HAIGH WORKMAN LTD
Civil & Structural Engineers

Engineering Report for Proposed Breakwater Structure and Beach Nourishment at Paihia Waterfront

for

Far North Holdings Ltd.

January 2019

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1 Introduction

1.1 Background

Far North Holdings Ltd holds resource consents CON200605454 and CON20112921501 for development of the Paihia Waterfront. The proposed development includes:

- improved public space by re-building of Horututu beach, and
- improved berthing facilities with greater protection from extreme storm wave events

In order to achieve the above outcomes, a number of studies have been undertaken in the past to outline a plan for the development. The proposed waterfront development incorporates a number of hard engineering structures in the bay to reduce the impact of extreme weather events on the foreshore and improve the resilience of the proposed development to the expected environmental loading.

The aspects of the proposed development that are have been approved Resource Consent include:

- a reef type breakwater between Motumaire Island and Taylor Island
- a reef type breakwater on the western side of Motumarie Island
- a rock abutment extending from Nihonui Point
- dredging of approximately 45000 cubic metres of material from the seabed to create a new navigation channel from the Paihia Wharf
- reclamation of approximately 2900 square metres of foreshore and seabed at the stream at the base of Flagstaff Hill
- placement of approximately 45000 cubic metres of sand and other material for the purpose of beach replenishment
- a rock abutment structure adjacent to the existing aquarium building for the purpose of beach protection

1.2 Purpose of this Report

The purpose of this report is to outline the preliminary engineering considerations for the project including:

- design criteria (Section 2)
- options considered and project description (Section 3)
- the existing physical environment (Section 4)
- assessment of the effects of the project on the existing physical environment (Section 5)
- mitigation measures to be implemented throughout the project (Section 6)

Following discussion of the above, conclusions for the project are presented (Section 7).

1.3 Previous Investigations

Wave climate and sediment transport studies have been carried out by Uniservices Ltd (University of Auckland) for Department of Conservation in 2006 as part of the early Resource Consent process. Following appeal of the Resource Consent, and in accordance with the Memorandum of Understanding between Department of Conservation and Far North Holdings Ltd, a further wave climate and sediment transport study was carried out by Beca Infrastructure Ltd. As part of that work, Beca engaged MetOcean Solutions Ltd to complete computer aided model simulations of the wave climate, using similar software as was used in the earlier work. The key reports reviewed are as follows;

Te Ti Beach Monitoring Survey, MetOcean Solutions Ltd, April 2012

Horotutu Beach - Design wave conditions and wave sheltering effects of proposed breakwater structures, Metocean Solutions Ltd, September 2011

Interpretation of Wave Study (letter report), Beca Infrastructure Ltd, October 2011

Condition of Horututu Beach, Beca Infrastructure Ltd, March 2011

Assessment of Effects of Proposed Waterfront Redevelopment: Paihia, Bay of Islands. Supplementary report on coastal geomorphology and coastal process, Auckland Uniservices Ltd, December 2006

1.3.1 *Uniservices*

This report concluded, amongst many things, that a nourished shoreline would protect part of the Paihia waterfront from erosion. It was identified that it would be possible that overtopping of the road in extreme conditions could be diminished by raising the level of the coastal margin and the beach strip through the renourishment process. It was concluded that this solution could alleviate the need for an offshore breakwater which would operate to dissipate aggressive wave attack on a small number of occasions in a single year, and that resources that would otherwise go to building and maintaining breakwater could be used to maintain a renourished shoreline.

Advice Note *- I recall there being some rebuttal to this statement by Raudkivi in evidence given at the Resource Consent hearing, however I am unable to locate that evidence. I recall that Raudivi presented that without the northern breakwater in place, a renourished beach would be severely diminished in an extreme event.*

1.3.2 *MetOcean*

The MetOcean report broadly comprised computer modelling of the wave climate in the Paihia basin for a range of wave conditions over a 12 year period. The purpose of that work is to determine wave heights and patterns during non-extreme weather conditions for consideration by Beca as to whether a stable replenished beach can be constructed without the northern breakwater.

MetOcean determined that Horututu beach experiences a relatively mild wave climate with the Islands providing a high degree of sheltering. Although Horotutu beach is more sheltered than Te Ti, it experiences a narrow directional range which may have consequence for beach stability.

The modelling indicates that the western breakwaters alone provide 15 % reduction in wave energy for wave heights greater than 0.5 m in the NW-N sector waves, but only 5 % reduction in waves from the NE sector. Further, MetOcean estimated the overall reduction in wave height under moderately energetic conditions due to both breakwaters is around 27%. For the 1997 storm simulation, the western breakwater alone provides only 8% reduction in wave height at Horotutu Beach, while the presence of both breakwaters reduce the wave heights by some 25%.

1.3.3 *Beca Ltd.*

The Beca Ltd report provides an interpretation of the MetOcean wave study report providing specific comment on the suitability of the various options presented for attenuation of the wave impact on Horututu Beach. Beca determined that the effect of the northern breakwater between Motumarie Island and Taylors Island will cause a reduction of significant wave height impacting the beach during storm events however it will cause more of a spread of waves in the vicinity of the beach. Beca indicated that the provision of the northern breakwater will not provide any reduction in longshore sediment transport along the beachfront.

