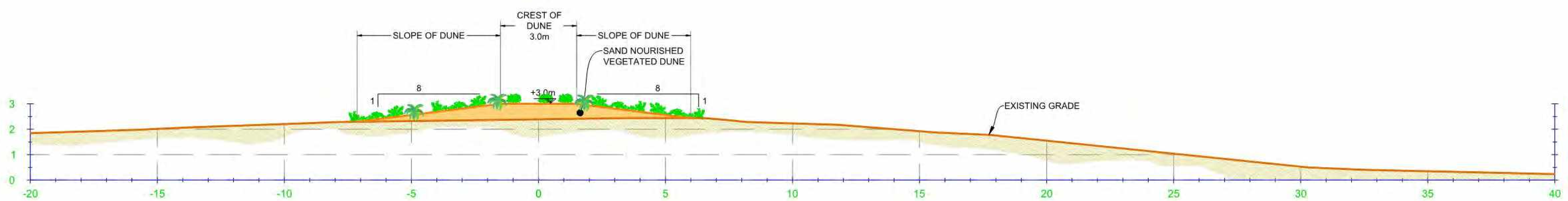

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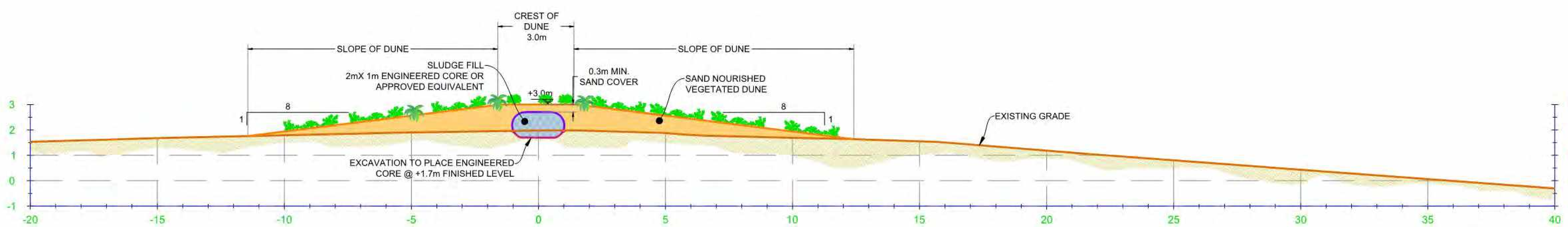

NOTES:

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3. Survey to be verified on site prior to start of works.

No.	Issued For:	No.	Revision (REV.)	Date YY/M/D
01	Client Review	01	N/a	3-April-23
02		02		

Project Title

BARBUDA PARADISE FOUND RESORT DEVELOPMENT

Client

BARBUDA PARADISE FOUND RESORT

Drawing Title

SAND DUNE SECTIONS

SMITH WARNER INTERNATIONAL

Unit 13, Seymour Park,
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Kingston 10, Jamaica, W.I.
Tel: (876)978-8950 /
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			REV.	SHEET
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Drawn by:	R. Lyn	Feb' 23		
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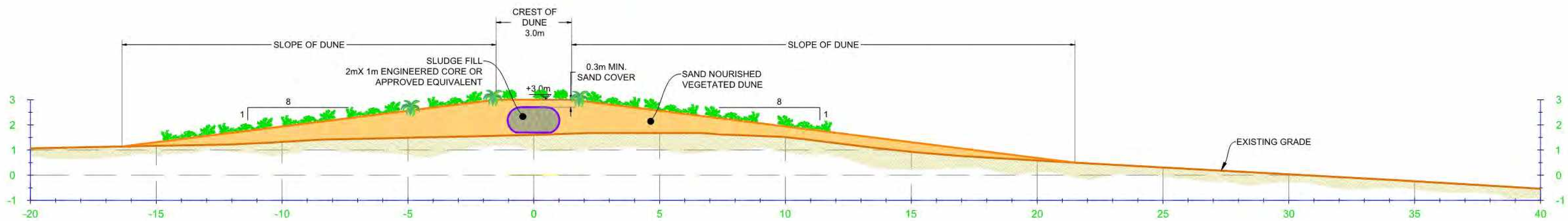

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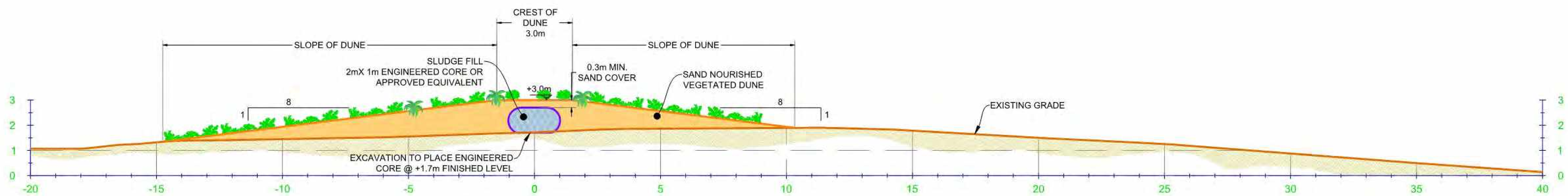

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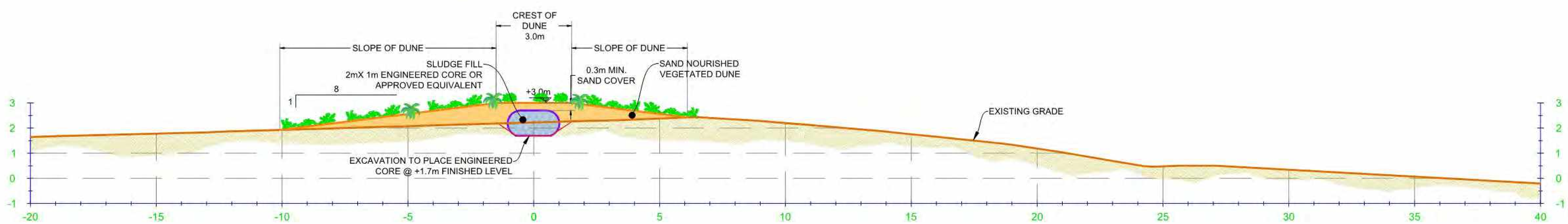

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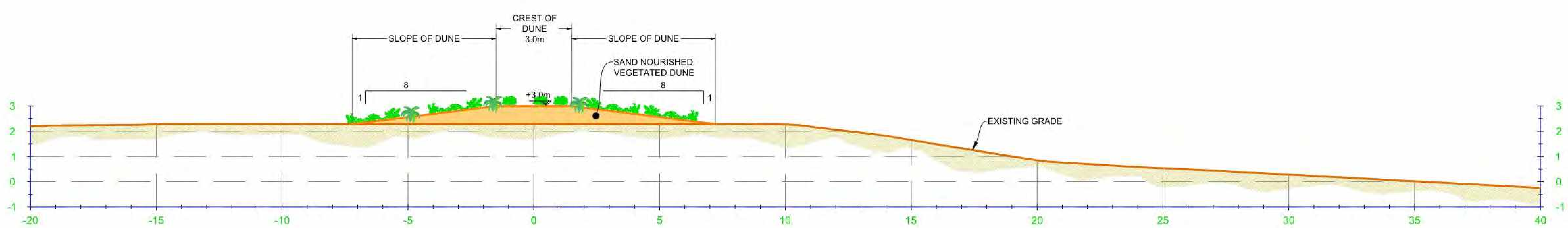

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BARBUDA PARADISE FOUND RESORT DEVELOPMENT

Client

BARBUDA PARADISE FOUND RESORT

Drawing Title

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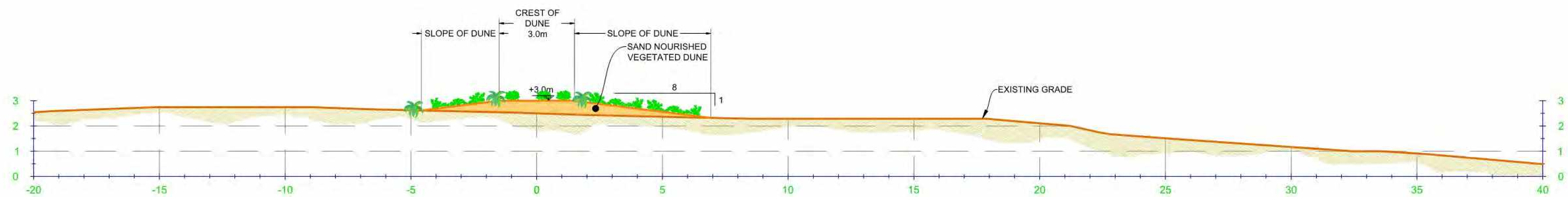

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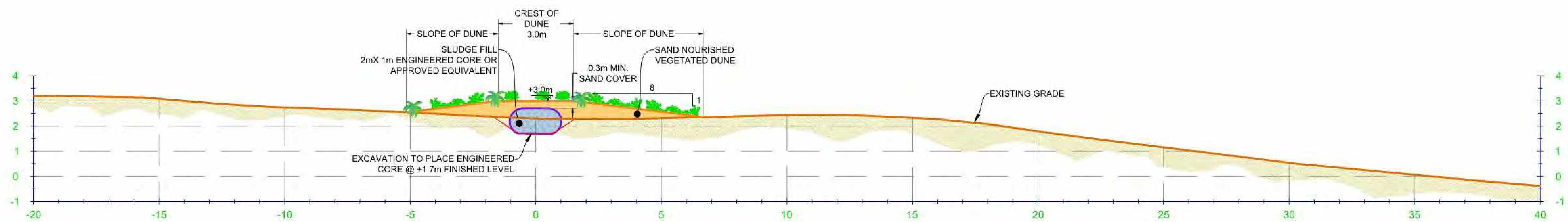

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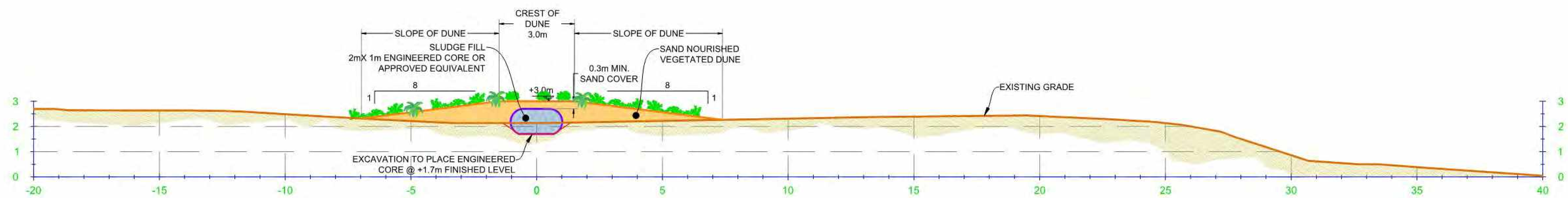

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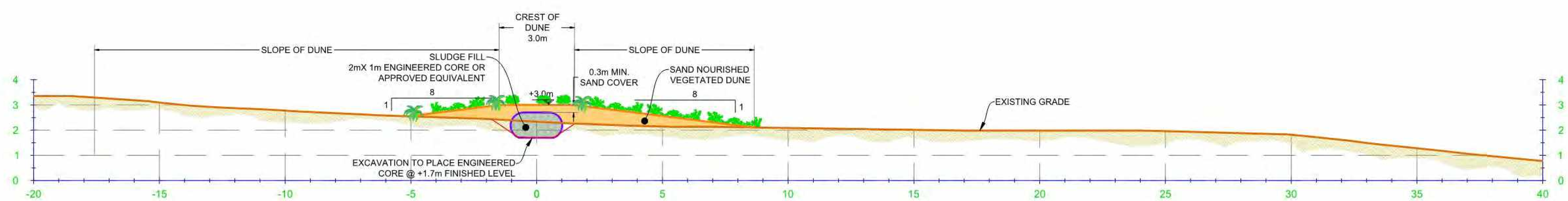

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BARBUDA PARADISE FOUND RESORT DEVELOPMENT

Client

BARBUDA PARADISE FOUND RESORT

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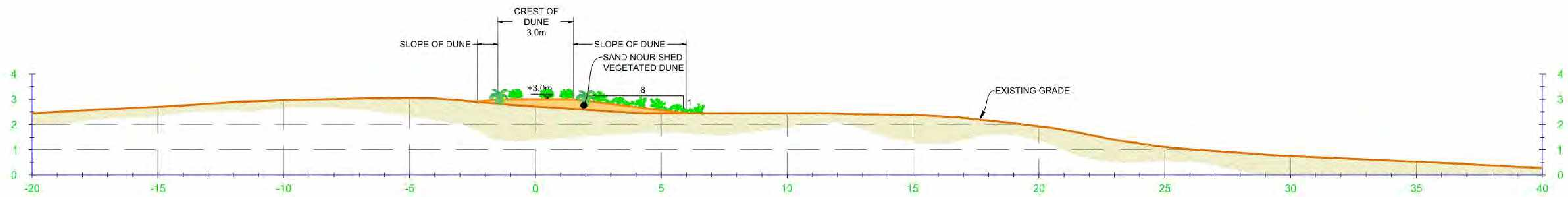

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01	Client Review	01	N/a	3-April-23
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Project Title
BARBUDA PARADISE FOUND RESORT DEVELOPMENT

Client
BARBUDA PARADISE FOUND RESORT

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Appendix E Disaster Management Plan

PARADISE FOUND DEVELOPMENT, BARBUDA

DISASTER MANAGEMENT PLAN

December 20, 2022

SUBMITTED BY

PRIME CONSULTANT

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PARADISE FOUND DEVELOPMENT, BARBUDA

DISASTER MANAGEMENT PLAN

December 20, 2022

1 INTRODUCTION

1.1 Authorization and Layout of Plan

This Disaster Management Plan (DMP) is submitted in response to a stipulation in the Terms of Reference (TOR) for an ESIA for this proposed development. It was prepared by Ecoengineering Consultants Limited as, Health, Safety and Environment (HSE) Subconsultant to Smith Warner International on this assignment. This DMP identifies credible risk scenarios associated with the construction and operation of the development, and sets out procedures for responding to those risks.

