Studies for the Preparation of The Bahamas Risk-Resilient Integrated Coastal Zone Management Program: Component B – Coastal Protection Interventions

Provision of coastal studies and interventions for risk-resilient coastal protection measures at specific pilot study sites.

Project Data Sheet for Central New Providence: Junkanoo Beach, Nassau

1. Objectives

The primary objective is to provide strategic, climate risk-resilient, integrated management for the coastline at Junkanoo Beach in Central Nassau, New Providence. This can then lead to effective and sustainable management improvement though interventions including hard and soft engineering. Central Nassau is very dynamic in both land use and activities, and the waterfront is a fantastic asset for the City and residents. Many developments seek to make the most out of this asset, one recent development in this area being at The Pointe (the property immediately east of Junkanoo Beach).

The potential future interventions should be focused on the 950 meter long public beach section that is Junkanoo Beach (the beach between the new development at The Pointe at the east end and Arawak Cay at the west end), and inclusion of the main Nassau Breakwaters.

Further studies are required to look at strategic use of the frontage and will embrace the influences of the ongoing and near future development, into an integrated medium to longer term strategy for the frontage, this will also capture the targeted interventions for Junkanoo Beach.

The proposed interventions will aim to reduce overtopping flood risk and coastal erosion, whilst providing regeneration opportunities for business, amenities, tourism and real estate development, through the identification of associated economic benefits. Much of this links to the overall Sustainable City Vision for Nassau[1].

The sub-objective includes providing a scheme of works to enhance coastal protection, reduce overtopping and beach erosion and provide economic benefits along Junkanoo Beach incorporating the main breakwaters.

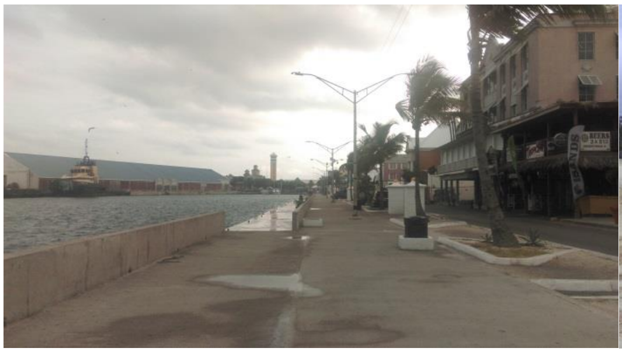
It is vital that this Project sits in the context of the Emerging and Sustainable Cities Initiative[1] of which Nassau is part. Many of the aspects covered in this Initiative whether it be climate change and urban development, fiscal and taxation application, public opinion and perception, investment in interventions and future monitoring of the effectiveness of these are inherently linked to the coastal zone in Nassau.

By enhancing the coastal zone and allowing this to be part of an improved resilience to climate and marine events, a wider improvement in the viability and sustainability of Nassau can be achieved. If the coastal edge is effectively managed then experience demonstrates that this can provide a massive injection of confidence to public and importantly private investment - in well considered and sustainable development. This can then lead to increasing employment and income streams. Conversely coastal city wide development programs that ignore the external factors associated with

[1] ERM (2016). Sustainable Cities: Nassau [Draft].

the sea, and fail to recognize potential vulnerability can derive wasted investments and reduction in confidence of those living and working near the coastline.

Figure 1: Access via promenades/along sea walls along the frontage currently varies and in many places is subject to frequent overtopping (for example Woodes Rogers Walk shown below).



Source: Mott MacDonald, 2016

Figure 2: Beach erosion/sand distribution at Junkanoo Beach means that the sand needs to be regularly cleared off the road and path ways.

Source: Mott MacDonald, 2016

2. Location

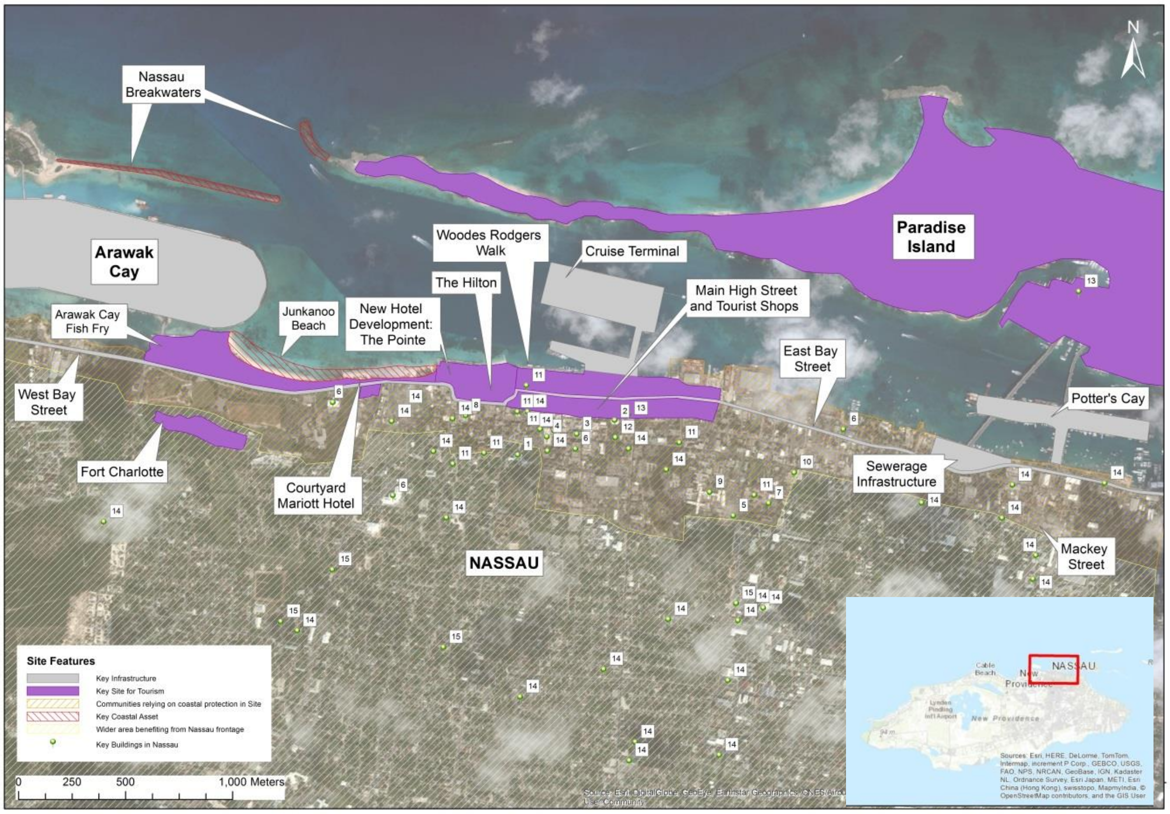
Nassau is the capital and largest city in The Bahamas. It is sited on New Providence Island which contains more than 70% of the total population of The Bahamas. Nassau city has a population of around 246,329 (2010 Census) and is considered to function as a business district for The Bahamas, with the majority of Government offices and Ministries sited in and around Nassau. Nassau is therefore a hub of economic activity for The Bahamas and is a critical strategic location for climate resilience.

The site defined here covers the stretch of frontage between Arawak Cay (west) to the new development ‘The Pointe’ (east) which is approximately 960 metres in length (see Figure 3). It is an important part of the tourism industry for The Bahamas being close to the downtown area and the cruise ship terminal. The frontage lends itself even at a high level management planning consideration to different sections, with their own characteristics and personality. Fundamentally these are:

- Arawak Cay and Nassau Harbour Breakwater: Industrial area, modern port, gateway to Nassau, some un-developed land.
- Arawak Cay to Junkanoo Beach: major tourism and recreation focus, local businesses ie Fish Fry, close connection to main artery road into Nassau West Bay Street, with associated services i.e. water and power located along and under it, hotels and restaurants on or close to the coastline and residential properties.
- The Pointe to Cruise Ship terminals: major hotel developments with commercial and government institutional buildings in near hinterland, many commercial business including service shops, retail and bars / restaurants, cruise facilities and supporting infrastructure.

- Cruise Ship terminals to Potter's Cay: old working wharf areas, locally in poor state of repair and derelict, local businesses in warehouses and open spaces, new marinas and park frontages and Potter's Cay development. Major assets also include water treatment plants.

Figure 3: Location Map



Reference for Key Buildings labelled:

1. Government House
2. The Supreme Court
3. Court of Appeal and Commonwealth
4. Central Bank of The Bahamas
5. CIBI First Caribbean International Banks
6. Government Building
7. Bahamas National Council of Disability
8. US Embassy
9. Princess Margaret Hospital
10. Doctor's Hospital
11. Museums
12. Nassau Public Library
13. Police Stations
14. Places of Worship
15. Schools

Source: Mott MacDonald, 2016 and ESRI mapping, 2016

3. Beneficiaries

Beneficiaries include:

- Residential properties;
- Local residents;
- Visitors/ tourists;
- Tourism economy;
- Shipping industry including users;
- Coastal hotels, bars and restaurants;
- National authorities, local authorities and planning agencies for the purpose of policy and planning decision making; and
- Numerous service providers that include water, drainage, electricity, fiber optics etc, especially with trunk routes along West Bay and Eat Bay Street.

There is a very transient population that occurs over a typical daily cycle that also varies through the week. When six (6) cruise ships are in harbour the frontage and high street west of the cruise terminal can be very busy with large numbers packed closely together, but on some Sunday evenings this area is nearly devoid of people. There are also other seasonal trends that occur with the presence of cruise ship visits and other visitors.

Many of the businesses here are aligned with this ebb and flow of people and are open accordingly from the high end jewelers and designer shops to the local bars on Junkanoo Beach. There is a major hotel presence at the British Colonial Hilton, soon to be joined by The Pointe Development, in addition to the development of the Courtyard Marriott by Junkanoo Beach. The effect of these developments is to bring in more people more regularly, however they are potentially at risk from coastal process and natural events, whilst also benefiting from the interface with the coastline.

The number of permanent residents are quite low in this frontage west of the Cruise Terminal, as many people travel in by car and bus to their places of work. East of the cruise terminal there are greater concentrations of residents and permanent commercial businesses south of East Bay Street.

As part of the current project there has been ongoing interaction with the Ministry of Tourism through the TAC representative Mr Earlston McPhee, and detailed information is being collated by Miss Georgina Delancy at the Ministry to provide the context of actual visitor surveys and numbers that flow through Nassau. Such information should be incorporated into future optioneering studies.

Ecosystems Services Considerations

In developing the overall structure for risk-resilient ICZM in The Bahamas, and the consideration of benefits of interventions under the current priority sites, and in the evaluations of the need for future interventions in The Bahamas, the incorporation of Ecosystems Services into those evaluations is very important.

However, following discussions with the BEST Commission, TAC and the IDB, it has been agreed that for this specific site, and considering the nature of the specific works proposed, that the value of instigating a full and thorough Ecosystems Services Analysis is not of value.

It should be noted however that the need for both environmental and ecological baseline surveys to inform option development, and feed into any Environmental and Social Management Plan to support planning decisions for the preferred option is still an important requirement.

4. Technical and economic justification

The frontage under consideration from Arawak Cay to the Pointe development provides the nearest beach to the main cruise terminal and the core commercial hub of Nassau with a number of hotels. Key coastal features nearby include:

- the Arawak Port and associated breakwater structure (Nassau Harbour Breakwater) that has been significantly damaged by storm events;
- the social hub of the Fish Fry areas with communal parking leading into the famous Junkanoo Beach;
- the new development of ‘The Pointe’ and the historic British Colonial Hilton;
- the commercial center up to the Cruise Terminals with the thoroughfares into the city center;

The direct hinterland includes major local and national assets including but not limited to: the lower Nassau Fort infrastructure and walls, the main road into the city from Bay Street, the main sewer, water treatment and water supply infrastructure, numerous businesses from high end chains to small vendors and the historical and financial center with many of the key Government Ministries.

There are many existing coastal protection assets along the frontage which provide important flood and erosion protection; however a number of them are recognized as being in a poor condition (such as the Nassau Harbour Breakwater). Furthermore, many of the sea walls allow a significant amount of overtopping which can flood footpaths and the road, and there is currently a high level of maintenance required regarding sediment movement on Junkanoo Beach. Therefore a number of interventions are required to upgrade defences, provide better resilience to flooding and to reduce maintenance efforts and spend over the long term.

Figure 4: Damaged east breakwater looking north west

Source: Baird

Technically the interaction between the main breakwaters and the current and wave conditions around Nassau Harbour is key to understanding the influence this has on the beach frontages and vulnerability of the overall coastline from future coastal erosion, increase in flood risk, sea level rise and coastal squeeze impacts.

Parts of Junkanoo Beach appear in a dynamic equilibrium with the current arrangements, but potential impacts of the new Pointe Development Marina and other structures that are to be built out from the current coastline are unknown at this time and may make this questionable. Between the western most outfall at Junkanoo Beach and Arawak Cay there is a definite westward migration of beach sediments, that strips the beach at the east end and accumulates it at the west end at Arawak Cay itself. This provides issues for the coastline here as coastal wall structures are undermined and a limestone platform is left which itself erodes. This increases erosion of the walls themselves. In areas where the beach is accumulating, sand covers the pathways and roads, providing a major nuisance and loss of valuable material, which requires ongoing maintenance, removal and replacement.

Ideally for technical completeness and value, the interaction between all the key elements should be considered together i.e. the breakwaters, dredged channel, existing and new development frontages. It has been suggested that modelling is undertaken as part of the design process to determine the detailed design of the breakwater and assess the potential influence of the breakwaters and erosion at the beach. This would provide further understanding of the coastal process and an integrated hard and soft engineering design for Junkanoo Beach that effectively maintains and enhances the beach providing additional amenity value and longer term climatic resilience of the coastline to natural events thereby protecting all the valuable existing and future assets.

Whilst all aspects of the integrated coastal management protection scheme for Junkanoo Beach must be considered together the following gives a brief background of each of the aspects.

The Main Breakwaters

The “abutment” section of the East breakwater (the transition/connection of the breakwater to Paradise Island) has been severely damaged, with a complete breach of the structure over a length of approximately 100 m. We understand that the damage occurred during the “Perfect Storm” in 1991, almost 20 years ago. As such, it appears that the wave agitation associated with this breach, as well as the materials that were displaced from the structure towards the channel, are not significant issues with respect to present operations in Nassau Harbour. Repair of the breakwater will be costly, and will only reduce the wave agitation in the harbour by a small amount. A cost/benefit analysis may be warranted to assess the need to repair the breach in the breakwater. The benefits could be further categorized for extreme storm waves versus typical (day to day) conditions. If the benefits are primarily for typical conditions, then the crest of the structure could be lower, allowing overtopping during severe storm events. However, the design of a low-crested structure would need to consider the risk of damage by severe overtopping to the crest and rear slope. This complex design issue is best addressed in a physical model.

The west breakwater (north of Arawak Cay) is also damaged having several breached areas. This breakwater provides protection to the port facilities at Arawak Cay which have been experiencing difficulties. Arawak Port Company have indicated that the condition of the breakwater is adversely affecting their capacity and efficiency, leading to reduced ship alongside time, and hindering un-loading activities. Further analysis may find that the west breakwater is a priority and that repairs to this portion of the breakwater would have the most benefit at this time

Based on very rough assumptions, we estimate that the per meter cost of the east breakwater repair would probably be in the range of USD 60,000 to 100,000. Over a 60 m gap in the breakwater, this

translates into 6 to 10 million for construction. On top of this, there would be mobilizations costs (15%), engineering costs (15%), supervision and environmental (10%). These extra costs could be in the range of 40% on top of the construction. This suggests that the final cost for the breakwater repair could be in the range of 8 to 14 million USD.

Note that these costs are based on approximate unit rates from past projects (roughly adjusted to Nassau), and are determined using very approximate water depths and assumed breakwater dimensions. The above costs would best be described as “engineering judgment” rather than a “cost estimate”.

Figure 5: Damaged east breakwater looking north west

Source: Plumgarden

Junkanoo Beach Frontage

As discussed elsewhere in this report the main issues at Junkanoo Beach are;

- Loss of sandy beach at certain locations (immediately west of groynes) thereby limiting the value of the beach asset and exposing seawalls to erosion.
- Damaged seawalls and footpath
- Flooding of main road (West Bay Street) and disused outfall on west end of Junkanoo Beach
- Sand deposits on the road south of the beach

West Bay Street drainage along this area is dependant in part on a drain at the east end at Nassau Street which drains into the nearby sheet pile jetty and at the west end at a drain in front of the Fort Charlotte rugby pitch. The road is known to flood between these locations regularly. The drain on West Bay Street in front of Fort Charlotte rugby pitch is often compromised due to blockages due to the large seagrapes leaves from the nearby vegetation. The chief drainage engineer for New Providence has suggested that the repair and upgrading of the existing outlet at the west end of Junkanoo Beach would help to alleviate flooding of this area. This outlt is located directly on the beach and as a result has been blocked as a result of sand washing into the outlet. Apparently this

has not been done to date due to health concerns of beach users who do not wish for drainage water to enter the beach area. This outlet is also an eyesore on the beach (see Figure 6 below). Recognising that the stabilisation of this beach is likely to require a new groyne near this area it is suggested that the outlet be repaired and upgraded to have a pollution control unit at the inlet and for the outlet to be located within the new groyne with the outlet a few feet clear of the seabed to limit the chances of future blockages.

Figure 6: Damaged Footpath Looking East (left). Looking west (Right)

Source: IDB

Figure 7: Damaged Drainage Outlet at West end of Junkanoo Beach

Source: IDB

5. Description

From the beginning of the project, potential options for coastal management in this area were considered for technical applicability and overall economic value. These have been presented to the TAC and also in multi stakeholder workshops. However, potential solutions and thinking have evolved

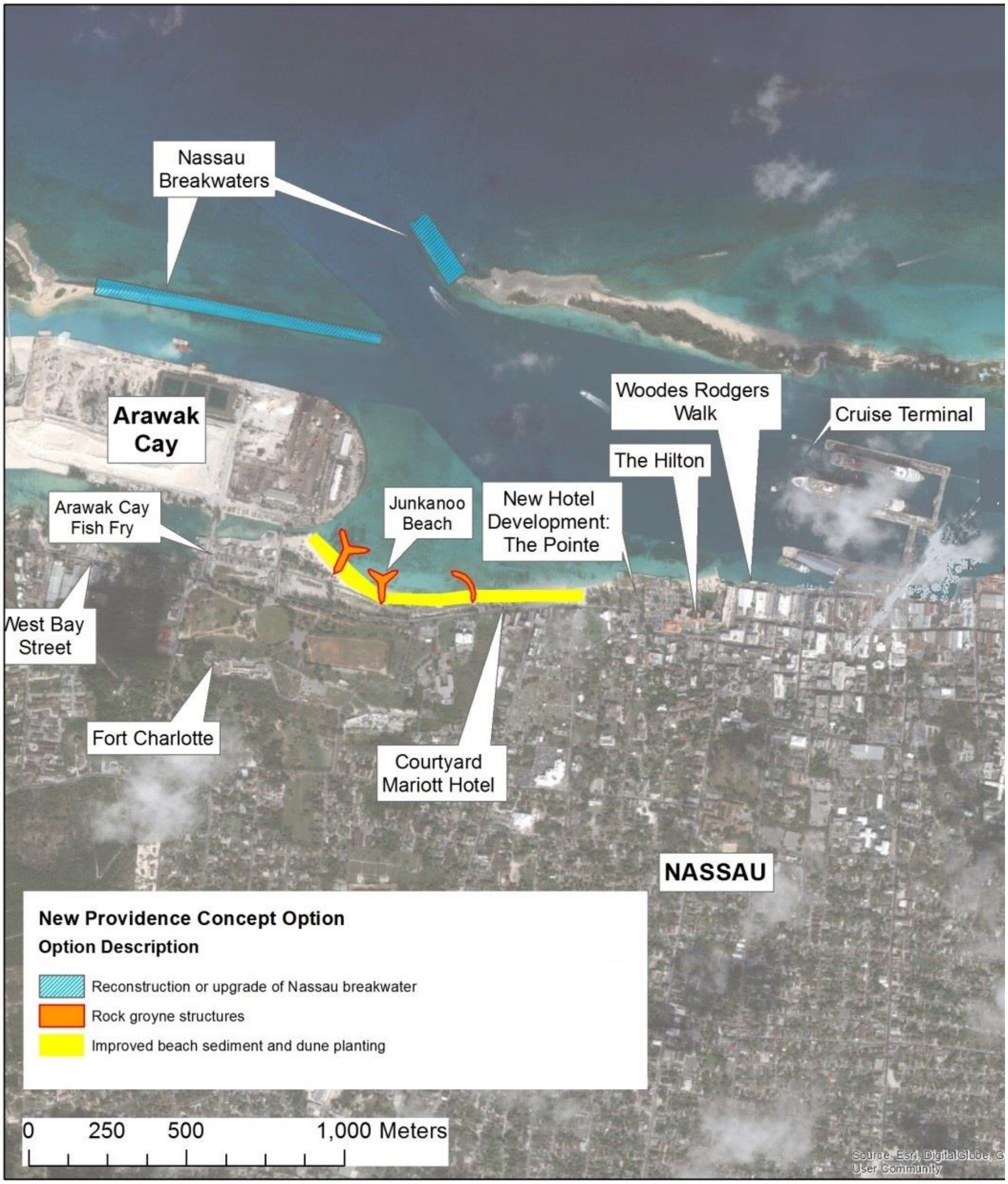
as more and more has been communicated and understood about other ongoing developments that are occurring without direct recourse.

The range of viable options for this area have been identified and analyzed and are presented in Appendix A. The results of Tables A1 and A2 demonstrate that there are a lot of different options which score as low risk for the frontage and this reflects the varied nature of the frontage. The final solution should further reflect this by combining different solutions in different areas of the frontage. The initial concept design has been selected to provide a low risk, sustainable option using Tables A1 and A2 and consists of:

- Upgrade of the Nassau Breakwaters
- Beach management through groyne structures
- Repaired/upgraded drainage at West Bay Street

This option is presented in Figure 7.

Figure 8: Preferred Concept Option



Source: Mott MacDonald, 2016 and ESRI mapping, 2016. Altered Blue Engineering 2016.

From this it has been determined that in order to obtain the best overall holistic and integrated design to meet over-arching strategic aspirations, the following preliminary list of activities and investments have been identified to be undertaken, and are presented below.

- Information, data review and analysis.
- Undertake surveys including:
  - Engagement surveys with the local communities and stakeholders to communicate the implementation of the option development;
  - Oceanographic data collection required to undertake hydrodynamic modelling; and
  - Development of a Digital Elevation Model of the frontage.
- Cost Benefit Analysis for proposed integrated coastal management protection scheme
- Detailed design of an integrated coastal management protection scheme.
- Construction and supervision of the proposed integrated coastal management protection scheme.
- Future monitoring (including beach monitoring), maintenance and operation of new coastal protection assets (annual in addition to periodically following large storms).

6. Products and indicators

Output:

- Baseline studies: Baseline 0, Target 4;
- Upgrade to Nassau Harbour Breakwaters to full 100 year design with climate resilience: Baseline 0, Target 2;
- Repaired/upgraded sea walls for a 50 year design life function with ability to have 50 years of climate adaption added later: Baseline 0m, Target ?m;
- Repaired/upgraded drainage outlet at west end of Junkanoo Beach: Baseline 0, Target 1;
- Provision of integrated coastal access way promenade or boardwalk to be integrated with development proposals: Baseline 0km, Target 1km and
- Beach control structures/protection that manages the beach effectively as a coastal amenity and coastal protection asset: Baseline 0m, Target 960m.

Outcome:

- Reduced flood and coastal erosion risk to Nassau.
- Increased overall resilience in the medium to longer term to flood and erosion climate risk;
- Increased resilience of critical infrastructure on or landward of coastal zone;
- Increased visitor numbers to Junkanoo Beach and Arawak Cay through greater beach area and improved access, ensuring an improved overall amenity – generating increased income from tourism;
- Improved safety for residents and visitors when in the coastal zone; and
- Reduced annual maintenance requirements of coastal assets and other infrastructure.

Indicator:

- Total stretch of more than 960m of coastal protection improvement works from a combination of activities under this project brief and other ongoing and future private and other public developments;
- Reduction in frequency of flooding of the main arterial West Bay and East Bay Street to a 1 in 75 year Standard of Protection;
- Increase in annual visitor numbers to Arawak Cay area and Junkanoo Beach by at least 10%; and
- Reduction in maintenance spend on beach maintenance and outfall structures and sea walls by 50% over the next ten years.

7. Estimated cost and source of financing

Activity	Estimated cost (USD)	Source
Baseline surveys	240,000	TBC
Detailed design	420,000	TBC
Construction*	13,300,000	TBC (Note: Arawak Port Development is willing to support)
Contract Management and Supervision Services including environmental (6%)	800,000	TBC
Total Capital Input	**14,760,000**	TBC
Future monitoring, maintenance and operation	Unknown at this stage	TBC

**Construction costs at this stage are high level and outline and would need to be defined in more detail following optioneering*

For the construction costs that have been summarized above, these can be broken down into core activities that will be needed in order to facilitate the works and meet the aspirations of the overall scheme for meeting risk resilient ICZM drivers, community, tourism and safety enhancements (USD$).

Currently the development of the pricing model revolves around two defined sections at Junkanoo Beach incorporating;

- The main breakwaters (estimated US$10m) and
- The Beach Frontage along Junkanoo to Arawak Cay (estimated US$3.7m)

Currently the works anticipated at the breakwaters would comprise, depending on option development and detailed design, either full re-construction of the severely damaged sections with consideration of different multi-layer breakwater construction or even different primary armour units such as Accropodes or Tetrapods to suit the local conditions, or a broader re-habilitation and upgrade of the full breakwater considering a more climate resilience approach.

For the works along Junkanoo, it is recognized that traditional methods adopted at Saunders Bay or Montague Bay or variations thereof can work well, depending on the outcomes of the earlier studies and modelling activities. However, there is a real opportunity to bring into consideration possibly more sustainable and environmentally sensitive approaches to local beach management that may include use of geo-textile sand filled structures or nearshore submerged eco-reefs for example. The design development process will assist in evolving this focus. There is always a compromise to be had between more maintenance heavy, adaptive and ‘softer’ engineering approaches against more robust with higher capital cost heavier engineered approaches.

A breakdown in the costs are provided in the two tables below, for the initial upfront studies and then the construction estimates respectively.

	Cost in US$	Cost in US$ with 20% risk	Rounded Approximate Cost (US$)
Option Development Report	$200,000.00	$240,000.00	$240,000.00
Hydraulic Modelling	$150,000.00	$180,000.00	$180,000.00
Benefit Cost Analysis	$50,000.00	$60,000.00	$60,000.00
Detailed Design	$350,000.00	$420,000.00	$420,000.00
Nassau Breakwater	$200,000.00	$240,000.00	$240,000.00
Junkanoo Beach	$120,000.00	$144,000.00	$145,000.00
Repaired/Upgraded Sea Walls and Drainage Outlet	$30,000.00	$36,000.00	$35,000.00

Element	Unit	Cost Per Unit (US$)	Number of Units	Total Cost (US$000)
Breakwater – Improve Resilience				**9,520**
New eastern breakwater sections	*Meters*	*92,000*	*60*	*5,520*
New western breakwater sections	*Meters*	*40,000*	*100*	*4,000*
Junkanoo Beach				**3,760**
New beach control structures (such as groynes)	*Meters*	*3,000*	*1000*	*3,000*
Extra over above for beach replenishment	*Meters*	*750*	*950*	*710*
Repairs/Upgrade to sea walls	*Ea.*	*25,000*	*1*	*25*
Repairs/Upgrade to Drainage Outlet	*Ea.*	*25,000*	*1*	*25*
Sub-total				***13,280***
Supervision including environmental (6%)				*800*

TOTAL	***14,080***

As part of that exercise we have undertaken an overall logistics and constructability assessment. The details of this are presented in Appendix B, but key highlights are summarized below.

<u>Key logistical and constructability issues for Central Nassau</u>

For the preliminary studies, optioneering and detailed design stages there are suitable flights, car hire, accommodation, and availability of companies and organizations locally in The Bahamas and / or in Nassau, and either teamed with / or undertaken by internationally competitive companies to undertake these activities.

For specialist survey such as geotechnical and geological investigations, then kit including drilling rigs for example would need to be shipped to Nassau. But this can be facilitated easily.

For the main works the key logistical issue is:

- There are a number of companies with equipment suitable for heavy works, such as Island Site Development, Bahamas Hot Mix, Bahamas Marine Construction or specialist activities such as breakwater rehabilitation or construction. Some of these works are quite specialist, again depending on the detailed design adopted, and it is likely that specialist contractor skills may be required internationally. The recent shoreline protection construction works at Saunder's Bay and Montague Bay, the original breakwaters, and Baha Mar demonstrate that similar works can be implemented in Central Nassau with its good port and urban hub characteristics.

8. Management model

The management of this studies and construction will be provided by the ICZM Project Execution Unit (PEU). Future owner-ship and options for Local Municipality, Ministry of Tourism, Physical Planning and Ministry of Works and Urban Development partnership would be considered as part of the Option Development Report.

9. Responsible institutions

Items	Lead institution	Participating institution
Baseline surveys	MoWUD	BNGIS/PPPB Authority/ Ministry of Tourism/ MoWUD/ OPM
Detailed Design	MoWUD	PPPB Authority/ Ministry of Tourism/ MoWUD/ OPM
Construction and supervision	MoWUD	Ministry of Tourism/ MoWUD/ OPM

Future monitoring, maintenance and operation (annual basis)	MoWUD? PPPB Authority?	PPPB Authority/ Ministry of Tourism/ MoWUD/ OPM

10. Calendar of execution

Items	Y1		Y2		Y3		Y4		Y5	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Baseline surveys				X	X					
Detailed design						X	X	X		
Construction and supervision								X	X	X

11. Studies needed for execution

a. Community/engagement surveys;
b. Cost Benefit Analysis
c. Metocean studies including modelling;

12. Procedure/environmental studies or others

An environmental and social impact plan is to be undertaken as part of the Option Development Report and should be reviewed by the BEST Commission.

As there is detailed design moving towards actual works then the planning process will have to be met which would include an Environmental Impact Assessment to be undertaken. The outcome of this may lead to the requirement of an Environmental Action Plan to be developed that would need to be adhered to by the successful contractor organization responsible for undertaking the works.

13. Positive and negative environmental and social impacts

Impacts	Positives	Negatives
Social	- Improving long term coastal resilience to a critical site for the country's main port, cruise terminal, tourist activities and local events; - Enabling opportunities for urban regeneration and enhancing tourism; and - Enabling opportunities to develop and expand the beach at Junkanoo to Arawak Cay for use by locals as well as	- West Bay Street is a very busy road and construction along here could temporarily impact traffic through the construction footprint as well as noise and vibration; - Temporary impact on the use of the beach/tourist facilities during construction – would need to plan construction carefully to not coincide with the high tourist season; and

	visitors. - to provide improved coastal access, with benefits for health and well-being of users.	- Potential for temporary impacts on navigation during construction of the breakwaters.
Environmental	- Opportunities to design the breakwater repairs such that it provides ecological enhancement and wider environmental benefits (e.g. water quality enhancement).	- Temporary impacts on marine ecology and birds during construction.

14. Priority and relation to other initiatives

This project will build on the work that has been undertaken by the BEST Commission, IDB and Consultants as part of the Feasibility Study for an Integrated Coastal Zone Management Programme in The Bahamas, and other relevant stakeholders to collect and review all available information. Furthermore, it will need to link and relate to regeneration and urban planning projects within Nassau.

Fundamentally this project is of a very high priority. Discussions with the Arawak Port Company have already indicated that the condition of the breakwater is starting to adversely affect their capacity and efficiency, leading to reduce ship alongside time, and hindering un-loading activities.

Some of the coastal sections just west of Junkanoo Beach are very quickly becoming critical as the shore platform lowers, and wave impact increase on the exposed wall potentially leading to undermining and failure, or ever increasing overtopping events and magnitude. Beach material losses are ongoing. The impacts of the new developments in this frontage could have impacts that are not fully understood in a broader context for Nassau.

15. Projects Benefits summary

The following table summarizes the key benefits of the proposed project and assigns a relative value score: 1 (low) to 5 (high).

Benefit Sector	Description	Score
Asset protection – residential and commercial properties	Commercial properties along the frontage will have an increased Standard of Protection.	3
Asset protection – infrastructure (including roads and services)	Key infrastructure including water and sewerage, key road links, and Arawak Cay as well as existing leisure and cruise ship terminals will be improved by the coastal zone management. Furthermore, West Bay Street provides a critical link into the city's business district as well as to Paradise Island.	6
Economy – relating to tourism	Many of the commercial properties within the area rely on tourism as the main income. There are also cruise ship terminals and marinas, which are key sites for tourism. The management options will have	4

	opportunities to enhance tourism income and visitor numbers.	
Economy – relating to everything but excluding tourism	This is a critical site for the country's main port, cruise terminal, tourist activities and local events. Should this area become more vulnerable to coastal hazards without any works there could be a large impact on the overall resilience of the capital city.	5
Social benefits/ benefits to the local community	The capital of Nassau contains over 70% of the Country's population and therefore there will be wider reaching benefits towards the broader communities that live within and around Nassau.	2
Environmental benefits – focusing on marine and coastal ecology	There are limited options within this frontage to provide enhancement due to the largely built up area. However there are potential opportunities to provide marine ecological enhancement if upgrading/renewing the Nassau Harbour Breakwater and protecting Junkanoo Beach (artificial reef/beach planting)	1

Appendix A: Viable options for engineering in Central Nassau – Arawak Cay to Potter's Cay.