Beca determined that the western breakwater/groyne structure will not cause any significant reduction in the wave climate however it will aid in the stability of the nourished beach system. The provision of an eastern groyne structure will further promote the stability of the beach while limiting the sediment transport into the commercial harbour.

Beca have indicated that some redistribution of the nourished beach sediment will be required from time to time to restore the design beach profile.

2 Design Criteria

2.1 Standards and Codes of Practice

The NZ Building Code compliance will be achieved primarily by the compliance of AS/NZS 1170 used in conjunction with the relevant material standards.

The following codes of practice and sources of reference are adopted for the design:

General:

- NZ Building Code
- BS6349 Part 1 and Part 4, Design of Maritime Structures

Loading:

- AS/NZS 1170.0 Structural Design Actions, Part 0: General Principles
- AS/NZS 1170.1 Structural Design Actions, Part 1: Permanent, imposed and other actions
- AS/NZS 1170.2 Structural Design Actions, Part 2: Wind actions
- AS/NZS 1170.5 Structural Design Actions, Part 5: Seismic actions
- NZ Transport Agency Bridge Manual (SP/M/022) Third Edition
- AS 4997:2005 Guidelines for the design of maritime structures

Reinforced Concrete:

- NZS 3101:2006 P1 & P2 Concrete Structures Standard
- AS/NZS 4671:2001 Steel Reinforcing Standard

2.2 Design Life

The design life of all structures is to be at least 50 years. Durability of reinforced concrete structures is to be at least 100 years.

2.3 Berthing Loads

The proposed breakwater/groyne structures will not be used for direct berthing of marine craft. Floating pontoons with pile restraints will be used for berthing/mooring of vessels if required. Access to the floating pontoons will be via a gangway which will not transfer any berthing or mooring loads to the shore. Berthing facilities is outside the scope of works for this report.

2.4 Vehicle Loads

There will be no vehicular access provided to the breakwater/groyne structures.

2.5 Services

No services are proposed for the various breakwater structures. The proposed groyne structure immediately adjacent to the existing aquarium building may have land based services extended to allow for serviced to potential future berthage at the western side of the Paihia Wharf. These will include:

- Water
- Power
- Communications
- Stormwater

2.6 Stormwater

No additional impermeable surfaces will be established as a part of this project. As such, the existing stormwater systems will not be required to accommodate any increased volumes.

2.7 Earthquakes

The seismic design shall be carried out using Importance Level 2 (i.e. general structure) in accordance with the Building Code.

2.8 Sea Level Rise

In accordance with the NZ Coastal Policy Statement (Policy 24 and 25) sea level rise (SLR) should be considered over a 100 year planning period.

As such, the effect of climate change and sea level rise on the coastal areas of New Zealand is provided by the Ministry for the Environment's national guidance manual Coastal Hazards and Climate Change: Guidance for Local Government (MfE, 2017) and the District Plan. MfE (2017) provides for the following sea level rise (SLR) scenarios to 2115: 0.7m as a base case, 1.0m for planning consideration. The Unitary Plan provides for a SLR of 1.0m for planning purposes.

2.9 Wave Overtopping

Overtopping due to wave attack is to be assessed based on the approach in the Rock Manual (2007) and UK Environmental Agency (1999). See Section 3.2.2 for the basis of establishing the crest level.

3 Project Outline

3.1 Options Considered

Although a rock armour breakwater structure is currently consented for development, a number of options for the protection of Horututu Beach and Paihia Wharf have been considered. These are outlined below:

3.1.1 *Rock Armour Structure*

A selection of rock armour reef breakwaters of approximately 170m (Motumaria to Taylors Island), 150m (Motumaria Western) and 100m (Nihonui Point) and a rock armour groyne structure 100m (Horututu Eastern) in length are considered. This option is in line with the currently consented plans.

Advantages

- Currently consented
- Will reduce the wave penetration to Horututu Beach
- Provides for sheltered berthage at Paihia Wharf
- Low maintenance type structure
- Simple structure

Disadvantages

- Visual eyesore on landscape
- Potential to settle over time
- Requires a larger footprint on seabed than other options
- Does not allow easy movement of marine life

3.1.2 *Floating Wave Attenuator Structure*

An alternative option of a floating wave attenuation structure between Taylors Island and Motumarie Island was also considered in place of the rock armour structure. This option differs from the arrangement in the current resource consent.

Advantages

- Less of a visual impact on the environment
- Less of an impact on the seabed as floating structure requires minimal disturbance of the seabed
- Potential amenity for access during calm conditions
- Allows for easily changing the structure layout due to transportability.
- Very little interference with sediment transport

Disadvantages

- Large amount of complex analysis and design required to ensure adequate wave attenuation and structural suitability of floating structure.
- Provides less wave attenuation than solid structure
- Sensitive to wave frequencies
- Less effective on long period waves
- May not be feasible due to wave conditions in the proposed location.

- No “off the shelf” systems available in New Zealand that would be suitable.
- Relies on mooring chains and anchors. Dynamic response to the incoming waves can result in fatigue problems and heavy mooring.
- Higher long-term maintenance requirements.

