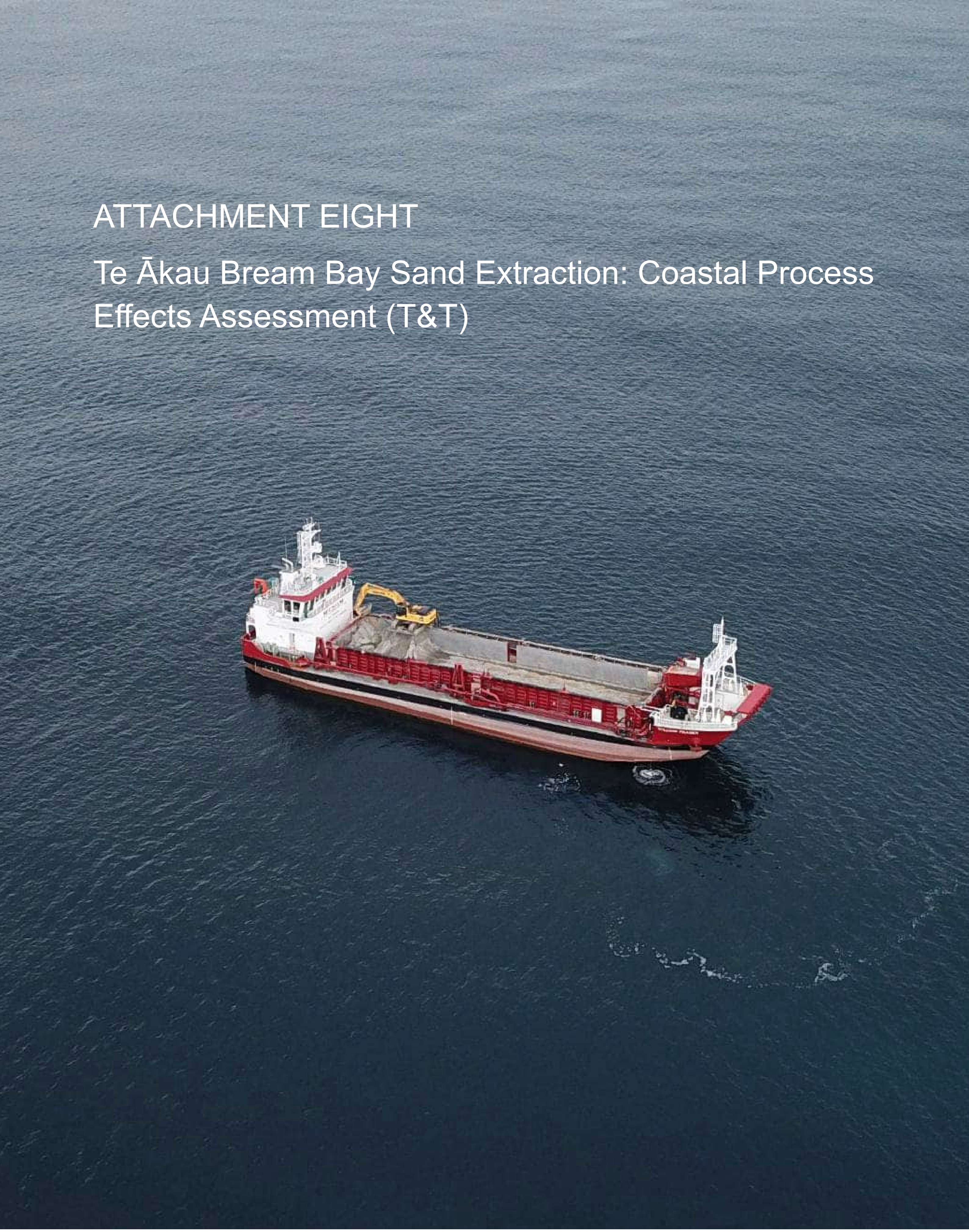
ATTACHMENT EIGHT

Te Ākau Bream Bay Sand Extraction: Coastal Process Effects Assessment (T&T)



McCALLUM BROS LTD

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REPORT

Tonkin+Taylor

Te Ākau Bream Bay Sand Extraction: Coastal Process Effects Assessment

Prepared for
McCallum Bros Ltd

Prepared by
Tonkin & Taylor Ltd

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Executive summary

Purpose

McCallum Bros Limited (MBL) is preparing a resource consent application to extract marine sand offshore of Te Ākau Bream Bay, Northland. This report provides an assessment of potential effects on coastal processes and landforms related to MBL's Te Ākau Bream Bay sand extraction proposal.

Application

The Te Ākau Bream Bay proposal is for offshore sand extraction of up to 8,450,000 m^3 of sand over a 35 year term of consent. Further details on volumes per year are provided in Section 1 and a detailed description of the proposal is provided by other application reports.

The intention of MBL's sand extraction proposal at Te Ākau Bream Bay is that **the activity is located sufficiently seaward of the beach and at sufficient depth to have negligible[1] direct or indirect effects on coastal processes and landforms.**

The next section provides a description of the coastal geomorphology terms that are material to understanding this effects assessment.

The shoreface

The shoreface is a term used to describe the section of a coastal profile that is shaped by coastal processes (e.g. waves shape sand bars). The shoreface also influences the behaviour of coastal processes (e.g. waves break on sand bars). Part of this assessment involves defining the seaward limit of the shoreface at Te Ākau Bream Bay to confirm that the sand extraction proposal is occurring in the offshore zone, seaward of the point where significant sediment transport occurs.

In coastal geomorphology, the shoreface is traditionally split into zones. The upper shoreface zone is the landward section of the submerged coastal profile and experiences dynamic changes in seabed level (e.g. bars and troughs) that vary the bed level on annual timescales (Figure E.1.1). During storm events, wave breaking and surf zone processes operate across the upper shoreface. The lower shoreface is the seaward section of the profile and is a zone of significant wave induced sediment transport, which is connected to the upper shoreface over decadal timescales. Wave shoaling occurs on the lower shoreface during larger events, which can mobilise sediment due to wave orbital motions interacting with the seabed. The offshore zone or continental shelf is located seaward of the lower shoreface and is an area of negligible net wave induced sediment transport.

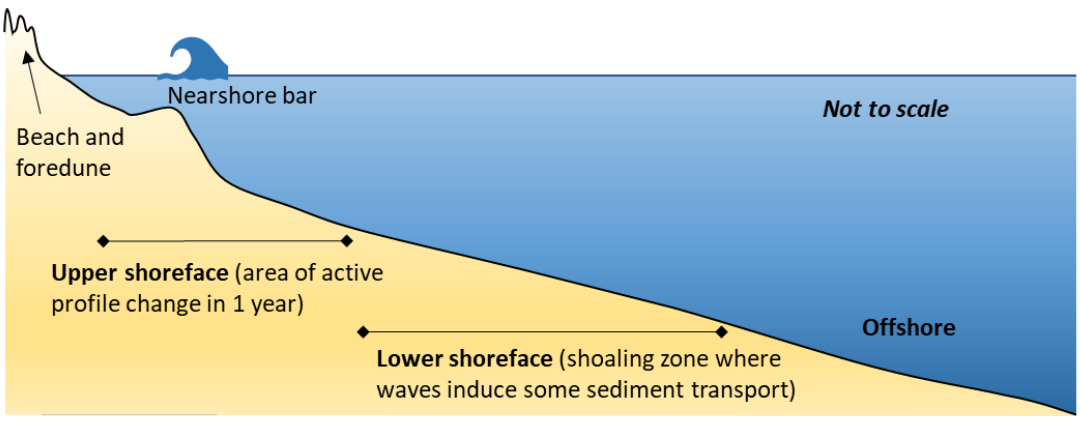


Figure E.1.1: Schematic coastal profile with exagerated features.

[1] A definition of a negligible effect on coastal processes is presented in Section 5.2 of this report.

Coastal effects context

Marine sand extraction can have an adverse effect on coastal processes and landforms if the activity occurs on the shoreface, where sediment is dynamically exchanged with the beach on decadal timescales. Potential effects include a direct sand volume deficit for the coastal profile, indirect draw-down of sand levels on the beach and altering wave or current processes approaching the coast. Poorly managed sand extraction, particularly in locations that are linked to the shoreline by coastal processes, can therefore result in beach erosion, which reduces coastal resilience to storms and impacts of sea level rise from climate change.

The effect of sand extraction on coastal processes and landforms is greatest if the activity is occurring close to shore, in relatively shallow water depths. The risk of sand extraction adversely affecting coastal processes and landforms decreases when the activity is offshore, in deeper water. Coastal process theory and international guidance on marine sand extraction indicate that the removal of sand from the seabed is likely to have a negligible effect on coastal processes and landforms if the activity is undertaken in the offshore zone, at a suitable depth and distance seaward of the beach. This location can be defined by the point of negligible wave induced net sediment transport.

The basis of this assessment is to investigate hydrodynamic and sediment transport processes operating in Te Ākau Bream Bay to define the limits of the shoreface. This allows assessment of whether the activity is proposed to be undertaken in the offshore zone that is sufficiently disconnected from the beach and surf zone.

Approach

The analysis presented in this report applies a range of methods to calculate the seaward limit of the shoreface at Te Ākau Bream Bay to confirm the location is suitable for sand extraction from a coastal process perspective.

Three methods were used to calculate the point of negligible connectivity between the active beach profile and the seabed:

- The empirically calculated inner Depth of Closure (DoC) as a standard definition of the upper shoreface boundary.
- The empirically calculated outer Depth of Closure (DoC) as a traditional definition of the lower shoreface boundary.
- The bed shear stress induced Depth of Transport (DoT) as a modern definition of the lower shoreface boundary based on improved physics and recent literature.

These approaches were informed by fundamental coastal process theory and up to date coastal geomorphology research. They align with the best available international guidance on conducting a coastal impact study for marine aggregate extraction from the UK (BMAPA/Crown Estate, 2013).

The shoreface zones at Te Ākau Bream Bay were calculated following the definitions and methods from a recent coastal geomorphology literature review (Hamon-Kerivel, et al., 2020). This included initially calculating the inner and outer depth of closure (DoC) using the empirical Hallermeier formulas, informed by site specific wave climate and sediment information.

Further analysis was undertaken to calculate the ‘depth of transport’ (DoT) based on bed shear stress, informed by site specific bathymetry, wave conditions, currents, and sediment characteristics. Results for the DoC and DoT analysis were compared with geometric features on the surveyed shoreface profile, as measured using multi-beam bathymetric survey transects, and across shore changes in sampled sediment grain size, which were used to sense check the empirical zonation.

Technical assessment

Four zones were identified based on methods outlined above, which were used to inform the coastal effects assessment. These include:

- **Zone 1**: The upper shoreface zone of significant morphological change, as defined by the inner depth of closure calculation, based on the Hallermeier formulation (Inner DoC).
- **Zone 2**: The lower shoreface zone of frequent sediment transport but negligible profile change, defined by the adopted DoT, where bed shear stress exceeds the threshold for significant sediment transport[2] for 12 hours per year, informed by a 90-percentile year (DoT).
- **Zone 3**: The lower shoreface zone of infrequent sediment transport, as defined by the 45 year average outer depth of closure (Hallermeier wave base equation, Outer DoC).
- **Zone 4**: The offshore area where wave induced sediment transport does not functional exchange with the shoreface at decadal timescales, being seaward of the 90 percentile DoT and for additional conservatism also being seaward of the 45 year average outer DoC.

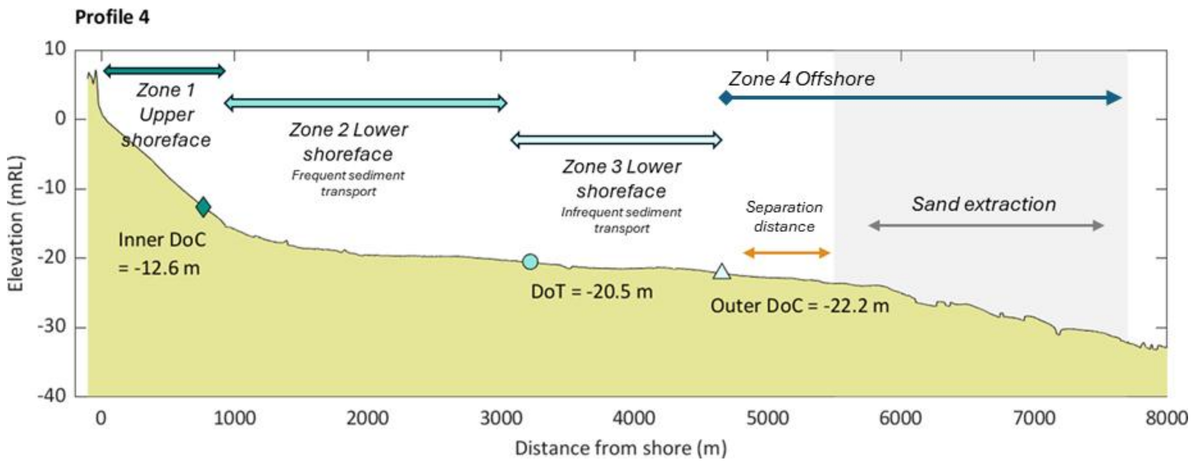


Figure E.1.2: Location of DoC and DoT and associated shoreface zones with respect to the application area for Profile 4.

The bathymetric profile surveys identify that a prominent change in slope occurs approximately 700 m offshore from the coast. The slope from the beach to a depth between -12.5 and -16 mRL[3] is relatively steep, then transitions in a concave shape to a gently sloping plateau. The plateau extends several kilometres offshore, with some sections having a convex bulge before a more pronounced seaward slope occurs again approximately 4 - 5 km offshore.

A synthesis of the results across all methods concludes that the upper shoreface, a zone of active profile change, is located on the steeper sloping section of the profile that transitions to a concave base at an average depth of -12.5 mRL, located 700 – 1,000 m offshore from the coast. This is defined by the inner depth of closure (DoC), which can extend seaward to -16 mRL on years with larger than normal wave events[4].

The start of the lower shoreface is characterised by a concave slope towards a gradually sloping or, in some locations, bulging upward plateau (refer to Profile 3 in Figure 3.4). We present two definitions

[2] Where significant sediment transport is defined by exceedance of the shear stress threshold for bed planing that causes the movement of sediment leading to a smoother, or "planed" sea floor surface.
[3] Levels are relative to New Zealand Vertical Datum 2016 (NZVD16), referred to as reduced level (RL).
[4] Extreme years are when the 12h exceeded wave height and associated period are higher than normal, such as during a notable ex-tropical cyclone event.

for the seaward limit for the lower shoreface. The modern DoT method, based on the physics of wave induced sediment transport using shear stress, shows the lower shoreface extends an average of 2.0 km from shore (i.e. -17.5 mRL), but can extend to 3.2 km from shore (i.e. - 20.5 mRL). The DoT is the favoured interpretation for defining the lower shoreface in recent literature due to improved physics compared to the traditional Outer DoC method (Hamon-Kerivel, et al., 2020). However, it is a relatively new concept that has not yet been applied in New Zealand. Therefore, we interpret this boundary as being the lower shoreface zone of frequent sediment transport to reflect how the equation represents significant sediment transport during annual extreme conditions.

The Outer DoC method has been used previously to define the lower shoreface boundary to inform sand extraction in New Zealand (e.g. Hilton et al., 1996). This definition for the lower shoreface boundary is based on international empirical data simplified into a basic formula based on grain size, mean water height, and mean wave period. Recent research has identified limitations to the outer DoC equation, identifying it as less suitable for embayed beaches where results do not match by geomorphic observation (Valiente, et al., 2019). For Te Ākau Bream Bay, the 45 year average outer DoC extends 2.9 km offshore (i.e. -19.1 mRL), but can extend to 4.6 km offshore (i.e. -22 mRL) at locations that have finer sediments and larger average waves. Due to the existing application in New Zealand, the outer DoC calculated by long term average conditions is still a useful parameter and in this assessment is interpreted as a lower shoreface boundary with infrequent or possible sediment transport.

The location of the proposed extraction area, with regards to the shoreface zones, is presented as a profile in Figure E.1.2 and a map in Figure E.1.3. Profile 4 is presented, as the location where the lower shoreface defined by the DoT and DoC is most seaward due to this location having sediment of a smaller average grain size and larger waves when compared to other analysis profiles. When interpolating the zones between profiles, a minimum distance of 1 km was used to separate the frequent transport zone from the inner depth of closure. Likewise, a minimum separation of 3.5 km from the inner depth of closure was used to map the lower shoreface zone of infrequent sediment transport. This minimum separation between zones is conservative and is based on giving more weight to Profile 4.

The proposed sand extraction area at Te Ākau Bream Bay is in the offshore zone, seaward of the lower shoreface as defined by the 90 percentile DoT or 45 year average outer DoC. There is a minimum separation distance of 880 m from the lower shoreface zone of infrequent transport (outer DoC definition) and the extraction area, providing additional space for uncertainty in future changes to the wave climate with climate change.

This assessment also considers how the proposed sand removal may alter waves and currents approaching the shore. The maximum extraction depth over 35 years (0.55 m lowering of the seabed, at an average rate of 0.016 m/yr) is not expected to alter waves approaching the coast in a way that would result in any measurable change to coastal landforms over and above the natural background variability.

The impacts of climate change were also considered in terms of sea level rise and a more energetic wave climate. The depth of closure would move landward with increasing submergence from sea level rise and is therefore not a factor that would increase risk with climate change. Climate change will have an unknown impact on the mean wave climate but will likely result in a larger extreme wave climate. The position of the outer DoC is sensitive to a possible 5% increase in mean wave height, but position of the DoT is not sensitive to a 5% increase in the annual extreme wave height. There is a suitable separation between the shoreface and proposed extraction area to allow for some uncertainty in how the wave climate may be altered by climate change over the next 35 years.