A number of options were scored against indicators for the works in Central Nassau (see Second Interim Report, Mott MacDonald 2016 for a detailed methodology). From this scoring it was concluded that due to the long stretch of coastline within this Pilot Site, it is likely that a number of solutions will be required to reduce the vulnerability of the area. These are likely to include the repair/re-construction of the breakwaters, improved drainage and repaired sea walls.

Table A1: Detailed scoring – note low risk/high opportunity = lower numbers.

	Coastal Processes	Cost	Buildability	Sustainability	Total Technical Risk	Habitats/ Wildlife	Fisheries	Water Quality	Visual Appearance	Total Environmental Risk	Public Safety	Recreation	Cultural Heritage	Total Social Risk	Economic Opportunities	Environmental Opportunities	Social Opportunities	Total Opportunities	Overall Effectiveness
Site 4 – New Providence, Arawak Cay to Potters Cay																			
Beach enhancement and management	1	1	1	2	**5**	1	2	1	0	**4**	1	0	0	**1**	1	2	1	**4**	**2**
Sea walls / linear defences	1	1	1	1	**4**	1	1	1	1	**4**	1	0	1	**2**	3	3	2	**8**	**1**
Offshore breakwaters attached or detached	2	3	2	2	**9**	2	2	1	2	**7**	2	1	0	**3**	2	1	1	**4**	**2**
Eco-Reefs	3	3	3	1	**10**	1	2	1	1	**5**	2	1	0	**3**	1	0	0	**1**	**3**
Geo textile / geo fabric solutions	1	1	2	2	**6**	1	0	1	1	**3**	2	1	0	**3**	2	3	2	**7**	**3**
Stepped Revetments / beach access	1	1	1	1	**4**	1	1	1	2	**5**	2	1	1	**4**	2	2	2	**6**	**2**
Protected walkways / boardwalks	1	1	1	2	**5**	1	0	0	1	**2**	1	0	0	**1**	2	2	1	**5**	**3**
Flood walls	1	1	1	2	**5**	2	1	0	2	**5**	1	1	1	**3**	2	2	3	**7**	**1**
Reclamation	3	3	2	2	**10**	2	2	1	1	**6**	1	0	1	**2**	1	3	1	**5**	**3**
Urban landscape enhancement	0	2	2	1	**5**	1	0	1	1	**3**	1	1	2	**4**	1	2	2	**5**	**4**
Hinterland transport and planning strategy	0	3	2	0	**5**	1	0	0	0	**1**	0	0	1	**1**	1	3	2	**6**	**5**
Drainage and integrated sewerage	0	2	1	2	**5**	1	0	1	0	**2**	0	0	0	**0**	2	2	3	**7**	**2**
Highway / asset modifications	0	3	3	1	**7**	2	1	2	1	**6**	0	0	2	**2**	2	3	1	**6**	**3**

Table A2: Summary of scores with weighting applied and the total scores– note low risk/high opportunity = lower numbers

	Total Technical Risk	Total Environmental Risk	Total Social Risk	Total Opportunities	Overall Effectiveness	Total Score
Beach enhancement and management	0.4	0.3	0.1	0.3	2	**3.1**
Sea walls / linear defences	0.3	0.3	0.2	0.7	1	**2.5**
Offshore breakwaters attached or detached	0.8	0.6	0.3	0.3	2	**4**
Eco-Reefs	0.8	0.4	0.3	0.1	3	**4.6**
Geo textile / geo fabric solutions	0.5	0.3	0.3	0.6	3	**4.7**
Stepped Revetments / beach access	0.3	0.4	0.4	0.5	2	**3.6**
Protected walkways / boardwalks	0.4	0.2	0.1	0.4	3	**4.1**
Flood walls	0.4	0.4	0.3	0.6	1	**2.7**
Reclamation	0.8	0.5	0.2	0.4	3	**4.9**
Urban landscape enhancement	0.4	0.3	0.4	0.4	4	**5.5**
Hinterland transport and planning strategy	0.4	0.1	0.1	0.5	5	**6.1**
Drainage and integrated sewerage	0.4	0.2	0	0.6	2	**3.2**
Highway / asset modifications	0.6	0.5	0.2	0.5	3	**4.8**

Appendix B

ACTIVITY AFFECTED	CONSIDERATION	COMMENT	COST IMPLICATION
Preliminary Studies Include **- Information and data review analysis** **- Existing condition assessment of coastal structures** **- Assessment of ecosystem services** **- Community surveys** **- Topographic survey, DEM for coast and inland between Arawak Cay and Potters Cay** **- Metocean studies, inclusive of oceanographic data collection and hydraulic modelling** **- Utility information gathering**	Are Local Consultants available with required expertise to perform consultancy scope	Consultants in Nassau should be able to perform preliminary studies. If local consultants cannot fulfil scope then foreign firms or foreign and local JV will have to be employed.	Use of foreign firms will increase costs over use of locally available firms if foreign consultants will need to be on island long term to complete scope.
	Are there vehicles available for rent locally	Rental vehicles available from companies stationed at the Linden Pindling International Airport. Reservations are recommended prior to arrival. Vendors include Avis Rent A Car and Hertz Rent A Car.	Estimated to be min. $63 - $95 per day for small passenger vehicle, up to $120 per day for a minivan. Cost for fuel estimated to be $5 - $6 per gallon.
	Are there adequate accommodations for Consultant teams	Accommodations closest to the project site are preferred. Rental homes or villas are the less expensive options for teams travelling. British Colonial Hilton Hotel, Sunset Resort, El Greco Hotel provide accommodations near the project site.	British Colonial Hotel offers rooms with rates starting at $159 per room per night. Sunset Resort offers rooms with rates starting at $165 per room per night. El Greco Hotel offers rooms with rates starting at $98 per room per night.
	Will equipment need to be transported to conduct studies for the project	Equipment that fits into a luggage can be transported on the plane. Larger size equipment will need to have arrangements made to transport separately by boat or freight plane.	Additional cost to be considered for larger items that need to be shipped.
	If so is this equipment available in the Bahamas	If equipment needs to be sourced from out of the country cost needs to be considered for shipping, custom duty tax and value added tax.	Additional cost to procure and ship equipment into the Bahamas.
	Do we have established contact with local authorities on island who have a stake in this project	Generate list of stakeholders and local authorities that need contact. Preliminary list of stakeholders include Local Governments, Ministry of Works, Water & Sewerage Corp., Bahamas Electricity Company, Bahamas Telecommunications Company, Cable Bahamas, Bahamas National Trust, Bahamas Environment, Science & Technology Commission.	
Optioneering **Preliminary Viable Options Include** **- Planting regimes** **- Highway/asset modifications** **- Hinterland transport and planning strategy** **- Beach enhancement and management** **- Geotextile/geofabric solutions** **- Eco-tourism access and facilities** **- Local beach recycling** **- Do nothing**	Are Local Consultants available with required expertise to perform consultancy scope	Consultants in Nassau should be able to assist with optioneering. If local consultants cannot fulfil scope then foreign firms or foreign and local JV will have to be employed.	Use of foreign firms will increase costs over use of locally available firms if foreign consultants will need to be on island long term to complete scope.
	Are there vehicles available for rent locally	Rental vehicles available from companies stationed at the Linden Pindling International Airport. Reservations are recommended prior to arrival. Vendors include Avis Rent A Car and Hertz Rent A Car.	Estimated to be min. $63 - $95 per day for small passenger vehicle, up to $120 per day for a minivan. Cost for fuel estimated to be $5 - $6 per gallon.
	Are there adequate accommodations for Consultant teams	Accommodations closest to the project site are preferred. Rental homes or villas are the less expensive options for teams travelling. British Colonial Hilton Hotel, Sunset Resort, El Greco Hotel provide accommodations near the project site.	British Colonial Hotel offers rooms with rates starting at $159 per room per night. Sunset Resort offers rooms with rates starting at $165 per room per night. El Greco Hotel offers rooms with rates starting at $98 per room per night.

Detailed Design	Are Local Consultants available with required expertise to perform consultancy scope	Consultants in Nassau should be able to perform detailed design. If local consultants cannot fulfil scope then foreign firms or foreign and local JV will have to be employed.	Use of foreign firms will increase costs over use of locally available firms if foreign consultants will need to be on island long term to complete scope.
	Are there vehicles available for rent locally	Rental vehicles available from companies stationed at the Linden Pindling International Airport. Reservations are recommended prior to arrival. Vendors include Avis Rent A Car and Hertz Rent A Car.	Estimated to be min. $63 - $95 per day for small passenger vehicle, up to $120 per day for a minivan. Cost for fuel estimated to be $5 - $6 per gallon.
	Are there adequate accommodations for Consultant teams	Accommodations closest to the project site are preferred. Rental homes or villas are the less expensive options for teams travelling. British Colonial Hilton Hotel, Sunset Resort, El Greco Hotel provide accommodations near the project site.	British Colonial Hotel offers rooms with rates starting at $159 per room per night. Sunset Resort offers rooms with rates starting at $165 per room per night. El Greco Hotel offers rooms with rates starting at $98 per room per night.
Construction and Supervision	Availability of Local Contractors to perform construction works to be determined	Local contractors based in Nassau will incur the least overhead cost. Local contractors based in Nassau will incur more overhead cost. Foreign contractors will incur the most overhead cost. If local contractors cannot fulfil scope then foreign contractors will have to be employed. There are a number of companies with equipment suitable for heavy works, such as Island Site Development, Bahamas Hot Mix, and Bahamas Marine Construction.	Costs for work permits, accommodation, ground transportation, per diem must be included for foreign contractors. Cost for accommodation, ground transportation and per diem must be included for Nassau contractors.
	Availability of Local Labourers to perform construction works to be determined	Local workers based in Nassau will incur the least overhead cost. Local workers based in Nassau will incur more overhead cost. Foreign workers will incur the most overhead cost. If local workers cannot fulfil scope then foreign workers will have to be employed. There are a number of companies with labourers suitable for heavy works, such as Island Site Development, Bahamas Hot Mix, Bahamas Marine Construction.	Costs for work permits, accommodation, ground transportation, per diem must be included for foreign workers. Cost for accommodation, ground transportation and per diem must be included for Nassau workers.
	How close is the nearest dock for receiving shipped goods, materials, equipment	Nearest dock to project site is in Marsh Harbour, Adequacy of docks to be determined based on the size of equipment/materials being shipped.	
	What is the condition of the nearest dock for receiving shipped goods, materials, equipment	Condition assessment to be performed for docks.	If an adequate dock is unavailable it will be necessary to have on constructed prior to the need for equipment and materials.
	Is there a fixed shipping route for movement of materials to the island or will special charter be required	Regular shipping routes and capacity of shipping vessels in the Bahamas to be determined. Should these not be found adequate it may be necessary to ship via private barge.	Special Charter will increase cost significantly
	If there is a fixed shipping route what is the frequency	Frequency of shipping routes to be determined.	
	Will a special charter need to be arranged for shipment of goods or materials	The need for special charter to be determined.	

	Is heavy equipment (drill rig, excavator, flatbed trucks, crane, etc.) available for use	Equipment available by local contractors in Nassau to be determined and compared to inventory of equipment necessary for successfully optioneered design. If heavy equipment is unavailable a boat will have to be chartered to barge the equipment to Nassau.	Cost will increase depending on the size and quantity of equipment that needs to be shipped to the island.
	Is there adequate availability of suitable construction materials and supplies on the island	An inventory of materials available on island will need to be performed and compared against materials required for the selected optioneered design.	Cost will increase depending on the type and quantity of material that needs to be shipped to the island.
	Are there vehicles available for rent locally	Rental vehicles available from companies stationed at the Linden Pindling International Airport. Reservations are recommended prior to arrival. Vendors include Avis Rent A Car and Hertz Rent A Car.	Estimated to be min. $63 - $95 per day for small passenger vehicle, up to $120 per day for a minivan. Cost for fuel estimated to be $5 - $6 per gallon.
	Are there adequate accommodations for Construction teams	Accommodations closest to the project site are preferred. Rental homes or villas are the less expensive options for teams travelling. British Colonial Hilton Hotel, Sunset Resort, El Greco Hotel provide accommodations near the project site.	British Colonial Hotel offers rooms with rates starting at $159 per room per night. Sunset Resort offers rooms with rates starting at $165 per room per night. El Greco Hotel offers rooms with rates starting at $98 per room per night.
	Is there an adequate area for laydown of construction equipment and materials	Need to determine suitable public land for contractor to store equipment and materials. Cadastral survey may be required to determine land ownership.	If public land is unavailable it may be necessary to use private land at a cost during the construction period.

Studies for the Preparation of The Bahamas Risk-Resilient Integrated Coastal Zone Management Program: Component B – Coastal Protection Interventions

Provision of coastal studies and interventions for risk-resilient coastal protection measures at specific pilot study sites.

Project Data Sheet for Central Long Island: Gray's Settlement to Scrub Hill Settlement

1. Objectives

The overall objective is to reduce flood risk vulnerability and improve the resilience of communities to flooding and coastal storm surge impacts both in the present day and in the context of climate change for the 11km stretch between Gray's Settlement to Scrub Hill Settlement.

The immediate objectives include:

(i) Undertake studies to identify the key flood risk areas; and

(ii) Provide infrastructure (both grey (e.g. conventional seawalls) and green (e.g. mangrove restoration) for increased resilience to high risk areas from flooding (both from overtopping, storm surges/hurricanes and from sea level rise).

The overall focus on this Pilot Site is therefore to provide increased resilience through a thorough assessment of hydrodynamics and climate change adaptation techniques. There will be a core focus on providing sustainable solutions incorporating ecosystem-based adaptation methods. The study site is an example of an area which is very vulnerable to flooding and storm damage, and although the overall impacts from these can be managed, they will never be completely mitigated. Therefore innovative and adaptive techniques are required alongside the more traditional hard engineering structures to provide a more sustainable and effective solution.

Key aims of the preferred solutions which are to be developed are to therefore include:

i. To reduce impacts from coastal storm surges and flooding;

ii. To provide adaptive measures with the uncertainty of climate change;

iii. To ensure continued usage of key infrastructure; in particular the main coastal road;

iv. To include the use of mangroves and coral reef re-habilitation as part of the overall risk-resilient improvements; and

v. To utilize existing infrastructure and hard defences as well as the island's more natural soft defences within the overall design.

Figure 1: Much of the critical infrastructure along Central Long Island is at risk from severe flooding and storm surges. Source: Sharrah Moss, 2015 – flooding of the main road in Long Island following Hurricane Joaquin in October 2015.

Figure 2: Shipping Vessel deposited inland by surge, Long Island (left), Flooding of runway at Deadman's Cay Airport (right) in Long Island following Hurricane Joaquin in October 2015.

2. Location

Long Island is an island in the South Bahamas, approximately 130km long and 6km wide at its widest point, and has a population of approximately 3094 (2010 Census). Long Island is characterized by cliffs and caves on the east Atlantic side of the island and softer sandy-edged slopes characterize the west side of the island, which has shallow waters adjacent to the Bahamas Bank.

The entire length of the island is dominated by a ridge with rolling hills, often exceeding 30 meters in height, with a maximum of 54 meters. The complex ridge is most consistent along the eastern shores, but there are many sections where hills span the entire width of the island. The largest flatland areas are in the vicinity of Deadman's Cay and Grays, and further north around Simms. Past and present farming has altered much of the vegetation. The main road along Long Island mainly traverses the western coast which has some unusual features, most notably the extensive wetlands along the southern half of the island. The most northern of these is known as Grand Pa's Channel, and an abandoned salt works occupies a large part of the southern area. Numerous canals and dykes serving these salt works have altered much of this landscape.

A somewhat exceptional feature of Long Island is the presence of two substantial cave systems. All islands have caves, this being a normal consequence of karst erosion, but Salt Pond Cave and the Cartwright Cave in central Long Island are among the two largest in the Bahamas. Dean's Blue Hole is the world's second deepest known salt water blue hole with an entrance below the sea level. It plunges 202 metres (663 feet) in a bay west of Clarence Town.

Being further south Long Island is relatively dry with an average rainfall of around 89 centimetres per year. While the dryness was the reason for the solar salt operations, occasional tropical storms and hurricanes created severe flooding leading to the demise of the salt operations and serious restrictions on agriculture.

Temperatures are tropical all the year round with exposure to NE Trade Winds accounting for the extensive modern sand dunes along most of the eastern shores. Vegetation is generally broad-leaved tropical hardwood with extensive mangroves along the western shores.

The site focuses on the area between Gray's Settlement and Scrub Hill Settlement due to the vulnerability of the roads, airport, other infrastructure and communities to extreme weather and storm surges (Figure 2).

The Island has two airports, Stella Maris in the north which is a port of entry and Deadman's Cay in the south which receives internal domestic air services only. The Island also has three (3) active sea ports that are able to receive mail boat deliveries. The ports are located in Clarence Town in the south and Salt Pond and Simms in the north.

Clarence Town is located south of the Deadman's Cay airport and is the Island's seat of local government and one of the larger settlements. Deadman's Cay and surrounding areas of Buckley's, Cartwrights, McKenzie's, Mangrove Bush, Petty's, Hamilton's and Scrub Hill together form the heart of the island with a concentration of over a third of the population. Other residential areas are distributed around the island with notable settlements at Salt Pond and Simms (the main and oldest settlement in the north). The island's economy is dependent largely on tourism and fishing.

The main highway 'Queens Highway' extends the full length of the island and is approximately 130 kilometers long. This single carriageway road maintains a relatively consistent width of approximately 6 metres. The road construction is comprised of crushed limestone road base sealed with a bituminous bound wearing course. There is no known positive drainage but some highway sections drain to adjacent ditches and natural ponds. The MOWUD have recently (approximately one year

ago) been constructing some 24 culverts and headwalls under the road linking the ponds/swamp areas to sea outfalls at various locations. These locations fall outside of this projects area of interest other than at Deadman's Cay where two culverts were installed.

Other recent works in the project area include the installation of a drainage well at Deadman's Cay Airport and Lower Deadman's Cay. Other works currently underway in the project area include the installation of 210 metres of seawall along the edge of the highway at Buckley's. The highway's horizontal alignment can generally be considered flat with higher sections located at the major settlements. A few exceptions exist which are low lying and susceptible to flooding. At times of heavy rainfall and flooding, the communities are cut off for days as there is no alternative means of access.

The section of highway in the middle third of the island linking Clarence town to Salt Pond (via Deadman's Cay) is well used and provides access to the Capital, Sea ports and Deadman's Cay airport and a number of community facilities, businesses and the main schools .

Figure 3: Map of Long Island

Table 1: Long Island Population

Settlement Name	Sex		Total	Total occupied dwellings	Average household size
	Female	Male			
Alligator Bay	33	33	66	19	3.47
Berrys	17	23	40	12	3.33
The Bight	15	12	27	9	3.00
Buckleys	28	26	54	16	3.38
Buckleys Hill	11	14	25	7	3.57
Burnt Ground	164	160	324	87	3.72
Carlton Hill	21	28	49	20	2.45
Cartwrights	61	48	109	48	2.27
Clarence Town	42	44	86	34	2.53
Combers	10	14	24	7	3.43
Deadman's Cay	57	53	110	47	2.34
Deans and Turtle Cove	7	8	15	5	3.00
Doctors Creek	40	24	64	16	4.00
Dunmore and Victoria Village	32	47	79	24	3.29
Glinton's	56	81	137	45	3.04
Gordons and Mortimers	42	32	74	27	2.74
Greys	15	22	37	13	2.85
Hamilton	94	102	196	74	2.65
Lower Deadman's Cay	143	129	272	116	2.34
Mangrove Bush	69	73	142	59	2.41
Mckanns	12	19	31	17	1.82
Mckenzie	24	19	43	17	2.53
Mckenzie and Hard Bargain	11	10	21	8	2.63
Miley and Lochabar	17	16	33	12	2.75
Millers	37	36	73	23	3.17
Millerton	42	48	90	32	2.81
Morrises and Bains	39	31	70	27	2.59
Morrisville	12	13	25	12	2.08
New Hope	40	36	76	30	2.53
Old Grays and Andersons	7	8	15	5	3.00
O'Neils	29	35	64	24	2.67
Pettys	41	38	79	32	2.47
Pinders	11	3	14	6	2.33
Roses and Taits	30	30	60	22	2.73
Salt Pond	54	44	98	32	3.06
Scrub Hill and Benzie	24	27	51	15	3.40
Seymour and Galliot Cay	44	37	81	28	2.89
Simms, Bos'n Hill And Scrub Hill	32	28	60	25	2.40
Stella Maris	43	37	80	32	2.50
Stevens	18	13	31	10	3.10
Thompson Bay	8	9	17	6	2.83
White House, Sam Mckinnons and Wemyss	17	14	31	11	2.82
Wood Hill, Fords and Cabbage Point	10	11	21	8	2.63
Total	**1,559**	**1,535**	**3,094**	**1,119**	**2.76**

Source: Department of Statistics of the Bahamas, Census 2010.

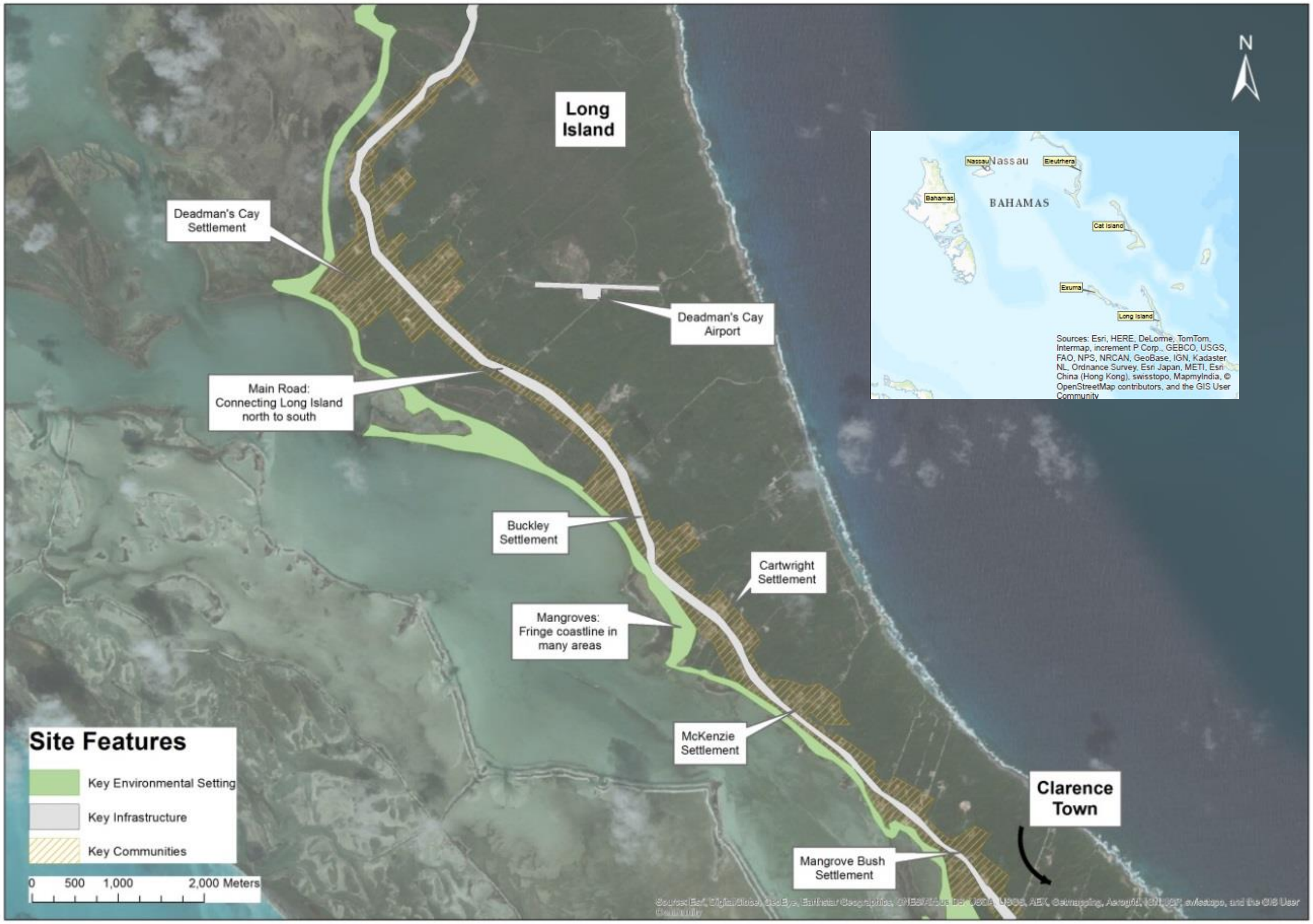


Figure 4: Location Map

Source: ESRI mapping, 2016

- National Capital
- Largest City
- Populated Place

GROUND WATER RESOURCES

Map Unit

FRESH WATER GENERALLY PLENTIFUL

1 — Moderate to enormous quantities of fresh water from shallow, fresh water lenses within poorly-stratified Pleistocene limestone aquifers. The water table is between 0 to 6 m (0 to 20 ft) of the surface.

FRESH WATER LOCALLY PLENTIFUL

2 — Unsuitable to large quantities of fresh water from shallow, fresh water lenses within poorly-stratified Pleistocene limestone aquifers. The water table is between 0 to 6 m (0 to 20 ft) of the surface.

3 — Unsuitable to small quantities of fresh water from shallow, fine-grained, well-sorted Holocene sandy aquifers. The water table is within 0 to 6 m (0 to 20 ft) of the surface.

FRESH WATER SCARCE OR LACKING

4 — Unsuitable quantities of fresh water from shallow, poorly-stratified Pleistocene limestone aquifers.

SURFACE WATER RESOURCES

5 — Surface water features including ponds, lakes, creeks and blue holes. Unsuitable to meager quantities of brackish to hypersaline water available. Features on some islands, such as Andros, Eleuthera, and Grand Bahama may contain seasonally fresh water.

6 — Areas dominated by wetlands. Unsuitable quantities of saline surface water available.

QUANTITATIVE TERMS

Enormous	≥	6 liters per second (L/s) (100 gallons per minute (gal/min))
Very Large	≥	3 to 6 L/s (50 to 100 gal/min)
Large	≥	1.5 to 3 L/s (25 to 50 gal/min)
Moderate	≥	0.6 to 1.5 L/s (10 to 25 gal/min)
Small	≥	0.25 to 0.6 L/s (4 to 10 gal/min)
Very Small	≥	0.06 to 0.25 L/s (1 to 4 gal/min)
Meager	≥	0.015 to 0.06 L/s (0.25 to 1 gal/min)
Unsuitable	<	0.015 L/s (0.25 gal/min)

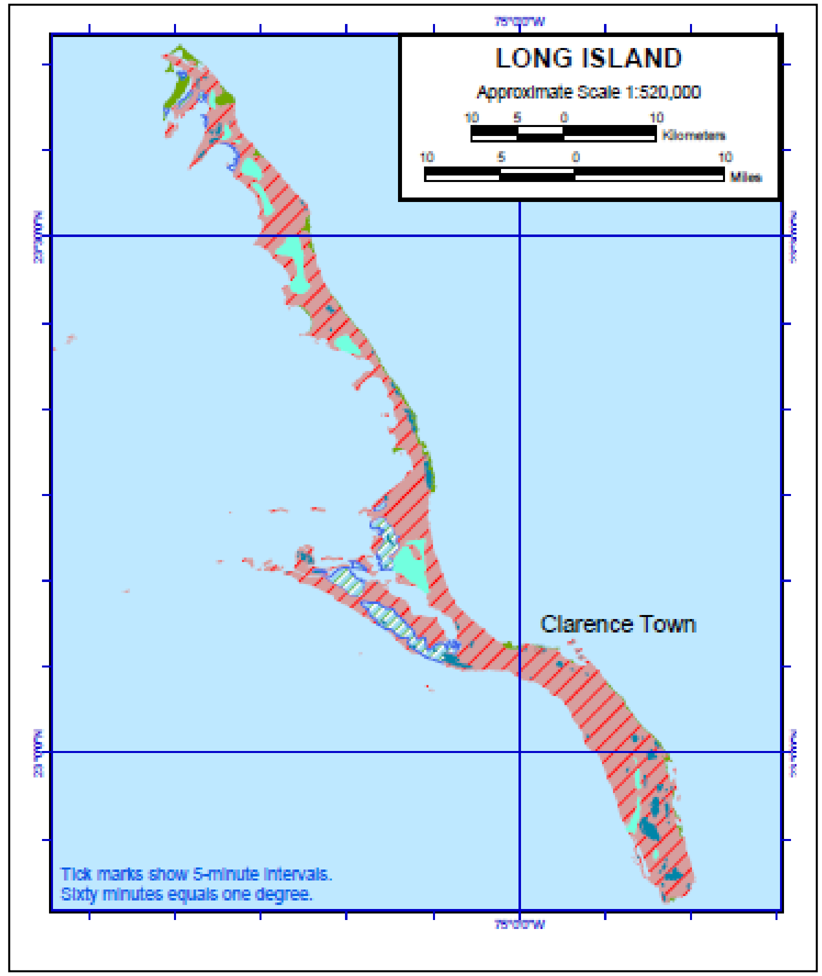


Figure 5: Water Resources in Long Island, Bahamas

Simms wellfield has serious salinity problems and no scope for expansion. It has been replaced with an RO plant recently. Long Island has to rely on the use of RO to meet its potable needs, and locating the site of new plants is the main challenge at this time.

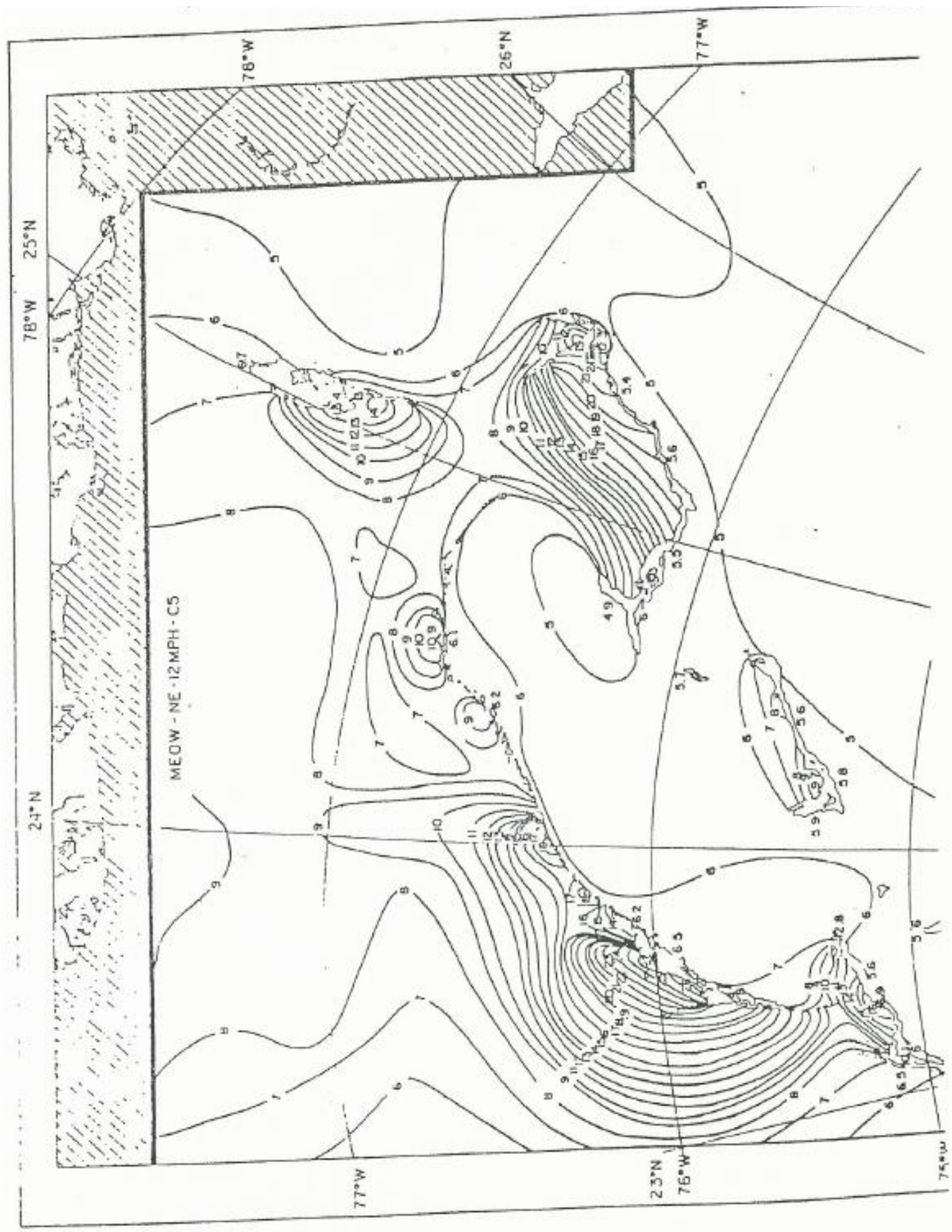


Figure 6: Storm Surge Atlas for Category 5 Hurricane travelling at 12 mph in NE direction.
Source: Bahamas SLOSH Model

Observations in The Bahamas suggest that storm surge produces most of the flooding associated with tropical storms that make landfall, or that closely approach a coastline. Recognizing this fact the Sea Lake and Overland Surges from Hurricane (SLOSH) computer model was applied to The Bahamas. An atlas was produced to provide maps of SLOSH-modeled heights of storm surge and extent of flooding, for various combinations of hurricane strength and direction of storm motion. The model has so far been applied only to the northern and central Bahamas and now needs to be expanded to include the remaining islands of the Bahamas. The findings should be integrated into the Bahamas National Geographic Information System (BNGIS) and be used to guide development in those areas vulnerable to severe flooding.