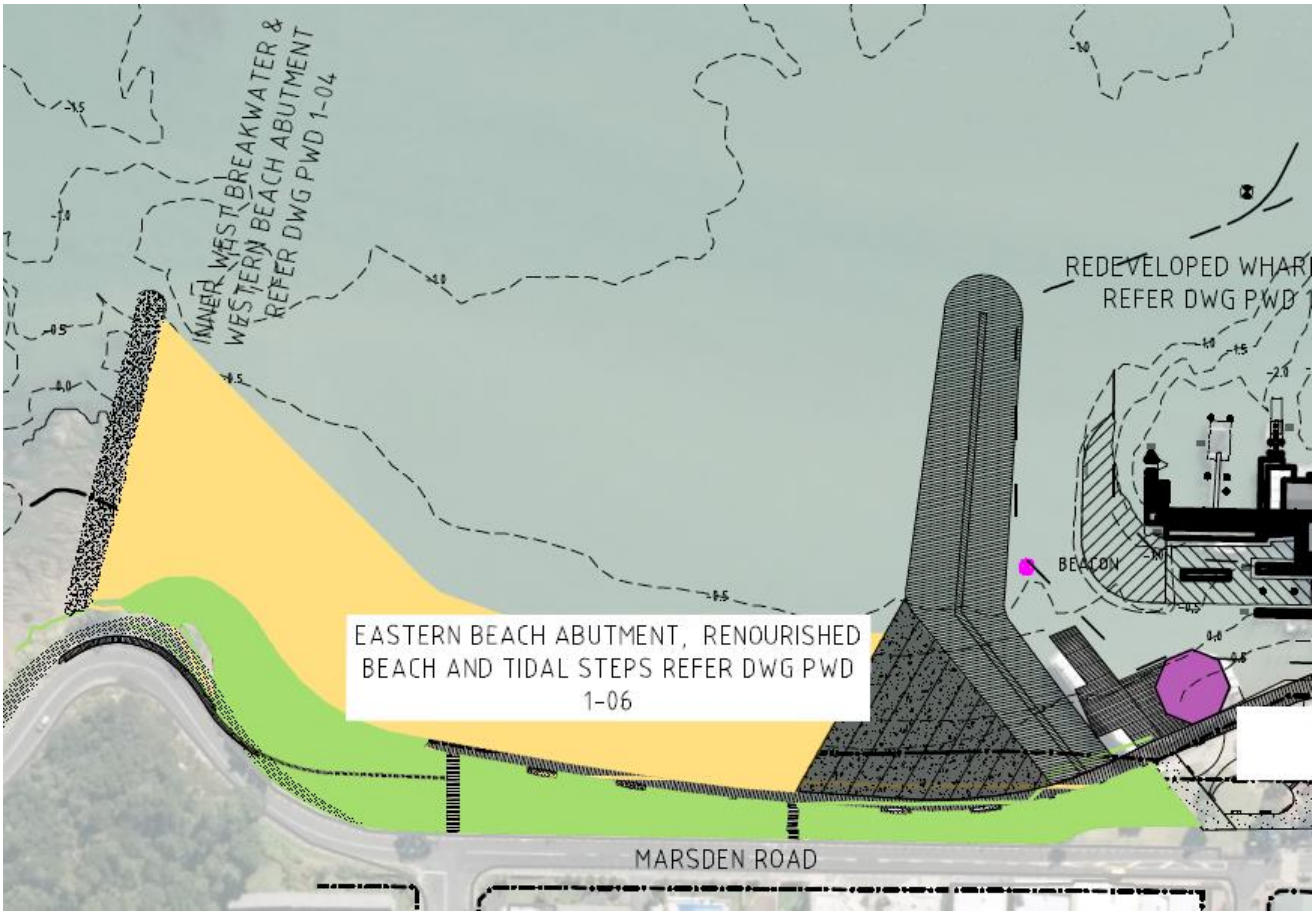
3.2 Project Scale

3.2.1 *Sizing - Plan*

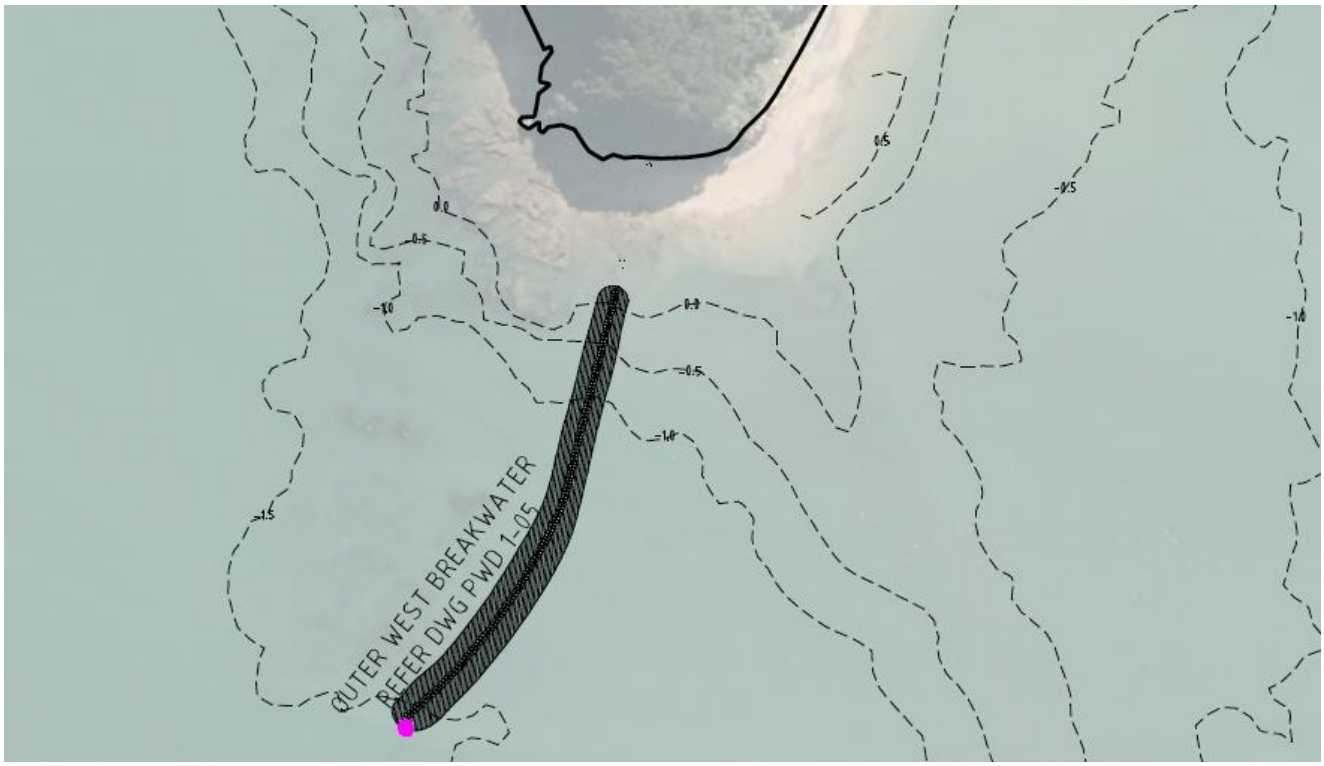
The groyne structure proposed for the bluff at the western end of Horututu Beach is to be a naturalistic headland formed of a combination of sandcrete and rock armour to extend approximately 60m from the high-water line. The width of the groyne is to be approximately 10m at the base. The footprint area of the new structure would be approximately 600m^2. The groyne structure to the east of Horututu Beach is proposed to be a standard rock armour structure to extend approximately 160m from the