PROPOSAL FOR BEACH ENHANCEMENT AND STABILIZATION INCLUDING BOULDER REEFS, BOULDER GROYNES AND BEACH SAND TO BE BUILT IN THE NEARSHORE.

at

North of Paynes Bay to Sandy Lane, St. James.

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT.

PLANNING APPLICATION NO. 0932/07/2024C

August 2026

VOLUME 2
IMPACT ASSESSEMNT REPORTS



Prepared by:

bain planning + development

INTRODUCTION

This volume of the Environmental and Social Impact Assessment comprises the main impact assessment reports. These are presented as standalone documents as follows:

- **Coastal Impact Assessment:** W.F. Baird and Associates Ltd. (Baird).
- **Social Impact Assessment:** Janice Cumberbatch

Sandy Lane Bay to Paynes Bay - Beach & Nearshore Improvement | Application 0932/07/2024C

Coastal Impact Assessment

July 20, 2026 | 13670.301.R3.Rev0

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Sandy Lane Bay to Paynes Bay - Beach & Nearshore Improvement | Application 0932/07/2024C

Coastal Impact Assessment

Prepared for:

Ms Leonor Gimenez de Mendoza
Sandy Lane Lot 7
Sandy Lane, Saint James
Barbados

Prepared by:

Baird.
Innovation Engineered.

W.F. Baird & Associates Coastal Engineers Ltd

For further information, please contact
Cabral Barriteau-Foster at +1 246 430 0845
cbarriteau-foster@baird.com
www.baird.com

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Executive Summary

The owner of Sandy Lane Lot 7, Bougainvillea, intends to stabilize and develop the beach and nearshore between Sandy Lane Bay and Paynes Bay. This headland encompasses the 500m long shoreline adjacent to Lots 4 – 9 and One Sandy Lane. Intended improvement is to benefit neighbouring beachfront properties and most importantly the beach going public using the West Coast of Barbados. The owner has hired W.F. Baird & Associates Coastal Engineers Ltd (Baird) as the coastal engineering consultant. The Government of Barbados' regulatory agency has requested an Environmental Impact Assessment (EIA) in support of the permit application process for this project. The regulator issued draft terms of reference outlining the topics to be covered in the EIA. The owner's consultant team has proposed updates to the draft terms of reference and prepared the EIA in response. This Coastal Impact Assessment (CIA) was produced by Baird as part of the EIA. It is to be read in conjunction with the entire EIA document.

The Coastal Impact Assessment is a study of the existing conditions in the study area and changes (both positive and negative) that could be expected as result of implementing the proposed design. The report focuses on the topics of beach morphology, infrastructure, wave climate and ecology. The existing conditions were characterized by using data from internal project fieldwork, research and monitoring agencies, published literature and previous Baird projects. The design is conceptual. Design objectives, masterplan, typical cross-sections and preliminary quantities are complete. Detailed cross-sections, quantities, specifications and the design report will be completed after the permit application process is complete. The detailed design will incorporate the content of the EIA and the conditions of the permit. Locations and dimensions of structures discussed here are presented for analysis of potential impacts and are subject to change. Analysis of coastal impacts were determined using industry standard methods for coastal engineering and marine ecology. The analysis is limited by the scope and the data available. Sediment budget, water quality and similar topics affect the study area but are driven by processes on a larger municipal scale beyond the scope of this report.

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Abbreviations

ASCE ..... Americal Society of Civil Engineers
CIA ..... Coastal Impact Assessment
CRMP ..... Coastal Risk Assessment and Management Program
CZMU ..... Coastal Zone Management Unit
EPD ..... Environmental Protection Department
EIA ..... Environmental Impact Assessment
HWM ..... High Watermark
LD ..... Lamont Datum
LIDAR ..... Light Detection and Ranging
M21SW ..... Mike21 Spectral Wave Model
M21FM ..... Mike21 Flow Model
MHHW ..... Mean high highwater level
SIA ..... Social Impact Assessment
SLR ..... Sea Level Rise
WL ..... Water level

1. Introduction

The owner of Sandy Lane Lot 7, Bougainvillea, intends to stabilize and develop the beach and nearshore between Sandy Lane Bay and Paynes Bay. This headland encompasses the 500m long shoreline adjacent to Lots 4 – 9 and One Sandy Lane. Intended improvement is to the benefit neighbouring beachfront properties and most importantly the beach going public using the West Coast of Barbados. The owner has hired W.F. Baird & Associates Coastal Engineers Ltd (Baird) as the coastal engineering consultant.

The wave climate at the site is dominated by north-westerly swells in the winter months. Less frequent storms produce waves from the west and south-west, which have a significant impact on beach morphology at the site. There are private properties at the edge of the beach and multiple retention structures along the shoreline including walls, a revetment, and gabion baskets. These hard structures have been damaged and undermined by ongoing erosion. Lateral access and dry beach areas are no longer available at the site.

In the 1980's and 1990's there was a wider continuous beach from Sandy Lane Bay to Payne's Bay which supported recreational activity. In the nearshore area there was a developed fringe reef extending the length of the headland. These features were habitat for the hawksbill turtle, coral colonies and other coastal and marine species. There has been a baseline decline in the surface area and quality of the beach and the reef and a decline in the diversity and abundance of the resident species of flora and fauna.

The proposed design responded to these issues with the following objectives:

- Stabilize the shoreline and restore the beach
- Facilitate continuous lateral access along the shoreline
- Reduce the wave energy in the nearshore and at the shoreline
- Enhance and preserve coastal and marine habitat

1.1 Project Description

The site is in Saint James on the west coast of Barbados, between Sandy Lane Bay to the north and Paynes Bay to the south. The site location, impact study area and footprint of the proposed structures are shown in Figure 1.1 and a concept render of the proposed design is shown in Figure 1.4. Relevant characteristics of the site include:

- The study area is 1 km along the shoreline and extends 0.5 km offshore with a total surface area of 0.5 km^2.
- The coordinates for the study area are in Table 1.1.
- The total footprint area of the proposed structures is 6500 m^2.
- The project is primarily on crown land.
- Minor areas of the design are on adjacent private property. This is caused by the progressive movement of the waterline inland.
- The bordering properties are Sandy Lane Lots 1 to 9 and One Sandy Lane.
- The High-water mark survey defining these boundaries is shown in 0.

The site is in the coastal zone and has a flat, low-lying profile. The coastal and marine spaces in the study area are categorized by six elevation-based sections each with their own features. These sections are labelled and illustrated in Figure 1.2. Sections 1-3 are further broken down for more detail and illustration of terminology in

Figure 1.3. These sub-sections and the terminology are referenced throughout this report. The proposed structures extend from the dry beach zone to the reef flat zone.

The dry beach zone is the most landward part of the beach that is consistently dry throughout seasonal cycles. The landward boundary of the dry beach zone is at the back of the beach and is often demarked by mature vegetation or hard infrastructure. The dry beach extends from the back of beach seaward to the high-water mark. Coastal vegetation and dunes establish in the dry beach zone indicating that the sand is stable and isolated from frequent wave or tidal activity.

The tidal zone is the envelope in which the waterline fluctuates during the tidal cycles. The landward extent is the high-water mark, and the seaward extent is the low-water mark, with the zone continuously changing between states of wet and dry.

The sub-tidal zone, which starts at the low water mark, is continuously submerged below the water line. The sub-tidal zone extends seaward to the end of our study area 500m offshore and is sub-divided into the reef flat, reef crest, and spur and groove zones. The physical and ecological characteristics of the marine zones are defined in Section 2.4 Ecology.

Table 1.1: Study area coordinates

ID	Latitude	Longitude
	Decimal degrees WGS 84	
1	59.64157 (west)	13.16548 (north)
2	59.64153 (west)	13.17524 (north)
3	59.63735 (west)	13.17518 (north)
4	59.63702 (west)	13.16543 (north)

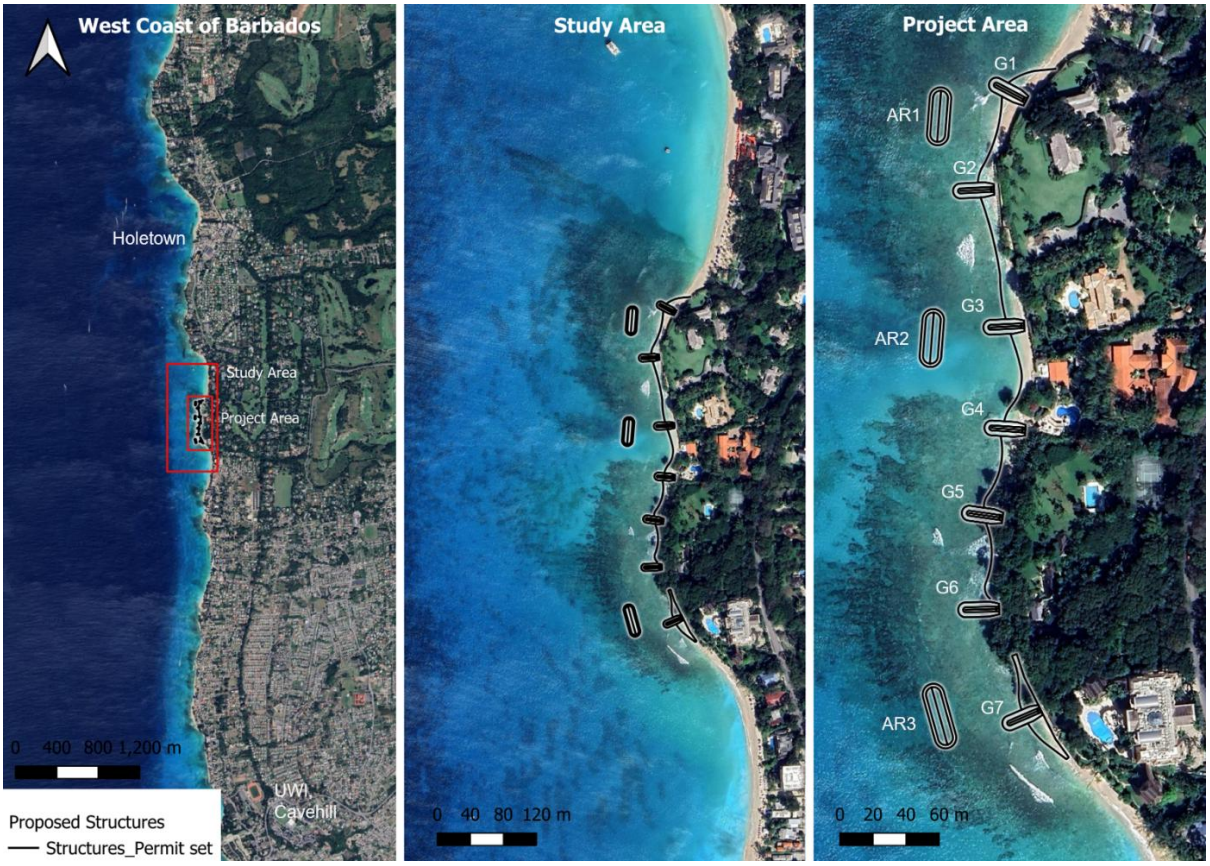


Figure 1.1: Location map (left), study area (centre), project area (right)

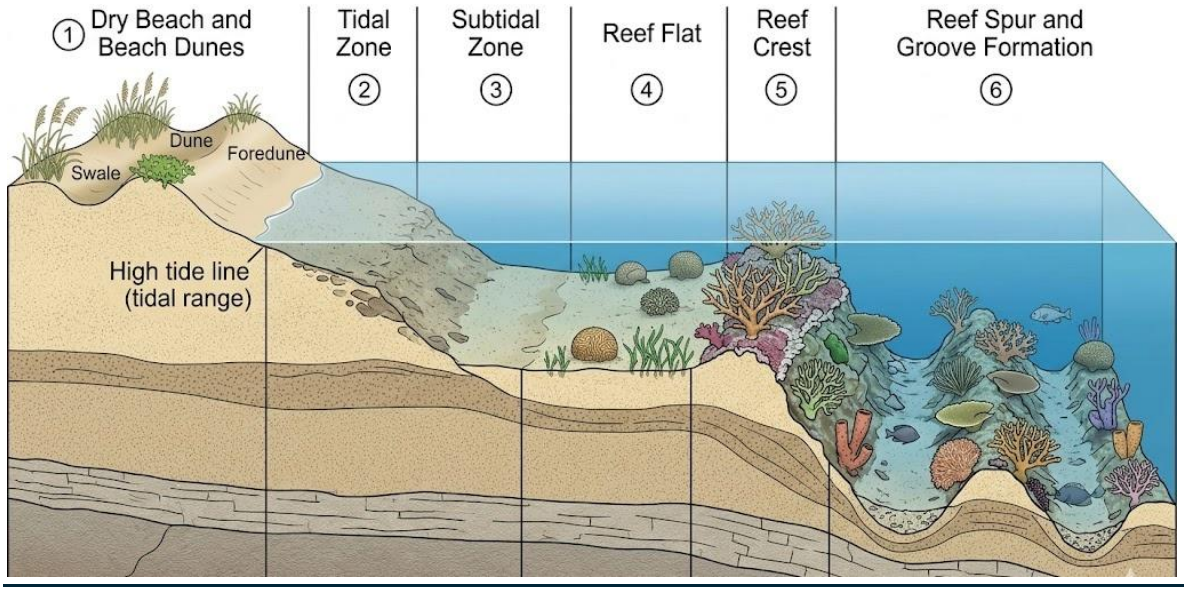


Figure 1.2: Elevation-based zones

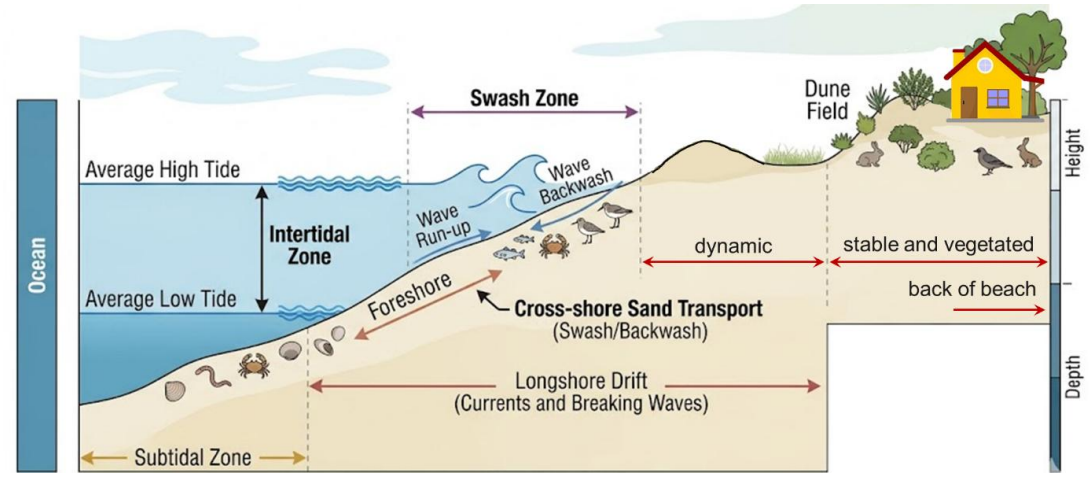


Figure 1.3: Beach profile sub-zones



Figure 1.4: Render of proposed design at low tide

1.2 Scope of Work and Methods

The Coastal Impact Assessment is a study of the existing conditions and expected outcomes as a result of implementing the proposed design. The analysis includes the project area which contains the structures and the study area which expands beyond the project area to include neighbouring locations. This is illustrated in Figure 1.1. The report focuses on the topics of beach morphology, infrastructure, wave climate and ecology and discusses existing conditions, impacts and mitigation for each topic.

Data for the Coastal Impact Assessment was sourced from internal project fieldwork, government sources, research and monitoring agencies, published literature and previous Baird projects. The design is conceptual. The design objectives, masterplan, typical cross-sections and preliminary quantities are complete. Detailed cross-sections, quantities, specifications and the design report will be completed after the permit application process is complete. The detailed design will incorporate the content of the EIA and the conditions of the permit. Locations and dimensions of structures discussed here are presented for analysis of potential impacts and are subject to change.

Analysis of coastal impacts were determined using industry standard methods for coastal engineering and marine ecology. The analysis is limited by the scope and the data available. Sediment budget, water quality and similar topics affect the study area but are driven by processes on a larger municipal scale beyond the scope of this report.

2. Existing Conditions

Existing conditions were characterized using data from Baird fieldwork in 2023 and 2026, research, monitoring agencies, published literature and previous Baird projects. The fieldwork used the same instrumentation and locations in 2023 and 2026. This allows for comparison of critical parameters over the three-year period and is specific to our study area. The ecology and bathymetry surveys were extended to more areas in 2026; data collection locations are shown in Figure 2.1.

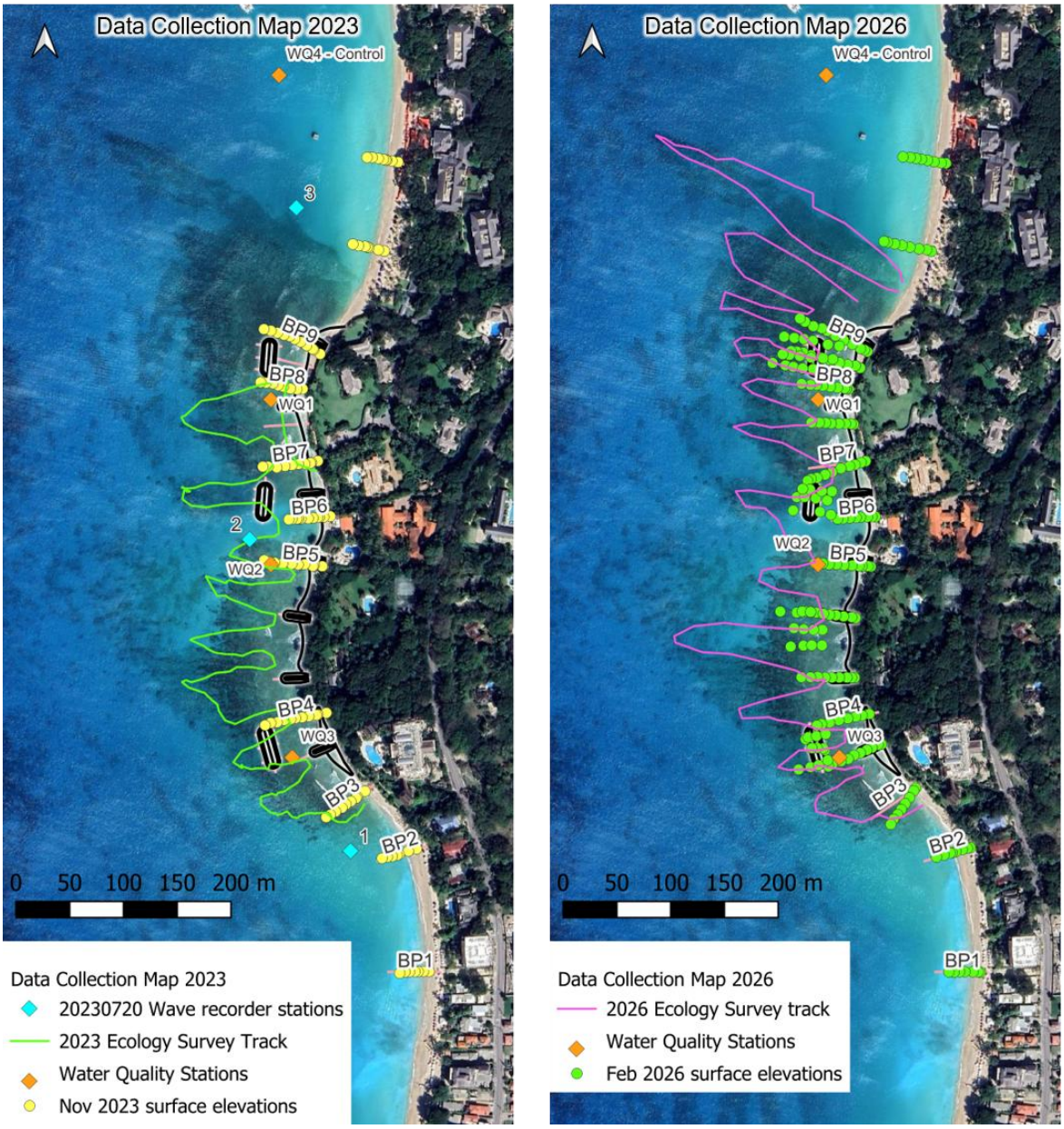


Figure 2.1: Data collection maps 2023 and 2026

2.1 Beach Morphology

The physical characteristics of the beach are critical to the prevailing conditions. This has a compounded impact on the ecology, wave climate and shoreline features. The beach morphology was characterized by analysing two data sets over short to medium-term and long-term timescales in the study area. The profiles measured the elevation of the sand surface starting from the back of beach and extending seaward to the sub-tidal zone as shown in Figure 2.2. The datasets include:

- The long-term dataset consists of surface elevation measurements from the Coastal Zone Management Unit (CZMU) from 1988 to 2026. The dataset covers 37 years and uses a range of techniques over that time.
- The short to medium-term dataset covers 11 years and consists of the 2015 LIDAR data (collected by the CZMU) and the 2023 and 2026 data that were measured by Baird using a total station and data collector.

