Little Shoal Bay

Coastal Processes Issues and Options Assessment

REPORT PREPARED FOR AUCKLAND COUNCIL

CONFIDENTIAL

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Revision	Details
2	Major restructure of report following Auckland Council comments. Also includes new shoreline management options.
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Executive Summary

The Issues

Coastal inundation and erosion pose a risk to Little Shoal Bay. King tides and storm surges have caused local flooding and the existing seawalls in the east of the bay are being undermined. Climate change is expected to increase the frequency and severity of flood and erosion events.

Little Shoal Bay has a wide variety of uses including public open space, parks and reserves, car parking and amenity/recreational use. The bay provides access to the foreshore for boat launching and retrieval, public toilets, exercise and barbeque facilities for public use. There is a boat hardstand and the headquarters of the local Sea Scouts. Many of these functions can be disrupted by inundation and erosion.

About this Report

Auckland Council have commissioned this study to explore the nature of these risks, how they might change and what could be done to manage them. The information gathered in this study will support the development of a long-term shoreline management approach with the community.

This report focuses on coastal edge evolution, current and future coastal hazard risk and potential coastal management responses. Additional work is likely to be required to fully explore landward inundation options.

Condition of Existing Assets

A visual inspection of existing coastal structures was undertaken during a site visit as part of this study. The seawall, stormwater culverts (external inspection only) and boat ramp appear in fair condition. Key issues are undermining of the seawall on eastern side of the bay and insufficient crest level to manage inundation risk.

Very little amenity beach is present at high tide. A temporary groyne structure has been constructed at the western end of the beach and a small volume of sand has accumulated up-drift of this structure.

Shoreline Management Options

The study provides initial consideration of a range of shoreline management options in section 4. These include:

- Option 1 - Do nothing
- Option 2 - Maintain existing shoreline management approach
- Option 3a – Beach Nourishment & Groynes
- Option 3b – Improve seawall
- Option 3c – Planting to manage erosion risk
- Option 4 – Adaptation (of landuse within the bay)

Comparison of Options

A preliminary qualitative comparison of options is developed in this report and summarised below:

- Option 4 - Adapting land use such that it is compatible with the risk (would likely provide a resilient risk management approach but would require a change to the way Little Shoal Bay is used.

- 'Option 1 - Doing Nothing' and 'Option 2 - Maintain the current approach' are likely to be the lowest cost options to implement (ignoring the cost of flood and erosion damages). These options are unlikely to provide an acceptable level of service into the future as the inundation risk changes due to climate change. They may provide a short-term solution until a long-term plan can be developed and implemented.

- 'Option 3a – Nourishment' and 'Option 3c – Planting' offer the best opportunity to add wider benefits (such as amenity and ecological enhancement).

- 'Option 3b – Repair/rebuild seawall' is likely to require significant capital cost and the design could be developed to suit the desired level of service.

Further analysis and agreement of priorities with council and stakeholders, including community and Iwi will be required in order to select the preferred shoreline management approach.

The Ministry for the Environment (MFE) advocate for an adaptive approach to risk management responding to the changing nature of the risk. It would be prudent to develop an adaptive risk management approach that recognises the community aspiration for the bay and the budgetary constraints of Auckland Council.

Recommendations

Little Shoal Bay is exposed to a range of coastal hazards. The existing seawalls on the eastern side of the bay are subject to undermining and, though their stability has not yet been compromised, a long-term plan for their removal, replacement or repair should be developed.

Flooding landward of Maritime Terrace is the focus of other studies. Inundation also affects the amenity infrastructure seaward of Maritime Terrace. We advocate for a cohesive approach to flood and erosion management that aligns with the community aspiration for, and the environmental sensitivities of, the bay.

In order to develop a long-term shoreline management approach, we recommend the following:

1) Engage with the community and Iwi to ascertain the aspiration for the future of Little Shoal Bay;
2) Consider how the natural hazards may affect that aspiration;
3) Develop, in more detail, the approaches for shoreline management and select a preferred shoreline management approach;
4) Develop the details of the preferred approach;
5) Secure funding & consent to implement this approach;
6) Procure construction and construct any new measures; and
7) Monitor the performance and condition of any new shoreline management infrastructure.

1 Introduction & Site Context

1.1 Problem Definition

By the nature of its coastal location, Little Shoal Bay is exposed to a range of coastal hazards. These pose a risk to the people that use this area commercially and recreationally and public infrastructure adjacent to the bay.

The principal risks arise from inundation and erosion. Further risks include interference of drainage of stormwater and environmental degradation. Climate change will increase the frequency and severity of flooding and the likelihood of erosion causing damage to existing infrastructure.

A plan is needed to manage these risks now and into the future. This study provides an initial assessment of the condition of existing assets, an overview of coastal processes in the bay and provides initial consideration of shoreline management options. Flood risk is the subject for other studies and this report focusses on options to address erosion risk and enhance amenity value.

1.2 Geographic Location

Little Shoal Bay is situated on the north shore of the Waitemata Harbour and west of State Highway 1, the northern motorway (Figure 1). Due to the proximity to the harbour, this area is exposed to coastal inundation and erosion risk. The study area comprises the area of land seaward of Maritime Terrace. This area of land is believed to be reclaimed using arisings from the construction of the Auckland Harbour bridge crossing.

Figure 1. Little Shoal Bay location, Auckland, North Island of New Zealand (Base-maps from LINZ Data).

1.3 Land Use

The area of land seaward of Maritime Terrace (Figure 2) is largely open space with a variety of uses including:

- Intertidal area including mangrove and a small low tide amenity beach;
- Boat ramp;
- Boat hardstanding & maintenance area;
- Car parking;
- Public open space including toilets, barbeque facilities, playground and exercise facilities; and
- Birkenhead Sea Scouts building.

Centrally to the site and immediately landward of the sloping rock masonry coastal structure is an area of hardstanding, covering an area of approximately 2900 m², currently being utilised by a Council tenant to store public leisure boats. Adjoining the northern end of the boat storage area lies further hardstanding in the form of a public car park for beach access (850 m²).

Adjacent to these areas of hardstanding to the east and to the west are areas of low-lying maintained open grassed areas for recreational usage. Both rise sharply at the extremes of the site to meet with residential properties perched on the hilltop overlooking the embayment.

Existing Council facilities and tenants occupy areas within the eastern edge of this grassed area of the site. Facilities include public toilets, barbeque area, playground / outdoor exercise equipment and the Birkenhead Sea Scouts headquarters.

Situated at the western end of the site and seaward of the coastal defences is a small accumulation of sand which is visible at high-tide and is the result of natural longshore processes in the area. This sand accumulation has buried the existing coastal structures for this area.

Figure 2 - Little Shoal Bay Embayment. Source Linz Data Service

To the north of the road is a large area of wetland and a recreational area consisting of tennis courts, bowling green and an expanse of level playing fields utilised for recreational cricket (~13,500 m²).

1.4 Bathymetry and Topography

1.4.1 Bathymetry

Little Shoal Bay bathymetry is characterised by low-gradient tidal flats in the intertidal zone and the subtidal zone (the area only infrequently exposed, during extreme low tides). This low gradient intertidal area, with small perched upper beach area, extends approximately 1 km offshore until the bathymetric slope drops to connect to the deeper main Waitemata Harbour channel.

Due to the low-energy conditions, Little Shoal Bay beach consists of relatively fine sediments. Since tidal currents increase in strength for larger water depths, the finest sediments occur on the mudflats and the upper intertidal zone, and the coarser sandy sediments occur in the lower intertidal zone.

Little Shoal Bay embayment depths indicate that there is a slight elevation in bed level across the embayment from Needles Eye Reserve to Halls Beach Reserve.