This Plan consists of five chapters and an appendix. The remainder of Chapter 1 defines an emergency and indicates levels of emergency, describes the background to this assignment, indicates the scope of the DMP and stipulates the distribution of this Plan and when it must be revised. Chapter 2 is a description of the proposed Paradise Found Development in Barbuda, and Chapter 3 pertains to emergency preparedness, providing administrative information and describing steps which must be taken in advance to ensure that emergencies can be addressed in an efficient and effective manner. Chapter 4 sets out steps to be taken when managing a risk incident, and finally Chapter 5 presents emergency response procedures for each of the credible risk incidents.

1.2 Definition and Levels of Emergency

1.2.1 Definition of an Emergency

NOTE: THROUGHOUT THIS DMP, THE TERMS "CREDIBLE RISK", "RISK INCIDENT" AND "EMERGENCY" ARE USED INTERCHANGEABLY.

During the construction and operation of the Paradise Found development, incidents may occur that put at risk the safety and welfare of employees, clients, visitors and the general public due to injuries, illness, negative environmental impacts and property damage/loss. These incidents are defined as emergencies when they cannot be controlled as part of normal construction or operation procedures. Instead, they must be addressed using structured procedures implemented by specially-designated and trained personnel, and with designated emergency response equipment and material.

1.2.2 Levels of Emergency

Three levels of emergency are defined in this DMP, based on the personnel and levels of resources required for response:

- A **Level 1 Emergency** is one which can be brought under control by Paradise Found and contractor personnel, using on-site resources. For example, injuries can be treated by site personnel who have been trained in first aid and fires can be put out by on-site personnel using on-site fire extinguishers

- A **Level 2 Emergency** is one where some assistance from on-island personnel and resources are required to bring the situation under control. In this case, for example, injured persons would require treatment at the Hannah Thomas Hospital; or there is a need for clean up after a storm surge, which might require assistance from the Barbuda Fire Department or a local cleaning company.

- A **Level 3 Emergency** is one where off-island personnel and resources are required to bring the situation under control. In this case, for example, injuries are serious enough for the victims to be taken to Antigua or beyond for treatment; and rebuilding is required after a hurricane or earthquake which will require more skilled artisans, construction equipment and construction material than is available on Barbuda.

1.3 Background

Paradise Found LLC proposes to construct and operate a resort development on approximately 391 acres (158 ha) of land along the south coast of Barbuda, in the vicinity of Gravenor's Bay, Coco Point and Princess Diana Beach (see Figure 1-1). In a letter dated March 5, 2015, the Barbuda Council indicated that this proposal had received the consent of the People of Barbuda; and a Crown Lease was issued for the land on March 9, 2016. Antigua and Barbuda Act No. 21 of 2015, the Paradise Found (Project) Act, 2015, also pertains to this development.

FIGURE 1-1: LOCATION MAP

Development Application #G10-2021 was submitted on April 14, 2021. This was reviewed by the Department of Environment, who recommended that an Environmental Impact Assessment (EIA) be prepared for this development. This recommendation highlighted environmental concerns pertaining to Hydrology and Drainage, Pollution of Wetlands, Desalination and Reverse Osmosis and Climate Change Impacts. Terms of Reference (TOR) were issued to guide the preparation of the EIA, and these stipulated that a Disaster Management Plan be prepared for the development. This document responds to that stipulation.

1.4 Scope of DMP

The scope of this DMP is defined by a Qualitative Risk Assessment, which is provided in the Appendix to this Plan. This Risk Assessment identified credible risk incidents associated with this development and rated them on the basis of consequences and likelihood using a Risk Rating Matrix. The Credible Risks and their ratings are summarized in Table 1-1 following. Specific response procedures are provided for each credible risk incident in Chapter 5.

TABLE 1-1 CREDIBLE RISKS AND RATINGS

CREDIBLE RISK	RATING
Hurricane Winds	MEDIUM
Storm Surges	MEDIUM
Excessive Rainfall	MEDIUM
Drought	LOW
Earthquake	LOW
Vehicular Accident	LOW
Fire in a Building	MEDIUM
Damaged Piping from an LPG Cylinder, leading to a Fire	LOW
Spillage from a Diesel Tank, leading to a Fire	LOW
Untreated Sewage Discharge Risk	MEDIUM

1.5 Distribution

This Plan will be distributed to the following Organizations and Agencies:

- Paradise Found LLC (Developer);
- the Contractor(s) on the Project;
- the Barbuda Council;
- the Barbuda Police Service;
- the Barbuda Fire Service,
- Hanna Thomas Hospital, and
- Neighbours who may be affected by a Risk Incident at Paradise Found.

Each revision to the Plan will be distributed to these agencies as soon as they become available (see Section 1.6, below).

1.6 Revising the Plan

This Disaster Management Plan will be routinely reviewed at least once each six months during the construction phase and once every two years during the operation phase of the development. In addition, it will be reviewed after every emergency and after every drill (see Section 3.6). The purpose of these reviews will be to ensure that the plan remains suitable, relevant and adequate to the construction and operation phases of the Paradise Found Development.

If it is deemed necessary to alter any element of the plan in order to improve its overall effectiveness, then these changes will be made by the Contractor's Health and Safety Officer and approved by the Construction Manager during the construction phase, and by Paradise Found's Health and Safety Officer and approved by Paradise Found's Manager during the operation phase. In either case, the plan will be considered to be revised only when it is signed by the persons who made the changes (Issued by) and who approved the changes (Approved by). Each signed revised plan will be circulated to the various agencies listed in Section 1.4, above. Plans that are no longer current will be taken out of circulation.

2 PROJECT DESCRIPTION

This project description is intended to provide information on the proposed Paradise Found Development, so as to facilitate a proper understanding of this Disaster Management Plan. As shown in Figure 1-1, this Development will be situated in the vicinity of Gravenor's Bay, Coco Point and Princess Diana Beach in Barbuda.

Due to the remote location of the project and the current lack of infrastructure on the island of Barbuda, the project must develop much of its own infrastructure and support facilities. The ambition of the project is that it should ultimately be as independent as possible in food, water, and energy. This is reflected in the Updated Masterplan (November 2022) which is shown in Figure 2-1.

2.1 Overview

This development will include the following facilities:

1) Nobu Beach Inn Clubhouse,
2) Guest Villas,
3) Arrival Area,
4) Beach Bar,
5) Nobu Restaurant / Satellite Restaurant,
6) Sales Village,
7) Spa,
8) Tennis and Kids Club,
9) Farm and Nursery,
10) Logistics and Staff Center, and
11) Home Sites.

The development will also include a road network, a drainage system, water supply, electricity supply and a wastewater treatment plant.

The following sections provide information on development under the following headings:

- Built Facilities,
- Farm and Nursery,
- Road Network,
- Drainage System,
- Water Supply,
- Electricity Supply,
- Wastewater Treatment Plant, and
- Road Traffic.

FIGURE 2-1: DEVELOPMENT PLAN

2.2 Built Facilities

The term "built facilities" is used here to include all of the facilities listed above except the farm and nursery. The proposed numbers of accommodation units within the development are shown in Table 2-1:

TABLE 2-1: NUMBERS OF ACCOMMODATION UNITS

FACILITY TYPE	NUMBER OF UNITS
Hotel	17
Hotel Villas	10
Hotel Estates	53
Inland Lots	27

Designs have not yet been completed for these buildings, but one important feature vis-à-vis project risk is that LPG Cylinders (see Photographs 2-1 and 2-2) will be installed both at the new restaurant and at individual homes. Based on present practice, the cylinders at the new restaurant are expected to be 100 lb cylinders, while those at the individual homes are expected to be 20 lb cylinders.

100 lb. Cylinder

20 lb. Cylinder

PHOTOGRAPHS 2-1 AND 2-2: LPG CYLINDERS

2.3 Farm and Nursery

A farm / nursery will be established to grow plants for use in landscaping the development. A small nursery already exists on site.

2.4 Road Network

Roads will be constructed within the site to service the various elements of the development. For these roads, approximately 80% will be unpaved and 20% will be paved. Two main access roads to the project site will be realigned (see Figure 2-2).

Phase 1 of the road realignment will involve re-routing the road towards the perimeter of the property at the north end of the property boundary (adjacent to Barbuda Cottages), while Phase 2 will involve improving and rehabilitating the old existing road that crosses the salt pond at the south end of the property. Currently neglected and dilapidated, this road previously provided access to Coco Point and Princess Diana Beach, and the new road realignment will maintain access to Gravenor's Bay, Coco Point and Princess Diana Beach. Paradise Found intends to restore this road while prioritizing the drainage and flow to the mangrove, thereby improving the ecological health and stability of the mangrove stands in that area.

2.5 Drainage System

As the Development is constructed, consideration will be given to catchment zones in each phase, collection of water, transportation or delivery of water, and disposal of water. The collected water will be conveyed in a closed pipe or open channel system to a point of disposal such as a bio-swale, soakaway, detention pond, or well. Other areas of the development site will be addressed in a more holistic and non-disruptive way. Rainfall will be handled more naturally, incorporating surface runoff and subsurface runoff, understanding that the existing natural ground is one of good percolation and subsurface runoff that conveys the water to the existing ponds and low-lying areas, filtering water as it travels. Rainwater harvesting systems can also be employed in this development, which will also assist in the management of stormwater runoff. The Development intends to use structural, vegetative, and managerial solutions to treat, prevent, and reduce water pollution caused by stormwater runoff.

Paradise Found intends to bolster the strength and health of the mangroves surrounding the salt pond area to protect the pond and the adjacent regions from future storms of all sizes. This will involve transplanting of mangrove plants where possible and restore the mangrove's health by ensuring that its tidal and freshwater hydrology is functioning normally so that the mangrove may repair itself over time.

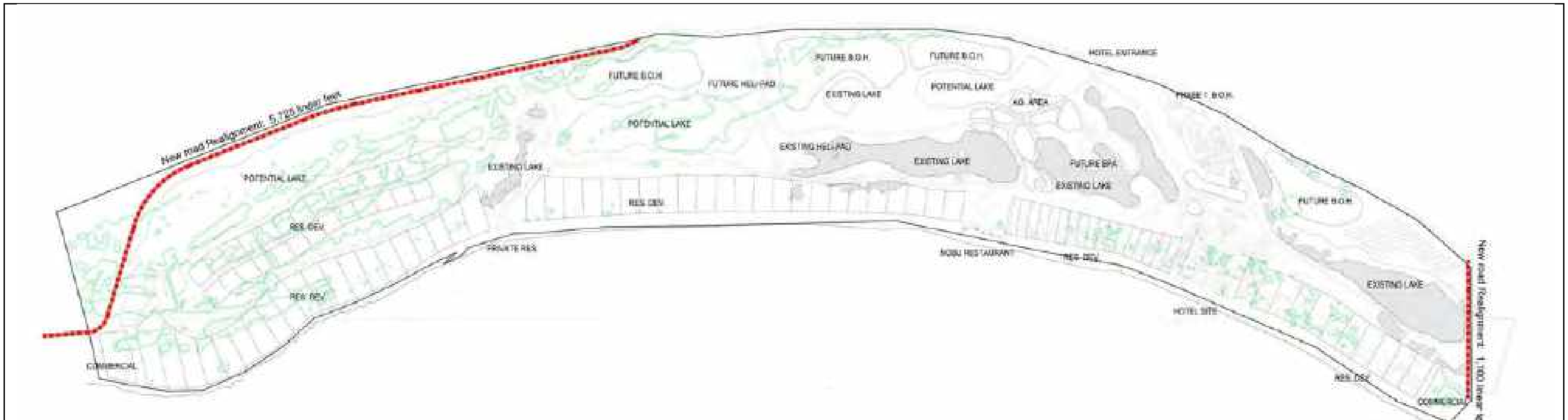

FIGURE 2-2: ROAD REALIGNMENTS 1 AND 2

2.6 Water Supply

Potable water for the hotel and private residences will predominantly be supplied by Flowtronex on-site seawater reverse osmosis desalination plants (SWRO) (there is currently a small SWRO unit and a well on the development site). Additional wells will be required for the new SWRO units. Brine water from the current SWRO unit is discharged into the hypersaline salt pond on site, and the additional SWRO units will either discharge into the same salt pond or into an injection well on the property.