The coordinates for both data sets are in Barbados National Grid (BNG), and the elevations are referenced to Lamont vertical datum (LD) in meters. The map of surface elevations data is shown in Figure 2.2. The LIDAR data set covers the entire island and surrounding ocean out to the 40 m contour.

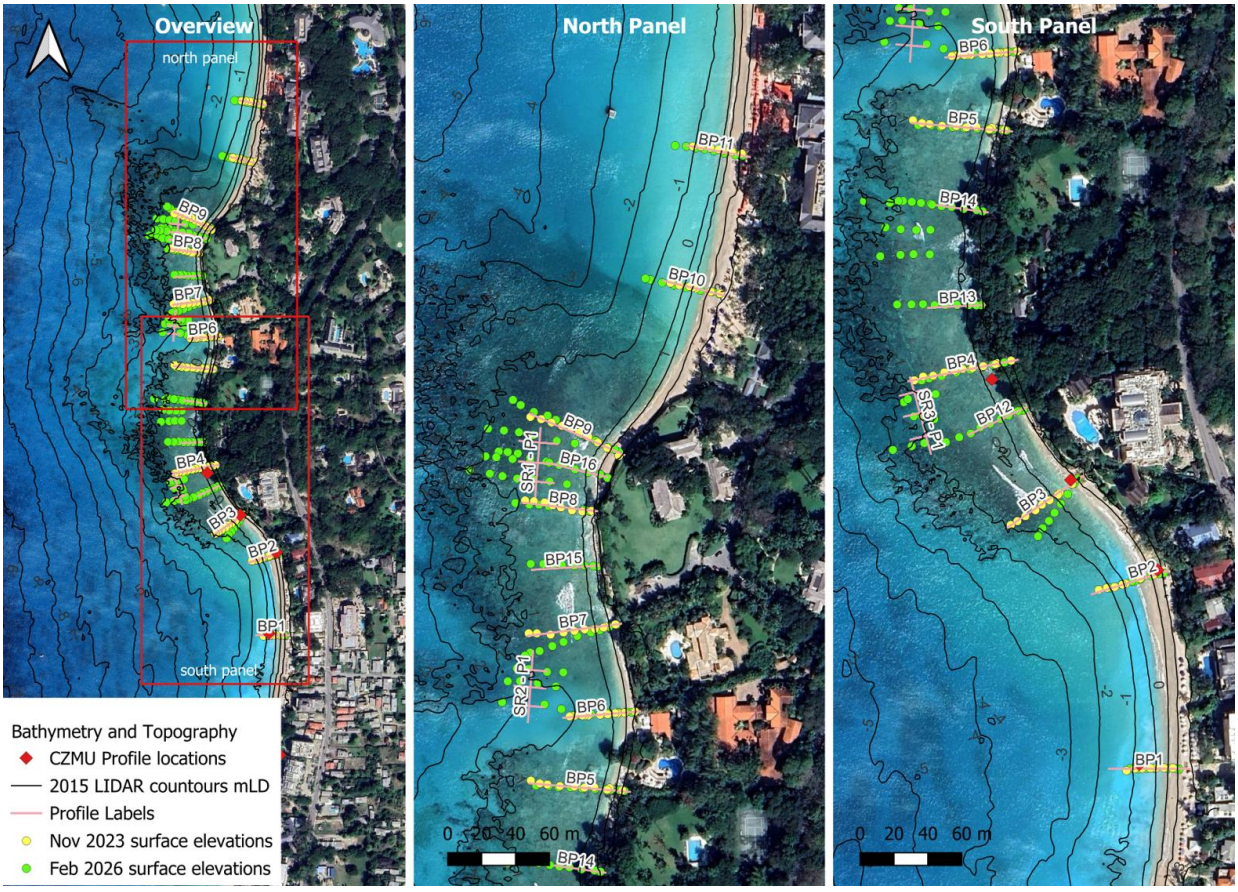


Figure 2.2: Elevation measurements map

2.1.1 Short to Medium Profiles

Beach profiles were measured in the footprint of each proposed structure. There are eleven beach profiles along the shoreline, each with the 2015, 2023 and 2026 surface elevations. Details on data collection methods are included in the Beach Morphology Report [1]. The short to medium term profiles demonstrates a progressive loss of beach sand and beach stability over the 11-year period. The profiles at Sandy Lane Bay and Paynes Bay are more stable than the profiles on the headland between the two bays.

Beach width, crest elevation and sand volume decreased, and beach slope increased over the eleven-year period, as shown in Table 2.1. These changes are more pronounced in the central headland profiles; further details are available in the Beach Morphology Report [1]. Charts showing the measured parameters and the average per year are shown in Figure 2.3, Figure 2.4, Figure 2.5 and Figure 2.6. Increased beach width, crest elevation and sand volume are all correlated to increased beach stability. Increased beach slope is correlated to decreased beach stability. These comparisons over the temporal and spatial extents reveal a progressive trend of beach decline that is common on the west coast.

Table 2.1: Averaged values of beach morphology parameters

	Width	Elevation	Beach Slope	Volume
	[m]	[m LD]	°	[m^3]
2015	13.8	1.6	7.5	2361
2023	9.4	1.1	8.1	1939
2026	6.6	1.0	8.1	1676

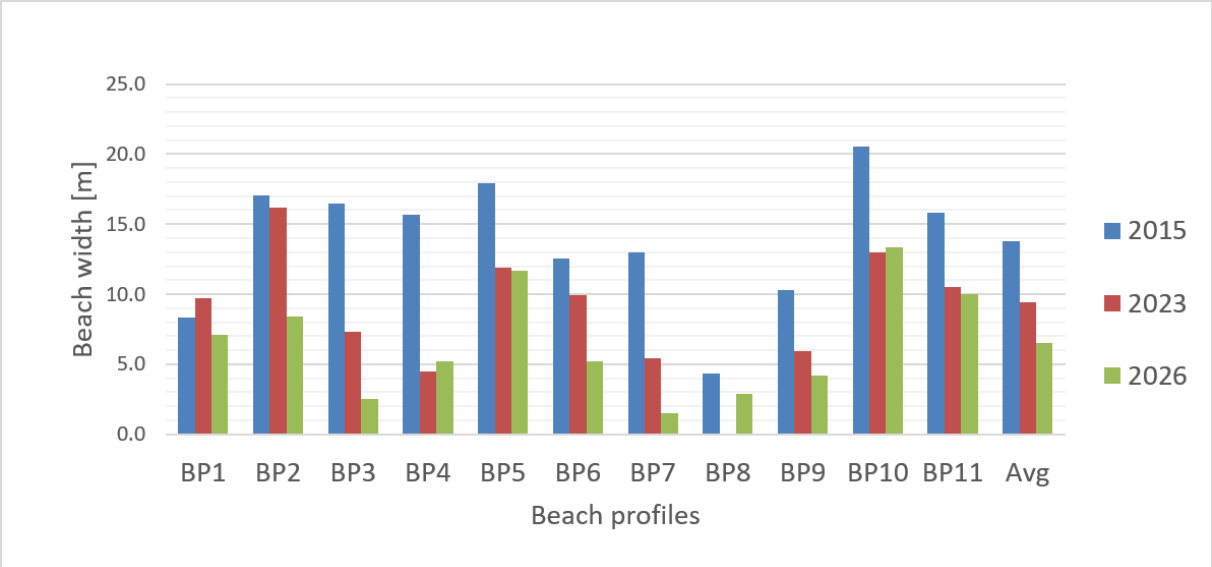


Figure 2.3: Beach widths 2015 to 2026

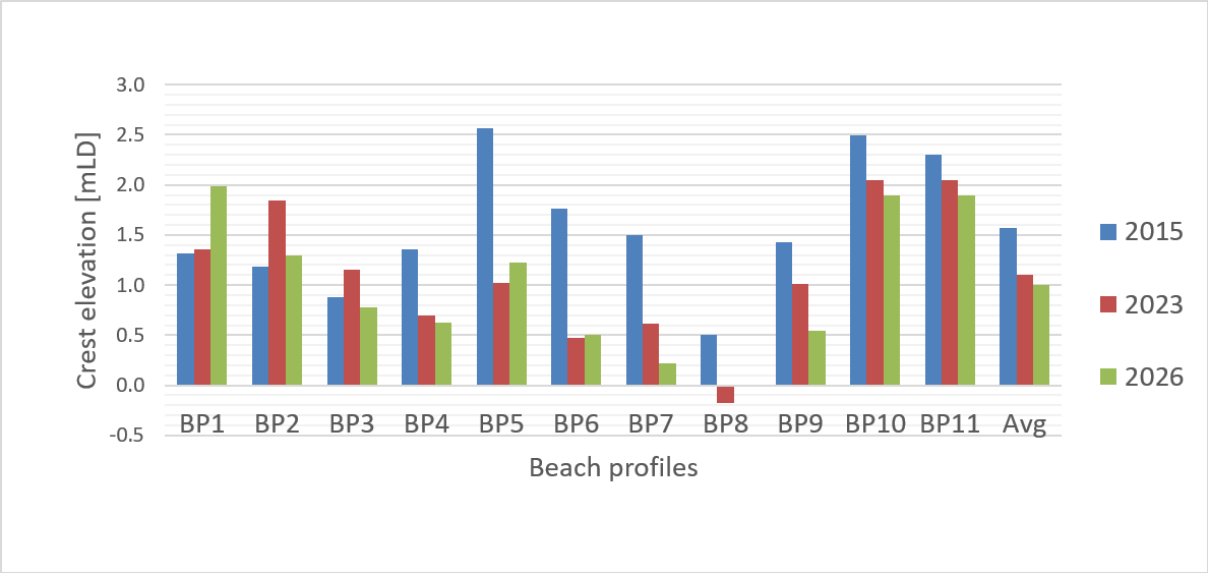


Figure 2.4 Beach crest elevations 2015 to 2026

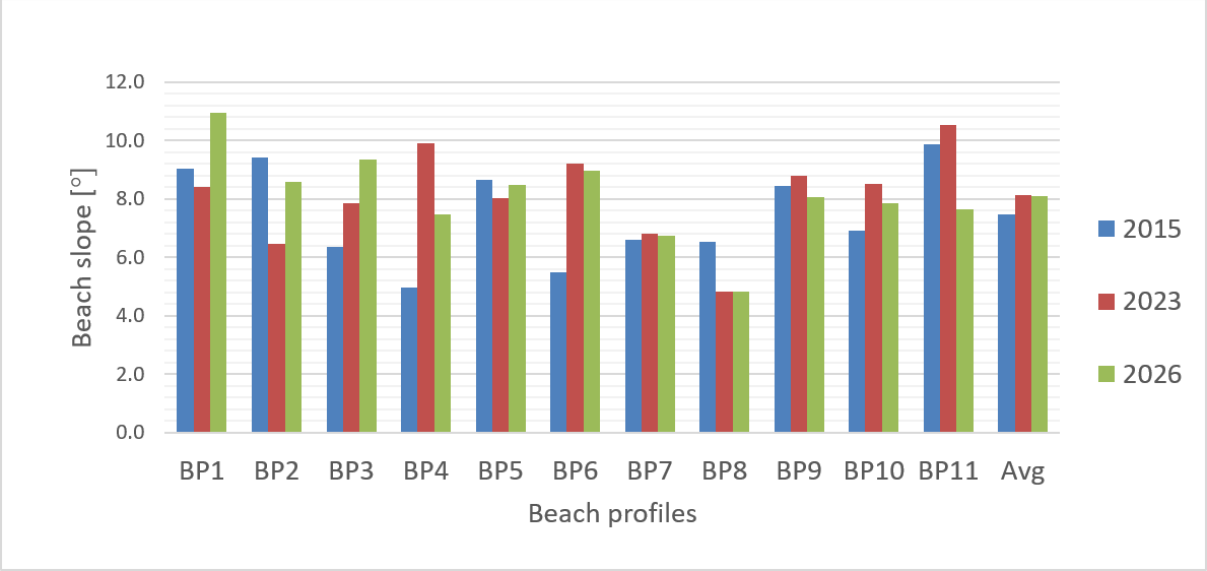


Figure 2.5: Beach Slope 2015 to 2026

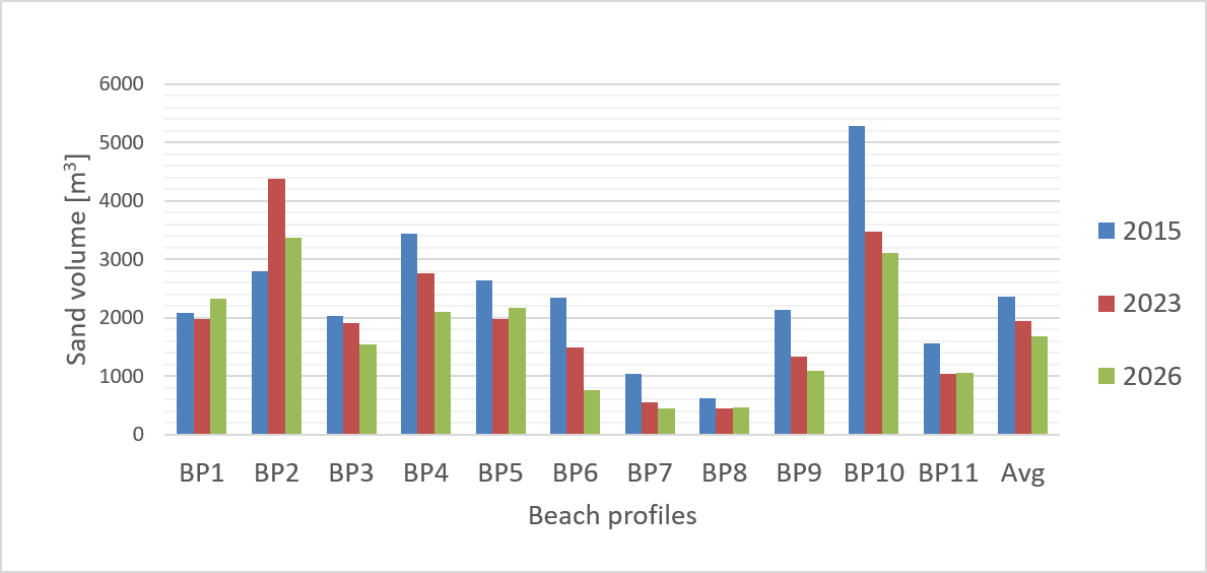


Figure 2.6: Sand volume 2015 to 2026

2.1.2 Long Term Profiles

There are four CZMU monitoring locations in the study area. BP2 was continuous over the longest period and was most suitable for long-term trend analysis. This is referenced as Paynes Bay (M) in the CZMU repository and covers 1988 to 2025. Figure 2.7 shows the beach width time series for that profile, where the beach width is defined as the distance from a back-of-beach reference point to position of the mean water level (0.35 m LD) on the face of the beach. The data shows a wide envelope around the trend line. In a typical year the beach width fluctuates by more than 5 m, with larger beach widths typically recorded in the summer periods and smaller beach widths recorded in the winter periods. Beyond the seasonal fluctuation the net beach width has been trending down from 1994 to 2025 with an average loss of 0.18 m per year over the 37-year period, for a total loss of about 6.7 m.

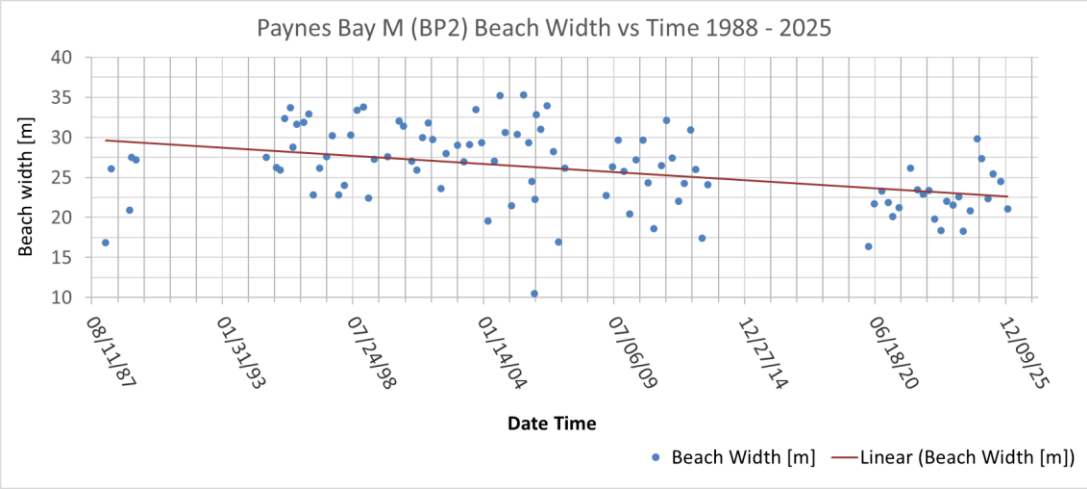


Figure 2.7: Paynes Bay M times series

2.1.3 Profile Trends

There are spatial and temporal changes identified in these datasets. The beach has incrementally lost sand between 1994 and 2025. At present, the beach is at an advanced stage of erosion, the sand volume is depleted and the beach is unstable. The minimum values of beach width, crest elevation and sand volume occur between profiles BP4 to BP8. Two of the three of the maximum decreases in the same metrics also occur between these two profiles. The instability and exposure in this area are higher than the areas north and south. If this trend remains constant, the beach will continue to deteriorate and the features inland of the beach will be more exposed. These observations are corroborated by multiple investigations in the area. [2], [3], [4].

These changes, while indicative of prevailing beach trends, also reflect seasonal, annual fluctuations prevalent on the west coast of Barbados. During the annual swell season, peaking from December to March, long period wave events from the north and north-northwest shape the beach and affect these parameters. Outside the swell season calmer more localized wave conditions shape the beach and affect these parameters. The swell season typically causes increased beach slopes and pushes beach sand to the southern end of the bays and beach cells along the west coast. Outside of the swell season the beach slope becomes gentler, and the sand is redistributed to northern parts of the bays and cells. Energetic wave events tend to move sand from the dry beach and tidal zones offshore to the subtidal zone. Most of the sand is moved back to the dry beach and tidal zones when calmer wave conditions resume. In extreme wave events, sand is moved offshore beyond the subtidal zone and does not return to the beach. The continuous seasonal movement and sand loss is important in the understanding the existing conditions and the expected changes discussed in the later sections.