Long Island is located within the area evaluated using the SLOSH model. It should be noted that this model is based on data which is dated and limited. However as indicated in the above Figure 6, the greatest surge experienced at Long Island is at the central west shore.

Furthermore, the area offshore of the project area has been proposed as a potential Marine Managed Area (see Figure 7 below). The Long Island Marine Management Area (LIMMA) is a multipurpose Marine Protected Area (MPA) that is being developed through participatory mapping discussions including local government officials, commercial fishermen, non-governmental organizations (NGOs) and university researchers, and is facilitated by the Bahamas National Trust (BNT) in collaboration with Ocean CREST Alliance (OCA), an NGO based on Long Island.

According to Ocean CREST Alliance, Long Islanders drew all of the MPA boundaries themselves. The proposed MPA protects 215,000 acres of coral reef, deep water, sand bars, wetlands, blue holes and sand banks. The proposal process, which is going over two years now continues to develop.

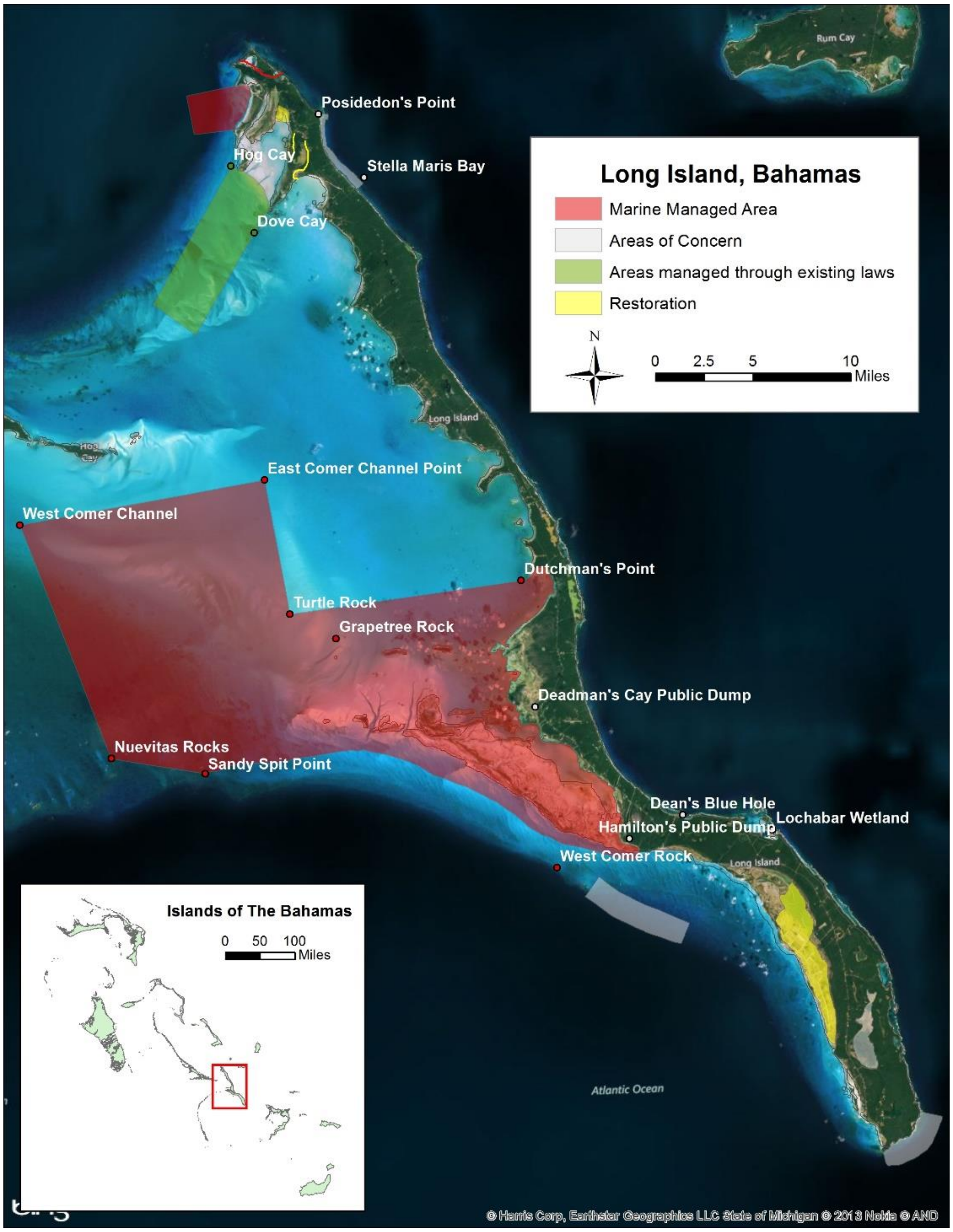


Figure 7: Long Island Marine Management Area (LIMMA) Locations

Source: Ocean CREST Alliance

3. Beneficiaries

Some detailed analysis of beneficiaries from the proposed outline interventions, from the local community, businesses, and other assets, have now been evaluated and the details are summarized below. Beneficiaries include:

- Local residents of communities of Deadman's Cay Settlement, Gray's and Old Gray's Settlements, Buckley's Settlement, Cartwright Settlement, McKenzie Settlement, Scrub Hill Settlement and Mangrove Bush Settlement (total of 571 people and 222 dwellings);
- Key services for the communities including churches, community centers and schools;
- Local residents' health – Deadman's Cay Community Clinic receives the highest outpatient visits of all clinics on Long Island;
- Overnight visitors and day visitors to Long Island for attractions such as bone fishing and visiting the blue holes;
- Key infrastructure including Deadman's Cay Airport, electricity, telecommunications and water infrastructure and main roads around the settlements;
- Wider communities across the Island through improving resilience of the access road running north to south along the Island;
- Local economy relating to tourism and fishery; and
- National Emergency Management Agency (NEMA) for vulnerability and disaster risk management.

Ecosystem Services consideration

There are opportunities to undertake a thorough ecosystem service approach to justifying implementation of coastal management options at this site. A detailed ecosystem service assessment is recommended for the site, however further to this an initial consideration of the baseline scoping is summarized below.

Type of Ecosystem Service (ES)	Is this ES present in the project area?	Is the project activity likely to have an impact on the ES?	Are the benefits of this ES likely to extend on a local, regional, national, or global scale?	Is the project likely to have a significant impact on any beneficiaries of the ES?	Does the client have direct management control or significant influence on the ES?	Does the project depend on this ES?	Based on the answers to the previous questions, is this a priority ES?
Provisioning Services							
Crops	Yes	Potentially	Local	Potentially	No	No	Yes
Fodder	Yes	Potentially	Local	Potentially	No	No	Yes
Capture fisheries	Yes	Yes	Local, Regional	Potentially	No	Yes	Yes
Aquaculture	Potentially	Potentially	Local	Potentially	No	No	Yes
Wild foods	No						No
Timber	Potentially	Potentially	Local	Potentially	Potentially	No	Yes
Energy (woodfuel / biomass)	No						No
Biochemicals/ medicine	No						No
Freshwater (supply)	No						No
Fibre	No						No
Genetic resources	No						No
Regulating Services							
Local climate regulation	No						No
Global climate regulation	No						No
Flood protection	Yes	Yes	Local, Regional	Yes	Yes	Yes	Yes
Air quality regulation	No						No
Erosion regulation	Yes	Yes	Local	Yes	Yes	Yes	Yes
Soil quality regulation	Yes	Potentially	Local	Potentially	Yes	No	Yes
Water quality regulation	Yes	Yes	Local, Regional	Potentially	Yes	No	Yes
Pollination	No						No
Disease and pest control	No						No
Noise regulation	No						No
Cultural Services							
Tourism & recreation values	Yes	Potentially	Local	Yes	Potentially	Yes	Yes
Wild species diversity	Potentially	Potentially	Local	Yes	Yes	No	Yes
Cultural & spiritual values	Potentially	No	Local	Potentially	Potentially	No	No
Scientific & knowledge values	No						No

4. Technical and economic justification

The primary driver for this site is to improve the resilience to coastal flooding, including flooding from overtopping, storm surges/hurricanes and future sea level rise. This area of Long Island was highlighted by the Technical Advisory Committee for ICZM in The Bahamas as a site which regularly experiences flooding of key infrastructure such as the main road and the airport.

In October 2015, Long Island was hit by Hurricane Joaquin. This event highlighted the vulnerability of this island to storm surges and flooding. The island was subjected to a 5.5m (18ft) storm surge which spread across much of the island and caused devastation. Long Island suffered the greatest percentage of damage across all Family Islands from Hurricane Joaquin, with an estimated $35,693,528 of damage[1]. The hurricane affected over 60% of the population of Long Island, equivalent to 3,094 people. It is estimated that 60% of dwellings were destroyed or damaged on Long Island, with a total damage associated with dwellings to be $18,908,500.

The recovery of the island has varied – with the power being reinstated to homes fairly quickly but with recovery of properties an ongoing battle. Furthermore, extensive damage to mangroves and other vegetation has occurred due to the storm surge. This included crop areas which have been destroyed as well as livestock areas – with some local residents suggesting losses of around 75% of their livestock[2].

The economic loss as well as social impact of the Hurricane has been significant, and increased resilience to reduce these losses in the future is required in this location. There have been various efforts including NEMA and there is a Economic Commission for Latin America and the Caribbean (ECLAC) Assessment of the Effects and Impacts Caused by Hurricane Joaquin that details the economic losses associated with Joaquin, namely

The main road that runs down the west of the island from north to south is particularly vulnerable in several locations where it runs along the shoreline. It is particularly at risk in low lying areas or where there is a reduced amount of mangrove system in front of it. This is the main road and the only road which connects the communities to Deadman's Cay Airport and the port at Clarence Town. Resources and commodities are transported and distributed using this road, and key infrastructure for electricity transmission, communication lines and in some areas the water supply. It should be noted that the Water and Sewerage Corporation is currently in the process of finalizing contracts to install water supply lines in the road from Gray's to Salt Pond in the north and Turtle Cove to Clarence Town and Locobar in the south, valued at approximately $7.5 million. This road is a key asset which, when closed for several days due to flooding, can cause a high level of disruption and economic losses. Furthermore, during an emergency response to storm surge or hurricane damage, access along the road is required to facilitate an effective response. The IDB Draft assessment of the effects and impacts of Hurricane Joaquin (2016) states *"Seawalls protect roads from the effects of sea floods that can destroy their base. Some of the existing seawalls along the roads did not withstand the effects of hurricane Joaquin and show severe damage. Most of the seawalls show inadequate design, and lack of reinforcement. They require reconstruction in order to restore the functionality of the main roads."*

The other key asset within this site is Deadman's Cay Airport. The airport and runway are flooded when there is heavy rain and it was reported by some that drainage is not as effective as it could be to facilitate recovery and movement of water away from the airport.

5. Description

From the beginning of the project, potential options for coastal management in this area were considered for technical applicability and overall economic value. These have been presented to the TAC and also in multi stakeholder workshops. The key issue with considering potential management

[1] IDB. (2016). Assessment of the effect and impacts of Hurricane Joaquin. [Draft].

[2] Local Residents. (2016). Personal Communication.

options for this Pilot Site has been the extent of the Pilot Site. It is broadly known that there are several areas where key weaknesses or vulnerabilities impact the overall resilience of the site. Therefore a number of projects have been identified within the project area to address the major issues within the area. It should be noted however that there are other locations along the main road In Long Island where flooding of the road is an issue. These locations will be identified in the next report only for future reference.

The locations that have been identified include key areas where properties are located on the shoreline and areas of the road which are lower in elevation and therefore present flood pathways and flood first, causing the whole road to become in-accessible. An Approximation of areas which need work for the purpose of costing have been taken from the local stakeholders who are knowledgeable of the extent of flooding. However, a detailed site specific topographic survey is required to identify the specific site/extent.

These areas include the following which are described in detail below;

- Scrub Hill
- Buckley's Seawall
- Deadman's Cay Airport
- Main Road, Gray's and Old Gray's

Overall General Area

The INVEST Software has identified the project area as an area that is particularly vulnerable and an area where the coastal ecosystems are particularly important in the reduction of vulnerability along the shoreline. According to the "Hurricane Joaquin - Situation Report #5 as of 6:00 pm on October 7th, 2015", coastal vegetation, inclusive of mangroves, and other native vegetation at considerable distance inland were severely damaged by storm surge and wind-shear.

During the site visit of 5^{th}/6^{th} January 2017 we were unable to visit much of the shoreline as it is necessary to access by boat. We were however able to visit the shallow banks to the west. In the 1970's, Diamond Crystal opened an extensive salt plant west of the town called Hard Bargain. The plant was said to have closed in 1982, due to its main plant in the US filing for bankruptcy. After the salt plant closed, a shrimp farming company called World Wide Protein (Bahamas) Ltd. moved in, only to close a few years later.

According to locals Diamond Crystal altered the waters to the west of the project site substantially. An extensive arrangement of sand banks and dykes were constructed, some with roads. These were altered significantly by destruction caused by Hurricane Joaquin in October 2015 whereby portions of the dykes were washed out. There are five locations where there was major wash out of the dykes, in the order of 280 cubic yards of material was washed out at some of these sites. When the tide changes water flows through these areas rapidly. According to locals this has affected the heights of tides along the project site area as well as the timing of the tides. It was suggested by the chief councilor that the tides are now 18 to 24 inches higher than before Hurricane Joaquin. The damage to the dykes has also allowed the passage of fish into the area and locals are pleased to be able to fish in the area. Further studies should be conducted to determine what alterations if any should be made to the dyke system.

Some of the vegetation damaged will recover naturally whist others will not or will take a long time to recover and can benefit from rehabilitation efforts. Therefore a study along the west coast of the project area to identify the likely extent of damage to vegetation, the most appropriate type and extent

of rehabilitation, the details of the proposed rehabilitation and identified teams/team to “champion” the restoration is likely to be particularly valuable in this area. The fact that consideration has been given to the protection of this area as a National Park further emphasizes the importance of this approach and would potentially provide a management system for such a scheme even if in partnership.

Like coral reefs, mangrove forests are extremely productive ecosystems that provide numerous goods and services both to the marine environment and people. Mangrove forests are home to a large variety of fish, crab, shrimp, and mollusk species. These fisheries form an essential source of food for thousands of coastal communities around the world. The forests also serve as nurseries for many fish species, including coral reef fish. This makes mangrove forests vitally important to coral reef and commercial fisheries as well. Mangroves also protect coastal areas from erosion, storm surge (especially during hurricanes), and tsunamis. The mangroves' massive root systems are efficient at dissipating wave energy. Likewise, they slow down tidal water enough so its sediment is deposited as the tide comes in, leaving all except fine particles when the tide ebbs. In this way, mangroves build their own environments.

Lewis and Marshall (1997) have suggested five critical steps are necessary to achieve successful mangrove restoration.

1. Understand the autecology (individual species ecology) of the mangrove species at the site, in particular the patterns of reproduction, propagule distribution and successful seedling establishment

2. Understand the normal hydrologic patterns that control the distribution and successful establishment and growth of targeted mangrove species

3. Assess the modifications of the previous mangrove environment that occurred that currently prevents natural secondary succession

4. Design the restoration program to initially restore the appropriate hydrology and utilize natural volunteer mangrove propagule recruitment for plant establishment

5. Only utilize actual planting of propagules, collected seedlings or cultivated seedlings after determining through Steps 1-4 that natural recruitment will not provide the quantity of successfully established seedlings, rate of stabilization, or rate of growth of saplings established as goals for the restoration project.

The single most important factor in designing a successful mangrove restoration project is determining the normal hydrology (depth, duration and frequency of tidal flooding) of the existing natural mangrove plant communities in the area in which you wish to do restoration. The normal surrogate for costly tidal data gathering or modeling is the use of a tidal bench mark and survey of existing healthy mangroves.

Scrub Hill

Scrub Hill is a particularly low lying area with hills to the east and marsh land to the immediate west. The majority of the locals recognize the flooding at Scrub Hill to be the most severe and it is considered a priority. The road floods after heavy rain (two days or more) and during hurricanes, during Hurricane Noel this was fresh water whilst during Hurricane Joaquin this was salt water. The

water level in Scrub Hill was reported to be 2 meters above the centre line of the road on Saturday 3rd October 2015 (after Hurricane Joaquin). This flooding lasted for over 3 weeks. A well has been constructed in this area however it has not been functioning for some time due a blockage.

The flood created great inconvenience to the population as the Capital, Clarence Town was cut off from the rest of the Island. The only way across the flood was by boat in the first few days and subsequently by large lorries. We were advised that some home owners in this area have abandoned their homes due to the frequency and severity of the flooding. The most sustainable solution to this problem would be the completion of a by-pass road. Given the forecast sea level rise and the likelihood of more category 4 and 5 hurricanes as a result of climate change as well as residents perceived readiness to move this is considered the preferred solution.

At present there are side roads off of the main road either end of the area of severe flooding. There is also a portion of a parallel road approximately 220 meters east of the main road. It is therefore only necessary to continue the parallel portion of the road to join the other side road. This portion of road is 900 meters long. It will be necessary to purchase the land and clear and pave a 900 meter length of road to provide a by-pass road. Concern would however remain for the alignment of the road as this alignment would introduce four 90 degree bends to the alignment. An alignment without these bends would be possible however this would require the purchase of more land and greater construction costs.

Figure 8: Aerial Image of Scrub Hill indicating proposed by-pass road location. Dotted red line indicates portion to be cleared and constructed and dotted blue line indicates portion for construction only.

Figure 9: Road through Scrub Hill indicating destroyed vegetation alongside the road from flooding.

Buckley's Seawall

Some of the most evident coastal road damage was in Buckley's where a 213 meter concrete sand bag revetment and guard rails were destroyed. A 700 foot long concrete sea wall is currently being built in this area. This area is fronted by mangrove some of which may have been damaged during construction. Whilst the seawall has a sloped face the slope is very steep. Whilst the Contractor advised that the sea rarely meets the edge of the road other than during severe storms further studies should be conducted to determine whether mangrove restoration would be feasible at this location with particular consideration given to the planting of mangrove amongst a revetment at the face of the wall thereby mitigating the negative impact that the seawall will have in reflecting wave energy on the nearby mangroves. Placing a revetment in this way will not only protect the nearby mangrove in the long term but will also protect the seawall and the road, extending their lives.

Figure 10: Buckley's Seawall under construction.

Deadman's Cay Airport

There have been some works installed at and near the airport at Deadman's Cay in the last couple of years in order to try to address the flooding issue at the airport in particular. A number of years ago three drainage wells were installed at the airport however it is understood that these are no longer functioning. In August 2015 a drainage well was installed at the airport. Additional drains were to be installed at the airport however it is understood that funding was limited and only one other well was drilled however this was at Lower Deadman's Cay.

The flood water from the airport drains back to the ocean via the culverts between Lower Deadman's Cay and Old Gray's. The main issue with this is that usually this area gets flooded before the airport flood water reaches the area. According to locals the culverts always have water in the area and this area floods before the airport does so provides little benefit. It was suggested that a flood gate would be the best solution in this instance.

Mangrove restoration for this area should be prioritized as there are a number of flooding issues in this area (also see Old Gray's and Gray's).

Other works to improve the flooding issue at the airport might include additional drainage wells at the airport, improved drainage channel to the sea, improved crossfall of runway and installation of swales and in the longer term the relocation of the airport although it is difficult to find an appropriate location on Long Island due to the topography and the location of the developed areas.

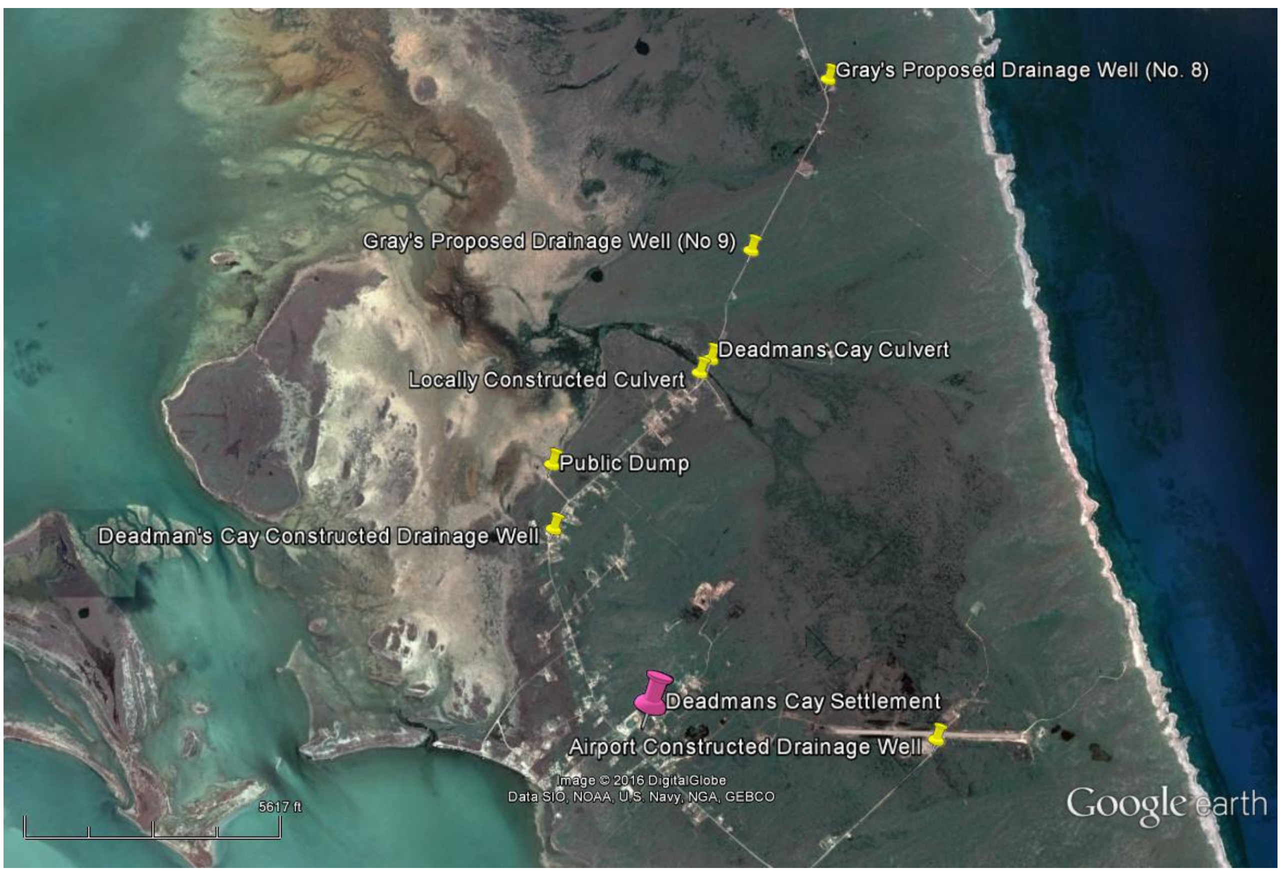


Figure 11: Aerial View of Deadman's Cay and Gray's showing some of the existing and proposed drainage structures

Figure 12: Map of Deadman's Cay Airport and Gray's showing contours

Source: B.K.S. Surveys Ltd.

Main Road, Gray's and Old Gray's

The highway at Gray's is reported to flood in two areas in particular. These are identified in Figure 11 above as Gray's drainage well (No. 8 and No. 9).

Gray's (North)

At the northern Gray's flooding location (drainage well No. 8) the road floods with heavy rain for a length of 730 meters. According to the chief councilor the area flooded to a depth of approximately 2 feet during Hurricane Matthew and was to the roofs of the nearby houses after Hurricane Joaquin. There are two small houses on the side of the road in this area and the flooding is close to a sharp

corner in the road. The situation is dangerous especially for persons travelling north who do not see the water around the corner and drive at speed into the water. Solutions include raising the road or a drainage well to better alleviate flood water.

It is estimated to cost $340,000 to raise the road 2.5 feet at this location to reduce flooding affects at the road. A drainage well is estimated to cost between $12,000. Whilst the raising of the road is more costly it will require less maintenance in the long run and could be more cost effective in the long term. However the drainage well requires maintenance and there is no Ministry of Works and Urban Development (MOWUD) representative resident on Long Island and flights are relatively costly. It is therefore suggested that a drainage well be installed with the inlet slightly raised to reduce the likelihood of blockage and a maintenance schedule managed for Long Island with regular visits to the island by the MOWUD.

Figure 13: Photograph along road at Gray's (North) looking north

Source: Blue Engineering Ltd.

Figure 14: Photograph along road at Gray's (North) looking south

Source: Blue Engineering Ltd.

Old Gray's (South)

At the southern Gray's flooding location (drainage well No. 9) the road floods with heavy rain for a length of approximately 200 meters. According to the chief councilor a truck flooded in this area and the road was flooded for approximately two days after Hurricane Joaquin. There are no developed properties in this area and the road is straight. Solutions include raising the road or a drainage well to better alleviate flood water. It is recommended, for the same reason as that given above for Gray's North location, to install a drainage well at this location.

A preliminary list of activities and investments to be undertaken are presented below. A range of viable options for this area were identified and analyzed and are presented in Appendix A. Appendix A highlights the importance of combining softer techniques such as planting regimes with other engineering solutions to ensure a sustainable and effective solution. Appendix A also highlights alterations to the highway as a preferred option.

- Optioneering Study to assess three key areas (however it is to be noted that this these are not separate pieces of work but an integrated solution combining drainage, structures and ecosystems):
  - Detailed design for Shrub Hill By-pass road.
  - Undertake detailed design for improvements in drainage at Deadman's Cay Airport (additional drainage wells and possible flood gate), Gray's and Old Grays (drainage wells);
  - Develop options and undertake detailed design for mangrove rehabilitation and planting, particularly in vulnerable places, linking in with the designs and options for the new seawalls and altered road infrastructure.
  - Further studies should be conducted to determine what alterations if any should be made to the dyke system. Attention should be given to the effects of climate change if restoration of dykes is to be considered. These studies should include Bathymetric Surveying, Deepwater Wave Hindcast, Nearshore Wave Transformation and Storm Surge/Inundation modelling for extreme events and to predict changes relating to sea level rise (SLR).

- Construction and construction supervision of the preferred solutions.
- Future maintenance and operation of structures and drainage (annual).

6. Products and indicators

Output:

- Optioneering study: Baseline 0, Target 1;
- Bathymetric Surveying: Baseline 0, Target 1;
- Storm Surge/Inundation modelling: Baseline 0, Target 1;
- Improved drainage to the Airport and road: Baseline 17km, Target 17km; and
- New By-pass Road at Shrub Hill: Baseline 17km, Target 17km; and
- Improved mangrove systems in vulnerable areas: Baseline is unknown at present, Target Allowance 35 ha.

Outcome:

- Increased resilience to flooding;
- Increased capacity of area to recover from extreme flood events; and
- Increased resilience of critical infrastructure.
- Increased ecosystems

Indicator:

- Increased time for recovery of airport and road following extreme events; and
- Decreased inundation extents and depths under storm events (to be monitored and compared by Bahamas National GIS Centre) – protection of the road to at least a 1 in 20 year return period flood event.

7. Estimated cost and source of financing

Activity	Estimated cost (USD)	Source
Optioneering study and detailed design	270,000	TBC
Construction and supervision – improved drainage*	50,000	TBC
Construction and supervision – By-pass road*	975,000	TBC
Construction and supervision – mangrove rehabilitation*	280,000	TBC
Total Capital Input	**1,575,000**	**TBC**
Future maintenance and operation (annual basis)	Unknown at this stage	TBC

*Construction costs at this stage are high level and draft at this stage and would need to be defined in more detail following optioneering. Supervision (including environmental) are estimated to be 6% of these figures.

For the construction costs that have been summarized above, these can be broken down into core activities that will be needed in order to facilitate the works and meet the aspirations of the overall scheme for meeting risk-resilient ICZM drivers, community, tourism and safety enhancements.

Currently the development of the pricing model revolves around three key elements that have been allocated the following budget estimates.

(i) West Coast Studies (US$200k)

(ii) Drainage improvements around the airport and the road (US$50k);

(ii) By-Pass Road (US$975k); and

(iii) Mangrove rehabilitation (US$350k).

As part of the costing exercise an overall logistics and constructability assessment has been undertaken. The details of this are presented in Appendix B, but key highlights are summarized below.

Key logistical and constructability issues for Long Island

- It will be necessary to purchase property for the by-pass road. It is understood through conversations with the chief councilor that the owner is willing to sell the property necessary for the by-pass road however the purchase of the property may be a time consuming task.
- There are docks available for supply of equipment and material at Deadman's Cay, Clarence Town and Stella Maris. If adequate dock is unavailable it will be necessary to use barges.
- There is limited accommodation on the Island for consultants however there are many direct flights from New Providence.
- It could be beneficial to construct/build as much as possible off the island and then transport to site by barge.

8. Management model

The management of the studies and construction will be provided by the ICZM project Execution Unit (PEU). Future ownership and options for Local Municipality, Ministry of Works and Urban Development and Bahamas National GIS Centre partnerships would be considered as part of the Option Development Report.

9. Responsible institutions

Activity	Lead institution	Participating institution
Option Development Reports, including topographic survey and Hazard Risk Assessment	BEST Commission	BNGIS Centre/ Local Government/ MOWUD/ NEMA
Optioneering study and detailed design	MoWUD	BNGIS Centre / Local Government/ BEST Commission/NEMA
Construction and supervision of improved drainage	MoWUD	Local Government/ BEST Commission
Construction and supervision – By-pass road	MoWUD	Local Government/ BEST Commission/NEMA
Construction and supervision – mangrove rehabilitation	BNT	Local Government/ MOWUD/ BEST Commission
Future maintenance and operation (annual basis)	MoWUD/ Local Government	BNGIS Centre / Local Government/ MOWUD/ BEST Commission/BNT

10. Calendar of execution

Activity	Year 1		Year 2		Year 3		Year 4		Year 5	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Optioneering study				X	X					
Construction and supervision of drainage improvements, works to the road and mangrove rehabilitation						X	X			

11. Studies needed for execution

- Baseline data review and collection;
- Bathymetric survey;
- Mangrove habitat mapping; and

12. Procedure/environmental studies or others

An environmental and social impact plan is to be undertaken as part of the Option Development Report and should be reviewed by both BNT and the BEST Commission.

13. Positive and negative environmental and social impacts

Impacts	Positives	Negatives
Social	- Reduction in frequency and extent of flooding on the road network and at the Airport; - Reduced recovery time and extent of flooding of the airport and road network after extreme events; - Improved resilience to climate change; and - Increased health, safety and security to communities.	- Temporary disruption of the road and airport during construction; and - Temporary disturbance from noise and vibration during construction.
Environmental	- Increase in mangrove areas and associated ecosystem services; - Reduced flooding; and - Improved drainage and therefore improvements to water quality.	- Construction of improved drainage has potential to impact mangrove areas through fresh water inundation; and - Temporary impacts through construction for example potential for increased suspended sediment in water courses.

14. Priority and relation to other initiatives

This study is to align with the overall ICZM policy framework of The Bahamas as well as the Marine Management Policy. This is a high priority area for The Government of The Bahamas, particularly following impacts from Hurricane Joaquin, and the Option Development Report would build on the initial work carried out by NEMA and BNGIS Centre.

15. Projects Benefits summary

The following table summarizes the key benefits of the proposed project and assigns a relative value score: 1 (lowest benefit) to 6 (highest benefit).

Benefit Sector	Description	Score
Asset protection – residential and commercial properties	Residential (and some commercial) properties situated along the coastline would have increased protection to flooding and hurricanes/ storm surges.	5
Asset protection – infrastructure (including roads and services)	The road is a critical link connecting the north and south of the island as well as being the main route for electricity and water supply. Furthermore the Airport is critical infrastructure at risk from flooding.	6
Economy – relating to tourism	There are only a small number of visitors to the Island. In particular, the blue holes attract tourists who need to travel from the Airport to the south or north of the Island.	1
Economy – relating to everything but excluding tourism	There are a number of areas of livestock and agriculture on the Island which are currently at risk from storm surges and flooding.	2
Social benefits / benefits to the local communities	The local communities are very much centered and distributed along the low lying west side of the Island. Works would reduce the risk from coastal flooding to these communities.	4
Environmental benefits – focusing on marine and coastal ecology	There is a real opportunity as part of the integrated coastal protection works to provide reef and/or mangrove habitat planting/ rehabilitation for wider benefits including reductions in wave energies.	3

Appendix A: Viable options for engineering on Long Island – Deadman's Cay Settlement to Mangrove Bush Settlement.

A number of options were scored against indicators for the works on Long Island (see Second Interim Report, Mott MacDonald 2016 for a detailed methodology). From this scoring it was concluded that due to the long stretch of coastline within this Pilot Site, it is likely that a number of solutions will be required to reduce the vulnerability of the area. These are likely to include mangrove rehabilitation/planting, improved drainage and focussed sea walls/raising of roads in focussed sections which are particularly low lying. However, to focus the coastal protection interventions in this area, more information will be required regarding where the most vulnerable areas are. Therefore, a strategic level study is proposed to allow a focussed consideration of the preferred intervention options in this area.

Table A1: Detailed scoring – note low risk/high opportunity = lower numbers.