Summary of effects on coastal processes and landforms

The level of effect was assessed for the proposed extraction area, the lower shoreface, the upper shoreface and the beach, considering waves, currents, sediment transport and possible climate change effects over the duration of the consent, and the associated morphological changes. The level of effect was interpreted using a definition table that guides the interpretation of potential effect levels, such as negligible, low and moderate (Section 5.2 of this report).

The overall effect of the proposed offshore sand extraction activity on coastal processes and landforms on the beach Te Ākau Bream Bay is **negligible,** and the shoreface area was assessed as **low.** The effect on processes and landforms within the proposed extraction area is moderate to negligible, as the seabed in this location will be directly disturbed by the extraction activity and sediment removal.

Monitoring

While the findings of this assessment are that the level of effects on the physical coastal environment outside the area of extraction is likely to be low to negligible, monitoring is still recommended to confirm and validate the findings of this assessment. Key areas for monitoring are to avoid the formation of large variations in seabed depth caused by repeated extraction over the same area, and early identification of any seabed lowering on the immediately landward of the extraction area and across the shoreface, through bathymetric surveying.

Conditions are recommended in the form of adaptive management to adjust the proposed extraction area or volume if monitoring identifies unexpected lowering of the shoreface.

Peer Review

This assessment has been independently peer reviewed by Derek Todd, Principal Coastal and Hazards Scientist at Jacobs (review completion letter in Appendix A).

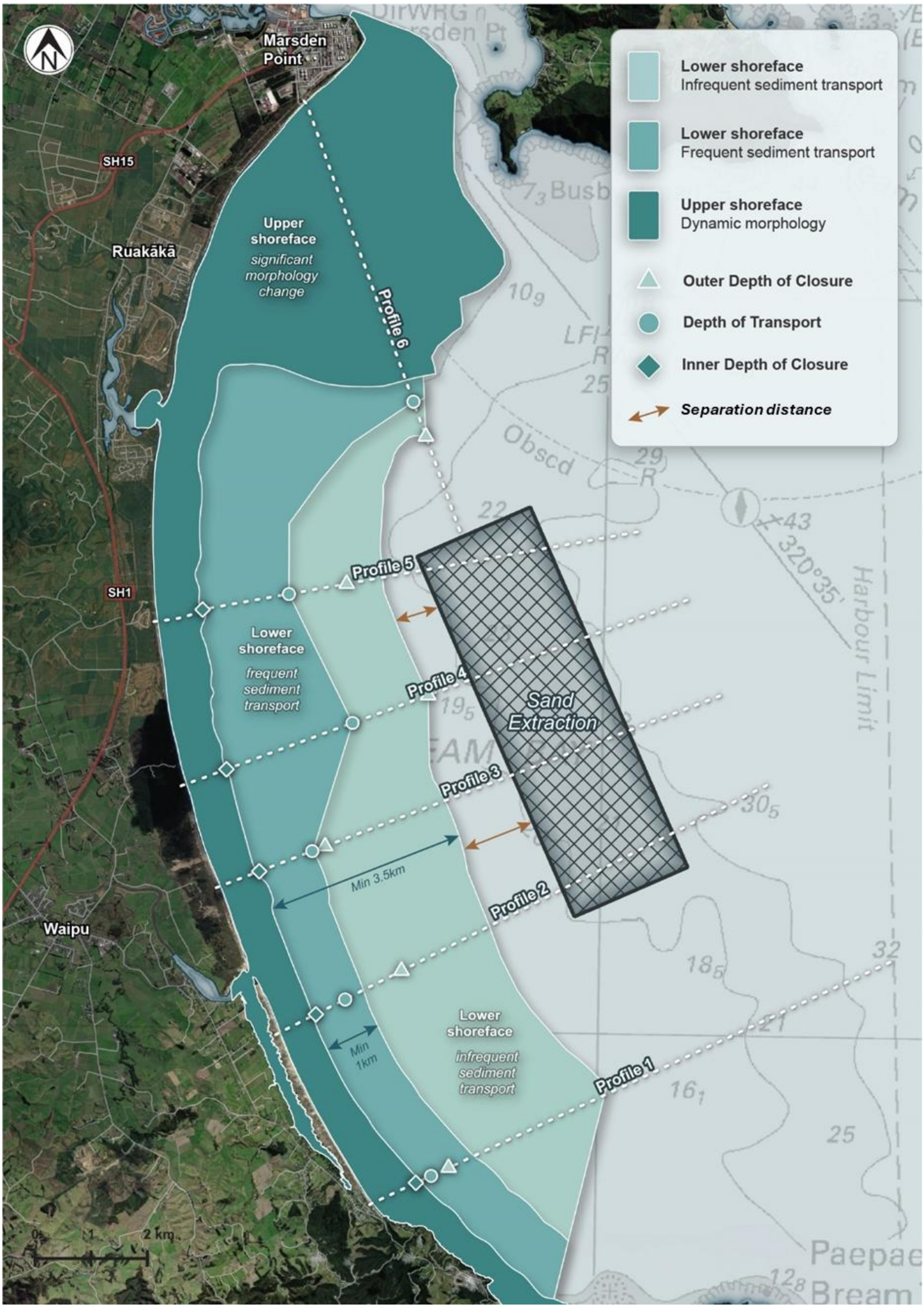


Figure E.1.3: Location of proposed sand extraction at Te Ākau Bream Bay in relation to shoreface zones.

1 Introduction

1.1 Background

McCallum Bros Ltd (MBL) is preparing a resource consent application to extract marine sand offshore of Te Ākau Bream Bay in Northland, New Zealand. MBL commissioned Tonkin & Taylor Ltd (T+T) to provide advice on the proposed extraction site and to assess whether the area is located sufficiently offshore to have less than minor effects on coastal processes in the surf-zone, beach, and dune environment.

This report sets out the proposed application and provides a detailed assessment of potential effects on coastal processes and is part of a suite of reports covering the environment and potential effects.

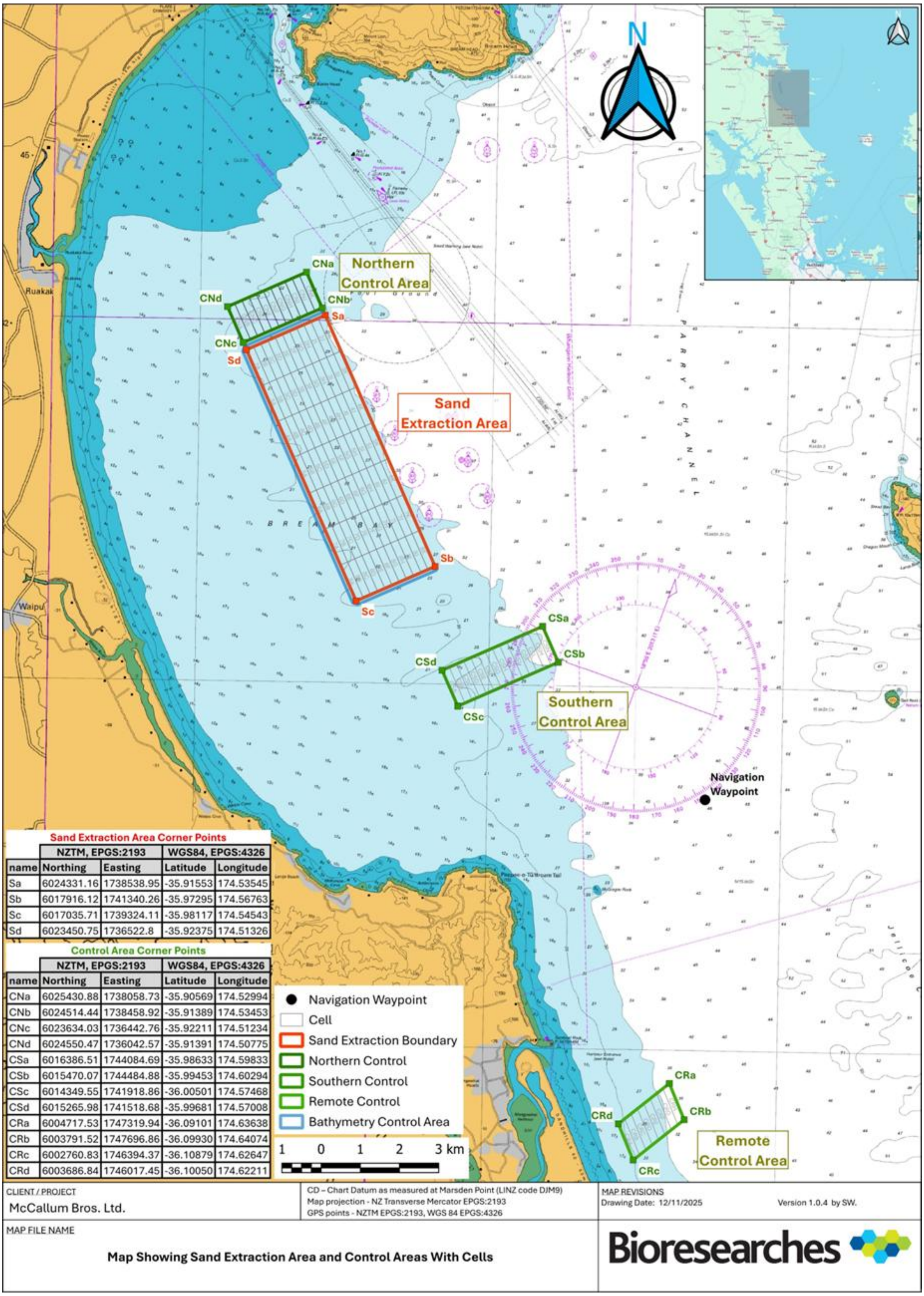
Project description

As shown in Figure 1.1, MBL is proposing to extract sand from an offshore area of Te Ākau Bream Bay. The sand extraction application area is in the centre of Te Ākau Bream Bay, west of the Northport anchorage area and southwest of both the harbour shipping channel and the rocky reef north of the anchorage area. The proposed extraction area is 15.4 km^2 (7 km alongshore and 2.2 km across shore comprising 77 No. 1,000 m x 200 m cells) and is located at a minimum distance of 4.7 km from the shoreline.

The proposed extraction volumes are:

- 150,000 m^3 per annum for the first 3 years.
- Max sand extraction volume per 1,000 m x 200 m cell not to exceed 5,000 m^3 per annum.
- Max rate of 15,000 m^3 per month for the first 3 years.
- 250,000 m^3 per annum for the remaining 32 years of the 35 year consent being applied for.
- Max rate of 25,000 m^3 per month from year 4 of the consent.
- Total maximum volume over the 35 years of 8,450,000 m^3.

Details of the extraction methodology are included in the Assessment of Effects Planning report and the McCallum Bros. Ltd. Operational Aspects Summary (McCallum, 2025).



Sand Extraction Area Corner Points

	NZTM, EPGS:2193		WGS84, EPGS:4326	
name	Northing	Easting	Latitude	Longitude
Sa	6024331.16	1738538.95	-35.91553	174.53545
Sb	6017916.12	1741340.26	-35.97295	174.56763
Sc	6017035.71	1739324.11	-35.98117	174.54543
Sd	6023450.75	1736522.8	-35.92375	174.51326

Control Area Corner Points

	NZTM, EPGS:2193		WGS84, EPGS:4326	
name	Northing	Easting	Latitude	Longitude
CNa	6025430.88	1738058.73	-35.90569	174.52994
CNb	6024514.44	1738458.92	-35.91389	174.53453
CNc	6023634.03	1736442.76	-35.92211	174.51234
CNd	6024550.47	1736042.57	-35.91391	174.50775
CSa	6016386.51	1744084.69	-35.98633	174.59833
CSb	6015470.07	1744484.88	-35.99453	174.60294
CSc	6014349.55	1741918.86	-36.00501	174.57468
CSd	6015265.98	1741518.68	-35.99681	174.57008
CRa	6004717.53	1747319.94	-36.09101	174.63638
CRb	6003791.52	1747696.86	-36.09930	174.64074
CRc	6002760.83	1746394.37	-36.10879	174.62647
CRd	6003686.84	1746017.45	-36.10050	174.62211

Figure 1.1: Location of MBL's proposed sand extraction in Te Ākau Bream Bay.

1.2 Datum and coordinates

All elevations presented in this report are relative to New Zealand Vertical Datum 2016 (NZVD16), which is referred to as reduced level (RL). The difference between NZVD16 and Chart Datum at Marsden Point is 1.746 m. The conversion from One Tree Point Vertical Datum (1964) to NZVD16 is +0.0678 based on LINZ benchmark DJM9. Coordinates used in this report are based on New Zealand Transverse Mercator 2000 (EPSG:2193).

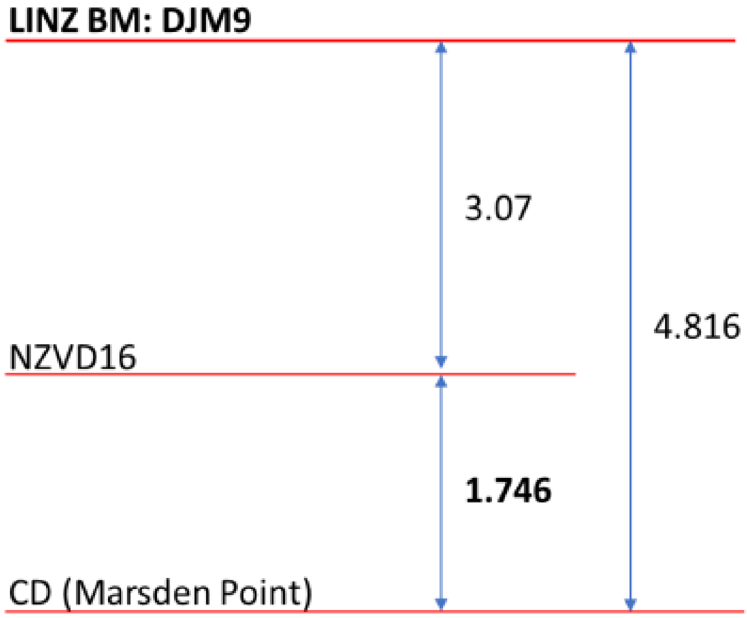


Figure 1.2: Vertical datums, from the DML (2024) bathymetric survey report.

2 General approach

The purpose of this assessment for the Te Ākau Bream Bay sand extraction proposal is to confirm that the activity is proposed to be undertaken in the offshore zone, with negligible connectivity to beach processes and, therefore a less than minor likelihood of impacting coastal processes that influence the beach and dune environment.

Three methods were used to calculate the point of negligible connectivity between the active beach profile and the seabed:

- The empirically calculated inner Depth of Closure (DoC_l) as a standard definition of the upper shoreface boundary.
- The empirically calculated outer Depth of Closure (DoC_i) as a traditional definition of the lower shoreface boundary.
- The bed shear stress induced Depth of Transport (DoT) as a modern definition of the lower shoreface boundary.

The assessment also considers geomorphic interpretation of the bathymetric profile and changes in sediment texture (grain size) for local validation of the DoC and DoT, using field data.

The Depth of Transport (DoT) calculation method developed by Valiente et al. (2019) is also used as a modern method for calculating the seaward limit of sediment transport. The DoT is the recommended method for defining the seaward limit of the lower shoreface in a recent coastal geomorphology review paper (Hamon-Kerivel, et al., 2020), instead of the outer DoC. In this assessment we put more weight on the DoT methods due to improved physics in the formulation when compared to the Outer DoC from the Hallermeier (1978) wave based formula. However, we still calculate and consider the outer DoC as this has been around longer and with a legacy of application in New Zealand.

These approaches align with the methods included in the best practice guidance note for conducting a coastal impact study for marine aggregate extraction from the UK (BMAPA/Crown Estate, 2013), which is the only available international guidance. A description of the methods set out in these approaches is presented in the following sections.

2.1 Depth of Closure

A basis of the Te Ākau Bream Bay sand extraction is that the activity is to be undertaken in an offshore location, where sediment transport processes are sufficiently decoupled from the beach, such that the activity has negligible direct or indirect impacts on the beach and dune landforms. This section introduces the concept of the 'depth of closure' and the different zones that are present on the shoreface profile.

Literature on coastal processes presents different naming conventions and terms for calculating the seaward limits of profile change and sediment transport on sandy beach environments. For this assessment, we adopt the terminology from Hamon-Kerivel et al. (2020) for defining the key shoreface profile zones. These are based on:

- The inner depth of closure, which is the seaward limit of measurable profile change.
- The outer depth of closure, which is the seaward limit of significant wave-induced sediment transport.

Following the definition of Hamon-Kerivel, et al. (2020), the coastal profile has the following zones (see Figure 2.1):

- **Surf and swash zone**: where breaking waves and wave energy dissipation occur under typical conditions.
- **The upper shoreface**, where bed level changes occur in response to wave processes, and sediment is exchanged with the beach on seasonal to annual timescales. The upper shoreface

has a landward limit at the fair-weather surf zone and a seaward limit at the (inner) depth of closure.

- The **lower shoreface** is where the bed level is not dynamic on annual or decadal timescales, but wave-induced sediment transport may infrequently occur during extreme weather events. The landward limit of the lower shoreface is the inner depth of closure and the seaward limit is the outer depth of closure, where wave-induced sediment transport becomes negligible. Hamon-Kerivel (2020) adopted the depth of transport (DoT) as the seaward limit for the lower shoreface.
- The **offshore zone** (also termed the shelf), where the bed levels are not dynamic, and is generally considered morphodynamically non-active (Valiente, et al., 2019).