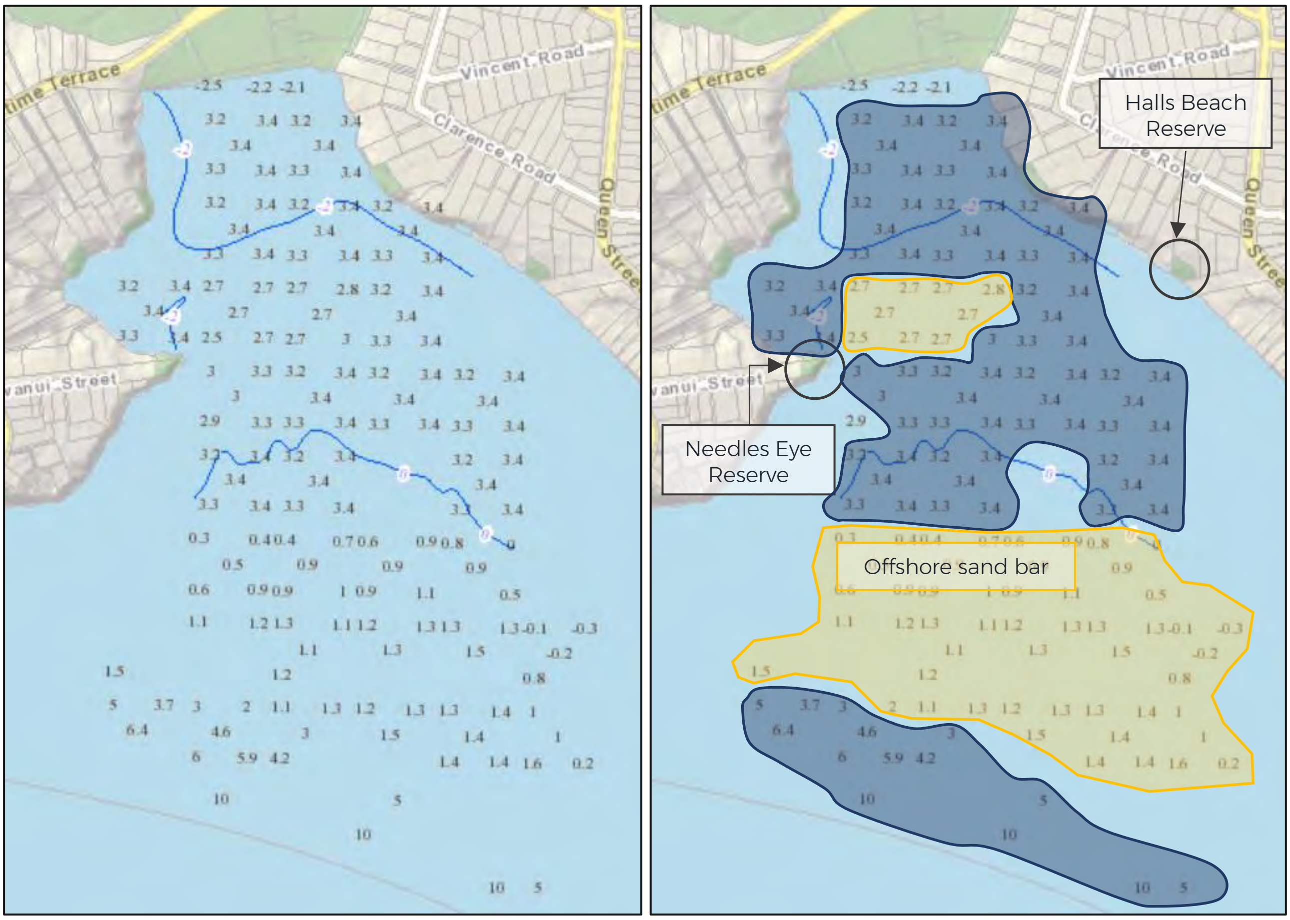

Figure 3. The images above both depict the Little Shoal Bay Bathymetric contours and for clarity the image on the right has been marked-up to identify the shallower areas (assumed offshore sand bars) and deeper area within the embayment (Source: Auckland Council GeoMaps)

Figure 4. Photograph of Little Shoal Bay from Needles Eye Reserve at low tide.

1.4.2 Topography

Contour data has been obtained from Auckland Councils Interactive GIS system Geomaps. The bay is within the lower lying area of the embayment overlooked by steep vegetated cliff faces to both the east, west and from the north.

Landward of the existing coastal defences the terrain is low lying and typically has an elevation of 1.5-2.0mAVD. This includes the boat yard hardstanding area, public facilities and barbeque recreational areas. The terrain rises steeply from this low-lying area at both the eastern and western extremes of the site from 2.0mAVD rising to 15.0mAVD at an approximate gradient 1v:1.5h. The topography rises even more steeply 1v:0.5h to the east of the site.

The Birkenhead Sea Scout Club house located is slightly raised within land that rises from approximately 2.75–4.5mAVD. The public playground situated to the north has an elevation of 3–5mAVD.

Maritime Terrace follows the contours of the surrounding open grassed / wetlands to the north and the hardstanding / public recreational facilities to the south (2.0 m AVD). The carriageway rises steadily with the terrain in the east at a gradient of 1:15 and 1:7 to the west.

Figure 5 - Topography of Little Shoal Bay area

1.5 Geology and Beach Characteristics

The area surrounding Maritime Terrace comprises of made ground formed through land reclamation during the construction of the Auckland Harbour bridge. This made ground is underlain throughout the area by interbedded and graded Sandstone, Siltstone or Mudstone as part of the Waitemata Group formed during the early Miocene epoch approximately 16 – 23 Ma (million years ago). (GNS, 2017).

Situated north-east of the site approximately 1.5km lies a basaltic lava flow from a now extinct volcano at Lake Pupuke. The lave flow stretches approximately 2km from source towards the site and consists of basalt lava, scoria cones, volcanic breccia, ash, lapilli and lithic tuff. The basaltic lava flow forms part of the Kerikeri Volcanic Group formed 2.6 Ma.

The foreshore deposits at the site consist of coarse to fine grained sediment with shell deposits, and the bathymetry within the embayment is a low-gradient tidal flats in the intertidal / subtidal zones and fluctuates by approximately 0.1 – 0.2m. Present further offshore are raised sand bars that are approximately 0.5 – 0.7m higher than the surrounding tidal flats.

1.6 Historic Context and Development of the Current Shoreline

Little Shoal Bay is a highly modified coastline and the aerial photography below shows that the study area was once an open tidal inlet (Figure 6, Figure 7 & Figure 21). The land seaward of Maritime Terrace has been reclaimed and comprise of surplus material deposited from the Auckland Harbour Bridge development and from historic industrial activity (Morphum Environmental Ltd, 2018).

Figure 6. Aerial Photography of Little Shoal Bay taken in June 1947 (Retrieved from Morphum Environmental Ltd (2018); Original source: Whites Aviation, Alexander Turnbull Library Collection).

Figure 7. Aerial Photography of Little Shoal Bay taken in March 1957 (Retrieved from Morphum Environmental Ltd (2018); Original source: Whites Aviation, Alexander Turnbull Library Collection).

Morphum Environmental Ltd (2018) describes the historical evolution of the area, with emphasis on the changes to the local stormwater drainage system. The drainage system changed from a natural drainage pattern to the construction of an open estuarine channel, followed by the placement of a large 1350 mm concrete culvert pipe along the western border of Little Shoal Bay in 1969.

Further modifications to the drainage system at Little Shoal Bay included:

- Construction of a high flow bypass (box culvert) under Maritime Terrace to increase the discharge capacity from within the Waitemata catchment (Figure 18) (Morphum Environmental Ltd, 2018).
- Land reclamation to the seawall now lining the inner part of Little Shoal Bay.
- Roadway development through Little Shoal Bay and other connection pathways.
- On the southern side of Maritime Terrace, the construction of a boat hardstand area.
- Creation of several recreation/sports areas.
- Formation of a new wetland/estuarine complex behind the reclaimed areas which were originally coastal embayment habitats.

2 Coastal Infrastructure Condition Assessment

2.1 Coastal Infrastructure

Little Shoal Bay benefits from a range of coastal infrastructure assets including:

- Seawalls (various forms of construction);
- Amenity beach / foreshore;
- Boat ramp;
- Groyne;
- Mangrove; and
- Stormwater culverts

The following notes and photos present an assessment of the condition of these asset as recorded during a site visit on the 30th of October 2019.

2.2 Seawalls

The reclaimed land within the bay includes a seawalls of various construction techniques (including mass & reinforced concrete walls, grouted rock walls).

Figure 8. Little Shoal Bay hard coastal structures

The seawalls are generally in fair to good condition with no obvious signs of displacement (cracking slumping, rotation, displaced blocks, etc.).

Some areas of foreshore lowering/undermining were observed along the eastern side of the embayment (Figure 9). It is likely that the erosion/undermining at the toe of the seawall is due to wave action causing bed lowering.

Figure 9. Undermining of grouted rock seawall on the eastern boundary of Little Shoal Bay.

There are some areas of local erosion and outflanking (Figure 12) at the ends of the existing seawalls.

Figure 10. Localised erosion on the eastern side of bay

2.3 Amenity Beach & Foreshore

There is a small amenity beach accessible at low tide. Some material has also accumulated updrift of the groyne (see Section 2.4). Some areas of the foreshore show small accumulations of debris at the high tide line.

Limited sediment input from offshore has been identified by observing intertidal bar growth (McNeil, 2001). The main sediment sources for Little Shoal Bay were identified to be cliff erosion, shell material and fine material from freshwater outflow (McNeil, 2001).

We have not been able to obtain any long-term records to support analysis of changes in beach sand volumes over time. Analysis of historic aerial photographs suggests that the position of the high tide line has remained stable (influenced by the presence of the seawalls). By inspection of the seawall, it appears that the eastern side of the bay has lost a quantity of material since the construction of the seawall. A vertical lowering of the foreshore landward of the seawall is estimated in the order of 200-500mm at the toe (Figure 9).

Figure 11. Eastern side of Little Shoal Bay showing accumulation of sediment and debris.

In the intertidal area, small wave ripple bedforms were observed (Figure 12). An absence of current bedforms suggests that orbital wave velocities generally govern the movement of deposited bed sediment rather than tidal currents. Tidal currents alone are only strong enough to transport very fine material during flood tides, when current velocities are highest, with wave energy playing an important role in sediment transport and resulting morphology. However, there is potential for fine sediments re-suspended in the water column by high wind-wave action would be removed by an ebb tide.

Figure 12. Small wave ripples on foreshore during low tide

2.4 Groyne

A groyne consisting of bulk bags each filled with approximately 1m^3 of sand (Figure 14) has been constructed adjacent to the concrete pipe and stormwater outfall. This structure has accumulated a small quantity of sediment on the updrift side. The difference in bed level between the east and west side (i.e. sediment deposition on the eastern side) of the structure indicates movement of sediment from east to west (Figure 14).

By inspection of satellite imagery (obtained from Google Earth), the construction of the groyne appears to have had only a very local impact on sediment movement. There is no evidence of erosion leeward of the groyne.

We estimate the extent of the accumulation of sediment to be approximately at a length of 15m seaward of the existing seawall and approximately 25m updrift along the shoreline. Assuming a triangular plan form and a typical depth of between 0 and 1m the total volume of accumulated sand could be in the region of 200m^3. A site topographic survey is required to assess these volumes more accurately.

The construction of a single groyne has had limited effectiveness in forming an amenity beach at the scale of the wider bay. In order to develop such an amenity beach across a wider width of the bay, it is likely that many groyne structures would be required. Further nourishment is likely to be required to supplement the modest amounts of sediment supplied by natural processes. This is discussed further in the shoreline management options section of this report.

Figure 13. Construction of groyne structure to retain sediment on the eastern side, and the outlet located on the west of Little Shoal Bay

The bags appear to be in fair condition with minor displacement and no obvious splitting or spilling. Such structures are typically temporary in nature with relatively short working lives. Deterioration and failure of the bags should be anticipated and bags removed (or replaced) before they fail to reduce the likelihood of release of plastic fibres into the environment.

Figure 14. Groyne structure consisting of commercial sandbags with the aim of disrupting the cross-shore sediment movement (Left: Photograph from WSP site visit on the 30th of October 2019; Right: Stuff.co.nz (July 31st 2019).