shoreline. The width at the base is to be approximately 16m. The footprint of the proposed structure would be approximately 2560m^2.

Between the two groyne structures either end of Horututu Beach would be a beach nourishment scheme that would provide a 15m wide berm at the top of the beach and a sandy beach with a gentle slope. The extent of the nourishment would be dependant on the sediment size used but would be at least 40m from the top of the berm.

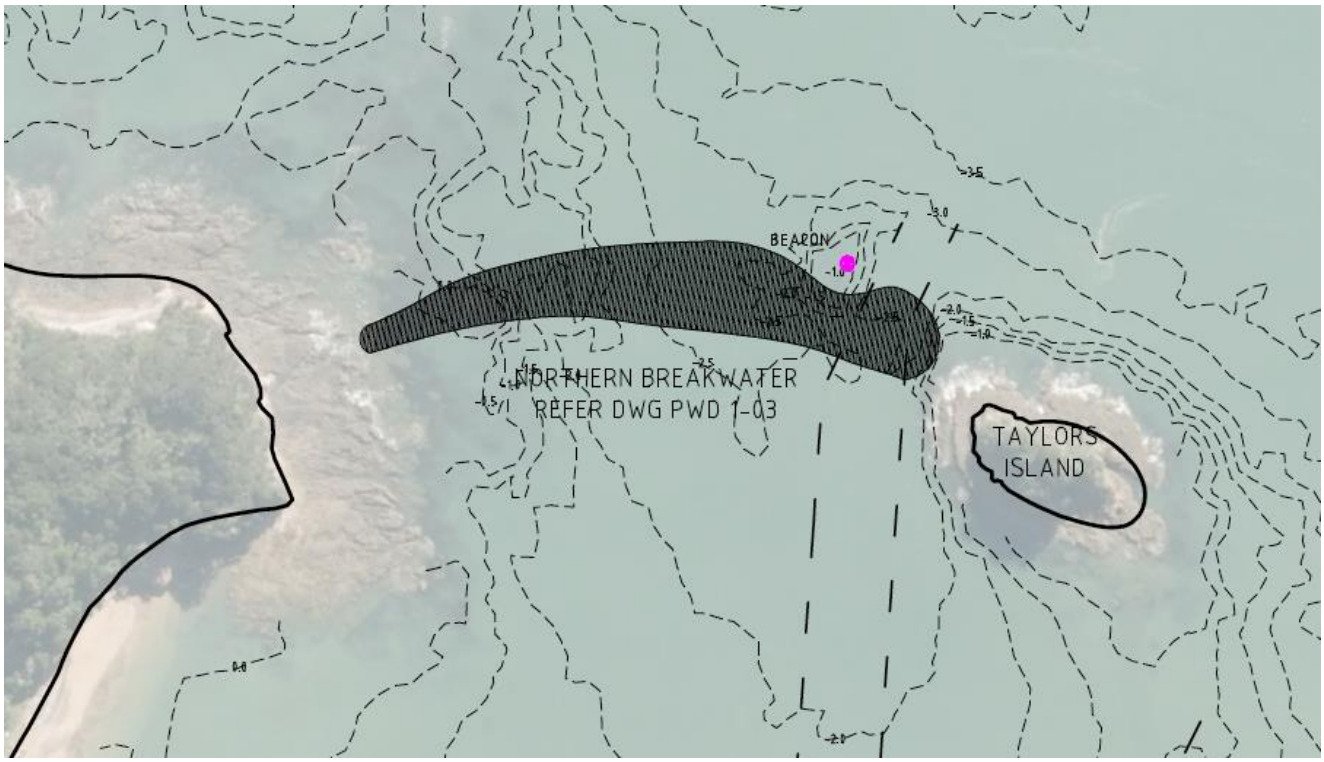
At the southern end of Horututu Beach a set of tidal steps is to be provided. The form and extent of these is yet to be determined.