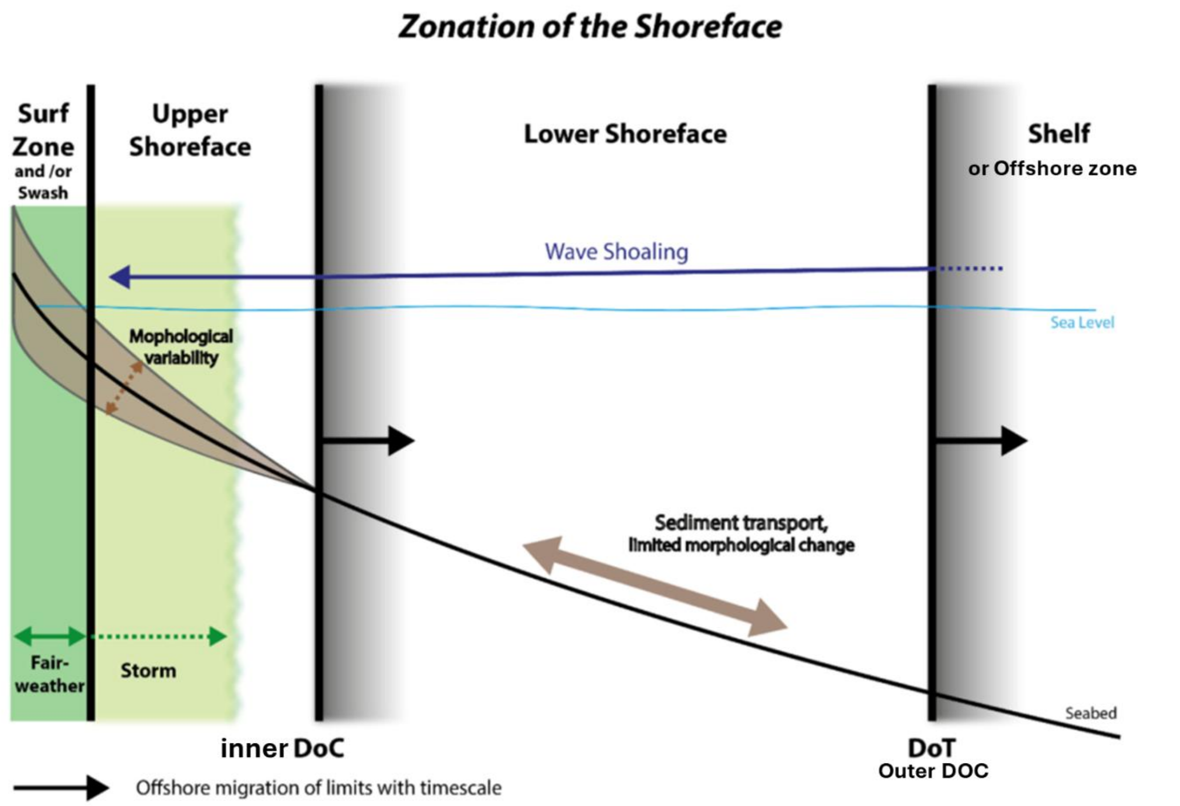


Figure 2.1: Shoreface zonation (annotated from source: (Hamon-Kerivel, et al., 2020)).

Previous research on sand extraction in New Zealand has focused on the Mangawhai-Pākiri embayment, located just south of Te Ākau Bream Bay. Research at Pākiri by Hilton, et al. (1996) identified the seaward limit of the lower shoreface at 25 m below mean sea level based on three lines of evidence, which was the value utilised to inform an offshore sand extraction application in 2023.

- The outer depth of closure of 25 m was calculated with the empirical equation for the wave base by Hallermeier (1978), with the values from Hilton, et al. (1996):

$d_i = (\overline{H}_s - 0.3\sigma_s)\overline{T}_s(\frac{g}{5000D})^{0.5}$ [eq. 1]

– Where:

$\overline{H}_s$ is the mean significant wave height averaged over at least 1 year = 1.044 m at Pākiri

σ_s is the standard deviation of significant wave height = 0.727 m at Pākiri

$\overline{T}_s$ is the mean significant wave period = 12 s at Pākiri

D is the median grain size = 0.32 mm (0.00032 m) at Pākiri

g is the gravitation constant

- A transition of profile slope from concave towards convex.
- A coarser band of sediment, indicating that coarser sediments are not transported by wave action.

For the effects assessment at Te Ākau Bream Bay, calculations were undertaken to define the outer depth of closure using Equation 1, which were cross-checked with the across shore change in profile geometry and sediment texture. This is consistent with Pākiri methods. that were accepted in expert conferencing at that time to define the seaward limit of the shoreface.

2.2 Depth of Transport

While the outer depth of closure calculation by Hallermeier (1978) is still widely used in coastal science and engineering, recent literature indicates that this is a highly sensitive equation and is not applicable in some coastal settings, which are typically sediment starved locations, or where geological controls influence the shoreface, such as embayed beaches that have headlands on either side. Te Ākau Bream Bay is an example of such headland control that may make the Hallermeier outer DoC less suitable. A more recent method for establishing the seaward limit of the lower shoreface is the Depth of Transport calculation (Valiente, et al., 2019) which is the recommended lower shoreface definition by Hamon-Kerivel et al. (2020) due to the improved sediment transport physics and match with geomorphic observations.

The depth of transport method calculates bed shear stress from wave orbital motions and tidal currents to identify the seaward limit for significant sediment transport during extreme conditions expected for 12 hours a year on average, where Valiente, et al. (2019) defines significant sediment transport as exceeding the bed shear stress threshold for a ‘bed plaining’ style of sediment transport. This separates the lower shoreface as a zone of sediment transport, and the upper shoreface as a zone of profile change. Research on the coast of South England found that the outer DoC calculation (Equation 1) results in a depth of 30 – 50 m with a mean wave height of 1.5 - 2 m which was inconsistent with local geomorphic evidence, where beach sediments were not present at those depths (Valiente, et al., 2019). Their proposed bed-shear stress method identified a DoT of 15 – 30 m, depending on the wave exposure at each site, which matched local geomorphology evidence (transition from sand to bed rock). The sites in England are also subject to macro tidal processes, which have an influence on sediment transport. Including tidal currents in the DoT calculation resulted in the shoreface extending deeper by 7 – 10 m.

This analysis presents a comprehensive assessment of the depth of transport (DoT) for Te Ākau Bream Bay as calculated using the bed shear stress method of Valiente, et al. (2019).

2.3 Best practice guidance

The best practice guidance on carrying out a coastal impact study for marine aggregate extraction (BMAPA/Crown Estate, 2013) was developed by the British Marine Aggregate Producers Association and The Crown Estate. The note provides best practice guidelines on carrying out a Coastal Impact Study (CIS) as part of an application to extract marine aggregates from the seabed around the English and Welsh coasts. The note outlines the terms of reference and essential elements of a CIS; including the data required to undertake a study, key components and their analysis, consideration of cumulative and in-combination impacts, as well as mitigation and monitoring options.

A CIS is intended to assess potential effects on the visible coast and includes bays and headlands, beaches, rock platforms, and cliffs together with underwater features on the nearshore seabed and offshore banks and bars.

The assessment needs to clearly define any seaward and/or landward limits of the coastline, including receptors that might be altered by offshore extraction and the choice of a nearshore boundary at which a CIS should evaluate any changes.

The initial extraction plan should contain an accurate representation of the proposed activity for assessment by the CIS, including any modifications made through the evaluation process. This should include the maximum amount of aggregate that might be extracted, including a post-extraction bathymetric modelling.

A CIS should then, as a minimum, assess whether coastlines could be unacceptably affected by the extraction plan. The CIS should include consideration of the following criteria:

- Changes in nearshore wave conditions because of changes in the patterns of wave transformation (e.g. refraction and dissipation) over the extraction area for both the current situation and the maximum amount of extraction using computational modelling. The modelling relied upon for this assessment is presented in the Surf Assessment Report undertaken by MetOcean Solutions (MOS, 2024).
- Changes in the nearshore tidal currents due to bed lowering in the extraction area. Based on measurements and modelling done by MetOcean Solutions (MOS, 2016), depth average currents are generally less than 0.15 m/s. Due to the low tidal currents in this area, this has been done by desktop assessment of previously published information.
- Any draw-down into the extraction area, of beaches or sandbanks, which has been done via the DoC and DoT assessments.
- Changes in sediment transport patterns, such as interrupting supply to coastal sandbanks, or beaches, have also been assessed using the depth of transport method.
- Changes to the form and function of any nearby sandbanks, based on the interpretation of output from the DoC and DoT methods.

The CIS assessment needs to consider exceptionally severe wave conditions, tidal levels, considering the combination of these on having the largest effect on extraction. Also, allowance should be made for changes in tidal levels relative to the land, and in waves, that might be brought about by global warming and associated climate change for the duration of the extraction application. The assessment included in this report considers these variables.

3 Background information

3.1 Location

Te Ākau Bream Bay is in the Northland Region of New Zealand (Figure 3.1), on the north-east coast of the Te Ika-a-Māui North Island at the northern end of the Hauraki Gulf/Tīkapa Moana. The Bay faces east, with an arc shape and is bound by Te Whara (Bream Head) to the north, and Paepae-o-tui (Bream Tail) to the south, both major headlands formed in volcanic outcrops (Nichol, 2002). The shoreline consists of an embayed sandy beach system that extends 22 km from Waipū Cove in the south, to Whangārei Harbour/Whangārei (Terenga Parāoa) in the north. The northern end of the beach system is Te Poupouwhenua (Marsden Point), which wraps around the harbour shoreline at One Tree Point.

The main development sections of the coast are Te Poupouwhenua (Marsden Point) which is a mostly industrial precinct to the north, Ruakākā which is a small settlement on the northern segment, and Waipū Cove which is a beach town at the southern end (Figure 3.1). Two rivers flow into Te Ākau Bream Bay and interrupt the continuous sand dunes. Ruakākā River flows into the coast near Ruakākā, and Waipū River flows into the Bay at the southern segment (Figure 3.1). The rivers separate the beach into three discrete segments that are approximately equal distances in length.

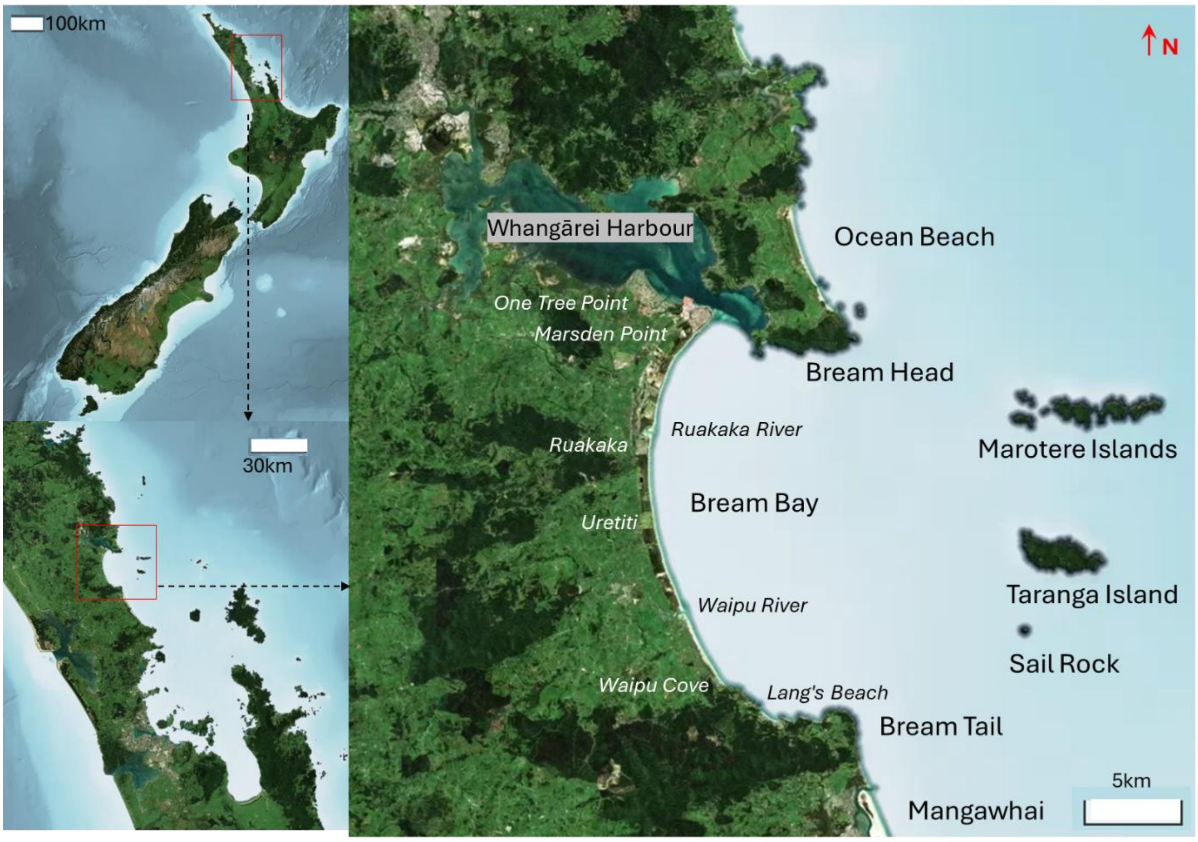


Figure 3.1: Location of Te Ākau (Bream Bay) (Source: LINZ Basemaps).

3.2 Geology

Coastal sediments at Te Ākau Bream Bay are a combination of late-Pleistocene and Holocene age coastal and river deposits (Figure 3.2). Pleistocene age dune systems at One Tree Point were dated to have formed 85 to 115 thousand years ago (Nichol, 2002). More recent dune formations that are closer to the active beach at Marsden Point were dated to be deposited in the Holocene, about 6 thousand years ago (Nichol, 2002). Research on the formation of One Tree Point and Marsden Point identifies these features as forming during sea level high stands, formed by deposition of marine sediments during periods of falling sea level (Nichol, 2002). The contemporary coastal compartment is most likely in a state of dynamic equilibrium, with limited sediment inputs compared to the formative conditions in the geologic past (Nichol, 2002). Rocky geology headlands and hills are identified in blue, orange, red and purple (Figure 3.2).

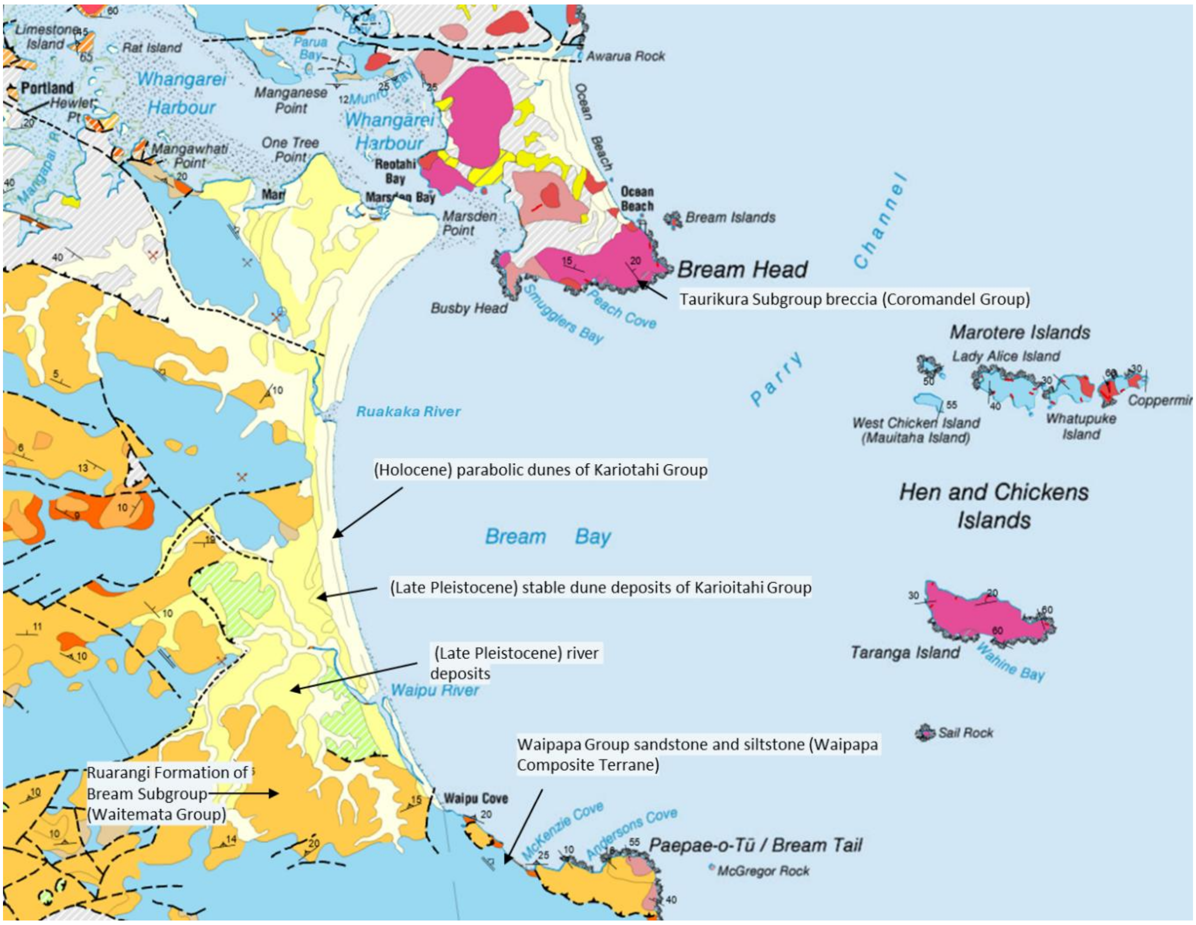


Figure 3.2: Geological map of Te Ākau (Bream Bay) (Source GNS 250k Geology[5]).

3.3 Topography

Te Ākau Bream Bay is characterised by a white sand beach that transitions into a sand dune system that formed over the late-Pleistocene and Holocene. Terrain levels were characterised by a regional LiDAR survey from 2019 that was sourced from LINZ (see Figure 3.3). The dune system extends landward in a series of undulating ridges and swales, with the most seaward section of the dune termed the 'foredune'. The foredune crest level is approximately 4.5 – 7.0 mRL between Waipū Cove and Waipū River, with the dune slope and toe varying depending on recent storm events. More details on beach profile changes are presented in Section 3.10. Between Waipū River and Ruakākā River, the dune system is less developed and transitions from a 6 -7 mRL foredune fronting the beach to inland Pleistocene dunes up to 20 mRL. Similar dune systems are present between Ruakākā River and Marsden Point, with foredune crests between 7 - 10 mRL, and some inland development that has levelled the historic dune sections.