Conscious of the scarcity of fresh water, this demand will be managed by employing water conservation techniques such as rainwater harvesting, installing water-efficient appliances and utilizing drought-tolerant landscape plants and turf grass. The Development plans call for the incorporation of rainwater harvesting into as many community buildings and residential homes as possible.

A minimum of ten days storage supply is planned for the Development. Water from these storage tanks will be piped to individual facilities through a system of buried distribution pipelines, fitted with valves as required. It is envisaged that this flow will be largely by gravity, but pumps will be installed where gravity flow will not be effective.

2.7 Electricity Supply

When fully built out, the projected electrical load demand for the Development will be 1.5MVA. Due to a lack of existing infrastructure on the island, the electrical power demand will initially be met through the use of diesel generators. To fuel these generators, diesel fuel will be stored on site in 9.1 m^3 volume (2.000 imperial gallons / 2,400 US gallons) tanks (see Photograph 2-3). Over time, the reliance on generators will be phased out in favor of more sustainable options, including photovoltaic systems and battery storage. The Development will eventually seek to be energy self-sufficient from these sustainable energy sources, with generators being available to provide a degree of redundancy.

2.8 Wastewater Treatment Plant

As no municipal wastewater treatment option is available on Barbuda, the Paradise Found development will construct a private facility to treat wastewater produced from the resort, while individual Beachfront Villas will be connected onto their own WWTPs. These will be aerobic treatment units which will produce effluent with a quality as summarized in Table 2-2. Treated effluent will be further disinfected with UV or chlorine and pumped out for landscape irrigation.

PHOTOGRAPH 2-3: EXISTING DIESEL FUEL TANK ON SITE

TABLE 2-2: BIONEST DESIGN EFFLUENT QUALITY

PARAMETER	EFFLUENT CONCENTRATION
pH	6.6 to 7.8
Total Suspended Solids	<2 mg/L
BOD_5	<2 mg/L
COD	<25 mg/L
Total Nitrogen	<12.5 mg/L
Faecal Coliform (after Chlorine Disinfection)	0 CFU/100 mL
Dissolved Oxygen	>3.2 mg/L
Chlorine Residual (after 30 min Contact Time)	>0.5 mg/L

Given the arrangement of wastewater treatment at individual buildings, there will be no need to provide central sewerage throughout the development. Instead, toilet water and gray water will be routed to the wastewater treatment plants through relatively short lengths of buried sewers. Manholes will also be provided where required to facilitate flow or to permit inspection and clearing of chokes.

2.9 Road Traffic

There will be an increase in road traffic during both the construction and operation phases of this Development. During construction, equipment and material must be transported to the site by road. The contractor is likely to bring some construction equipment to the island for use on this project. This will arrive on Barbuda on ships and will be transported to the site on lowboy trucks. Some construction material will be sourced locally (gravel and sand, premixed cement and asphalt), which will be transported to the site in dump trucks. Other construction material (cement, precast concrete culvert pipes, PVC pipes, roofing sheets, doors and windows, plumbing material and electrical items) will be imported to the island by ship either in shipping containers or as bulk cargo. From the port, these materials will be transported to the site by road.

During the operation of the Development, supplies will be transported to the site in vans and trucks, and waste material will be hauled to the landfill in trucks. Visitors to the Hotel, Villas and Homes will access the site in cars, either owned or rentals, or by taxis.

3 EMERGENCY PREPAREDNESS

This chapter presents information and describes tasks which must be undertaken before an emergency occurs, to ensure that Paradise Found is prepared to address emergencies in an efficient and effect manner.

3.1 Organization Charts and Responsibilities

This section presents organization charts and describes responsibilities for the construction and operation phases of this project. Responsibilities will be described in significantly more detail in Chapter 5, Emergency Response Procedures.

3.1.1 Construction Phase

Figure 3-1 shows the organization chart for the construction phase of this project. For a disaster which occurs during the construction phase, responsibilities will be as described generally below.

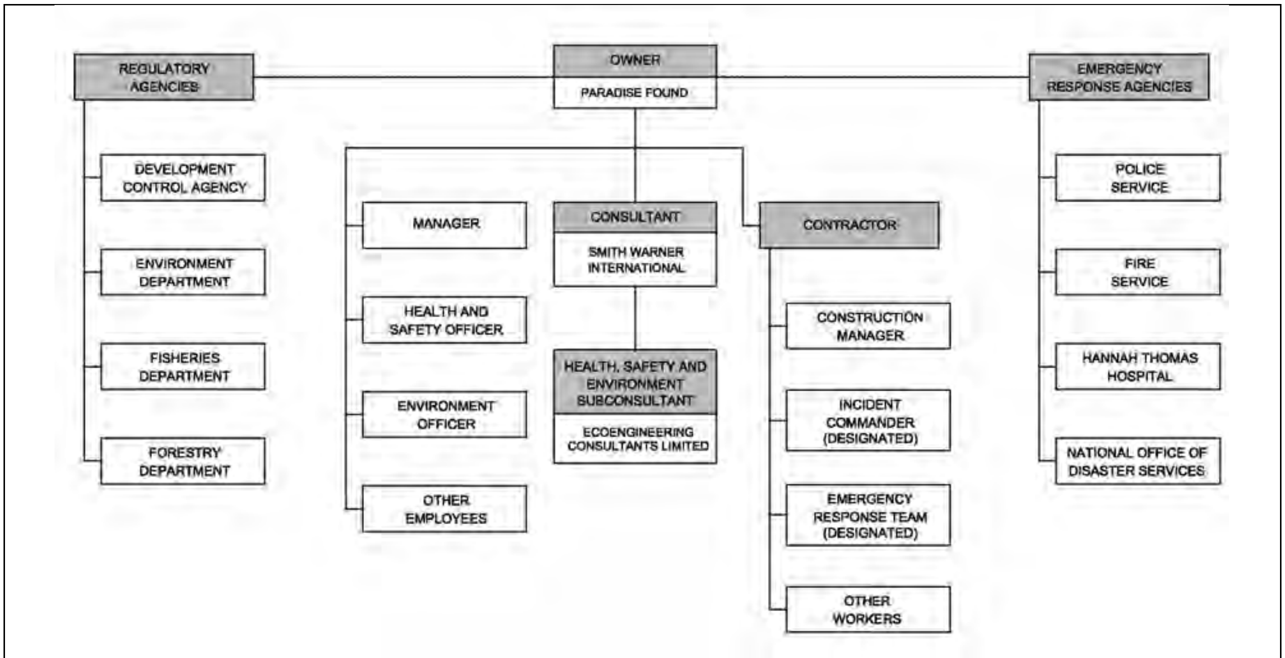

FIGURE 3-1: CONSTRUCTION PHASE ORGANIZATION CHART

a) Paradise Found

During the construction phase, Paradise Found should be staffed with a Manager, a Health and Safety Officer, an Environmental Officer and other staff. As owner of the project, Paradise Found, the Owner, will have the following responsibilities:

- Authorize the spending of funds for implementing the emergency response plan.
- Liaise with and request any additional resources or equipment needed from external agencies.
- Declare and conclude emergencies in consultation with the Contractor and the Consultant. Decision-making will rely on information provided by the National Office of Disaster Services (NODS)., especially in the case of natural disasters.

The Paradise Found Manager will represent Paradise Found in the day-to-day oversight of the construction works and the implementation of the emergency effort. He will supervise the Health and Safety Officer, the Environmental Officer, and other employees such as technicians. The Health and Safety and Environmental Officers will assist in assessing the safety and environmental condition of the site following a disaster. They will also verify that the response effort and recovery works are effectively implemented and that the site is suitable for resumption of construction.

The Consultant will liaise with the Owner, the Contractor, and the Project Manager in the aftermath of a natural disaster or a fire to advise on:

- The safety of buildings and infrastructure following disasters such as fires, earthquakes and hurricanes which can potentially affect integrity.
- Recovery efforts required for construction to resume.

b) The Contractor(s)

The Contractor will be responsible for constructing the facility and associated works in accordance with the design drawings and specifications. The Contractor's team will be headed by a Construction Manager, who will manage the work of his own staff and subcontractors. His team will also include a designated Incident Commander who will be responsible for the overall management of the response; and an Emergency Response Team which will be made up of firefighters, first aiders, wardens, communications personnel, etc.

The Construction Manager and her/his team will be responsible for:

- Ensuring all information is communicated clearly and calmly to the public and staff.
- Roll call and accountability of all persons at the muster points.

- Ensuring all injured persons are removed from the affected area and are seeking medical care as necessary.

- Reporting to the Paradise Found Manager.

c) Emergency Response Agencies

The Emergency Response Agencies will discharge the following responsibilities:

- The Police Service's responsibilities include:
  - Maintenance of Law and Order,
  - Search and Rescue,
  - Traffic and Crowd Control,
  - Identification of deceased individuals,
  - Establishment of incident command and control.

- The Fire Service's responsibilities include:
  - Assist in detecting, controlling, and suppressing fires.
  - Coordinate national resources for search and rescue operations during an emergency or disaster that is beyond the capabilities of Paradise Found.
  - Search and rescue (land and water).

- Hannah Thomas Hospital will provide ambulance transport and medical attention.

- The National Office of Disaster Services, who will:
  - Inform citizens of an impending or ongoing disaster.
  - Work alongside other first responders, emergency personnel, and private enterprises to reduce the impacts of hazards on the affected site personnel.
  - Verify that adequate evacuation / egress plans exist for Paradise Found.
  - Verify that emergency response plans for Paradise Found are prepared, updated, and implemented as necessary.

d) Regulatory Agencies

Among the Regulatory Agencies:

- The Development Control Authority will advise Paradise Found on rebuilding standards which must be adhered to if buildings and infrastructure which have been damaged or destroyed.

- The Environment, Fisheries and Forestry Departments will be responsible for overseeing the environmental performance of the project. They will also assess damage to environmental components of the site following a hurricane or storm surge and advise on appropriate options which may be adopted during the recovery phase.

3.1.2 Operation Phase

Figure 3-2 shows the organization chart for the operation phase of this project. Responsibilities of the Owner, the Emergency Response Agencies and the Regulatory Agencies are described generally in this section.

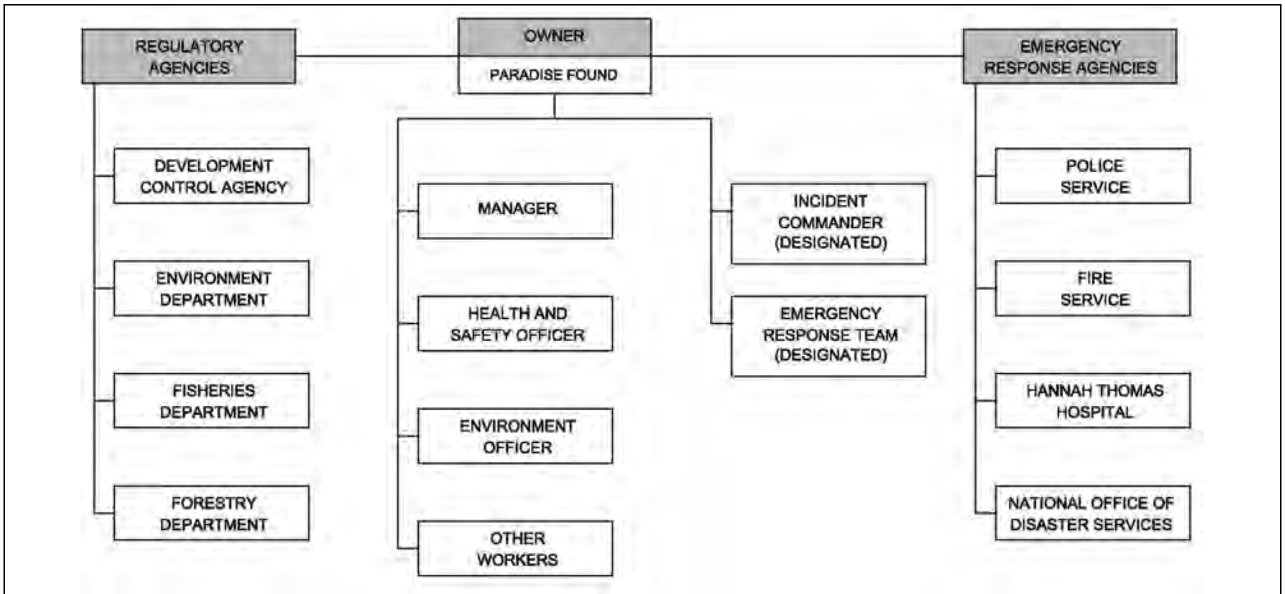

FIGURE 3-2: OPERATION PHASE ORGANIZATION CHART

a) Paradise Found

Staff of Paradise Found during the operation phase should be the same as described in Section 3.1.1 for the construction phase. Paradise Found as Owner will have the following responsibilities:

- Authorize the spending of funds for implementing the emergency response plan.
- Liaise with and request any additional resources or equipment needed from external agencies.
- Designate and train an Incident Commander and an Emergency Response Team.
- Declare and conclude emergencies.

The Paradise Found Facility Manager will represent the Owner in the day-to-day operation of the resort, oversight of the construction works and the implementation of the emergency effort. He will supervise the Health and Safety Officer, the Environmental Officer and other employees. The Health and Safety Officer will be responsible for accounting for all visitors and staff at the muster points; ensuring all injured persons are removed from the affected area and are seeking medical care as necessary; and assessing the safety of the site for re-entry. Environmental

Officers will assess the environmental condition of the site following a disaster, particularly as it relates to the presence of pollutants. These officers will also verify that the response effort and recovery works are effectively implemented and that the site is suitable for continuation of operations.