The proposed reef structure immediately south of Motumarie Island is to be approximately 140m in length and have a width at the base of between 10m and 14m. The footprint of the proposed reef structure is to be 1700m^2.



The proposed northern reef breakwater is to close the channel between Moutumariew Island and Taylors Island and is approximately 160m in length. The width at the base will be approximately 30m. The overall footprint of the structure occupies approximately 3800m^2 of the sea floor.



3.2.2 *Sizing – Crest Level*

The crest level for the structures between Moutumarie Island and the western side of Horututu Beach are to be approximately +2.3m C.D. to form a reef structure at low tide. The crest level of the northern breakwater and the eastern groyne on Horututu Beach is to be +4.0m C.D.

Setting the crest levels requires a judgement based on a balance between everyday functionality and wave overtopping during an extreme event (and consequential damage). As no pedestrian access is to be provided to the northern breakwater structure, the determining factor for the crest height is the wave penetration through the structure to the commercial harbour.

3.3 Geotechnical Considerations

No geotechnical investigations for the proposed structure locations have been carried out to date. It is expected that bedrock suitable for founding the structures is present near to the seabed surface. Prior to the construction, borehole investigations should be carried out to confirm the suitability of the seabed for the construction of the proposed structures.

3.4 Rock Protection

An initial assessment of the wave climate expected to be impacting on the northern reef breakwater indicates a significant wave height of 3.3m is to be sustained. Primary rock armour thickness on the northern face of the breakwater of approximately 1.8m with a D_{n50} of 0.9m over a core with a D_{n50} of 0.33m is required.

An initial assessment of the wave climate expected to impact on the western reefs or groynes indicates a significant wave height of 1.7m is to be sustained. Primary rock armour thickness on the western face of the structures needs to be approximately 1.4m thick with D_{n50} of 0.69m over a core with a Dn50 of 0.22m.

3.5 Dredging

Dredging material from within the commercial marina and the relocated navigation channel is to be used for the proposed reclamation within the foreshore development by others.

3.6 Promenade& Tide Steps

The foreshore development project is to include a new promenade and tide steps along the front of the proposed beach to provide access to the water and other amenities.

3.7 Services

There are currently no provisions for additional services to any of the reef breakwater structures. Where power is required for marine navigational aids, this will be provided by solar devices.

3.8 Stormwater

The existing stormwater outlets along Horututu Beach will need to be diverted such that they are not impacted by the proposed beach re-nourishment.

3.9 Construction Materials

3.9.1 *Breakwater/Groyne Core*

The core of the northern breakwater structure is to be constructed of quarry run with an average Dn50 of 0.33m to allow a notional permeability of 0.5 for use in the Van Der Meer equations. The quarry run rock to be used shall have a minimum unconfined compressive strength of 50MPa and meet the requirements of the CIRA Rock Manual (2007).

The core of the groyne structures is to be constructed of sandcrete to form an impermeable core. The sandcrete is to have a minimum cement content of 9%.

3.9.2 *Geotextile*

A geotextile material will be provided on the sloping outer faces of the structure core to act as a separation and filter layer between the bund core and the underlayer rock armour. The geotextile used is to comply with the requirements of AS 3706.

3.9.3 *Rock Armour*

Rock armour is to be provided on the sloping outer faces of the bund core both to reduce wave runup and protect the core from scour over time. The rock to be used shall have a minimum compressive strength of 50Mpa and meet the requirements of the CIRA Rock Manual (2007).

3.9.4 *Naturalistic Headland*

The proposed naturalistic headland for the bluff between Te Ti Beach and Horututu Beach above the low water line is to be formed of a sandcrete bund and high strength geogrid reinforced gunite surface. The sandcrete is to be a 9% cement mixture to stabilise the core. The gunite surface is to have various natural oxides blended with the mix to mimic a natural variation in colour throughout.