[5] https://data.gns.cri.nz/geology/

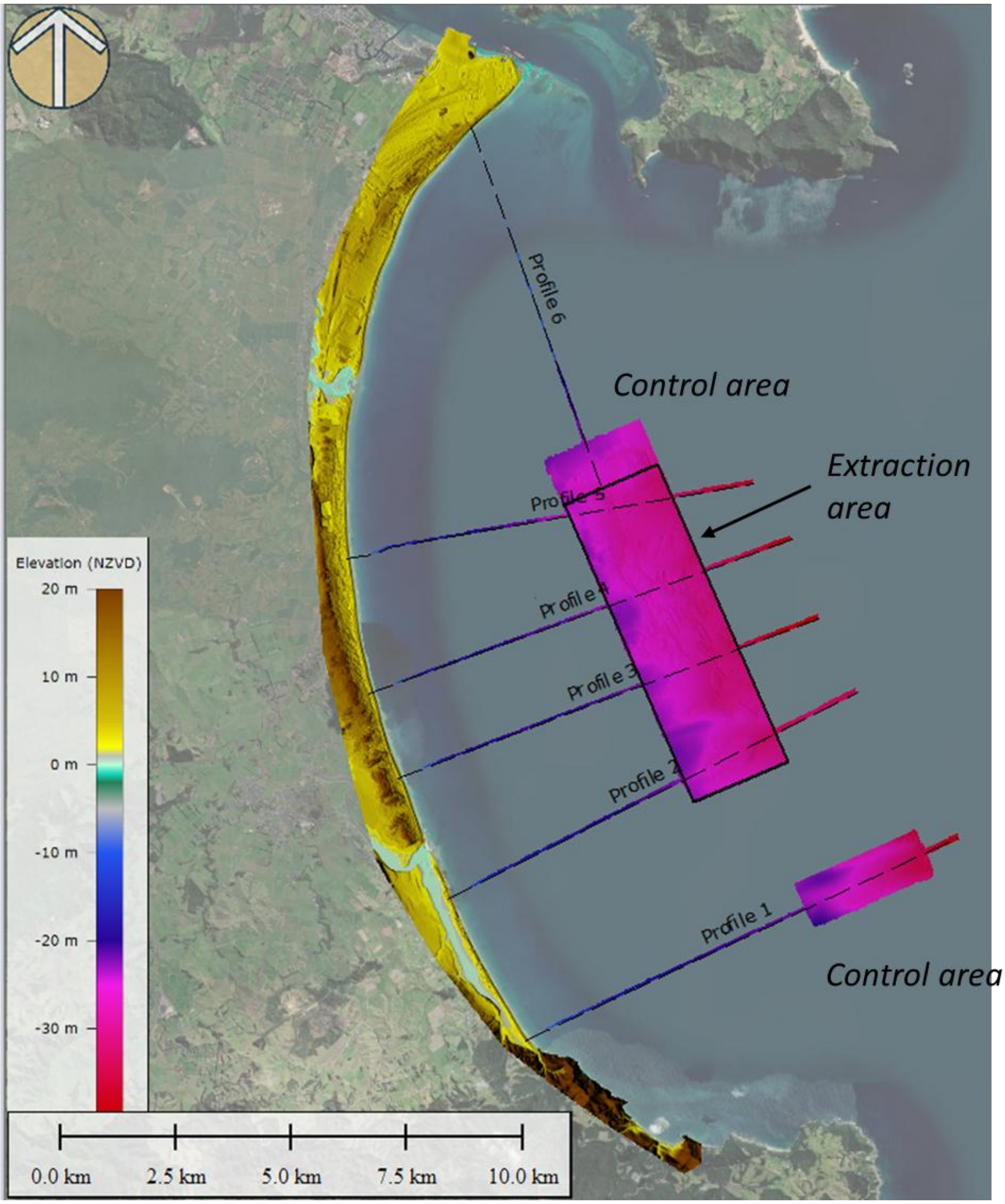


Figure 3.3: Topographic and bathymetric data collected for Te Ākau Bream Bay coast and nearshore. The proposed extraction area is in the black rectangle.

3.4 Bathymetry

3.4.1 Surveys and data

A detailed bathymetric survey was undertaken by Discovery Marine Ltd. (DML) that covered the proposed extraction area, the proposed monitoring control sites, and six shore profiles that extend from offshore of the extraction site to an inshore depth of approximately 5 m (Figure 3.3). Surveys were undertaken in the first quarter of 2024 and provided to T+T as gridded data at 1 m resolution.

Bathymetry in areas not captured by the 2024 DML survey was informed by hydrographic charts and data from LINZ. A copy of the survey report is included in Appendix A.

3.4.2 Bathymetric profiles

Bathymetric profiles are shown in Figure 3.4 and the distance from the coast to the landward edge of the proposed extraction area is shown in Table 3.1. The LINZ chart identifies a bathymetric feature of Mair Bank, which is a shallow shoal south of the Whangārei harbour entrance. The shoal extends south to Ruakākā River and offshore to approximately 5 km. A bathymetric profile of the shoal was collected on Profile 6. The bathymetric profiles show the shoal slopes from -5 mRL 400 m offshore of the beach, to -11 mRL at the seaward limit of the shoal. The seaward slope is approximately 2.1 degrees and drops to a level of -20 mRL, which is more consistent with the wider embayment.

Bathymetric Profile 5 is located south of Ruakākā and intercepts the northern end of the proposed extraction area. The landward extent of the survey is -5 mRL located 330 m offshore of MHWS line. The profile drops in a concave shape from -5mRL to -15 mRL, located 1.1 km of the beach. From - 15 mRL, the shoreface slope becomes gradual, at -0.17 degrees to a distance 8 km offshore of the beach. Some undulations and bedform features are noted on the profile. Profile 5 intercepts the proposed extraction area at a depth of -25 mRL. The seaward limit of the proposed extraction area is a depth of -32 mRL. Profile 5 has some undulation in the terrain until 6 km offshore then a smooth slope to 8.5 offshore.

Bathymetric Profile 4 is located halfway between Waipū River and Ruakākā River and intercepts the central area of the extraction zone. The landward extent of the survey is -6 mRL located 400 m offshore of MHWS line. The profile drops in a linear slope (-0.95 degrees) from -5 mRL to -15 mRL, located 1.0 km off the beach. From -15 mRL, the shoreface slope is concave for 1.8 km to a depth of -20 mRL. The slope from -20 mRL to the extraction boundary is -0.07 degrees, with some undulating features. The proposed extraction area's landward boundary is -23.5 mRL, with an increase in slope (to - 0.21 degrees) across the proposed extraction area, to a depth of -31 mRL at the seaward boundary.

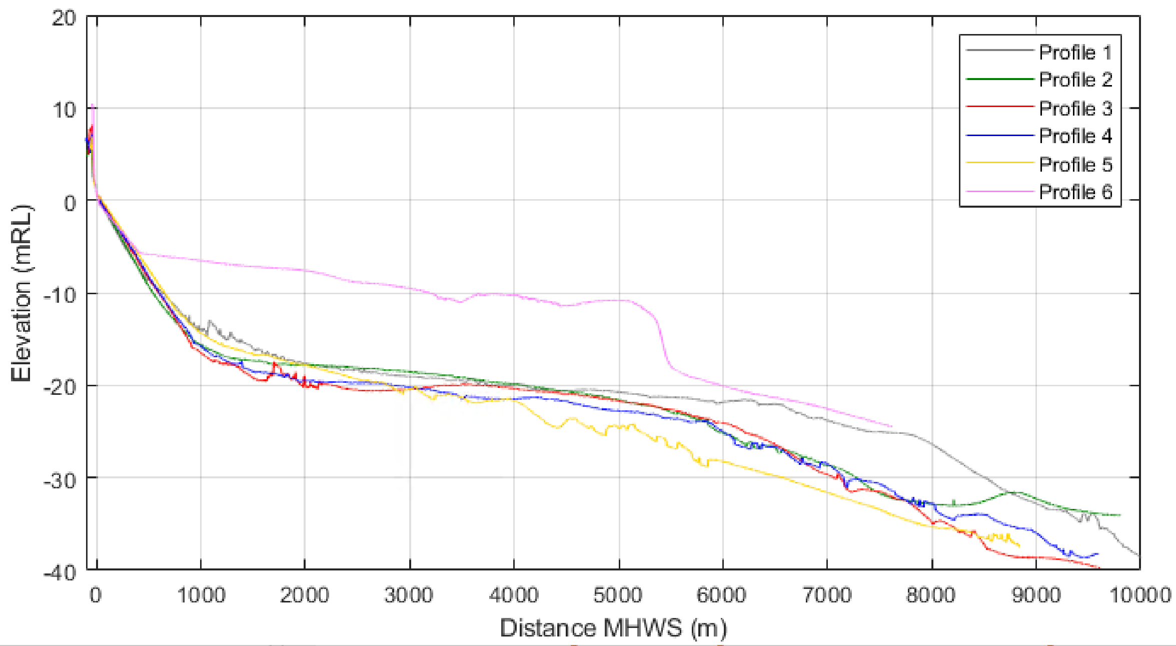


Figure 3.4: Proposed extraction area bathymetry and long section across the landward boundary.

Bathymetric profile 3 is located to the north of the Waipū River mouth and extends to a shallow depth of -5.5 mRL, located 335 m offshore. The upper shoreface slope is -1 degree to the -15 mRL contour before the profile curves concave to a 3 km long plateau at around -20 mRL. The toe of the upper shoreface slope has a ridge feature and the lower shoreface convex bulges before sloping seaward from approximately 4 km offshore. Depth at the extraction boundary is -22.7 mRL, with the seabed sloping down (-0.26 degrees) to -32 mRL at the seaward extent of the extraction boundary.

Bathymetric profile 2 is located south of the Waipū River mouth and extends to a shallow limit of - 7.5 mRL, which is 400 m offshore of the beach. The upper shoreface slopes down to -15 mRL at a slope of -0.85 degrees before curving concave and flattening to a gentle slope of -0.08 over 4 km before the extraction site. The proposed extraction area is on a downward slope of -0.25 degrees, from -23 mRL at the landward boundary to -32 mRL at the seaward boundary.

Bathymetric profile 1 is located at Waipū Cove and extends through the monitoring control site. The profile extends to a landward limit of -5.2 mRL, which is 300 m offshore of the beach. The upper shoreface drops to -14 mRL at a slope of -1.2 degrees, with undulating ridges before a gradual lower shoreface plateau (-0.06 degrees) that extends to a distance 5.5 km offshore of the beach.

Table 3.1: Location and elevation of proposed extraction/control area on each profile

	Distance from MHWS (m)	Seabed level at landward boundary of the proposed extraction area (mRL)
Profile 1[1]	6,699	-22.5
Profile 2	5,726	-23.0
Profile 3	5,648	-22.7
Profile 4	5,499	-23.5
Profile 5	4,876	-25.0
Profile 6	7,266	-23.2

1. **Profile 1 intersects through the southern control area, refer Figure 3.3.**

The literature shows that there are a wide variety of shoreface morphologies and a major factor controlling the variability in morphology is the sediment supply or availability. Increased sediment abundance is reflected in the successive development of sorted bedforms and shoreface connected ridges and ultimately to convex shoreface morphologies. The shoreface profile at Te Ākau Bream Bay best fits the 'convex' morphology type from Hamon-Kerivel et al., (2020), which they interpret as meaning increased sediment abundance when compared to a concave profile.

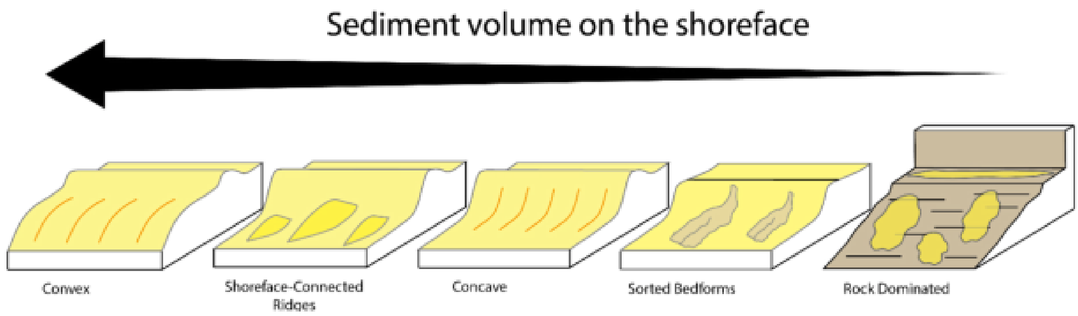


Figure 3.5: Shoreface morphological classification as a function of sediment supply evolving from starved erosion (Far right) to prograding shoreline to the left. Source: (Hamon-Kerivel, et al., 2020).

3.4.3 Proposed extraction area

A long section of the seabed depth on the landward side of the proposed extraction area is presented in Figure 3.6. The average seabed level along the long section is -23.4 mRL and levels vary from -25.6 to -21.9 mRL due to the presence of alongshore bedforms. The long section shows a series of ridges and swales, with crests spaced approximately 1.5 km apart and a crest to trough height of approximately 2 m. The average seabed level in the proposed extraction area is -27.5 mRL and levels vary between -21.9 and -33.8 mRL. Bathymetry of the extraction site is presented in Figure 3.6 showing a more detailed view of the proposed extraction area that demonstrates a complex underwater terrain that is influenced by ridges that protrude about a quarter or halfway across the proposed extraction zone.

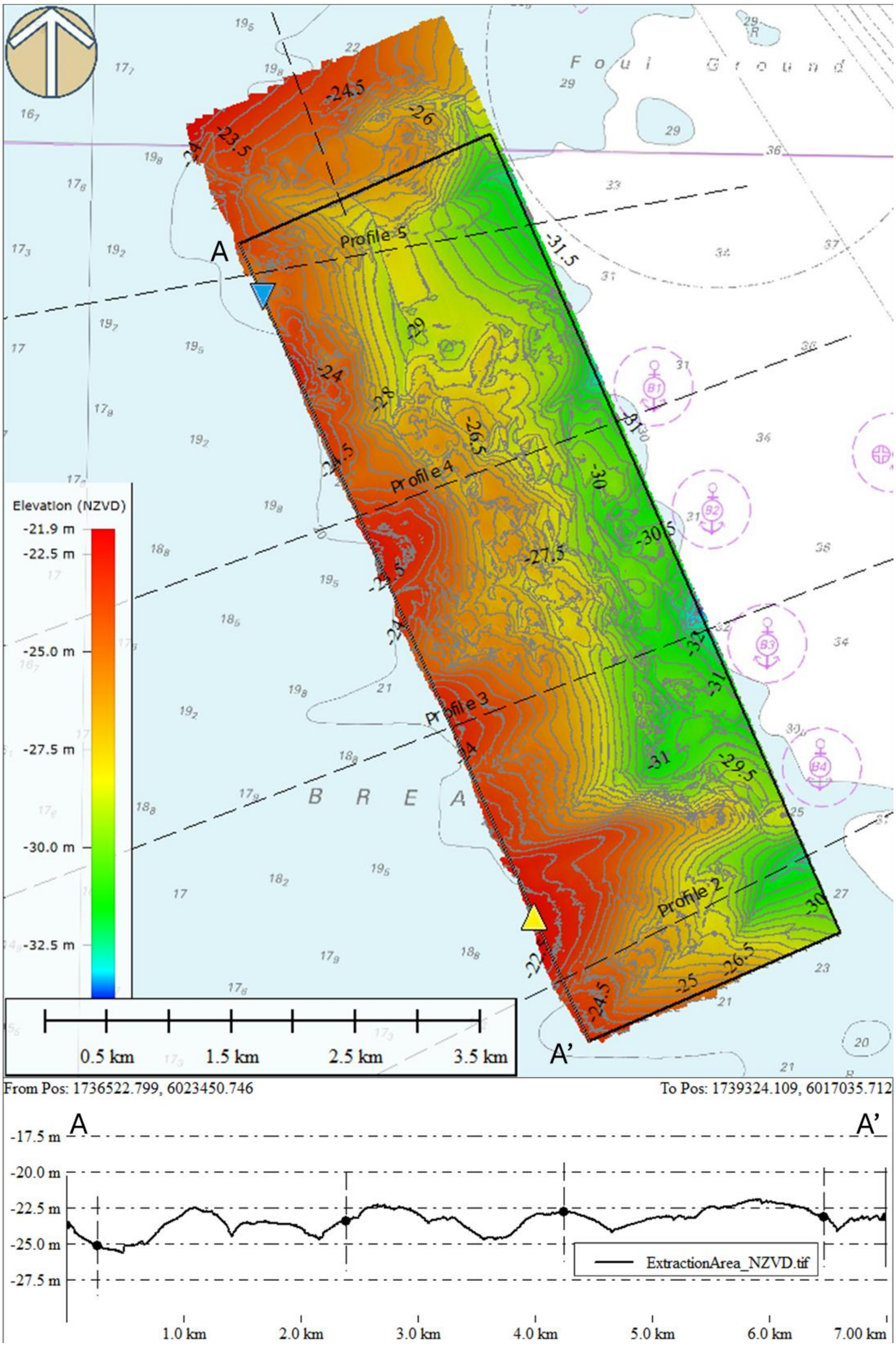


Figure 3.6: Proposed extraction area bathymetry and long section across the landward boundary.