2.5 Boat Ramps / Foreshore Access

The foreshore can be accessed at two locations. The first is directly from the hardstand area and the second is approximately 100m due east at the end of the concrete wall.

The vertical/inclined seawall along Little Shoal Bay includes boat ramps (Figure 15, Figure 16). Both access points appear in fair to good condition with no obvious structural defects. Both access points are covered in sand and debris.

Figure 15. Boat ramp

Figure 16. Debris and sediment accumulated on the top of the boat ramp

2.6 Mangrove

Mangroves are present on the western side of the embayment. Mangroves are known to trap sediment and accelerate land-building processes in tide-dominated coastal environments (Chaudhuri, et al., 2019). Figure 17 shows mangroves at the western edge of Little Shoal Bay which appear to have locally increased foreshore level by trapping sediment.

Figure 17. Mangroves at the western side of Little Shoal Bay

2.7 Stormwater Culvert

Twin box culverts discharge stormwater at the western end of the bay. No internal inspection has been undertaken but the culverts appear to be in fair condition. One of the culverts is partially blocked by debris and vegetation which would reduce the capacity to discharge stormwater.

Figure 18. Box Culverts in Little Shoal Bay, showing the left box culvert partially blocked by debris and vegetation

3 Coastal Processes

3.1 Water Levels

3.1.1 Water Levels and Climate Change

Tide Levels for Auckland Port are provided by LINZ Service Data. By using the LINZ Data Service standard port tidal levels[1], the MSL offset to AVD-46 would be 0.16 m. Table 1 shows the tidal levels for the Port of Auckland, converted from Chart Datum (CD) to Auckland Vertical Datum 1946 (AVD-46).

Table 1. Tidal level elevations converted to AVD-46 from LINZ Service Data Auckland Port.

MHWS	MHWN	MLWN	MLWS	Spring Range	Neap Range	MSL	HAT	LAT
1.62	1.08	-0.74	-1.29	2.91	1.82	0.16	1.96	-1.69

Mean sea-level (MSL) offset to AVD-46 was recalculated for the Waitemata Harbour and Port of Auckland (NIWA, 2013), giving a resulting MSL of 0.15 m AVD-46. The extreme sea-level for Little Shoal Bay are shown in Table 2 for different Annual Recurrence Intervals (ARI).

Table 2. Present day extreme sea-level (excluding waves, w.r.t. AVD-46) in the Waitemata Harbour, Little Shoal Bay, location 9 in original document (NIWA, 2013).

ARI (years):	2	5	10	20	50	100	200
Water level (m AVD-46)	2.10	2.18	2.23	2.29	2.36	2.41	2.46

The above extreme water levels were derived using hydrodynamic models, which were calibrated against tide-gauge and wave buoy measurements to obtain both storm-tide and wave set-up outputs along the coastline (NIWA, 2013).

3.2 Waves

The Waitemata Harbour entrance faces the waters of the Hauraki Gulf with the Coromandel peninsula and islands situated eastwards of the Waitemata Harbour. These islands provide a natural barrier of protection to the harbour waters from incoming eastern waves, making the study area a naturally sheltered zone.

The Waitemata harbour is a tidal-dominated estuary. Tidal currents dominate wave energy and control the morphodynamic behaviour (Bosboom & Stive, 2015). The Waitemata Harbour entrance statistics[2] are shown in

[1] LINZ Data Service standard port tidal levels: https://www.linz.govt.nz/sea/tides/tide-predictions/standard-port-tidal-levels (last accessed 30th of November, 2019)
[2] To access MetOcean Solutions visit https://metoceanview.com/

Table 3, They indicate that the Waitemata Harbour entrance is a low wave energy area with most counted waves being under 0.5 m.

Table 3 Wave data statistics for Waitemata Harbour entrance. Data from MetOcean Solutions Limited MSL SWAN model for the Hauraki Gulf.

	Model grid data point location	Highest monthly average mean wave height	Wave count			Dominant incoming wave direction
			Wave heights between 0 and 0.5 m	Wave heights between 0.5 and 1.0 m	Wave heights between 1.0 and 1.5 m	
Waitemata Harbour entrance	36.836S 174.822E	0.13 m	96.26%	3.70%	0.04%	North

The Waitemata Harbour is a tide-dominated but naturally sheltered area from wave action from the wider Hauraki Gulf. Little Shoal Bay constitutes an embayment within the Waitemata Harbour, and is therefore further protected from offshore waves. Wave energy is dissipated through processes of refraction as they travel over different depths, diffraction around headlands, shoaling and friction.

3.2.1 Wave and Wind Climate

Even though offshore wave action is low, wind generated waves, or fetch limited waves, can impact Little Shoal Bay. The fetch limited wave height at a location inside the harbour can be assessed for a known directional wind speed and fetch length.

Directional wind speeds have been assumed for Little Shoal Bay in accordance with design code AS/NZS 1170.2:2011. The 10 and 50-year ARI directional wind speeds are presented in Table 4.

Table 4. Extreme wind speeds from AS/NZS 1170.2.2011.

ARI (years)	Directional wind speed (m/s)							
	N	NE	E	SE	S	SW	W	NW
10	31	34	36	34	31	34	36	34
100	37	41	43	41	37	41	43	41

The values obtained for the Auckland region using the AS/NZS 1170.2.2011 are considered to be conservative for Little Shoal Bay. The Hauraki Gulf hindcast model by MetOcean also provides wind information, including extrapolated wind extremes. Extrapolate extremes using a Gumbel distribution are shown below in Table 5, and the wind rose diagram showing an annual prevailing SW direction is presented in Table 6.

Table 5. Wind data extreme values for Waitemata Harbour entrance. Data from MetOcean Solutions Limited MSL SWAN model for the Hauraki Gulf.

ARI (years)	Wind speed (m/s)
10	18.5
100	21.6

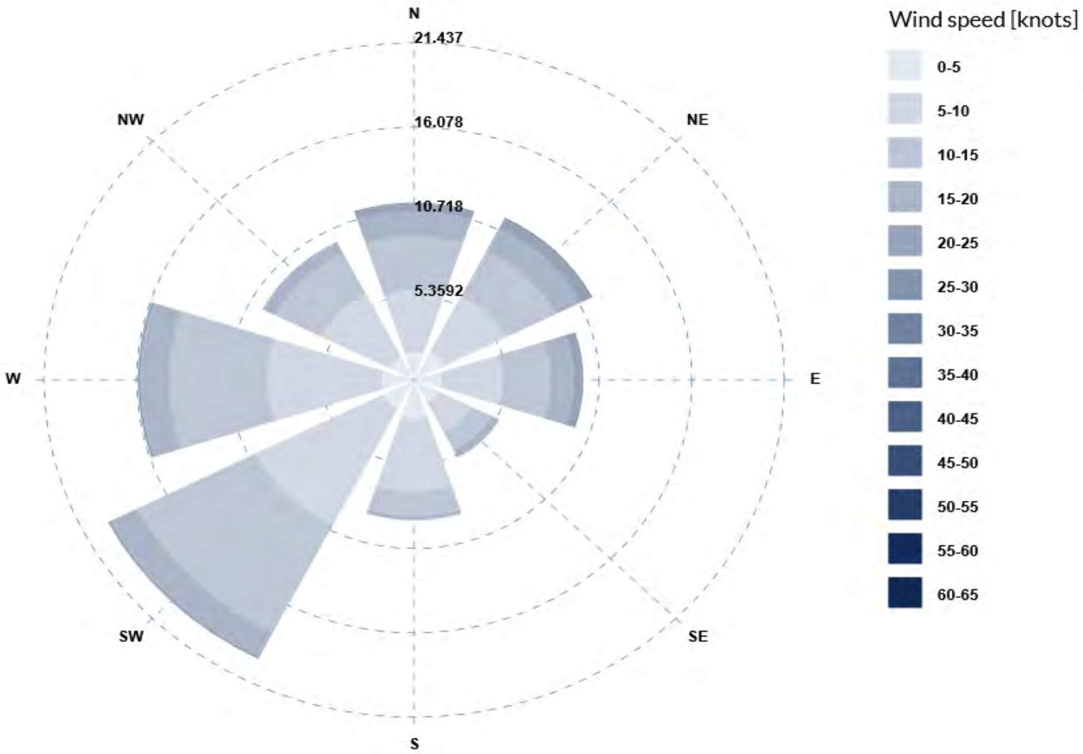

Figure 19.Wind rose diagram for the Waitemata Harbour entrance, annual wind speed [1 knot = 0.514 m/s] (Source: MetOcean Solutions Limited MSL SWAN model for the Hauraki Gulf)

Figure 20. SW fetch distance from Little Shoal Bay (Measured with Auckland Council's Geomaps viewer: https://geomapspublic.aucklandcouncil.govt.nz/viewer/index.html)

Several methods were used to calculate the wind generated waves, these include fetch and wind speed forecasting curves from USACE (1984), BS (2000) and Groen & Dorrestein (1976). Given the information provided in Table 4 and Table 6, a maximum fetch available was measured as shown in Figure 20. It should be noted that the distance of the fetch, at high tide, is approximately 4.7 km from the southwest with wave energy considered to be interrupted by the presence of the Meola Reef located within the Waitemata Harbour, approximately 2 km northeast of Point Chevalier / Coyle Park. The region will be subject to an increase in wave height during strong winds from a west-southwest direction resulting in wave refraction across the site from Halls Beach Reserve.

The fetch-limited wind wave results are shown in Table 6 below.

Table 6. Calculated fetch-limited wind generated waves.