3.10 Construction Methodology

3.10.1 *Mobilisation and Set-up*

Mobilisation for a dredging and construction operation at Paihia Waterfront is likely to include the following activities:

- Transporting of site offices to the construction site. A critical issue will be to provide adequate space (on the land and on the water) for contractor's site establishment.
- Site establishment including set up of site offices, secure compound, work shop, etc. Also a temporary berthing facility may be required at the site or nearby.
- Connection of site services, phone, power, water, sewage, etc.
- Assigning plant to the project, pre-project maintenance of plant, renewal of certification as required, servicing and delivery to site.
- Consent/approval notifications and issuing of any maritime notifications as required.

3.10.2 *Testing under bund soil strengths*

No preliminary geotechnical investigations have been carried for the proposed locations however it is anticipated that bedrock in the proposed locations is relatively close to the surface.

Under bund soil testing will be carried out ahead of any required dredging works. The removed soft material will be used as fill material under the proposed beach nourishment of Horututu Beach. The soil testing operation will be carried out by an experienced geotechnical subcontractor working under the supervision of geotechnical engineers. The soil testing will confirm the depth of key and undercut areas.

3.10.3 *Establishment for Dredging Facility*

Any required under bund dredging will be carried out by an excavator mounted on the barge with bucket position control to accurately achieve the required foundation depth. As it is dredged, the dredged material will be loaded into a barge and delivered to the proposed beach nourishment location, or to an approved disposal site.

3.10.4 *Core Shaping*

The required finished level for the core is at approximately +2.4m CD. As this level is above the high tide level, it is intended that an excavator will be operating from the breakwater core to complete construction to the final rock armour levels and to trim the sides of the core to the design levels. The core has been designed with an approximately 3m wide crest at finished level to provide sufficient space for the excavator.

The seaward faces of the core including the toe will be placed with a greater degree of positional accuracy than the rest of the core. Positioning equipment similar to that used for the dredging excavator will be utilised for placing this material, while the excavator with the position control will trim the surface back to the required line. The completed surface will be surveyed using a combination of land based and marine surveying to demonstrate compliance with the project requirements.

3.10.5 *Rock Revetment Construction*

Rock armour will be placed over the finished core slopes as soon as access is available. Just prior to the rock armour layer being placed the geotextile layer will be laid over the core surfaces.

Piles of armour layer rock or steel pins will be placed over the geotextile to anchor it as it is laid and the position of the geotextile will be monitored. Below the water level, divers will monitor the positioning of the geotextile and placing of the holding down rock. Geotextile will be placed over the full length of the outer slopes and the toe. It is anticipated that the placement of the geotextile will take up to 2 weeks.

The placement of the rock armouring over the bund will follow the placement of the geotextile. A land based long reach excavator will be used to place the rock armour which will be delivered to the work face by barge.

The completed surface of the armoured breakwater will be surveyed using a combination of land based and marine surveying to demonstrate compliance with the project requirements.

3.10.6 *Beach Nourishment*

After the rock armouring of the eastern and western groynes at Horututu Beach is complete, the remaining activities required to finish the beach nourishment will be carried out. Sand of an appropriate nominal diameter will be sourced from offshore dredgings between Pakiri and Mangawhai heads and transported to site by barge before being placed and shaped to the correct profile. During the beach nourishment phase, stormwater management systems along the nourished beach will be installed.

3.10.7 *Naturalistic Headland*

The naturalistic headland will be constructed on top of the existing natural bluff rock and blend in with the existing rock. The sandcrete core is to be keyed into the natural rock to ensure the stability of the structure. The sandcrete is

to be mixed either on site or on a barge in a portable pug mill mixing plant and placed by excavator. Once the sandcrete core has been complete, the plastic geogrid reinforcing is to be layered over the bund and the high strength gunite can be sprayed. The sprayed gunite is then to be immediately hand shaped to a naturalistic looking form.

4 Existing Physical Environment

4.1 Existing Hydraulics

The bay of islands is a large drowned valley with numerous arms and extends some 30 kilometres inland from Cape Brett. Hydraulic conditions are governed by the well-defined tidal channel, from north of Tapeka Point through to the Waikare Inlet. The mean tidal range is 2.0 metres

Tides levels at the proposed location of the works are summarised in Table 1.

Table 1 Tide Levels

Condition	Level (CD-m)
Mean High Water Springs (MHWS)	2.3
Mean High Water Neaps (MHWN)	2.1
Mean Sea Level (MSL)	1.4
Mean Low Water Neaps (MLWN)	0.6
Mean Low Water Springs (MLWS)	0.3

Storm surge in a harbour is due to low pressure weather systems and on-shore winds. Tonkin & Taylor (2017) has modelled storm surges selected Northland region coastal locations and probabilistic values (in combination with tides) are given in Table 2 for Paihia.

Table 2 Storm Surge Levels

Event	Water Level (CD-m)
Current 1% AEP Storm Tide	3.0
Current 1% AEP Static Water Level	3.3
Current 1% AEP Run-up Level	5.0

In accordance with the NZ Coastal Policy Statement (Policy 24 and 25) sea level rise (SLR) should be considered over a 100 year planning period. MfE (2008) gives guidance which would result it:

- SLR of 0.7m to 2115 as a base case
- SLR of 1.0m to 2115 for planning consideration.

4.2 Wave Climate

The predominant wave climate within the bay is along the harbour in both a north and southerly direction. Paihia waterfront is generally protected from these wave directions by Motomarie Island and Taylors Island.