2.2 Infrastructure

The shoreline infrastructure in the area includes walls, stairs, boulders, gabions and walkways. Baird inspected the visible structures in 2023 [2] and in 2026. These structures had limited functionality in 2023, and this declined in 2026. The 2026 inspection is divided into seven locations based on the land parcels identified in the HWM survey. These are illustrated in Figure 2.8 and the high watermark survey is attached in 0. For each location the condition and functionality of shoreline features are qualitatively assessed. The ranking method is described in Shoreline Structure Inspection Report [3]. The inspection results are summarized in Table 2.2. The damage and functionality ratings are explained in Table 2.3 and are based on the ASCE Waterfront Facilities Inspection and Assessment Manual [5].

Shoreline features at Lots 4 – 9 have sustained major or severe damage. There are no purpose-built shoreline features at public access. At One Sandy Lane the features have minor damage and are in better condition than the other sections on the shoreline. Walls and stairs are the most common features along the shoreline with seven of the eight locations having both features, with varied levels of damage. The frequency of stairs is indicative of the history of pedestrian traffic and demonstrates the importance for lateral access. In four locations there are multiple sets of stairs. The stairs are the most damaged feature in the project area.

The change in surface colour and texture on these features indicates that in the past beach surface elevation was higher than it is now. Previously buried sections at the base of these features are now exposed. Erosion of the shoreline adjacent to the wall and stairs is the most common performance issue and has created lateral access issues at seven of the eight locations. Overtopping was observed at four of the eight locations. Discussion of the damage and the performance issues at each lot are detailed in the Shoreline Structures Inspection Report and examples are shown in Figure 2.9. The damage conditions and non-performance are all influenced by the reduction in beach width and useable dry beach surface area. This is discussed in the section 2.1 Beach Morphology.



Figure 2.8: Land parcels adjacent to the highwater mark

Table 2.2: Damage Condition and functionality of shoreline features

No	Parcel	Length	Damage condition of shoreline features							Performance	
		m	Wall	Fence	Stairs	Boulders	Water course	Walkway	Gabions	LA	OT
1	Lot 4	77	ND	ND	ND	MJ	ND	n/a	n/a	no	no
2	Lot 5	85	MD	ND	MD	SV	n/a	MD	n/a	no	yes
3	Lot 6	50	MN	n/a	MN	n/a	n/a	n/a	SV	no	no
4	Lot 7	44	MN	n/a	MN	n/a	n/a	n/a	n/a	no	yes
5	Lot 8	64	MJ	MD	MD	n/a	n/a	n/a	n/a	no	yes
6	Lot 9	72	SV	SV	SV	MD	n/a	n/a	n/a	no	yes
7	Public Access	15	n/a	n/a	n/a	n/a	n/a	ND	n/a	yes	no
8	“One Sandy Lane”	149	MN	n/a	ND	n/a	MN	n/a	n/a	no	no

Table 2.3: Legend for damage and functionality ratings

Damage Rating	Abbreviation	Performance	Status	
No defects	ND	Lateral access (LA) available	yes	no
Minor Damage	MN	Overtopping (OT) observed	yes	no
Moderate Damage	MD			
Major Damage	MJ			
Severe Damage	SV			
Not available	n/a			



Figure 2.9: Shoreline structures in the study area February 2026

2.3 Waves, Currents, and Water Levels

Multiple agencies have produced analysis and measurements of wave, current and water level parameters in Barbados over the past 30 years. In 2015 the CZMU used measured data and long-term wave modelling to define the wave climate at select locations around Barbados including in the nearshore point in Paynes Bay [6]. The study divided the wave climate into summer and winter seasons between May to December and January to April respectively. In the summer period average wave height and wave period are smaller with waves more frequently approaching from the west. These waves may have originated from the east and transformed around both the north and south ends of Barbados and take on a nearshore westerly direction. The summer period includes the Atlantic hurricane season, during which individual storms may cause unique combinations of wave direction, elevated wave heights and water levels for a few days. In the winter season average wave height and wave period are larger and the wave conditions will include periodic swell waves that approach from NNW to NE direction from the north Atlantic. The 2024 Sandy Lane Lot 7 permit application report includes wave and current measurements, wave modelling and design waves for the proposed concept [2]. The measurement locations used are shown in Figure 2.1. The recorded wave heights ranged from 0.15 - 0.4 and correlates with the 2015 wave climate developed by the CZMU.

For this CIA Baird used numerical modelling to characterize the wave climate and to develop performance criteria for the proposed concepts. Critical parameters for the wave climate on site include waves heights, wave periods and water levels. Baird maintains a historic repository of global wave data from 1980 to 2025. This 46-

year data set provides deep water wave conditions, offshore of Barbados, which define the boundary conditions for a MIKE 21 Spectral Wave (M21SW) model of the site to simulate the 46 years of wave climate conditions at our location.

Baird validated the model by comparing the simulated wave height time series to the recorded waves height time series from July 21st to September 9th, 2023, as shown in Figure 2.10. There are five prominent peaks in the data series that correspond to storm systems and elevated wave heights. The two larger events are well correlated in time. The storm events occur at the same time for both modelled and measured time series. The wave heights show that the modelled values are consistently lower than the measured. This is typical on the west coast and indicative of local wave activity that is captured in the measurement but not replicated in the model. This systematic underestimation is accounted for in the design process.

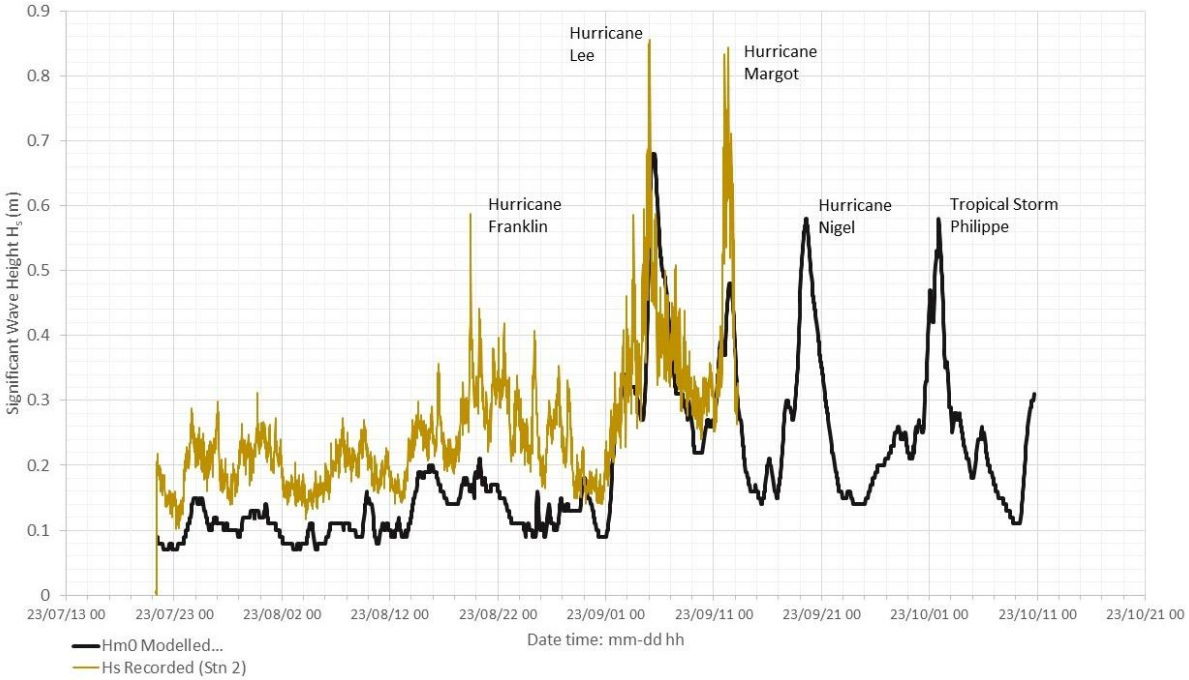


Figure 2.10: Wave height time series recorded vs modelled

The bathymetric mesh for the numerical modelling was derived from a 2001 bathymetry chart, 2015 LiDAR data collected under the CRMP project for the CZMU and 2026 bathymetry surveys at the footprints of the proposed structures. The mesh covering the study area is shown in Figure 2.11. The model covers all of Barbados in varying degrees of detail, with increased mesh resolution at the study area.

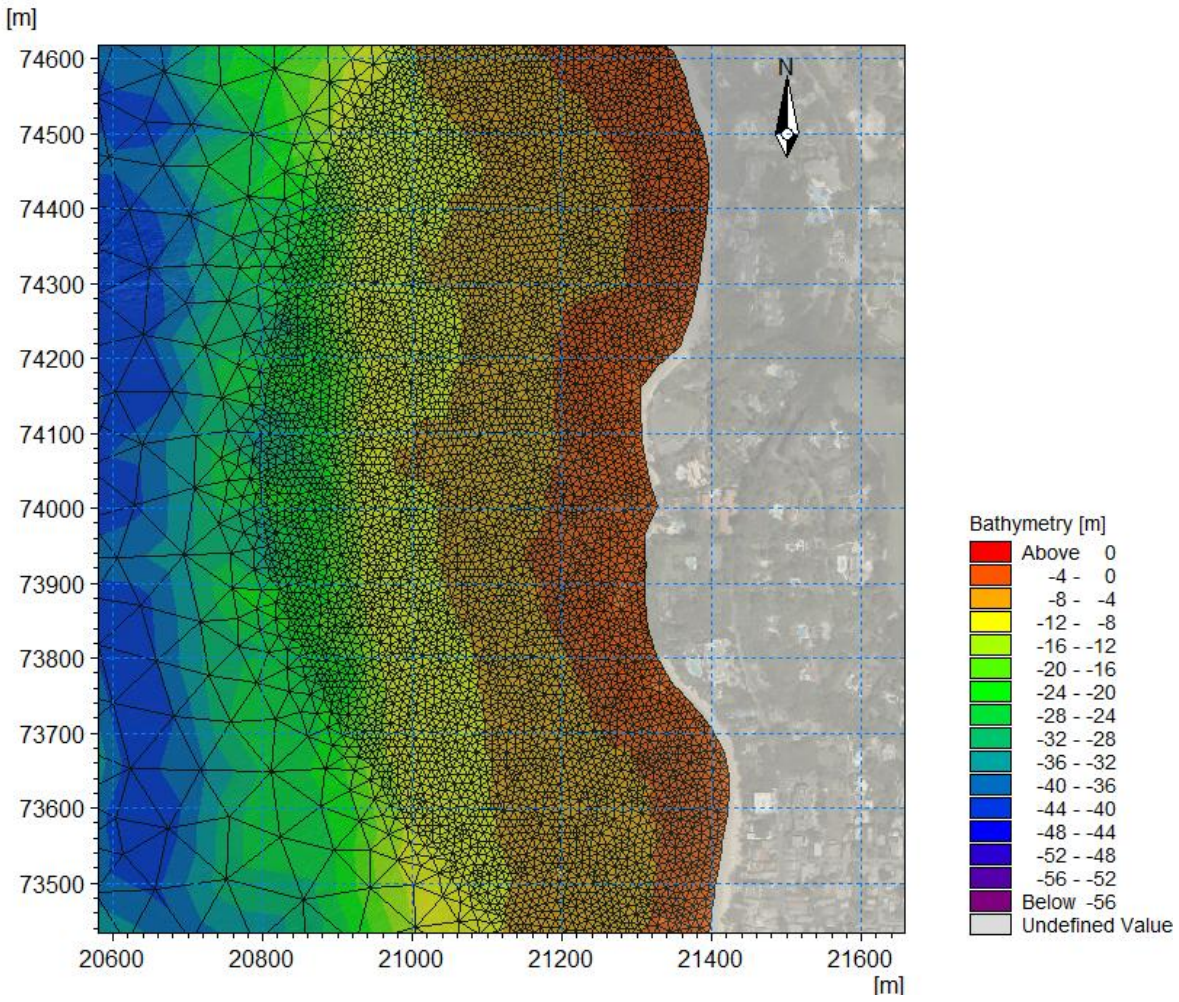


Figure 2.11: M21SW Model Mesh used for Coupled Wave and Hydrodynamic Modelling

Baird has undertaken numerous studies along the west coast of Barbados and has developed a standard set of water level design conditions. Table 2.4 shows a summary of the tidal conditions for Barbados.

Table 2.4: Typical Water Level Design Conditions for Barbados West Coast

Description	Elevation (m CD)	Elevation (m LD)
Highest Astronomical Tide (HAT)	+1.53	+1.06
Mean Higher High Water (MHHW)	+1.13	+0.66
Mean Sea Level (MSL)	+0.83	+0.36
Mean Lower Low Water (MLLW)	+0.53	+0.06
Lowest Astronomical Tide (LAT)	+0.03	-0.44

Storm surges are caused by wind and pressure effects associated with the passage of a hurricane. Storm surges may cause short-term increases in water levels in the range of 1 m or more during the most severe storms. Wave setup at the beach could be higher, with a rule of thumb of about 10% of the offshore wave height. However, design conditions must consider the design life of the structures, the frequency of storms and the probability of wind, pressure, wave and tide effects increasing water level. For example, it is not appropriate to take a very severe storm surge and assume it is added to a HAT value. Instead, typical surge levels are added to MHHW, SLR and sea level anomaly (typically in the order of 0.1 to 0.2 m) to develop an overall recommended water level for the site. The sea level anomaly is caused by concentrated freshwater discharge from South American rivers that temporarily change density and salinity. The design water level is represented with constant constituents and variable constituents. The constants are MHHW and SLR and are expected to occur for each storm in the design life of the project. The variable constituents are wind setup, wave setup and storm surge. These are event specific and vary based on the wind, wave and pressure fields.

Baird measured current speed and direction at four locations in the study area from July to September 2023. This is discussed in detail in the permit application report that preceded this CIA [2]. The peak current speeds occurred during swell events. The maximum current speed recorded was 0.39 m/s. Maximum currents coincided with increased wave heights during storm events. This is indicative of wave generated currents; these currents may vary locally depending on the position in the wave field and currents are likely higher than this in some areas during larger wave events (and significantly higher during the design event).

2.3.1 Surfing

Barbados has been a surf destination since the 1960's [7]. At present the Barbadian surf industry includes invitational competitions, surfing schools, international sponsorship and a cadre of amateur and professional surfers [8]. There is a recognized surf break at Sandy Lane inside the study area. It is seasonal and is only viable in specific months of the year during the days when a northerly swell event is occurring. The break is an important asset for tourism, recreation, employment and competition. It offers opportunities for the surfing community to gain experience and training [9] [10].

The swell event February 9 to11, 2026 demonstrated the surf breaks at Sandy Lane. Baird fieldwork during this time recorded surfers using the breaks as shown in Figure 2.12. The consultancy team engaged two representatives from the surf community to characterize the Sandy Lane surf break. These representatives were from the Barbados Surfing Association and a surf instructor based at the Paynes Bay Fish Market. Baird staff and the surfers met on two separate occasions, went to the surf breaks and used a handheld GPS to map out the extents. The surfers also shared their opinions on the project. This is covered in the Social Impact Assessment Chapter of the EIA.

The surfers identified two surf breaks in the study area. The surf break at to the north of the existing reef area (also north of the proposed artificial reefs) is popular and is referenced on multiple apps and websites used for activity mapping [11] [12]. The surf break to the south of the existing reef and proposed artificial reefs is less popular and less frequently used.



Figure 2.12: Surfing at Sandy Lane to Paynes Bay

2.4 Ecology

The study area includes coastal and marine habitats. The coastal habitat includes the dry beach, the tidal and sub tidal zones. Most of the dry beach has been eroded, and the remaining beach is in the tidal zone. There are platforms of beach rock in the tidal zone at Lot 8.

There are two inland watercourses connected to the beach. Sand deposits block the mouth of both water courses until there is flow in the watercourse. There was no flow in either watercourse during the fieldwork conducted for this report in February 2026.

Important data sources for ecology are listed in Table 2.5. The map of ecology data is shown in Figure 2.13.

Table 2.5: Ecology data sources

ID	Name	Date
1	Sandy Lane Lot 7 Site Preliminary Marine Assessment	September 2023
2	Rapid [ecological] survey of Sandy Lane Lot 7 site	February 2026
3	Quantitative [ecological] assessment of eleven proposed structure footprints	February 2026
4	Sandy Lane [Water Quality] Monitoring	September 2023
5	Sandy Lane [Water Quality] Monitoring	February 2026
6	CRMP Lidar Survey and Benthic Classification	2015

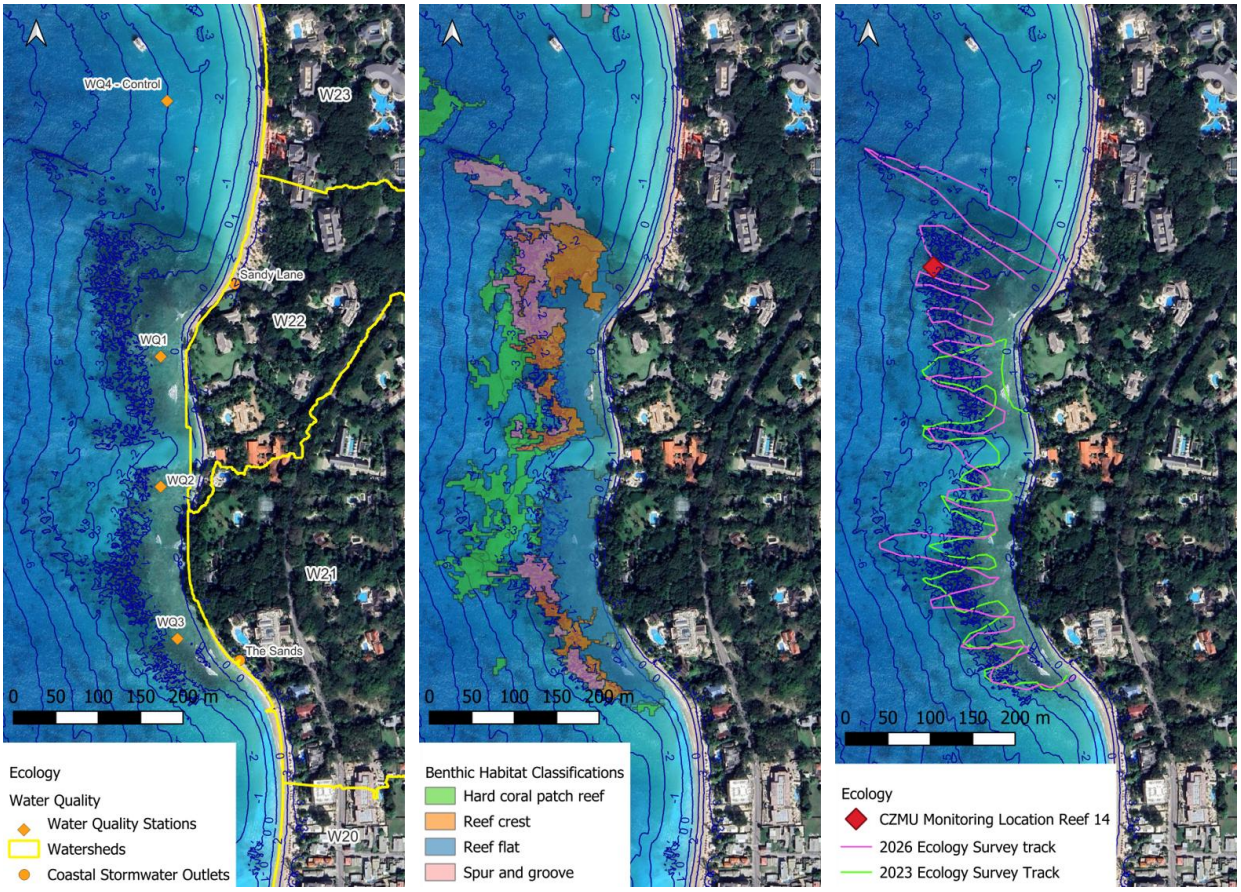


Figure 2.13: Water quality map (left) ecology survey map (centre), benthic classifications (right)

2.4.1 Hawksbill Sea Turtles

The dry beach and back of beach areas are privatized and enclosed. There are walls, stairs and boulders in the tidal zone throughout the study area and there is limited space for the development of coastal habitat or occupation by corresponding species [3], [4]. Hawk's bill turtles nested on the dry beach areas between 2008 and 2014. The Barbados Sea Turtle project recorded 3242 turtle activities in the project area and the adjacent Sandy Lane Bay between 2008 and 2014 [13]. As shown in Figure 2.14, Baird observed turtle activity on the beach and on the reef during the 2023 survey. During the 2026 survey there was no dry beach zone, but turtle activity was observed on the reef [14] [4]. As discussed in the Beach Morphology section, the beach width has reduced progressively and with it the nesting habitat of the hawksbill turtle. There is now less habitat available for nesting and there is also less data available on turtle activity because the obstructed pedestrian access is impeding the conservation efforts of the Barbados Sea Turtle project.