	Coastal Processes	Cost	Buildability	Sustainability	Total Technical Risk	Habitats/ Wildlife	Fisheries	Water Quality	Visual Appearance	Total Environmental Risk	Public Safety	Recreation	Cultural Heritage	Total Social Risk	Economic Opportunities	Environmental Opportunities	Social Opportunities	Total Opportunities	Overall Effectiveness
Site 3 – Deadman's Cay to Mangrove Bush Settlement, Long Island																			
Beach enhancement and management	2	1	1	2	**6**	1	2	1	0	**4**	1	0	0	**1**	1	2	1	**4**	**3**
Geo textile / geo fabric solutions	1	1	2	2	**6**	1	0	1	1	**3**	2	1	0	**3**	2	3	2	**7**	**3**
Do Nothing	2	0	0	0	**1**	3	2	2	2	**9**	3	2	3	**8**	3	3	3	**9**	**5**
Local beach recycling	1	1	1	3	**6**	1	2	1	0	**4**	1	1	0	**2**	3	3	3	**9**	**4**
Planting regimes	2	1	1	0	**4**	1	1	1	1	**4**	0	0	1	**1**	2	1	2	**5**	**2**
Eco-tourism access and facilities.	0	2	1	0	**3**	0	0	0	0	**0**	0	0	1	**1**	1	2	0	**3**	**4**
Hinterland transport and planning strategy	0	3	2	0	**5**	1	0	0	0	**1**	0	0	1	**1**	1	3	2	**6**	**3**
Highway / asset modifications	0	3	3	1	**7**	2	1	2	1	**6**	0	0	2	**2**	2	3	1	**6**	**2**

Table A2: Summary of scores with weighting applied and the total scores– note low risk/high opportunity = lower numbers

	Total Technical Risk	Total Environmental Risk	Total Social Risk	Total Opportunities	Overall Effectiveness	Total Score
Beach enhancement and management	0.5	0.3	0.1	0.3	3	**4.2**
Geo textile / geo fabric solutions	0.5	0.3	0.3	0.6	3	**4.7**
Do Nothing	0.1	0.8	0.9	0.8	5	**7.6**
Local beach recycling	0.5	0.3	0.2	0.8	4	**5.8**
Planting regimes	0.3	0.3	0.1	0.4	2	**3.1**
Eco-tourism access and facilities.	0.3	0	0.1	0.3	4	**4.7**
Hinterland transport and planning strategy	0.4	0.1	0.1	0.5	3	**4.1**
Highway / asset modifications	0.6	0.5	0.2	0.5	2	**3.8**

Appendix B

ACTIVITY AFFECTED	CONSIDERATION	COMMENT	COST IMPLICATION
<u>**Preliminary Studies Include**</u> **- Baseline data collection and review** **- Topographic survey (recommend coast to coast coverage)** **- Sea level rise modelling** **- Storm surge assessment** **- Vulnerability assessment** **- Utility information gathering**	Are Local Consultants available with required expertise to perform consultancy scope	Consultants in Nassau should be able to perform preliminary studies. If local consultants cannot fulfil scope then foreign firms or foreign and local JV will have to be employed.	Use of foreign firms will increase costs over use of locally available firms if foreign consultants will need to be on island long term to complete scope.
	Is there a fixed airline route from Nassau to Long Island?	The Deadman's Cay Airport is closest to the project site. Sky Bahamas and Southern Air provide steady service to this airport.	The cost for commercial airlines is much less expensive than chartered flights.
	If there is a fixed airline route what is the frequency of service	Sky Bahamas provides one (1) daily flights to and from the island. Southern Air provides two (2) daily flights to and from the island. Flights are available every day of the week.	The average cost for a roundtrip is $250 - $270 per person. Ticket prices vary depending on the season.
	Will a special charter need to be arranged for movement of personnel	Special charter may only be necessary during visits with Client or Government personnel at major milestones.	$8,000 per roundtrip to Deadman's Cay (Odyssey Aviation), limited to same day.
	Are there vehicles available for rent locally	Rental vehicles available from individuals on the island. Contact is necessary prior to arrival. Vendors include Ellen's Inn, Mr. T's Car Rentals and Unique Wheels Rentals.	Estimated to be min. $65 - $85 per day for small passenger vehicle, up to $100 per day for a minivan. Cost for fuel estimated to be $5 - $6 per gallon.
	Are there adequate accommodations for Consultant teams	Accommodations in settlements closest to the project site are preferred. Rental homes or villas are the less expensive options for teams travelling. If no accommodations can be found then visits will be limited to day trips. Greenwich Creek Lodge and Ellen's Inn are the closest accommodations to the project site, located in Cartwrights and Deadman's Cay respectively.	Ellen's Inn is a bed and breakfast offering single and double bed rooms, with rates ranging from $90 - $105 per room per night. Greenwich Creek Lodge offer single and double occupancy with rates ranging from $125 - $145 per room per night.
	Will equipment need to be transported to conduct studies for the project	Equipment that fits into luggage can be transported on the plane. Larger size equipment will need to have arrangements made to transport separately by boat or freight plane.	Additional cost to be considered for larger items that need to be shipped.
	If so is this equipment available in the Bahamas	If equipment needs to be sourced from out of the country cost needs to be considered for shipping, custom duty tax and value added tax.	Additional cost to procure and ship equipment into the Bahamas.
	Do we have established contact with local authorities on island who have a stake in this project	Generate list of stakeholders and local authorities that need contact. Preliminary list of stakeholders include Local Governments, Ministry of Works, Water & Sewerage Corp., Bahamas Electricity Company, Bahamas Telecommunications Company, Cable Bahamas, Bahamas National Trust, Bahamas Environment, Science & Technology Commission.	

	Planning and subdivision regulations should be reassessed for minimum structure height, road minimum elevation and level of drainage with consideration for recent major storm activity.	Many roadways were inaccessible during an extended amount of time during Hurricane Joaquin.	
Optioneering **<u>Preliminary Viable Options Include</u>** **- Planting regimes** **- Highway/asset modifications** **- Hinterland transport and planning strategy** **- Beach enhancement and management** **- Geotextile/geofabric solutions** **- Eco-tourism access and facilities** **- Local beach recycling** **- Do nothing** **Environmental and Social Impact Plan**	Are Local Consultants available with required expertise to perform consultancy scope	Consultants in Nassau should be able to assist with optioneering. If local consultants cannot fulfil scope then foreign firms or foreign and local JV will have to be employed.	Use of foreign firms will increase costs over use of locally available firms if foreign consultants will need to be on island long term to complete scope.
	Is there a fixed airline route from Nassau to Long Island?	The Deadmans Cay Airport is closest to the project site. Sky Bahamas and Southern Air provide steady service to this airport.	The cost for commercial airlines is much less expensive than chartered flights.
	If there is a fixed airline route what is the frequency of service	Sky Bahamas provides one (1) daily flights to and from the island. Southern Air provides two (2) daily flights to and from the island. Flights are available every day of the week.	The average cost for a roundtrip is $250 - $270 per person. Ticket prices vary depending on the season.
	Will a special charter need to be arranged for movement of personnel	Special charter may only be necessary during visits with Client or Government personnel at major milestones.	$8,000 per roundtrip to Deadmans Cay (Odyssey Aviation), limited to same day.
	Are there vehicles available for rent locally	Rental vehicles available from individuals on the island. Contact is necessary prior to arrival. Vendors include Ellen's Inn, Mr. T's Car Rentals and Unique Wheels Rentals.	Estimated to be min. $65 - $85 per day for small passenger vehicle, up to $100 per day for a minivan. Cost for fuel estimated to be $5 - $6 per gallon.
	Are there adequate accommodations for Consultant teams	Accommodations in settlements closest to the project site are preferred. Rental homes or villas are the less expensive options for teams travelling. If no accommodations can be found then visits will be limited to day trips. Greenwich Creek Lodge and Ellen's Inn are the closest accommodations to the project site, located in Cartwrights and Deadmans Cay respectively.	Ellen's Inn is a bed and breakfast offering single and double bed rooms, with rates ranging from $90 - $105 per room per night. Greenwich Creek Lodge offer single and double occupancy with rates ranging from $125 - $145 per room per night.
Detailed Design	Are Local Consultants available with required expertise to perform consultancy scope	Consultants in Nassau should be able to perform detailed design. If local consultants cannot fulfil scope then foreign firms or foreign and local JV will have to be employed.	Use of foreign firms will increase costs over use of locally available firms if foreign consultants will need to be on island long term to complete scope.
	Is there a fixed airline route from Nassau to Long Island?	The Deadmans Cay Airport is closest to the project site. Sky Bahamas and Southern Air provide steady service to this airport.	The cost for commercial airlines is much less expensive than chartered flights.
	If there is a fixed airline route what is the frequency of service	Sky Bahamas provides one (1) daily flights to and from the island. Southern Air provides two (2) daily flights to and from the island. Flights are available every day of the week.	The average cost for a roundtrip is $250 - $270 per person. Ticket prices vary depending on the season.
	Will a special charter need to be arranged for movement of personnel	Special charter may only be necessary during visits with Client or Government personnel at major milestones.	$8,000 per roundtrip to Deadmans Cay (Odyssey Aviation), limited to same day.

	Are there vehicles available for rent locally	Rental vehicles available from individuals on the island. Contact is necessary prior to arrival. Vendors include Ellen's Inn, Mr. T's Car Rentals and Unique Wheels Rentals.	Estimated to be min. $65 - $85 per day for small passenger vehicle, up to $100 per day for a minivan. Cost for fuel estimated to be $5 - $6 per gallon.
	Are there adequate accommodations for Consultant teams	Accommodations in settlements closest to the project site are preferred. Rental homes or villas are the less expensive options for teams travelling. If no accommodations can be found then visits will be limited to day trips. Greenwich Creek Lodge and Ellen's Inn are the closest accommodations to the project site, located in Cartwrights and Deadmans Cay respectively.	Ellen's Inn is a bed and breakfast offering single and double bed rooms, with rates ranging from $90 - $105 per room per night. Greenwich Creek Lodge offer single and double occupancy with rates ranging from $125 - $145 per room per night.
Construction and Supervision	Availability of Local Contractors to perform construction works to be determined	Local contractors based in Long Island will incur the least overhead cost. Local contractors based in Nassau will incur more overhead cost. Foreign contractors will incur the most overhead cost. If local contractors cannot fulfil scope then foreign contractors will have to be employed. Rowdy Boys Construction and Stefan Knowles Construction are a couple of the companies with equipment suitable for heavy works.	Costs for work permits, accommodation, ground transportation, per diem must be included for foreign contractors. Cost for accommodation, ground transportation and per diem must be included for Nassau contractors.
	Availability of Local Labourers to perform construction works to be determined	Local workers based in Long Island will incur the least overhead cost. Local workers based in Nassau will incur more overhead cost. Foreign workers will incur the most overhead cost. If local workers cannot fulfil scope then foreign workers will have to be employed. Rowdy Boys Construction and Stefan Knowles Construction are a couple of the companies with labourers suitable for heavy works.	Costs for work permits, accommodation, ground transportation, per diem must be included for foreign workers. Cost for accommodation, ground transportation and per diem must be included for Nassau workers.
	How close is the nearest dock for receiving shipped goods, materials, equipment	Nearest dock to project site is in Deadmans Cay, Clarence Town and Stella Maris. Adequacy of docks to be determined based on the size of equipment/materials being shipped.	
	What is the condition of the nearest dock for receiving shipped goods, materials, equipment	Condition assessment to be performed for docks.	If an adequate dock is unavailable it will be necessary to have on constructed prior to the need for equipment and materials.
	Is there a fixed shipping route for movement of materials to the island or will special charter be required	Regular shipping routes and capacity of shipping vessels in the Bahamas to be determined. Should these not be found adequate it may be necessary to ship via private barge.	Special Charter will increase cost significantly
	If there is a fixed shipping route what is the frequency	Frequency of shipping routes to be determined.	
	Will a special charter need to be arranged for shipment of goods or materials	The need for special charter to be determined.	
	Is heavy equipment (drill rig, excavator, flatbed trucks, crane, etc.) available for use	Equipment available by local contractors in Long Island to be determined and compared to inventory of equipment necessary for successfully optioneered design. If heavy equipment is unavailable a boat will have to be chartered to barge the equipment to Long Island.	Cost will increase depending on the size and quantity of equipment that needs to be shipped to the island.

	Is there a fixed airline route from Nassau to Long Island?	The Deadmans Cay Airport is closest to the project site. Sky Bahamas and Southern Air provide steady service to this airport.	The cost for commercial airlines is much less expensive than chartered flights.
	If there is a fixed airline route what is the frequency of service	Sky Bahamas provides one (1) daily flights to and from the island. Southern Air provides two (2) daily flights to and from the island. Flights are available every day of the week.	The average cost for a roundtrip is $250 - $270 per person. Ticket prices vary depending on the season.
	Will a special charter need to be arranged for movement of personnel	Special charter may only be necessary during visits with Client or Government personnel at major milestones.	$8,000 per roundtrip to Deadmans Cay (Odyssey Aviation), limited to same day.
	Is there adequate availability of suitable construction materials and supplies on the island	An inventory of materials available on island will need to be performed and compared against materials required for the selected optioneered design.	Cost will increase depending on the type and quantity of material that needs to be shipped to the island.
	Are there vehicles available for rent locally	Rental vehicles available from individuals on the island. Contact is necessary prior to arrival. Vendors include Ellen's Inn, Mr. T's Car Rentals and Unique Wheels Rentals.	Estimated to be min. $65 - $85 per day for small passenger vehicle, up to $100 per day for a minivan. Cost for fuel estimated to be $5 - $6 per gallon.
	Are there adequate accommodations for Construction teams	Accommodations in settlements closest to the project site are preferred. Rental homes or villas are the less expensive options for teams travelling. If no accommodations can be found then visits will be limited to day trips. Greenwich Creek Lodge and Ellen's Inn are the closest accommodations to the project site, located in Cartwrights and Deadmans Cay respectively.	Ellen's Inn is a bed and breakfast offering single and double bed rooms, with rates ranging from $90 - $105 per room per night. Greenwich Creek Lodge offer single and double occupancy with rates ranging from $125 - $145 per room per night.
	Is there an adequate area for laydown of construction equipment and materials	Need to determine suitable public land for contractor to store equipment and materials. Cadastral survey may be required to determine land ownership.	If public land is unavailable it may be necessary to use private land at a cost during the construction period.

Studies for the Preparation of The Bahamas Risk-Resilient Integrated Coastal Zone Management Program: Component B – Coastal Protection Interventions

Provision of coastal studies and interventions for risk-resilient coastal protection measures at specific pilot study sites.

Project Data Sheet for East Grand Bahama Causeways

1. Objectives

The overall objective is to support transport links and reduce vulnerability of structures and communities to flooding while providing ecological enhancements to marine habitats, species and the environment. In parallel to this there is a need to reduce erosion and flood risk to critical infrastructure local to the causeways.

The sub-objectives include:

(i) Through modelling and marine ecological services further identify potential ecosystem benefits to the proposed Marine Protected Area in East Grand Bahama;
(ii) Support ecosystem services in reducing vulnerabilities associated with coastal processes by supporting marine and coastal habitats and species:
(iii) Through modelling and optioneering assess options for modifying and/or removing causeways and/or improving drainage to achieve the overall objective; and
(iv) Based on the optioneering and modelling, undertake modification to a number of causeway/creek systems in East Grand Bahama.

Many of the problems that are associated with flooding and infrastructure issues in East Grand Bahama are as a result of the installation of causeways in the 1900s in order to provide access routes for the logging industry. The construction of roads through creeks on East Grand Bahama (and indeed elsewhere in The Bahamas) is associated with the use and reliance on old engineering structures that were least costly. These appear to have been constructed without the broader consideration of impacts on marine ecology and flood risk, and further have not provided the most sustainable of solutions (with various levels of deterioration seen in some of the structures).

It is critical therefore that the projects, studies and works to be undertaken at these sites aim to move away from the traditional causeway engineering designs to provide more sustainable innovative designs which aim to:

- Reduce whole life maintenance spend;
- Increase the resiliency of the structure;
- Have wider environmental benefits on the marine ecology; and
- Have wider flood risk benefits.

Figure 1: Improvements in the drainage are required to the causeways such as the one pictured below on the approach to McLean's Town.

Source: Mott MacDonald, 2016

Figure 2: Improvements in the stability of the infrastructure is required. Recent damage can be seen on the causeway linking McLean's Town to Grand Bahama mainland.

Source: Mott MacDonald, 2016

2. Location

Grand Bahama Island is anomalous in its orientation in the archipelago. The island extends along the southwestern margin of Little Bahama Bank and covers 1,112 km2, making it the fourth largest island in the Bahamas. The island can be broadly split into three areas: Freeport, East Grand Bahama and West Grand Bahama. This study focuses on East Grand Bahama and the creek systems that run across the island. In particular, the focus is on several causeways that have been built across the creek systems at the east end of the island near McLean's Town (Figure 3).

Grand Bahama island resides in the most north western portion of the archipelago. Being the closest to Florida, it is an important tourist destination and is home to the second largest city in the Bahamas. This island has vast beaches, extensive cave systems, wetlands and both pine and coppice forest. The island has extensive mangrove wetlands along the northern and eastern margins of the island. Most of the development is in the cities of Freeport and Lucaya and occur along the southern coast.

Grand Bahama shares the Little Bahama Bank with Abaco, but unlike that island it is very flat, the highest point being just 20.7 meters above sea level. It also lacks the long ridges that characterize most other islands, and even small cays. This is to a large extent due to its location along the southern margin of the Little Bahama Bank, where it is sheltered from the prevailing NE Trade Winds and winter northerlies. Only the gentler southeastern winds of summer have created land from the sea at the edge of this bank, and initially the island was little more than a series of low-lying cays. In this respect it has a lot in common with Andros, and the Joulter cays are probably proto-island masses of this type. To the east, the sequence of about eight large cays stretching from McLean's Town to East End Point are relicts of what the rest of the island must have once looked like.

The northerly location of Grand Bahama ensures a more marked winter-summer regime, and greater rainfall, than the islands to the south. Annual rainfall averages 152.4 centimetres (Bahamas Department of Meteorology). The winter months are markedly cooler than elsewhere in the Bahamas, this being the only island ever recording falling snow!

The extent of level land and higher rainfall has ensured the development of large water lenses, and associated with these, extensive Caribbean Pine forests. Many were logged in the 20th century but were left to recuperate since the 1970's. Abundant water and the logging industry led to the establishment of a new town in the 1960's and today Freeport/Lucaya is the second largest city of the Bahamas. The flat topography facilitated the construction of numerous sub-divisions with canals, and marinas, which at the same time provided much needed landfill material.

The principal tourism destinations in the Bahamas are located on Nassau/Paradise Island, and Freeport/Grand Bahama Island. According to the Immigration Card and Research & Statistics Department Grand Bahamas has a population of 51,756 (2010 Census) with the majority of the population living in or near Freeport/Lucaya. In 2015 the total number of visitors to Grand Bahama was 246,517. This represents 16% of the total visitors to the Bahamas, though it has seen a much greater portion of tourists in past years. The majority of tourists do not visit East Grand Bahama. Those that do are usually visiting to fish in the nearby waters, there being five official fishing lodges in the area. Some of these visitors have second homes in Deep Water Cay. Others visit the area to travel by ferry to Abaco.

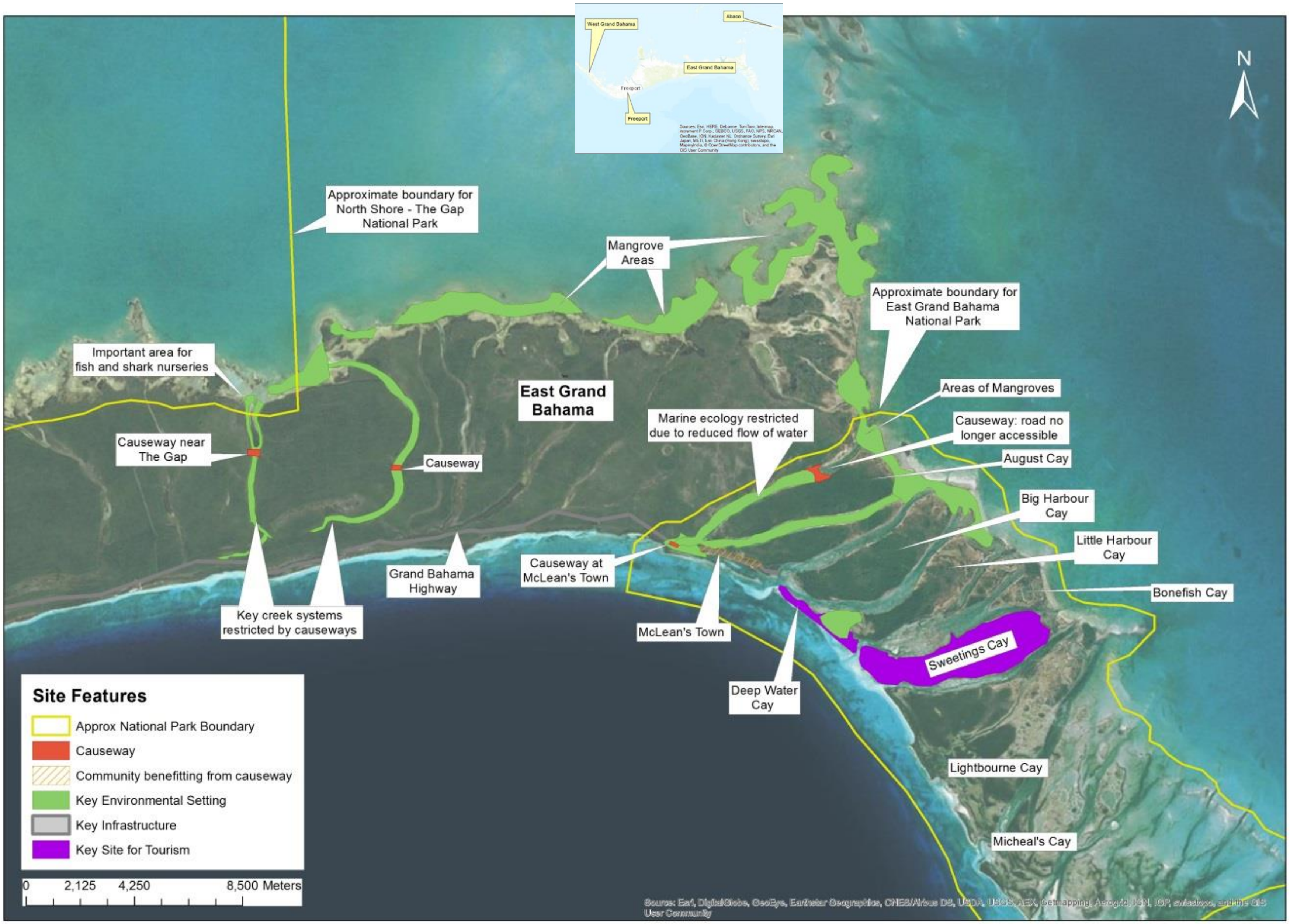
The sites are within a newly proposed Protected Area called East Grand Bahama National Park which is ranked as one of the most important sites by Bahamas National Trust (BNT) for biodiversity conservation (Figure 3) and very close to another of the proposed National Parks, namely Northshore. Grand Bahama currently has three national parks but each of these parks are quite small relative to the size of the island. The BNT is proposing the expansion of two of the current sites to incorporate some very important natural features as well as two new sites that would ensure the protection of valuable resources for the future of Grand Bahamians. The habitats of the Northshore and East End of Grand Bahama all support the lucrative bonefishing industry that the communities of East Grand Bahama heavily rely on, valued at $141million according to the BNT.

The mangrove fringing along tidal creeks and large channels provide appropriate habitat for a variety of commercially important fish, and numerous birds that thrive on the islets that make up the chain of the East Grand Bahama Cays. The tidal flats in this area are known as prime bonefishing grounds that economically benefit fly-fishermen in East End, including the fishing communities of Sweetings Cay and McClean's Town.

This area is also famed for its Zodiac Caverns, a network of interconnected underground caves and inland blue holes, explored by expert cave divers from the early 1980s. This unique cave system represents some of the most highly decorated caves in The Bahamas, attracting world class cave divers on an annual basis. Continued research in these caves has revealed a highly diverse troglobitic ecosystem, only found in the darkest parts of the caves.

The extensive intact mangrove forests are corridors to the offshore reef system for commercially important species of fish (groupers, snappers grunts) and lobster, that move out to the deeper reefs as adults. From an ecological perspective, these habitats are also critical to providing shoreline protection from extreme weather systems. A unique feature of patch reef communities adjacent to extensive seagrass and oceanic holes are found within the creek system of Big Thrift Harbour, showcasing a variety of marine life, including spotted eagle rays, turtles, fish, lobsters, and corals including the threatened Staghorn coral, that were once important reef builders but are now uncommon in The Bahamas. The fishing communities of East End are heavily dependent on this reef system for daily sustenance, and therefore worthy of protection to ensure existing and potential threats safeguard their livelihoods.

Figure 3: Location of the East Grand Bahama site



Source: Mott MacDonald, 2016 and ESRI mapping, 2016

Figure 4: Named Locations of the Causeway Project sites

Source: Blue Engineering, 2016 and BNT (2016) IWECO Project Document

Descriptions of each site

The following descriptions are provided based on site visit on 14th December 2016 and the Rapid Ecological Assessment conducted for the area by the BNT, April 6th to 9th 2016.

West Gap Creek

Gap Creek is within the proposed Northshore/Gap National Park, it opens to the north of Grand Bahama and is approximately 3.5 km in length, with a causeway blocking the creek approximately 1.6 km from the creek mouth in the north. North of the causeway, the creek has an east and a west branch that run parallel to each other and open in the same area. Along the east branch of the creek, there is a boat ramp providing access to the creek just north of the causeway.

The creek is shallow close to both sides of the causeway (approximately 1m deep) where it has filled in with fine sediment as a result of the causeway. Through the creek there are a number of deep holes in the rock that may lead to deeper subterranean caverns (based on their depth and the appearance of freshwater seeps).

While dwarf mangroves were the most common mangrove community type throughout the creek on the north side of the causeway, On the west branch of the north side of the creek, fish communities were generally lower than on the east side.

South of the causeway, fringing mangroves were larger and more developed, probably due to the fact that they were growing in fresh water. The prop roots, however, were choked with cyanobacteria and filamentous algae mats, providing little fish habitat. Very few fish were observed south of the causeway. Along the causeway itself small Gambusia (mosquitofish) minnows, gray snapper (Lutjanus griseus), barracuda (Sphyraena barracuda) and a turtle were observed. The presence of these marine species in the freshwater system suggests occasional over-wash of the causeway during severe storm surge events.

The salinity of the creek was found to decrease as travelling inland from the north. The south side of the creek is freshwater indicating no regular connection to the north side of the causeway.

Figure 5: Location of West Gap and Ridge Creek Causeways and Accesses to the Gap Causeway

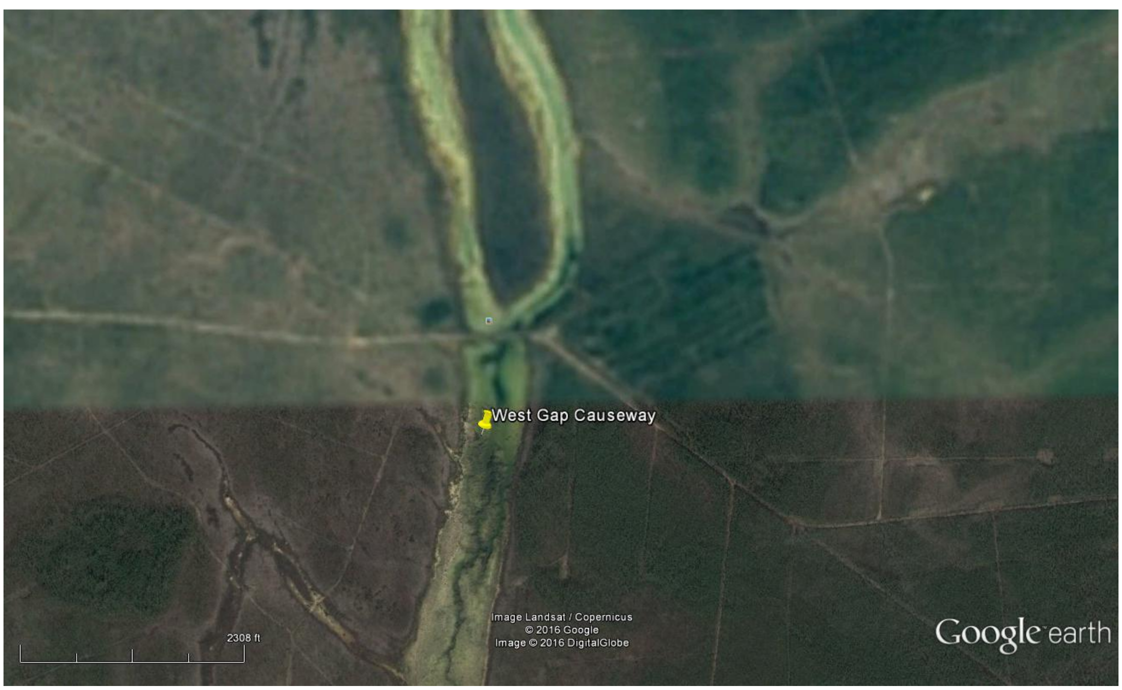


Figure 6: Location of West Gap Causeway


Figure 7: West Gap Causeway looking west south west.


Figure 8: West Gap Causeway looking south.


Figure 9: West Gap Causeway looking west North West.

Ridge Creek

Ridge Creek is approximately 3 km to the east of the Gap Creek at the mouth, and the creek and mangrove system extend approximately 6 km inland until a causeway with an elevation of approximately 2m blocks the system and isolates it from the remaining mangrove system to the south.

It appears that there is some freshwater seepage in inland portions of the creek system where hard-bottom substrate pocked with solution holes may promote this freshwater influx. Freshwater on the south side of the causeway indicates that there is no clear channel connecting the mangroves to the north of the causeway, to the main creek channel. Periodic inundation by sea water immediately to the north of the causeway may occur on extreme high tides and during storm surges, which appear to at least occasionally reach the top of the causeway, based on evidence of old flotsam in one location on the causeway.

Fish and benthic communities to the north of the causeway were more diverse and generally denser in the Ridge Creek system than the Gap Creek system. Benthic communities ranged from hard-bottom to bare mud, to mud and sand with varying amounts of seagrass and macroalgae, with more seagrass towards the mouth of the creek. Differences in benthic communities likely reflected local differences in the underlying bedrock and amount of flow through an area.
South of the causeway, water depths were extremely shallow. Some algae and small minnows were observed in the areas described above where there was water.

Figure10: Location of Ridge Creek Causeway

August Creek

August Creek is at the far east of Grand Bahama, within the proposed East Grand Bahama National Park area. This creek to the West of August Cay was blocked by a causeway (Snapper Island Causeway), approximately 2.75 km inland of the north mouth. To the south of this portion of the creek is another causeway (McLean's Town Causeway), and the main road connecting McLean's Town to Grand Bahama where a small culvert restricted water flow to the south. August Creek bends at this location to the north east where it connects again to the north.

Northeast of Snapper Island Causeway is a sand and mud area. Closer to the mouth of the creek to the northeast, there is a deep (>2m deep in places) channel with a hard-bottom and sand substrate. At least one deep hole (likely connected to a cave system) was observed in the channel. There are tall fringing mangrove communities along the creek, with large snapper and grunt populations similar to open mangrove habitats. Close to the causeway, there are high densities of fish species. Benthic communities in this area were heavily vegetated with seagrass and Laurencia species, an important nursery habitat for Nassau grouper, lobster, and other species.

Southwest of the causeway is dominated by bare mud, substrates were muddy close to the causeway, with minimal vegetation. Substrates were muddy throughout this area, but several blue holes surrounded by hard-bottom were noted in the creek system nearby. Unlike the other two creek systems, fish populations were fairly abundant on the south side of Snapper Island Causeway, although they were lower than the northeast side. This is likely because of the connection to the sea through the culvert at the Causeway near McLean's town and the connection via the creek to the East of August Cay.

Juvenile bonefish were observed from the boat south of Snapper Island Causeway. Further south, near McLean's Town there more snappers and grunts, probably because of the connection to the sea in this area, which allows for some larval fish to enter the system. Benthic communities at sites close to Snapper Island Causeway were bare mud, but sites near McLean's Town had up to 26% seagrass growing in sand and mud.

Figure 11: Location of Snapper Island and McLean's Town Causeways

Figure 12: Snapper Island Causeway west end from south

Figure 13: Snapper Island Causeway east end from south

Figure 14: August Creek west edge from south side of Snapper Island Causeway looking south west

Figure 15: McLean's Town Causeway looking east

Figure 16: McLean's Town Causeway looking west

Figure 17: North side of McLean's Town Causeway looking north

Figure 18: Fish at end of culvert at north side of McLean's Town Causeway looking north

Figure 19: South side of McLean's Town Causeway looking south

Figure 20: Earth dam on south side of McLean's Town Causeway looking south

Figure 21: End of culvert on south side of McLean's Town Causeway looking south

3. Beneficiaries

Beneficiaries include:

- Local residents of communities such as McLean's Town (approximately 30 residential properties) that use key infrastructure including access road and service provision which relies on the road for access (including electricity and water in some instances);
- Residents, overnight visitors and day visitors to Sweetings Cay, Deep Water Cay and Abaco, and for fishing/boat trips from McLean's Town (note, Deep Water Cay notably for bonefishing and Abaco notably for lobster);
- National authorities and planning agencies such as Bahamas National Trust in planning objectives for National Parks and the proposed Marine Protected Areas;
- Local communities relying on the economy relating to tourism and fishery; and
- National Emergency Management Agency for vulnerability and disaster risk management.
- Water and Sewerage Corporation and Residents as a result of reduced potential for flooding of wellfields and residential domestic wells.

<u>Ecosystem Services consideration</u>

There are opportunities to undertake a thorough ecosystem service approach to justifying implementation of coastal management options at this site. A detailed ecosystem service assessment is recommended for the site, however further to this an initial consideration of the baseline scoping is summarized below.