ARI (years)	USACE (1984)		BS (2000)		Groen & Dorrestein (1976)	
	Wave height	Period	Wave height	Period	Wave height	Period
SW wind speeds from AS/NZS 1170.2.2011						
10	1.10	3.20	2.00	5.00	2.00	3.60
100	1.35	3.40	2.50	5.50	2.00	3.60
Wind speeds from MetOcean Solutions Limited MSL SWAN model for the Hauraki Gulf.						
10	0.70	2.70	0.90	3.60	1.30	3.00
100	0.74	2.80	1.20	4.00	1.10	2.80

If considering the wind speeds from the MetOcean Solution hindcast model which are more realistic for Little Shoal Bay, and not as generic as the extreme wind speeds calculated for the Auckland region with the AS/NZS 1170.2.2011, the results are as follows:

- The USACE (1984) curves for 9 m depth was used assuming an average bed level of approximately -6 m CD on LINZ Chart NZ 5322 with 3 m of water elevation along the subtidal areas. This curve yielded an approximate fetch limited wave height around of 0.70 m and wave periods of less than 3.00 s for both annual recurrence intervals selected.
- By comparison the chart in BS (2000) gave approximate wave heights of 1.00 m and wave period of approximately 4.00 s.
- The Groen & Dorrestein (1976) chart, with a 30 m/s wind speed limit of applicability, provided the highest waves of 1.10 m and 1.30 m, with wave periods around 3.00 s.

Wells-Green (1975) studied currents, waves and sediment transport in the upper Waitemata Harbour: the largest observed wave occurred during 10.3 m/s easterly wind and was of the order of 0.49 m high with a period of 2.4 seconds. The Upper Waitemata Harbour eastern fetch length is greater than Little Shoal Bay's SW fetch length, indicating that an equivalent condition for Little Shoal Bay would likely have generated smaller waves. Little Shoal Bay wave climate is therefore considered to be calm throughout most of the year.

3.2.2 Vessel Generated Waves & Sediment Transportation

Another aspect to consider within the Waitemata Harbour is the vessel generated waves. A research paper by Osborne & Boak (1999) measured waves, currents, suspended sediments and beach morphological responses using fast-response sensors over 13 months at Torpedo Bay.

Torpedo Bay is located at the entrance of the Waitemata Harbour, and, therefore, it is more exposed to ship induced waves than Little Shoal Bay: It is considered that the results found in Osborne & Boak (1999) could be extrapolated to Little Shoal Bay with a degree of conservatism.

The main finding of this study (Osborne & Boak, 1999) are the following:

- Vessel generated waves reach maximum heights of 0.85 m, with an average significant wave height of 0.3 m.
- The periods associated with the vessel generated waves oscillate between 2 and 6 seconds on the foreshore.

- The vessel generated waves groups presented a nonlinear form, making them able of entraining and suspending significant quantities of bottom sediment, which results in nearshore increased turbidity.
- The vessel generated waves resulted to be a substantial amount of the total available energy to transport sediment at Torpedo Bay. Vessel generated waves showed to contribute to sediment transport as much as twice relative to wind-generated waves.

In spite of the short-term fluctuations in seabed elevation of up to ± 10 cm in response to large vessel induced waves, and the induced sediment transport, the net effect of both wind and vessel generated waves on sediment transport and foreshore response appeared to be insignificant (Osborne & Boak, 1999).

Assuming that sediment composition is similar in both bays, the stated findings and conclusion may be applicable for Little Shoal Bay in a smaller scale as the study area is less exposed to vessel generated waves than Torpedo Bay.

3.3 Shoreline Morphology

Little Shoal Bay is subject to accretion of sediment from the harbour and the addition of sediment from stormwater discharges that contribute to the filling of the Waitemata basin (ARC, 2008). Activities such as dredging also act to significantly alter the basins natural sediment cycle.

Aerial imagery (Figure 21) shows that Little Shoal Bay has no high-tide beach. During high tides the sea is in direct contact with the seawall and other hard-structures along the coastline.

Figure 21. 2018 - Little Shoal Bay aerial image (Source: LINZ Data Service)

A Masters Thesis entitled 'Cliff erosion in the Waitemata Harbour and Hauraki Gulf' (Brodnax, 1991) identified 4 main types of erosion in the Waitemata Harbour: mechanical wave erosion (hydraulic action, corrosion, attrition), bioerosion, sub-aerial erosion (mass movement) and erosion resulting from weathering. Calculated erosion rates in the harbour varied from 0.05 m/year and 0.35 m/year, with rates of the order of 0.125 m/year in the inner harbour (Brodnax, 1991). The sediment eroded is likely to contribute as a positive input into the sediment budget of the Waitemata Harbour.

Past studies (Brodnax, 1991; ARC, 2008; Hume, 1983; Hume & McGlone, 1986; Hume, et al., 1992) and the need for dredging of the Waitemata Harbour may be indicative of an underlying accretion process within the harbour. A more precise study on sediment budget of the harbour may be able to corroborate that assumption.

Little Shoal Bay is in an embayment within the harbour. The study area has been considered a coastal cell to describe the following observations:

- It is possible that part of the sediment from the Upper Waitemata Harbour and other discharge and/or erosion locations may be accumulating in the west side of the Northcote headland, and subsequently transported to Little Shoal Bay flats.
- Aerial imagery indicates that sediment transport takes place around the headland between Chelsea Bay and Little Shoal Bay with incoming tide: sediment transported from Chelsea Bay to Little Shoal Bay. No other satellite images indicate transport from Little Shoal Bay to Chelsea Bay, nonetheless it is believed that this is still possible during flood tides.
- Aerial imagery shows sediment transport around the Northcote headland both in west and east direction, indicating sediment movement around the headline both in ebb and flood tide.

Because of the sheltered nature of the embayment and the long Northcote headland, the embayment may tend to trap sediment. Once the sediment is trapped in Little Shoal Bay, sediment recirculation within the area is likely to occur.

3.4 Coastal Hazards

3.4.1 Erosion

Little Shoal Bay is a highly modified coastal environment where land reclamation and seawalls have influenced the evolution of the coastline. Since the reclamation, erosion risk has been managed by maintenance of the seawalls.

The construction of hard structures can lead to acceleration of foreshore lowering. This is a consequence of reflection of wave energy that can induce sediment mobilisation and transport. This can lead to removal of material seaward of the toe of the structure.

These seawalls have experienced localised undermining & erosion. Site observations along the eastern boundary of the embayment indicate foreshore bed level lowering (Figure 9, Figure 10). The magnitude of the foreshore lowering is in the range of 200-500mm though no survey has been undertaken at this stage. It is difficult to estimate the volume of material lost from the foreshore without further information.

Analysis or aerial/satellite imagery is unlikely to provide evidence for the rates of erosion given the small scale of the changes in Little Shoal Bay (vertical movements in the order of hundreds of mm) and the presence of the seawalls (limiting any lateral movement). Longer trend analysis is also not likely to be possible given the reclamation of land in the bay.

Aerial photography also shows the removal of mangroves that took place at the western side of Little Shoal Bay. The removal of mangroves may also enable the remobilisation of sediment and change the morphodynamics of the bay.

If the seawalls were to fail or be removed, it is likely that the slope landward of the walls would relax to a more stable angle. The nature of the material, location of groundwater, wave action and presence of vegetation would affect what angle the slope adjusted to. A 1v:5h slope would cause landward movement of the coastline in the order of 5-10m (assuming a retained height of between

1 & 2m). Landward movement of the coastline could threaten some of the existing landuse (car park, boat hardstand, public open space).

3.4.2 Inundation

The area seaward of Maritime Terrace has suffered from coastal inundation in recent years, especially during king tide events (Figure) (Morphum Environmental Ltd, 2018). These events directly inundate low-lying areas adjacent to the coastline and reduce the ability to drain stormwater leading to localised flooding landward of Maritime Terrace (the subject of other studies).

Auckland Council and Auckland Emergency Management have a Hazard Viewer that allows users to visualise coastal inundation for different coastal inundation annual recurrence intervals (ARI) (Figure 22).

Figure 22. Coastal inundation for present day 5 and 20-year return period

The area landward of Maritime Terrace is subject to regular inundation (with an annual exceedance probability of at least 20%). Such flooding of the boat hardstand and car park poses a risk to users of these areas and an environmental hazard should contaminants be released.

Flooding is likely to increase in frequency and severity as result of climate change. Current guidance project 2120 mean sea level could be over 1m above those experienced today (MfE, 2017). Further increased frequency and severity of storms could lead to greater overtopping volumes and increased erosion rates.

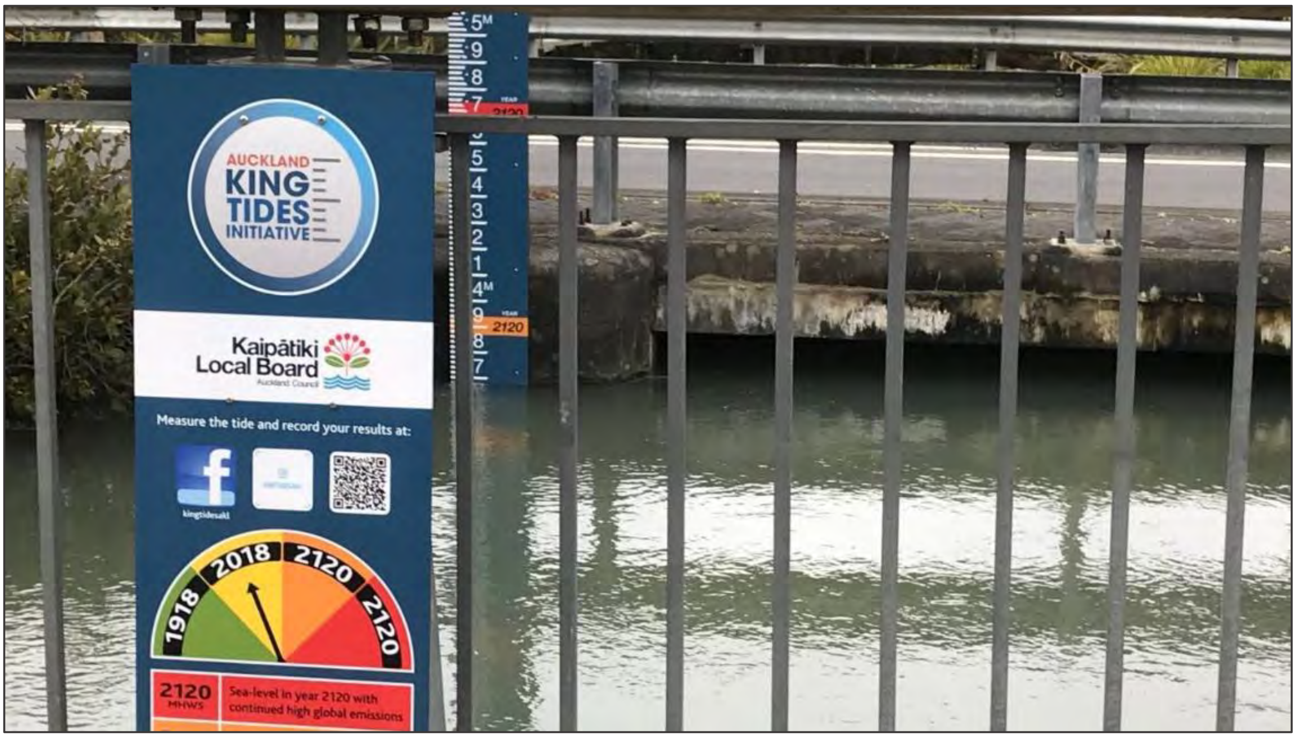

Figure 23 - Box Culverts in Little Shoal Bay, showing a mean high springs scenario almost reaching the orange line, which represents a water elevation prediction as best-case scenario of greenhouse gas emission until 2120 (Source: Stuff – Little Shoal Bay: Rising sea level)