Figure 2.14: Turtle activity, on the reef (left), on the dry beach (right)

2.4.2 Reefs

The marine habitat includes the subtidal zone, reef flat, reef crest and spur and grove. There are two reefs in the study, separated by a shore perpendicular channel with sand substrate. The reef to the north is Sandy Lane Reef 14 and is monitored as part of the CZMU Reef Monitoring Programme. Reef 14 extends to 120 m offshore. It is made up of the sub-tidal zone, reef flat, reef crest and spur and groove.

The sub-tidal zone extends to 10 m offshore with water depths up to - 0.5 m LD. The seabed profile is flat with coral rubble, eroded rock platform substrate with intermittent patches. Flora and fauna are minimal in this area but include turf algae, knobby brain coral (Diploria clivosa) and rock boring urchins (Echinometra sp.). An example of the sub-tidal zone is shown Figure 2.15.

The reef flat is between 10 m and 40 m offshore with water depths up to -1 m LD. The reef flat profile is gently sloping with eroded rock platforms covered in turf algae. The coral cover was sparse and included knobby brain coral (Diploria clivosa). There were also rock boring urchins The reef flat is shown in Figure 2.16.

The reef crest is between 40 m and 90 m offshore with water depths up to -2 m LD. This area had more developed framework and species diversity than the reef flat. The coral cover during the 2026 inspection was lower than expected. The coral species included mountainous star coral (Orbicella faveolata), boulder star coral (Orbicella annularis), brain corals (Diploria clivosa and Pseudodiploria strigosa). The other species observed here were white encrusting zooanthid (Palythoa caribaeorum), blue tangs and black sea urchin (Diadema antillarum) as shown in Figure 2.17.

The spur and groove zone is between 50 m and 120 m offshore with water depths up to -4 m LD. This zone is present intermittently in project area. In some locations the reef crest and the spur and groove are at similar water depths and distance offshore. The reef to south has significantly less spur and groove than the northern reef. Coral cover and species diversity were lower than the 2023 survey. The colonies observed included massive starlet coral (Siderastrea siderea), mountainous star coral (Orbicella faveolata), great star coral (Montastraea cavernosa), and finger coral (Porites porites). The colonies surveyed were damaged and some were destroyed. Examples are shown in Figure 2.18. Blue Tangs, Ocean Surgeons, black sea urchins (Diadema antillarum) and a hawksbill turtle were also observed during the survey.

The Barbados Coral Reef Monitoring Programme has evaluated Sandy Lane reef on 5-year intervals from 1982 to 2022 in partnership with various research institutions. The CZMU published an assessment Barbadian reef health for 2022 based on this monitoring programme. Sandy Lane reef is labelled reef 14 in their programme is in our area as shown in Figure 2.13. There are multiple publications that characterize the health of the reef. The CZMU Coral Reef Report Card 2022 assigned reef health index (RHI) of 2.3. The RHI score ranges from the lowest score of 1.0 to the maximum of 5.0 for a healthy reef. Sandy Lane reef #14 is in poor health with poor coral cover, and very poor fish density [15]. The CZMU report indicates that this is an improvement in RHI as compared to 2017. The CZMU 2022 survey data shows that the benthic cover is 83% algae, 6% hard coral, 4% sponges and less than 1% gorgonians [16]. Centre for Resource Management and Environmental Studies CERMES UWI found that in 2009 the Sandy Lane reef #14 had a visual health index of 1.45. This used a similar scoring system as the CZMU 2022 RHI index. The reef health was between 1(very bad) and 2 (bad). CERMES ranked Sandy Lane reef #14 at 37 of 43 west coast reefs for visual health index. The highest rank reef scored 3.75 and the lowest ranked reef scored 1 [17].

The ecological surveys completed for this project indicate that health, diversity and density of habitat and the species throughout the study area have declined between 2023 and 2026. There have been multiple bleaching events, in 2023 and 2024, and multiple extreme wave events which have contributed to the decline [4] [18]. Hurricane Beryll passed southwest Barbados July 1st, 2024, exposing the site, and the entire west coast, to extreme conditions which eroded the dry beach zone, and destroyed reef colonies in the reef flat, reef crest and spur and groove zones [4] [18]. Review of existing literature demonstrates that prior to the significant decline in the last three years the reef habitat at this location was in poor health with low coral cover in 2009 and 2022 [15] [16] [17].



Figure 2.15: Coral rubble in the sub-tidal zone



Figure 2.16: Reef flat, low-profile framework with turf algae (left), knobby brain coral colonies (right)

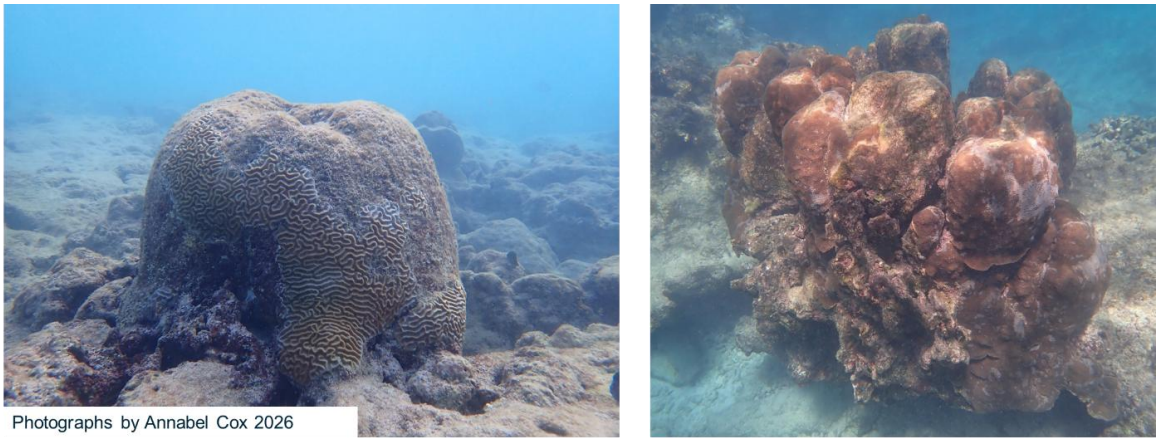


Figure 2.17: Reef crest, damaged brain coral (left) and unhealthy boulder star coral (right)



Figure 2.18: Spur and groove, finger coral Porites porites (left), great star coral Montastraea cavernosa (right)

2.4.3 Water Quality

Water quality on the west coast has been researched over the last two decades. Input sources affecting water quality include ocean currents from South America, subterranean ground seepage and terrestrial run-off [19]. As urbanization progresses more nutrients and sediments are delivered to the waterfront and dispersed at sea. The percentage of rainfall that converts to run-off increases as land areas become less natural and less permeable. The run-off from rainfall on the west coast is collected through gullies and watercourse that discharge at the waterline. This causes plumes of water with elevated concentrations of nutrients and sediments in the nearshore.

McGill University has published research that investigated four of these rainfall events in 2006 and observed that discharge from the Holetown Lagoon changed water quality conditions at the Bellairs Reef, 600 m northwest of the discharge point on the shoreline [19]. That research took place 1.5 km north of our study area. There are two water courses in the study area, labelled as Sandy Lane and The Sands in the left panel of Figure 2.13. These watercourses have smaller catchments than the Holetown lagoon but have comparable interactions with the beach and the nearshore. The Sandy Lane watershed (W21) is 0.5 km^2 in area and The Sands watershed (W22) is 2.5 km^2. The Holetown Lagoon watershed (W26) is 9.9 km^2 in area. [20]. The investigation demonstrated that water discharged from the Holetown Lagoon during rainfall events had elevated levels of turbidity, suspended solids, phosphorus and nitrates. Bellairs reef experienced elevated concentrations of the same parameters between 17 and 67 hours after discharge. The sources of contamination included construction sites, fertilizers and laundry detergent. It is likely that the two outlets in the study area discharge similarly enriched run-off and which has caused adverse water quality conditions in the study area and on the fringe reefs. Bellaris reef is 600 m from the discharge point. The Sandy Lane reef is less than 400 m from two outlets identified.

Baird tested water quality at four locations in the study area on September 15th, 2023, and January 21st, 2026. At each location samples were collected at 1 m and 2 m below the surface. The parameters tested and the corresponding results are shown in Table 2.6. The Environmental Protection Department (EPD) has published standards for water quality parameters in the ocean around Barbados [21]. Recorded temperatures in September 2023 exceed the ambient standard maximum limit of <31°C in all samples. Turbidity values exceeded the ambient standard of 1.5 NTU at three stations (WQ1, WQ2 and WQ3) in 2023 and at all stations in 2026. When the two water courses, W21 and W22, are discharged into the study area, the seawater quality is likely to change in response. Testing the water quality of the discharge from the watercourses is beyond the scope of this EIA. The size of the catchment area, proximity of the outlets and land-use profile in the catchment indicates that the discharge is a significant influence on the water quality in the study area.

Table 2.6: Water quality test results

ID	pH		DO [mg/l]	DO [mg/l]	Sal [ppt]	Sal [ppt]	Tur [NTU]	Tur [NTU]	Temp [°C]	Temp [°C]
Ambient Std	7.0-8.7		n/a		30-38		≤1.5		<31	
	Sep23	Jan26	Sep23	Jan26	Sep23	Jan26	Sep23	Jan26	Sep23	Jan26
Ctrl 1m	7.99	8.17	7.02	8.77	33.1	36.9	1.08	1.92	31.3	26.3
Ctrl 2m	8.11	8.22	6.87	8.52	32.9	36.9	1.19	1.75	31.2	26.2
WQ1 1m	8.18	8.21	8.5	8.71	32.6	36.9	1.87	1.65	31.7	26.7
WQ1 2m	8.22	8.21	8.61	8.64	32.9	36.9	2.17	1.07	31.7	26.5
WQ2 1m	8.19	8.18	8.3	8.8	32.6	36.5	2.99	2.2	31.7	26.5
WQ2 2m	n/a	8.19	n/a	8.69	n/a	36.6	n/a	2.83	n/a	26.6
WQ3 1m	8.17	8.13	8.02	8.51	33.1	36.6	1.6	2.49	31.3	26.8

3. Proposed Improvements

Baird has developed this design for the owner of Sandy Lane Lot 7 (Bougainvillea) in response to the deteriorating coastal and marine conditions at the site. The objectives of the design are as follows:

- Stabilize the shoreline and restore the beach.
- Facilitate continuous lateral access along the shoreline.
- Reduce the wave energy reaching the shoreline at the site.
- Enhance coastal and marine habitat.

The design includes:

- Three offshore artificial boulder reefs.
- Seven flow-through groynes.
- Sand nourishment for 500 m of shoreline.
- Reconfiguration of existing structures.

The design process is at the permit stage. The project development roadmap is shown in Figure 3.1. The preferred layout from the concept stage is illustrated in Figure 1.4. Engineering details will be developed based on the impacts and mitigation strategies discussed in this CIA and in the overarching regulatory process review process. All proposed interventions are located between the reef flat zone and the back of beach. There are no structures proposed in the reef crest or spur and grove zones. Design development will refine locations, dimensions and orientations of the proposed structures. There are existing impermeable structures along the shoreline that have destabilized the beach and do not align with the project objectives. The design includes proposals to reconfigure these structures to support project objectives.

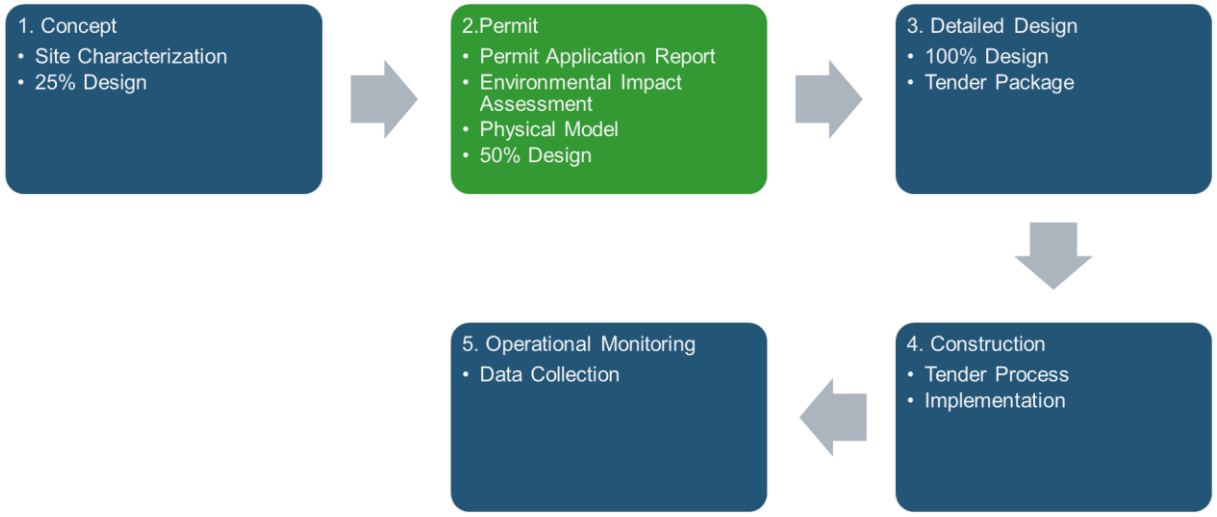


Figure 3.1: Project roadmap

3.1 Artificial Reefs (Breakwaters)

Boulder breakwaters will be placed in the reef flat or reef crest zone. The structures reduce water depth at specific location and triggers wave breaking before reaching the shore, creating calmer conditions in the sub-

tidal zone and at the shoreline and improving beach stability. This is illustrated in Figure 3.2. The orientation, location, dimensions, and boulder properties of each breakwater are determined based on the marine habitat, bathymetry, wave climate and performance needs. The boulder matrix creates interstitial voids and are suitable habitat for many marine species. The boulders provide hard surfaces for coral recruitment. The crest of the boulder structure is maintained at or close to mean sea level to minimize the aesthetic influence and maintain the vista. An example of an existing boulder breakwater on the west coast of Barbados and a typical cross section for our breakwaters are shown in Figure 3.3. There are three proposed breakwaters labelled AR1, AR2 and AR3. Each offshore reef will be equipped with navigation lights allowing users to locate the structures in poor conditions of poor visibility. Preliminary locations and dimensions are shown in the drawings in Appendix D.

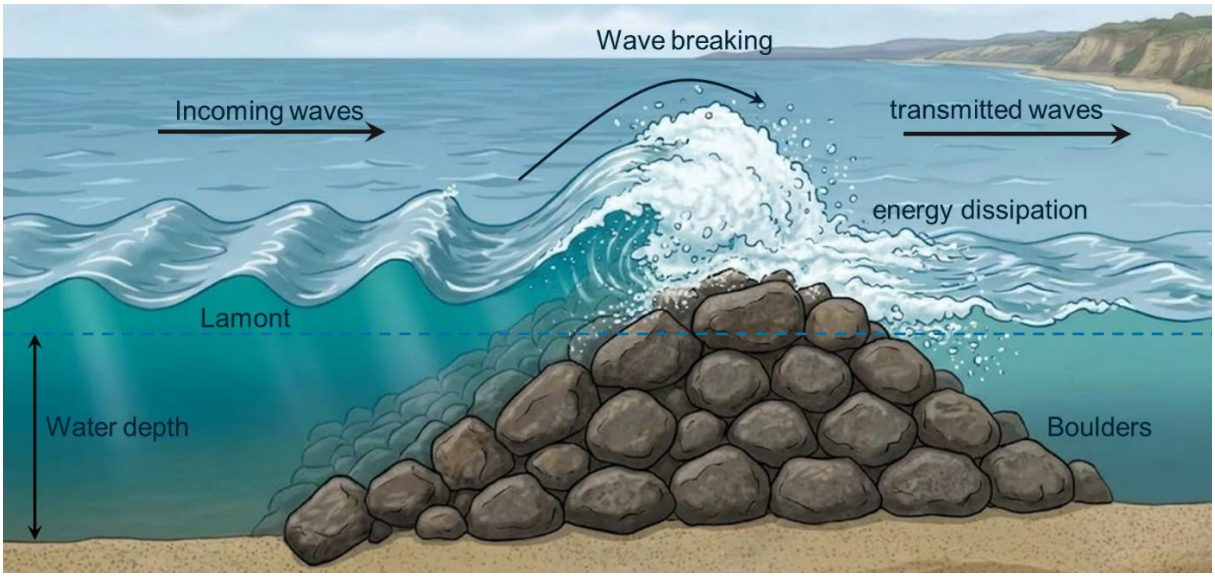


Figure 3.2: Breakwater energy dissipation

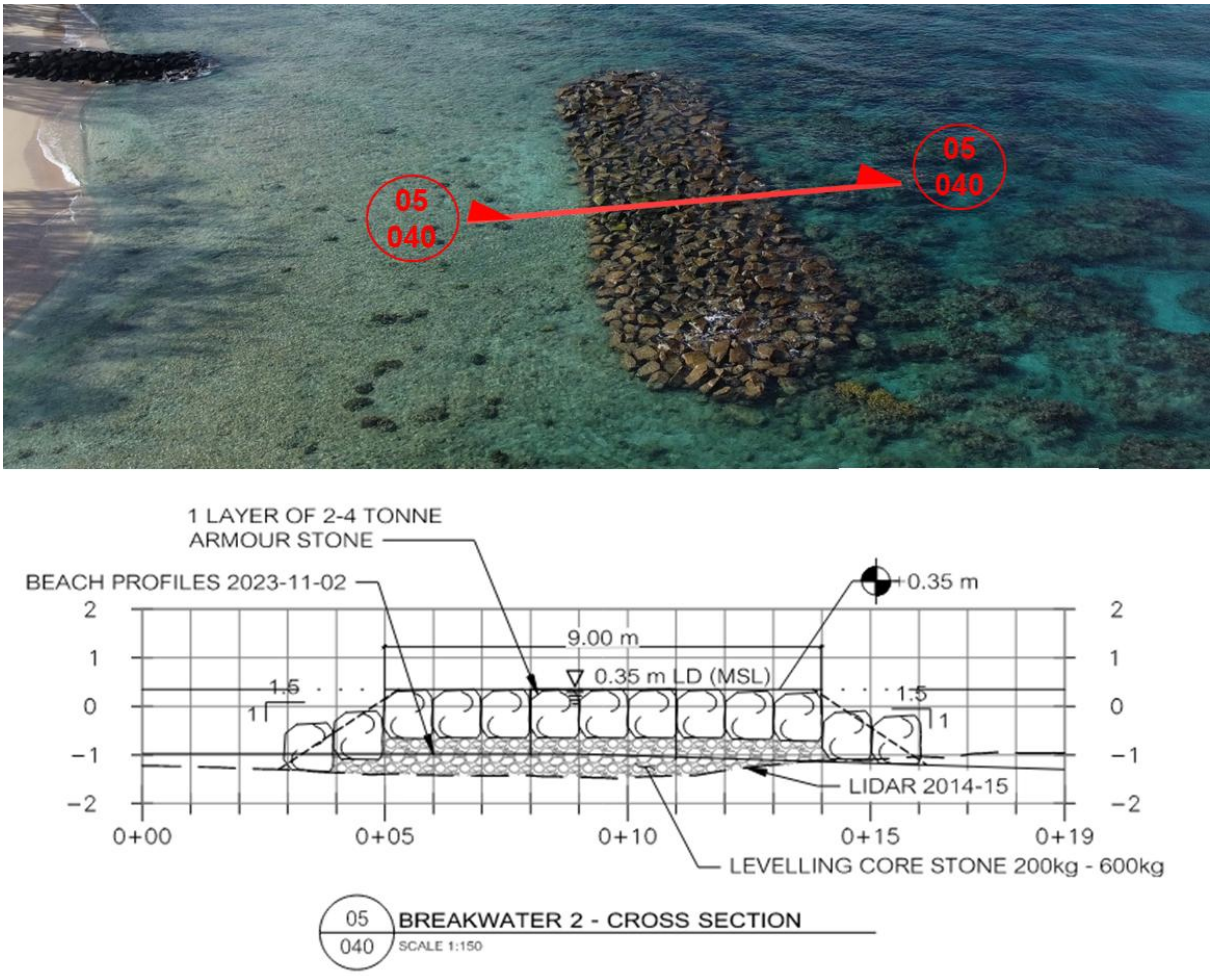


Figure 3.3: Typical cross-section (top), completed breakwater (bottom)

3.2 Groynes

Flow through boulder groynes are semi-permeable sediment barriers that regulate sand movement and stabilize the shoreline. The groynes are positioned perpendicular to the shoreline and extend from the land end of the dry beach to the reef flat zone. The dimensions, locations, and orientation are based on the performance requirements for the beach, the orientation of the shoreline and for lateral access along the beach. An example of an existing groyne on the west coast of Barbados is shown in Figure 3.3 and the conceptual cross section for the proposed groynes is shown in Figure 3.5. Groynes reduce sand movement but do not eliminate it completely, which mitigates downdrift impact concerns. There is an access point placed at the landward end each groyne with concrete steps. These steps are buried when the beach elevation matches the groyne elevation and aid lateral access when the beach elevation fluctuates and become less than the groyne elevation. There are seven proposed groynes arrayed along shoreline.