Type of Ecosystem Service (ES)	Is this ES present in the project area?	Is the project activity likely to have an impact on the ES?	Are the benefits of this ES likely to extend on a local, regional, national, or global scale?	Is the project likely to have a significant impact on any beneficiaries of the ES?	Does the client have direct management control or significant influence on the ES?	Does the project depend on this ES?	Based on the answers to the previous questions, is this a priority ES?
Provisioning Services							
Crops	Potentially	Potentially	Local	Potentially	No	No	Yes
Fodder	Potentially	No	Local	Potentially	No	No	No
Capture fisheries	Yes	Yes	Local, Regional	Yes	Yes	Yes	Yes
Aquaculture	Potentially	Potentially	Local	Potentially	No	No	Yes
Wild foods	No						No
Timber	Potentially	Potentially	Local	Potentially	Potentially	No	Yes
Energy (woodfuel / biomass)	No						No
Biochemicals/ medicine	No						No
Freshwater (supply)	No						No
Fibre	No						No
Genetic resources	No						No
Regulating Services							
Local climate regulation	Potentially	Potentially	Local	No	Yes	No	Yes
Global climate regulation	No						No
Flood protection	Yes	Yes	Local, Regional	Yes	Yes	Yes	Yes
Air quality regulation	No						No
Erosion regulation	Yes	Yes	Local	Yes	Yes	Yes	Yes
Soil quality regulation	No						No
Water quality regulation	Yes	Yes	Local, Regional	Potentially	Yes	No	Yes
Pollination	No						No
Disease and pest control	No						No
Noise regulation	No						No
Cultural Services							
Tourism & recreation values	Yes	Potentially	Local	Yes	Potentially	Yes	Yes
Wild species diversity	Yes	Potentially	Local	Yes	Yes	No	Yes
Cultural & spiritual values	Potentially	No	Local	Potentially	Potentially	No	No
Scientific & knowledge values	Potentially						Yes

4. Technical and economic justification

The primary drivers for intervention and improvements in coastal protection, including the modification and/or removal of causeways in East Grand Bahama is the flood and erosion protection of critical infrastructure and development of related marine habitats/ecology through environmental enhancement. Currently some causeways and surrounding areas are experiencing regular flooding, and/or cracking/erosion of the road which has been attributed to the inadequate drainage infrastructure under the road. At McLean's Town the road is the only link for the communities McLean's Town and the Eastern Cays to the rest of Grand Bahama especially as the ferry dock is located east of the causeway. Furthermore, the increased flushing and movement of water around the Cays and throughout the east of the island is likely to support coastal biodiversity and boost and support coastal marine ecology/biology of the area, having both environmental, social and economic benefits; and

The construction of roads and causeways during the pine logging era (first half of the 1900s) has been suggested to have caused degradation of the mangrove creek systems (such as Big Water Bush Creek and Little Water Bush Creek). Water flow is being restricted by inadequately sized culverts and a lack of culverts or other means of water passage (not reflecting latest climate related rainfall forecasts/tidal flow forecast etc.) (Bahamas National Trust, *personal communication February 2016*). To understand more about the impacts on mangrove systems it is important to place this in perspective. Biotic activity within mangrove forests, where the trees are the central feature of the ecosystem, has led to the development of unique substrate or bio-geomorphology in intertidal and coastal areas. Colonies of mangroves have developed under the influence of a range of physical factors such as strong tidal flows and dramatic changes in the environment that accompany alternating flooding and drying of the habitat. In turn, mangroves are sensitive to several environmental gradients that respond either directly or indirectly to particular landform patterns and physical processes (Woodroffe, 1992; Mazda and Kamiyama, 2007).

Since Watson (1928) first demonstrated a correlation between the tidal regime and the species zonation of mangroves in Malaysia, physical processes such as tidal regime and the elevation of bottom substrate have become increasingly recognized as important factors in the structure of mangrove ecosystems (Chapman, 1944; Lugo and Snedaker, 1974; Carlson et al., 1983; Bunt et al., 1985). Understanding the link between strong and weak tidal flows in the area and its impacts are crucial and reduction in nutrient rich daily tidal process and biodiversity is well documented. Among the various types of water movement within mangrove areas, tidally driven currents are crucially important. The physical environment that supports mangrove ecosystems is basically formed by the tidal motion of seawater with a diurnal or semi-diurnal period, although the tide does deform significantly in mangrove swamps due to the high density of mangrove trees and roots (Mazda and Kamiyama, 2007). Watson (1928), Lugo and Snedaker (1974) and Bunt *et al*. (1985) proposed that the mangrove community is tolerant of tidal inundation and the periods of inundation and salinity that accompany tidal inundation. Essentially this reduction in tidal flows and associated water quality has potentially caused a reduction in the critical marine biodiversity (species and habitats) that are found in the creek systems. The health of the mangrove creek systems is critical for the communities that live in this area (as flood protection and nursery habitats), in addition to the wider importance of these areas for biodiversity and species availability elsewhere in the Bahamas. Mangroves provide many ecosystem services but one of the main services they provide is protection of coastal environments from flooding and wave action.

Mangroves and reefs not only have ecological value, but also social and economic significance. The Bahamas National Trust is currently considering many of these areas for inclusion in Marine Protected Areas (MPA). The areas that are proposed for designation and are currently being reviewed by GOBH are displayed in Figure 3). The symbiotic link between current BNT work regarding MPA proposed designation is quite evident and is best illustrated in preservation of the surrounding mangrove forests which are corridors to the offshore reef system that not only support coastal ecosystem adaptation strategies but also important commercial fish species (groupers, snappers grunts) and lobster, that move out to the deeper reefs as adults but also used these

ecosystems as a developmental habitat. In summary these habitats provide critical ecological services while providing shoreline protection from extreme weather systems.

There are several causeways within the region that fully or partially block the creek system. There is an opportunity to therefore undertake a number of interventions to improve the mangrove creek systems and the services these provide, whilst maintaining critical infrastructure routes and improving the engineering robustness of these infrastructure links where necessary. Further consideration of flood and erosion protection (both via natural planting of mangroves and the engineering design of the causeways) is required. The main causeways identified for modification are West Gap Creek, Snapper Island Causeway, McLean's Town Causeway; and Ridge Creek Causeway, in order of ecological priority according to the BNT. Further details based on BNT's findings are given below.

5. Description

The range of viable options for this area have been identified and analyzed and are presented in Appendix A. It is concluded at this stage (which is prior to required surveys and studies for a full optioneering process) that the likely solutions will be as follows;

- West Gap Creek – removal of the causeway and replanting with relevant native species to restore water flow;
- Snapper Island Causeway – removal of the causeway and replanting with relevant native species to restore water flow;
- McLean's Town Causeway – installation of a new box culvert or a small bridge coupled with plantings and sills; and
- Ridge Creek – installation of a box culvert coupled with plantings and sills.

These restoration efforts will allow improved flushing of water and reduce flood risk. In addition, mangrove re-habilitation is likely to provide a solution to increase the diversity of marine ecology as well as providing stabilization for infrastructure and reduced flood risk for infrastructure and communities. The key causeways for initial consideration are further detailed below;

West Gap Creek Causeway

The causeway at West Gap Creek is approximately 470 feet long and 35 feet wide. This system would benefit greatly from restoring water flow where the causeway bisects the creek. Because there is evidence of a creek channel leading right up to the causeway, and a deep, but unconnected mangrove creek system on the other side of the causeway, removing part or all of the causeway would reconnect this system. Likely results of the reconnection include an increase in the area serving as suitable habitat for snappers, grunts and other species. The health of fringing mangroves south of the causeway, suggests that there would be both qualitative and quantitative improvements to marine fish habitat by restoring connectivity. Sites north of the causeway, particularly on the west branch of the creek, are likely to benefit from increased water flow and flushing that are likely the results of this part of the creek being "choked off" by the causeway. Increased water flow is likely to reduce the accumulation of mud, increase water depths, allow more vegetation to grow and provide higher quality habitat for snappers, grunts and other species. In addition, removing the blockage at the causeway may create a buffer for surrounding areas during storm surges by allowing seawater to penetrate deep into the mangrove system and avoid widespread flooding of pinelands.

From an ecological perspective, complete removal of the causeway to allow maximum flow throughout the creek system is recommended as the preferred option. Doing this will greatly improve the health of the ecosystem while still maintaining access roads from the main road to access the east and west sides of the creek. Nevertheless, it is recognized that maintaining a road that goes East-West in this area may have some value. In this case installing large (~2m diameter or greater) culverts or bridges connecting both the East and West branches of the creek to the southern mangrove area is recommended to maintain flow through both sides of the creek system as an alternative option to consider. In restoring water flow to the system, regardless of which option is

taken, an expert on mangrove trees should be consulted to determine if the mangroves to the south of the causeway would be able to tolerate a rapid change in salinity or if a slower acclimation process is necessary.

Snapper Island Causeway, August Creek

The causeway at Snapper Island is approximately 470 feet long and 35 feet wide. Removing at least a section of this causeway near the tall fringing mangroves (west side of the causeway) will provide the greatest ecological connectivity between the two sides of the causeway and improve the quantity and quality of fish habitat. Because the site to the northeast of this system has the greatest diversity of fish and harbored juveniles of key fish species, including parrotfish and grouper, increasing habitat availability in this system may have positive impacts on nearby reefs.

The restoration of this site also has significant support from the surrounding communities. The Local Government representatives for the area voiced the concerns from the community to open up this creek to provide a more even flow of water through the creek, reduce flooding of the nearby pine woodlands from storm surge and provide a safer fishing area for the fishermen in the community during periods of inclement weather.

McLean's Town Causeway, August Creek

The causeway at McLean's Town is approximately 150 feet long and 40 feet wide. Intervention is required at McLean's Town where the causeway represents the only roadway connecting McLean's Town (which is on a previous Cay) to the mainland. The causeway is therefore critical to maintaining access to settlements in East Grand Bahama (McLean's Town, Sweetings Cay and Deep Water Cay which is the oldest Bonefish Lodge in The Bahamas). The road also provides access to Pinders dock and the Abaco ferry service (which runs twice daily) as well as a development at the end of the road where there has been recent dredging for a marina. Furthermore, the site is within a proposed National Park protected area (East Grand Bahama National Park which is ranked as one of the most important sites by Bahamas National Trust (BNT) for biodiversity conservation). Approximately 1,500 feet of the road in this area is understood to flood during spring high tides and has been flooded for over a week during hurricane conditions. The area is vulnerable to increased storm frequency and intensity and has been prioritised for intervention by local communities who have lobbied to the Government of The Bahamas (GOBH) for restoration efforts here for more than a decade.

The two 24 inch diameter culverts beneath McLean's Town Causeway at the southwest end of August Creek provide some water flow between the sea and the creek, but the small diameter and long length of the culvert, as well as its angle, makes this connection of minimal value for allowing larval or juvenile fish to enter the creek system or for sub-adults and adults to exit the creek system as they move to reefs. Increasing water flow in this area by removing the existing culvert and expanding the connection would increase water flow, improve larval/juvenile supply to the mangrove creek system and improve the connectivity between the mangroves and offshore reefs. The culverts are damaged, quarry is washing out from the road and the causeway is eroding at the edges and in need of repairs. Repairs would provide an opportunity to expand the connection which would likely impact the creeks on either side of August Cay, increasing connectivity between the sea and a large mangrove system. The connection should be at least 2m in width, and a bridge would be preferable to an enclosed culvert(s) to facilitate sub-adult and adult fish movement between the creeks and open water. Consideration should also be given to raising the road to alleviate the flooding issues.

Ridge Creek

The causeway at Ridge Creek is approximately 150 feet long and 40 feet wide. Partial or total removal of the causeway in this area is likely to have minimal impact on marine life in this system since significant tidal flow rarely, if ever seems to reach the causeway. While digging a channel to improve tidal exchange to the north may further increase tidal exchange in this area, the shallow depths of bedrock >1km north of the causeway is likely to limit the amount of exchange and the value

of areas close to the causeway for marine species. Opening up the causeway may, however, restore hydrology during storm surges and allow water to flow in the historic wetland system, buffering the impact of storm surges to adjacent pinelands.

The proposed approach to the restoration shall be the Living Shorelines methodology for project interventions. This methodology has typically been used for low energy shorelines and has potential for tidal creek areas which are low energy. Living Shorelines are designed to help reduce coastal risks and improve resiliency through incorporation of natural and nature-based features in addition to non-structural and structural measures in a practice referred to as SAGE (Systems Approach to Geomorphic Engineering) developed by the United States Army Corps of Engineers (USACE) and National Oceanic and Atmospheric Administration (NOAA) (see www.habitat.noaa.gov/livingshorelines). SAGE promotes a hybrid engineering approach that integrates soft or green measures with hard or gray ones. The goals of Living Shorelines include:

- Stabilizing the shoreline and reducing current rates of shoreline erosion and storm damage;
- Providing ecosystem services (such as fish habitat) and increasing flood storage capacity; and
- Maintaining connections between land and water ecosystems to enhance resilience.

These goals align with those of the proposed project and the project will seek to design restoration interventions in line with the Living Shoreline or SAGE practice. Green interventions can include plantings, sills and edges while gray interventions will include culverts and bridges.

The project will enable a feasibility analysis for each proposed restoration and design of the best intervention for each site. Parameters to be assessed in the optioneering studies will include safety for users, functionality (including movement of wildlife), consistency with national plans, policies and regulations, and cost effectiveness.

The research assumption is that the methodology employed will improve the health and functionality of the East Grand Bahama Ecosystem. Through the assessments and monitoring completed during the project, the research assumption will be confirmed or refuted. As the project progresses, opportunities to adapt the methodology will be employed, hence adaptive management. All project interventions will be thoroughly documented so any lessons learned can be shared locally and globally.

A preliminary list of activities and investments to be undertaken for the project area is presented below.

- Hydrodynamic and Ecosystem services assessment study to focus on:
    - Data review and data gap analysis, to be undertaken though liaison with Bahamas National Trust (note BNT Rapid Ecological Assessment has already been conducted) ;
    - Undertake baseline surveys including key species/habitat/ecology mapping to drive an ecosystem services assessment (note BNT Rapid Ecological Assessment has already been conducted); and
    - Undertake hydrodynamic modelling to determine the impact of removing/modifying causeways and drainage including tide measurements and a water quality assessment (note BNT Rapid Ecological Assessment has already been conducted which included salinity measurements). Studies could include;
        - Tidal elevations – to determine the typical levels experienced within the creeks on a daily basis (especially at Mc Lean's Causeway) and estimate a worst case scenario during a high spring tide
        - Creek discharge rates/flushing times – to find amount of water potentially leaving and entering the creeks (especially useful to see how much water is allowed to flow past the causeways on a regular basis and how much of the

flow has contributed to blockage and conversely how the flow has affected their degradation). Note this study is not allowed for in the following budget.
        - Topographic and bathymetric surveys - limited to local to the causeways to provide cross sections either side of the causeway given limited budget. More extensive surveys could be used to estimate the water volumes within the creeks.
        - Current measurements – to observe the direction of water flow during tidal flood and ebb and alongside other studies can allow for better prediction of current measurements following removal.
    - Analysis of historical aerial/satellite imagery to determine if there has been any inundation of the cays over the years as a result of sea level rise (SLR) or hurricane damage
- Optioneering study to:
    - Develop options for the causeways and recommend a preferred solution;
    - Assess and quantify environmental and economic benefits of the solution; and
    - Concepts to maximize the use of green infrastructure in the area.
    - Studies by mangrove specialist to determine best approach to removing/modifying causeways
- Detailed design.
- Construction and construction supervision of the preferred options.
- Future monitoring of the ecological benefits and maintenance of causeway drainage (annual).

Hydrodynamic modelling as described above is extensive and will allow a better understanding of the coastal situation within the creeks and also estimate for extreme events. Although only a few of these studies might be considered in the short term (especially within a strict budget) the ideal ones that should implemented are tides and currents in order to have an idea of the amount of water being affected by the current location of the causeways. Data of this sort (collected across the long term) can then be used to feed into future modeling studies when capacity is sufficiently built within the MOWUD. These suggested technical studies can be used as monitoring initiatives within the creeks so that the effect of new/removed structures on the environment can be better observed and understood.

6. Products and indicators

Output:

- Hydrodynamic studies: Baseline 0, Target 1;
- Ecosystem services assessment: Baseline 0, Target 1;
- Optioneering study: Baseline 0, Target 1; and
- Improvements in the drainage infrastructure: Baseline 0, Target 3-4 number culverts; and
- Improvements to Marine Ecology in the area: Baseline: Poor (to be determined); Target: Good (indicators to be determined).

Outcome:

- Increased knowledge of hydrodynamic climate;
- Increased ecosystem service knowledge of the area;
- Increased resilience to climate risk;
- Increased resilience of critical infrastructure; and
- Increased ecological targets (to be determined with BNT).

Indicator:

- Minimum of 3 causeways modified/improved within 4 years;
- Decreased frequency of flooding in the project area to a return period to be determined in the optioneering study over the next 100 years;

- Decreased maintenance of infrastructure required over a 10 year period; and
- Ecological indicators to be developed with BNT – to be determined (for example this is likely to include a % of mangrove replantation/reforestation and a % increase in species found within specific creeks) – to be implemented by Year 4.

7. Estimated cost and source of financing

Activity	Estimated cost (USD)	Source
Hydrodynamic and Ecosystem services assessment study	300,000	TBC
Optioneering Design Report	50,000	TBC
Detailed design	80,000	TBC
Construction*	1,648,000	TBC
Contract Management and Supervision Services including environmental (6%)	98,880	TBC
Total Capital Input	**2,176,880**	TBC
Future monitoring, maintenance and operation (annual basis)	Unknown at this stage	TBC

*Construction costs at this stage are high level and draft at this stage and would need to be defined in more detail following further analysis

A breakdown in the costs is provided in the two tables below, for the initial upfront studies and then the construction estimates respectively.

	Rounded Approximate Cost (US$)
Ecology and modelling	**300,000**
Ecology Surveys	*60,000*
Hydrodynamic Modelling	*170,000*
Ecosystem service assessment	*70,000*
Optioneering Study	**50,000**
Optioneering	*50,000*
Detailed Design	**80,000**
Detailed design including ground investigations	*80,000*

Element	Unit	Cost Per Unit ($)	Number of Units	Total Cost ($)
Installation of new culvert system in McLean's Town Causeway (including paving)	Per culvert system	400,000	1	400,000
Raise road to improve flood risk of McLean's Town Causeway (average 0.46m raise))	Per m length of road	200	300	60,000
Excavation of West Gap Causeway	Meters cubed	77	2660	205,000
Excavation of Snapper Island Causeway	Meters cubed	47	13250	630,000
Excavation of portion of Ridge Creek Causeway	Meters cubed	77	565	43,000
Excavation of waterway at Ridge Creek Causeway	Meters cubed	62	4000	250,000
Mangrove rehabilitation at all causeways	Ha	500	120	60,000
SUB-TOTAL				1,648,000
Contract Management and Supervision Services including environmental (6%)				98,880
TOTAL				**1,746,880**

We have further undertaken an overall logistics and constructability assessment. The details of this are presented in Appendix B.

It should be noted that these figures account for a re-sale value for the excavated material of $10 per cubic yard (local measurements) and assume that the majority of the excavated material can be sold or reused in the project.

It should be noted that consideration has been given to the installation of a series of culverts/bridge at the Gap in particular to enabled continued east-west access across the causeway however this is considered unfeasible given the high cost (approximately $1.3 million for an75 foot long opening), low level of traffic across the causeway and the fact that either side can be accessed from the main road. Traffic from the

east wishing to access the west side of the causeway to access Riding Point to the north to launch their marine vessels would need to travel an additional 4.3 miles to access this location via the main road.

It should also be further noted that with the causeway in place travelers are able to circumnavigate 2.3 miles of the main road, however this portion of the highway is not a particularly heavily flooded area and flooding issues are more extensive in this area therefore this alternative route does not provide much relief during flooding.

8. Management model

The management of the studies and construction will be provided by the ICZM Project Execution Unit (PEU). Future owner-ship and options for Local Municipality and Bahamas National Trust partnership to be considered as part of the optioneering study.

9. Responsible institutions

Activity	Lead institution	Participating institution
Hydrodynamic and Ecosystem services assessment study	MoWUD	BNT/ Local Government/ BEST Commission
Optioneering	MoWUD	BNT/ Local Government/ BEST Commission
Detailed design	MoWUD	BNT/ Local Government/ BEST Commission
Construction and supervision	MoWUD	BNT/ Local Government/ BEST Commission
Future monitoring, maintenance and operation (annual basis)	MoWUD	BNT/ Local Government/ BEST Commission

10. Calendar of execution

Activity	Y1		Y2		Y3		Y4		Y5	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Hydrodynamic and Ecosystem services assessment study				X	X					
Optioneering					X	X				
Detailed design						X	X			
Construction and supervision							X	X		

11. Studies needed for execution

- Further habitat and ecology mapping as outlined in the BNT Rapid Ecological Assessment;
- Traffic surveys;
- Hydrodynamic modelling; and
- Ground Investigations at specific intervention sites to determine depth to rock if risk not an option for construction costs (note an add measure contract is recommended for this project).
- Environmental and Social Impact Management Plan

12. Procedure/environmental studies or others

An environmental and social impact plan will be required as part of the optioneering study and should be reviewed by both BNT and the BEST Commission.

13. Positive and negative environmental and social impacts

Impacts	Positives	Negatives
Social	- Improved infrastructure linking communities to the mainland; - Reduction in flooding occurring on the roads reducing disruption; - Improved access for visitors; and - Improved environment (see below) increasing tourism appeal and local fishing opportunities.	- Temporary impacts during construction – impact on access to communities on Cays and fishing locations will need to be carefully considered and mitigated during construction impacts; and - Temporary impacts during construction – acoustic noise, vibration and traffic from construction vehicles.
Environmental	- Increased flow of water improving Mangrove health, marine biodiversity & ecology; and - Opportunities to enhance and align with National Park Protected Area (mangroves (species and habitats) and improvements in associated water quality).	- Risk of temporary increased suspended sediments in the water column to be controlled during construction as well displacement of local and coastal marine species; and - Optioneering to assess potential impact of increased flows/increased salinity on mangrove ecology.

14. Priority and relation to other initiatives

This study is to align with the overall ICZM policy framework of The Bahamas as well as the Marine Management Policy. The site is within a proposed established Protected Area, East Grand Bahama National Park, which is ranked as one of the most important areas by Bahamas National Trust (BNT) for biodiversity conservation. The improvements to the infrastructure will also support the community of McLean's Town who have been lobbying for improvements to the area for a number of years.

15. Projects Benefits summary

The following table summarizes the key benefits of the proposed project and assigns a relative value score: 1 (lowest benefit) to 6 (highest benefit).

Benefit Sector	Description	Score
Asset protection – residential and commercial properties	Does not directly protect any residential or coastal properties.	1
Asset protection – infrastructure (including roads and services)	Key driver is protection and resilience of the causeway as a key asset linking communities and facilitating movement of products/ services.	6
Economy – relating to tourism	There are a small number of tourists who travel to McLean's Town to visit Sweetings Cay, Deep Water Cay and Abaco. These visitors rely on the transport links to access McLean's Town.	3
Economy – relating to everything but excluding tourism	Fishing currently takes place in the area, which could benefit from improved marine life.	2
Social benefits / benefits to the local communities	The community relies on some of these causeways for access and services, however the community does depend on the local marine life (fishing and attracting tourists) and they are very keen to see the marine ecology improved.	4
Environmental benefits – focusing on marine biodiversity and coastal ecology	This is an area which is part of the East Grand Bahama National Park and is a proposed Marine Protected Area. Increasing water quality through increased flushing could increase the marine ecology biodiversity in the area. Improvements in water quality and associate marine biota will also have longer term positive effects on commercial fisheries by developing habitats for new marine species to grow.	5

16. References

IWECO Project Document, Implementing Land, Water and Ecosystem Management in The Bahamas

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Appendix A: Viable options for engineering at East Grand Bahama.

A number of options were scored against indicators for the works in East Grand Bahama (see Second Interim Report, Mott MacDonald 2016 for a detailed methodology). From this scoring it was concluded that it is likely that the preferred option for this area will look at improving drainage and potentially revising layouts of the existing causeways to improve the marine ecology in the area. This is in addition to providing improved resilient infrastructure and reduced flood risk.

Table A1: Detailed scoring – note low risk/high opportunity = lower numbers

	Coastal Processes	Cost	Buildability	Sustainability	Total Technical Risk	Habitats/ Wildlife	Fisheries	Water Quality	Visual Appearance	Total Environmental Risk	Public Safety	Recreation	Cultural Heritage	Total Social Risk	Economic Opportunities	Environmental Opportunities	Social Opportunities	Total Opportunities	Overall Effectiveness
Site 6: East Grand Bahama Causeways																			
Improvements to road network	2	2	2	2	**8**	2	2	2	2	**8**	1	1	1	**3**	2	1	1	**4**	**2**
New bridges	1	2	3	2	**8**	2	1	1	2	**6**	1	1	1	**3**	2	1	1	**4**	**2**
Planting regimes/ invasive species	1	1	1	1	**4**	1	1	1	1	**4**	0	0	0	**0**	3	1	2	**6**	**4**
Eco-tourism access and facilities	1	2	2	1	**6**	0	1	1	1	**3**	1	1	1	**3**	1	2	2	**5**	**5**
Drainage	2	1	2	2	**7**	1	2	2	1	**6**	0	0	0	**0**	3	1	3	**7**	**2**

Table A2: Summary of scores with weighting applied and the total scores – note low risk/high opportunity = lower numbers

	Total Technical Risk	Total Environmental Risk	Total Social Risk	Total Opportunities	Overall Effectiveness	Total Score
Improvements to road network	0.7	0.7	0.3	0.3	1	**3**
New bridges	0.7	0.5	0.3	0.3	2	**3.8**
Planting regimes/ invasive species	0.3	0.3	0	0.5	4	**5.1**
Eco-tourism access and facilities	0.5	0.3	0.3	0.4	5	**6.5**
Drainage	0.6	0.5	0	0.6	2	**3.7**

Appendix B

ACTIVITY AFFECTED	CONSIDERATION	COMMENT	COST IMPLICATION
<u>Preliminary Studies Include</u> **- Baseline data review and gap analysis** **- Assessment of ecosystem services** **- Ecological monitoring** **- Topographic survey (recommend coast to coast coverage)** **- Hydraulic modelling, inclusive of hydrodynamic flows and water quality** **- Utility information gathering** **Optioneering**	Are Local Consultants available with required expertise to perform consultancy scope	Consultants in Nassau or Grand Bahama should be able to perform preliminary studies. If local consultants cannot fulfil scope then foreign firms or foreign and local JV will have to be employed.	Use of foreign firms will increase costs over use of locally available firms if foreign consultants will need to be on island long term to complete scope.
	Is there a fixed airline route from Nassau to Grand Bahama?	The Grand Bahama International Airport is closest to the project site. Sky Bahamas and Bahamas Air provide steady service to this airport.	The cost for commercial airlines is much less expensive than chartered flights.
	If there is a fixed airline route what is the frequency of service	Sky Bahamas and Bahamas Air each provide more than four (4) daily flights to and from the island. Flights are available every day of the week.	The average cost for a roundtrip is $180 - $210 per person. Ticket prices vary depending on the season.
	Will a special charter need to be arranged for movement of personnel	Special charter should not be necessary (minor possibility during visits with Client or Government personnel at major milestones).	$5,600 per roundtrip to Freeport (Odyssey Aviation), limited to same day if necessary.
	Are there vehicles available for rent locally	Rental vehicles available from individuals on the island. Contact is necessary prior to arrival. Vendors include Brad's Car Rentals, KSR Rent-A-Car Company and Island Jeep & Car Rental.	Estimated to be min. $50 - $75 per day for small passenger vehicle, up to $70 - $95 per day for a minivan. Cost for fuel estimated to be $5 - $6 per gallon.
	Are there adequate accommodations for Consultant teams	Accommodations in settlements closest to the project site are preferred. Rental homes or villas are the less expensive options for teams travelling. If no accommodations can be found then visits will be limited to day trips. Ocean Pearl Bonefishing Resort and Hideway Beach Club Villa are the closest accommodations to the project site, located in High Rock. Auntie Anne's B&B and Seagrapes B&B are a couple other accommodations located in Freeport.	Ocean Pearl Bonefishing Resort offers double bed rooms, with rates ranging from $76 - $88. Hideway is a villa for six (6) people with a rate of $350 per night. Auntie Anne's is a bed and breakfast in Freeport offering double bed rooms, with rates ranging from $85 - $95 per room per night. Seagrapes B&B is a bed and breakfast in Freeport offering double bed rooms, with rates of $95 per room per night.
	Will equipment need to be transported to conduct studies for the project	Equipment that fits into luggage suitable for most flights can be transported on the plane. Larger size equipment will need to have arrangements made to transport separately by boat or freight plane.	Additional cost to be considered for larger items that need to be shipped.
	If so is this equipment available in the Bahamas	If equipment needs to be sourced from out of the country cost needs to be considered for shipping, custom duty tax and value added tax.	Additional cost to procure and ship equipment into the Bahamas.
	Do we have established contact with local authorities on island who have a stake in this project	Generate list of stakeholders and local authorities that need contact. Preliminary list of stakeholders include Local Governments, Ministry of Works, Water & Sewerage Corp., Bahamas Electricity Company, Bahamas Telecommunications Company, Cable Bahamas, Bahamas National Trust, Bahamas Environment, Science & Technology Commission.	

<u>Preliminary Viable Options Include</u> **- Improvements to road network** **- Drainage** **- New bridges** **- Planting regimes** **- Eco-tourism access and facilities** **Environmental and Social Impact Plan**	Are Local Consultants available with required expertise to perform consultancy scope	Consultants in Nassau or Grand Bahama should be able to assist with optioneering. If local consultants cannot fulfil scope then foreign firms or foreign and local JV will have to be employed.	Use of foreign firms will increase costs over use of locally available firms if foreign consultants will need to be on island long term to complete scope.
	Is there a fixed airline route from Nassau to Grand Bahama?	The Grand Bahama International Airport is closest to the project site. Sky Bahamas and Bahamas Air provide steady service to this airport.	The cost for commercial airlines is much less expensive than chartered flights.
	If there is a fixed airline route what is the frequency of service	Sky Bahamas and Bahamas Air each provide more than four (4) daily flights to and from the island. Flights are available every day of the week.	The average cost for a roundtrip is $180 - $210 per person. Ticket prices vary depending on the season.
	Will a special charter need to be arranged for movement of personnel	Special charter should not be necessary (minor possibility during visits with Client or Government personnel at major milestones).	$5,600 per roundtrip to Freeport (Odyssey Aviation), limited to same day if necessary.
	Are there vehicles available for rent locally	Rental vehicles available from individuals on the island. Contact is necessary prior to arrival. Vendors include Brad's Car Rentals, KSR Rent-A-Car Company and Island Jeep & Car Rental.	Estimated to be min. $50 - $75 per day for small passenger vehicle, up to $70 - $95 per day for a minivan. Cost for fuel estimated to be $5 - $6 per gallon.
	Are there adequate accommodations for Consultant teams	Accommodations in settlements closest to the project site are preferred. Rental homes or villas are the less expensive options for teams travelling. If no accommodations can be found then visits will be limited to day trips. Ocean Pearl Bonefishing Resort and Hideway Beach Club Villa are the closest accommodations to the project site, located in High Rock. Auntie Anne's B&B and Seagrapes B&B are a couple other accommodations located in Freeport.	Ocean Pearl Bonefishing Resort offers double bed rooms, with rates ranging from $76 - $88. Hideway is a villa for six (6) people with a rate of $350 per night. Auntie Anne's is a bed and breakfast in Freeport offering double bed rooms, with rates ranging from $85 - $95 per room per night. Seagrapes B&B is a bed and breakfast in Freeport offering double bed rooms, with rates of $95 per room per night.
Detailed Design	Are Local Consultants available with required expertise to perform consultancy scope	Consultants in Nassau or Grand Bahama should be able to perform detailed design. If local consultants cannot fulfil scope then foreign firms or foreign and local JV will have to be employed.	Use of foreign firms will increase costs over use of locally available firms if foreign consultants will need to be on island long term to complete scope.
	Is there a fixed airline route from Nassau to Grand Bahama?	The Grand Bahama International Airport is closest to the project site. Sky Bahamas and Bahamas Air provide steady service to this airport.	The cost for commercial airlines is much less expensive than chartered flights.
	If there is a fixed airline route what is the frequency of service	Sky Bahamas and Bahamas Air each provide more than four (4) daily flights to and from the island. Flights are available every day of the week.	The average cost for a roundtrip is $180 - $210 per person. Ticket prices vary depending on the season.
	Will a special charter need to be arranged for movement of personnel	Special charter may only be necessary during visits with Client or Government personnel at major milestones.	$5,600 per roundtrip to Freeport (Odyssey Aviation), limited to same day.