3.5 Sediments

3.5.1 Sediment sources

There are a limited number of non-biogenic sediment sources for the Te Ākau Bream Bay embayment. River input of sediment to the shoreline is thought to be negligible when compared to sand body generated by historic sources (Nichol, 2002). The northern end of the Bay at the mouth of the Whangārei Harbour effectively traps sediment arriving from the catchments and inputs from erosion of headlands and cliffs are also relatively low (Nichol, 2002). The primary sediment source for the sandy barrier construction and the ebb tide delta at the entrance to Whangarei Harbour has been the nearshore and inner shelf deposits on the floor of Te Ākau Bream Bay (Schofield, 1970). These deposits belong to the Hauraki B Sand Facies, which is interpreted as a reworked derivate of the Hauraki A Sand Facies. Both these Facies are derived from the rhyolitic provenance of central North Island and were delivered to the continental shelf by the paleo Waikato River during low sea levels of the last glacial maximum (Schofield, 1970). **The historic sediment supply that formed the coastal system is no longer active** and the current sediment budget is considered functionally closed for this assessment, with negligible sediment inputs to the coast or nearshore.

3.5.2 Sediment size

Early research of beach sediment grading (Schofield, 1970) identified sections of beaches between Langs Beach and 2 miles north of Waipū having the coarsest sediment size, with median grain size (D50) ranging from 0.22 to 0.45 mm while the beaches near Marsden Point had median grain sizes of between 0.16 to 0.19 mm.

For this project, sediment sampling was carried out along the surveyed beach and shoreface profile transects within the proposed extraction area and the northern control area. Along the profile transects, sediment samples were collected every 500 m. Samples were assessed to calculate the representative grain size on the shoreface for use in the depth of closure calculations (Figure 3.7). The median grain size (D50) and the 90th percentile size (D90) from all sample locations on the shoreface were averaged to inform the calculation with some very fine and very coarse outliers removed and is presented for each profile in Table 3.2.

Table 3.2: Grain size details across the Shoreface for each profile

Location	Average D50 (µm)	Standard deviation (µm)	Average D90 (µm)
Profile 1	270	60	490
Profile 2	250	32	530
Profile 3	230	43	425
Profile 4	195	19	360
Profile 5	227	73	455
Profile 6	221	104	370
All profiles	232	55	438

Seafloor backscatter measurement is a by-product of multibeam bathymetry and can provide a qualitative high-level indicator of the possible nature of the seafloor. Because backscatter data directly relates to sediment grain-size and seafloor roughness, it has the ability to provide qualitative information on the composition, i.e. the nature, of the substrate as well as indirectly providing information relevant to fauna and flora (Lurton, 2015).

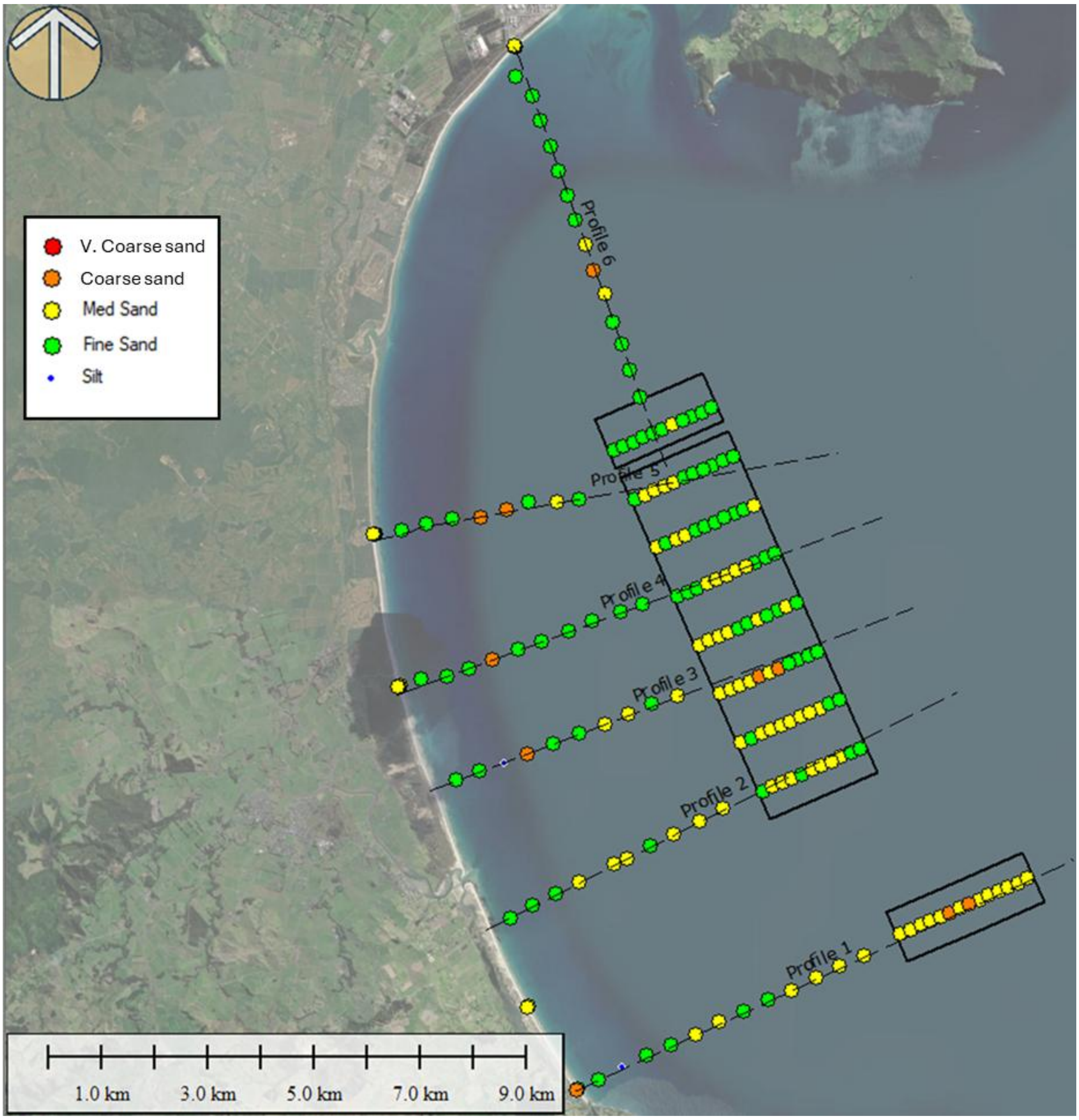


Figure 3.7: Sediment samples with colour indicating grain size classification.

Geological and biological seabed attributes can be ground-truthed through physical sampling of the seabed (sediment cores or grabs) and assessed visually through camera or video techniques which can provide information about the interface roughness and the presence of biological or mineral scatterers. Sediment grain size and density, as well as seafloor roughness, often require separate analysis prior to ground truthing.

The backscatter survey was interpreted with the assistance of sediment samples and underwater photos (photos collected by Bioresearches for MBL as part of the marine ecology assessment) to understand the seabed types on the ridges and swales through the proposed extraction area. The north and east side of the ridges are typically characterised by backscatter values around -29 to -30 decibels, which indicates harder elements on the seabed. In this case, the seabed photos show a presence of shells in these locations, which are identified by orange colours in Figure 3.8.

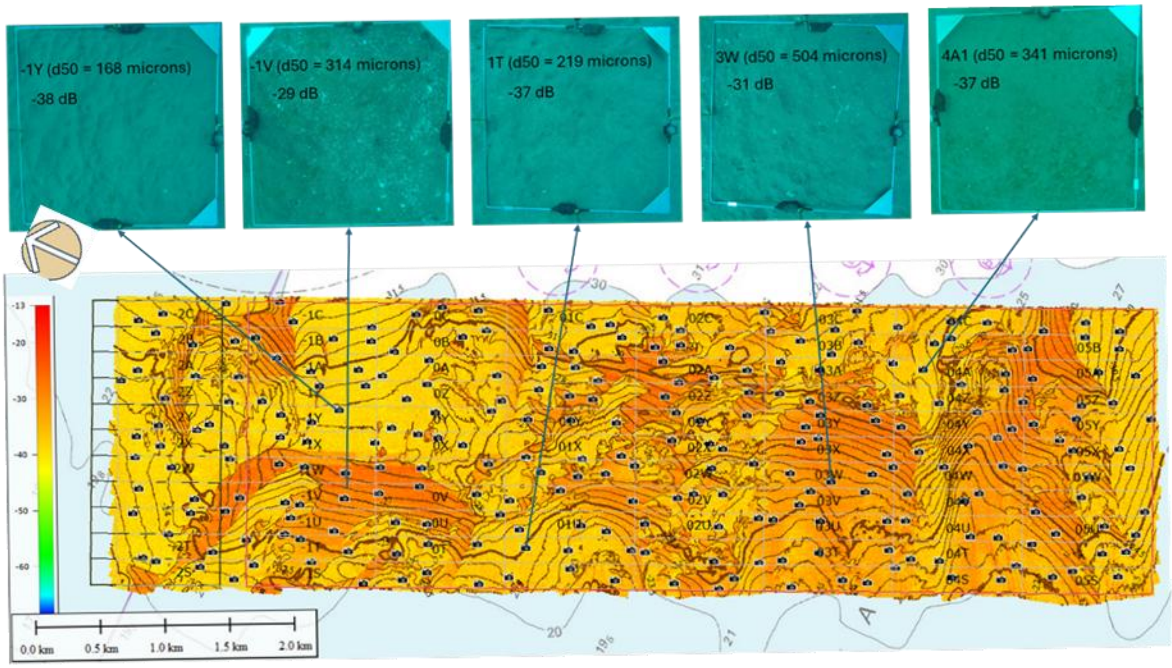


Figure 3.8: Detail of bathymetry with colour scale of backscatter values (decibels) and representative photos mapped to specific backscatter values. Map is rotated and covers the full extraction area.

Backscatter values of lower than -35 m (the more yellow shaded areas in Figure 3.8) are more representative of finer sediments and/or the absence of shelly deposits.

3.5.3 Subsurface sediment cores

Subsurface sediment samples were collected by MBL during the application preparation, under the supervision of geotechnical consultants from T+T. Vibracores were undertaken at 24 locations within the proposed extraction area and an additional 33 cores were taken in the surrounding seabed area. The locations of the vibracores are shown in Figure 3.9.

Sampling was carried out to a maximum depth of 4.9 m below the seabed surface with a mean depth of 2.1 m (depth range 0.97 m to 4.9 m). The achieved depth does not equal the limit of sand. In many cases the depth of core recovered was limited by operational constraints and equipment.

The recovered material was analysed by T+T to understand the sediment characteristics and facies. The core samples can be broadly described as fine to coarse sand with minor shells. Beds containing silt and peat were also identified. Variation in the lateral distribution and bed thicknesses between investigations is apparent. Transects through the extraction area are shown in Figure 3.10.

Results from Te Ākau Bream Bay sampling can also be compared to sub-surface sampling from the Mangawhai-Pākiri Sand Study (MPSS, 1999), which presents an analysis of 17 vibracores conducted south of Te Arai Point that identified 3 main facies. Facies 1 consisted of surficial, fine to medium sands dated up to 8,100 years BP (before present) that constitute Holocene sediment. Facies 2, fine to medium-grained, dark to orange-brown sand, containing well-preserved sedimentary structures and peat layers with a material age of >30,000 years BP. Facies 3 appeared at water depths greater than 30 m, containing thick shell layers dating >40,000 years BP. The material characteristics of the recovered core samples at Te Ākau Bream Bay closely align with Facies 2 of the MPSS.

The MPSS identified the basal Pleistocene contact between facies 1 and 2 as orange-brown sand with rip-up clasts attributed to wave action during a period of lower sea level. The Holocene source was identified as being visually consistent with the surficial sand in each vibracore.

Based on our visual assessment all vibracores, except vibracore VB 20.01, recovered only Holocene sand. Vibracore VB 20.01 encountered a distinct change of sand facies at 1.35 m depth below the seafloor which presented as a change in colour from grey to orange brown and a slight increase in density. We interpret that the core recovered from 1.35 to 2 m in vibracore VB 20.01 is part of the older Facies 2 sediments and therefore, not part of the Holocene sediment. There is a vibracore some 70 m adjacent to this location (VB 20), which extends to 2.2 m below the seabed, and there is no identifiable change in colour. This suggests the Facies 2 seabed level is undulating, possibly part of an irregular dune system, and VB 20.01 might have intersected with the top of one of those features.

Example core annotations are presented in Figure 3.10, showing the sand features in the context of the seabed profile and potential extraction depth (0.55 m over 35 years). More sections are presented in the geotechnical report in Appendix D. Carbon dating on shell fragments from the Mangawhai-Pākiri Sand Study indicates the upper 1-2 m of nearshore and inner shelf sediments (Facies 1) underwent mixing since the mid-Holocene. Variations in bedding thickness, colour, and grain size in the upper 2 m of our samples could be attributed to this mixing.

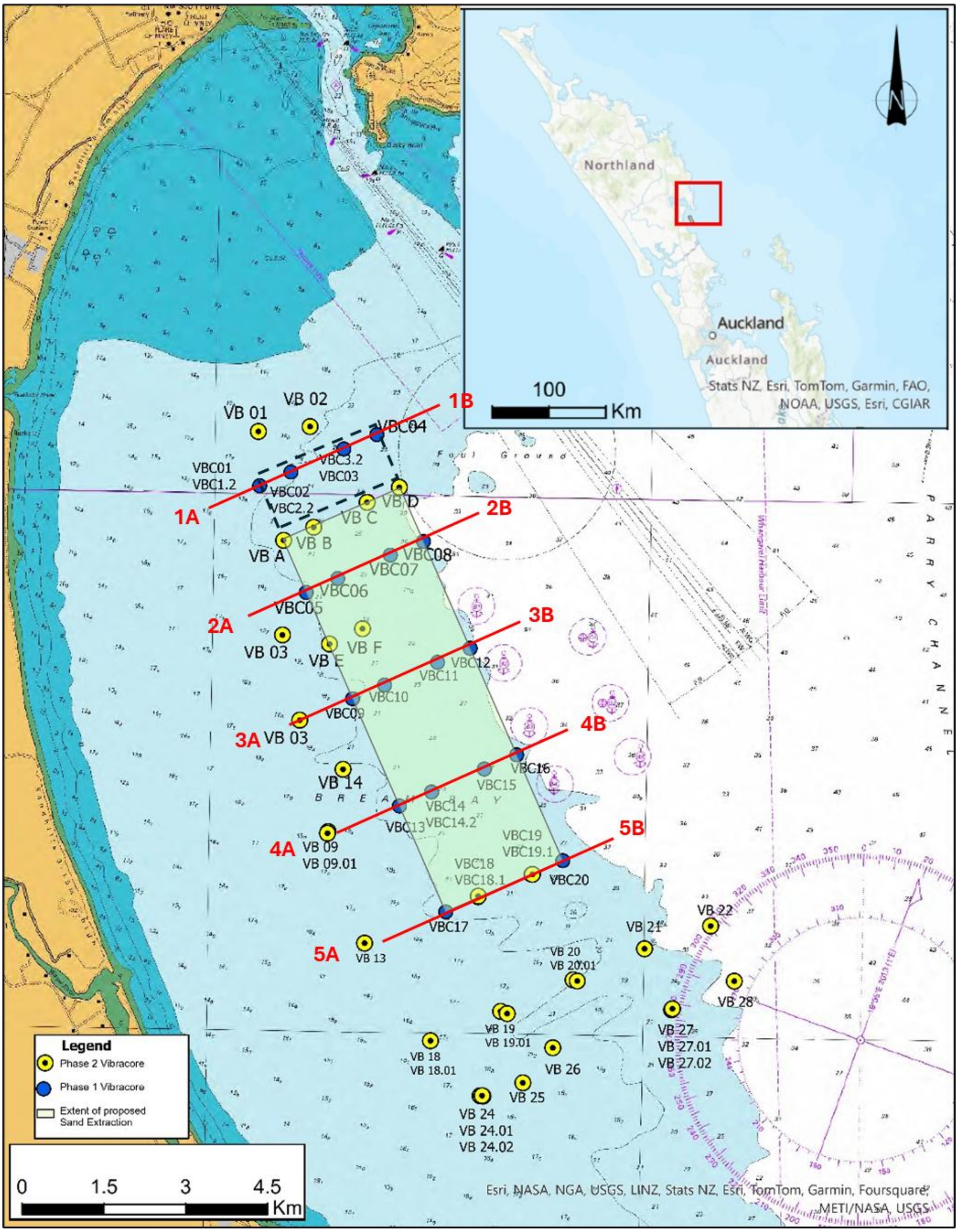


Figure 3.9: The vibracore investigation locations at Te Ākau Bream Bay within the application area. The black dashed line represents the northern ecological control ecological control area, and the green represents the application area.