In the aftermath of a natural disaster or a fire, Paradise Found may need to hire a consultant to advise on the safety of buildings and infrastructure following disasters such as fires, earthquakes, and hurricanes, which can potentially affect structural integrity.

The designated Incident Commander will be responsible for the overall management of the response and overseeing the Emergency Response Team made up of firefighters, first-aiders, wardens, communications personnel, etc. He will also liaise with the other members of the response team; obtain up-to-date information and ensure all information is communicated clearly and calmly to the public and staff.

b) Emergency Response Agencies

The responsibilities of specific Emergency Response Agencies comprise:

- The Police Service, whose responsibilities include:
- Maintenance of Law and Order,
- Search and Rescue,
- Traffic and Crowd Control,
- Identification of deceased individuals,
- Establishment of incident command and control.

- The Fire Service will:
- Assist in detecting, controlling, and suppressing fires.
- Coordinate national resources for search and rescue operations during an emergency or disaster that is beyond the capabilities of Paradise Found.
- Search and rescue (land and water).

- The Hannah Thomas Hospital will provide ambulance transport and advance emergency medical attention.

- The National Office of Disaster Services who will:
- inform citizens of an impending or ongoing disaster.
- Work alongside other first responders, emergency personnel, and private enterprises to reduce the impacts of hazards on the affected site personnel.
- Verify that adequate evacuation / egress plans exist for Paradise Found.
- Verify that emergency response plans for Paradise Found are prepared, updated, and implemented as necessary.

c) Regulatory Agencies

The responsibilities of specific Regulatory Agencies comprise:

- The Development Control Authority (DCA) will advise Paradise Found on rebuilding standards which must be adhered to if buildings and infrastructure which have been damaged or destroyed are to be reconstructed.

- The Environment, Fisheries and Forestry Departments will be responsible for overseeing the environmental performance of the project. They will also assess damage to environmental components of the site following a hurricane or storm surge event and will advise on appropriate options which may be adopted during the recovery phase.

3.2 Muster Points and Evacuation Routes

Muster points and evacuation routes must be chosen relatively early in the construction and operation phases. Muster points are relatively safe locations where persons can gather when an emergency occurs, to verify that everyone is accounted for and available to receive instructions. On this project, multiple muster points will be required. Evacuation routes will be used to move from the hotel, the villas and houses to the appropriate muster point in each case. Muster points and evacuation routes must be clearly marked and maintained unobstructed throughout the construction and operation phases.

3.3 On-Site Resources

Equipment and materials must be provided on site to respond to emergencies. This should include:

- Buildings designed and designated as Emergency Shelters,

- A Siren System at the Hotel to warn Guests and Staff when an Emergency arises,

- Oversized Water Tanks to provide Fire Fighting Water in storage,

- Fire Extinguishers in the Hotel and in individual Houses,

- Adequately stocked First Aid Kits in the Hotel and in individual Houses,

- Supplies of Non-Perishable Food in the Hotel and in individual Houses,

- Generators at the Hotel for use in case of Loss of Electricity Supply, and

- Walkie-Talkie Radio Sets for use by Incident Commanders and Emergency Response Teams.

3.4 Training

All personnel who will be called upon to respond to an emergency must be trained in advance to carry out their functions. The training will include the following:

- **Construction Manager** and **Paradise Lost Project Manager** must receive project-specific training on what constitutes a risk incident, to whom this information is to be communicated and by what method communication is to be done.

- Designated **Incident Commanders** must be trained in Incident Command and Incident Analysis. Standard courses on these topics are available in the West Indies (for example, in Barbados, Jamaica and Trinidad and Tobago).

- **Other Members of the Incident Response Team** must be trained in First Aid, including CPR. Again, standard First Aid Courses are available in the West Indies (for example, in Barbados, Jamaica and Trinidad and Tobago).

Each training course listed above will have a period of validity (for example, three years in the case of First Aid Training), and training must be repeated before the end of that period of validity in each case.

3.5 Drills

Drills may take the form of desk-top exercises or full-scale exercises. The first two sub-sections below describe these two types of drills, and the third summarizes the frequencies of drills.

3.5.1 Desk-Top Drills

A Desk-Top Drill consists of group discussions where participants talk through the steps which will have to be taken in the event of the type of emergency under consideration, guided by a Moderator. An Auditor will also be present to listen to the discussion and take notes, but the Auditor will not take part in the discussions.

At the end of the Desk-Top Drill, the Auditor will report to the group on:

- What went Right - instances where the group demonstrated a proper understanding of the necessary steps;

- Problems Encountered – instances where particular steps were misunderstood or were forgotten altogether;

- Recommendations for Additional Training - based on the results above; and

- Recommendations of Changes – ways in which specific steps may be altered to improve their effectiveness.

The purpose of the Audit is NOT to assign blame, but rather to continually improve emergency response capabilities.

3.5.2 Full-Scale Drills

During a full-scale drill, personnel are expected to perform the necessary steps under the supervision of the Incident Commander and assisted by the Emergency Response Team. Such drills are vital to ensure that personnel understand and are competent in responding to different types of emergencies. Because they are more disruptive to normal operations, Full-Scale Drills are undertaken less frequently than Desk-Top Drills. Full-Scale Drills are also audited as described for Desk-Top Drills in Section 3.5.1.

3.5.3 Frequency of Drills

Table 3-1 summarizes the topics, types and frequencies of drills on this project.

TABLE 3-1: TOPICS, TYPES AND FREQUENCIES OF DRILLS

TOPIC	TYPE	FREQUENCY	PARTICIPANTS
Tropical Storm and Hurricane Preparedness Drill (including High Winds, Storm Surges and Intensive Rainfall)	Desk-Top	Twice per year, once before the start of the Rainy Season and once during the Rainy Season	- Construction Phase: Building Contractor(s) and Paradise Found Personnel. - Operation Phase: Paradise Found Personnel and available house owners.
Drought Preparedness Drill	Desk-Top	Once per year	Paradise Found Personnel and Landscaping Service Providers.
Earthquake Preparedness Drill	Desk-Top	Twice per year	- Construction Phase: Building Contractor(s) and Paradise Found Personnel. - Operation Phase: Paradise Found Personnel and available House Owners.
Vehicular Accident Drill	Desk-Top	Twice per year	- Construction Phase: Building Contractor(s) and Paradise Found Personnel.

TOPIC	TYPE	FREQUENCY	PARTICIPANTS
			- Operation Phase: Paradise Found Personnel and Available House Owners.
	Full-Scale	Every 18 months	Paradise Found Personnel
Fire Drill	Desk-Top	Twice per year	- Construction Phase: Building Contractor(s) and Paradise Found Personnel.
			- Operation Phase: Paradise Found Personnel and available House Owners.
	Full-Scale	Every 18 months	Paradise Found Personnel and Available House Owners.

3.6 Communication Systems

Several types of communication systems will be used on this project during emergencies, as shown in Table 3-2.

TABLE 3-2: COMMUNICATION SYSTEMS

PARTY 1	PARTY 2	COMMUNICATION SYSTEMS
Paradise Found Manager	Designated Incident Commander	i. Word-of-Mouth, ii. Mobile Phones
Paradise Found Manager or Incident Commander	Police Service, Fire Service, Ambulance or Hannah Thomas Hospital	Telephone (see Contact Numbers in Table 3-3)
Incident Commander	Emergency Response Team Members	i. Mobile Phones, ii. Walkie-Talkie Radios
Paradise Found Manager or Incident Commander	Owners Occupiers of Villas and Houses	Telephone (contact list to be developed and updated continuously by the Paradise Found Manager's Secretary as villas and houses are occupied.
Paradise Found Manager or Incident Commander	Neighbours who may be affected by a Risk Incident at Paradise Found Development	Telephone (contact list to be developed and updated fortnightly by the Paradise Found Manager's Secretary.

TABLE 3-3: PHONE NUMBERS OF KEY RESPONSE AGENCIES

RESPONSE AGENCY	PHONE NUMBER
Hannah Thomas Hospital	+1 (268) 460 0076
Ambulance Service	+1 (268) 736 5100
Fire Service Emergency Numbers	911 or 999
Police Service Emergency Numbers	911 or 999
National Office of Disaster Services	+1 (268) 462 4206

4 MANAGING AN EMERGENCY

This chapter describes the steps in managing an Emergency, as defined in Section 1.2.

4.1 Declaring an Emergency

Identifying an Emergency is the responsibility of the Construction Manager during the construction phase, and the Paradise Found Manager during the operation phase. As soon as an Emergency is identified, the Construction Manager or the Paradise Found Manager will declare the Emergency and notify the designated Incident Commander.

4.2 Activating the System

Immediately upon being notified that an Emergency has been declared, the Incident Commander will assume responsibility for activating and implementing the Emergency Response System. Activating the system will consist of the following actions:

- Assemble the Emergency Response Team.
- Rapidly analyse the incident and identify at-risk parties.
- Notify at-risk parties of the emergency.
- Determine the level of emergency (see Section 1.2.2).
- Notify the Hospital, Ambulance Service, Fire Service and Police Service of the emergency. This notification will be <u>for immediate action</u> in the case of Level 2 or Level 3 emergencies, but <u>for information only</u> in the case of a Level 1 Emergency.

Communication systems in each case are listed in Section 3.6.

4.3 Release of Equipment and Material

Once an Emergency has been declared, the Construction Manager and the Paradise Found Manager must instruct their subordinates that equipment and material on the site are to be released to the Incident Commander upon request for use in emergency response. The person releasing equipment and material must keep lists of what has been handed over, including the date and time of handing over.

4.4 Risk Reduction Measures

The heart of this Disaster Management Plan, as with any Emergency Response Plan, is the implementation of risk reduction measures. This task may be required in the design phase, the construction phase, or the operation phase of the project, depending on the nature of the measures to be implemented. Table 4-1 summarises risk reduction measures to be implemented on the Paradise Found Development.

TABLE 4-1: SUMMARY OF RISKS AND RISK REDUCTION MEASURES

RISK	BRIEF DESCRIPTION	RISK REDUCTION MEASURES	RISK SIGNIFI-CANCE
Hurricane Winds	Wind associated with a major hurricane (Category 3 or higher)	○ Design buildings to resist wind loads as prescribed in the Caribbean Unified Building Code (CUBiC). ○ Inform arriving visitors about evacuation procedures. ○ Arrange for evacuation when a hurricane watch, or warning is issued. ○ Provide specially reinforced buildings within the development to serve as hurricane shelters for staff and any visitors who cannot (or decide not to be) evacuated ahead of the arrival of a hurricane.	**MEDIUM**
Storm Surges	Surges resulting from a tropical cyclone passing through the Region.	○ Observe the 100-foot (30 m) setback which has been established for Barbuda. ○ Design shoreline buildings on 8 to 10 foot (2.4 to 3 m) stilts to cater for storm surges.	**MEDIUM**
Excessive Rainfall	Intensive rainfall resulting from a tropical cyclone crossing or close to Antigua and Barbuda, or due to other weather phenomena.	Design the on-site drainage system to efficiently remove storm water from the vicinity of buildings and landscaped areas (this will reduce but not entirely eliminate consequences of an excessive rainfall event).	**MEDIUM**
Drought	Mechanical failure of a desalination plant during a	○ Stand-by arrangements for the purchase of potable water	**LOW**

RISK	BRIEF DESCRIPTION	RISK REDUCTION MEASURES	RISK SIGNIFI-CANCE
	period of drought.	until the desalination plant is repaired. ○ Arrange for the timely repair of the desalination plant, including the availability of skilled technicians and the purchase of parts.	
Earthquake	Antigua and Barbuda are situated in a seismically-active zone and have experienced tremors and aftershocks.	Design earthquake-resistant structures as specified in the Caribbean Unified Building Code (CUBiC).	LOW
Vehicular Accident	Accident involving a truck during the construction phase, or cars, vans and trucks during the operation phase.	○ Provided Defensive Driving training for employees of the development, especially those who drive trucks. ○ Car rental companies must ensure that the guest who will be driving have valid drivers licenses, and are aware that driving in Barbuda is on the left hand side of the road.	LOW
Fire in a Building	Fire in any building at the hotel, the villas or the individual houses.	○ Provide Fire Hydrants every 100 feet (30 m) along the roads within the Development. ○ Store of Water for Fire Fighting within the Development. ○ Provide Fire Alarms and Sprinkler Systems in each building. ○ Inform visitors about fire alarm and evacuation procedures.	MEDIUM
Risk at an LPG Cylinder	Damaged piping from a 100 lb or 20 lb LPG cylinder, leading to a fire	○ Shut off the Cylinders when they are not in use, and ○ Routinely inspect the LPG piping for signs of damage or rusting, and replace if these are found.	LOW

RISK	BRIEF DESCRIPTION	RISK REDUCTION MEASURES	RISK SIGNIFI-CANCE
Risk at a Diesel Tank	Spillage from a diesel tank, leading to a fire	○ Adhere to the standard practice of providing Secondary Containment around the Diesel Tank, ○ Remove spilled Diesel from the Secondary Containment as soon as practicable, and ○ Provide a foam-type Fire Extinguisher within the Development.	**LOW**
Untreated Sewage Discharge Risk	Arises out of the failure of one or several of the 91 sewage treatment systems which will be constructed at the hotel, the villas and the houses; leading to eutrophication in the receiving pond and/or human health concerns.	○ Select wastewater treatment systems that are adequately sized to receive the combination of toilet waste and grey water from the hotel, villas and houses; ○ Carefully choose the types of chemicals which are used in toilets, sinks and bathrooms and for laundering at the hotel, villas and houses; so that they are not incompatible with the aeration of aerobic wastewater treatment systems. ○ Maintain and repair all of the wastewater treatment systems in strict accordance with the manufacturer's recommendations. To facilitate this, have a standing arrangement with a suitably competent firm to undertake this work on a regular schedule.	**MEDIUM**

4.5 Evacuation (When Necessary)

All Emergencies do not require evacuation, but arrangements must be made in advance to effect rapid evacuation if this becomes necessary. Such arrangements would include:

- Designate members of the Emergency Response Team to check buildings to ensure that no one is left behind.
- Provide wheelchairs and stretchers, with attendants, to remove persons who require assistance (elderly persons, the infirm and those who may be affected by smoke inhalation).
- Arrange for vehicles to transport persons off-site, as required.
- Activate emergency shelters, as required.