4 Shoreline Management Options

Little Shoal bay is a sheltered (low wave energy) environment and the likelihood of an erosion event causing significant impact is low. The bay is low lying and has infrastructure in close proximity to the coast. Inundation may also release contaminants (for example paint residue or residual fuel or oil on the boat hardstand).

Consequences of erosion and inundation of land seaward of Maritime Terrace include:

- Temporary (during and immediately after the flood event) or permanent disruption to land use (e.g. boat ramp unusable, boat hardstand flooded, park inundated, loss of reserve land)
- Damage to infrastructure (flooding of buildings, erosion affecting stability of structures, damage to road or buried infrastructure)
- Environmental impact of inundation or erosion (damage to non-salt tolerant plant species, release of contaminants from inundation or erosion, loss of trees due to undermining/erosion)

A variety of shoreline management options could be implemented to reduce the likelihood or impact of the erosion risk. The desired level of service for erosion and inundation risk management is likely to depend on the consequence of the natural hazard on the land use. For example, periodic loss of beach material or repairable damage to seawalls could be managed reactively (i.e. after such an event). Sudden collapse of the seawall leading to significant damage to the boat ramp or advance buildings might be less acceptable and may warrant further investment in risk management.

Below we develop a range of options to manage erosion risk. They are likely to provide differing levels of service (i.e. different frequency and severity of erosion risk). The choice of preferred shoreline management approach will require further consideration of the future land use and the appetite for risk.

Options developed below include:

- Option 1 – Do Nothing
- Option 2 – Maintain Existing Shoreline Management Approach
- Option 3 – Protect
  - Option 3a – Beach Nourishment & Groynes
  - Option 3b – Improve seawall
  - Option 3c – Planting to manage erosion risk
- Option 4 - Adapt

4.1 Option 1 - Do Nothing

A 'Do Nothing' option is presented as a baseline against which other management approaches can be compared.

This management approach would comprise:

- Anticipate deterioration of existing seawalls
- Anticipate increase in inundation frequency and depth due to climate change
- Cease maintenance of existing erosion risk management infrastructure (a separate option is presented below that includes continued maintenance)

Existing seawalls would deteriorate and eventually fall into disrepair as erosion at the toe would continue and eventually sections of the wall will crack, rotate and collapse. With the failure of the seawall, the landward slope would relax from near vertical to a more gentle slope (perhaps 1v:5h) with a landward movement of the coast by some 5-10m. Boat access ramps would also sustain damage and eventually become unusable.

Lower lying areas around the site would be subject to increased frequency and depth of inundation. The frequency and severity of inundation may mean that land use on the areas of land behind the seawall would change eventually perhaps reverting to coastal wetland as prior to the reclamation. In the interim, saltwater tolerant uses (coastal wetland parks/reserves rather than public open spaces, boatyard & Sea Scout HQ) could occupy the space until such point that the frequency of inundation makes those uses untenable.

4.2 Option 2 - Maintain Existing Shoreline Management Approach

The second option presented is 'Maintain Existing Shoreline Management Approach'. This is likely to be the lowest level of investment (if 'Do Nothing' is discounted) but also the lowest level of service.

This option might comprise:

- Reactive maintenance to extend the life of the existing seawalls. Anticipate increasing frequency of maintenance as assets age and climate change increases loading.
- Replacement of seawalls to same levels at the end of life
- Anticipate increase in frequency and severity of inundation

The maintenance approach for the existing assets is on a reactive basis. A cycle of periodic inspections can result in maintenance activities if they reveal significant defects.

Known issues that might require intervention in the short term include undermining of the seawalls on the eastern side of the bay and end effect erosion of the same walls. Further vegetation encroachment downstream of the stormwater culverts may require intervention.

Other maintenance & operational activities may include:

- Boat ramp inspection and maintenance
- Vegetation management and mowing within parks and reserves
- Management of other council owned infrastructure (car park, picnic site, playground, toilets) which might be required more frequently if damaged by coastal hazards

- Mangrove vegetation management (i.e. planting mangrove where beneficial or removing where detrimental)

Maintaining these existing assets may be sufficient to manage the erosion risk in the bay in short to medium timeframes.

4.3 Option 3 – Protect

We present a number of 'Protect' options that look to reduce the erosion and inundation risk to the area landward of the coastline. These options are likely to require significant capital investment and will require ongoing maintenance investment to sustain the desired level of service.

Options considered include:

- Groyne field and nourishment of the beach
- Improve seawall
- Soft engineering approaches to erosion risk management

4.3.1 Option 3a – Beach Nourishment & Groynes

Creation of a wider beach could have dual benefits in terms of flood and erosion risk management and increased amenity value.

Creation of a beach in this location would likely require nourishment (import of sand) in combination with structures that reduce the risk of the sand being taken away from the beach by the ongoing morphological processes in the bay. The beach may effectively manage the erosion risk depending on the design, spacing of groynes and shape/slope of the resulting beach.

This option might comprise:

- Construction of a number of groyne structures
- Import of a significant quantity of sand
- Maintenance of the groynes and periodic top-up of the nourishment
- Periodic reprofiling the beach & reworking of the sand to sustain the desired beach profiles

The introduction of groynes (timber, rock, concrete or submerged geotextile sand filled containers) perpendicular to the foreshore has the potential to trap sediment moving within the sediment cell. This material would accrete between the groynes and over time raise to form a natural barrier increasing the areas coastal structures.


Figure 24. Timber and geotextile sand filled containers. (Photographs sourced from geograph.co.uk and researchgate.net respectively. Last accessed 22nd November 2019). Note these structures may not be appropriate for Little Shoal Bay

The coastal process review suggests that the existing temporary groyne has only accumulated modest quantities of material by natural processes. It is therefore likely that some additional nourishment will be required to supplement this material in order to create a useable amenity beach and to provide a seawall alternative (i.e. a gently sloping beach replacing/burying the existing seawall).

Figure 25 - Potential locations of groynes along foreshore perpendicular to existing coastal structures (Source: Auckland's Geomaps Interactive Viewer).

Further sediment movement and hydrodynamics investigations will be required to determine the required geometry and configuration of the groynes and to reduce the risk of impact on other regions of the Waitemata Harbour.

Nourishment may also be periodically required during the operational life of the shoreline management scheme. Further periodic beach reprofiling may be required to sustain a gentle beach profile.

The creation of an artificial beach in this location poses a number of technical challenges. Firstly the sheltered wave climate and gently sloping foreshore create a challenge to ensuring sufficient exposure to waves to ensure a self-cleaning beach (Mangor, 2017). Secondly the source of beach fill material must be closely specified to ensure it remains insitu (similar or slightly courser that natural material).

The design of an artificial beach or nourishment scheme needs more detailed consideration and better topographic information. Below we develop an initial concept based on the assumed topography and the evidence of the material retained by the ad-hoc groyne structure.

Figure 26- Initial concept for the design of an artificial beach or nourishment scheme

To create a beach the full 200m length of the little shoal bay frontage could therefore require some 3,000m³ of imported beach fill sand (assuming the above typical section). Information provided from Auckland Council relating to the Mairangi Bay scheme suggests costs of nourishment could be in the order of $100/m³ suggesting a cost of $300k for the nourishment component. The total cost of a nourishment scheme is likely to be significantly more when the cost of groyne construction, seawall demolition, accommodation/access works, design, consenting, risk contingency, etc. is added.

4.3.2 Option 3b – Improve seawall

An alternative 'Protect' option is to modify or replace the existing seawall to address the current and future erosion risk. Any seawall improvement option could also be designed to raise the crest level to reduce the risk of inundation.

This option might comprise:

- Underpinning of the toe of the existing seawall and increase the crest height; or
- Removal/burying of the existing seawall and construction of a new seawall.

The erosion at the toe of the existing seawall does not appear to have caused noticeable movement in the seawall (such movement might be evident by observation of rotation, slumping or cracking of the wall). This provides time for repairs or replacement options to be developed and implemented. Underpinning would work by filling the voids beneath the existing wall to provide a more stable foundation and fill the voids created by local foreshore lowering. Any replacement wall might include a deeper foundation to provide greater resilience against future foreshore lowering at the toe of the seawall.

To significantly reduce the inundation risk, a raised defence would need to provide a continuous crest level tying into high ground at either side of the bay. Provision would need to be made to provide access over the raised defence (by ramps or flood gates) and to provide backflow prevention on the stormwater outfalls. A raised defence is likely to need to be kept modest in height (~1m) to reduce visual impact. A walkway on top of a raised wall (or embankment) could provide another means of avoiding loss of the sea view from those using this amenity area.