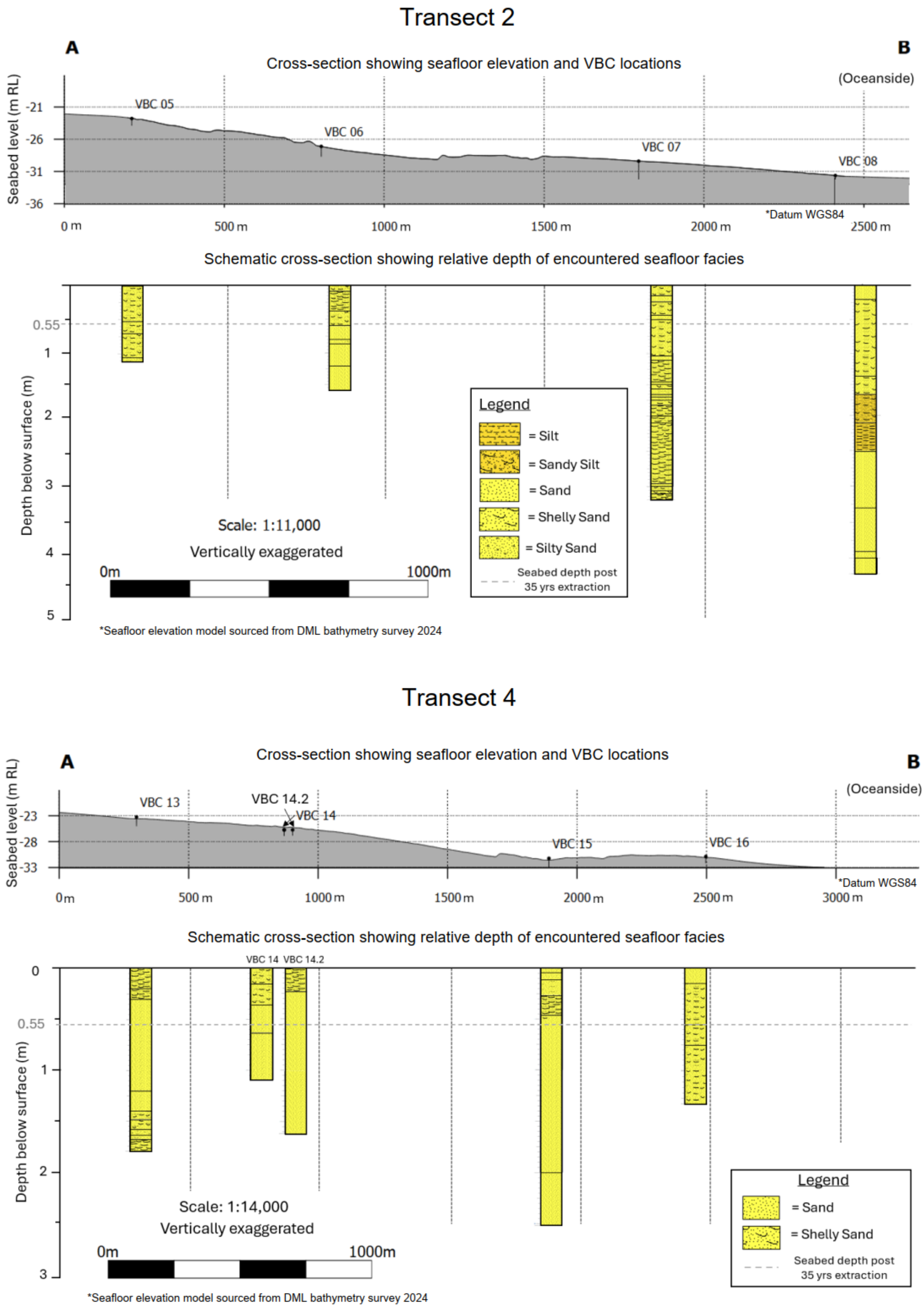


Figure 3.10: Graphic logs of VBC 05 – VBC 08 (Transect 2) and VBC 13 – VBC 16 (Transect 4), and their locations at Te Ākau Bream Bay along a cross-sectional profile of the sea floor (20x vertical exaggeration).

3.6 Water levels

Key components that determine water level are:

- Astronomical tides.
- Barometric and wind effects, generally referred to as storm surge.
- Medium term fluctuations, including El Nino-Southern Oscillation (ENSO) and Inter-decadal Pacific Oscillation (IPO) effects.
- Long-term changes in sea level due to wave transformation processes through wave setup and run-up.

We examine each of these components in the sections below.

3.6.1 Tides

Tide levels for Marsden Point are presented in Table 3.3, based on the LINZ Nautical Almanac which was updated in 2024 based on the average predicted values over the 18.6 year tidal cycle. The spring tide range is 2.23 m, and the neap tide range is 1.33 m. The tide in Te Ākau Bream Bay is semi-diurnal with approximately 12.25 hours between high and low tide.

Table 3.3: Astronomical tides for Marsden Point (Source: LINZ 2024)

Tide level	Chart Datum (m)	NZVD (2016) mRL
Highest Astronomic Tide (HAT)	3.03	1.28
Mean High Water Springs (MHWS)	2.73	0.98
Mean High Water Neaps (MHWN)	2.29	0.54
Mean Sea Level (MSL)	1.62	-0.13
Mean Low Water Neaps (MLWN)	0.96	-0.79
Mean Low Water Springs (MLWS)	0.50	-1.25
Lowest Astronomic Tide (LAT)	0.16	-1.59

3.6.2 Storm surge

Storm surge results from the combination of barometric setup from low atmospheric pressure and wind stress from winds blowing along or onshore which elevates the water level above the predicted tide (Figure 3.11). Storm surge applies to the general elevation of the sea above the predicted tide across a region but excludes nearshore effects of storm waves such as wave setup and wave run-up at the shoreline.

Previous studies of storm surge around New Zealand's coastline have concluded that storm surge appears to have an upper limit of approximately 1.0 m over and above the tidal water level (MfE, 2004). Given the perceived upper limit of storm surge for New Zealand, a standard storm surge of 0.9 m is considered representative of a return period of 80 to 100 years (MfE, 2004).

An extreme value analysis of hourly sea level data for Marsden Point was done using a Weibull distribution. The resulting extreme water levels for a range of return periods for Marsden Point are shown in Table 3.4. These results, provided by NIWA with respect to MSL (2010 - 2019), were corrected to NZVD2016 using offsets included in (NIWA, 2020) and offset levels provided by NRC.

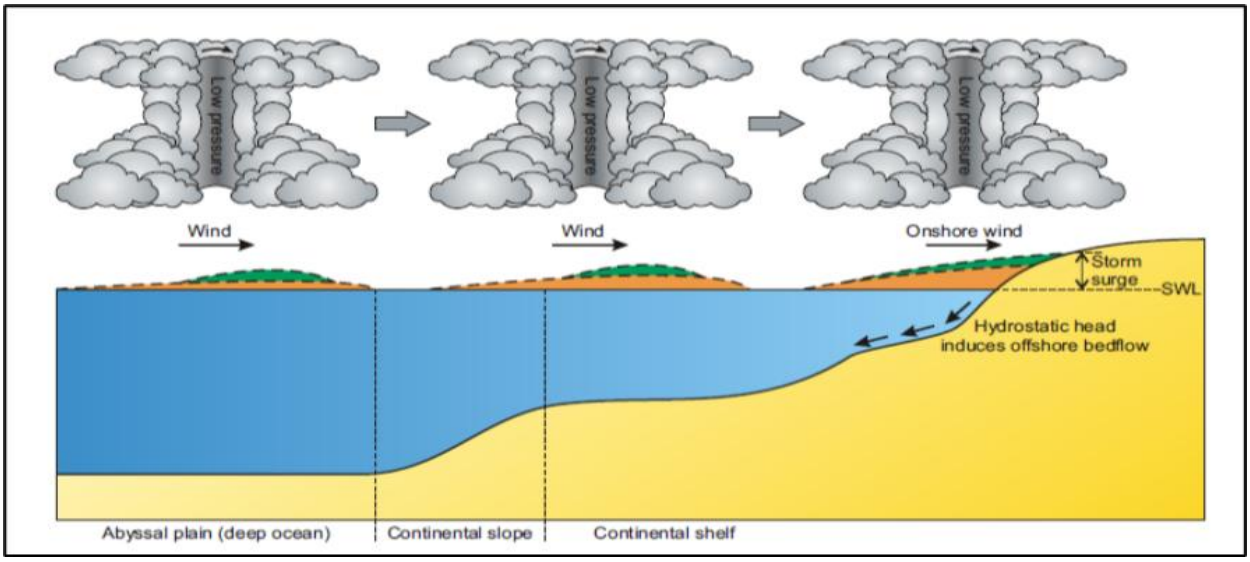


Figure 3.11: Processes causing storm surge (Source: (Shand, 2010)).

Table 3.4: Storm tide levels for Marsden Point (Source, (T+T, 2021))

Return period storm tide	Water level (m, NZVD)	Water level (m, Chart Datum)
5 yr	1.42	3.17
10 yr	1.46	3.21
20 yr	1.52	3.27
50 yr	1.60	3.35
100 yr	1.67	3.42

3.6.3 Medium term fluctuations and cycles

Atmospheric factors such as season, ENSO (El Niño-Southern Oscillation), and IPO (Interdecadal Pacific Oscillation), can all affect the mean level of the sea at a specific time. Seasonal fluctuations and IPO phase changes can both be in the order of ±4 to 8 cm and ENSO fluctuations can be in the order of ±12 cm. The combined effect of these fluctuations may be up to 0.25 m (Bell, 2019).

3.6.4 Long term trends

Historic sea level rise in New Zealand has averaged 1.81 ± 0.05 mm/year from around 1900 to the present, with the rate doubling to 2.44 mm/year for the period 1961 to 2018 compared to data from 1900 to 1960 (Bell, 2019). Data from Marsden Point shows the area is exhibiting a rate of 2.2 ± 0.6 mm/year.

The IPCC has produced the latest climate change projections (IPCC, 2021). This has been downscaled by NIWA (NZ SeaRise Programme). The SLR projections for each SSP in the present day, 2070 and 2130 are given in Table 3.5 for a site centrally located in Te Ākau Bream Bay. The 2070 time period is associated with the likely end of life of a consent if it were granted and 2130 provides a perspective of at least 100 years. NZ SeaRise projections use a baseline of 1995 - 2014 with a mid-point (zero) at approx. 2005.

Table 3.5: Sea level rise predictions (50th percentile) for various projection scenarios (metres above 2005 baseline) at site 929, Te Ākau Bream Bay

Time frame	Emission Scenario				
	SSP1-1.9M	SSP1-2.6M	SSP2-4.5M	SSP3-7.0M	SSP5-8.5M (H+)
2030	0.11	0.11	0.11	0.13	0.11 (0.16[1])
2070	0.25	0.29	0.35	0.45	0.44 (0.57[1])
2130	0.51	0.62	0.82	1.21	1.25 (1.71[1])

[1] 83rd percentile

Vertical land movement is the average long-term rate of change over multiple decades on the land surface and can include processes such as tectonic movements and subsidence that cause land to move up or down. This can impact relative sea level rise at any location. The NZSeaRise website suggests that the vertical land movement (VLM) rate at site 929 located centrally in Te Ākau Bream Bay is -0.8 ± 2.3 mm/year (i.e. potentially sinking but significant uncertainty). The SLR projections for the present day, in 2070 and in 2130 with VLM for each SSP are given in Table 3.6. The year 2070 provides a conservative representation of the end date of a 35 year consent duration and 2130 represents a period of at least 100 years, that is consistent with the requirements of the NZCPS.

Table 3.6: Sea level rise predictions including VLM for various projection scenarios for the 50th percentile (M) and 83rd percentile (H+) for the SSP5-8.5 projection (2005 baseline)

Time frame	SSP1-1.9M	SSP1-2.6M	SSP2-4.5M	SSP5-8.5M (H+)
2030	0.13	0.13	0.13	0.14 (0.24)
2070	0.31	0.35	0.41	0.50 (0.75)
2130	0.63	0.74	0.94	1.38 (2.01)

The modelling also includes the potential for a low likelihood, high consequence event of marine ice cliff instability (MICI), although this scenario is characterised by deep uncertainty due to limited process understanding and limited availability of evaluation data. If this event does occur, sea level changes could be in the order of 2 to 5 m at 2150.

3.6.5 Climate change effects on storms, winds, storm tide and waves

NIWA has investigated possible future changes to storm surge and wave climate around New Zealand for present day conditions and then with future scenarios of climate change based on the IPCC emission projections. The results of this assessment suggest the southern New Zealand region would expect only small increases in mean annual wave height (generally less than 2 to 3%) with slight increases on the western and southern coasts, but small decreases in mean wave height elsewhere. For the extreme wave height, increases of between 0 to 5% could be expected with a lower likelihood of increases up to 15%.

The University of Auckland developed a set of historical and projected wave climatology's from 3 global climate models (GCM) and two projected pathways. Waves were downscaled in non-stationary mode and historical boundaries were obtained from 20 years (1986 – 2006) of wave data from three GCMs (ACCESS1-0, CNRM-CM5 and MIROC5). The future wave climate boundaries and wind forcing are from two 20 year (2026 – 2046, 2080 – 2100) ensembles of wave climate projections from the same GCMs under two different representative concentration pathways (RCP 4.5, RCP 8.5). The mean annual significant wave height for the historic and for 2026 and 2081 are shown in Table 3.7 for the three climate models. The results show variable predicted changes in wave height from the historic data, with some anomalous results from the MIROC5 modelling for RCP8.5 2026 that are not carried through to 2081. However, changes are relatively small and assuming a 5% change in mean annual wave height in 2081 is considered conservative.

Table 3.7: Mean annual significant wave heights in Te Ākau Bream Bay from University of Auckland Wave Data Tool

Site (-36, 174.6) depth 36.6 m	Mean annual Hs (m) for different climate models		
Time period	**Access1.0**	**CNRM-CM5**	**MIROC5**
Historic (1986-2006)	0.8	0.7	1.1
RCP4.5 2026	0.8	0.7	1
RCP8.5 2026	0.8	0.8	1.3
RCP4.5 2081	0.9	0.8	1
RCP8.5 2081	0.8	0.8	1.1

For future climate change scenario testing, a sea level rise increase of 0.35 m and a 5% increase in mean wave height have been used to evaluate potential effects including climate change. The 0.35 m increase in relative sea level is based on a plausible 35 year consent from 2025 to 2060, which is a rate of 10 mm/yr. This rate of 10 mm/yr is within the confidence interval for a range of projections encompassing SSP2-4.5, SSP3-7.0 and SSP5-8.5. The potential influence of sea level rise is a landward movement of the depth of closer landward proportional to the increase in water depth.

3.7 Wind climate

The annual wind climate within Te Ākau Bream Bay has been developed from WRF (Weather Research and Forecast Model) hindcast wind data and is shown in Figure 3.12. The hindcast wind data shows winds are predominantly from the west/southwest but strong winds can come from all directions, with the strongest winds associated with tropical cyclones from the east/north-east.

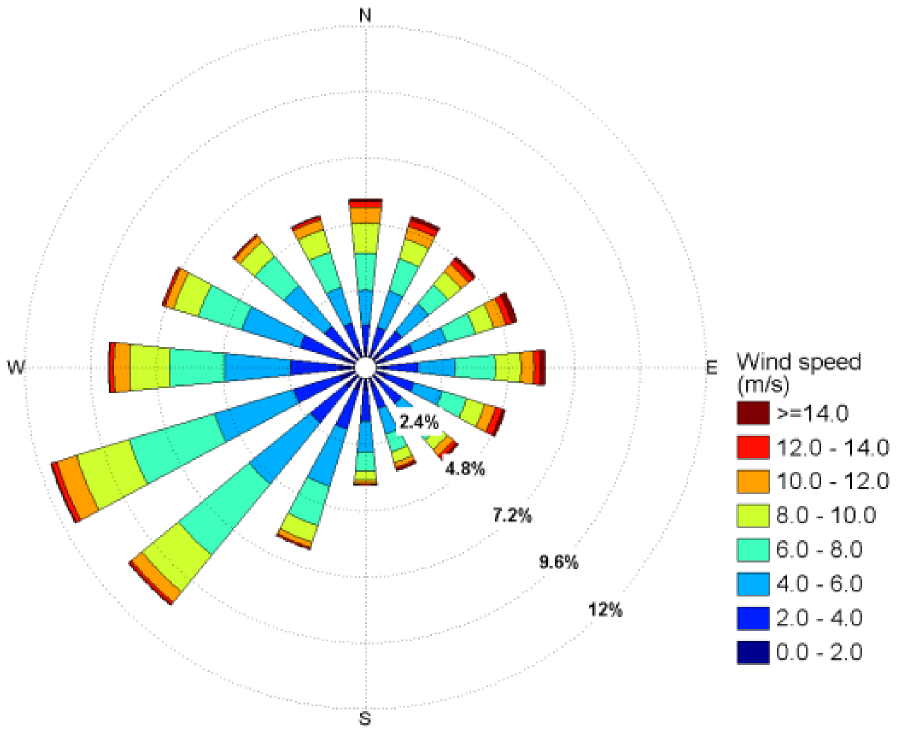


Figure 3.12: Annual wind rose plot at the wave rider buoy in Te Ākau Bream Bay that shows the direction from which the wind is coming (Source: (MOS, 2016)).

3.8 Wave climate

3.8.1 Wave data

The wave climate in Te Ākau Bream Bay was analysed using both the measured wave conditions from the North Port wave buoy and a 45 year wave hindcast. The 45 year wave hindcast was obtained using an industry standard model undertaken by MetOcean Solutions and consists of hourly wave conditions at 36 locations between 1979 and 2024 (MetOcean Ltd, 2024). The five main output locations used to inform the assessment are indicated in Figure 3.13 as triangles at the seaward boundary of cross shore profiles and one at the location of the wave buoy where measured wave data is available (indicated with the diamond in Figure 3.13).