4.6 Ending an Emergency

When an Emergency has been brought fully under control and risks have been eliminated, the Incident Commander will declare that it is ended. Buildings and areas must be assessed by competent persons for safe re-entry and safe resumption of construction or operation work. The members of the Emergency Response Team will return to their normal duties, and other persons can return to the locations from which they were evacuated. Equipment which was released for use in emergency response will be returned to the persons from whom it was obtained, along with any unused materials.

4.7 Post-Emergency Review

As soon as convenient after the Emergency has ended, a Post-Emergency Review should be conducted. Participants should include the Paradise Found Manager, the Construction Manager (if the emergency was during the construction phase), the Incident Commander, the Emergency Response Team and representatives of Government Response Agencies (if available). As with drills (see Section 3.5), the review should focus on:

- What went Right - instances where the steps taken were effective in addressing the emergency and reducing risk;
- Problems Encountered – instances where particular steps were not effective or could not be undertaken for practical reasons;
- Recommendations of Changes – ways in which specific steps may be altered to improve their effectiveness, and
- Recommendations for Additional Training - based on the results above.

Again, the purpose of the Review is **NOT** to assign blame, but rather to continually improve emergency response practices. Information from this post-emergency review is to be used to revise and update the Disaster Management Plan, as appropriate.

5 EMERGENCY RESPONSE PROCEDURES

This chapter outlines general procedures for a number of critical incidents, including natural disasters that may occur during the construction and operation of the development. These include:

- Hurricane Winds,
- Storm Surges or Excessive Rainfall,
- Drought,
- Earthquake,
- Vehicular Accident,
- Fire, and
- Untreated Sewage Disposal Risk.

5.1 Hurricane Winds

Antigua and Barbuda have experienced a total of 21 tropical cyclones (tropical storms and hurricanes) since 1950, of which 6 were major hurricanes. Given the type of damage which can result from hurricane winds, Paradise Found must ensure that there are specially-reinforced buildings within the development to serve as hurricane shelters for staff and any visitors who cannot (or decide not to) be evacuated ahead of the arrival of a hurricane, and ensure access to such buildings as needed.

As a hurricane approaches Barbuda, the National Office of Disaster Services (NODS) will issue a Hurricane Watch to indicate a possible threat within 48 hours, followed by a Warning to indicate that a hurricane is expected in 36 hours or less. On being informed of a Hurricane Watch for the island, steps will be taken to protect people and equipment such that construction or operation can resume efficiently afterwards. The following actions will be taken on receipt of official bulletins from NODS.

5.1.1 Construction Phase Emergency Response

For Hurricanes which arise during the Construction Phase:

a) The Incident Commander will:

- Declare the level of the emergency depending on the severity of the tropical cyclone; and update the level of emergency if the intensity of the hurricane changes.
- Assemble the Emergency Response Team.
- Assume control of Emergency Shelters.
- Arrange for inspecting / “sweeping” areas to ensure all personnel and visitors have been accounted for.

- Coordinate emergency response at Paradise Found with national emergency response efforts.
- Notify external agencies such as Fire Service, Police Service and the Hospital if rescue or medical attention are required.
- Issue evacuation orders (when appropriate).
- Request from the Contractor any additional equipment or materials that are needed for emergency response.
- Advise the Paradise Found Manager of any injuries so that the next of kin may be notified.
- Declare when the emergency has ended, on advice from Government Agencies.

b) The Contractor will:

- Ensure that glass windows are boarded up when a Hurricane Warning is issued.
- Ensure that fuel reserves for generators are filled and units are operational.
- Secure equipment and materials onsite or remove them to a safe storage location.
- Send workers home sufficiently early to ensure that on-site personnel are out of harm.
- Ensure that all workers who remain on site have safe accommodation and arrange for temporary accommodation / shelters for workers.
- Select and notify the employees who are to return to the site after the storm has passed.
- Provide or acquire any additional equipment or material needed from emergency response as requested by the Incident Commander.
- Inform the Incident Commander of any injuries or fatalities.
- Notify workers of the all clear once the Incident Commander has declared that the emergency has ended.

Throughout any incident response period, the Contractor will inform and update the Paradise Found Manager of actions taken.

c) The Paradise Found Manager will notify the next-of-kin of any injured persons.

d) Staff, Visitors and Other Persons who remain on site will:

- Remain in a safe area and not attempt to evacuate or leave the area unless absolutely necessary or when instructed to do so by a member of the Emergency Response Team.
- Check their surroundings for hazards (such as debris, flooding, etc.), and report such to the Emergency Response Team.
- Notify the Emergency Response Team of any injured persons.
- Provide assistance to the Emergency Response Team as and when requested.

5.1.2 Operation Phase Emergency Response

For Hurricanes which arise during the Operation Phase, the basic approach would be to evacuate visitors from Barbuda as long as there is sufficient advance notice, and the ferries and planes continue to operate. The Paradise Found Manager and her / his staff will assist visitors in arranging flights and getting them to the airport or sea port. In addition:

a) The Incident Commander will undertake the same tasks as listed in Section 5.1.1(a), except that equipment and material will be requested from the Paradise Found Manager.

b) The Paradise Found Manager will undertake the tasks listed for the Contractor in Section 5.1.1(b), and will notify the next-of-kin of any injured persons (see Section 5.1.1(c).

c) On-site Personnel and Visitors will undertake the same tasks as listed in Section 5.1.1(d).

5.2 Storm Surges or Excessive Rainfall

Tropical Cyclones (tropical storms and hurricanes) may result in storm surges and excessive rainfall which can cause flooding of the site, but storm surges may also result from tropical cyclones passing some distance from Barbuda and excessive rainfall may occur independent of tropical cyclones. Periods of excessive rainfall are normally forecast by the Meteorological Office, but forecasting of storm surges is not available. Following the declaration of an Emergency arising from a storm surge or excessive rainfall by the Construction Manager (construction phase) or the Paradise Found Manager (operation phase), the following actions will be undertaken.

5.2.1 Construction Phase Emergency Response

For Storm Surges or Excessive Rainfall which occur during the Construction Phase:

a) The Incident Commander will:

- Declare the level of the emergency depending on the level of damage which has been experienced.
- Assemble the Emergency Response Team.
- Assume control of on-site Emergency Shelters.
- Arrange for inspecting / "sweeping" areas to ensure all personnel and visitors have been accounted for.
- If an island-wide emergency response effort has been mounted, coordinate the Paradise Found emergency response with that effort.
- Notify external agencies such as Fire Service, Police Service and the Hospital if rescue or medical attention are required.
- Issue evacuation orders (when appropriate).
- Request from the Contractor any additional equipment or materials that are needed for emergency response.
- Advise the Paradise Found Manager of any injuries so that the next of kin may be notified.
- Declare when the emergency at Paradise Found has ended.

b) The Contractor will:

- Fuel generators and bring them into use as required. If on-site generators have been damaged by flooding, replacement units must be obtained as soon as practical.
- Secure equipment and materials onsite or remove them to a safe storage location.
- Send home workers who are not immediately required for the emergency response, but advise them when they should return to work.
- Ensure that all workers who remain on site have safe accommodation and arrange for temporary accommodation / shelters for workers.
- Provide or acquire any additional equipment or material needed from emergency response as requested by the Incident Commander.

- Inform the Incident Commander of any injuries or fatalities.
- Notify workers of the all clear once the Incident Commander has declared that the emergency at Paradise Found has ended.

Throughout any incident response period, the Contractor will inform and update the Paradise Found Manager of actions taken.

c) The Paradise Found Manager will notify the next-of-kin of any injured persons.

d) Staff, Visitors and Other Persons who remain on site will:

- Remain in a safe area and leave the area when instructed to do so by a member of the Emergency Response Team.
- Check their surroundings for hazards (such as debris, flooding, etc.), and report such to the Emergency Response Team.
- Notify the Emergency Response Team of any injured persons.
- Provide assistance to the Emergency Response Team as and when requested.

5.2.2 Operation Phase Emergency Response

For Storm Surges or Excessive Rainfall which occur during the Operation Phase:

a) The Incident Commander will undertake the same tasks as listed in Section 5.2.1(a), except that equipment and material will be requested from the Paradise Found Manager.

b) The Paradise Found Manager will undertake the tasks listed for the Contractor in Section 5.2.1(b) and will notify the next-of-kin of any injured persons (see Section 5.2.1(c)).

c) On-site Personnel and Visitors will undertake the same tasks as listed in Section 5.1.1(d).

5.3 Drought

This emergency relates to a mechanical failure of a desalination plant at the time of a drought. Such an event can affect both construction and operation of Paradise Found Development, but it will be more significant during operation of the resort because of the potentially large number of visitors who will be present on a continuous basis.

This is one type of emergency when the Incident Commander may not assume control of the situation and call up the Emergency Response Team. Instead, desalination plant failure during a drought can be managed by the Construction Manager (construction phase) or the Paradise Found Manager (operation phase).

5.3.1 Construction Phase Emergency Response

In the event of the mechanical failure of an on-site desalination plant during a drought during the construction phase,

a) the Contractor will:

- Liaise with the Paradise Found Manager to request an emergency water supply from off-site sources.
- Temporarily discontinue construction work activities which require a significant water supply.
- Temporarily demobilize construction workers from the site, keeping only Security Personnel, the Incident Commander and Members of the Emergency Response Team in case another type of emergency should arise.

b) the Paradise Found Manager will:

- Assist the Contractor in obtaining an emergency water supply from off-site sources.
- Temporarily discontinue high-water-demand activities such as watering of landscaped areas.
- Temporarily demobilize employees from the site, keeping only Supervisory Staff and Security Personnel who are required to secure and maintain the site.

c) All personnel who remain on site while the desalination plant is non-functional will obey all emergency water conservation measures temporarily instituted by the Construction Manager or the Paradise Found Manager.

5.3.1 Operation Phase Emergency Response

In the event of the mechanical failure of an on-site desalination plant during a drought during the operation phase,

a) the Paradise Found Manager will:

- Request an emergency water supply from off-site sources.

- Respond to the needs of any visitors who encounter a situation where water is critically needed.

- Advise all guests of the situation and the length of time that it is expected to take to repair the desalination plant.

- Assign administrative staff to assist guests who decide to leave in making travel arrangements.

- Temporarily discontinue high-water-demand activities such as circulating water in swimming pools and watering of landscaped areas.

- Temporarily demobilize employees from the site, keeping only Supervisory Staff, Security Personnel and a Skeleton Staff to maintain the reduced operation of the Development.

b) All persons (staff, homeowners and visitors) who remain on site while the desalination plant is non-functional:

- Must obey all emergency water conservation measures temporarily instituted by the Paradise Found Manager.

- Will advise the Paradise Found Manager if any situations arise where water is critically needed.

5.4 Earthquake

In the event of an earthquake, all personnel must take cover to protect themselves until tremors have subsided. Emergency response can then commence. Following the declaration of an Emergency arising from earth tremors and aftershocks by the Construction Manager (construction phase) or the Paradise Found Manager (operation phase), the following actions will be undertaken.

5.4.1 Construction Phase Emergency Response

If an earthquake occurs during the construction phase,

a) The Incident Commander will:

- Declare the level of the emergency depending on the severity of damage caused by the tremors and aftershocks; and update the level of emergency if the intensity of the hurricane changes.

- Assemble the Emergency Response Team.

- Assume control of on-site Emergency Shelters.
- Arrange for inspecting / “sweeping” areas to ensure all personnel and visitors have been accounted for.
- On completion of the structural inspection by the Contractor, declare and cordon off any areas of the site that are unsafe and therefore access by untrained personnel is not permitted.
- Coordinate emergency response at Paradise Found with national emergency response efforts.
- Notify external agencies such as Fire Service, Police Service and the Hospital if rescue or medical attention are required.
- Issue evacuation orders (when appropriate).
- Request from the Contractor any additional equipment or materials that are needed for emergency response.
- Advise the Paradise Found Manager of any injuries so that the next of kin may be notified.
- Declare when the emergency has ended when the site has been rendered safe and all injured persons have been cared for.

b) The Contractor will:

- Conduct a head count of construction workers and advise the Incident Commander of any persons who are not accounted for.
- Verify that emergency access / egress routes are clear and safe.
- Control persons entering the site.
- Conduct an inspection of buildings and structures and inform the Incident Commander of any buildings and structures which are unsafe.
- Ensure that generators are fuelled and operational.
- Secure equipment and materials onsite or remove them to a safe storage location.
- Send non-essential workers home in a timely fashion to ensure that on-site personnel are out of harm.