Raised earthworks may provide a more cost-effective means to raise the crest (capital costs of earthworks would likely be less than that of building new seawall structures). These earthworks could be formed landward of the existing seawall and could be integrated within a landscaped park/reserve area. The trade-off might be land required to construct the raised defence meaning less space for other land uses.

This option is likely to require significant upfront capital and ongoing revenue investment. Costs are highly dependant on the nature of the works and therefore difficult to estimate. Seawalls might cost in the order of $10-20k/m. At 200m the main frontage could therefore cost $2-4m to construct.

4.3.3 Option 3c – Planting to manage erosion risk

The presence of vegetation can reduce erosion risk by holding soils/beach materials together and dissipating wave energy. Such approaches tend to have lower levels of service compared to hard structures (that is they offer less protection to erosion and may require more frequent maintenance). They require time to establish and provide the desired performance and require maintenance.

Such an option for Little Shoal Bay would change the character of the bay. It may also impede the use of the amenity beach and provide visual impact that disrupts views from the parks & reserves.

This option might comprise:

- Establishment of additional mangrove stands to reduce wave energy arriving at the shore and trap sediment
- Establishment of planted slope as an alternative to the existing seawall (perhaps removing the seawall and forming a more gentle slope that can be planted to provide some erosion protection.

Mangroves are known to trap sediment and accelerate land-building processes in tide-dominated coastal environments (Chaudhuri, et al., 2019). A soft engineering approach to management of the area could therefore comprise the introduction of the native New Zealand mangrove species (*Avicennia marina*) that thrives in the temperate climate of upper regions of the North Island of New Zealand. The flow direction / sediment movement within the bay is in an anti-clockwise motion during flood tide with the sediment transported primarily dominated by wave induced currents. Given the sheltered nature of the embayment the majority of the sediment is likely to be entrapped within this sediment cell and recirculated from Fisherman's Wharf Reserve to Needles Eye Reserve. This means there is only a finite volume of material available to be trapped by any new mangrove stands and there would be a limited build-up of the foreshore.

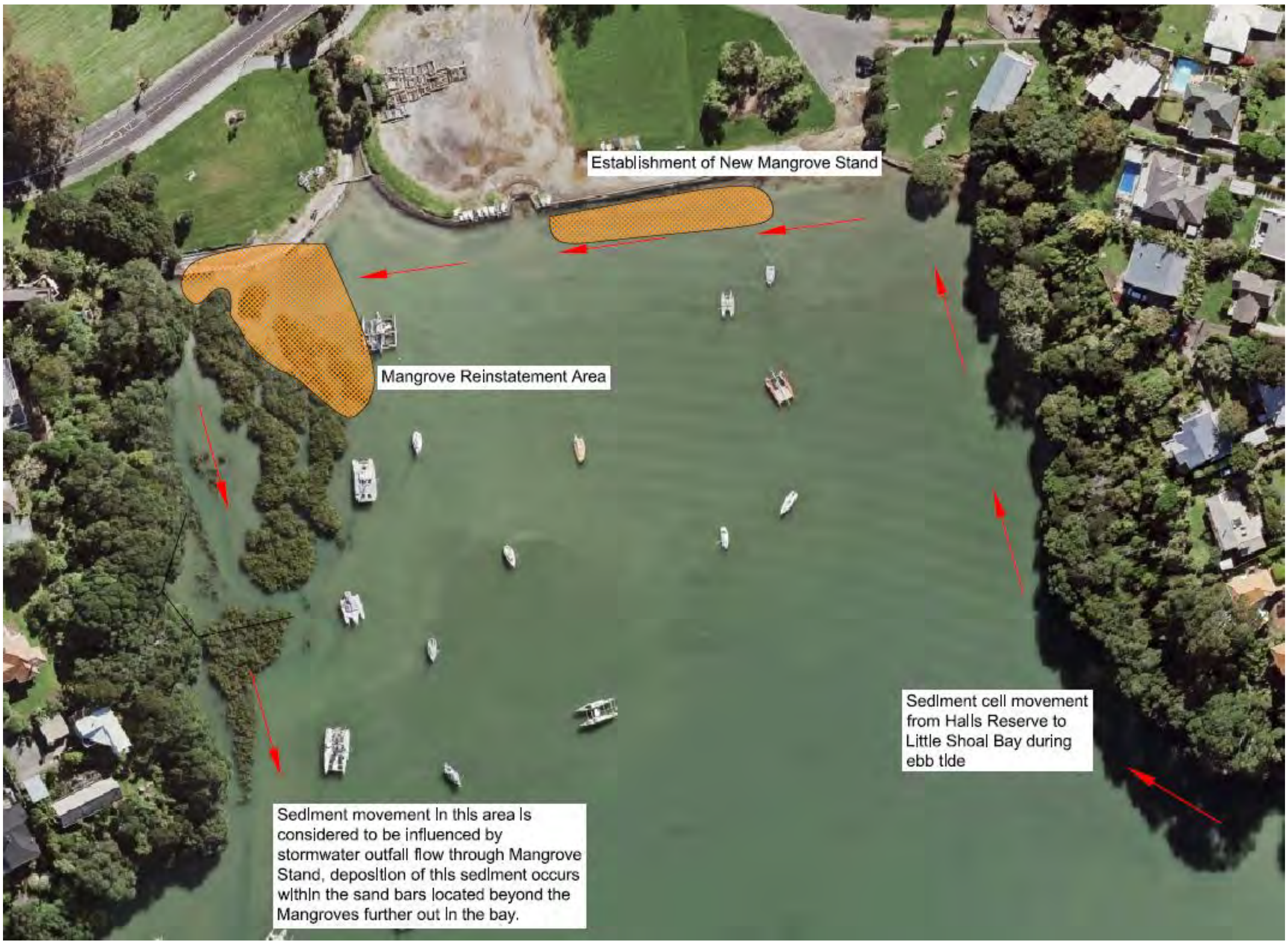

Figure 27 – Aerial imagery of Little Shoal Bay outling hydrodynamic and sediment cell movement. (Source: Auckland's Geomaps Interactive Viewer).

New Zealand Coastal Policy Statement policy 26 (2) (NZCPS, 2010) recognises the potential that mangrove stands have within the marine environment for reducing coastal erosion, and their potential to create a natural buffer against coastal hazards. Besides the reduction in coastal erosion/inundation from this option, mangroves enhance the ecological value of an area by providing nurseries for animals, refuge and protection, habitats for birdlife, and by increasing organic matter in the local environment supporting both estuarine and terrestrial fauna and flora.

The planted slope as a replacement for the seawall could comprise species similar to that recommended in Auckland Councils coastal planting guidance (Figure 28). Such a solution would require some land behind the existing seawall. Further maintenance of the slope and planting would be required after any storm damage.

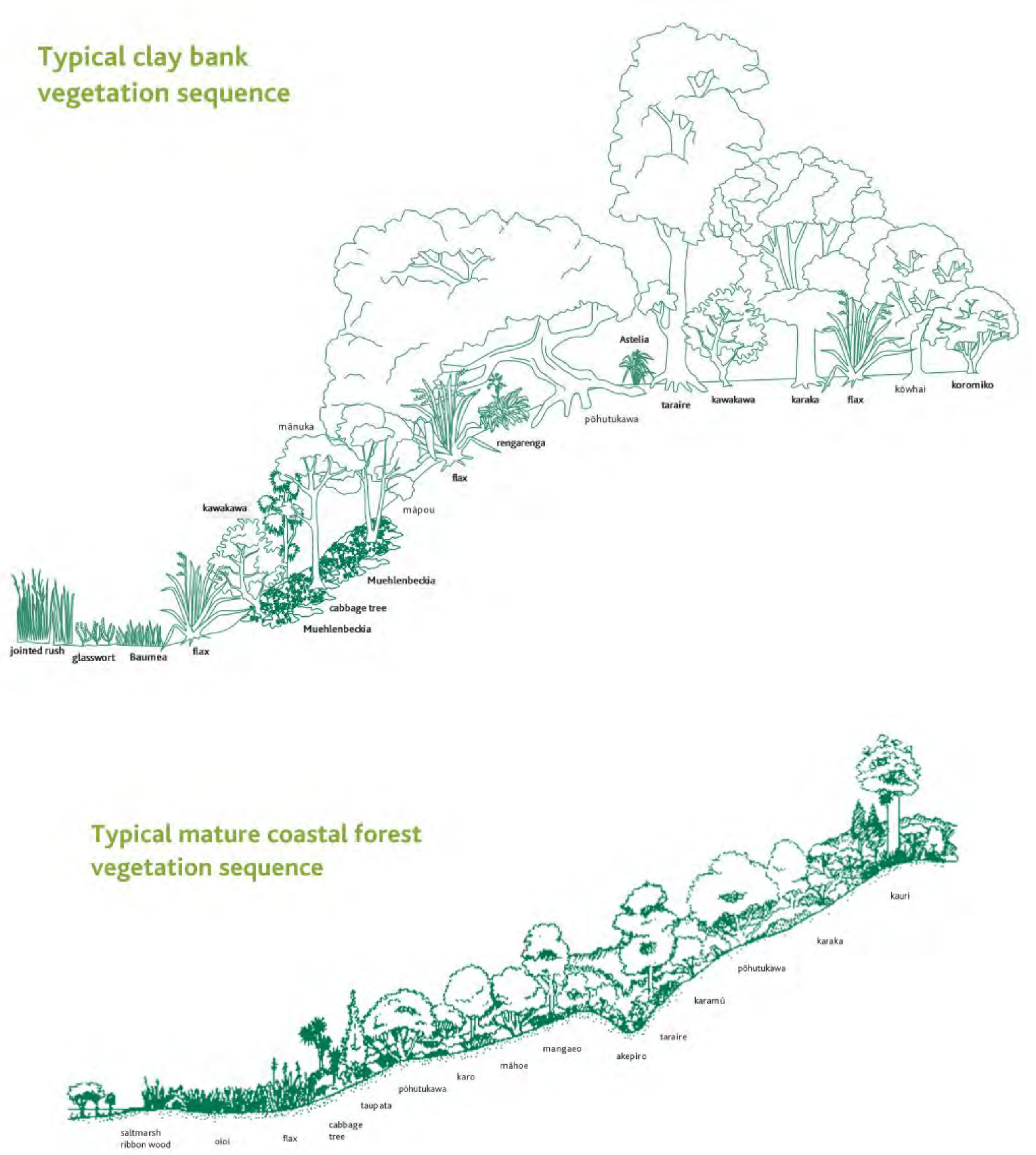

Figure 28 - Coastal planting from Auckland Council

It is unlikely that a dune planting scheme would be viable in this location due to the nature of the bay (no dry high tide beach, limited space for dune creation, limited supply of wind blown sand, etc.).