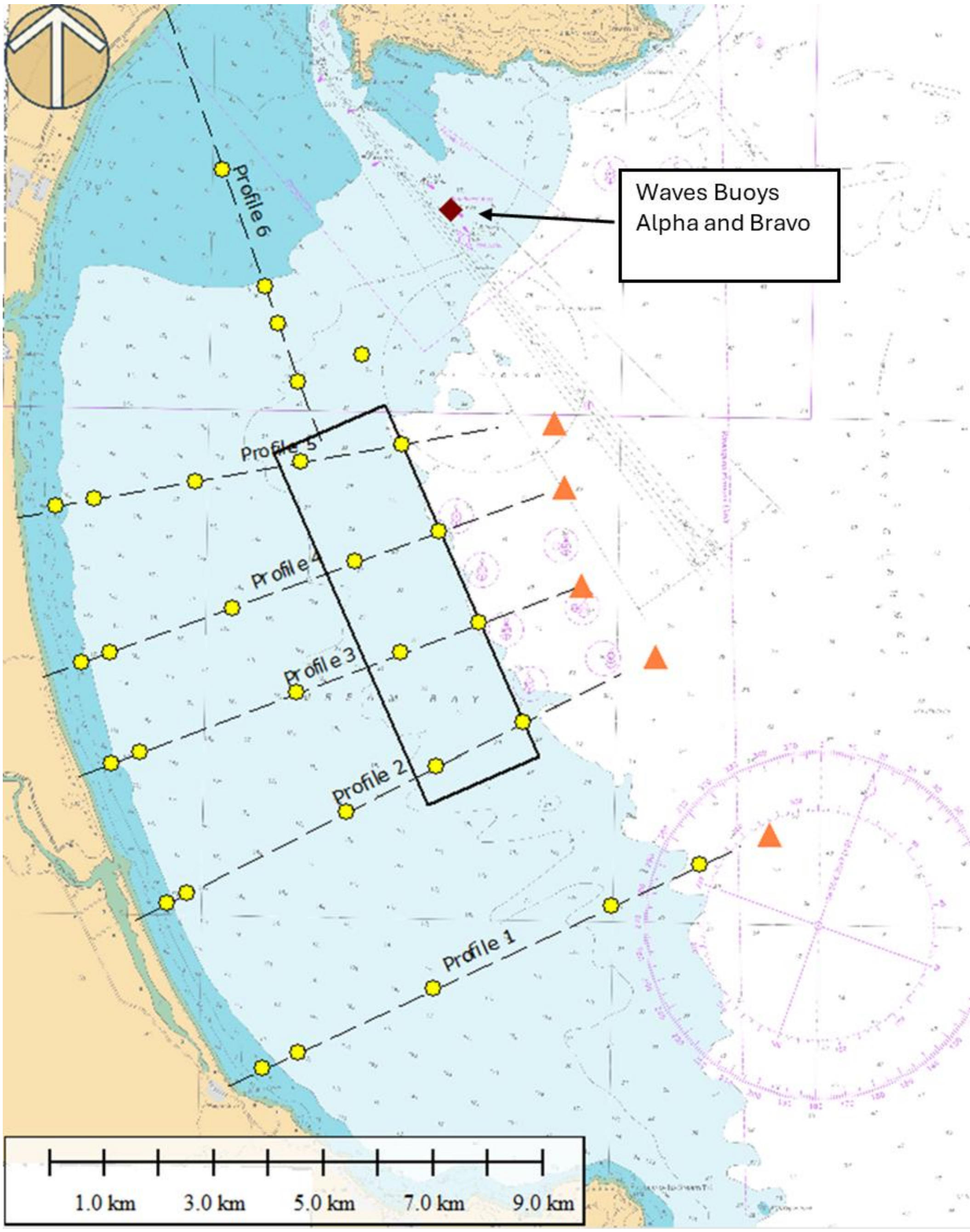


Figure 3.13: Location of wave climate points used to inform this assessment. The orange triangles indicate the output points of the 45 years wave hindcast from MetOcean Solutions used offshore of each transect. The diamond triangle indicates the location of the wave buoy. Yellow points are at each 5 m change in elevation.

3.8.2 Typical wave climate

3.8.2.1 Modelled wave climate

A summary of the wave climate at all locations is presented in Figure 3.14 and Figure 3.15. Figure 3.14 presents the relationship between significant wave height (H_s), peak wave period (T_p) and occurrence (in % of time) for all 396,649 timeseries points. Figure 3.14 shows that the wave climate at the different profiles presents quite a wide range of wave heights and periods, where small waves (up to ~1 m significant wave height) with peak wave periods between 8 and 10 seconds are the most common. The average peak wave period for all profiles is 9 seconds. Large waves (up to 6 m H_s) do occur, but very rarely. Wave periods associated with more extreme events range between 8 – 16 seconds, with the average peak period associated with wave heights exceeding 12 h/yr being 11 s.

Figure 3.15 presents the relationship between significant wave height (H_s), peak wave direction (degrees), and occurrence (% of time). This figure shows that the most common waves for all profiles come in from the northeast and have a significant wave height of up to 1 m. For the location of the wave buoy, the most common waves come in from the east, as waves from the north and northeast are blocked by the presence of Bream Head. Local wind waves from all directions are generated locally with significant wave heights up to ~1.5 m.

The highest waves can come in from both the northeast and the southeast. Depending on the location in Te Ākau Bream Bay, these waves can be blocked by the presence of islands in the Hen and Chicken/Taranga-Marotere Islands. This is visualised in Figure 3.16, where the wave direction scatter plots for profile 1 and profile 5 output points are plotted on top of the contour lines for Te Ākau Bream Bay. This Figure shows that large waves are coming in from the southeast at profile 1, but these waves are blocked by Taranga Island and do not reach up to profile 5. Similarly, large waves from the northeast at profile 5 are partly blocked by the presence of Taranga Island and do not all reach up to profile 1.

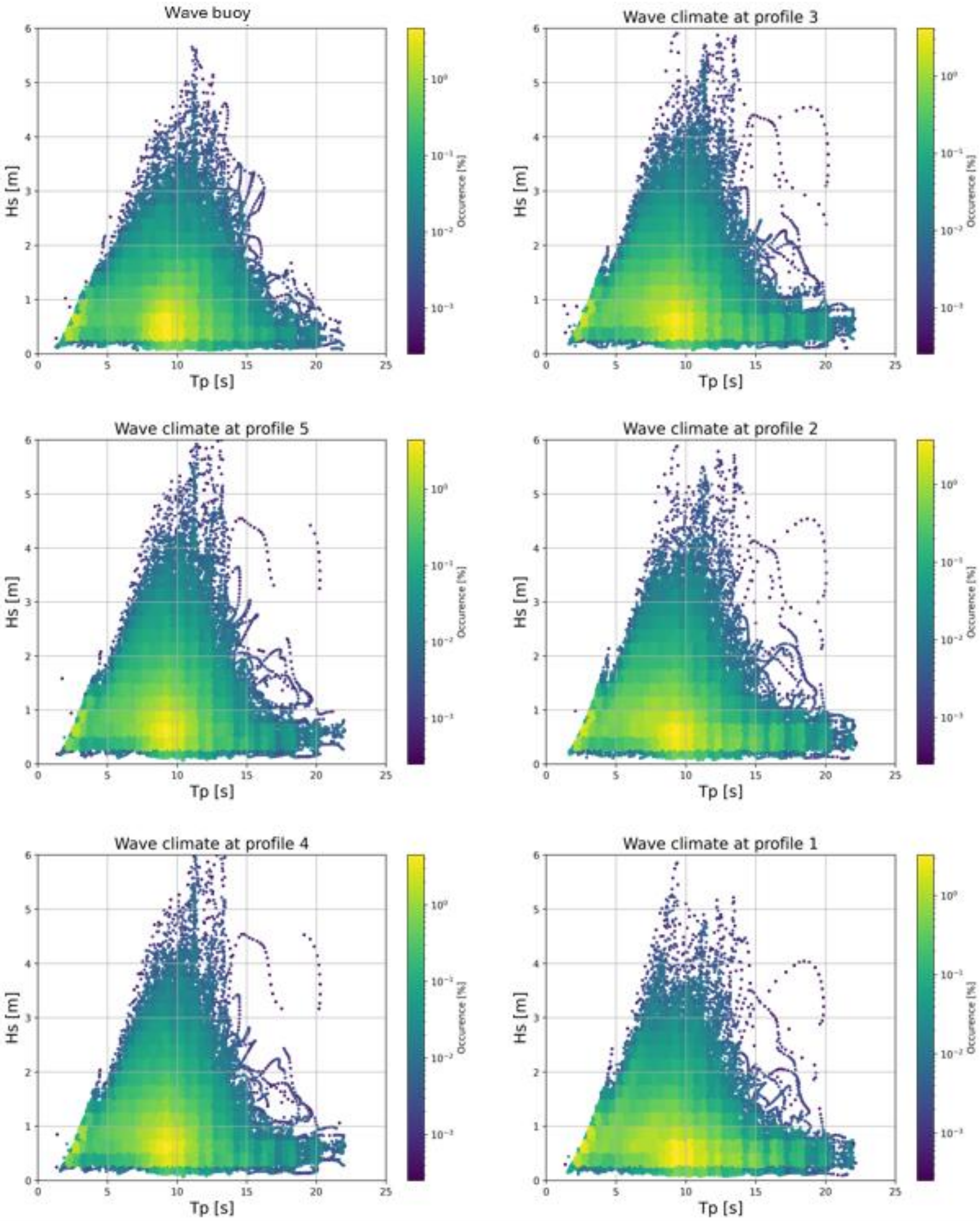


Figure 3.14: Relationship between significant wave height (H_s), peak wave period (T_p), and occurrence (% of time) at all output locations from MetOcean Solutions' hindcast.

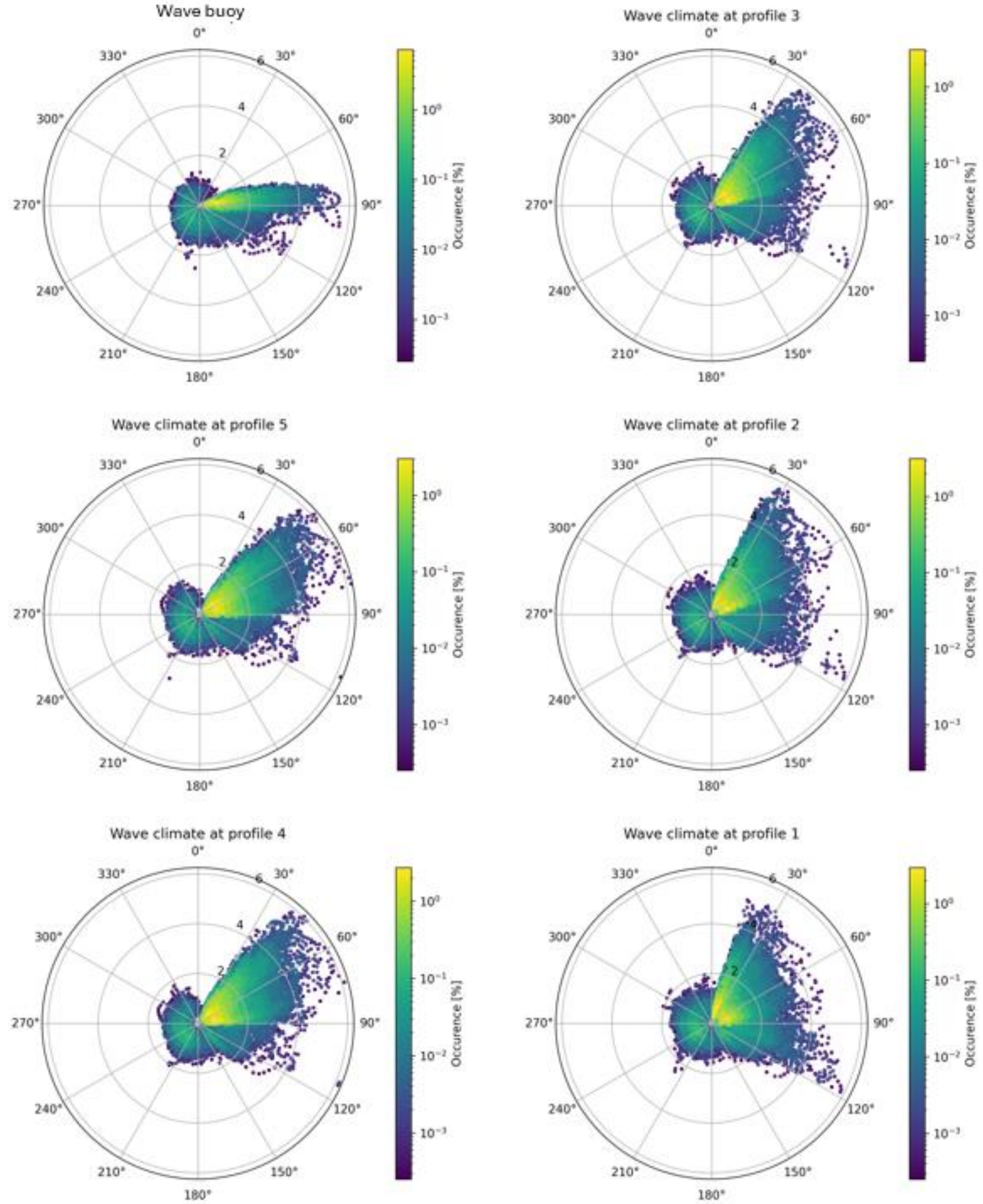


Figure 3.15: Relationship between significant wave height (H_s), peak wave period (T_p), and occurrence (% of time) at all output locations from MetOcean Solutions' hindcast.

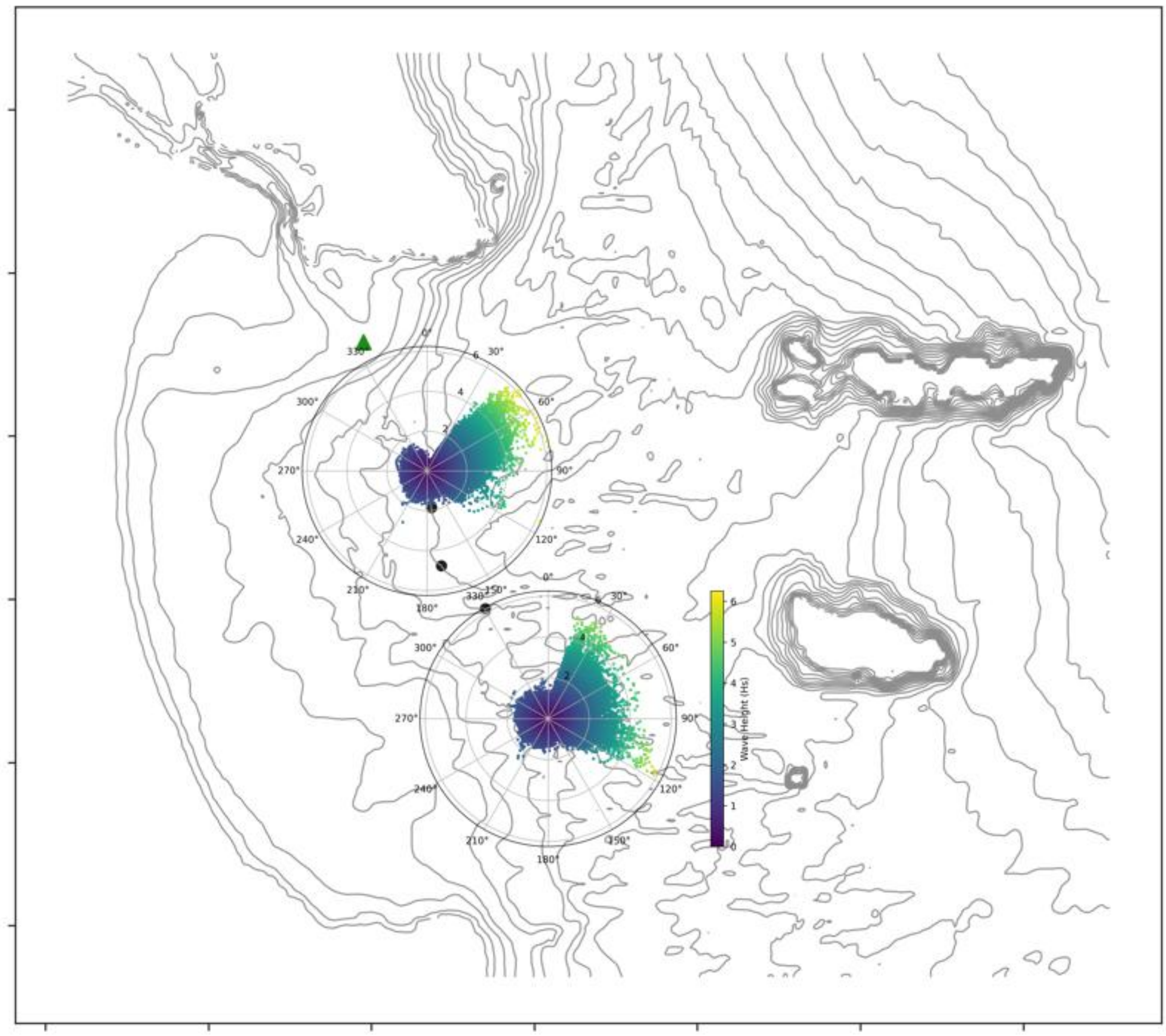


Figure 3.16: Wave direction scatter plots at profile 1 and profile 5, plotted on top of the contour lines of Te Ākau Bream Bay. The colour in the scatterplots is linked to the significant wave height.

Table 3.8 lists the wave statistics for the different profiles in Te Ākau Bream Bay. These statistics are based on the full 45 year wave hindcast from MetOcean Solutions.

Table 3.8: Wave statistics at different locations in Te Ākau Bream Bay

Wave condition	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5
Maximum Hs	5.85	5.88	5.90	6.14	6.19
P99% Hs	2.58	2.80	2.85	2.93	2.96
P90% Hs	1.31	1.45	1.49	1.57	1.59
P75% Hs	0.91	1.00	1.04	1.09	1.11
P50% Hs	0.63	0.70	0.71	0.76	0.77
P25% Hs	0.44	0.49	0.50	0.54	0.54

Note: That p99% Hs indicates the 99th percentile significant wave height.

3.8.2.2 Measured wave climate

Figure 3.13 shows the location of two wave buoys: Alpha and Bravo buoy. At Alpha buoy, measured wave conditions are available for the period from 1/1/2007 until 17/2/2023, and at Bravo buoy, measured wave conditions are available for the period from 2/1/2020 until 30/3/2024. The significant wave height statistics for both Alpha and Bravo buoys are listed in Table 3.9.

Table 3.9: Significant wave height statistics (Hs) for observed wave conditions at Alpha and Bravo buoy

Percentile [%]	Hs Alpha buoy [m]	Hs Bravo buoy [m]
Maximum Hs	7.00	4.50
P99% Hs	2.70	2.50
P90% Hs	1.41	1.40
P75% Hs	0.94	0.80
P50% Hs	0.60	0.60
P25% Hs	0.40	0.40

Note: Based on measurements over a period of 16 years (Alpha buoy) and 4 years (Bravo buoy).