- Ensure that all workers who remain on site have safe accommodation and arrange for temporary accommodation / shelters for workers.
- Inform workers when they are expected to return to work.
- Provide or acquire any additional equipment or material needed for emergency response as requested by the Incident Commander.
- Inform the Incident Commander of any injuries or fatalities.
- Notify workers of the all clear once the Incident Commander has declared that the emergency has ended.

Throughout any incident response period, the Contractor will inform and update the Paradise Found Manager of actions taken.

c) The Paradise Found Manager will notify the next-of-kin of any injured persons.

d) Staff, Visitors and Other Persons who remain on site will:

- Remain in a safe location until the tremors have abated and departure from the site is approved by the Incident Commander.
- Check their surroundings for hazards (such as fire, spills, hazardous structures etc.), and notify a member of the Emergency Response Team of such hazards.
- Notify a member of the Emergency Response Team of any injured persons.
- Provide assistance to the Emergency Response Team as and when requested.

5.4.2 Operation Phase Emergency Response

For tremors and aftershocks which occur during the operation phase,

a) The Incident Commander will undertake the same tasks as listed in Section 5.4.1(a), except that equipment and material will be requested from the Paradise Found Manager.

b) The Paradise Found Manager will undertake the tasks listed for the Contractor in Section 5.4.1(b) and will notify next of kin of injured persons (see Section 5.4.1(c).

c) On-site Personnel and Visitors will undertake the same tasks as listed in Section 5.4.1(d).

5.5 Vehicular Accident

Vehicular accidents are another instance when deployment of the full Emergency Response Team may not be necessary. Depending on how far the accident occurs from the site, the Police and Ambulance may arrive on the scene before personnel can be mobilized from the site, and they will begin emergency response without awaiting the arrival of Contractor or Paradise Found personnel. Notwithstanding, at least the Incident Commander must visit the scene of the accident as soon as practical after it has occurred. Therefore, the Incident Commander must be dispatched to the scene by the Construction Manager (if the accident has occurred during the construction phase), or by the Paradise Found Manager (if the accident has occurred during the operation phase). In addition, at least two members of the Emergency Response Team should be put on standby until the Incident Manager has evaluated the seriousness of the accident.

Upon arrival at the scene of the accident, the Incident Commander will:

- Initiate first aid to injured parties if she/he arrives before the ambulance, or assist the ambulance personnel if they arrive first.
- Call in other members of the Emergency Response Team if additional help is required.
- Advise the Paradise Found Manager of the names of injured parties so that the next of kin can be notified.
- Establish the Level of Emergency. An accident will always start as a Level 2 Emergency because the Police will be involved, but it may escalate to a Level 3 Emergency if the doctors at Hannah Thomas Hospital determine that injuries are so severe that the patients must be taken off-island for treatment.
- Gather and document information on the nature of the accident and possible causes, as well as the names and contact information of the Police Officers on the scene and any witnesses.

5.6 Fire

A fire can occur in a building or can result from a leak at the diesel tank or from a gas leak from LPG cylinders. Following the declaration of an Emergency related to a fire on site by the Construction Manager (construction phase) or the Paradise Found Manager (operation phase), the following actions will be undertaken.

5.6.1 Construction Phase Emergency Response

a) The Incident Commander will:

- Declare the level of the emergency depending on the size of the fire and the risk of spreading; and update the level of emergency if the fire escalates.

- Assemble the Emergency Response Team.
- Inform the Fire Service of the Fire, and clearly indicate whether they are required on site.
- Assume control of on-site Emergency Shelters.
- Designate a sufficient Exclusion Zone around the Fire where only the Fire Service and the Emergency Response Team may enter.
- Arrange for inspecting / “sweeping” areas to ensure all personnel and visitors have been accounted for.
- Call out the Fire Service if the Fire threatens to escalate beyond the capability of on-site resources to contain it and extinguish it.
- Notify external agencies such as Ambulance Service, Police Service, and the Hospital if rescue or medical attention are required.
- Issue evacuation orders (when appropriate).
- Request from the Contractor any additional equipment or materials that are needed for emergency response.
- Advise the Paradise Found Manager of any injuries so that the next of kin may be notified.
- Declare when the emergency has ended, on advice from Government Agencies.

b) The Contractor will:

- Ensure that all valves are open to permit the free flow of water from the Fire Water Tank to the Hydrants closest to the Fire.
- Ensure that generators are fuelled and operational.
- Conduct a head count of all Construction Workers to ensure that they are all accounted for.
- Secure equipment and materials onsite or remove them to a safe storage location.
- Send non-essential workers home in a timely fashion to ensure that on-site personnel are out of harm.
- Ensure that all workers who remain on site have safe accommodation and arrange for temporary accommodation / shelters for workers.

- Select and notify the employees who are to return to the site after the fire has been extinguished.
- Provide or acquire any additional equipment or material needed for emergency response as requested by the Incident Commander.
- Inform the Incident Commander of any injuries or fatalities.
- Notify workers of the all clear once the Incident Commander has declared that the emergency has ended.

Throughout any incident response period, the Contractor will inform and update the Paradise Found Manager of actions taken.

c) The Paradise Found Manager will notify the next-of-kin of any injured persons.

d) Staff, Visitors and Other Persons who remain on site will:

- Remain in a safe location until the fire has been extinguished and entry into restricted areas has been approved by the Incident Commander.
- Check their surroundings for hazards (such as smouldering material, spills of fuel or lubricants, hazardous structures, etc.), and notify a member of the Emergency Response Team of such hazards.
- Notify a member of the Emergency Response Team of any injured persons.
- Aid the Emergency Response Team as and when requested.

5.6.2 Operation Phase Emergency Response

For fires which occur during the operation phase,

a) The Incident Commander will undertake the same tasks as listed in Section 5.6.1(a), except that equipment and material will be requested from the Paradise Found Manager.

b) The Paradise Found Manager will undertake the tasks listed for the Contractor in Section 5.6.1(b) as well as notify next-of-kin of injured persons as indicated in Section 5.6.1(c).

c) On-site Personnel will undertake the same tasks as listed in Section 5.6.1(d).

5.7 Untreated Sewage Discharge Risk

This is yet another type of emergency where the Incident Commander and full Emergency Response Team need not be mobilized. Instead, the response can be managed by the Construction Manager (during the construction phase) or the Paradise Found Manager (during the operation phase.

a) When it is discovered that a sewage treatment system has failed, the appropriate manager will:

- Notify all staff, construction workers and visitors of the situation.
- Contact the Supplier of the Sewage Treatment System (construction phase) or the contracted Repair and Maintenance Service Provider and arrange for them to come to the site and attend to the problem in the shortest time practical.
- Arrange to have an Engineer trace the path by which untreated sewage is flowing to one of the ponds.
- In consultation with the appropriate Health, Safety and Environment Officers, establish a Restricted Zone around the receiving salt pond.
- Ensure that any person who begins to show symptoms of a gastro-intestinal illness is taken to see a private doctor or taken to the Hannah Thomas Hospital.

b) All other persons on site must obey the restricted zone to avoid contact with sewage-contaminated water.

Annex 1

DISASTER MANAGEMENT PLAN:
QUALITATIVE RISK ASSESSMENT

This Qualitative Risk Assessment, which forms an appendix to the Disaster Management Plan for Paradise Found Development in Barbuda, begins with an Initial Risk Identification, followed by description of the Risk Rating Method. Each succeeding section pertains to the rating of a specific Credible Scenario.

A.1 INITIAL RISK IDENTIFICATION

Risks associated with this development include those arising from Natural Hazards as well as those arising from project activities. Led by Ecoengineering Consultants Limited (Ecoeng), the Smith Warner International (SWI) Team identified the following risks for analysis:

- Hurricane Winds,
- Storm Surges,
- Excessive Rainfall,
- Drought,
- Earthquake,
- Vehicular Accident,
- Fire in a Building,
- Risk at an LPG Cylinder (damaged piping from an LPG Cylinder, leading to a Fire),
- Risk at a Diesel Tank (spillage from a Diesel Tank, leading to a Fire), and
- Untreated Sewage Discharge Risks.

Useful information pertaining to each of these risks was obtained during meetings with Government Agencies in July, 2022. Based on that information and Ecoeng's considerable experience in preparing Qualitative Risk Assessments (QualRAs), these risks were developed into Credible Scenarios (see subsections below).

The Terms of Reference for the EIA for Paradise Found Development suggests that climate change risk should also be addressed in this DMP. Projected effects of climate change in the West Indies[1] include:

- More Frequent and More Intense Tropical Storms and Hurricanes,
- Longer Dry Seasons and Shorter Wet Seasons,
- Rise in Sea Levels and Increased Likelihood of Storm Surges,
- More Intense Rains leading to Increased Flash Floods.

All of these effects are included among the risks listed above, so a separate analysis of climate change risk to this Development was not considered necessary.

[1] https://www.caribbeanclimate.bz/blog/2013/06/25/climate-change-and-the-caribbean-what-do-we-need-to-know/

A.1.1 Hurricane Winds

This Credible Scenario relates to wind associated with a major hurricane (Category 3 or higher). Antigua and Barbuda have experienced a total of 21 tropical cyclones[2] (tropical storms and hurricanes) since 1950, of which 6 were major hurricanes:

- Baker[3] in 1950 – Category 3 with sustained winds of 185 km/h in the vicinity of Antigua and Barbuda;
- Dog[4] in 1950 - Category 4 with sustained winds of 130 km/h and gusts of 144 km/h in the vicinity of Antigua and Barbuda;Donna[5] in 1960 – Category 3 in the vicinity of Antigua and Barbuda;
- Luis[6] in 1995 – Category 4 with sustained winds of 217 km/h in the vicinity of Antigua and Barbuda;
- Georges[7] in 1998 – Category 3 with sustained winds of 151 km/h and gusts up to 186 km/h in the vicinity of Antigua and Barbuda; and
- Irma[8] in 2017 – Category 5 with sustained winds of 285 km/h in the vicinity of Antigua and Barbuda.

A.1.2 Storm Surges

Unlike Hurricane Winds, which are worst when hurricanes pass over or close to Barbuda, Storm Surges may also be generated by tropical cyclones that pass some distance from Barbuda. Information provided by the Development Control Authority at a meeting on July 14, 2022, is that storm surges of 8 to 10 feet (2.4 to 3 m) have been experienced in Barbuda.

A.1.3 Excessive Rainfall

Excessive / Intensive Rainfall is frequently associated with hurricanes and other tropical cyclones, of which the following are examples:

- Hugo[9] in 1989 caused extensive flooding in Antigua;
- Jose[10] in 1999 caused flooding in Antigua and Barbuda;
- Lenny[11] in 1999 caused 65% flooding in Barbuda; and
- Omar in 2008 resulted in 230 mm of rainfall in Antigua and Barbuda.

Excessive rainfall may also occur independent of tropical cyclones, and the effects of Climate Change in the West Indies appear to be increasing the frequency of excessive rainfall which is not associated with hurricanes and tropical cyclones. The location of this project closely

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[2] https://en.wikipedia.org/wiki/Category:Hurricanes_in_Antigua_and_Barbuda
[3] https://en.wikipedia.org/wiki/Hurricane_Baker_(1950)
[4] https://en.wikipedia.org/wiki/Hurricane_Dog_(1950)
[5] https://en.wikipedia.org/wiki/Hurricane_Donna
[6] https://en.wikipedia.org/wiki/Hurricane_Luis
[7] https://en.wikipedia.org/wiki/Hurricane_Georges
[8] https://en.wikipedia.org/wiki/Hurricane_Irma
[9] https://en.wikipedia.org/wiki/Hurricane_Hugo
[10] https://en.wikipedia.org/wiki/Hurricane_Jose_(1999)
[11] https://en.wikipedia.org/wiki/Hurricane_Lenny

adjacent to salt ponds increases the potential for flooding as water levels in the ponds increase due to excessive rainfall.

A.1.4 Drought

Fresh water is a scarce commodity in Barbuda. The mean annual rainfall on the island[12] is only 939.8mm (37 inches), and ground water sources are generally brackish. As a result, potable water must be produced by desalination. The Drought Risk Map[13] for Barbuda, prepared by the Organization of American States, shows the project area to be in a zone of high drought risk. This scenario envisages mechanical failure of the desalination plant during a drought.

A.1.5 Earthquake

Antigua and Barbuda are situated in the northern Leeward Islands, in a seismically-active zone. Examples of recent earthquakes in the vicinity of Antigua and Barbuda are:

- Magnitude 5 Earthquake[14] on February 16, 2022, 53.6 km ESE of Falmouth, Antigua; and
- Magnitude 5 Earthquake[15] on September 20, 2021, located 71.5 km ESE of Falmouth, Antigua.