	Are there vehicles available for rent locally	Rental vehicles available from individuals on the island. Contact is necessary prior to arrival. Vendors include Brad's Car Rentals, KSR Rent-A-Car Company and Island Jeep & Car Rental.	Estimated to be min. $50 - $75 per day for small passenger vehicle, up to $70 - $95 per day for a minivan. Cost for fuel estimated to be $5 - $6 per gallon.
	Are there adequate accommodations for Consultant teams	Accommodations in settlements closest to the project site are preferred. Rental homes or villas are the less expensive options for teams travelling. If no accommodations can be found then visits will be limited to day trips. Ocean Pearl Bonefishing Resort and Hideway Beach Club Villa are the closest accommodations to the project site, located in High Rock. Auntie Anne's B&B and Seagrapes B&B are a couple other accommodations located in Freeport.	Ocean Pearl Bonefishing Resort offers double bed rooms, with rates ranging from $76 - $88. Hideway is a villa for six (6) people with a rate of $350 per night. Auntie Anne's is a bed and breakfast in Freeport offering double bed rooms, with rates ranging from $85 - $95 per room per night. Seagrapes B&B is a bed and breakfast in Freeport offering double bed rooms, with rates of $95 per room per night.
Construction and Supervision	Availability of Local Contractors to perform construction works to be determined	Local contractors based in Grand Bahama will incur the least overhead cost. Local contractors based in Nassau will incur more overhead cost. Foreign contractors will incur the most overhead cost. If local contractors cannot fulfil scope then foreign contractors will have to be employed. Waugh Construction, Smith Construction and A&C Heavy Equipment and Construction are a few of the companies with equipment suitable for heavy works.	Costs for work permits, accommodation, ground transportation, flights, equipment and material shipping and per diem must be included for foreign contractors. Cost for accommodation, ground transportation, flights, equipment and material shipping and per diem must be included for Nassau contractors.
	Availability of Local Labourers to perform construction works to be determined	Local workers based in Grand Bahama will incur the least overhead cost. Local workers based in Nassau will incur more overhead cost. Foreign workers will incur the most overhead cost. If local workers cannot fulfil scope then foreign workers will have to be employed. Waugh Construction, Smith Construction and A&C Heavy Equipment and Construction are a few of the companies with labourers suitable for heavy works.	Costs for work permits, accommodation, ground transportation, flights, equipment and material shipping and per diem must be included for foreign workers. Cost for accommodation, ground transportation, flights, equipment and material shipping and per diem must be included for Nassau workers.
	How close is the nearest dock for receiving shipped goods, materials, equipment	Nearest commercial dock to project site is Freeport. Adequacy of docks to be determined based on the size of equipment/materials being shipped.	
	What is the condition of the nearest dock for receiving shipped goods, materials, equipment	Condition assessment to be performed for docks. Freeport should be more than adequate to receive large shipments.	Though very unlikely, if an adequate dock is unavailable it will be necessary to have an alternative solution available.
	Is there a fixed shipping route for movement of materials to the island or will special charter be required	Regular shipping routes are available to Freeport. This is adequate to accommodate the equipment etc. McLean's Town dock (Pinder's Dock) is approximately 52 miles closer than Freeport and a preferred location however access is more restricted. Capacity of shipping vessels to be determined. Should these not be found adequate it may be necessary to ship via private barge. A balance of ground transportation and shipping costs will need to be determined once accessibility is	Special Charter will increase cost significantly

		determined. It should also be noted that some access routes may require improvements to better enable large construction equipment access to the sites. As there is adequate road access, barging to the specific sites is not considered the preferred option.	
	If there is a fixed shipping route what is the frequency	Frequency of shipping routes to be determined. The nearby transshipment terminal owned by Statoil may be a possible option for off loading of materials and equipment. Seacor provides a regular service to Freeport from Port Everglades every Monday, Tuesday and Thursday.	
	Will a special charter need to be arranged for shipment of goods or materials	Seacor provides a regular service to Freeport from Port Everglades every Monday, Tuesday and Thursday. The need for special charter to be determined. Most construction materials of high quality are available in Grand Bahama. It is also considered a well-used shipping route.	
	Is heavy equipment (drill rig, excavator, flatbed trucks, crane, etc.) available for use	Equipment available by local contractors in Grand Bahama to be determined and compared to inventory of equipment necessary for successfully optioneered design. If heavy equipment is unavailable on Grand Bahama the equipment will need to be shipped to Grand Bahama (see Seacor).	Cost will increase depending on the size and quantity of equipment that needs to be shipped to the island.
	Is there a fixed airline route from Nassau to Grand Bahama?	The Grand Bahama International Airport is closest to the project site. Sky Bahamas and Bahamas Air provide steady service to this airport.	The cost for commercial airlines is much less expensive than chartered flights.
	If there is a fixed airline route what is the frequency of service	Sky Bahamas and Bahamas Air each provide more than four (4) daily flights to and from the island. Flights are available every day of the week.	The average cost for a roundtrip is $180 - $210 per person. Ticket prices vary depending on the season.
	Will a special charter need to be arranged for movement of personnel	Special charter should not be necessary (minor possibility during visits with Client or Government personnel at major milestones).	$5,600 per roundtrip to Freeport (Odyssey Aviation), limited to same day if necessary.
	Is there adequate availability of suitable construction materials and supplies on the island	An inventory of materials available on island will need to be performed and compared against materials required for the selected optioneered design. Most construction materials of high quality are available in Grand Bahama. It is also considered a well-used shipping route.	Cost will increase depending on the type and quantity of material that needs to be shipped to the island.
	Are there vehicles available for rent locally	Rental vehicles available from individuals on the island. Contact is necessary prior to arrival. Vendors include Brad's Car Rentals, KSR Rent-A-Car Company and Island Jeep & Car Rental.	Estimated to be min. $50 - $75 per day for small passenger vehicle, up to $70 - $95 per day for a minivan. Cost for fuel estimated to be $5 - $6 per gallon.

	Are there adequate accommodations for Construction teams	Accommodations in settlements closest to the project site are preferred. Rental homes or villas are the less expensive options for teams travelling. If no accommodations can be found then visits will be limited to day trips. Ocean Pearl Bonefishing Resort and Hideway Beach Club Villa are the closest accommodations to the project site, located in High Rock. Auntie Anne's B&B and Seagrapes B&B are a couple other accommodations located in Freeport.	Ocean Pearl Bonefishing Resort offers double bed rooms, with rates ranging from $76 - $88. Hideway is a villa for six (6) people with a rate of $350 per night. Auntie Anne's is a bed and breakfast in Freeport offering double bed rooms, with rates ranging from $85 - $95 per room per night. Seagrapes B&B is a bed and breakfast in Freeport offering double bed rooms, with rates of $95 per room per night.
	Is there an adequate area for laydown of construction equipment and materials	Need to determine suitable public land for contractor to store equipment and materials. Cadastral survey may be required to determine land ownership.	If public land is unavailable it may be necessary to use private land at a cost during the construction period.

Project Data Sheet for Andros Island: Natural Infrastructure Solutions
(Component 2)

1. Objective:

The objective of this component is to enhance communities' resilience to coastal hazards and climate-related impacts through the implementation of pilot projects on Andros that demonstrate the effectiveness of restoring of natural habitats for coastal protection in line with the Andros Master Plan.

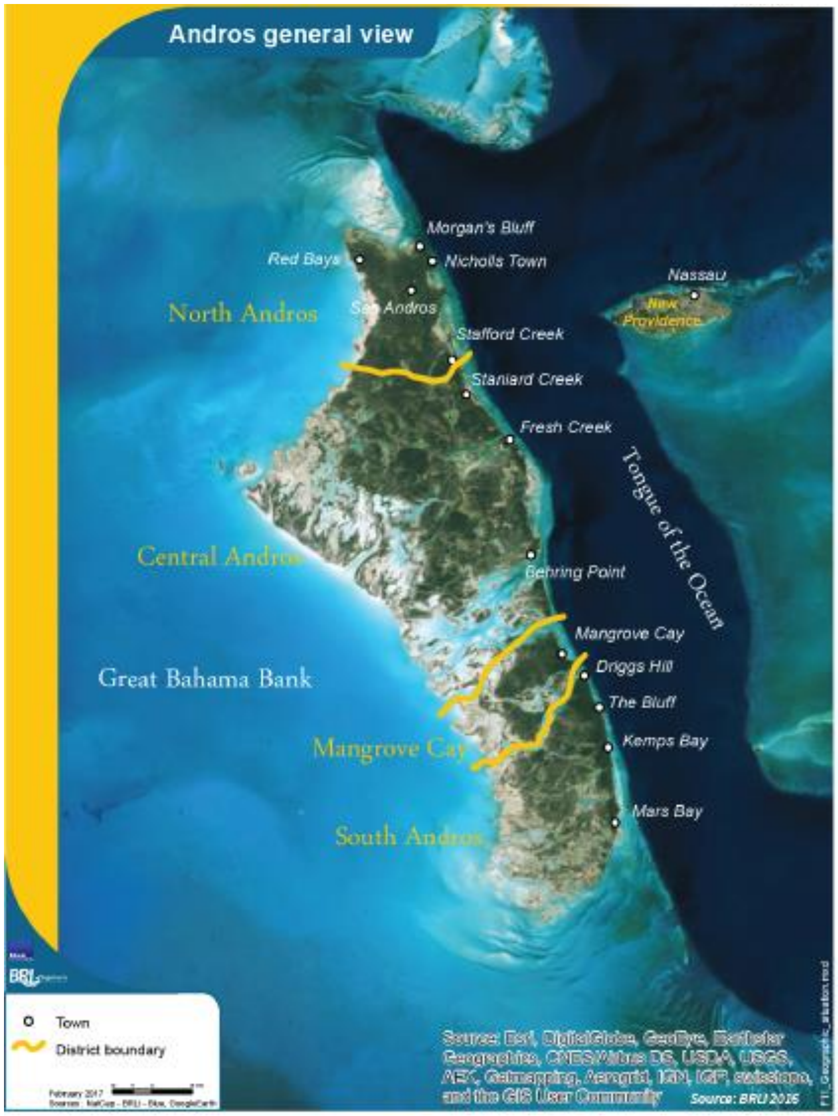
A recent study by The Natural Capital Project on Andros, an island endowed with unique coastal and estuarine ecosystems and where nearly 40 miles of the populated east coast is highly vulnerable to storms and sea-level rise, found that coastal habitats such as mangrove and coppice forests, coral reefs and seagrass reduce coastal risks along almost 71% of the coastline and that the implementation of a plan leveraging ecosystem services to fill development gaps could further reduce the length of shoreline at risk from erosion and flooding by 20%.

Hence on Andros, the potential for leveraging natural ecosystems to provide coastal protection and other co-benefits (e.g., habitat for fisheries and to support tourism activities) is high, but requires tools and science to help planners evaluate where they should allocate resources to conserve or restore these habitats. Hence, a set of preliminary baseline studies will first need to be conducted to inform the selection of priority sites for demonstration projects applying socioeconomic and biophysical suitability parameters, as well as baseline inventories and diagnostics to inform the design and implementation of nature-based solutions.

2. Location:

2.1 Andros Island

Andros is by far the largest Bahamian island, although this is somewhat misleading, as it comprises a number of separate islands. Andros is characterized by a low-lying, muddy western coast with extensive seagrass beds and mangroves. The West coast borders the Great Bahama Bank, a shallow bank which extends more than 100km offshore. In contrast, the eastern side of the island is flanked by an island-long barrier reef before rapidly dropping off into deep water approximately 3km offshore. Proposed interventions will be on the East coast since it is home to the majority of people, settlements and infrastructure on the island.



Although Andros has a well-defined coastal ridge, which reaches just over 30.5 meters, and exceeds 18.3 meters at many locations north of Fresh Creek, it is similar in origin and structure to Grand Bahama. South of Fresh Creek the landscape is less distinguished with fewer creeks, lower relief, and smaller lakes. Apart from the east coast, little of North Andros exceeds 6 meters in elevation. The eastern shores of Andros are exposed to the almost continuous NE Trade winds blowing year-round, but is quite sheltered inland. North Andros receives some 152.4 centimeters of rain a year, which helps sustain the by far largest reservoirs of fresh water in the country. One of these lenses is known to have a central thickness in excess of 30.5 meters. No account of Andros would be complete without mentioning its remarkable blue holes. Over 100 of these have been identified on land and in the sea, with depths exceeding 121.9 meters in a few cases.

The main characteristic of the east coast is a striking fault line running just inland from the shoreline, clearly visible from South Bight south to Mars Bay, where it continues offshore. This probably accounts for the relative straightness of the coast, and is also the location for many elongated blue holes along its line.

2.2 Site Selection

As noted above, activities to be financed under the Andros Component, will include a number of studies needed to refine the list of specific sites selected for demonstration for full nature-based solutions. Biophysical and socioeconomic parameters will be applied. For instance, for nature-based solutions to be viable it will be important to ensure selected sites have relatively low wave exposure.

At least one demonstration project will be implemented in each of the 4 Districts on Andros (North Andros, Central Andros, Mangrove Cay and South Andros) and covering a total area of approximately 200 ha. Actual site location will be further validated through local community consultations, and strategic potential for sustainable livelihoods and opportunity for local economic benefit.

2.3 Preliminary Results for site Selection

2.3.1 InVest Coastal Vulnerability Results

The InVEST Coastal Vulnerability model results indicated that on Andros, nearly 40 miles of the populated east coast of Andros is highly vulnerable to storms and sea-level rise, with **coastal habitats such as mangrove and coppice forests, coral reefs and seagrass reducing the risk of almost 71% of the coastline.** District specific results were as follows:

- Marine and coastal habitats **in North Andros** reduce risk of coastal flooding and erosion to 87 miles (64%) of the shoreline.
- **In Central Andros**, marine and coastal habitats help to reduce risk to more than 12 miles of shoreline that otherwise would be at high and medium-high risk.
- **In South Andros**, marine and coastal habitats help to reduce risk to 53% of its shoreline. This is significant as South Andros has a number of highly vulnerable stretches of coastline (*24% of the coastline in this district is highly vulnerable*), driven by high wave exposure and surge potential, low relief and sandy shorelines.

The InVEST Coastal Vulnerability model was used to identify several locations on Andros ***where*** people were at high risk of exposure to coastal hazards and ***where*** mangrove restoration may mitigate that risk. Subsequent analysis was done at these specific sites, using a more dynamic wave modeling approach to determine ***how much*** mangrove needed to be restored. Understanding ***where and how much*** habitat is likely to be effective at providing coastal protection is a multi-step process that often requires several kinds of modeling approaches, beginning with an understanding of risk.

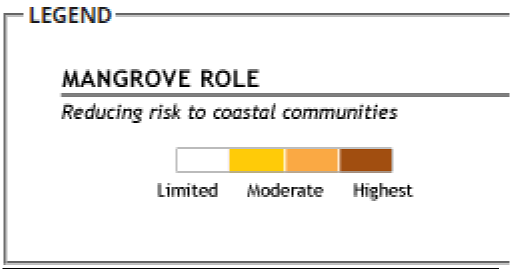


***Figure 1.* Andros Map showing Priority Conservation areas where mangrove is likely to reduce risk without sea level rise (Source: [Natural Capital Project])**

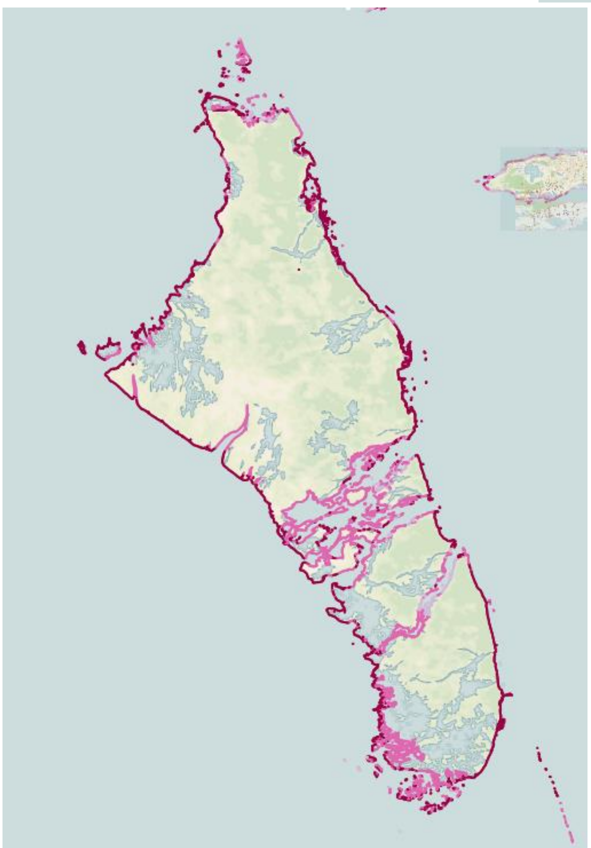
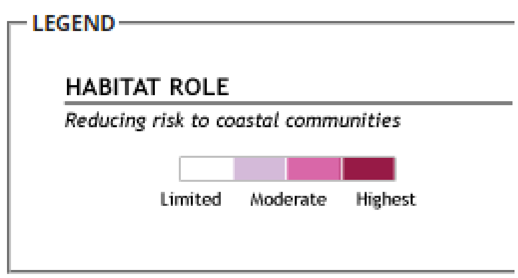


Figure 2. Andros map showing where habitats currently reduce risk to coastal communities with sea level rise (Source: [Natural Capital Project])



2.3.2. Initial site visits to inform identification of potential Nature-based Solution Sites.

Initial field visits were conducted during three separate visits during 20 – 28th May 2016, 17th August 2016 and 28 November – 2 December 2016, 16th. These provided a preliminary assessment of potential sites for nature-based interventions to be considered, and is provided in the section below.

Potential nature-based solution sites were identified by firstly identifying vulnerable areas using the INVEST software and locations that may be appropriate for nature-based solutions (i.e. low wave energy, evidence of natural solutions having been present in the area previously and areas that would benefit from alterations). Sites were visited and prioritized based on visual observations. However nature-based solutions are usually heavily reliant on hydrodynamics and substrate conditions as well as other factors. Site visits did not determine hydrodynamics or substrate conditions. Further studies will be necessary to determine the appropriateness of these locations to nature-based solutions and the extent of alterations necessary. This list of potential sites is provided for an appreciation of the extent of consideration of sites as well as to provide background for future projects and alternative project locations if the proposed site locations are found not to be appropriate for a nature-based solution. The following list is provided listed from north to south for ease of reference.

The sites that were considered potential project locations in North Andros were as follows (north to south);

- Lowe Sound
- New Town, South Mastic Point
- London Creek Causeway
- North Stafford Creek
- Staniard Creek East Beach (I)
- Small Hope Bay, Love Hill (I)
- Fresh Creek (I)
- North Burnt Rock/South Moxey Town (M/I)
- Kemps Bay (in front of the administrators' office and regatta site)
- Blister Rock
- Johnson Bay Dock
- Deep Creek Seawall
- North Pleasant Bay
- South Pleasant Bay

The majority of the above sites lend themselves to a nature-based solution such as mangrove rehabilitation other than those which are considered for invasive removal indicated with (I). These locations are further described below.

Figure 3: Locations of all potential sites identified in Andros.

I. North Andros

The sites that were considered potential project locations in North Andros were as follows (north to south);

- Lowe Sound
- New Town, South Mastic Point
- London Creek Causeway
- North Stafford Creek
- Sandy Beach

These locations are further described below.

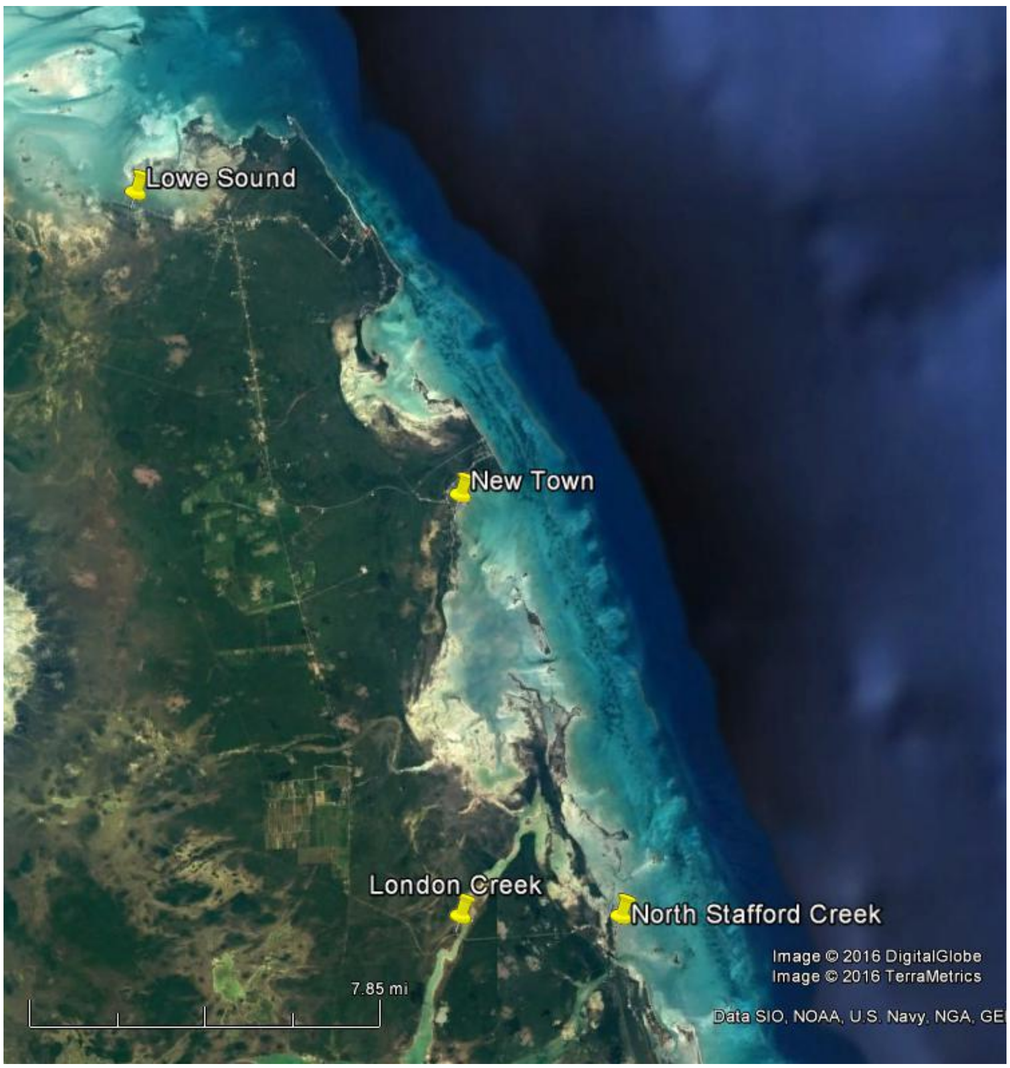


Figure 4: Locations all potential sites identified in North Andros.

i. Lowe Sound

Lowe Sound is located at the northernmost tip of Andros. Lowe Sound is unlike the rest of the developed parts of Andros other than Red Bays (on the West Coast). All other developed areas of Andros are on the East Coast where there is the Great Barrier reef close to shore, as well as New Providence and the Bahama Banks west of the Exumas providing protection (see Figure 5 below which indicates bank energy types in the Bahamas). Lowe Sound, at the northernmost point of Andros is more exposed to ocean funnel affects from the east but more importantly its foreshore is shallow for a number of kilometers and the north shoreline is bay shaped such that it captures energy.

Houses, businesses and infrastructure (approximately 92 in total) are close to and in some cases directly on the shoreline. The population of Lowe Sound is 712 (2010 Census) which is the second largest settlement in Andros after Nicholl's Town (825).

When coastal buildings or roads are threatened, usually the first suggestion is to "harden" the coast with a seawall. The construction of a seawall usually displaces the open beach that it is built upon. They also prevent the natural landward migration of an eroding beach. It is believed that the installation of a 1,500 foot long seawall and 5,000 foot of rock revetment along much of the shore at Lowe Sound directly and indirectly removed mangrove at the shore.

This area experienced extensive damage during hurricane Matthew mainly as a result of water levels above the roof levels of buildings along the shoreline. North Andros was severely impacted by hurricane winds and flooding from storm surges of 9 to 12 feet (2.7 to 3.7 m), resulting in significant damages to the housing sector. The boat ramp and businesses are on a man-made peninsula known as Darrell Island that protrudes into the water where the buildings were destroyed. The storm destroyed these buildings, as well as buildings on the north side of the road. Some buildings on the south side of the road were destroyed and all others were damaged to differing degrees.

A nature based solution is suggested for this location given the low wave energy at this location. Mangrove restoration is suggested as a solution in particular given that the seawall construction removed the mangroves and the recent destruction in the area as well as a strong will of the residents not to relocate. Also, this area is the main fishing location for North and Central Andros and many fishermen, local and foreign travel to this location to launch their boats to fish, fishing being a major source of income for the island.

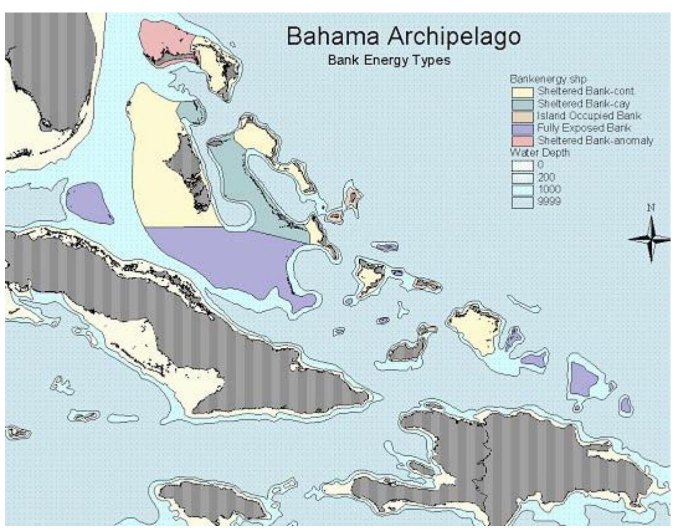


Figure 5: Bank Energy Types in the Bahamas

Figure 6: Aerial view of Lowe Sound

Figure 7: Aerial view of North West Lowe Sound (top), 3D Model of North West Lowe Sound (bottom), North Andros. Source: NatCap

Figure 8: Lowe Sound Seawall, North Andros.
Source: Blue Engineering

ii. New Town, South Mastic Point

The road is beside the shoreline along a 260 meter stretch at New Town which is in South Mastic Point. This location is approximately 4 km from the barrier reef and there are sand banks nearby to the south. A seawall has been constructed at this location to protect the road and the cemetery behind the road. The water is at the seawall during high tides and is in a state of disrepair. West of the road and cemetery is wetland. The road provides the only access route to approximately 59 properties to the south that are mainly residential properties. Evidence suggests that there was beach and mangroves in this area prior to the construction of the seawall.

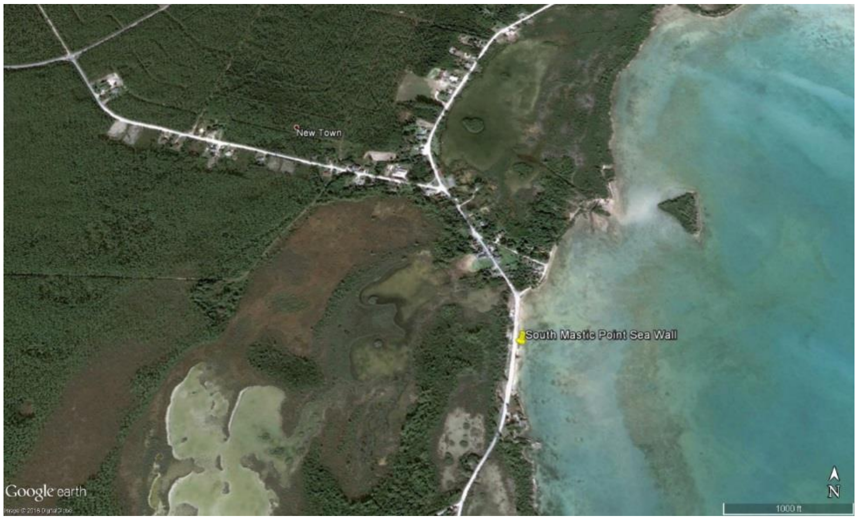


Figure 9: South Mastic Point Seawall, New Town, South Mastic Point, North Andros.

Figure 10: South Mastic Point Seawall, New Town, looking north

Figure 11: South Mastic Point Seawall, New Town, looking south

iii. London Creek

There is a 425 foot long, 40 foot wide causeway that was built when the roads were constructed in Andros. This causeway was constructed without any structures to allow water flows and thereby restricts flow of the creek. This portion of road is the only road that connects the north with the south and is known to flood with spring high tides and storms. The causeway has also been recognized by many as a major environmental issue in particular by the bonefishing association. The installation of a series of culverts or a bridge is suggested as a solution. This project is unlikely to be feasible in this project given the requirement for nature based solutions and the limited funding available for the project.

Figure 12: Location of London Creek Causeway

iv. North Stafford Creek

The road in Stafford Creek north of the Creek itself is directly along the shore for 1.5 km. There are approximately 16 developed properties directly along this stretch and a cemetery at the north extent. There is a seawall that is approximately 150 meters long in the middle of this stretch of shore. South of the seawall there are approximately 9 developed properties and a dock and ramp at the end of the road. It is unknown if water is provided to these properties in the road corridor. The road provides the only likely public access for these properties however there are a number of track roads that have been created from the west to the areas south of the seawall.

The seawall is heavily compromised with large holes in the base of the seawall at locations where the water is able to enter behind the seawall and has eroded away the backfill to the wall. The road in this area was recently repaved and electricity poles line the road directly behind the seawall.

The barrier reef is approximately 4 km from the seawall. There is evidence nearby that mangroves would have lined this shore prior to the construction of the seawall. There is no longer any mangrove in front of the seawall other than a single medium sized plant. This suggests that this area would be appropriate for a nature-based solution of mangrove restoration.

Figure 13: North Stafford Creek Seawall Location

Figure 14: North Stafford Creek Seawall looking north

Figure 15: North Stafford Creek Seawall

v. Sandy Beach near Staniard Creek Town

The beach near Staniard Creek Town is a 3.5km long sandy beach. Locals suggested that they have noticed erosion of the beach. The beach faces the east and is 3.7 km from the barrier reef. There are small sand banks between the shore and the reef in places. The beach fronts the Town of Staniard Creek with a population of 188 (2010 Census). The beach is lined extensively with casuarina and other vegetation. The removal of the casuarina is considered likely to improve the health of the beach in the long term.

Figure 16: Sandy Beach near Staniard Creek Town looking north

II. Central Andros

The sites that were considered as potential project locations in Central Andros were as follows;

- Small Hope Bay, Love Hill (I)
- Fresh Creek (I)

i. Small Hope Bay, Love Hill

There is inundation of the main road in this area during high spring tides. The main road provides the only on land route between the north and south of the island. A road was constructed to access the shoreline through the mangrove in this area a number of years ago. This road has severed flows through the mangrove area and is the main culprit for recent flooding in the area. There is currently a project underway to place culverts beneath the road to allow flows between the two sides of the road. Due to the fact that there is currently a project underway at this location to relieve this issue this area is not further considered for the purposes of this project. However, the beach in this area is a tourist attraction and is also suffering from erosion possibly as a result of the extensive introduction of invasive species along this beach. The beach is approximately 1.7 km long in this area. There are no developments along this beach other than the Small Hope Bay Hotel. The road and developed properties are located 0.2 to 0.9 km west of the beach. This location is therefore not further considered at this time due to the limited beneficiaries.

Figure 17: Small Hope Bay Lodge Beachfront looking south
Source: Blue Engineering Ltd.

Figure 18: Small Hope Bay Lodge Beachfront looking north
Source: Blue Engineering Ltd.

Figure 19: Road to access shoreline through mangrove looking west
Source: Blue Engineering Ltd.

(ii) Fresh Creek

Fresh Creek is the main developed area in Central Andros and is identified in the recent Andros Master Plan as the main ecotourism region in Andros. It is also where the international airport is

located. A casuarina forest has been growing and expanding at the east beach south of the creek since a large hotel was destroyed in the 1970s (see photographs below).

Figure 20: Fresh Creek south east beach 2001 (same scale as below)

Figure 21: Fresh Creek south east beach 2014 (same scale as above)

Figure 23: Fresh Creek looking north west, site location is at the bottom left

This beach is located close to the only Government owned hotel in the country which is currently suffering. It is also located close to an old lighthouse, the Androsia factory. It is also the only beach close to the developed area of Fresh Creek. There is potential to improve the beach by the removal of casuarinas and landscaping the area to include footpaths and educational information boards on beach nature and incorporating the history of the lighthouse and shipwrecks for instance. It would be best to remove all casuarinas in this area however this would be a large project due to the need to remove all casuarinas and landscape an area estimated at approximately 9 hectares, to make the project most sustainable.

III. Mangrove Cay

The sites that were considered potential project locations in Mangrove Cay were as follows (north to south);

- North Burnt Rock
- Burnt Rock Seawall

i. North Burnt Rock (Adjacent to the Airport)

There is evidence of beach erosion at this location however the road is 180 meters or more from the shoreline at this location and there is little infrastructure at present in need of protection, there being approximately 3 residential properties on this shoreline. Therefore whilst erosion is evident the project is not further considered given the limited beneficiaries.


Figure 24: North Burnt Rock looking north **Figure 25: North Burnt Rock looking north.**
Source: Blue Engineering Ltd.

Figure 26: North Burnt Rock/Moxey Town Location (red line indicates extent of invasive)

ii. Burnt Rock Sewall

This is a portion of road that is directly on the seafront. There is a 160metre long seawall along this portion of road however the road is flooded during storms and spring high tides. This is particularly problematic during hurricanes as it restricts access between the north and south of the island and the two hurricane shelters. On assessment, an alternative road alignment was identified that has been completed to a large extent. The grading and paving of the last mile to complete this bypass road is considered the best option at this time.

Figure 27: Burnt Rock Sewall looking south west
Source: Blue Engineering Ltd.

IV. South Andros

The sites that were considered potential project locations in South Andros were as follows (north to south);

- Kemps Bay (in front of the administrators office and regatta site)
- Blister Rock
- Johnson Bay Dock
- Deep Creek Seawall
- North Pleasant Bay
- South Pleasant Bay

These locations are further described below.