Figure 3.4: Completed groyne

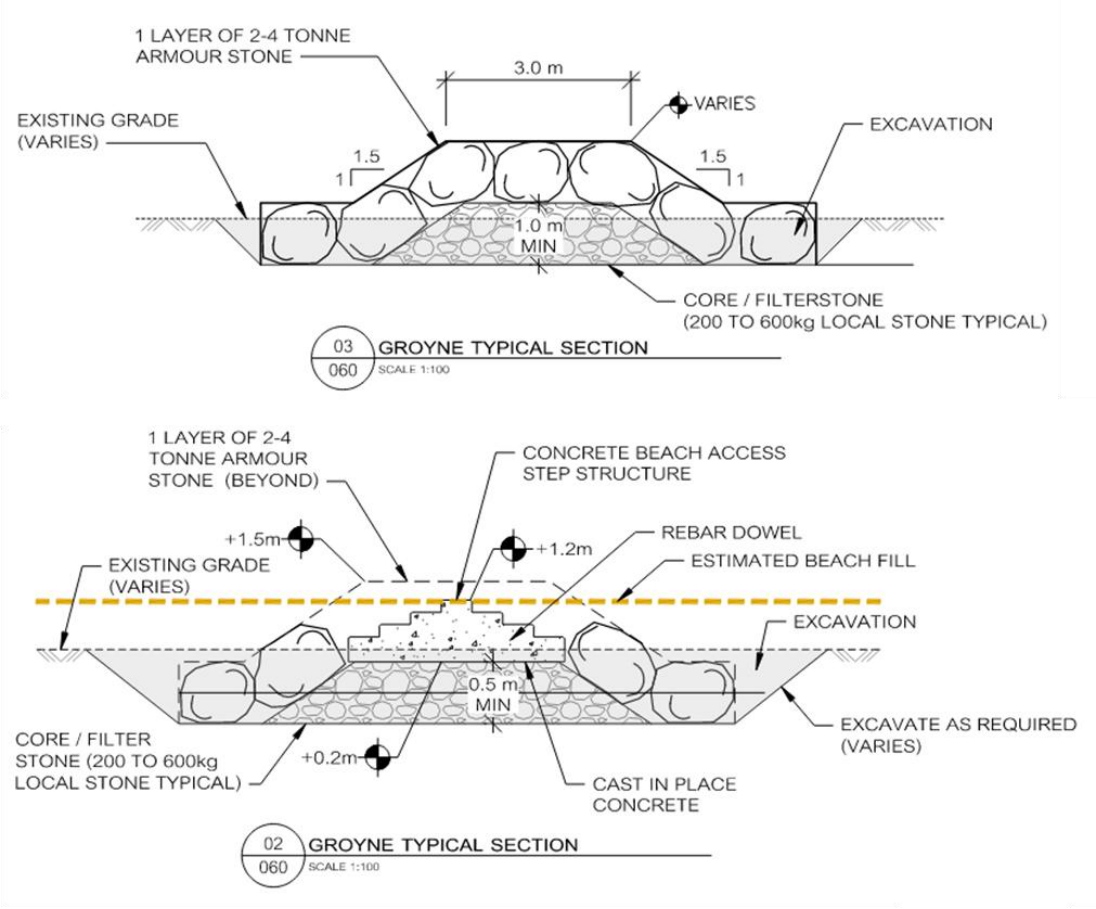


Figure 3.5: Typical sections through groyne

3.3 Beach Nourishment

Beach nourishment is a requirement of almost all coastal projects in Barbados, especially those on the west coast where there is a regional sand deficit. The beach is visible and is the first point of contact for most users. It is a critical part of the project's user experience, the habitat creation and wave dissipation capacity. Beach nourishment benefits the project in the following ways:

- The nourishment satisfies the sand demand created by the proposed structures and adjacent existing beach areas. This minimizes the risk of sand deficit impacts to neighbour beaches.
- The wider beaches attenuate more wave energy than impermeable surfaces.
- Beach nourishment creates lateral access.
- Beach nourishment creates habitat for species that burrow or nest on the beach.
- The beach area facilitates user activities.

Beach dimensions and particle properties influence beach performance and appearance. This includes beach width, crest elevation, particle size distribution, colour, density, angularity and chemical composition. These are chosen based on all the criteria previously discussed. These parameters are chosen based on similarity to the existing beach conditions, sea level rise and performance requirements. The preferred option is to use native

sand harvested in the marine environment or sand with comparable physical, chemical and aesthetic properties. Nourished sand is often selected with a particle size and density larger than that of the native sand. This increases beach stability but must also be balanced with maintaining texture and performance suitable for users and resident species. The beach width and slope influence the point at which wave breaking and energy dissipation occurs along the profile, as illustrated Figure 3.6. Wider beaches offer greater stability; more sand available in the budget and more protection from extreme wave attack.

An example of the proposed beach profile at a west coast location 3 km north of the study area is shown in Figure 3.7. The crest elevation is +1.2 m and the additional crest with is 3 m. The profile then slopes down to the sub-tidal zone at 1:8. This is a slope of ~7° to horizontal.

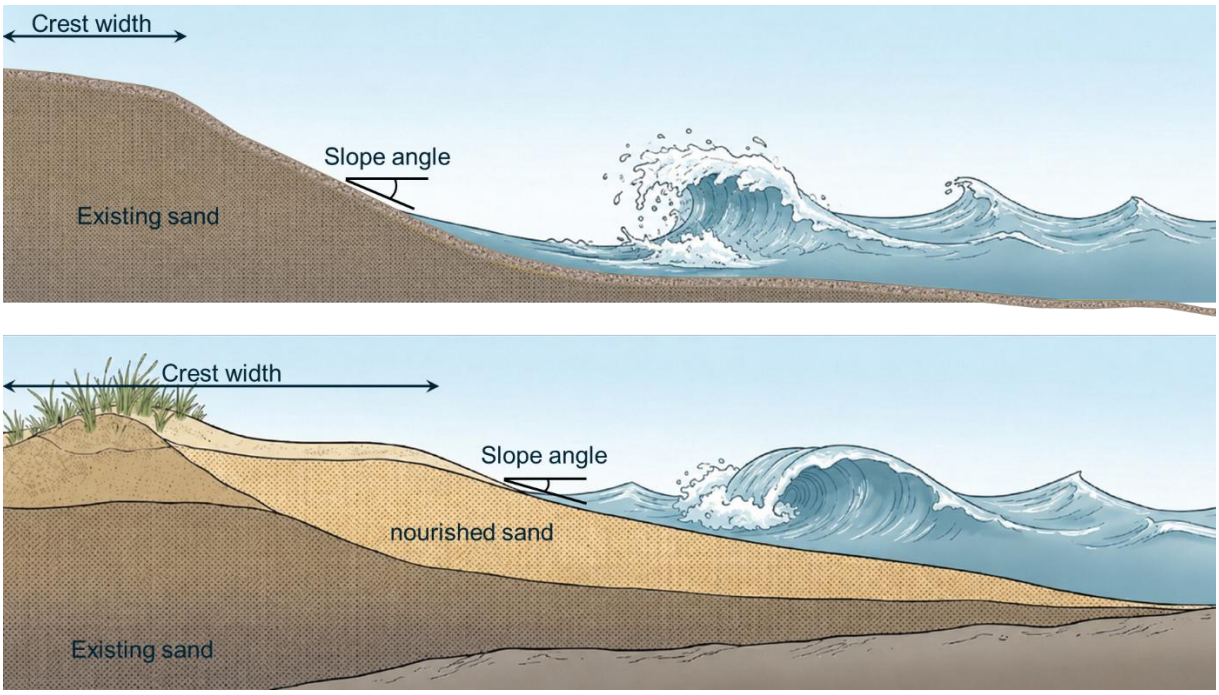


Figure 3.6: Depleted beach profile (top) and replenished beach profile (bottom)



Figure 3.7: Completed sand nourishment

3.4 Existing Structures

There are existing impermeable structures such as vertical walls and staircases along the shoreline that. reflect wave energy as opposed to dissipating it. Examples of reflective surfaces on the shoreline are shown in Figure 3.8. Wave reflection accelerates erosion and reduces beach stability. Beach stabilization requires reduced wave reflection at the shoreline, perhaps through the addition of permeable surfaces, removal of impermeable surfaces or combinations of both.



Figure 3.8: Reflective surfaces on the shoreline

3.5 Proposed Concept

The project concept uses each of the improvements discussed above. The chosen concept, shown in Figure 3.9, supports the design objectives and avoids the sensitive habitat offshore while focusing on the relatively barren reef flat zone. It reduces the energy along the 500 m long headland and creates pedestrian access between Sandy Lane Bay to the north and Paynes Bay to the south. There are multiple existing structures that are proposed for reconfiguration. Redesign of these features will improve the beach stability and the user experience on the shoreline. This concept will be developed during detailed engineering. The detailed design will incorporate the information from the permit application process and specifically the environmental impact assessment. The breakwaters, or artificial reefs (AR), are labelled AR 1 to 3. The groynes are labelled G1 to G7. Updated drawings are attached in Appendix 0, including the masterplan, footprint coordinates and typical cross-sections for the artificial reefs, groynes and beach nourishment.

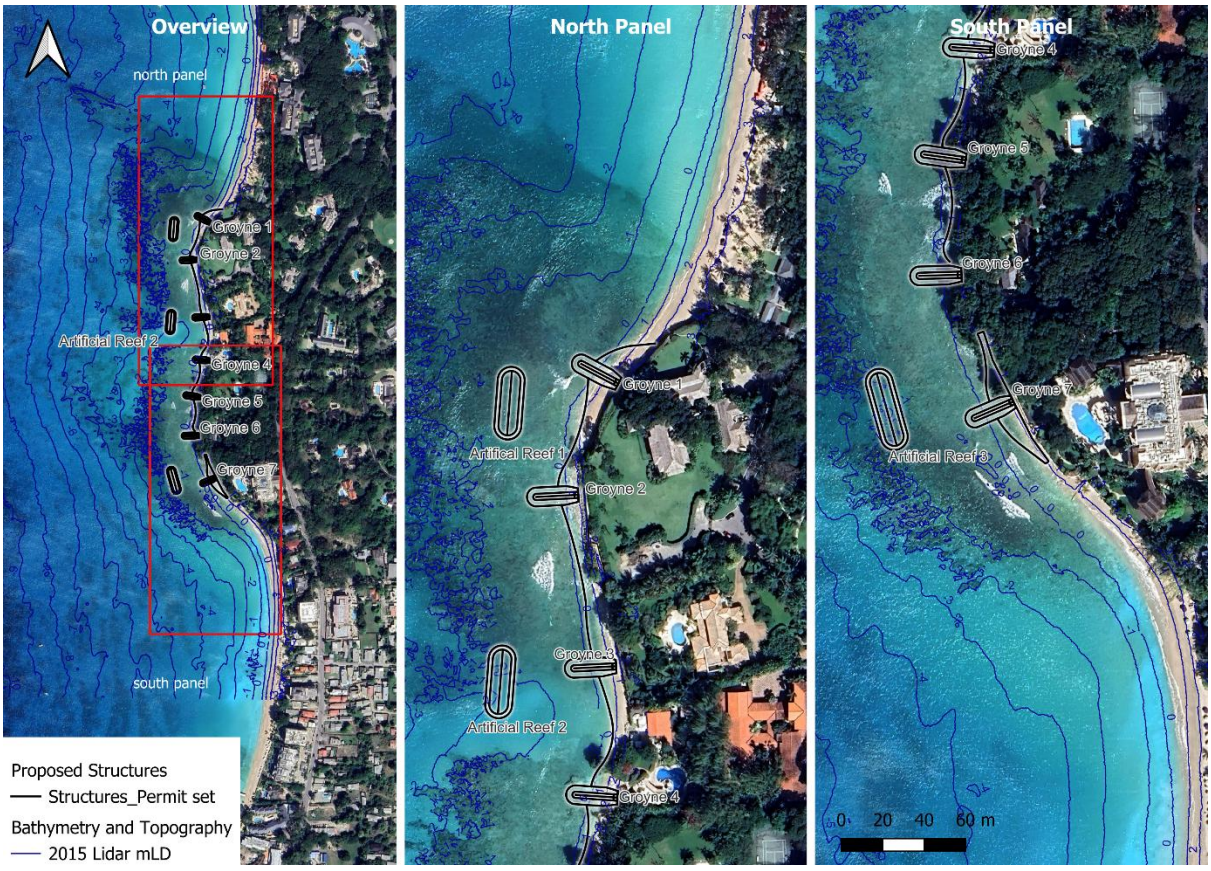


Figure 3.9: Proposed beach enhancement concept

3.5.1 Quantities

The proposed concept includes 11 new structures comprised of boulders and sand. The quantities are shown in Table 3.1 and are taken from the permit application drawings in Appendix D. The project requires 8800 tonnes of stone and 6000 tonnes of sand.

Table 3.1: Preliminary quantities

ID	Structure	Item	Quantity	Unit
1	AR1	Armour Stone	900	tonnes
2		Core Stone	100	tonnes
3	AR2	Armour Stone	900	tonnes
4		Core Stone	500	tonnes
5	AR3	Armour Stone	1400	tonnes
6		Core Stone	300	tonnes
7	G1 to G7	Armour Stone	3200	tonnes
8		Core Stone	1500	tonnes
	Sub-total boulders		8800	tonnes
9	Beach Nourishment	Sand	6500	tonnes
	Total		**15300**	**tonnes**

4. Impacts

4.1 Beach Morphology

Beach erosion, which consists of the loss of large volumes of sand from the nearshore zone, has been a national issue in Barbados for the last two decades, as it has been for most Caribbean territories. Changes in beach width and shoreline location are more easily measured than beach volume and are used as indicators of erosion. Section 2.1 Beach Morphology proposed an indicative rate of 0.18 m of beach width lost per year.

Estimating changes in sand volume and morphological impacts to the beach is complex. Beach erosion is caused by myriads of underlying connected processes that act over varied spatial and temporal scales. Sea level rise, reef health, urbanization and tropical cyclones all drive changes in beach volume on the west coast of Barbados and in the study area. Coastal Hazards Chapter 13, Beach Erosion: Causes and Stabilization discusses these drivers based on the beach morphology observed in Florida USA [22].

The proposed design includes hard structures that will retain larger volumes of sand in dry beach and tidal zones in the project area. The design will nourish the areas along the shoreline and between the boulder structures with enough sand to exceed their retention capacity. This avoids sequestering native sand on the shoreline and instead adds more sand volume to the system. Placing excess nourishment has been successfully implemented at locations along the west and south coast of Barbados over the last decade. It offers an on-demand reserve on the shoreline in the event of erosion and allows a larger buffer before erosion causes beach functions to be impacted. The proposed concept includes 6500 metric tonnes of beach sand to be retained by the structures and kept in reserve for continued sediment transport to adjoining areas.

The crest elevation is +1.2 m LD, the beach width increase is 5 m and the beach slope is 1v to 8h. The beach toe is at an average depth -1 m LD. These dimensions are indicative; day to day measured dimensions are dynamic and will fluctuate seasonally.

The boulder structures and the sand will change the hydrodynamic processes in the area. The beaches will be exposed to less wave energy and will be able to dissipate more wave energy. Sand loss will continue at a reduced rate compared to that without the protective structures. Extreme waves may still move sand offshore to unretrievable locations, but less frequently and at a slower rate than today.

Increased sand volume in the study area will not eliminate the overarching sand deficit along the west coast of Barbados. This sand deficit is expected to continue and incrementally erode the nourished sand. This adjacent sand deficit also means that as healthy beaches typically involve a redistribution of sand along the shoreline, this will involve more loss than gain of sand for the study area, since adjacent areas have little sand available.

The design includes periodic sand renourishment. The quantity and frequency of renourishment is based on the estimated erosion rate estimated from the available data. The long-term average change in beach width over the 37-year data set is 0.18 m/year. Applied to the design dimensions with 25% contingency this results in 300 m^3 of sand along the 550 m project shoreline each year. Assuming renourishment at 10-year intervals (following an average 1.8 m loss of beach width) we estimate 3000 m^3 or 4500 tonnes per decade.

4.2 Infrastructure

Engineered coastal structures are frequently used in Barbados. Coastal structures are the primary method of creating the desired outcomes for this project since they provide the protection required to retain sand more effectively. The existing shoreline infrastructure is a composite patch work of hard surfaces installed

incrementally by individual properties. This was often in response to specific issues observed at that property over the short term and not necessarily based on the stability or utility of the entire coastal cell extending from Sandy Lane Bay to Paynes Bay. Many of the walls and stairs were installed in the dry beach zone, which has been eroded and transitioned to the tidal zone. The structures are not functional and are not designed for exposure to wave energy and tidal cycles. These structures dissipate minimal wave energy and together act as hard reflective shoreline on an exposed headland. This is detailed in the section 2.2 Infrastructure above.

The owners of Lot 7 have reported that pedestrians moving along the shoreline have been trapped in the tidal zone in front of their property. This is likely due to rising tide during the walk along the 500 m of shoreline of which Lot 7 is at the halfway point and offers more beach area than the adjacent properties. The owners of Lot 7 have offered trapped pedestrians access to their property to leave the shoreline safely. This is an example of the demand for lateral access which correlates with beach user survey data reported in the Social Impact Assessment.

The proposed design will add new boulder and sand structures, will reduce the reflective surfaces on the shoreline and will restore access on the shoreline. The features in the dry beach, tidal and sub-tidal zones will be purpose built for the wave climate and to allow continual sand transport through the study area. Stairs to private properties and the transition to public access will be integrated into dry beach zone to accommodate fluctuations in sand volume. Refer to section 3 Proposed Improvements for further details on the proposed structures.

4.3 Waves, Currents, and Water Levels

Localized nearshore changes to the wave climate are expected to be limited to the locations that are sheltered by the three artificial reefs. The intent of the artificial reefs is to transform of incoming waves and dissipate wave energy offshore. The modelled wave climate was used to simulate representative scenarios with existing conditions and then with the proposed structures installed. Performance parameters were then compared to estimate the impact on the wave climate.