At meetings on July 11, 2022, the representatives of the Hannah Thomas Hospital and the Police Service both indicated that earthquake risk should be addressed in this analysis.

A.1.6 Vehicular Accident

The potential for vehicular accidents arises both during the construction phase and the occupancy phase of the Paradise Found Development. During the construction phase, there will be a significant number of vehicles (cars as well as trucks) transporting personnel, equipment, material and waste to and from the project site. During the occupancy phase, the majority of visitors to Paradise Found Development are expected to rent vehicles which they will drive themselves. Visitors from North America and Europe will be unfamiliar with driving on the left side of the road.

A.1.7 Fire in a Building

The potential for fire in a building exists for the Paradise Found Development, as it exists for any built development.

12 https://www.weather-atlas.com/en/antigua-and-barbuda-climate#climate_text_1
13 https://www.oas.org/pgdm/hazmap/drought/bar_map.pdf
14 https://www.ccrif.org/publications/hazard-event-report/preliminary-event-briefing-earthquake-antigua-and-barbuda-february?language_content_entity=en
15 https://www.ccrif.org/publications/hazard-event-report/final-event-briefing-earthquake-antigua-and-barbuda-september-20?language_content_entity=en

A.1.8 Risk at an LPG Cylinder

LPG Cylinders will be installed both at the new restaurant and at individual homes. Based on present practice, the cylinder at the new restaurant is expected to be 100 lb cylinders, while those at the individual homes are expected to be 20 pound cylinders. Damage to the cylinders themselves is very uncommon, so this Credible Scenario is based on damage to the line connecting the cylinder to the stove, leading to leakage of LPG gas and subsequently a fire.

A.1.9 Risk at a Diesel Storage Tank

Diesel Storage Tanks will be used within the development to provide fuel for generators, desalination plants, etc. Based on the size of the diesel tank presently on site, the tank in the new development is expected to be 9.1 m^3 in volume (2.000 imperial gallons / 2,400 US gallons). Complete failures of such tanks are very uncommon, so this Credible Scenario is based on a spill of diesel during loading the tank or from failure of the piping, followed by ignition.

A.1.10 Untreated Sewage Discharge Risks

When Phases 1 and 2 of this Development come into operation, the estimated potable water demand will be 682,000 L/day (150,000 gallons per day). Applying a conversion factor of 85% potable water to sewage, an estimated 580,000 L/day (128,000 gallons per day) of sewage will be produced on this site. Almost 12% of this amount will come from the Hotel and Back of House Facility, and this will be treated in a 68 L/day (15,000 gallons per day) Bionest aerobic treatment unit. The remaining 88% will be treated in smaller individual treatment units at individual villas and houses. Based on a total of 90 villas and houses, there will be 91 wastewater treatment systems on this property at full build-out. This scenario is based on the mechanical or biological failure of several of these wastewater treatment systems, resulting in the release of poorly treated or untreated sewage into surface drainage, leading to one or several of the salt ponds on site.

A.2 RISK RATING METHOD

Risk is defined as a factor of the consequences of a Credible Scenario and the likelihood of occurrence. In this Qualitative Risk Assessment, the level of risk is determined using a Risk Rating Matrix, as will be described in this section.

A.2.1 Consequences

The risk ranking matrix used on this assignment is based on:

- Consequences to Persons,
- Consequences to the Environment, and
- Financial Consequences.

In each case, the consequences are defined at five levels of severity:

1. Minor,
2. Notable,
3. Significant,
4. Important, and
5. Major.

These levels are defined in the following sub-sections.

A.2.1.1 Consequences to Persons

Consequences to persons relate to injury or fatality, and the levels of consequences are as follows:

LEVEL OF CONSEQUENCE	DEFINITION
Minor	Injury / illness that can be treated with first aid, not requiring the attention of a medical professional.
Notable	Injury / illness requiring trained medical attention without time away from work or a hospital stay.
Significant	Injury / illness requiring a stay at the hospital.
Important	Loss of one life or irreversible health damage or physical injury without loss of life.
Major	Death of more than one person.

A.2.1.2 Consequences to the Environment

Consequences to the environment relate to damage to plants or animals, or discharges/emissions that affect ambient noise, air quality, water quality or soil conditions. The levels of consequences are as follows:

LEVEL OF CONSEQUENCE	DEFINITION
Minor	Impacts which affect a limited area and will naturally remediate over time.
Notable	Impacts which are reversible but require proactive steps in the short term to afford remediation.
Significant	Damage which can only be remediated using sustained measures in the medium to long term.
Important	Permanent, irreversible damage to a common species or an environmental component which is prevalent locally.
Major	Permanent, irreversible damage to a rare or endangered species or locally unique environmental component.

A.2.1.3 Financial Consequences

Financial consequences relate to damage to property or possessions, expressed as replacement cost. The levels of consequences are as follows:

LEVEL OF CONSEQUENCE	DEFINITION
Minor	Less than $US 25,000.
Notable	$US 25,000 to $US 249,999.
Significant	$US 250,000 to $US 499,999.
Important	$US 0.5 million to $US 1.49 million.
Major	More than $US 1.5 million.

A.2.2 Likelihood

The likelihood that a specific Credible Scenario will occur is also expressed at five levels, as follows:

LEVEL OF LIKELIHOOD	DEFINITION
Near-impossible	Has never been reported previously in the West Indies.
Improbable	Reports of previous occurrence in the West Indies are few or not well documented.
Occasional	Not expected to occur more than once in a decade.
Probable	Expected to occur between once per decade and once per year.
Frequently Occurs	Expected to occur more than once per year.

A.2.3 Risk Rating Matrix

This matrix was used to rate each of the Credible Scenarios listed in Section A.1:

CONSEQUENCES				LIKELIHOOD				
SEVERITY	Applicable Type			A Near Impossible	B Improbable	C Occasional	D Probable	E Frequently Occurs
	To Persons	To the Environ	Financial					
1: Minor				LOW	LOW	LOW	LOW	LOW
2: Notable				LOW	LOW	LOW	MEDIUM	MEDIUM
3: Significant				LOW	LOW	MEDIUM	MEDIUM	HIGH
4: Important				LOW	MEDIUM	MEDIUM	HIGH	HIGH
5: Major				MEDIUM	MEDIUM	HIGH	HIGH	HIGH

This matrix is formatted as follows:

- The first column lists the five levels of consequences (lowest to highest, top to bottom).
- The next three columns indicate the type of consequence which is applicable to the analysis, the applicable cell being marked with an "X".
- The next five columns each pertain to a different level of likelihood (lowest to highest, left to right).
- Within the last five columns, the risk rating corresponding to each combination of consequence and likelihood are shown as "Low" (coloured in green), "Medium" (coloured in yellow) and "High" (coloured in red).

To apply this matrix, risk reduction measures for a particular Credible Scenario are determined. The applicable levels of consequence and likelihood for that Credible Scenario are evaluated, assuming the effective implementation of the risk reduction measures. The values are then applied to the respective rows and columns, and the risk rating is given by the cell where they intersect. Where a scenario gives rise to consequences of more than one type, the one with the highest level is used.

The interpretation of the risk ratings are as follows:

- Risks rated "Low" are considered to be tolerable.
- Risks rated "Medium" should be reduced As Low as Reasonably Practicable (ALARP). That is, additional risk reduction measures must be sought in an attempt to reduce the rating to "Low". However, "Medium" risks are tolerated if it is not possible to reduce them to "Low" after applying the additional risk reduction measures.
- Risks which are rated "High" are considered to be unacceptable, and must be reduced to "Medium" or "Low" by applying additional risk reduction measures. If it is not possible to reduce the risk of a Credible Scenario below "High", then the activities giving rise to that scenario should not be undertaken.

A.3 SCENARIO 1 - HURRICANE WINDS

This scenario pertains to winds associated with a major hurricane.

A.3.1 Risk Reduction Measures

Three risk reduction measures are available to address this scenario:

- Design buildings to resist wind loads as prescribed in the Caribbean Unified Building Code (CUBiC).
- Inform arriving visitors about evacuation procedures.
- Arrange for evacuation of visitors when a hurricane watch or warning is declared.

- Provide specially reinforced-buildings within the development to serve as hurricane shelters for staff and any visitors who cannot (or decide not to be) evacuated ahead of the arrival of a hurricane.

A.3.2 Consequences

Assuming the effective implementation of the risk reduction measures above, the projected consequences of this Scenario are:

- Notable Injuries to Persons (requiring trained medical attention without time away from work or a hospital stay); and
- Significant Damage to Properties ($US 250,000 to $US 499,999).

A.3.3 Likelihood

The frequency of major hurricanes passing within 120 km of Barbuda is once every 15 years[16]. This is classified as an "Occasional" level of likelihood.

A.3.4 Rating

This scenario is rated as a Medium Risk, as shown below.

CONSEQUENCES				LIKELIHOOD				
SEVERITY	Applicable Type			A Near Impossible	B Improbable	C Occasional	D Probable	E Frequently Occurs
	To Persons	To the Environ	Financial					
1: Minor				LOW	LOW	LOW	LOW	LOW
2: Notable	✖			LOW	LOW	LOW	MEDIUM	MEDIUM
3: Significant			✖	LOW	LOW	MEDIUM	MEDIUM	HIGH
4: Important				LOW	MEDIUM	MEDIUM	HIGH	HIGH
5: Major				MEDIUM	MEDIUM	HIGH	HIGH	HIGH

[16] http://www.antiguamet.com/Climate/STATS/AntiguaBarbudaTCClimo.pdf

A.4 SCENARIO 2 - STORM SURGES

This scenario pertains to surges arising from tropical cyclones.

A.4.1 Risk Reduction Measures

During a meeting on July 14, 2022, the Development Control Authority advised on two risk reduction measures:

- Barbuda has a 100 foot (30 m) setback from the shoreline, which is greater than the setback in Antigua.
- Buildings should be designed on 8 to 10 foot (2.4 to 3 m) stilts to cater for storm surges.

A.4.2 Consequences

Assuming the effective implementation of the risk reduction measures above, the projected consequences of this Scenario are:

- Notable Injuries to Persons (requiring trained medical attention without time away from work or a hospital stay); and
- Notable Damage to Properties ($US 25,000 to $US 249,999).

A.4.3 Likelihood

Storm surges may arise from minor as well as major hurricanes, and named storms can pass within 120 km of Barbuda is once every 3 years[17]. This is classified as a "Probable" level of likelihood.

A.4.4 Rating

This scenario is rated as a Medium Risk, as shown below.

CONSEQUENCES				LIKELIHOOD				
SEVERITY	Applicable Type			A Near Impossible	B Improbable	C Occasional	D Probable	E Frequently Occurs
	To Persons	To the Environ	Financial					
1: Minor				LOW	LOW	LOW	LOW	LOW
2: Notable	✖		✖	LOW	LOW	LOW	MEDIUM	MEDIUM
3: Significant				LOW	LOW	MEDIUM	MEDIUM	HIGH
4: Important				LOW	MEDIUM	MEDIUM	HIGH	HIGH
5: Major				MEDIUM	MEDIUM	HIGH	HIGH	HIGH

[17] http://www.antiguamet.com/Climate/STATS/AntiguaBarbudaTCClimo.pdf

A.5 SCENARIO 3 - EXCESSIVE RAINFALL

This scenario pertains to intensive / excessive rainfall, which may be associated with tropical cyclones or may occur at other times.

A.5.1 Risk Reduction Measures

The only practical measure to reduce this risk is to design the on-site drainage system to efficiently remove storm water from the vicinity of buildings and landscaped areas. This will reduce but not entirely eliminate consequences of an excessive rainfall event.

A.5.2 Consequences

Assuming the effective implementation of the risk reduction measure above, the projected consequences of this Scenario are:

- Notable Water Damage to Properties ($US 25,000 to $US 249,999); and
- Minor Water Damage to Landscaped Areas (affecting a limited area which will naturally remediate over time.).

A.5.3 Likelihood

Rainfall sufficiently intense to cause flood damage is expected to occur up to once per year, but not more than once per year. This is classified as a “Probable” level of likelihood.

A.5.4 Rating

This scenario is rated as a Medium Risk, as shown below.

CONSEQUENCES				LIKELIHOOD				
SEVERITY	Applicable Type: To Persons	To the Environ	Financial	A Near Impossible	B Improbable	C Occasional	D Probable	E Frequently Occurs
1: Minor		✖		LOW	LOW	LOW	LOW	LOW
2: Notable			✖	LOW	LOW	LOW	MEDIUM	MEDIUM
3: Significant				LOW	LOW	MEDIUM	MEDIUM	HIGH
4: Important				LOW	MEDIUM	MEDIUM	HIGH	HIGH
5: Major				MEDIUM	MEDIUM	HIGH	HIGH	HIGH

A.6 SCENARIO 4 - DROUGHT

This scenario pertains to drought conditions, and envisages mechanical failure of the desalination plant during a drought.

A.6.1 Risk Reduction Measures

Two risk reduction measures are available to address this scenario:

- Have stand-by arrangements for the purchase of potable water until the desalination plant is repaired.
- Have a standing contract for the timely repair of the desalination plant, including the availability of skilled technicians and the purchase of parts.

A.6.2 Consequences

Even with the risk reduction measures above, temporary loss of water supply will have the following consequences:

- Notable cost of Repair of the Desalination Plant and Purchasing of Water ($US 25,000 to $US 249,999); and
- Minor Drought Damage to Landscaped Areas (affecting a limited area which will naturally remediate over time).