4.4 Option 4 - Adapt

An adaption response to the inundation and erosion risk involves developing alternate uses for the land that is exposed to these risks that are less sensitive to these hazards. In other words, learning to live with the risks.

The adaptation may be to the way the land is used and the amenities/facilities located in the area exposed to the risk. It might also be in the nature of the landscaping and planting to have a higher tolerance to periodic inundation with saltwater.

This option might include:

- Change of land use from boatyard/parking to reserve
- Change in planting of the seaward edge of the park with more salt tolerant species
- Relocation of some assets landward (or raised) such as the Sea Scout headquarters, public toilets, barbeque area and parking facilities.

To implement an adaptation approach, the first stage would be to identify land uses, assets and plants that might be vulnerable to damage from inundation and erosion. Options would be explored to identify alternative land uses or measures to make those assets less vulnerable (flood proofing, moving landward or raising floor levels).

These measures could be implemented immediately or at some point in the future in response to climate change. They may be implemented by direct action or potentially by plan change.

4.5 Initial Comparison of Options

Four alternative management options have been developed. Each would have a different impact on the erosion risk in Little Shoal Bay and may influence the frequency, extent and depth of flooding of the area seaward of Maritime Terrace. These options are also likely to have very different upfront (capital) and ongoing (revenue) cost profiles.

The choice of preferred option is likely to depend upon:

- The desired level of service in terms of frequency of inundation and tolerance for erosion
- The public/community/Iwi aspiration for Little Shoal Bay
- Budget available for capital and operational expenditure and appetite for risk
- The timing and severity of the impact of climate change
- The ability to obtain consent for the proposed works
- A range of physical constraints including ground conditions and adjacent infrastructure

Below is an initial qualitative comparison of options. Options have been ranked 1 (low/best) to 6 (high risk/worst). Weighting for importance may also influence the selection of preferred shoreline management approach. Cost benefit analysis and delivery risk analysis would also be required to support the selection of a preferred approach.

Table 7 - Qualitative comparison of options

Option		Erosion risk	Inundation risk	Whole of life cost	Wider benefits
1	Do Nothing	6	6	1	6
2	Maintain existing	4	5	2	5
3a	Beach nourishment & groynes	3	3	5	1
3b	Improve seawall	1	1	6	4
3c	Planting to manage erosion risk	5	4	3	2
4	Adapt	2	2	4	3

'Option 1 - Doing Nothing' and 'Option 2 - Maintain the current approach' are likely to be the lowest cost options to implement (ignoring the cost of flood and erosion damages). They are unlikely to provide an acceptable level of service into the future as the inundation risk changes due to climate change.

'Option 3a – Nourishment' and 'Option 3c - Soft Defences' offer the best opportunity to add wider benefits (such as amenity and ecological enhancement).

Lowest inundation risk is likely to be achieved by Option 3b improved defences. The crest level could be designed to reduce overtopping to a desirable/safe level during design events. This option is likely to have significant capital costs and may be difficult to consent (refer to NZ Coastal Policy Statement suggesting a preference for soft defences and seawalls only as a last resort).

Adapting land use such that it is compatible with the risk (Option 4) would likely provide a resilient shoreline management approach but would require a change to the way Little Shoal Bay is used.

Further analysis and agreement of priorities with council and stakeholders, including community and Iwi will be required in order to select the preferred shoreline management approach.

The Ministry for the Environment (MFE) advocate for an adaptive approach to risk management responding to the changing nature of the risk. It would be prudent to develop an adaptive risk management approach that recognises the community aspiration for the bay and the budgetary constraints of Auckland Council.

5 Summary & Recommendations

Little Shoal Bay is exposed to a range of coastal hazards. The existing seawalls on the eastern side of the bay are subject to undermining and, though their stability has not yet been compromised, a long-term plan for their removal, replacement or repair should be developed.

Flooding landward of Maritime Terrace is the focus of other studies. Inundation also affects the amenity infrastructure seaward of Maritime Terrace. We advocate for a cohesive approach to flood and erosion management that aligns with the community aspiration for, and the environmental sensitivities of, the bay.

We recommend the development of a long-term adaptive shoreline management approach. Such a programme of work might include:

1) **Engagement with the community** and Iwi to ascertain the aspiration for the future of Little Shoal Bay. Understanding the aspiration for the bay would enable consideration of the impact of any shoreline management scheme to be understood. Further it might provide opportunities for delivering wider benefits from a shoreline management approach and it might identify additional funding sources and assist in building support before any lodgement of consent applications. Engagement is likely to continue throughout many subsequent stages of design, consenting, construction and operation/maintenance;

2) **Consider how the natural hazards may affect that aspiration**. The current and future risk is likely to influence how Little Shoal Bay can be used by the community. Overlaying the community aspiration with the current and future hazard will enable consideration of this interaction;

3) **Develop the approaches for shoreline management** and **select a preferred option**. The selection of a preferred option depends on a wide number of variables. Typically, business cases for investment and multi-criteria analyses have been used to select the prefered management approaches for shoreline management. Further the transition from current management to future approach needs to be considered. Adaptive pathways are currently advocated to provide resilient communities into the future in response to climate change;

4) **Develop the details of the preferred approach**. Further data will be required to support the development of the preferred shoreline management option. This might include environmental, topographic, geotechnical parameters, landownership details, buried service information, contaminated land information, etc. that will be required to understand the performance of any future shoreline management option. Refinement of the concept will enable consideration of the impact of the proposed approach on the community and environment;

5) **Secure funding & consent to implement this approach**. Funding for shoreline management and management of the parks and reserve and adaptation to climate change may come from a number of sources (including public and private bodies). These funding sources will have differing requirements and timeframes to secure funding. Shoreline management works may require a range of consents under the Resource Management Act and other pieces of legislation. Works below the mean high water mark also require additional consents;

6) **Procure construction and construct any new measures**. Procurement of shoreline management works will require preparation of a range of contractual documents (drawings, specifications, construction contracts, etc. Depending on the funding sources, different procurement approaches might be required. Once a construction contractor has been selected and appointed the construction can be undertaken. Careful consideration of timing of the construction works may be required (especially for earthworks and planting). Public use of the beach will also vary, and works may be required to avoid peak beach usage times. Construction duration will be dependent upon the nature of the works; and

7) **Monitor the performance and condition** of any new shoreline management infrastructure. Whichever approach is selected and implemented it is suggested that ongoing monitoring of performance will be required and maintenance of the assets should be anticipated. This may include maintenance by both Auckland Council and perhaps local community groups (common in the case of planting schemes, beach clean-ups etc.).

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Appendix A
Little Shoal Bay - Coastal Processes and Risk Management Assessment)

(Ecological Assessment for Coastal Processes and Concept Design Assessment)

ENVIRONMENT
& HEALTH

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Little Shoal Bay – Ecological Assessment for Coastal Processes and Concept Design Assessment

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Dear Ryan,

This letter provides a high-level ecological assessment of the concept designs prepared by WSP NZ for Auckland Council to support the development of a long-term management plan for the Little Shoal Bay area.

Scope of Assessment

Little Shoal Bay is on the western coast of Northcote Point in Auckland. The bay is low-lying and prone to coastal inundation and erosion, and there are increasing risks from the effects of climate change, specifically from predicted sea level rise. To address these issues, WSP NZ have prepared a high-level coastal processes and concept design assessment. This ecological assessment has been prepared by Ramboll NZ to complement the WSP NZ assessment. We provide an assessment of the potential ecological outcomes of the five concept assessment approaches considered by WSP NZ.

The concept design options for Little Shoal Bay as proposed by WSP NZ are:

- Option 0 – Do Nothing: Ongoing monitoring of coastal inundation.
- Option 1 – Managed Retreat: Removal/relocation/realignment of assets, buildings, services.
- Option 2 – Protect: Mangrove reinstatement or planting additional mangroves.
- Option 3 – Protect: Realignment of existing seawall.
- Option 4 – Protect: Groyne construction along foreshore.

Ecological Setting

Little Shoal Bay, within Waitemata Harbour, is part of a tidal-dominated estuary with tidal flats exposed during low tide. Little Shoal Bay has a highly modified coastline with development occurring over the last 70 years, as described by WSP NZ, including land reclamation, construction of seawalls, roadways and other pathways, modifications to the drainage system, and formation of an estuarine wetland. Such modification has shaped the current ecological values of the bay. There is no high tide beach as seawater extends right to the seawall and constructed defences; at low water, the tide has retreated outside the confines of the bay, meaning that the entire bay is an intertidal environment. This intertidal zone extends to approximately 1 km from shore where the slope drops distinctly to the main channel within the harbour and covers approximately 7.3 ha. Mangroves are present on the western side of the embayment, over an area of approximately 3,600 m^2. Little Shoal Bay is dominated by fine sediments, particularly in the upper intertidal area.

Parts of the bay and surrounding terrestrial environment are identified as Significant Ecological Areas (SEAs) under the Auckland Unitary Plan (2019[1]), as listed in Table 1.

Table 1 List of Significant Ecological Areas from the Auckland Unitary Plan (2019) in the vicinity of Little Shoal Bay.