The design water levels were based on storm setup, high tide, and sea level rise (SLR). M21SW model coupled with the MIKE21 Flexible Mesh hydrodynamic model (M21FM) were used to model sample hurricanes and generate extreme wave setup. The 10-year, 25-year, and 50-year design storms were selected to represent smaller and larger wave events with the 50-year event being more southerly while the 10-year and 25-year events being more northerly. The modelled storm surge includes atmospheric pressure, wind, and wave setup. The water level was modelled at a high-tide level of 0.66 m LD (MHHW), and an allowance for SLR of 0.20 m, resulting in a base water elevation of 0.85 m LD. The model was run with each storm's corresponding wind/pressure field timeseries with surge and setup superimposed. The minimum air pressure and maximum wind speeds for the 10-, 25-, and 50-year storms were 1006 hPa and 21.4 m/s, 998 hPA and 21.2 m/s, and 1004 hPa and 32.8 m/s, respectively.

Representatives of the offshore hurricane wave and surge values were selected from recent wave climate studies Baird has done on the west coast. Offshore waves were transformed to nearshore using M21SW to establish typical design conditions at the locations of the structures. Offshore maximum significant wave heights and peak wave periods applied at the model boundary for the 10-year, 25-year, and 50-year storms were Hs = 4.6m (Tp = 8.9s), Hs = 7.2m (Tp = 10.6s), and Hs = 15.1m (Tp = 15.6s), respectively. The structures are in water depths ranging from 0.5 to 1.7 m. These shallow water depths limit the maximum wave height that can occur at the structure. There is a risk of seabed scour causing an increase in water depth and in turn wave height during extreme conditions. The 2015 benthic classification map shows the artificial reefs are founded on reef flat substrate. Seabed sand deposits are expected be laminar and underlaid by hard pavement with limited potential for scour. Sub-surface conditions may have changed considerably since 2015.

Sub-surface investigations were not included in this scope. We assumed hard substrate without scour for this modelling effort. Figure 4.1 and Figure 4.2 show the impact the proposed structures will have on the wave heights during a 25-year storm with water levels at MHHW and MHHW with SLR, respectively. The proposed structures will not impact on the surf breaks which are depicted by the dashed polygons.

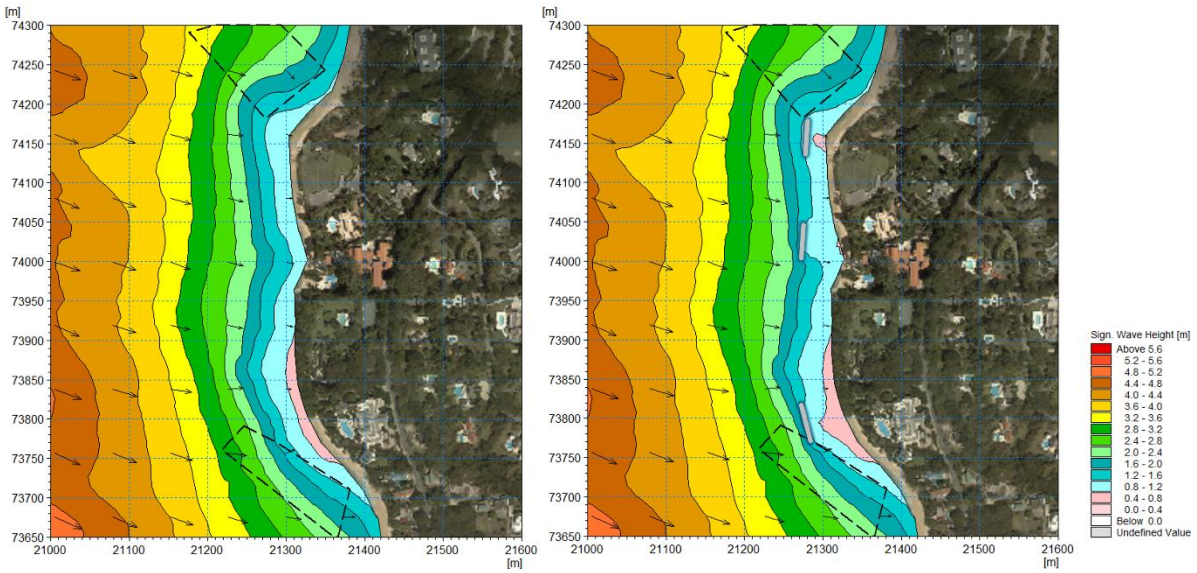


Figure 4.1: Simulated wave heights for existing (left) and design (right) conditions for the 25-year storm at MHHW with dashed surf breaks

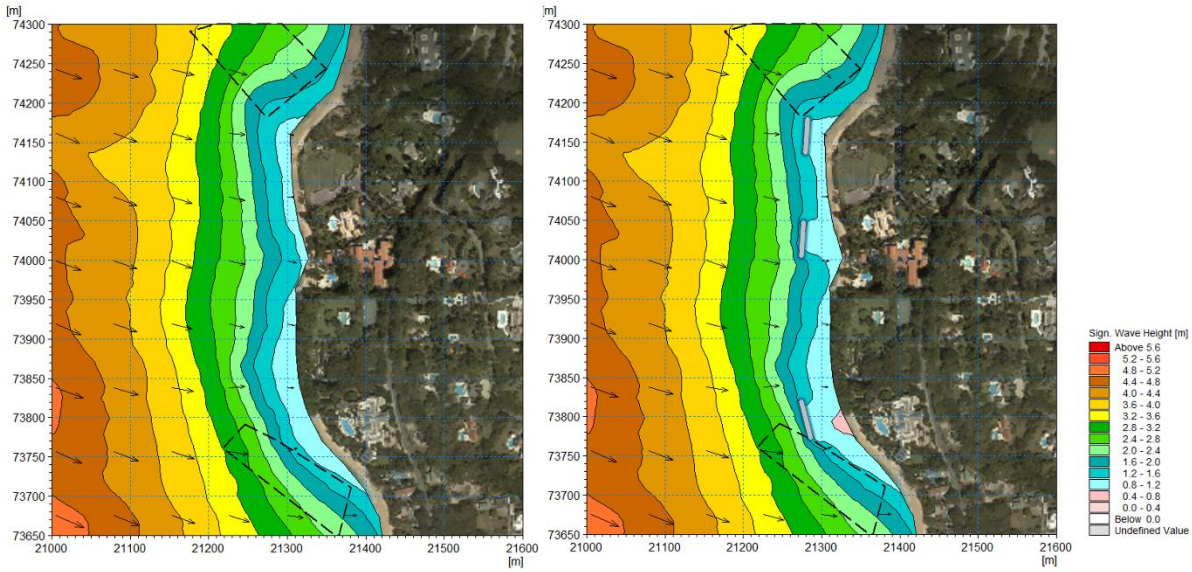


Figure 4.2: Simulated wave heights for existing (left) and design (right) conditions for the 25-year storm at MHHW plus SLR with dashed surf breaks

The modelling results indicate that the breakwaters reduce the wave height by approximately 30 percent at the locations marked by a red ‘x’ in Figure 4.3. The difference in water level is negligible between existing and proposed conditions at these locations.

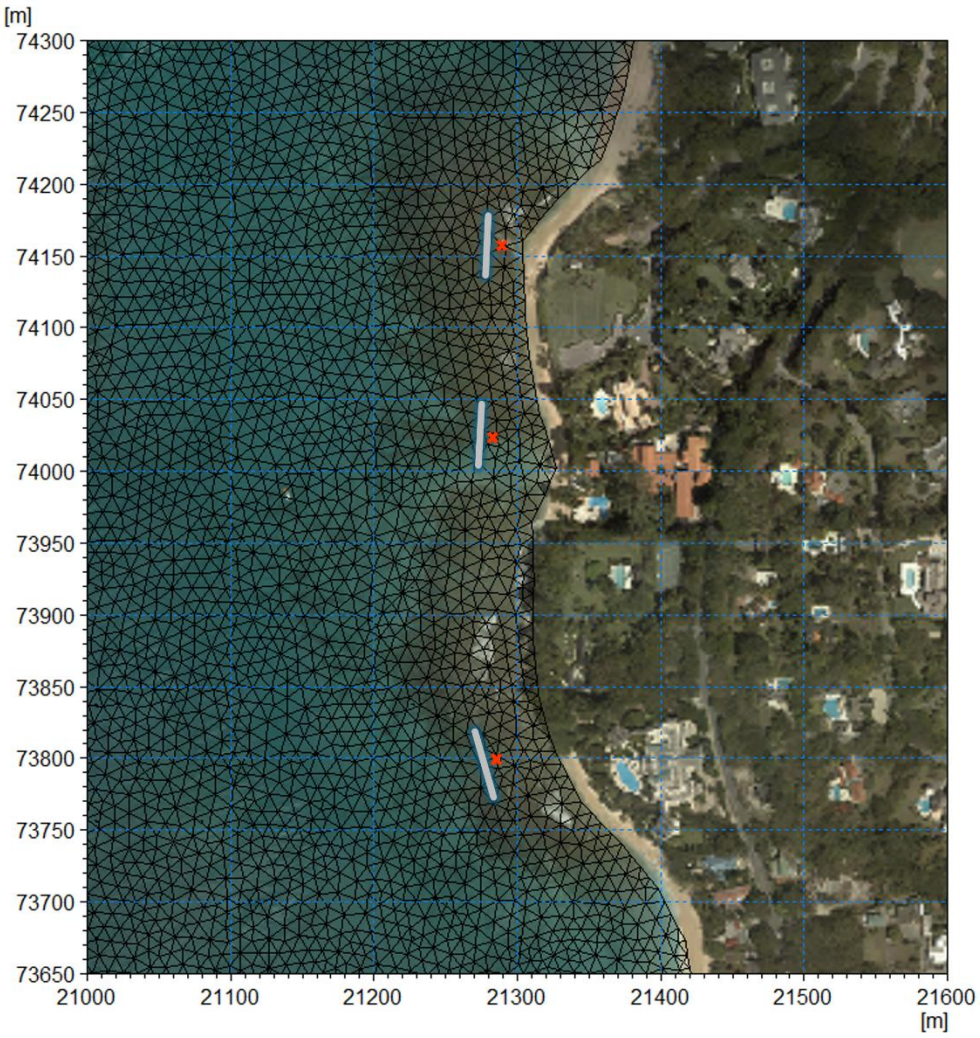


Figure 4.3: Wave height model extraction point locations

Based on previous experience with similar shallow structures (all in less than 2 m of water) the currents in the vicinity of the structures will not create dangerous swimming conditions except during significant swell wave events at which time all beaches should be closed. The movement of water inshore of the submerged structures is also considered to be adequate for flushing and maintaining ambient water quality comparable with adjacent areas.

4.3.1 Surfing

Reducing nearshore wave energy is a project objective. There is a risk of reduced wave energy at the surf break changing the user experience. To assess this risk, we mapped out the surf breaks and compared it to the proposed design footprint and modelled wave climate. The Barbados Surfers Association and a Paynes Bay surf instructor have provided GPS coordinates demarcating the start and end points of the surf break. There are multiple start and endpoints for the surf break, which vary with the wave direction, wave height and tide, which have been used to create footprints of the two surf breaks. The direction of travel is estimated by the relative locations of the matching start and endpoints. The fitness tracking and social media platform Strava

has published a surfing heatmap on its website. The global map shows the areas used by its users for surfing and shows concentrated activity in the polygon of the Sandy Lane surf break [12]. The surf break information is shown with the design footprint in Figure 4.4.

The Sandy Lane surf break is to the north of the proposed design and 6 m away from AR1. This is a left break and moves surfers to the northeast of their start point with minimal risk of interacting with of AR1 while surfing [11]. The local surfers advised that the corner closest to AR1 is not used during low tide because of the existing high-profile pavement and limited freeboard. Bathymetry in the AR1 footprint ranges from -0.6 m LD to -0.9 m LD, which translates to a freeboard range between 0.3 m to 0.6 m at low tide. The incoming waves used to surf in the direction of the arrow are not expected to be influenced by AR1. The AR1 location is an impact hazard and is known to the surfing community based on their avoidance of that location during low tide. It is unlikely to be used for surfing. We do not expect the proposed structure to change the performance of the waves at the Sandy Lane break because those waves do not interact with AR1 before they move to the shoreline. The 6 m clearance between the break and AR1 is limited and requires further investigation.

The Paynes Bay surf break is to the south of the proposed design and 2 m away from artificial reef 3. This is a right break which moves surfers to the southeast away from the proposed structures. The bathymetry in AR3 footprint ranges from -0.7 m LD to -1.7 m LD, which translates to a freeboard range between 0.4 m and 1.4 m during low tide. This clearance between the Paynes Bay Break and AR3 is less than ideal; however, the definition of the surfing breaks in approximate and this is near the edge of the identified area rather than in the middle. AR3 is landward of the start point of the break. Waves and surfers will travel adjacent to it as they progress towards the shoreline. These factors present an increased risk of AR3 changing wave performance inside the surf break and an increased risk of surfers interacting with AR3 while using the Paynes Bay surf break. The clearance between the breakwater and A3 is inadequate and requires further investigation.

The design team will evaluate minor realignment of AR1 and AR3 at the detailed design stage. The intent will be to reduce the risk of impact to the identified surf breaks. Realignment of the structures can also be considered in the context of the design objectives and how they are impacted by the adjustments.

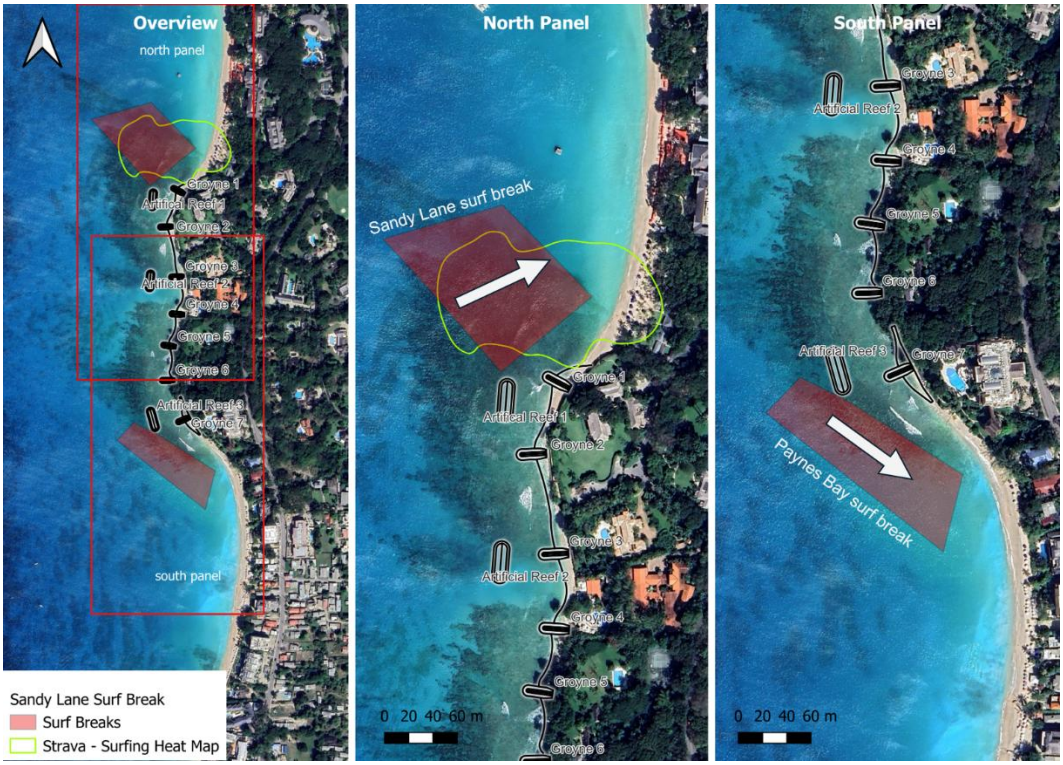


Figure 4.4: Map of surf breaks and proposed design footprint

4.4 Ecology

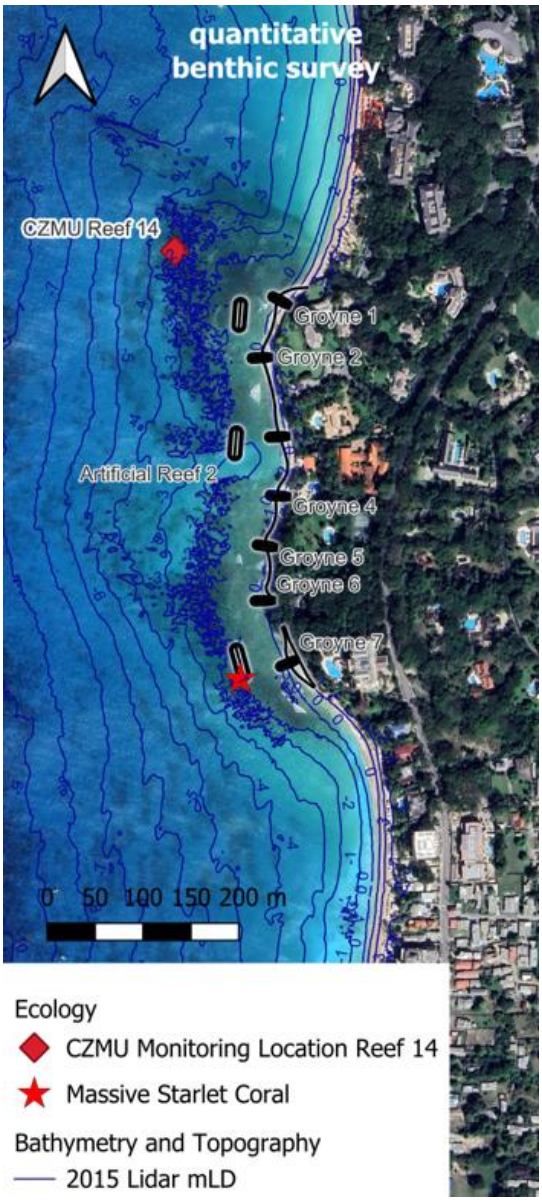


Figure 4.5: Quantitative benthic survey map

4.4.1 Habitat and Species

There is extensive habitat degradation and low species abundance in the study area. Hawk's bill turtle nests, reef building hard corals and sea urchins are all in decline. The distressed existing condition reduces the potential negative impacts on the already limited biota and increases the potential benefit of creating new habitat opportunities. Most of the available research explores negative impacts of engineered interventions on viable habitat [18] [19] [23] [24]. Less research explores the positive impacts of interventions on deteriorated habitat.

These interventions will occur in the dry beach, tidal, sub-tidal, reef flat and reef crest zones. The groynes and artificial reefs will impact the flora and fauna over an area limited to the proposed footprint and an immediate surrounding buffer. The size of the buffer is an open discussion in literature and is dependent on wave and current conditions. Existing habitat and resident species in the footprint will be altered, although often in a positive manner. The boulder structures are proposed in barren locations and can introduce diversity of substrate to the area. These selected areas typically have low reef cover and low species abundance to minimize potential adverse impacts. The existing habitat and species in the footprints are discussed in section 2.4.2.

The impact of beach nourishment on the flora and fauna occurs in the footprint and beyond it. The footprint of the proposed beach nourishment is limited to the tidal and subtidal zone and excludes the offshore zones. The abundance of resident species is expected to temporarily decline in the project area during intervention and directly after. Research from North Carolina in 2013 and 2014, Netherlands in 2001 and 2012, New Jersey in 2001 all found temporary declines in abundance of various types of invertebrate species resident in the footprint at the time of nourishment [24]. This included species of donax, amphipods and polychaete. The research also found that the abundance of these species recovered 1 to 4 years after nourishment.

Beach nourishment causes temporary increases in turbidity. The intensity, duration, and extent of the turbidity depend on sediment composition, wave climate and placement method. Turbidity reduces sunlight penetration and visibility in the water column. Less light and visibility are available for marine species. This limits coral growth and impedes feeding and navigation of benthic species [19]. Coral cover under and in proximity to the beach nourishment is minimal or zero. This area has historically been a beach and is subject to the natural variation in the beach width. The expected widening of the beach will be in line with recent beach fluctuations and historical coverage.