A.6.3 Likelihood

The project area is situated in an area of high drought risk (see Section A.1.4), but the likelihood of mechanical failure of the desalination plant during a drought is not expected to occur more frequently than once every 10 years. This is classified as an “Occasional” level of likelihood.

A.6.4 Rating

This scenario is rated as a Low Risk, as shown below.

CONSEQUENCES				LIKELIHOOD				
	Applicable Type							
SEVERITY	To Persons	To the Environ	Financial	A Near Impossible	B Improbable	C Occasional	D Probable	E Frequently Occurs
1: Minor		X		LOW	LOW	LOW	LOW	LOW
2: Notable			X	LOW	LOW	LOW	MEDIUM	MEDIUM
3: Significant				LOW	LOW	MEDIUM	MEDIUM	HIGH
4: Important				LOW	MEDIUM	MEDIUM	HIGH	HIGH
5: Major				MEDIUM	MEDIUM	HIGH	HIGH	HIGH

A.7 SCENARIO 5 - EARTHQUAKE

This scenario pertains to tremors and aftershocks arising from earthquakes located some distance from Barbuda.

A.7.1 Risk Reduction Measures

The appropriate risk reduction measure is to design earthquake-resistant structures as specified in the Caribbean Unified Building Code (CUBiC).

A.7.2 Consequences

The historical record shows no severe structural damage from earthquakes in the recent past. As such, the credible consequences would be minor damage to structures (less than $US 25,000). Personal injury is not considered a credible consequence.

A.7.3 Likelihood

Based on the historical record, damage to structures from earthquakes is not expected to occur more frequently than once every 10 years. This is classified as an “Occasional” level of likelihood.

A.7.4 Rating

This scenario is rated as a Low Risk, as shown below.

CONSEQUENCES				LIKELIHOOD				
SEVERITY	Applicable Type			A Near Impossible	B Improbable	C Occasional	D Probable	E Frequently Occurs
	To Persons	To the Environ	Financial					
1: Minor			X	LOW	LOW	LOW	LOW	LOW
2: Notable				LOW	LOW	LOW	MEDIUM	MEDIUM
3: Significant				LOW	LOW	MEDIUM	MEDIUM	HIGH
4: Important				LOW	MEDIUM	MEDIUM	HIGH	HIGH
5: Major				MEDIUM	MEDIUM	HIGH	HIGH	HIGH

A.8 SCENARIO 6 - VEHICULAR ACCIDENT

This scenario involves a vehicular accident involving an employee or guest at the development.

A.8.1 Risk Reduction Measures

To address this scenario, employees of the development should be provided with Defensive Driving training, especially those who drive trucks. Persons responsible for renting cars to guests must ensure that the guest who will be driving has a valid drivers license, and are aware that driving in Barbuda is on the left hand side of the road.

A.8.2 Consequences

At a meeting with the Barbuda Police Service on July 11, 2022, Ecoeng was informed that there are very few traffic accidents on the island, resulting in minor vehicular damage and personal injury. Serious injuries and fatalities are not a problem.

A.8.3 Likelihood

As noted above, there are reported to be very few accidents in Barbuda. Based on this statement from the police, it is anticipated that the likelihood of a traffic accident involving an employee or visitor to Paradise Found development would be Probable (expected to occur between once per decade and once per year).

A.8.4 Rating

This scenario is rated as a Low Risk, as shown below.

	CONSEQUENCES			LIKELIHOOD				
	Applicable Type							
SEVERITY	To Persons	To the Environ	Financial	A Near Impossible	B Improbable	C Occasional	D Probable	E Frequently Occurs
1: Minor	X		X	LOW	LOW	LOW	LOW	LOW
2: Notable				LOW	LOW	LOW	MEDIUM	MEDIUM
3: Significant				LOW	LOW	MEDIUM	MEDIUM	HIGH
4: Important				LOW	MEDIUM	MEDIUM	HIGH	HIGH
5: Major				MEDIUM	MEDIUM	HIGH	HIGH	HIGH

A.9 SCENARIO 7 - FIRE IN A BUILDING

This scenario involves a fire at one of the buildings at the development. At a meeting with the Fire Department on July 11, 2022, Ecoeng were informed that the only fire truck on the island is based at the airport, so it will take approximately 15 minutes for the fire truck to reach a fire in the Paradise Found development. Further, the Fire Service is equipped to fight fires in multi-storey buildings (more than 2 floors) nor at closely-spaced buildings.

A.9.1 Risk Reduction Measures

At the meeting on July 11, 2022 (see above), the Fire Service recommended the following risk reduction measures pertaining to a building fire at Paradise Found:

- Provision of Fire Hydrants every 100 feet (30 m) along the roads within the Development;
- Storage of Water for Fire Fighting within the Development;
- Provision of fire Alarms and Sprinkler Systems in each Building; and
- Inform visitors about fire alarm and evacuation procedures.

A.9.2 Consequences

Even assuming that the risk reduction measures listed above are effectively implemented, a fire can result in significant damage ($US 250,000 to $US 499,999) before it is put out, especially if it spreads to a second building. The presence of fire alarms will alert occupants to evacuate the building when a fire begins, but it is possible that an occupant can suffer notable injury (requiring trained medical attention without time away from work or a hospital stay) from smoke inhalation (for example) before being evacuated.

A.9.3 Likelihood

The Barbuda Fire Department did not provide information on the frequency of building fires on the island, but based on experience elsewhere in the West Indies this is expected to be an Occasional Scenario (not expected to occur more than once in a decade).

A.9.4 Rating

This scenario is rated as a Medium Risk, as shown below.

CONSEQUENCES				LIKELIHOOD				
SEVERITY	Applicable Type			A Near Impossible	B Improbable	C Occasional	D Probable	E Frequently Occurs
	To Persons	To the Environ	Financial					
1: Minor				LOW	LOW	LOW	LOW	LOW
2: Notable	✖			LOW	LOW	LOW	MEDIUM	MEDIUM
3: Significant			✖	LOW	LOW	MEDIUM	MEDIUM	HIGH
4: Important				LOW	MEDIUM	MEDIUM	HIGH	HIGH
5: Major				MEDIUM	MEDIUM	HIGH	HIGH	HIGH

A.10 SCENARIO 8 - RISK AT AN LPG CYLINDER

This scenario pertains to damaged piping from an LPG Cylinder, leading to a Fire.

A.10.1 Risk Reduction Measures

The measures available to reduce the risk of this scenario are:

- Shut off the Cylinders when they are not in use, and
- Routinely inspect the LPG piping for signs of damage or rusting, and replace if these are found.

A.10.2 Consequences

A fire associated with this scenario can result in:

- Significant Injury (requiring a stay at the hospital) to Persons in the Kitchen; and
- Notable Damage ($US 25,000 to $US 249,999) to the building.

A.10.3 Likelihood

Incidents of this type have been reported in the West Indies, but they are very few. This is therefore considered to be an Improbable Scenario.

A.10.4 Rating

This scenario is rated as a Low Risk, as shown below.

CONSEQUENCES				LIKELIHOOD				
SEVERITY	Applicable Type: To Persons	To the Environ	Financial	A Near Impossible	B Improbable	C Occasional	D Probable	E Frequently Occurs
1: Minor				LOW	LOW	LOW	LOW	LOW
2: Notable			X	LOW	LOW	LOW	MEDIUM	MEDIUM
3: Significant	X			LOW	LOW	MEDIUM	MEDIUM	HIGH
4: Important				LOW	MEDIUM	MEDIUM	HIGH	HIGH
5: Major				MEDIUM	MEDIUM	HIGH	HIGH	HIGH

A.11 SCENARIO 9 - RISK AT A DIESEL TANK

This Scenario relates to spillage of fuel at a Diesel Tank leading to a Fire.

A.11.1 Risk Reduction Measures

The measures available to reduce the risk of this scenario are:

- Adhere to standard practice of providing Secondary Containment around Diesel Tanks,
- Remove spilled Diesel from the Secondary Containment as soon as practicable, and
- Have a foam-type Fire Extinguisher available within the Development.

A.11.2 Consequences

A fire associated with this scenario can result in:

- Significant Injury (requiring a stay at the hospital) to Persons in the vicinity of the Diesel Tank at the time of the Fire;
- Significant Damage (which can only be remediated using sustained measures in the medium to long term) to Vegetation in the area of the Diesel Tank; and
- Minor Damage (Less than $US 25,000) to the Diesel Tank itself. Damage to Buildings is not anticipated since the Diesel Tank will be situated some distance from buildings.

A.11.3 Likelihood

Incidents of this type have been reported in the West Indies, but they are very few. This is therefore considered to be an Improbable Scenario.

A.11.4 Rating

This scenario is rated as a Low Risk, as shown below.

CONSEQUENCES				LIKELIHOOD				
SEVERITY	Applicable Type			A Near Impossible	B Improbable	C Occasional	D Probable	E Frequently Occurs
	To Persons	To the Environ	Financial					
1: Minor			X	LOW	LOW	LOW	LOW	LOW
2: Notable				LOW	LOW	LOW	MEDIUM	MEDIUM
3: Significant	X	X		LOW	LOW	MEDIUM	MEDIUM	HIGH
4: Important				LOW	MEDIUM	MEDIUM	HIGH	HIGH
5: Major				MEDIUM	MEDIUM	HIGH	HIGH	HIGH

A.12 SCENARIO 10 – UNTREATED SEWAGE DISCHARGE RISK

This scenario relates to the failure over time of several of the 91 wastewater treatment systems on this site, leading to the release of untreated or poorly treated sewage into surface drains which discharge into the salt ponds on site.

A.12.1 Risk Reduction Measures

In several parts of the West Indies (for example, Trinidad and Tobago) there is a history of failure of small biological sewage treatment systems due to inappropriate selection of units, the introduction of harmful chemicals (such as the use of strong bleaches to clean the toilets) or lack of adequate maintenance. Risk reduction measures are therefore:

- Select wastewater treatment systems that are adequately sized to receive the combination of toilet waste and grey water from the hotel, villas and houses;
- Carefully choose the types of chemicals which are used in toilets, sinks and bathrooms and for laundering at the hotel, villas and houses; so that they are not incompatible with the aeration of aerobic wastewater treatment systems.
- Maintain and repair all of the wastewater treatment systems in strict accordance with the manufacturer's recommendations. To facilitate this, have a standing arrangement with a suitably competent firm to undertake this work on a regular schedule.

A.12.2 Likelihood

The implementation of the risk reduction measures listed above will reduce but not entirely eliminate the possibility of failure of wastewater treatment units at Paradise Found Development. The large number of units (91, total) also increases the likelihood that at least some of them will fail over time. Based on experience elsewhere in the West Indies, it is estimated that failures will occur more frequently than 1 every 10 years, defined as "probable".

A.12.3 Consequences

Two sets of consequences may be anticipated when poorly or untreated sewage is discharged to the salt ponds:

- Eutrophication, and
- Human Health Consequences.

Eutrophication[18] describes the process by which excessive plant and algal growth occurs due to the increased availability of one or more limiting growth factors needed for photosynthesis, such as nutrient fertilizers. Untreated sewage is rich in nitrogen and phosphorus, and so it is a contributor to eutrophication. Eutrophication creates dense blooms of noxious, foul-smelling phytoplankton that reduce water clarity, limiting light penetration, reducing growth and causing die-offs of plants. Furthermore, high rates of photosynthesis associated with eutrophication can deplete dissolved oxygen and dissolved inorganic carbon, and raise pH; all of which adversely affect plant and animal life in water bodies. Eutrophication can be reversed, but requires sustained measures in the medium term. The environmental consequence is therefore defined as "significant" (see Section A.2.1.2)

Sewage and wastewater contain bacteria, fungi, parasites, and viruses[19] that can cause intestinal, lung, and other infections such as diarrhea, fever, cramps, and sometimes vomiting, headache, weakness, or loss of appetite. The presence of such contaminants in the salt ponds may lead to potential exposure of persons to sewage by hand-to-mouth contact or by wiping the face with contaminated hands or gloves. Exposure can also occur by skin contact, through cuts, scratches or penetrating wounds. Certain organisms can also enter the body through the surfaces of the eyes, nose and mouth and by breathing them in as dust, aerosol or mist. The illnesses listed above often require a stay at hospital for treatment, so this human health consequence is defined as "significant" (see Section A.2.1.1).

A.12.4 Rating

This scenario is rated as a Medium Risk, as shown below.

CONSEQUENCES				LIKELIHOOD				
SEVERITY	Applicable Type			A Near Impossible	B Improbable	C Occasional	D Probable	E Frequently Occurs
	To Persons	To the Environ	Financial					
1: Minor				LOW	LOW	LOW	LOW	LOW
2: Notable				LOW	LOW	LOW	MEDIUM	MEDIUM
3: Significant	X	X		LOW	LOW	MEDIUM	MEDIUM	HIGH
4: Important				LOW	MEDIUM	MEDIUM	HIGH	HIGH
5: Major				MEDIUM	MEDIUM	HIGH	HIGH	HIGH

18 https://www.nature.com/scitable/knowledge/library/eutrophication-causes-consequences-and-controls-in-aquatic-102364466/

19 https://dhss.delaware.gov/dph/files/sewagefaq.pdf