For Paihia waterfront the main wave attack direction is from NE to N. This has a limited wind fetch of 10km. As there is no recorded wave climate with the harbour, hindcasting was used to estimate the wave climate. A previous study by Lawson and Treloar has modelled the wave climate in the vicinity of Motumarie and Taylors Islands and determined the significant wave height for the 50 year ARI event is 3.3m.

4.3 Sedimentation

The existing shoreline at Paihia waterfront is effectively stable with minimal sediment movement. The effects of commercial ferry operations contributes more to the sedimentation of the area than natural processes.

4.4 Stormwater

At present, stormwater from Marsden Road is untreated prior to discharge to the harbour. The stormwater is discharged into the sea with the majority of the stormwater related contaminants settling within the nearshore area.

5 Assessment of Effects

5.1 Tides, Currents and Storm Surge

The maximum current velocity through the Horututu Beach to Motumarie Island area will remain approximately the same under the proposed configuration due to the permeability of the proposed structures.

5.2 Wave Climate

The proposed northern breakwater and western groyne structures have been found to moderately reduce the wave climate penetrating to Horututu Beach.

5.3 Sedimentation

Sedimentation of the waterfront area is expected to be reduced as the impermeable groyne structures will aid in the reduction of longshore sediment transport into the commercial harbour area. There may be higher than current levels of sediment transport into the commercial harbour in the early stages following the construction as the beach settles into equilibrium. Once equilibrium is achieved, there will be minimal longshore transport of sediments.

5.4 Breakwater Structure

The construction of a northern breakwater between Motumarie and Taylors Islands to protect Horututu Beach will provide moderate wave attenuation at the beach. The effect of the breakwater will increase the spread of the waves compared to the existing situation. While this means that the beach would be less prone to cross shore sediment transport during storm events, there is not expected to be any change in the long shore sediment transport potential for the site.

The presence of the northern breakwater will reduce the post storm swell wave conditions which will reduce the amount of natural beach re-building if sand is moved offshore during a storm.

The presence of the western and eastern groyne structures at Horututu Beach will promote planform curvature of the beach which will aid beach stabilisation while reducing the longshore sediment transport into the commercial harbour.

5.5 Beach Nourishment

The sediment size used for the nourishment will have a significant impact on the profile and stability of the proposed nourished beach. A larger sediment grain size will promote beach stability and reduce the risk of sediment migrating along the shoreline to the commercial harbour berths.

5.6 Construction

5.6.1 *Traffic Effects*

In order to limit the amount of traffic to Marsden Road associated with the project, the majority of material deliveries can be made by sea with barges. Over the course of the breakwater construction, it is estimated that there will be approximately 50 heavy vehicle movements to and from the site with peak deliveries estimated to be during the

establishment and disestablishment phases. In addition there will be car vehicle arrivals related to construction, engineering and client staff movements.

An allowance of 3 car vehicles per day should be allowed for.

5.6.2 *Noise Effects*

The construction of the breakwater core will generate minimal noise in the area as plant requirements are minimal. Wind direction will have a significant impact on noise levels reaching the foreshore during this stage of the construction.

The activities required for the construction of the groynes and beach nourishment are likely to be the most noticeable in terms of increasing noise levels at the foreshore.

5.6.3 *Construction Site*

The establishment by a contractor of a site compound in the immediate location of the works will be limited by the availability of space. Any site compound to be established on the waterfront will need to have strict traffic management applied to it so as to not effect the flow of traffic along Marsden Road.

5.6.4 *Construction Duration*

Depending on construction sequencing, the total duration of the construction is estimated to be in the region of 15 to 20 months. There are a large number of variables that will affect the programming of the project. The largest single stage of construction, the beach nourishment, is very dependent on the rate of supply of sand to site. This is in turn dependant on weather as the sediment is to be barged to site. The weather will therefore have a significant impact on the duration of the project. This is similarly applicable to the supply of rock for the breakwater and groyne structures.

Construction sequencing will also have a significant impact on the program. Where elements can be carried out concurrently, a significant time saving can be made. For example, completion of the groyne structures concurrently with the northern breakwater will introduce efficiencies to the project.

Provision of a storage space on site would have a significant impact on rate of land based deliveries and potentially on duration of works. Where a large site compound is provided with ample storage space, the delivery of rock armour material by land can be spread over a longer period, reducing the peak daily deliveries. Where delivery of materials to site by barge along the coast is prohibited by inclement weather, a temporary loading zone for barges could be established in the Opua commercial area to allow transport of materials by road.

6 Mitigation Measures

6.1 Monitoring

During the dredging operations and construction of the breakwater and beach nourishment, silt and sedimentation control measures will be implemented. The objective of silt and sedimentation controls while constructing the breakwater and beach nourishment shall be to minimise all possibilities of release of silt, sediment or any other pollutants into the coastal marine environment.

An environmental monitoring programme will be developed in conjunction with Far North District Council. This is likely to include:

- Intensive monitoring of major components of the proposed works to verify discharge of suspended solids, pH levels, and soluble and sediment-bound contaminants are within acceptable parameters.
- Regular monitoring of potential adverse effects of the construction works to provide verification that the discharge of suspended sediment, alkalinity and soluble and sediment-bound contaminants from the works remain within acceptable levels.
- Sampling from a number of “control” sites for both ebb and flood tides and test sites at the 200m and 50m mixing zone boundaries.