Mitigation through placement methods is discussed in section 6 Monitoring & Mitigation. Washing the sand before nourishment reduces the intensity turbidity during placement. Containment barriers surrounding the footprint the extent of the turbidity plume. These methods are also used for boulder products. Examples of beach nourishment turbidity are shown in Figure 4.6.

Beach nourishment increased the potential for sedimentation. Sand may be transported offshore and deposited on the reef pavement. This is most prevalent during energetic wave conditions such as storm and north swells. Sedimentation smothers coral colonies, covers hard pavement, inhibits coral recruitment and disrupts benthic species [19] [23]. However, this will only occur if sedimentation is of sufficient magnitude and duration; short periods of sedimentation are a natural occurrence where sediment is moved by waves. An example of sedimentation at Sandy Lane reef is shown in Figure 4.7; this is believed to have occurred through natural processes as construction was not ongoing in the vicinity at the time of these photographs.

Placement methods are important at the construction stage for limiting the extent and intensity of the impact on habitat and species. The proposed design reduces impact by locating the nourishment in the dry beach, tidal and sub-tidal zones. The areas have limited habitat coverage and low species abundance. This is discussed in section 2.4.2. The proposed nourishment is integrated with a system of boulder structures that modify the wave climate and regulate sediment movement. This limits offshore migration of sediment to reef pavement with greater ecological value.



Figure 4.6: Beach nourishment turbidity



Figure 4.7: Sedimentation on reef platforms

4.4.2 Hawksbill Sea Turtles

The dry beach zone is absent throughout most of the study area. The tidal zone transitions directly into the private properties and green spaces inland of the beach. The dry beach zone is discussed in section 2.3 and is the nesting habitat for the hawksbill turtle nests. Hawksbills and their nests are protected by legislation in Barbados and in the USA [25] [26]. They are critically endangered and are protected by international organizations and agreements including the UN Convention on International Trade in Endangered Species of Wild Fauna and Flora CITES and the UN Specially Protected Areas and Wildlife protocol SPAW [27], [28]. Hawksbill turtles in Barbados nest in the dry beach zone of low wave energy climates, in unconsolidated sand, near vegetation, at a mean elevation of approximately +1.5 m LD and set back a mean horizontal distance of approximately 8 m inland from the high-water mark [29]. These are general characteristics of nesting habits. A range of nesting locations will occur, especially in marginal habitat.

Similar conditions existed in the project area prior to 2016 but have since changed. The Barbados Sea turtle project has recorded less turtle nesting in the study area in the last ten years (2016 – 2026) in comparison with the preceding ten years. This is partially due to the reduction of the dry beach area. It is also affected by the lack of pedestrian access for the turtle rescue teams. The increased use of mechanical cleaning equipment on the beach disturbs signs of turtle activity, making identification of the nests more challenging[1].

[1] This information is from email correspondence between Baird & Associates and a representative of the Barbados Sea Turtle Project.

The proposed design will create conditions more suitable for hawksbill turtle nesting. The re-instatement of the dry beach will offer improved nesting opportunities. Specifically, the increase in beach width, crest elevation and wave sheltering have been correlated with more successful turtle nesting in Barbados [13] [29].

Hard structures and sand nourishment, in the dry beach zone, present risks to hawksbill turtles and their nests. Groynes form barriers to lateral sea turtle movement on the beach. The sudden change in sand elevation and the voids between the boulders are hazards for turtles. Nests close to hard structures may experience changes in temperature, moisture content and depth which may impact the success rate of turtle nesting [30]. However, the proposed structures include flow-through groynes, which typically do not have large changes in elevation and have fewer deep openings between structures. The structures also tend to stabilize the beach and should lessen the potential for nests to become exposed during an erosion event. These factors should mitigate the potential adverse impacts in a region that is seeing fewer successful nesting activities.

The mechanical properties of the sand particles also impact nests and hatchlings. The density, size, shape and chemical composition of the proposed sand particles influence the nesting success rate. Similar mechanical properties to the native sand, that previously constituted the beach, create more favourable conditions while divergent mechanical properties create less favourable conditions [30].

Recommendations for beach habitat favourable to hawksbill turtle nesting in Barbados and beyond are published and readily available [13] [26] [29] [30]. These include:

- Increased coastal vegetation such as sea grape coccoloba uvifera and goat's foot yam Ipomoea pes-caprae
- Using naturally occurring marine sand as opposed mechanically processed sand.
- Less hard structures.
- Creating beach widths with adequate threshold elevations and horizontal distances from the waterline.
- Developing calmer wave climates at the shoreline
- Allowing for pedestrian access for turtle conservation.

These recommendations have been considered in the concept design and will be carried through to the detailed design phase of the project. Hard structures are necessary as a replacement for the hard reef framework that previously sheltered the shoreline from wave energy. There are opportunities to modify the design, maximize the dry beach area and include coastal vegetation. Pedestrian access and calmer wave conditions are design objective and suitable for turtle nesting.

There are trade-offs that must be considered. From the perspective of turtle nesting, a much wider beach with vegetation would be preferred. However, this may not be ideal for marine species that may have habitat close to the shoreline. A balanced approach that considers many different aspects must be achieved.

4.4.3 Coral Coverage in Project Area

For each structure in the tidal and sub-tidal zones we characterized the benthic habitat by determining percentage mean coral reef cover. This is an expression of how much of the footprint surface area is occupied by coral reef. The data were recorded in photo-quadrats taken along transects in each footprint. We used Coral Points Count with excel extension (CPCe) processing software to scan the image, classify substrates and use the random point count method to determine the percentage mean coral cover. Collection and processing of the photo quadrat is discussed in greater detail in the ecology survey report for 2026 [4] and the CPCe processing software is detailed in a journal article [31].

The mean coral cover for each of the proposed structures is listed in Table 4.1. The highest coral cover is 2% at groyne 2 and the lowest coral cover is 0.17% at groyne 6 with an average per structure coverage 0.82%. This is below the 10% threshold value for continued accretion of reef framework [32]. Artificial Reef 3 AR3 is encroaching on a mature colony of massive starlet coral (siderastrea siderea) shown in Figure 4.8. Despite the overall low coverage, this colony is significant. AR3 will be re-oriented in detailed design avoid encroaching on the coral colony.

The three boulder structures in the reef flat zone will create new opportunities for marine habitat. Similar structures in comparable locations along the west coast have recruited coral colonies and attracted marine species. There are two breakwaters 500 m north of our location at Holetown that were designed by Baird and installed in 2015. We surveyed the structures in 2021 and found coral colonies and various fish species distributed across the breakwaters. This was previously sand substrate with no hard framework. An overview of the location and images of the coral colonies are shown in Figure 4.9, Figure 4.10 and Figure 4.11. This is an example of an engineered increase in habitat coverage and species abundance in a comparable condition close to the study area.

Table 4.1: Coral occurrence and mean percentage cover February 2026

Structure	No. of Quadrats	Total no. of Coral Points	No. of Coral Colonies	No. of Quadrats with Corals	Mean % Coral Cover
Artificial Reef 1	37	25	53	26	1.35
Artificial Reef 2	38	13	33	13	0.68
Test Site[2]	48	12	36	18	0.50
Artificial Reef 3	36	31	41	19	1.72
Groyne 1	8	4	11	5	1.00
Groyne 2	10	10	34	6	2.00
Groyne 3	10	1	2	2	0.20
Groyne 4	9	2	6	3	0.44
Groyne 5	13	4	5	4	0.62
Groyne 6	12	1	4	2	0.17
Groyne 7	12	2	5	3	0.33
Total	**233**	**105**	**230**	**101**	**0.82[3]**

[2] At the time of this report there is not structure proposed for this location. This location improved data coverage in a critical area.
[3] This value is an average as opposed to a total.

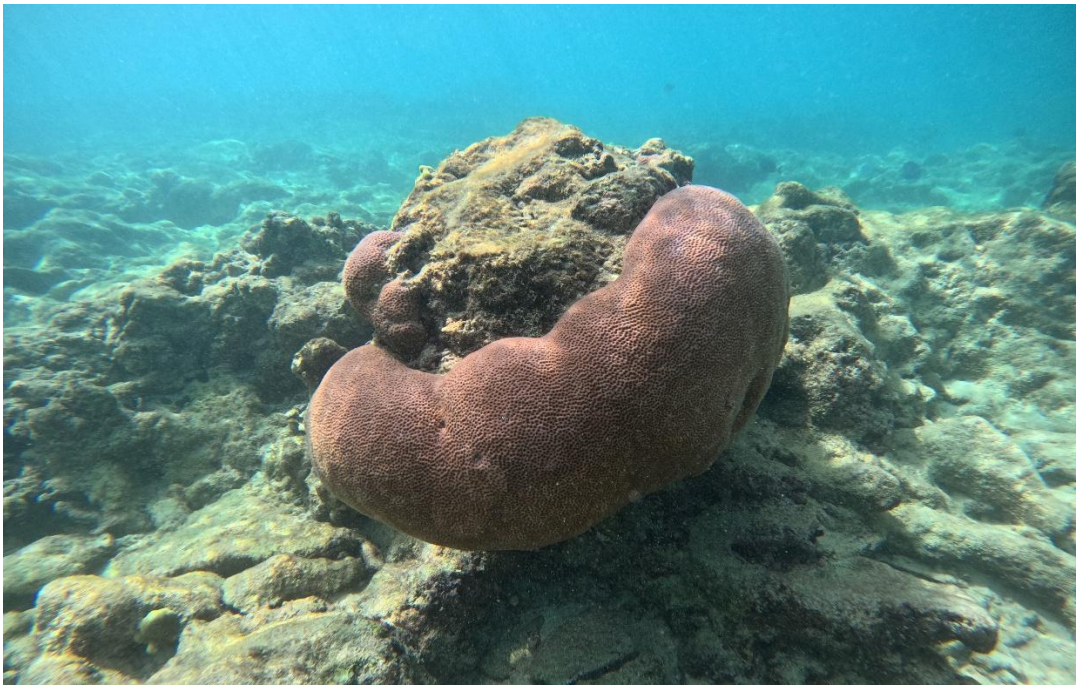


Figure 4.8: Massive starlet coral (siderastrea siderea) in AR3 footprint

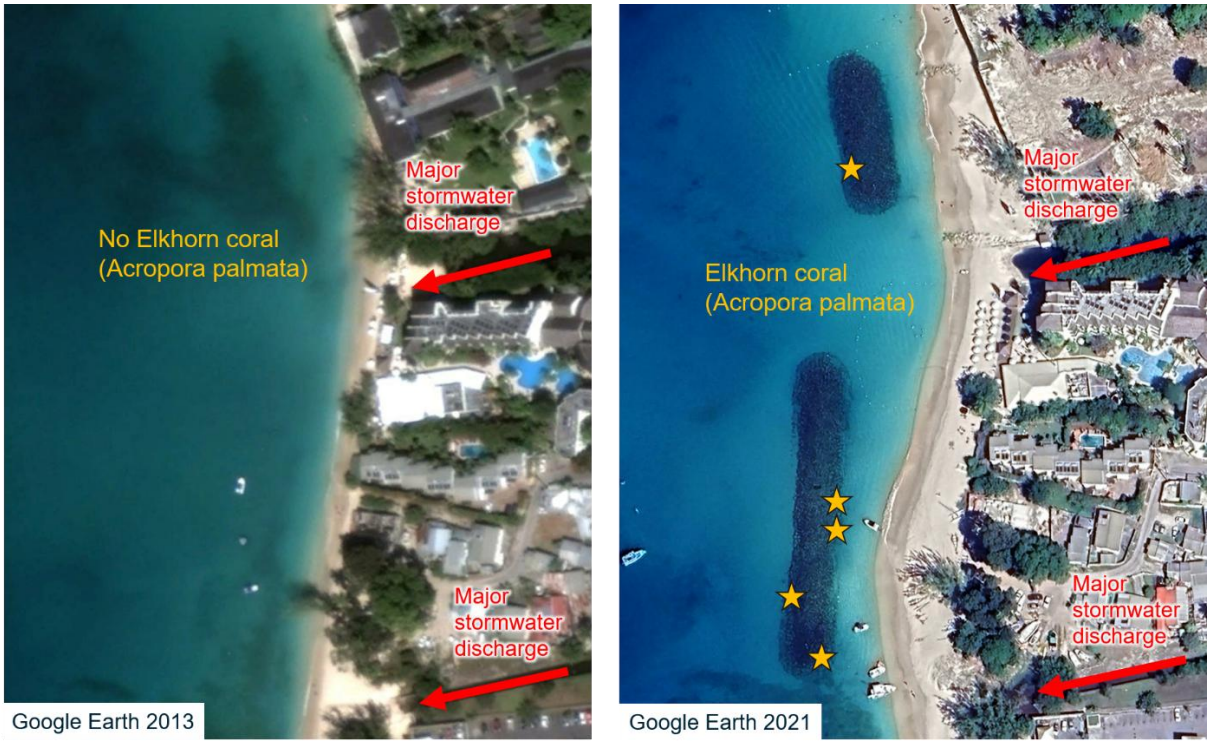


Figure 4.9: Sub-tidal zone at Holetown before and after breakwater installation

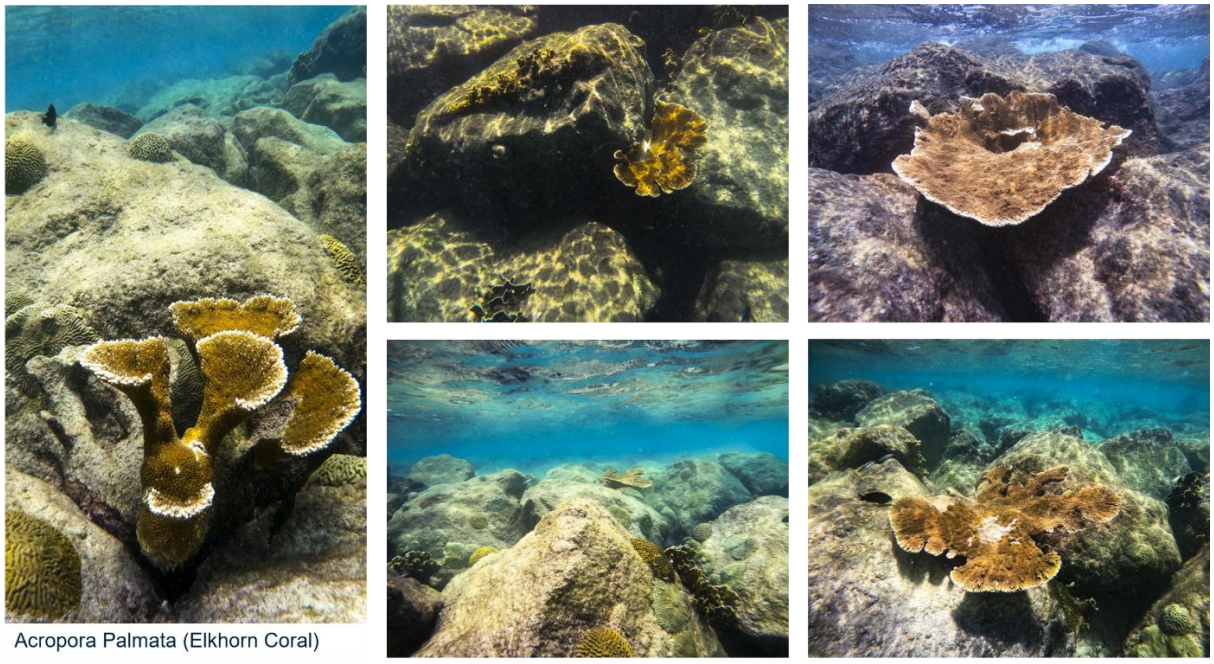


Figure 4.10: Coral colonies established on the boulder matrix at Holetown

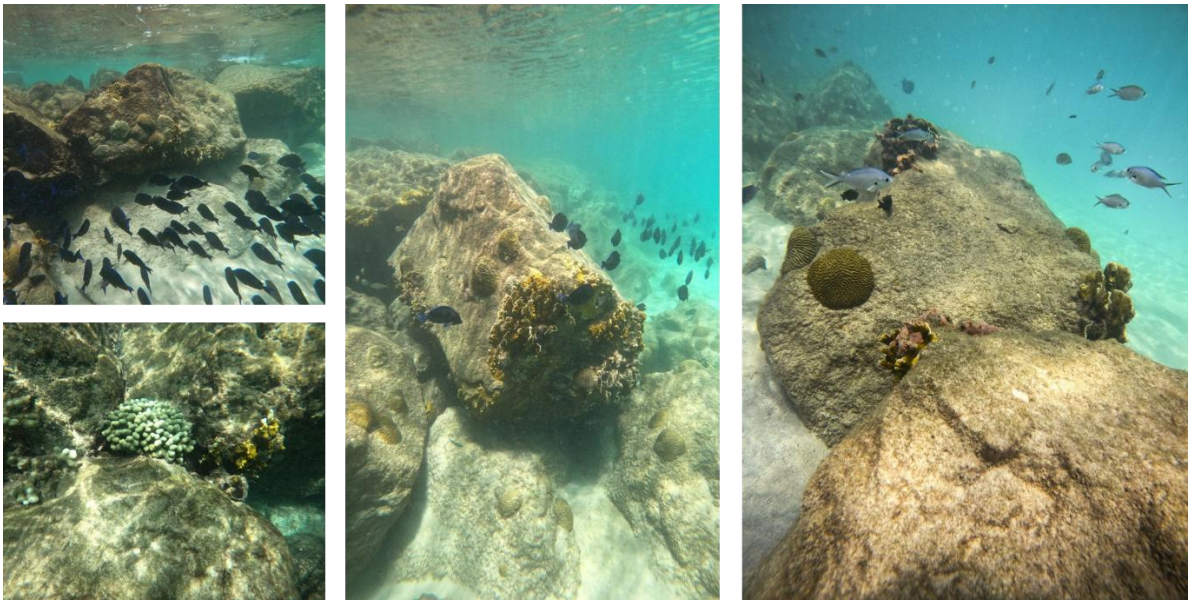


Figure 4.11: Fish species in and around the boulder matrix at Holetown

4.4.4 Water Quality

Anthropogenic activity in Barbados has impacted seawater quality on the west and south coast. The implementation of the proposed project expected to have positive and negative impacts on water quality in the study area. The project impacts on water quality can be caused by changes in user activity, sources of contamination and wave climate. However, a wider beach can also provide benefits for water quality as the

beach slows the movement of water into the sea, filters inland water and helps to prevent the further loss of shoreline infrastructure and erosion of contaminants into the sea.

The materials and equipment used to construct the proposed system will introduce sources of potential contamination. The boulder structures will comprise limestone, granite or a combination of the two. The sand source has not yet been confirmed. Previous projects along the west coast have used sand from local marine sources or from river deposits in Guyana. Of the proposed structures, the beach nourishment is expected to introduce most of the water quality contaminants. As the sand is introduced to the tidal and sub-tidal zones, the microscopic particles in the sand are mobilized creating plumes of turbidity. However, this turbidity increase is temporary and not out of character compared to the turbidity generated by storm events and discharge from inland watercourses.

Beaches filter inland groundwater and surface run-off. Beach berms intercept debris and provide opportunities for collection and diversion at the shoreline before dispersal at sea. Beaches host microbial communities in ground water aquifers that breakdown nutrients from inland sources and reduce the risk of eutrophication. Californian researchers found that these microbes are adversely affected by saltwater intrusion in the beach aquifer [33]. Restoration of the dry beach and reduction of wave energy has the potential to provide opportunities for beach aquifer microbes and increased chemical filtration.