Significant Ecological Area	Description
SEA-M2w	Areas that are identified as significant wading bird areas. Covers most of the bay and all mangroves but excludes the zoned mooring area. SEA-M2 areas are of regional, national or international significance which do not warrant an SEA-M1 identification as they are generally more robust.
SEA_T_8169	The wetland on the northern side of Maritime Terrace Identified for all five values considered in the Unitary Plan – representativeness; threat status and rarity; diversity; stepping-stones, migration pathways and buffers; and uniqueness or distinctiveness.
SEA_T_8177	Small area of terrestrial vegetation at the end of Awanui Street. Identified for representativeness, threat status and rarity, and as a stepping-stone, migration pathway or buffer
SEA_T_8179	Clifftop terrestrial vegetation amongst residential streets on the western side of Little Shoal Bay. Identified for representativeness, and threat status and rarity.
SEA_T_8226	Clifftop terrestrial vegetation along the eastern edge of Little Shoal Bay. Identified for representativeness, and threat status and rarity.

[1] https://unitaryplan.aucklandcouncil.govt.nz/pages/plan/Book.aspx?exhibit=AucklandUnitaryPlan_Print

Based on a high-level examination of the current conditions at Little Shoal Bay, the ecological value of the intertidal marine environment within the bay is moderate to high[2], primarily with reference to wading birds.

Based on a high-level examination of the current conditions at Little Shoal Bay and the location of SEAs, the ecological value of the surrounding terrestrial and wetland environment is high to very high, primarily with reference to regional representativeness and rarity, and the very high ecological values attributed to wetlands nationally. The terrestrial ecology of most importance to this assessment is the wetland because this area is currently affected by coastal inundation. The clifftop vegetation is very unlikely to be influenced by the proposed concept design options.

Ecological Outcomes of Concept Design Options

Option 0 – Do nothing
Observations made during site visits in late 2019 indicate that some of the existing habitat modifications and the current hydrological conditions are having ongoing impacts on the ecological values of Little Shoal Bay. Specifically, these include:

- Erosion (introducing terrigenous sediment and material into the coastal environment);
- Coastal inundation (resulting in deposition of sediment and waterborne debris in the intertidal zone and transitioning of low-lying terrestrial vegetation to saltwater tolerant species); and,
- Unauthorised construction in the coastal marine area (resulting in intertidal habitat disturbance and loss).

These ecological effects would continue to occur under Option 0.

These effects are known, direct and ongoing, and occur throughout the extent of the bay and into the low-lying terrestrial areas. The magnitude of these ecological effects is likely to remain low in the immediate future (5-10 years) being a minor shift away from existing conditions but with discernible changes to the underlying character, but possibly resulting in a moderate to high magnitude of effects in the longer term (50-100 years) as climate change effects have a greater impact as the loss or alteration of one or more key elements (i.e., intertidal area becomes subtidal, changes from terrestrial to saltwater tolerant vegetation) of the existing conditions are partially or fundamentally altered.

Therefore, the potential level of ecological effects from Option 0 for the intertidal region is very low to low in immediate future but may be moderate further in time, and for the low-lying terrestrial habitat is low to moderate in the immediate future but high to very high further in time.

Option 1 – Managed retreat
Option 1 involves the removal of coastal protection and relocation or realignment of assets, buildings and infrastructure further inland as part of a long-term plan. This option would ultimately result in the low-lying estuarine area being reclaimed by the rising sea. The potential magnitude and level of effects of Option 1 would be the same as for Option 0 in the immediate term. That is, erosion, inundation and habitat alteration resulting in very low to low levels of effects for the intertidal zone and low to moderate levels of effects in the low-lying terrestrial area.

However, in the long-term and in consideration of continual sea level rise, the magnitude of ecological effects on both intertidal and low-lying terrestrial areas would be very high with the total loss or very

[2] The assessment of ecological effects follows Ecological Impact Assessment (EcIA) guidelines produced by the Environment Institute of Australia and New Zealand (EIANZ, 2018). The EcIA approach has been developed for terrestrial and freshwater ecology, while this assessment focussed on the coastal marine area (CMA). However, the EcIA guidelines has been adapted herein for the marine environment, and the purpose of the EcIA is applicable, such that, the approach is "to provide reliable information about, and interpretation of, the ecological implications of any project or policy".

major alteration to key elements of the existing baseline conditions such that the character will be fundamentally changed or lost. More specifically, this option would result in the loss of current wading bird habitat in the foreshore and in notable alterations to the wetland as it exists.

These changes should be weighted against be the presence of newly created marine and coastal habitat that may still be suitable for wading birds and possibly the extension of the wetland which would improve the representativeness of this type of habitat regionally and nationally. On balance, we consider that, from an ecological perspective, Option 1 is more likely to result in a positive effect and net gain in ecological values.

Option 2 – Protect: Mangrove reinstatement or planting additional mangroves
Option 2 would involve the reinstatement and extension of the existing mangrove stand, some of which has been previously removed without authorisation. The New Zealand Coastal Policy Statement 2010[3] recognises mangroves as providing important ecological services that reduce erosion and create natural buffers against coastal hazards, as well as enhancing the ecological value of coastal areas through the provision of habitat for birds, macrofauna and estuarine fish.

The areas of proposed mangrove reinstatement and establishment identified by WSP NZ are both located within the marine SEA. The extent of the area proposed for reinstatement is approximately 1,000-1,200 m^2 while the extent of newly established mangrove is approximately around 800 m^2. The footprint of these habitat alterations is approximately 2-3% of the intertidal zone within Little Shoal Bay. Therefore, in the immediate term, the magnitude of habitat loss or disturbance resulting from this option would be moderate, resulting in a partial change to the ecological character, and the potential level of effects on intertidal ecology would be low to moderate.

However, in the longer term, it is possible that mangroves could expand naturally within the bay as sedimentation and infill of the bay occurs. As noted by Lundquist et al. (2014), climate change is anticipated to result in changes in mangrove distribution in New Zealand, and the ability of mangroves to respond to sea-level rise is determined by their ability to colonise and extend shoreward, the availability of suitable substratum, and whether sediment accretion balances erosional processes. Ultimately, whether naturally or as part of reinstatement and establishment, an increase in mangrove habitat in the long term would likely result in a positive ecological outcome and net gain in ecological values due to the range of ecological services provided by mangroves. It is uncertain, however, how sea level rise would affect these mangrove habitats in the far future (50-100 years). This option would maintain current terrestrial ecological values through the buffering of seawater inundation provided by the extended mangrove stands, therefore the magnitude and level of ecological effects on terrestrial values would be negligible or positive.

Option 3 – Protect: Realignment of existing seawall
Option 3 would involve the development of new sea defence structures setback to accommodate the predicted sea level rise. These structures would be setback from the intertidal zone and provide protection from coastal erosion and coastal inundation. Essentially, this option allows for a balance of ecological effects between Options 0 (do nothing) and 1 (managed retreat). The defence structures are expected to be created in areas of low terrestrial ecological value (e.g., grassed areas), and consideration of ecological impacts during construction could be readily managed with typical consent conditions such as management of vegetation removal or disturbance to for example, birds and lizards. Therefore, in the immediate term, the potential magnitude and level of effects of Option 3 would be the same as for Option 0 such that ongoing erosion, inundation and habitat alteration would result in very

[3] https://www.doc.govt.nz/globalassets/documents/conservation/marine-and-coastal/coastal-management/nz-coastal-policy-statement-2010.pdf

low to low levels of effects for the intertidal zone and low to moderate levels of effects in the low-lying terrestrial area on the shoreward side of the seawall.

In the longer term, changes to the intertidal zone would continue to occur as a result of sea level rise (i.e., to a subtidal environment) meaning the magnitude of ecological effects on intertidal areas would be very high with the total loss or very major alteration to key elements of the existing baseline conditions such that the character will be fundamentally changed or lost. However, in the longer term, the consequences of coastal inundation and erosion would be managed by the new defence structure, allowing for current terrestrial ecological values to be maintain or improved as they are afforded protection by the seawall.

Option 4 – Protect: Groyne construction along foreshore
Option 4 would involve the installation of several groynes perpendicular to the existing sea defences, to stem sediment and hydrodynamic movement within the bay, raise the primary sea defence and force the high tide line further offshore. The groynes would be constructed of timber or submerged geotextile sand containers. This option proposes the most invasive changes to the intertidal area of Little Shoal Bay. The proposed groynes would result in the immediate loss, disturbance and alteration of some intertidal habitat by the removal of soft substrate and the introduction of hard substrates. This option would have a moderate to high magnitude of effect on the intertidal zone through the, potentially, major loss or alteration of the key features of the existing conditions, specifically wading bird habitat. The introduction of new submerged substrates (timbers) also has the potential to provide ideal colonisation surfaces for invasive, non-indigenous marine species, such as the Mediterranean fanworm (*Sabella spallanzanii*[4]). These effects would be permanent, with the exception that some of the intertidal habitat may become subtidal as sea level rises. The level of potential ecological effects on the intertidal zone would be high to very high.

However, the consequences of coastal inundation and erosion on terrestrial ecology would be mitigated by this option, allowing for current terrestrial ecological values to be maintain or improved as they are afforded protection by the raising of the primary sea defence.

Closing Statement

The ecological outcomes of the five concept design options are varied for all options and when considering terrestrial or marine intertidal ecology. The key considerations in making decisions on ecological matters should include:

- Effects on wading bird habitat, which is recognised as a Significant Ecological Area under the Auckland Unitary Plan
- Effects on the intertidal seafloor, as this affects the quality and extent of habitat available to wading birds.
- Effects on the wetland habitat to the north of Maritime Terrace, as this affects a nationally and regionally threatened habitat.
- The potential for introduction of marine pests and invasive non-indigenous species, which will likely be more strongly managed under proposed inter-regional marine pest pathway plans[5].
- The potential for positive ecological outcomes versus potential adverse effects, such as increased wetland habitat extent, and protected and/or extended wading bird habitat.

We would be happy to discuss these outcomes further with WSP NZ, as needed, in light of the other considerations assessed against these options.

[4] https://marinebiosecurity.niwa.co.nz/sabella-spallanzanii/, https://marinepests.nz/
[5] pers. comm. Melanie Tupu, Auckland Council, December 2019.

Yours sincerely

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