7 Project Cost Estimate

Haigh Workman Ltd have carried out a cost estimate for the proposed various packages of work associated with the beach nourishment and protection. This has been carried out on the basis of the following:

- No computer modelling of the structures was carried out
- Rough volume estimates (±20% confidence) were calculated by hand on the basis of average height of the structures, plan area of the structures and the assumption that the structure occupies 60% of the space above due to the sloping sides of the structures.
- Volumes for the beach nourishment are on the basis of the Haigh Workman Ltd beach volume analysis letter dated 15th August 2008.
- Estimates for landscaping are based on previous Far North Holdings Ltd estimates.

On the basis of the above, the cost estimate for delivering the proposed beach nourishment and protection is as per Table 3 below. A further breakdown of the cost estimate is provided in Appendix X

Table 3 Project Cost Estimate

Item No.	Item Description	Subtotal
1	**Breakwater**	$ 2,478,445.43
2	**Groynes**	
2.0	*Horututu Beach West Abutment*	$ 2,123,287.32
2.1	*Horututu Beach East Abutment*	$ 1,148,465.61
2.2	*Outer West Breakwater*	$ 913,864.26
3	**Beach Nourishment**	$ 2,233,976.00
5	**Landscaping/Sea Steps**	$ 1,676,000.00
	TOTAL	$10,574,038.62

8 Conclusions and Recommendations

8.1 Conclusions

A number of options for the protection of the proposed beach nourishment works have been considered. These include a floating wave attenuation structure and a solid breakwater structure. The floating wave attenuator structure has been identified as the preferred option by Far North Holdings Ltd due to the minimal visual impact of the system on the area. Although not the preferred option, the solid breakwater structure will provide better protection to the beach nourishment scheme and provide a more cost-effective solution.

The various structures that form the system to protect the beach nourishment works all have different structural forms with differing width at base, crest elevation and structural arrangement. The detailed design of these structures is yet to be carried out. The northern breakwater structure is to be a rock structure with a crest elevation of +4m C.D.. The outer western breakwater is to be a rock structure with a crest elevation of +2.3m C.D.. The western abutment of Horututu beach is to have a solid sandcrete core with a high strength gunite shell that is formed to look like a naturalistic headland. The crest elevation of the western abutment is to vary from +4m C.D. at the berm of the beach to 0m C.D. following the slope of the nourished beach. The eastern abutment of Horututu beach is to be of rock construction with a crest elevation of +4.0m C.D..

The proposed works will result in the creation of approximately 3750m^2 of a recreational amenity area on the berm of the proposed beach with a further 4000m^2 of sloping sandy beach above the current high-water line. This new beach and associated berm will provide a public friendly amenity for locals and tourists while also serving to reduce the risk of coastal inundation associated with severe storm events. It is anticipated that the provision of the breakwater structure between Motumarie Island and Taylors Island will reduce the number of days in the year where operators cannot use the commercial harbour due to inclement weather.

The proposed structures will result in a reduction in the significant wave height impacting the proposed beach nourishment location and increase the stability of the beach sediments. The northern breakwater will increase the variability in wave directions penetrating to the beach while dissipating a significant portion of the wave energy. The resultant is a reduction in the anticipated cross shore sediment transportation and a more stable cross shore beach profile. The western abutment and “reef” breakwaters will dissipate a significant portion of the wave energy from the north west. Although wave overtopping of the reef breakwater will occur, the waves will break on the structure reducing the energy. The abutments either end of Horututu beach will retain the nourished sediment in the longshore direction, forming a stable salient beach plan.

The works are estimated to have a construction period of approximately 15 to 20 months. During this time, heavy marine vehicle traffic to the site will be expected to increase significantly. The frequency of deliveries to site by water is severely dependant on the weather conditions between the supply locations and the site. Elevated noise levels would be expected for a portion of the works as the equipment required to place rock armour can be noisy however this is not expected to be excessive.

No additional treatment of the stormwater runoff is expected to be required as no new impermeable surfaces are to be created. Stormwater outlets currently discharging to Horututu beach will need to be relocated to discharge through the eastern beach abutment.

The cost of the proposed brach nourishment scheme and associated protection structures is anticipated to be in the region of NZ$10,600,000 + GST.

8.2 Recommendations for Further Investigations

The size and extent of the various structures associated with the proposed works are heavily dependent on the geotechnical conditions present under each structure. The cost estimates to date have a ±20% accuracy as there is no existing available geotechnical data for the various structure locations. In order to refine the cost estimates for the works, it is proposed that the following tasks be undertaken:

- Geotechnical boreholes be drilled at each of the proposed structure sites to determine depth to suitable bearing layers for the structure bases.
- Three-dimensional modelling of the proposed structures is carried out in 12D or similar civil modelling software to establish accurate volumetric quantities for the various components of each of the proposed structures.
- Identification of a suitable local source of rock for the various proposed structures as this is the largest component of the works.

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Appendix A – Drawings

Drawing No.	Title	Scale

Appendix B – Volume Calculations

Appendix C – Cost Estimate