Boulder products are inert and their performance specifications will stipulate threshold mechanical properties that limit the potential to introduce unwanted materials into the sea water. The specifications will require the products to contain less than 5% of foreign materials. Typical out of specification materials include fine sediment particles and organics. We estimate 15,300 tonnes of material will be permanently placed in the study area for this project. 5% of our total material mass is 765 tonnes of potential out of specification materials delivered during the process, although much lower values are expected. For example, when placing an armour stone (e.g. a 4-tonne boulder) it would be highly unusual to have 200 kg of unwanted material on the boulder. The total value of unwanted materials should be well below 5% of the total mass of material.

The construction equipment and temporary access structures may also introduce contaminants including fine sediment and petroleum products. Quality control procedures during the construction phase are used to limit the introduction of contaminants. This is discussed in further detail in section 6 Monitoring & Mitigation.



Figure 4.12: Turbidity plume during construction

5. Assessment

Both positive and negative impacts to the coastal and marine environment are expected and must be considered. The impacts are grouped under the same topics used to establish existing conditions. Baird has applied to the International Seabed Authority's EIA methodology to guide the definitions and ranking system for the impacts [34]. Each impact is assessed and ranked on six criteria that describes how the impact affects the coastal and marine receptors. Receptors are the features and\or constituents of the environment that experiences the impacts and include materials in the land and seascape, the biota, the persons and the organizations that exist or act in the study area. The definitions of the criteria, the ranks and the receptors are defined in Table 5.1 and Table 5.2.

There are nineteen impacts that are grouped as negative in Table 5.3 and positive in Table 5.4; these impacts are sorted from high to low significance. Three receptors are assigned to each impact as the constituents most affected by the impact. Negative impacts have been assigned "unknown" likelihood when enough information is not yet available to estimate the potential for occurrence. These impacts have proven relevant in past similar projects and will be reassessed based on the detailed design, the regulatory requirements and the construction methods.

Table 5.1: Definitions of impact criteria

	Criteria	Rank	Definition
1	Nature		Type of change
		Positive	Beneficial to receptor(s)
		Negative	Detrimental to receptors(s)
2	Pathway		How the change interacts with the receptors
		Direct	Direct interaction with receptor(s)
		Indirect	Indirect interaction with receptor (s)
3	Spatial Scale		The geographical extent of the change.
		Project area	Footprint of the structures
		Study area	Defined EIA area of influence
		Regional	Parish or district of the study area
		National	Territorial boundaries of country
4	Temporal Scale		The duration of the change
		Short-term	Construction and monitoring period
		Medium-term	The decade after implementation
		Long-term	Multiple decades after implementation
		Permanent	The foreseeable future
5	Likelihood		The potential for the change to occur
		Certain	Expected to occur
		Likely	Probability of occurring is greater than not
		Unlikely	Probability of occurring is less than not

	Criteria	Rank	Definition
		Rare	Can occur in exceptional circumstances
6	Significance		Importance of this change to the receptors.[4]
		Low (-)	Within standards / guidelines
		Medium (-)	Outside of standard and can be adjusted to meet standard
		High (-)	Outside of standard and cannot be adjusted to meet standard
		Low (+)	On the smallest spatial or temporal scales
		Medium (+)	On medial spatial or temporal scales
		High (+)	On largest spatial or temporal scales

Table 5.2: Receptors

	Receptor	Definition
1	Beach habitat	Sand areas that support coastal vegetation and cover for species.
2	Reef habitat	Hard substrate and framework that supports coral and cover for resident species.
3	Beach species	Flora and fauna that reside or rely on the beach (seagrape, crustaceans, turtles)
4	Reef species	Flora fauna that resides or relies on the reef (urchins, juvenile fish, reef builder coral,
5	Public	Non-commercial beach users
6	Commercial	Business interest
7	Agencies	Regulatory, conservationist, academic institutions
8	Private	Operations on private land in or adjoining the project area

[4] Significance can be either positive (+) or negative (-)

Table 5.3: Negative Impacts

#	Topic	Impact	Nature	Pathway	Spatial	Temporal	Likelihood	Significance	R1	R 2	R3
1	Ecology	Damage/loss of reef	Negative	Direct	Study area	Medium	Likely	High (-)	Reef habitat	Reef species	Public
2	Infrastructure	Increased nearshore obstructions	Negative	Direct	Project area	Long	Certain	Medium (-)	Public	Commercial	Agencies
3	Waves Climate	Change in surf break performance	Negative	Direct	Study area	Long	Unlikely	Medium (-)	Public	Commercial	Private
4	Ecology	Damage/loss of beach	Negative	Direct	Project area	Short	Unlikely	Medium (-)	Beach habitat	Beach species	Public
5	Ecology	Increased turtle nesting hazards	Negative	Direct	Project area	Long	Likely	Medium (-)	Beach species	Public	Agencies
6	Ecology	Increased nearshore sedimentation	Negative	Indirect	Study area	Medium	Unknown	Medium (-)	Reef habitat	Reef species	Public
7	Ecology	Increased contamination	Negative	Indirect	Study area	Short	Unknown	Medium (-)	Reef habitat	Reef species	Public
8	Ecology	Increased turbidity	Negative	Direct	Study area	Short	Certain	Low (-)	Reef habitat	Reef species	Public

Table 5.4: Positive Impacts

#	Topic	Impact	Nature	Pathway	Spatial	Temporal	Likelihood	Significance	R1	R 2	R3
1	Infrastructure	Improved pedestrian access	Positive	Direct	Project area	Medium	Certain	High (+)	Public	Private	Agencies
2	Ecology	Creation of hard benthic substrate	Positive	Direct	Project area	Long	Certain	High (+)	Reef habitat	Reef species	Public
3	Waves Climate	Reduced shoreline wave energy	Positive	Direct	Project area	Long	Certain	Medium (+)	Reef habitat	Beach habitat	Beach species
4	Ecology	Creation of beach	Positive	Direct	Project area	Medium	Likely	Medium (+)	Beach habitat	Beach species	Public
5	Morphology	Increased sand volume	Positive	Direct	Study area	Medium	Likely	Medium (+)	Beach habitat	Beach species	Public
6	Morphology	Increased beach stability	Positive	Direct	Study area	Medium	Likely	Medium (+)	Beach habitat	Beach species	Public
7	Morphology	Reduced sediment transport rate	Positive	Direct	Project area	Medium	Likely	Medium (+)	Beach species	Public	Private
8	Morphology	Increased sediment budget	Positive	Indirect	Regional	Medium	Certain	Medium (+)	Public	Private	Agencies
9	Infrastructure	Reduced shoreline hard surfaces	Positive	Direct	Project area	Medium	Likely	Medium (+)	Public	Private	Commercial
10	Waves Climate	Calmer wave climate	Positive	Direct	Project area	Long	Likely	Medium (+)	Public	Private	Reef species
11	Ecology	Increased filtration of inland water	Positive	Direct	Project area	Medium	Certain	Medium (+)	Reef habitat	Reef species	Beach species

6. Monitoring & Mitigation

The Environmental Monitoring and Mitigation Plan (EMMP) is a draft, high-level document prepared to demonstrate the feasibility of managing and reducing the identified environmental and social impacts. It provides indicative mitigation and monitoring measures based on the current level of project information. The EMMP will be updated following the regulatory approval process and detailed design development. The final EMMP will be prepared during the construction stage and will reflect the approved design, construction methods, and site-specific requirements.

6.1 Environmental Performance Objectives

The project team recognizes its responsibility to minimize the effects on the environment during all phases of the project, including construction, operation, and end-of-life and seeks to provide leadership by promoting environmental awareness and accountability. The project team will commit the necessary resources to meet the following environmental objectives:

- **Habitat and Species** - To limit negative impacts on turtle nesting areas, coral reefs and beaches.
- **Water Quality** - To minimize the source of contamination during construction operations.
- **Risk Reduction** - To minimize the environmental, health, and safety risks to employees and the public, by employing safe technologies and operating procedures and by constantly being prepared for emergencies.
- **Education and Training** - To increase awareness and understanding of environmental issues by our employees.
- **Public Information** - To keep employees and the public informed on environmental issues relating to project operations.
- **Quality Management** - To establish regular inspections and periodic audits of the project's operations by suitably qualified professionals.

6.2 Environmental Management and Monitoring Plans

6.2.1 Mitigation Strategy

The design and construction of groynes, beach nourishment and offshore boulder structures shall follow the mitigation hierarchy, prioritizing the avoidance of environmental impacts, followed by minimization, restoration or rehabilitation, and, where necessary, offset measures. This approach aims to reduce adverse effects on coastal processes, marine habitats, water quality, and ecosystem functioning throughout the project lifecycle. Avoidance is the preferred mitigation measure and is incorporated in the planning and design stages. Where impacts cannot be entirely avoided, measures will be implemented to minimize their magnitude, duration, and spatial extent. Areas temporarily disturbed during construction shall be restored to an extent practicable. If significant residual impacts remain after avoidance, minimization, and restoration measures have been implemented, appropriate offset measures, consistent with regulatory requirements, may be considered.

6.2.2 Beach Habitat & Species

6.2.2.1 Design Phase

- **Sea Turtle-Friendly Design:** Design groynes with low-profile crests and gradual beach transitions to minimize the formation of steep slopes that could impede nesting Hawksbill turtles or hatchling movement.
- **Preservation of Beach Width:** Optimize the design to increase the dry beach width and elevation suitable for sea turtle nesting under normal tidal conditions. Topographic beach surveys and shoreline monitoring will be undertaken during pre-construction, immediately post-construction, and as recommended by the regulators.
- **Native Sand Specifications:** Beach nourishment sand specifications shall closely match the native beach sediment in grain size distribution, mineral composition and permeability. Sand shall consist of rounded particles and be free of excessive silt, clay, organic material, contaminants, or debris. Laboratory grain size will be analysed and visually inspected prior to material placement. However, the properties of nourishment sand depend on available supply and sources of beach nourishment sand are limited and often inconsistent.
- **Vegetation Protection and Enhancement:** Existing native dune and back-beach vegetation shall be retained wherever practicable. Where vegetation is disturbed, replanting with native coastal species, such as coccoloba uvifera or Ipomoea pes-caprae, shall be undertaken to maintain habitat quality and provide suitable conditions for turtles and other species in the dry beach. Vegetation will be surveyed and recorded.
- **Construction Footprint Minimization:** Temporary access routes, stockpiles, and staging areas shall be located away from sensitive habitat and native vegetation wherever feasible. A daily inspection will be conducted.

6.2.2.2 Construction and Post-Construction Phase

- **Pre-Construction Nesting Survey:** Qualified environmental personnel shall inspect the beach prior to construction to identify active sea turtle nests and nesting activity.
- **Nest Relocation:** Where construction activities cannot avoid active nests, relocation shall be undertaken only by authorized personnel in accordance with established protocols developed by the Barbados Sea Turtle Project and applicable environmental permits. Throughout the nesting season, relocated nests, hatchling emergence success, and relocation records will be monitored.
- **Construction Timing:** Where practicable, major beach works shall be scheduled outside the peak sea turtle nesting and hatching season.
- **Avoid Sand Compaction:** Construction equipment movement on nourished beach areas shall be minimized. Placement methods shall avoid excessive compaction of beach sediments to maintain suitable nesting conditions. Visual inspections will be conducted.
- **Controlled Equipment Access:** Heavy machinery shall remain within designated construction corridors to minimize disturbance of beach habitats and vegetation.
- **Noise Disturbance:** Noise reduction systems will be used on equipment when possible, and work will be scheduled during daylight hours to minimise disturbance.
- **Vegetation Restoration:** Coastal vegetation will be considered as part of the back of beach landscaping where feasible. Pre-existing coastal vegetation shall be restored promptly following construction. Proposed vegetation will be native coastal species.



Figure 6.1: Protected flagged turtle nests

6.2.3 Reef Habitat & Species

6.2.3.1 Design Phase

- **Avoid Sensitive Marine Habitats:** Locations of groynes and offshore boulder structures will avoid ecologically valuable marine habitats, including live coral colonies, reef crests and areas supporting high biodiversity. Final structure locations shall be informed by pre-construction ecological surveys. There will be pre-construction benthic habitat mapping, GPS verification of construction limits, and routine environmental inspections during construction.
- **Nature-Based Reef Design:** Artificial reefs shall be designed to mimic natural reef morphology by incorporating variable crest elevations, irregular surfaces, crevices, and a spur-and-groove planform using additional boulders. The design shall maximize habitat complexity and increase opportunities for coral larval settlement, fish shelter, and overall biodiversity. Post-construction dive inspections, underwater photography, and habitat complexity assessments will be conducted immediately following construction, and as recommended by regulatory agencies.

6.2.3.2 Construction and Post-Construction Phase

- **Controlled Equipment Access:** Heavy machinery shall remain within designated construction corridors to minimize disturbance of beach habitats and vegetation.
- **Coral Transplantation:** Where impacts to healthy coral colonies cannot be avoided, suitable coral colonies shall be relocated by qualified marine biologists to approved receptor sites following established coral transplantation protocols and applicable regulatory requirements. Different monitoring methods will be undertaken such as baseline coral surveys, photographic monitoring, coral survival assessments, and measurements of coral health.
- **Fish, Benthic and Coral Recruitment Monitoring:** Colonization of the artificial reef shall be monitored to assess the success of habitat creation and ecological recovery. Changes in reef fish populations and benthic communities will be monitored to evaluate ecological performance. Underwater Visual Census

(UVC), underwater photography, and habitat complexity assessments will be done pre-construction, post-construction and as recommended by regulatory agency.

- **Water Quality:** Routine monitoring of ambient and sediment plume water quality during construction, with corrective actions implemented if predefined thresholds are exceeded. Corrective actions include offsite quality control, cleaning of materials and equipment, increased containment methods and suspension of contamination related tasks.

6.2.4 Turbidity and Sedimentation

The following mitigation measures will be implemented to minimize turbidity generation and sedimentation during the construction of the groynes and offshore boulder structures:

- **Turbidity Monitoring:** Turbidity levels will be monitored continuously by direct observation and turbidity meters before, during, and after in-water construction activities to verify compliance with applicable environmental thresholds and to identify the need for corrective actions if elevated turbidity is observed.
- **Use of Turbidity Barriers:** Silt curtain, or similar enclosures, will be installed around active construction areas to contain suspended sediments and limit their dispersion into surrounding areas. Barriers will be regularly inspected and maintained throughout construction.
- **Pre-washing of Materials:** Sand, and boulder materials will be washed offsite prior to delivery to remove fine sediments and dust that could contribute to increased turbidity during placement.
- **Controlled Material Placement:** Construction materials will be placed carefully using appropriate equipment and methods to minimize disturbance of the seabed and reduce the resuspension of sediments.
- **Construction Timing:** In-water works will be scheduled, where feasible, during periods of calm sea conditions to reduce sediment dispersion and maximize the effectiveness of turbidity control measures.
- **Minimization of Seabed Disturbance:** Construction activities will be confined to the minimum area necessary, and repeated disturbance of the seabed will be avoided wherever practicable.
- **Adaptive Management:** If monitoring indicates turbidity levels exceed established threshold values, construction activities will be reviewed and modified as necessary. Additional mitigation measures, such as improving turbidity barrier performance, adjusting construction methods, or suspending in-water works, will be implemented until acceptable conditions are restored.

6.2.5 Public Awareness

A comprehensive stakeholder communication plan will be executed, as outlined in the Social Impact Assessment (SIA), to provide timely information on project activities, construction schedules, access restrictions, environmental protection measures, and potential temporary impacts. Communication methods may include community meetings, public notices, social media updates and direct engagement with affected stakeholders.

Clear signage at beach access points and other appropriate locations will be installed, informing the public of construction activities, restricted areas, safety hazards, and expected project timelines.

Installation and maintenance of navigational lights, markers, and any other required aids to navigation on the offshore artificial reefs and associated marine structures will be undertaken in accordance with the requirements of the relevant maritime authority.

6.2.6 Surf Breaks

The locations of the artificial reefs will be reviewed considering that AR3 is adjacent and has the potential to change wave performance inside the surf break and increase the risk of surfers interacting with it while using the Paynes Bay surf break. The design team will evaluate minor realignment of AR1 and AR3 at the detailed design stage.

6.3 Contractor Environmental Requirements

All contractors will comply with the environmental requirements established in the EMMP, including implementation of mitigation measures, environmental training, incident reporting, environmental monitoring, and stakeholder communication obligations.

6.4 Resources, Training and Capacity Building

Appropriate staffing, equipment, facilities, and financial resources will be provided to ensure effective implementation of the EMMP. Personnel involved in the project will receive environmental induction and task-specific training relevant to their responsibilities.

6.5 Emergency Response

Maintaining construction equipment to prevent fuel, oil, or hydraulic fluid leaks, with spill prevention. Emergency response procedures will be established to address environmental incidents such as fuel spills, hazardous material releases, severe weather events, equipment failures, and other unforeseen emergencies. Response procedures will include notification protocols, containment measures, and post-incident reporting.

6.6 Stakeholder Engagement and Grievance Management

A stakeholder engagement process will be maintained throughout the project with routine reporting. A formal grievance mechanism will enable stakeholders to submit concerns or complaints, which will be documented, investigated, and addressed in a timely manner. The main stakeholders include the Coastal Zone Management Unit (CZMU), the National Conservation Commission, the Fisheries Division and The Wild Isle Trust that oversees the Barbados Sea Turtle Project, fisherfolk from the Paynes Bay area, as well as representatives of the Barbados Surfing Association and Paynes Bay surfers and residents.

6.7 Closure and Decommissioning

Where applicable, a closure and decommissioning plan will be developed to ensure that all project infrastructure and debris is removed or left in a safe and environmentally acceptable condition, and that disturbed areas are restored to the extent practicable following project completion.

7. Conclusions

The beach and marine environment between Sandy Lane and Paynes Bay are degraded. The volume of sand on the shoreline has declined steadily over the past three decades. Dry beach was historically a consistent feature, and the loss of beach sand means that this beach has now been replaced by hard infrastructures or transient beach. This represents a loss in important habitat for the hawksbill turtle and other species. The dry beach area allowed pedestrian access along the shoreline. The hard structures now in place along the shoreline present elevated safety risks for pedestrians. This risk is exacerbated during high tide, at night, during periods of higher erosion, in energetic wave conditions or any combination of these circumstances. The historic dry beach was a soft feature that dissipated wave energy at the shoreline. The walls that have become exposed from behind the dry beach reflect wave energy accelerating sand movement at the shoreline. It is unlikely that the sand volume and beach area will increase without intervention.

The existing infrastructure is damaged. Many of the structures were intended to function in dry conditions and were not designed for the tidal and wave conditions they are now exposed to. The structures were installed by individual landowners for their own specific interest but now act as part of larger coastal headland. Without the dry beach the hard structures act as a continuous hard shoreline, on an exposed headland making beach accretion less likely.

Ecological conditions have deteriorated. The reef framework is in poor health and has lower than expected coral cover. Species abundance and diversity have reduced throughout the study area over several decades and over the last three years, possibly in response to Hurricane Beryl in 2024. Extreme wave energy and bleaching have degraded the coral reefs in recent years. Temperature and turbidity values were outside of national ambient standards in 2023 and 2026. There are two significant watercourse outlets that drain a combined catchment of 3 km^2 into the study area that continue to bring upland pollutants into the nearshore area and continue to stress the environment.

The proposed design uses boulder, and sand structures to change the wave nearshore climate and increase wave energy dissipation. The artificial reefs create shallow water depths offshore and trigger wave breaking. The nourished beach increases the budget of available sand, dissipates wave energy and forms and barrier between inland and spaces. The groynes regulate sediment transport. All structures create more opportunities for habitat and resident species.

The CIA identified eight negative impacts and proposes mitigation options for each. The most significant negative impact identified was the risk of damage to reef habitat and the follow-on impact to the dependent species. This habitat is already in decline on the west coast. The tidal, sub-tidal and reef flat zones have minimal habitat and low species abundance. The structures are in these areas to minimize long term impacts. Short-term impacts during construction will be managed in the design specification and construction methods.

There are eleven positive impacts identified in the CIA. These improve conditions for the biota, the beach users and residents by creating more useable spaces and protecting the areas from elevated wave energy.

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