Figure 28: Location of Potential Site Locations in South Andros (excluding Blister Rock)

i. Kemps Bay (in front of the administrators office and regatta site)

This stretch of beach has been significantly eroded during hurricane Matthew however it is not in an area identified by the INVEST software as being particularly vulnerable and it is possible that this area would restore itself back to its original profile with time. The administrators office as well as many of the other government offices are located at this location however whilst they are close to the shoreline they are at a relatively high location. The regatta site however is not at a high elevation.

Figure 29: Beach Erosion in front of the Kemps Bay Regatta Site
Source: Blue Engineering Ltd.

Figure 30: Beach Erosion in front of the Kemps Bay
Source: Blue Engineering Ltd.

Figure 31: Beach Erosion in front of the Kemps Bay
Source: Blue Engineering Ltd.

ii. Blister Rock

Blister rock location suffers from debris deposited on the road following storms. This location is at the dump access road site. The frequency that this becomes an issue is approximately once a year and requires a payloader to clear the road which can usually be completed within a day without great difficulty. There are no other infrastructure for protecting other than the road which is not eroded at present. Also, the dump site is located away from the shoreline beyond relatively high ground and is therefore somewhat protected.

iii. Johnsons Bay Dock, Kemps Bay near South Andros Lodge

This dock is located right beside the South Andros Lodge, a bonefishing lodge. The dock is most likely used by the lodge's fishing boats. There are some obvious signs of erosion and rocks have been placed to act as groins, and most likely to protect the dock.

Figure 32: Johnson Bay Dock Aerial View

Figure 33: Johnson Bay Dock looking south
Source: IDB

iv. Deep Creek (coastline just south of the creek at Deep Creek)

This portion of shoreline is directly south of the creek at Deep Creek and extends for some 5,500 feet. The road along this stretch is located very close to the shoreline. There are approximately 15 residential properties on the west side of the road. There is a seawall along a portion of this coastal stretch. Elsewhere there is a rocky outcrop with some vegetation at the road edge however the road is currently being eroded during storms and it's stability is compromised and it is unsafe to travel at one portion in particular.

The Government is currently looking to provide protection to the road, it being the sole road to access between the north and south of the island. The settlements south of this area include the

southern portion of Deep Creek, Little Creek and Mars Bay. This represents a population of approximately 200 people, there being some 130 residential properties south of this location. Whilst the majority of the properties are residential there are some bonefishing lodges and a resort (namely Mars Bay Bonefish Lodge and The Pointe Resort & Marina). The Mars Bay Dock was also recently reconstructed and dredging conducted making it an important location for many residents and tourists. The road reservation also provides for the electricity supply to those in the south (another 8 miles south to Mars Bay) and will soon accommodate the new water main to serve the same. To the east of this location there is a sand bank 800 – 1200 meters from the shore followed by the barrier reef which is approximately 3.5 km from the shore. Given the nature of this location and the presence and proximity of these protective structures this location is considered likely to be a feasible site for a nature based solution which would provide protection to the road and residential properties in the area.

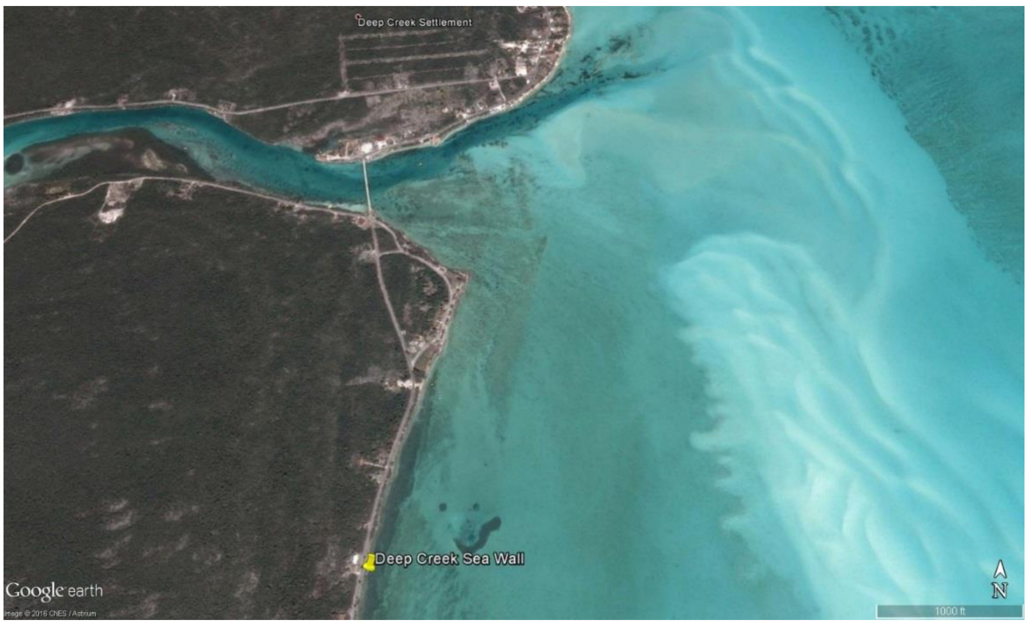


Figure 34: Deep Creek Location Aerial

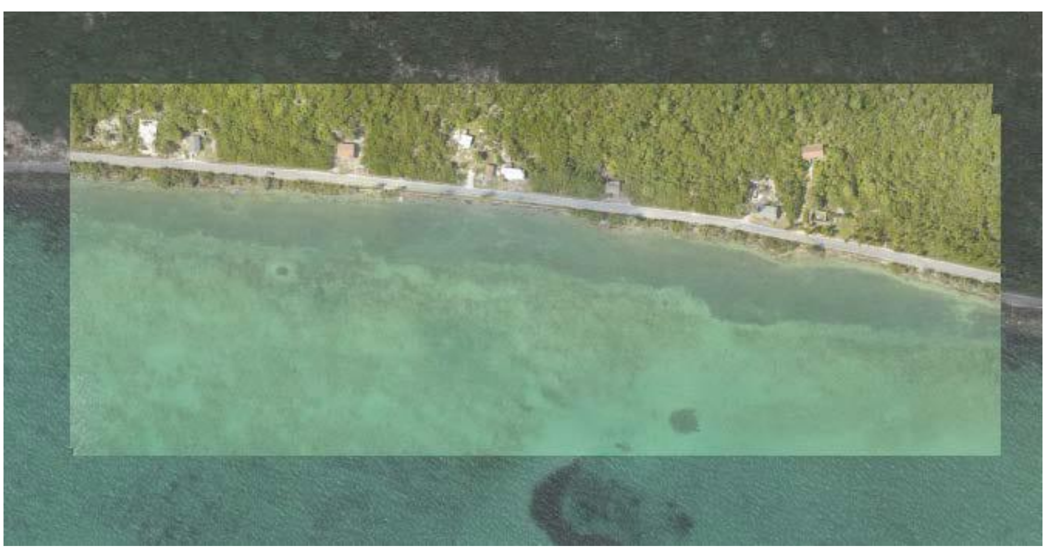


Figure 35: Deep Creek Aerial View
Source: NatCap

Figure 36: Deep Creek 3D Model looking west
Source: Nat Cap

Figure 37: Deep Creek Seawall looking south
Source: Blue Engineering Ltd.

Figure 38: Deep Creek seawall looking south
Source: Blue Engineering Ltd.

Figure 39: Deep Creek Rocky shore looking south
Source: Blue Engineering Ltd.

v. Pleasant Bay North (north of Little Creek)

Similar to South Pleasant Bay (see below).

Figure 40: North Pleasant Bay aerial view (top), 3D model (bottom)
Source: NatCap

vi. Pleasant Bay South (behind Bahamas Holy Bible Mission Church)

This site is an approximately 4,500 feet long beach stretch which is close to the road and fronted by a church and approximately 20 residential properties. There are some mangroves south of the area and the odd mangrove seedling along the shore. The beach front is also inhabited by invasive casuarina trees, known to facilitate beach erosion by displacing deep-rooted vegetation. Existing vegetation makes it a very interesting site for nature-based solutions including mangrove restoration and planting and/or casuarina eradication.

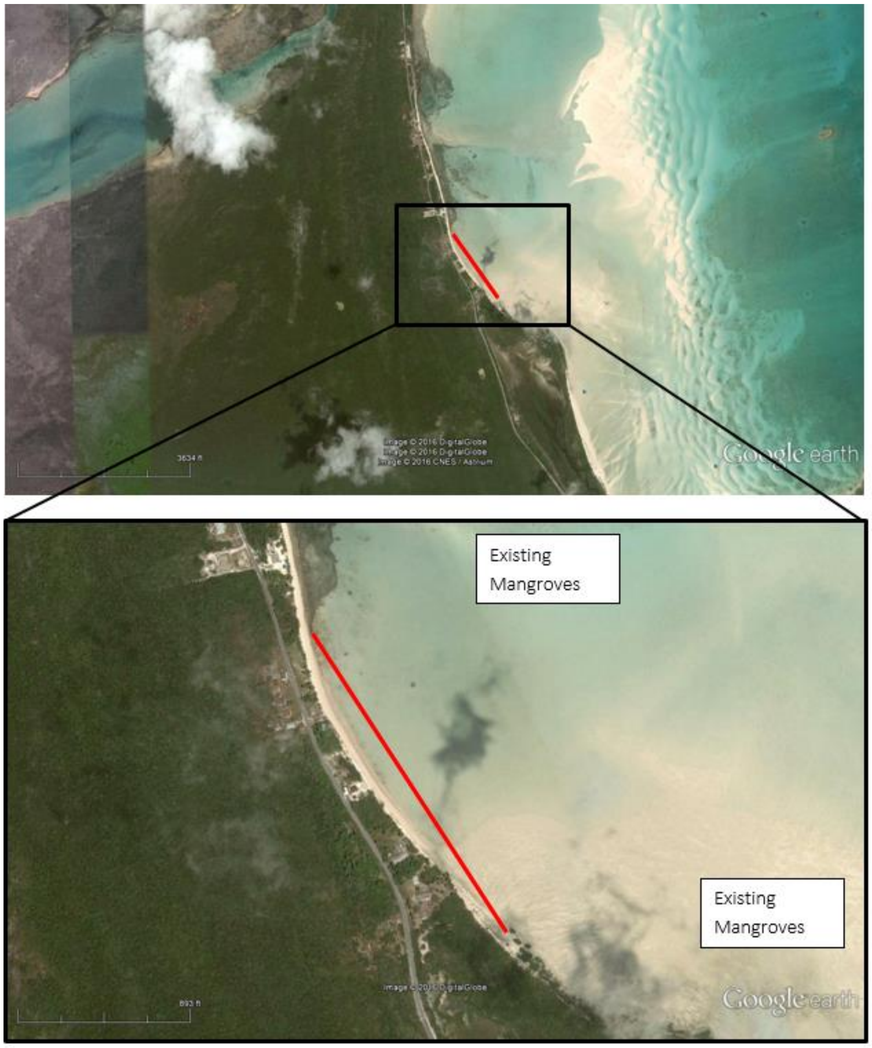


Figure 41: South Pleasant Bay (south of Little Creek). Possible mangrove restoration area.

Figure 42: South Pleasant Bay looking north

Figure 43: South Pleasant Bay looking south

Figure 44: Erosion caused by casuarina (left), mangrove seedlings (right)

Figure 45: South Pleasant Bay at northern extent damaged seawall

2.3.3. Results on preliminary proposed priority sites

Initial site visits and InVest results, indicated the following locations may be considered for the provision of nature-based shoreline solutions. These are listed in order of priority with summarized reasoning;

Mangrove Rehabilitation

- **Lowe Sound, North Andros**
  - Low wave energy and shallow area with evidence of mangroves having been present prior to the installation of a seawall.
  - Most vulnerable area according to INVEST model
  - Largest population after Nicholls Town, the majority of which is directly on the shore.
  - Lowe Sound is considered the fishing capital of North and Central Andros, many fishermen travelling long distances to fish from this location and the locals being reliant on this fishing location for their livelihood.
  - Recent damage during Hurricane Matthew has verified vulnerability of this area.
  - Locals are determined not to re-locate.
  - There is evidence that there once was mangrove along the shore where there is now a seawall.

- **Deep Creek, South Andros**
  - Shallow area protected by both the barrier reef and substantial sand banks.
  - Road is currently eroding away and stability of the road is compromised and is unsafe to travel at one particular portion at present.
  - The road provides the only access route for approximately 200 residents as well as a resort, fishing lodge and a recently improved dock.
  - The road accommodates the electricity lines and will soon accommodate a new water line which will cost approximately $5.5 million to install.

- **New Town Seawall, South Mastic Point, North Andros**
  - Shallow area with evidence of mangroves having been present prior to the installation of a seawall.
  - This location provides the only access route for 59 properties.
  - Seawall is in a state of disrepair
  - The cemetery behind the seawall is vulnerable.
  - The road floods at present

- **North Stafford Creek**
  - Road directly along the shore for 1.5 km.
  - There are approximately 16 developed properties directly along this stretch and a cemetery at the north extent.
  - The seawall is heavily compromised with large holes in the base of the seawall at locations where the water is able to enter behind the seawall and has eroded away the backfill to the wall
  - There is evidence nearby that mangroves would have lined this shore prior to the construction of the seawall, suggesting that this area would be appropriate for a nature-based solution of mangrove restoration.

Casuarina Eradication

The following locations have been identified as areas where casuarinas are likely to cause beach erosion presently or in the near future. They are also areas where the beach is of high value and there are communities nearby likely to support the project;

- **Fresh Creek**
- **Staniard Creek**

3. Beneficiaries:

The importance of ensuring the proposed restoration activities generate important socio-economic benefits, entail that the following set of criteria will be taken into consideration during site selection:

- Existing or planned **residential development** potentially at high risk from erosion/coastal flooding
- Existing or planned **industrial/commercial** (incl. fishing & productive land) area potentially at high risk from erosion/coastal flooding
- **Significant infrastructure** at high risk from erosion/coastal flooding e.g. main roads, bridges, pipelines, main services etc.
- Important **tourism area** (or potential area) at high risk from erosion/coastal flooding
- Locally/nationally important **ecological/environmental assets** at high risk from erosion/coastal flooding/climate change e.g. protected sites, nature reserves, mangrove, turtles, birds etc.
- **High urgency** identified for the need to control risks relating to build assets using coastal management intervention measures.
- Potential for beneficial **amenity and tourism** outcomes through control of risk using coastal management measures.
- Potential for **social benefits** of protection through control of risk using coastal management measures.
- Potential for creating a **sustainable environment/ecosystem services**

It is envisaged, beneficiaries will include:

- **Local residents**
- **Overnight and day visitors**
- **Local fishermen fishing in and around the proposed sites**
- **Dock users**
- **Local tourism lodges**
- **Local communities involved in restoration activities**
- **Road users**
- **Youth through education programs and involvement in restoration activities**

Moreover, a gender targeted approach will be used in in community resilience activities to increase the participation of women.

4. Technical and Economic Justification:

4.1. High vulnerability

A small island developing nation, The Bahamas is particularly concerned about the effects of a changing climate over the next years to decades. All of the islands are extremely low-lying, placing people and property at high risk to sea-level rise and coastal erosion and flooding from storms. During the latest Hurricane (Hurricane Matthew October 2016) wind speeds were said to have reached 140 mph (225 km/h), and a number of tornados were spawned. The community of Lowe Sound near the northern tip of Andros experienced heavy winds that came first from the east and then the north. As the wind shifted—around 14:00 UTC on 6 October—it brought a heavy and rapid storm surge, which some locals described as being like a tsunami. The surge reached 12 feet (3.7 m) high and advanced about 3 miles (5 km) inland. It retreated within 45 minutes, leaving devastated buildings and large areas of standing water[1]. Other major climate risks include saltwater intrusion and ocean warming. Moreover, global warming has the potential to further increase hurricane flooding, both by hurricane intensification and by sea level rise (Mousavi, 2011).

The passage of Hurricane Matthew through The Bahamas in October 2016 marked the second time in just over a year that the country was affected by a Category 4 hurricane, with some of its greatest impact being felt on the country's population centres of New Providence and Grand Bahama, as well as in the district of North Andros. Hurricane Matthew cost The Bahamas more than three times as much as Hurricane Joaquin did. The total was approximately $438.6 million. (ECLAC, 2016). In its recommendations on how to build a framework for long-term resistance against future disaster events, the ECLAC report noted that the Bahamian Government should consider the inclusion of green infrastructure in its approach to buffering wave energy, protecting shorelines, and implementing other coastal defence measures. Adding that "the country's resilience is bound tightly to that of its natural environment" and that "where opportunities exist, utilizing a green/natural approach can reduce costs, improve biodiversity, abate erosion and significantly reduce maintenance costs".

4.2 Cost-effective solution

While seawalls have historically been used to mitigate these effects, these are expensive to build and maintain and often have adverse and unintended consequences (Burgess et al. 2004, Hillen et al. 2010). For many years many millions of dollars have been spent on the construction of seawalls as they have generally been the sole response to coastal erosion in the Bahamas. Marine and coastal habitats—primarily coral reefs, seagrass, and coastal forests—can attenuate waves and surge associated with storms, in some cases mitigating flooding and coastal erosion (Barbier et al. 2008, Zhang et al. 2012, Spalding et al. 2014). A nature-based approach proves particularly relevant in the context of Andros, an island endowed with unique coastal and estuarine ecosystems and habitats.

Shoreline erosion is due to number of factors which may include offshore dredging, removal of sand from beaches and sand dunes, construction on the beach or immediately offshore, or vegetation removal. The main cause of sea wall building has generally been the construction of roads too close to the shoreline in the past. This has meant that the natural processes of beach and dune development have been interrupted, with resultant erosion. As Neil Sealey demonstrates in his report "Coastal Erosion and Seawall Construction in the Bahamas" many sea walls are located where the road is close to the shoreline, and this is what caused the problem originally. Further consideration needs to be given to moving the road back from the

[1] Assessment of the Effects and Impacts of Hurricane Matthew, ECLAC & IDB

shoreline and restoring the beach and dune artificially. Where this is currently not feasible alternative solutions should be sought.

Marine and coastal habitats—primarily coral reefs, seagrass, and coastal forests—can attenuate waves and surge associated with storms, in some cases mitigating flooding and coastal erosion (Barbier et al. 2008, Zhang et al. 2012, Spalding et al. 2014). A nature-based approach proves particularly relevant in the context of Andros, an island endowed with unique coastal and estuarine ecosystems and habitats. Using native vegetation to stabilize the shoreline can be an effective way to reduce shoreline erosion. The benefits are many: installation of natural shorelines are much less costly than seawalls; natural shorelines are less likely to fail than seawalls; natural shorelines provide natural habitat unlike seawalls and natural shorelines not only functionally better, but are often more aesthetically pleasing.

In suitable physiographic and ecological conditions, nature-based coastal protection infrastructure is an effective solution to enhance resilience to coastal risks. Comparison of costs between nature-based defense projects and engineering structures has shown for instance that salt-marshes and mangroves can be two to five times cheaper than a submerged breakwater for wave heights up to half a meter (Narayan, S., 2016). A recent study by (Bayraktarov, 2016) on the cost and feasibility of marine coastal restoration found that while coral reefs and seagrass were among the most expensive ecosystems to restore, mangrove restoration projects were typically the largest and the least expensive per hectare. The study also found that techniques in mangrove restoration that achieved highest survival rates of were those where the facilitation of natural mangrove recovery was achieved through planting of seeds, seedlings, or propagules (72% of observation on survival), planting of saplings or small trees (11% of observation on survival), reconversion of aquaculture ponds to mangrove habitat (9% of observation on survival), and hydrological restoration (5% of observation on survival).

4.3 Results of simulation studies on Andros

Using 2015 as a baseline and projecting 25 years in the future to 2040 the ecosystem service analysis conducted in the context of the Andros Master Plan work estimated that under the Sustainable Prosperity and Conservation scenario in which coastal ecosystems are safeguarded, ecosystems, climate and coastal resilience of Andros would be enhanced by reducing the risk by 20-30 miles, which would otherwise be highly vulnerable to erosion and flooding in Business as Usual and Intensive Development scenarios (NatCap, 2016). In economic terms, this could also lower economic cost associated with damage from hurricanes for instance.

- ### Lowe Sound

Figure 46: Location of simulated cross-shore profile at Lowe Sound
Source: NatCap

Width of restored mangrove buffer (m)	Maximum Water Level at seawall (m) (overtopping)	% Reduction of MWL at seawall
0m	0.95m	0%
50m	0.81m	15%
100m	0.70m	26%
200m	0.60m	36%
500m	0.53m	44%

Table 2. Modeled reduction in maximum water level (MWL) overtopping the seawall at Lowe sound as a function of the width of mangrove buffer restored.

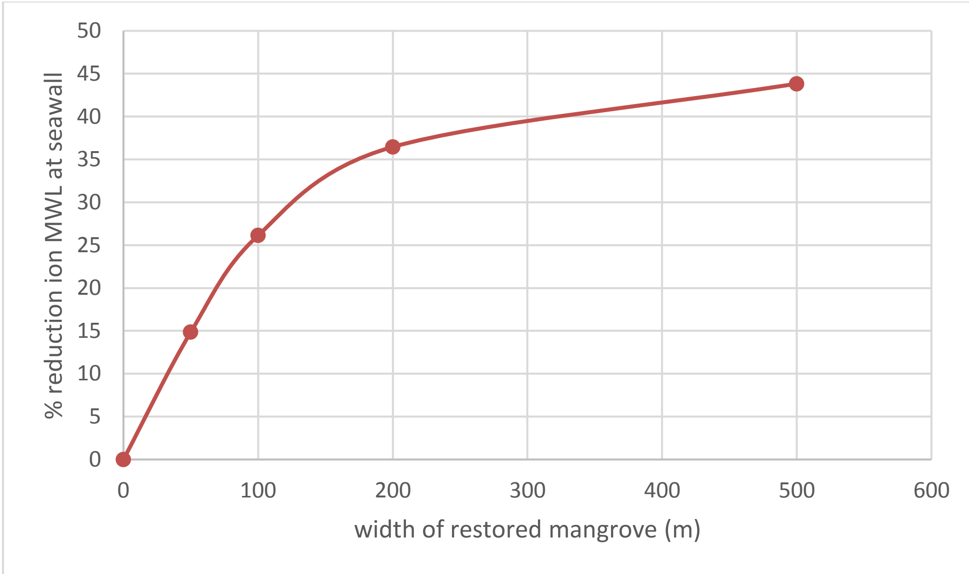


Figure 47: Modeled reduction in maximum water level (MWL) overtopping the seawall at Lowe sound as a function of the width of mangrove buffer restored. The plot suggests the greatest coastal protection services are provided within the first 200m of restored buffer.

- ### South Mastic Point

Figure 48: Location of simulated cross-shore profile at South Mastic Point

Width of restored mangrove buffer (m)	Maximum Water Level at seawall (m) (overtopping)	% Reduction of MWL at seawall
0m	1m	0%
50m	0.72m	28%
100m	0.28m	72%
200m	0.26m	74%
500m	0m	100%

Table 2: Modeled reduction in maximum water level (MaxWL) overtopping the seawall at South Mastic Point as a function of the width of mangrove buffer restored.

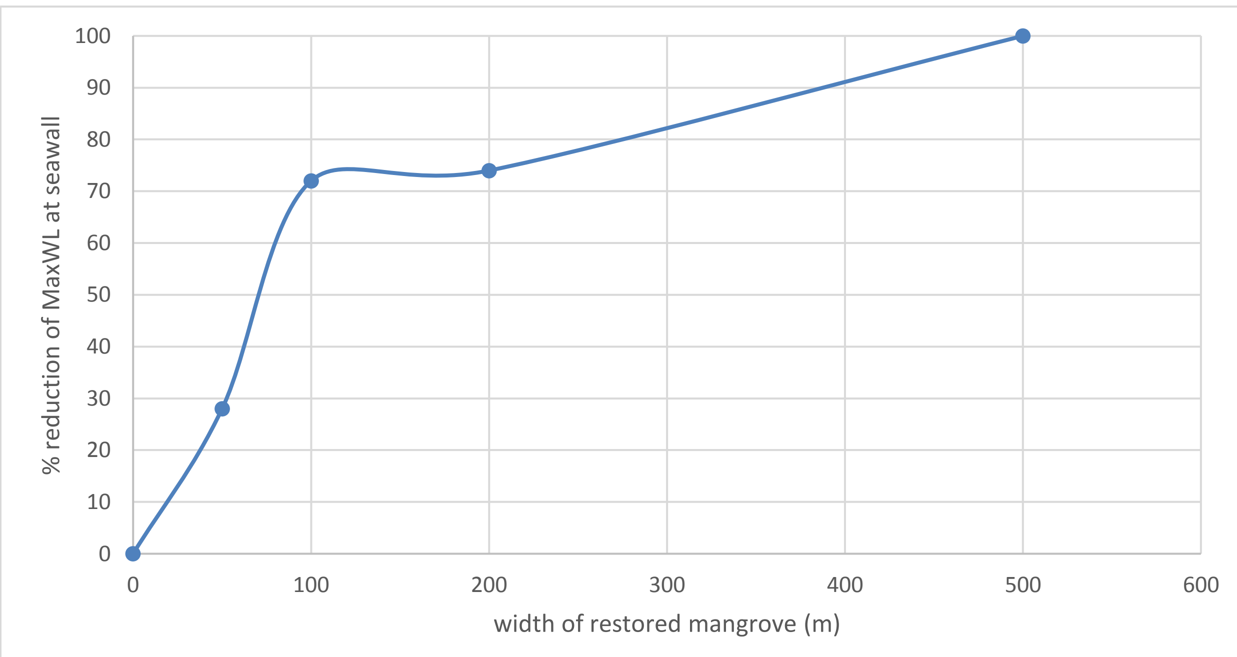


Figure 49: Modeled reduction in maximum water level (MaxWL) overtopping the seawall at South Mastic Point as a function of the width of mangrove buffer restored. The plot suggests the greatest coastal protection services are provided within the first 100m of restored buffer with no overtopping achieved at 500m of restored mangrove buffer.

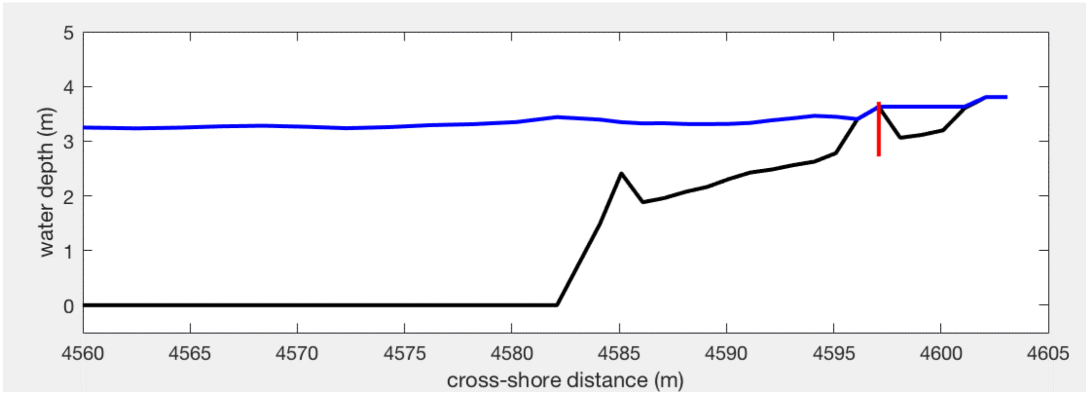
Width of restored mangrove buffer (m)	Maximum Water Level at graveyard wall (m) (overtopping)	% Reduction of MaxWL at graveyard wall
0m	0.06m	0%
50m	0m	100%

Table 3: Modeled reduction in maximum water level (MaxWL) overtopping the graveyard wall (on the far side of the road) at South Mastic Point as a function of the width of mangrove buffer restored.

At South Mastic Point wave modeling approach was also used by the Natural Capital Project team to look at the potential for a restored mangrove buffer (0m-500m wide) to reduce water levels and seawall overtopping from a simulated category 4 hurricane (storm duration of 6 hours, significant wave height of 10m, peak wave period of 12sec, added storm surge of 1m). Results suggested the potential for mangrove to reduce the degree of overtopping of the seawall by up to 72% with 100m of restored mangrove, and 100% with 500m of restored mangrove buffer (Table 2). The relationship between the extent of mangrove restoration and the degree of wave attenuation is non-linear, such that the first 100m of width of restored mangrove provide the greatest increase in service per area restored, with additional smaller gains per area restored up to 500m .A second scenario looked at the potential for restored mangrove to mitigate overtopping of the wall fronting the graveyard during the same storm. Results suggest that no overtopping of the graveyard wall is achieved with 50m of restored mangrove buffer, representing a reduction in maximum water levels at the graveyard wall from 0.6m to 0m .

In Central Andros at Small Hope Bay, a project is currently underway that would improve the causeway arrangement to allow for better circulation of coastal waters to the mangrove forests. Existing mangrove forests buffer a road slightly inland from shore that has experienced flooding in recent years, but the health of this mangrove field is in decline, likely due to the circulation issues described above. A large storm was simulated and the presence of a healthy mangrove forest versus what would happen should the mangroves die out from low circulation explored. For a very intense storm with storm surge and tide of 5m, significant wave heights (H_s) of 14 m and peak k period of 14s (roughly equivalent to a hurricane category 5), in the absence of mangrove (or very deteriorated mangrove) water levels at the road would reach approximately 2m, with strong implications for flooding and infrastructure damage. However, if mangrove is restored uniformly throughout, water levels at the road would be virtually none.

Mangrove restoration is something relatively new to the Bahamas. Craig Dahlgren partnered with The Nature Conservancy and The Bahamas National Trust (BNT) and conducted some of the first efforts to restore mangroves at Bonefish Pond, New Providence in July 2013. After one year, just under half of the



mangroves planted were still alive and many showed significant growth. While just under 50% survival may not seem like a lot, many of those that died were:

- planted at the high and low tolerance ranges of the species in this system,
- from freshwater systems and planted to a salt water environment, or
- ones whose root systems were compromised when they were dug up and not expected to have high survival.

The plantings with the greatest survival and remarkable growth were those planted as propagules or small "seedlings". Mangroves from a nursery averaged 50% survival, with much of the mortality thought to be from root damage when plants were removed from their plastic pots. Improved handling techniques during plantings may greatly improve these results.

Surviving mangroves appear to be stabilizing the shoreline of the channel, enhancing natural mangrove recruitment rates, and providing habitat for fish. Prior to the restoration and rehabilitation efforts, the area had no fish. One year later parts of the area are teemed with small snapper, damselfish and needlefish, barracuda and even bonefish! Further monitoring will continue to document changes in mangrove and fish communities as part of this project.

4.4 Socio-economic and environmental benefits

On Andros, tourism, lobster production and coastal protection services depend, in part, on approximately 6,500 square miles of functional coastal and marine habitat. Hence, protecting and restoring natural buffers like mangroves, coral reefs and seagrass not only will contribute to enhancing the island's coastal climate resilience, but also key to support economic activities including tourism and fisheries which local communities rely on for their livelihood.

The mangrove forests of The Bahamas are dominated by one or more species of mangrove (*Avicennia*, *Laguncularia* and *Rhizophora*,) with other plant species in drier areas. They encourage sedimentation, hold the sediments in place, and help build land. They also provide nursery habitats for many marine animals, including commercial fishery species, and habitat for water fowl and other fauna.

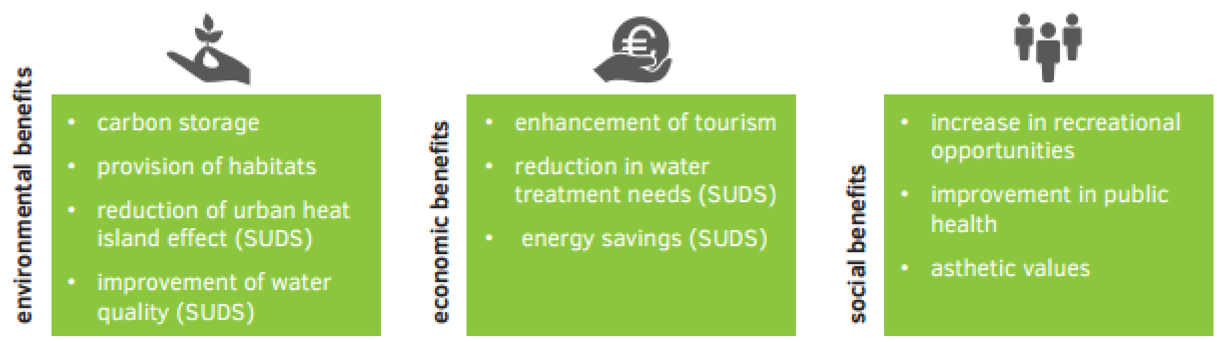


Table 4. Benefits of nature-based solutions in addition to flood protection (sdapted from Ashley et al. 2012)

4.5 Community participation and ownership

Local ownership of the project and effective community participation are considered to be crucial in the implementation of this component to achieve sustainable impacts. In particular, by promoting participation and creating a sense of local ownership it is expected that sustainable change in attitudes will be encouraged towards the management and wise use of coastal natural habitats. Community- or volunteer-based marine restoration projects usually have lower costs (Bayraktarov, 2016).

The establishment of sustainable and meaningful community involvement in coastal resource rehabilitation and management cannot be achieved however through a single project – inevitably – restricted in scope and area, and which has a limited timeframe and deadlines (Claridge and O'Callaghan,1997). Rather, effective community participation in environmental and socio-economic rehabilitation and management is a long-term process, a project, such as this one, should be seen as part of a step-by-step process leading in the direction of improvement.

5. Description:

The program will finance studies, technical assistance and the procurement of goods and services for pilot restoration efforts in at least one priority site for each District for a total area of approximately 200 ha, through the following set of activities:

(i) Baseline studies for selection of priority sites for demonstration projects applying socioeconomic and biophysical suitability parameters;
(ii) Stakeholder consultations and validation workshops of pilot sites;
(iii) Pilot site assessments including baseline inventories and diagnostics to inform design and implementation of nature-based solutions;
(iv) Implementation of conservation and restoration activities (e.g. mangrove reforestation, casuarina eradication) as nature-based solutions for coastal protection informed by technical studies and assessments conducted in previous activities;
(v) Management plan for pilot sites including maintenance and monitoring plan; and
(vi) Communication plan including community awareness activities and preparation of replicable guidelines to inform future rehabilitation efforts.

The potential role of ecosystems in coastal protection depends on a variety of factors such as the type of habitat, magnitude and return period of the coastal hazard, shoreline type and elevation. The most obvious indicator of site suitability is the presence of vegetation already growing. This can be extended by other factors such as the slope, elevation, tidal range, salinity, substrate and hydrology (Clark, 1995; French, 2001). Several of these factors also affect the suitability of an area for habitat rehabilitation (e.g., mangroves and seagrass require soft sediments). Hence **a number of studies have to be conducted prior to defining the proposed intervention.**

- Baseline inventories and diagnostics, including gap analysis of existing data for the target areas, to be undertaken through liaison with relevant agencies involved in the planning and conservation of the marine and coastal environment.
- Shoreline coastal studies, including the following dependent on project type;
    - Mangrove rehabilitation –
        - Spatial mapping including habitat mapping (GPS coordinates of mangrove habitats)
        - Hydrodynamic Studies (depth, extent, duration and frequency of tidal flooding);

    ▪ Sediment Studies, Field survey methods to include collection of sediment samples for grain size analyses as well as sediment chemistry (hydrocarbons, heavy metals etc.)
    ▪ Beach profiles – from drone data already conducted with field verification
    ▪ Water quality - field survey methods using water samples taken back to a laboratory and in situ samplers. The latter will measure: pH, oxygen, salinity, temperature, conductivity and turbidity. Laboratory analyses will include: total organic carbons, hydrocarbons, nutrients, fecal and bacterial coliforms etc.
    ▪ Biodiversity surveys
    ▪ Fish surveys (species, abundance, sizes)
    ▪ Mangrove habitat (No. prop roots, water depth, sediment depth, tree height)
    ▪ Benthic surveys
    ▪ Data provides the baseline on which environmental impact assessments can be undertaken for coastal interventions.
  o Invasive Eradication
    ▪ Land ownership studies
    ▪ Spatial mapping including habitat mapping
    ▪ Beach profiles;
- o Feasibility of options to determine the final designs and recommendations for nature based solutions to shoreline stabilization in target areas.

These studies will feed into the project, the rehabilitation-key components of which are outlined in the concept figure below.

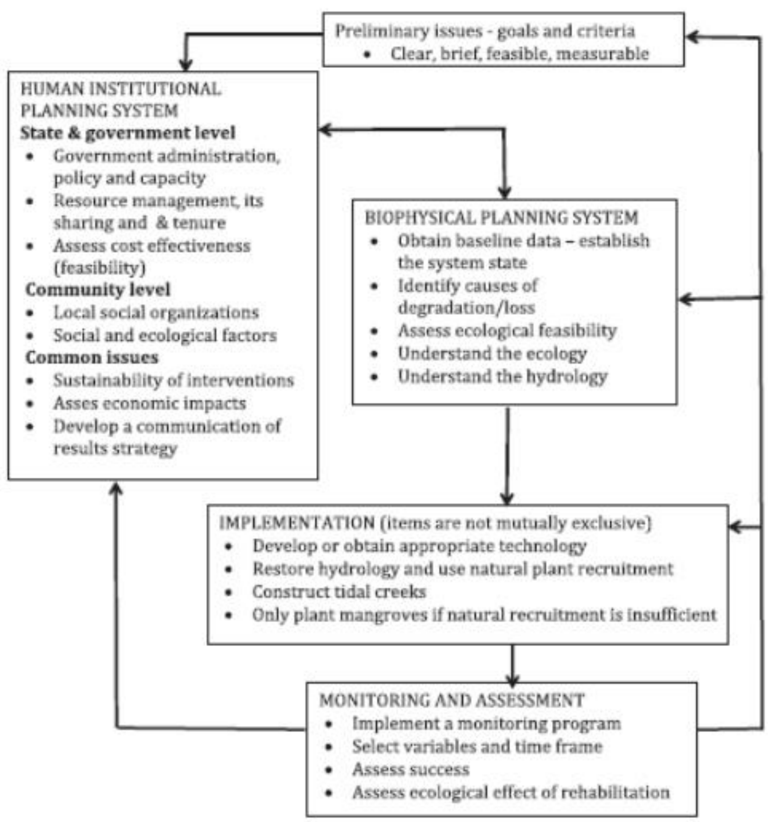


Figure 50: A concept for rehabilitation-key components
Source: Wetlands Ecol. Manage (2014) 22:587-604)

5.1 Description and Extent of proposed demonstration projects

- **Lowe Sound, North Andros**

The above studies will be conducted to determine the feasibility of mangrove rehabilitation. There are small patches of mangrove at present however it is understood that there was dense mangrove in this area prior to the construction of a seawall and revetments along the shore. Measures will be necessary to reduce the impact the seawalls and potentially the revetments have on the environment in front of them so that the environment is favourable to the growth of mangrove. These measures might include one or more of the following;

- Rip-rap at face of seawall
- A rock berm approximately 8 feet away from the seawall to provide a living shoreline in front of the seawall (mangrove in between);
- Beach nourishment with temporary groynes (these groynes would be located only for a sufficient time for the mangroves to accumulate adequate sediment for erosion to occur without the groynes (studies will need to determine the likley rate of accretion which may vary between 1 to over 17 millimeters per year in mangrove forests (Krauss et al. 2010[2]; McKee 2011[3]));
- Beach nourishment with permanent groynes;
- Improvements to man-made alterations along the shoreline;
- Nearshore shallow breakwaters (these could be low cost structures such as geotextile tube breakwaters;
- Nearshore artificial island;
- Removal of seawall and relocation of road and settlement of Lowe Sound

The latter of these measures are unlikely to be preferable however they are listed for consideration when determining the type and extent of studies carried out. The preferred solution is considered likely to be a combination of the placement of rip-rap at the face of the seawall, rock berm, beach nourishment and temporary or permanent groynes.

An indication of the extent of the works is illustrated in the figure below. Potentially 2.4 km of shoreline would receive mangrove rehabilitation including beach nourishment and possibly groynes. The length of rip-rap or rock berm is estimated at 960 meters. The width of mangrove rehabilitation is suggested at 200 meters to provide approximately a 36% reduction in the maximum water level at the seawall during a category 4 hurricane.

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[2] Krauss, K. W. et al. 2010. Ecosystems, 13, 129-143.

[3] McKee, K. L. 2011. Estuarine, Coastal and Shelf Science 91: 475-483.

Figure 51: Extent of activities at Lowe Sound: mangrove rehabilitation (red line), rip-rap or rock berm (bright green) and possible breakwater location (indicative, broken yellow or black lines)

Figure 52: Rock berm in front of a golf course seawall in Florida

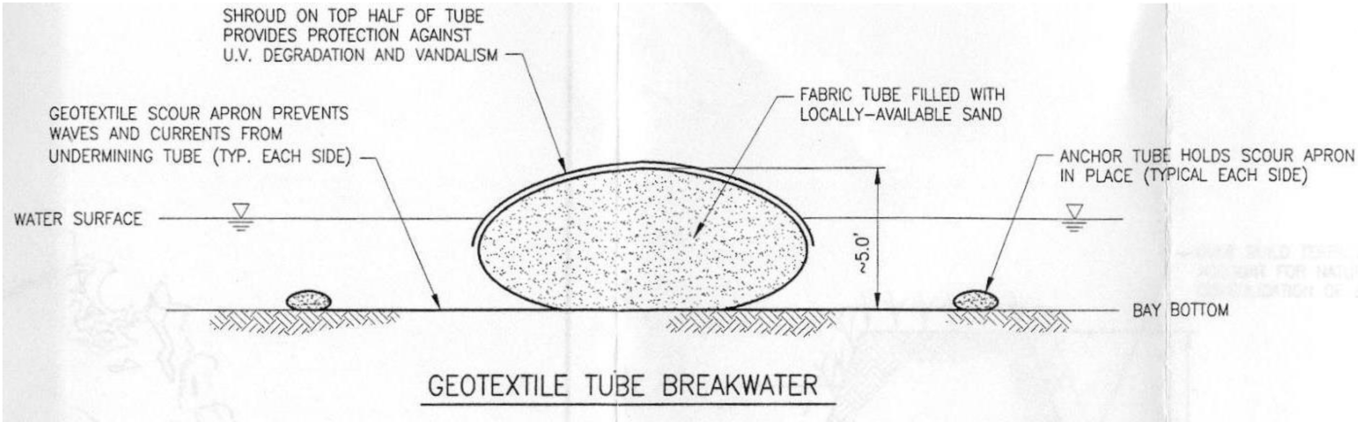

Figure 53: Geotextile tube breakwater

- **South Mastic Point**

South Mastic Point is similar to Lowe Sound in terms of the likely solutions. An indication of the extent of the works is illustrated in the figure below. Potentially 420 metres of shoreline would receive mangrove rehabilitation including beach nourishment and possibly groynes. The width of mangrove rehabilitation is suggested at 100 metres to provide up to 72% reduction in the maximum water level at the seawall during a category 4 hurricane.

Figure57: Extent of activities at South Mastic Point: mangrove rehabilitation and rip-rap or rock berm (red line) and possible breakwater location (indicative, broken yellow)

- **Fresh Creek**

Casuarina pines are present along a majority of the eastern coastline of Andros. This beach has casuarina the length of it which extends some 2 km, with similar beaches beyond a small headland at the end. The casuarina exists extensively in this area however the project would focus on the north end of this beach

where there is a public access and it is frequented by tourists as well as locals as one of the better beaches in the area. As described earlier there is opportunity for improving the beach by the removal of casuarinas and landscaping the area to include footpaths and educational information boards on the natural beach environment and incorporating the history of the lighthouse and shipwrecks as well as the casuarina eradication project for instance. It is suggested that the project be phased addressing the northern most portion of the beach at the shoreline and immediately behind in the first phase, an area of approximately 1 hectare (170 m of shoreline), and extending the project to greater than 9 hectares (total of 770m of shoreline - see figure below). Portions of the beach further south could be used as controls to illustrate the benefits of the project.

Control options should include;

- Pull young saplings and discard them in an appropriate place and burn
- Remove small stands manually
- Remove large stands by cutting trees and applying herbicides
- Employ basal bark treatment
- Hatch and squirt tree, then inject with herbicides

Reference should be made to other casuarina removal projects in particular those carried out in the Bahamas. Such project include those carried out by Friends of the Environment in Abaco and BNT and the Ministry of the Environment and Housing, Forestry Unit at Governor's Harbour Airport for determination of best practices.

Figure 54: Extent of activities at Fresh Creek: casuarina removal (red line) phase 1 of casuarina removal (indicative, broken yellow)

- **Staniard Creek**

Casuarina pines are present along the eastern coastline of the island that is at Staniard Creek. This beach has casuarina the length of it which extends some 3 km. The casuarina exists extensively in this area however the project would focus on the north end of this beach where there is more infrastructure and it is frequented by tourists and locals as one of the better beaches in the area. It is suggested that the project addresses the northern most portion of the beach at the shoreline and immediately behind in, an area of approximately 1.7 hectares (970 m of shoreline - see figure below), and that this be suggested to be extended to some 4.5 hectares (3 km of shoreline - see figure below) in the future. Portions of the beach further south could be used as controls to illustrate the benefits of the project.

Figure 55: Extent of activities at Fresh Creek: casuarina removal (red line) phase 1 of casuarina removal (indicative, broken yellow)

- **North Burnt Rock/South Moxey Town**

Casuarina pines are present along the eastern coastline of Mangrove Cay at North Burnt Rock and South Moxey Town. This beach has casuarina pines the length of it which is approximately 1 km. Casuarina removal is suggested for the entire length to provide long term benefits to the area.

Figure 56: Extent of activities at North Burnt Rock/South Moxey Town: casuarina removal (red line).

5.2. Climate Change

The net effect of physical and biological processes determines whether a mangrove can accommodate changes in sea level[4]. Studies of mangroves can provide an indication of the likelihood of the mangrove rehabilitation to accommodate such changes. The rate of accretion can also be monitored over time using a surface elevation table (SET) to measure the change in sediment level.

Unfortunately, mangrove rehabilitation has often been carried out simply by planting mangrove seedlings without adequate site assessment, or subsequent evaluation of the success of planting at the ecosystem level (Field, 1996). Moreover, for economic reasons, mangrove reforestation efforts are often limited to only one or two tree species (e.g. Gan, 1995). This raises obvious questions regarding habitat change and reduced ecological function in mangrove plantations compared to natural, mixed species mangrove forests. Biodiversity is widely regarded to be important in maintaining genetic richness, ecological functioning and the resilience of the ecosystem (Schultze & Mooney, 1993; Heywood, 1995). Genetic research on mangrove rehabilitation is therefore recommended to be able to better increase resiliency in particular with regards to climate change.

Further consideration should also be given to genetic studies on rehabilitated areas to improve resiliency to climate change in particular.

[4] Krauss, K.W. et al. 2014. How mangrove forests adjust to rising sea level. New Phytologist (Tansley Review) 202 (1)

5.3 Monitoring and maintenance

Table 5: Monitoring and maintenance of mangrove rehabilitation projects.

Action	Comment
Take regular aerial photographs of the site	Effective way of getting an overview
Monitor mangrove species that develop	Checks correctness of original provenance of propagules and seeds. Mis-identification of seeds and propagules can lead to failure
Monitor growth as a function of time	Common measurements are: density of seedlings or trees (no. of trees ha-1), diameter at breast height (DBH) (cm), height (m) and volume (m3 ha-1). The annual increments of these parameters should be determined
Monitor growth characteristics	Determinations could include: stem structure, node production, phenology, fruiting and resistance to pests
Record level of failure of seedlings	Provide a scientific reason for lack of success
Record impact of pests and diseases	Note nature of pests and diseases and steps taken to eradicate the problem
Record level of rubbish accumulation	Note source of rubbish and steps taken to minimize the problem
Record impact of grazing, cutting, fish ponds and fishing	Note source of such external pressures and the steps taken to minimize the problems, e.g.: fencing; law enforcement
Adjust density of seedlings and saplings to an optimum level	The degree of thinning, replanting or natural regeneration should be noted in detail. Growth should be monitored
Estimate cost of rehabilitation project	The estimation of cost should include all aspects of the undertaking including the purchase of land and any legal costs
Monitor impact of any harvesting	This should be part of any long-term record of a rehabilitation project
Assess characteristics of a rehabilitated mangrove ecosystem	This involves detailed measurements of the fauna, flora and physical environment of the new mangrove ecosystem and comparison with nearby similar undisturbed mangrove ecosystems. Genetics is also of interest.
Measure the success of the rehabilitation project against the original criteria that were established	This is rarely done but is an essential outcome

Elements of an invasive plant management monitoring plan include;

- statement of problem and invasive plant management objectives
- monitoring objectives for target species (level of accuracy and precision)
- sampling design (to achieve monitoring objectives)
- field sampling methods
- data management and analyses

- evaluation of monitoring results in achieving invasive plant management objectives
- adjustment of management actions or invasive plant management objectives if needed

5.4 Stakeholder and community engagement will be a central element of this component, with a view of promoting local participation and engagement to achieve a sustainable impact. Pilot projects and nature-based solutions will be tailored to the unique conditions of each site. They will be designed and implemented to: (i) enhance the adaptive capacity of Androsians and the ecosystems on which they depend to cope with the anticipated impacts of climate change; and (ii) provide a cost-effective means of restoring coastal habitats and associated co-benefits (e.g., fisheries, carbon sequestration, improved aesthetics for tourism and recreation).

There are a number of grassroots organisations in Andros including the following;

- The Andros Conservancy and Trust (ANCAT) Bahamas is a non-governmental, non-profit organization, founded in 1999 to protect, preserve, enhance, and restore Andros Island's natural resources and marine environment

- Bahamas National Trust (BNT) and the BNT's Discovery Club - a network of over 74 individual school clubs that manage over 1000 students between the ages of 7 and 25 on 10 Bahamian islands. The programme is dedicated to inspire and educate Bahamian youths to become knowledgeable environmental stewards through fun, conservation-based classroom lessons, hands on activities and field trips. Discovery Clubs exist in Red Bays, Behring Point, Bowen Sound, Fresh Creek and Nicholl's Town, Burnt Rock and High Rock.

- The Nature Conservancy works with many partners to ensure that Andros is protected. At present they are working with the Andros Conservancy and Trust (ANCAT), the Bahamas National Trust (BNT), and Green Force, to establish an underwater coral nursery, where endangered fragments of staghorn and elkhorn corals are given a chance to grow and thrive. It's a community-driven project; they are training locals to scuba dive so they can help plant, clean and maintain corals in the nursery.

- Nature's Hope in South Andros, is partnering with The Nature Conservancy to establish the island's first conservation center, which will serve as a hub for environmental activities for the community.

- The South Andros Handicraft and Manufacturing Association (SAHMA) officially launched the South Andros Coastal Restoration, Land Degradation and Coconut Project on April 10 2016 at the South Andros Craft Centre in Motion Town, Long Bay Cays, South Andros.

- Bahamas Sportfishing Conservation Association - mission is to promote conservation of habitats, marine life as well as a sustainable fishery in The Bahamas.

- Forfar Field Station (on the eastern shore of Andros Island in Blanket) - International Field Studies most popular field study program. Facilitate research and promote science educiton in marine biology, island ecology, geology, or island culture. Their goals are to provide opportunities for students to learn about their environment, in all disciplines, through direct field study experiences, to provide the structure for developing an intensive field study program with competent leadership, to promote educational and scientific activities through direct field experiences, and to cooperate with school systems so students may receive academic credit for field studies.

There are various other parties that conduct research in Andros as well as schools that get involved in volunteer projects and a number of entities have an interest in these projects and would be willing to be involved. The proximity of these entities to project sites has been considered in determining project sites.

Local communities can play an important role in the prevention, early detection and control of alien invasive plant species and the rehabilitation of mangroves. Residents of a community are the most important stakeholders and as such should be part of any program that affects their community. Another reason for community involvement is that efforts to control or eradicate an invasive species or rehabilitate mangroves may be expensive, but involving residents would result in lower cost. Many individuals in The Bahamas also know the landscape very well and can identify many plants by common names. They may have some knowledge of the plants but are ignorant of the environment and economic impact. By providing the necessary training to local residents more could be done to arrest the invasive plant species problem quickly and more successfully and rehabilitate mangroves.

Community based management is an approach that involves local residents to participate in organizing programs, planning, implementing, monitoring and reporting strategies to ensure success. This program should be headed by the Local Government and coordinated by local nature-based solutions councils. These councils should be the legal body for providing training for local residents and any materials that must be used in the invasive plant and mangrove rehabilitation management programs.

Such a project must first engage volunteers in a planned education program on the Casuarina tree and methods for eradication and Mangroves and the rehabilitation of mangroves. In addition to workshops and seminars posters and brochures could be developed to educate the public about invasive plants and mangroves. Second, the planting of native plant species and monitoring to prevent recovery of the Casuarina tree and the monitoring of mangroves.

5.6 Participatory Monitoring

Participatory monitoring should be developed as a community organising activity, to engage the local community in tracking the success or failure of their efforts, and in prescribing mid-course corrections. A simplified, highly graphic data sheet could be created to allow all community members to participate, even those uncomfortable with reading. Community organisers and members of the academic monitoring team could lead community groups in indoor discussions about monitoring, and then head to the field for full day monitoring events, once or twice a year. The results of each event should be discussed and saved for comparison over time.

5.7 Nature-based solutions

- **Mangrove Restoration**

There are six critical steps that are necessary to achieve successful mangrove rehabilitation:

1. Understand the autecology (individual species ecology) of the mangrove species at the site; in particular the patterns of reproduction, propagule distribution, and successful seedling establishment.

2. Understand the normal hydrologic patterns that control the distribution and successful establishment and growth of targeted mangrove species.

3. Assess modifications of the original mangrove environment that currently prevent natural secondary succession (recovery after damage).

4. Design the rehabilitation program to restore appropriate hydrology and, if possible, utilize natural volunteer mangrove propagule recruitment for plant establishment.

5. Only utilize actual planting of propagules, collected seedlings, or cultivated seedlings after determining (through the steps above) that natural recruitment will not provide the quantity of successfully established seedlings, rate of stabilization, or rate of growth of saplings established as objectives for the restoration project (Lewis and Marshall 1997).

6. Monitor and manage the rehabilitation program.

- **Eradication of Invasive Species**

Another nature based solution to improve coastal resilience has been proven to be the removal of invasive species. Invasive species have been identified as a key threat to biodiversity globally. In The Bahamas, invasive species that pose threats to native biodiversity were identified in the 2003 and 2013 National Invasive Species Strategy; these species include invasive plants, Australian Pine (Casuarina equisetifolia) and Ground Orchid (Eulophia graminea) which are found in the Andros Ecosystem. In the past several years, a significant threat to marine species has entered the Bahamian waters in the form of the Lionfish (Pterois volitans). The numbers of lionfish have increased from 2, initially sited in 2006, to tens of thousands throughout the Bahamian archipelago in 2009. It is likely to have an impact not only on native biodiversity, but also on fisheries. It is also feared that they are impacting other species as well as coral reefs through their predation of herbivores that keep the reefs free of algae.

Beach erosion is always due to sand loss in some form and can only be reversed by restoring or replacing the sand supply. Casuarinas and any other form of sand dune destruction will all also cause sand to be lost. This is widely recognized throughout the region, and reported (Craig et al[5]) particularly in South Florida. Casuarina induced erosion is unfortunately endemic on many of the islands of the Bahamas including Andros in particular. Casuarina induced beach erosion has been documented in North Andros at Small Hope Bay (Neil Sealey 2005)[6] where the removal of casuarinas has provided the beach arrangement directly in front of the area of removal.

[5] Craig, R.M., Smith, D.C. and Ohlsen, A.C., 1978, Changes occurring in coastal dune formation and plant succession along the Martin County coastline. Soil and Crop Science Society of Florida, Proceedings: 37, p. 14-17.

[6] Sealey, N., 2005, Small Hope Bay – The Cycle of Casuarina-Induced Beach Erosion.

Table 1: Possible Nature-based Solutions (NBS) identified for Andros

NBS	Description	Methods of risk reduction
VEGETATED DUNES	A natural barrier to the destructive forces of wind and waves, sand dunes are our first line of defense against coastal storms and beach erosion. They absorb the impact of storm surge and high waves, preventing or delaying flooding of inland areas and damage to inland structures. Dunes provide habitat for highly specialized plants and animals, including rare and endangered species. They can protect beaches from erosion and recruit sand to eroded beaches	○ Breaking of offshore waves. ○ Attenuation of wave energy. ○ Act as barriers against waves, currents, storm surges and tsunamis ○ Reduce washover currents. ○ Reduce wind speed.
CORAL REEF RESTORATION	Proactive actions to repair or replace disturbed or damaged reefs to return them to their previous state or, in other cases, to enhance them.Coral reefs naturally protect coasts from erosion and flooding by absorbing wave energy, as well as supplying and trapping sediment found on adjacent beaches. Coral reefs reduce wave energy by up to 97 percent (Ferrario et al. 2014). Unlike artificial breakwaters that require significant maintenance costs, coral reefs are self-sustaining as long as they remain healthy. Healthy reefs can provide a significant part of coastal protection even during cyclones under strong wave conditions (Blanchon et al. 2010).	○ Breaking of offshore waves, attenuation of wave energy. ○ Coral reefs protect shorelines by absorbing and dispersing a significant part of the wave energy that otherwise would be transmitted onshore ○ Generate massive amounts of carbonate structure, which allows them to keep pace with sea level ○ Vitally important as a source of food, shelter, medicine, and cultural and aesthetic value to coastal communities.
MANGROVES PLANTING AND RESTORATION	Mangrove restoration is the regeneration of mangrove forest ecosystems in areas where they have previously existed. Since environmental impacts are an ongoing threat, to successfully restore an ecosystem implies not merely to recreate its former condition, but to strengthen its capacity to adapt to change over time**.**	○ Wave attenuation and/or dissipation ○ Shoreline stabilization ○ Soil retention ○ Reduction in peak water level heights ○ Debris capture ○ Absorb low magnitude wave energy, reduce wave heights, and reduce erosion from storms and high tides. ○ Facilitate sedimentation and dampen wave stress; alleviate impact of moderate Tsunami waves ○ Over the longer term (decades to centuries), mangroves can alter the surface elevation of the shore, the local geometry and the location of channels all of which also influence the height of surges.
CASUARINA ERADICATION	Removal of the casuarinas tree from coastal areas and replanting of the dune ridge with native vegetation will restore the dune and providing an effective barrier against wave	○ Removal of casuarinas from coastal areas and replanting of the dune ridge with native vegetation will restore the dune and provide an effective barrier against wave action

	action. Eradication of casuarina trees, facilitates native species regrowth and beach dune stabilization.	○ Once established, it radically alters the temperature, light and soil chemistry of beach habitats, and with its strong root systems that bind the edges of the dune it prevents growth of native vegetation resulting in the decline of the attendant sand dune and exposure to coast erosion.

6. Products and indicators:

Output:

- Baseline study for selection of priority sites in Andros(#study). Baseline 0; Target 1
- Stakeholder validation workshops in each District (#workshops). Baseline 0; Target 4
- Site specific assessment for nature-based interventions (#pilot sites). Baseline 0; Target 4
- Coastal Ecosystem Restoration (#ha). Baseline 0; Target 200
- Communication and community participation plan (#plan). Baseline 0; Target #1.

Outcome:

- Agencies capacity for planning strengthened
- Local communities' awareness raised on nature based solutions and importance of protecting coastal ecosystems.
- Reduced flood and coastal erosion risk;
- Increased resilience of critical infrastructure
- Reduced maintenance requirements to coastal assets and infrastructure
- Improved beach aesthetics

Indicator:

- Minimum 600 metres of shoreline stabilized in any district (North, Central and South Andros as well as Mangrove Cay), and an overall total length of coastline for all districts of 5.5 km,
- Increased coastal protection benefits
- Restoration of natural habitats favor fauna and flora regeneration
- Erosion rate decreased
- Increase in mangrove coverage and absorption of CO_2 emissions
- Androsians trained and educated on importance of coastal ecosystems protection and restoration

7. Estimated cost and source of financing:

Natural infrastructure for hazard resilience in Andros	$3,000,000
Baseline studies for selection of priority sites for demonstration projects: *applying socioeconomic and biophysical suitability parameters (shoreline vulnerability, coastal change assessment, ecosystem services assessment, mangrove assessment and vulnerability mapping)*	*$200,000*
Stakeholder consultation and validation workshops	*$10,000*
Advisor on nature-based solutions best practice	*$50,000*
Assessments, baseline studies and diagnostics at pilot sites to inform design and implementation of nature-based solutions (autoecology, hydrologic patterns, genetics, modification of original environment) and management plan including maintenance and monitoring plan	*$700,000*
Conservation and restoration activities in 4 pilot sites	*$2,000,000*
Communication Plan *including community awareness activities and preparation of replicable guidelines to inform future rehabilitation efforts*	*$40,000*

Estimation of costs for proposed demonstration sites.

Element	Unit	Cost Per Unit ($)	Number of Units	Total Cost ($)
Lowe Sound				**1,116,000**
Rip-rap/rock berm/geotextile at the face of the seawall/revetment	m	150	960	144,000
Beach nourishment and temporary or permanent groynes.	m	105	2,400	252,000
Mangrove rehabilitation	ha	15,000	48	720,000
South Mastic Point				**285,600**
Rip-rap/rock berm at the face of the seawall/revetment	m	150	470	70,500
Beach nourishment and temporary or permanent groynes.	m2	105	2,400	252,000
Mangrove rehabilitation	ha	8,000	4	33,600
Pleasant Bay				**237,312**
Beach nourishment and temporary or permanent groynes.	m2	30	4,800	144,000
Mangrove rehabilitation	ha	8,000	11	91,200
Casuarina removal	ha	15,000	0.1	2,112
Fresh Creek				**135,000**
Casuarina removal and native planting Phase 1	ha	15,000	1	15,000
Casuarina removal and native planting Phase 2 +3	ha	15,000	8	120,000
Casuarina removal and native planting All Phases				135,000
Staniard Creek				**24,750**
Casuarina removal and native planting	ha	15,000	2	24,750
North Burnt Rock/South Moxey Town				**18,000**
Casuarina removal and native planting	ha	15,000	1	18,000

Construction Sub-Total	**1,816,662**
Supervison including Environmental (6%)	**109,000**
SUB-TOTAL	**1,925,662**
Studies	**239,000**
Spatial mapping including habitat mapping (GPS coordinates of mangrove habitats)	2,000
Hydrodynamic Studies (depth, extent, duration and frequency of tidal flooding, waves and currents);	80,000
Sediment Studies, Field survey methods to include collection of sediment samples for grain size analyses as well as sediment chemistry (hydrocarbons, heavy metals etc.)	7,000
Beach profiles – from drone data already conducted with field verification.	30,000
Water quality - field survey methods using water samples taken back to a laboratory and in situ samplers. The latter will measure: pH, oxygen, salinity, temperature, conductivity and turbidity. Laboratory analyses will include: total organic carbons, hydrocarbons, nutrients, fecal and bacterial coliforms etc.	10,000
Biodiversity surveys	5,000
Fish surveys (species, abundance, sizes)	20,000
Mangrove habitat (No. prop roots, water depth, sediment depth, tree height)	20,000
Benthic surveys	15,000
Education/Training	50,000
Detailed Design Total	**15,000**
Detailed design	*15,000*
Future maintenance and operation (including installation of flood rules for elevation measurement at known flood locations, beach profiles and community participation) (annual basis)	**50,000**
Year 1 M&E	10,000
Year 2 M&E	10,000
Year 3 M&E	10,000
Year 4 M&E	10,000

Year 5 M&E	10,000
SUB-TOTAL	**304,000**
TOTAL	**2,229,662**

8. Management model:

The Bahamas National Trust will be single-source contracted to implement the coastal habitat participatory restoration and monitoring activities envisaged under Component 2. It is qualified and has experience of exceptional worth for the assignments. The BNT is a non-governmental, non-profit, membership organization governed by an independent council that includes representatives from the public and private sectors, as well as from international scientific institutions. The BNT's mission is to conserve and protect the natural resources of The Bahamas, through stewardship and education for present and future generations. The BNT is uniquely qualified to conduct these activities given its exhaustive experience successfully implementing environmental research and monitoring, education.

Options for management will be considered within the Feasibility Studies, including option for partnerships with local municipalities and NGOs to facilitate community involvement and education.

9. Responsible/ Relevant institutions:

Items	Lead institution	Participating agencies
Gap analysis, data collection, technical studies, feasibility and designs	BNT/Natural Capital Project	BNT/MoE / local municipality/NGOs (local, TNC)/schools
Construction, incl. supervision	BNT	BNT/MoE / local municipality/NGOs (local, TNC)/schools
Operation & Maintenance (incl. monitoring and evaluation)	BNT	BNT/MoE / local municipality/NGOs (local, TNC)/schools

10. Calendar of execution:

Activity	Year 1		Year 2		Year 3		Year 4	
Technical Studies	x	x	x					
Implementation of Nature-based solutions			x	x	x	x	x	
Communication Plan						x	x	

11. Procedure/environmental studies others:

None needed given positive environmental impacts anticipated of interventions

12. Positive and negative environmental and social impacts

Impacts	Positives	Negatives

Social	- Environmental improvements provide amenity area/access for local residents - Sustains community through improved shoreline for fishing - Protects transport links (e.g. road) for sustainable communities, tourism and industry)	-
Environmental	- Improved ecology - Improved visual characteristics of frontage - Protection of the road avoids construction of new road sections	

13. Priority and relation to other initiatives

The proposed component will build on the work that has been undertaken under the technical assistance (financed by BH-T1040) "Ecosystem-Based Development for Andros". The general objective of this operation was to ensure that the natural capital (biodiversity and ecosystem services [ES]) of Andros, the largest island in the archipelago of The Bahamas, is mainstreamed in the design and implementation of development strategies with a view to ensuring the future well-being of all Bahamians including Andros island residents. The TC, was designed to address critical gaps and needs in support of evidence-based decision making on Andros' future development and to propose an actionable master plan which mainstains the economic value of ecosystem services through sustainable use and identifies investment options. In this regard, the implementation of nature-based solutions on Andros is perfectly aligned with the recommendations the Sustainable Prosperity scenario set forth in the Andros Master Plan, which highlighted the relevance of nature based solutions for coastal protection on Andros. Moreover, a number of resulting technical studies provide critical primary data which will serve to inform the selection of priority sites for demonstration projects.

14. Project Benefits Summary

The following table summarizes the key benefit features of the proposed project and assigns a relative value score: 1 (low) to 5 (high).

Benefit sector	Description	Score
Asset Protection	- Coastal road, services and property - Touristic assets protected and improved aesthetics	**3**
Socio-economic	- Supports local community and fishing industry - Strategic road connection between local communities and industry/communities - Environmental education of local communities	**3**
Environmental	- Improved biodiversity - Improved delivery of ecosystem services	**4**