For Alpha buoy, the measured and modelled significant wave height H_s was plotted for the period 1/5/2020 to 31/5/2020. This is shown in Figure 3.17. As can be seen from the Figure, the significant wave height of the highest modelled waves seems to be underpredicted compared to the observed significant wave height. This was supported by the results shown in Figure 3.18, where the observed and modelled significant wave height that is exceeded during 12 hours per year H_{s12t} is plotted for each year in the 16 year observation period at Alpha buoy. As can be seen from the Figure, the H_{s12t} seems to be underpredicted in the MetOcean Solutions hindcast. Although there is quite some scatter in the ratio between $H_{s12t,observed}$ and $H_{s12t,modelled}$, the average ratio was calculated to be 1.4.

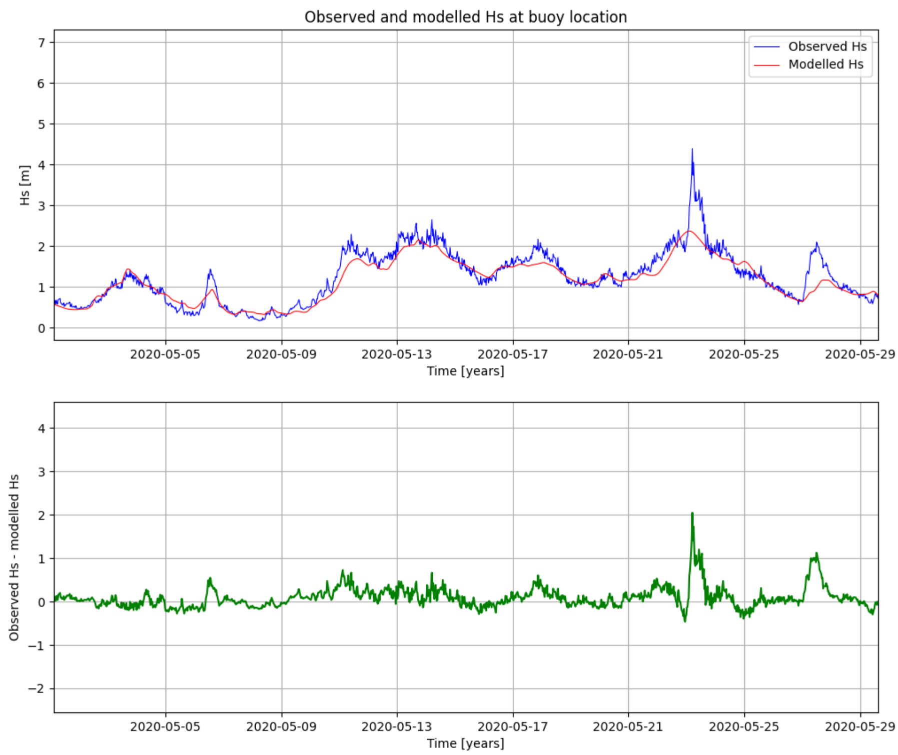


Figure 3.17: Upper plot: observed and modelled significant wave height H_s for the period 2020-5-1 till 2020-5-31. Lower plot: difference between observed and modelled significant wave height H_s.

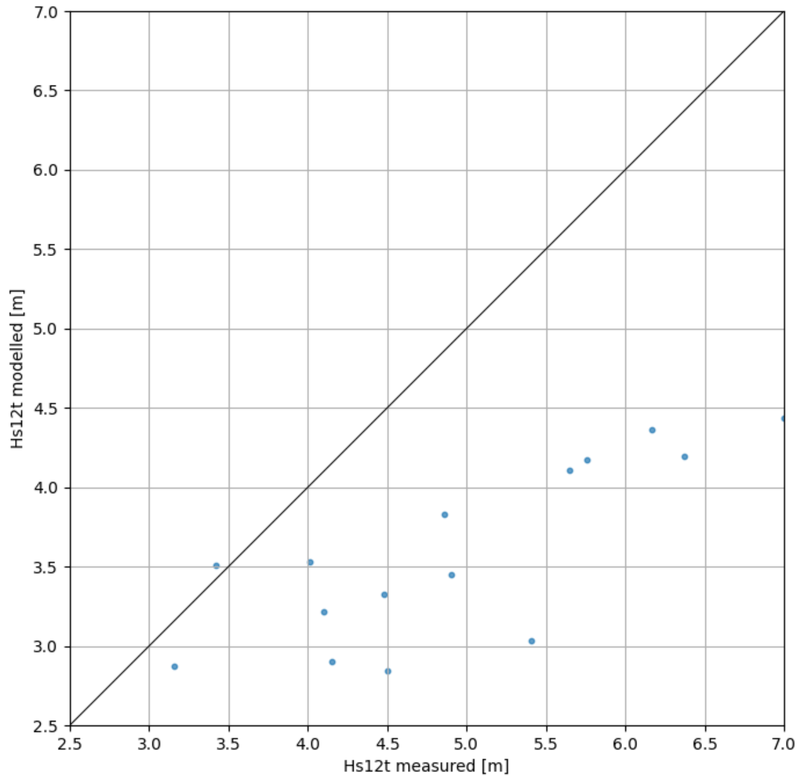


Figure 3.18: Scatterplot of the observed and modelled significant wave height that is exceeded during 12 hours per year H_{s12t}, for each year in the 16 year observed wave parameters timeseries at Alpha buoy.

3.8.3 Extreme events

In addition to an analysis of the typical wave conditions, an extreme value analysis was undertaken to understand the wave height potential for events that may occur outside of the 45 year hindcast period (Table 3.10). The results include the wave buoy location and a point at the seaward end of each profile in the 45 year hindcast. These extreme wave heights are not corrected for a potential model under-prediction. The most extreme wave heights occur at the northern section, offshore of profiles 4 and 5.

Table 3.10: Average return interval (ARI) significant wave heights (m)*

ARI	Wave buoy**	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5
1 year	3.61	3.65	3.82	3.90	4.06	4.10
2 years	4.05	4.18	4.51	4.58	4.64	4.67
5 years	4.53	4.67	5.04	5.12	5.18	5.21
10 years	4.86	5.01	5.38	5.46	5.54	5.57
20 years	5.18	5.32	5.69	5.77	5.88	5.91
50 years	5.59	5.71	6.06	6.15	6.31	6.34
100 years	5.89	5.99	6.32	6.43	6.62	6.64
200 years	6.19	6.26	6.56	6.68	6.92	6.95

*Based on the full 45 year wave hindcast from MetOcean.

**Based on model output at the buoy locations, not based on measurements.

The wave height exceeded for 12 hours a year is used to calculate the inner DoC and DoT. When adjusted for hindcast model under-prediction using a factor of 1.4 (calculated above in 3.8.2.2), the 12 h/yr exceeded wave height at the site ranges between 5.0 m at Profile 1, to 5.8 m at profiles 4 and 5. The average across all profiles is 5.6 m (Table 3.11). The peak period associated with the 12 h/yr exceeded wave height averages to be 11 s for all profiles.

Table 3.11: 12 h/yr exceeded wave height and associated period (calibrated)

ARI	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5	Average
Hs 12h/yr (m)	5.00	5.50	5.70	5.80	5.80	5.60
Tp 12h/yr (s)	10.3	11.3	11.4	11.3	11.3	11.1

3.9 Tidal circulation

The large-scale oceanography of northern New Zealand is dominated by a general west to east movement of oceanic water from the Tasman Sea. Part of this flow temporarily attaches to the northeastern New Zealand continental shelf as it flows toward the Eastern Pacific, forming a south eastward flowing current of subtropical water, the East Auckland Current. Due to the narrow continental shelf in the Hauraki Gulf region, the proximity of the East Auckland Current has significant implications for the inner shelf and coastal zone physics and nutrient supply (Zeldis, 2004).

In the analysis of current meter data from 5 locations inside the Gulf, (Grieg, 1990) observed that the strongest signal in the time series was associated with tidal forcing. Maximum recorded flows were in the order of 0.25-0.4 m/s throughout the Gulf except near Cape Colville where 0.8 m/s was recorded. Using current meter observations, (Sharples, 1998) inferred that seasonal and weather-band variability in the strength of vertical stratification has a marked effect on the observed tidal currents through the addition of a baroclinic tide, which is highly non-linear. They also found that surface mean flows observed throughout all deployments were generally along the shelf edge, and towards the southeast at speeds of 0.2-0.3 m/s and reaching 0.6 m/s at times near Cape Brett.

Based on findings from the Mangawhai-Pākiri Sand study (Bell, 1997), mean currents in the wider Te Ākau Bream Bay lower water column were generally weak, with a median speed in the range of 0.04 – 0.07 m/s and a 90% speed less than 15 cm/s apart from the headland area off Cape Rodney. The tidal contribution to measured currents was less than 25% of the variability in mean current. The remainder of the current was generated by non-tidal effects such as winds, density stratification and oceanic intrusions. Near bed currents, particularly in shallower areas are dominated by wave processes, although mean currents contribute to the mass movement of sediment.

Tidal modelling was carried out within Te Ākau Bream Bay as part of the Refining New Zealand channel deepening project (MOS, 2016) to characterise the circulation in the continental shelf waters within the Bay. A 10 year hindcast was performed using the locally validated ROMS hydrodynamic model that used 3-hourly atmospheric forcing from the Weather Research and Forecasting model that covers the entire coastal environment around New Zealand. Validation was achieved with four ADCP measurement campaigns undertaken between January and July 2016 (Figure 3.19).

A comparison of the measured and modelled data at ADCP2 was carried out (Figure 3.22) and the correlation between the model and measured dominant V-component of the not-tidal velocity was good. There was a larger variation between the modelled and measured U-component, but as this component was very low (rarely exceeding 0.05 m/s) the difference was not considered to have a significant impact on the model performance (MOS, 2016).

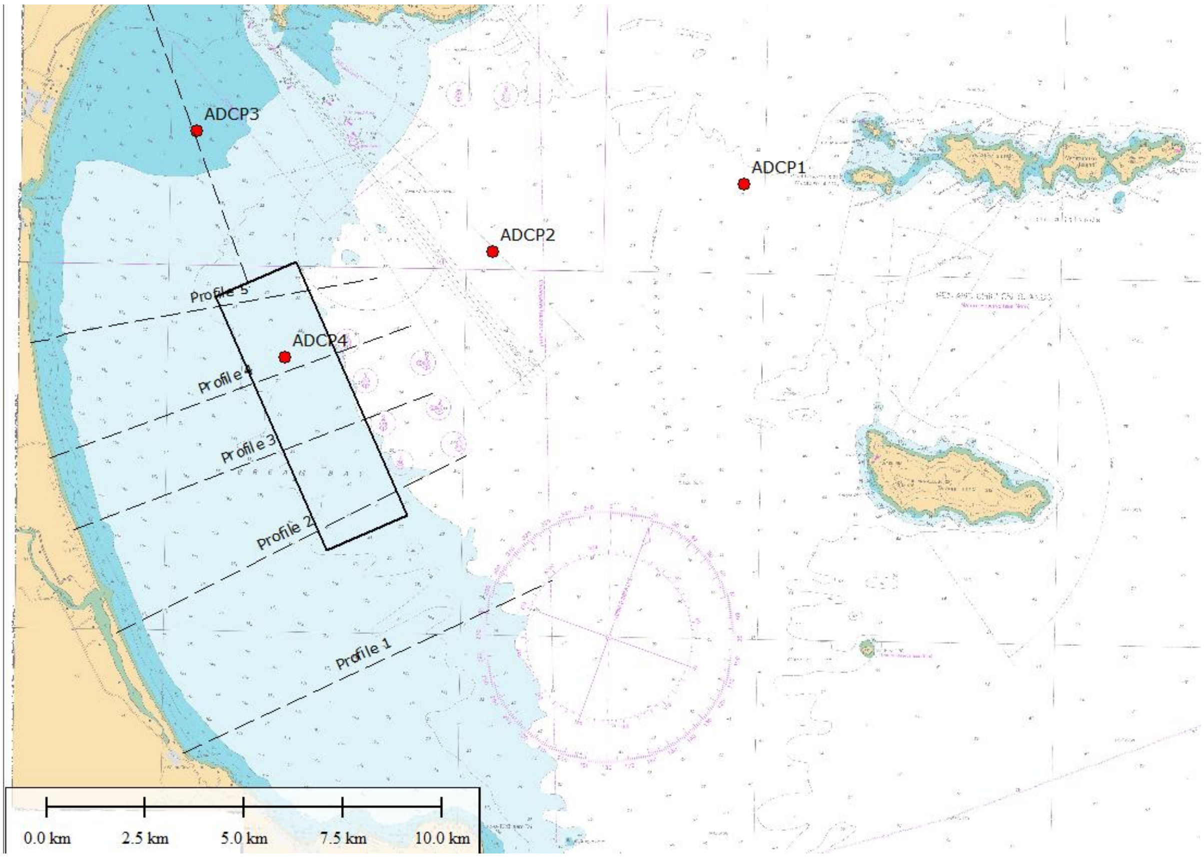


Figure 3.19: Location of current meters in relation to proposed extraction area (Source: (MOS, 2016)).

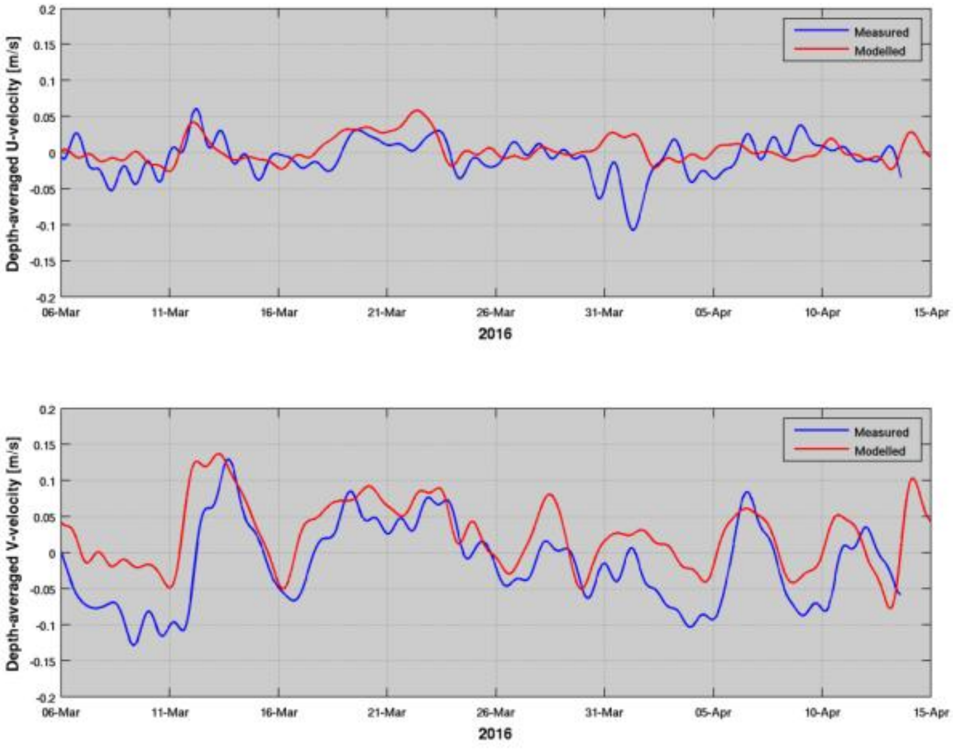


Figure 3.20: Time series of modelled and measured non-tidal depth-averaged current velocity at ADCP2 from 5 March to 14 April 2016 (source: (MOS, 2016)).

The measured currents at ADCP4 situated in the area of proposed extraction is shown in Figure 3.21 and Figure 3.22. The results show slightly higher velocities than at ADCP2, but of a similar magnitude to those identified by (Bell, 1997). Currents were generally less than 0.15 m/s and typically being between 0.05 to 0.1 m/s. The current direction is variable and indicative of significant non-tidal effects. These results are like those found in the earlier studies. Using the results of the 10 year (2000-2010) ROMS hindcast the climatological flow patterns in Te Ākau Bream Bay based on mean current speeds are shown in Figure 3.23. This highlights the current pattern as being north to south, not onshore and offshore.

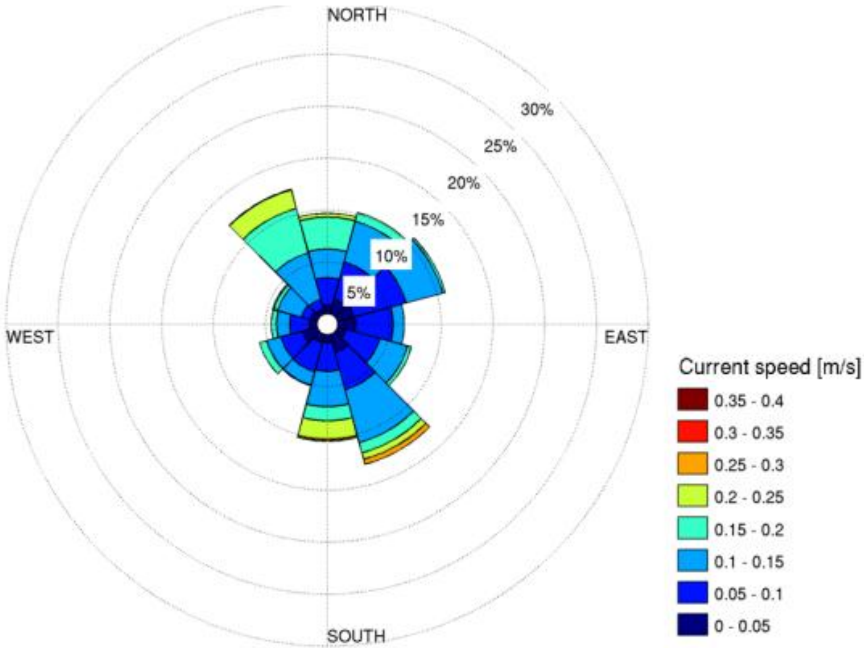


Figure 3.21: Tidal current speed rose at ADCP4 showing direction of where currents are moving to (source: (MOS, 2016)).

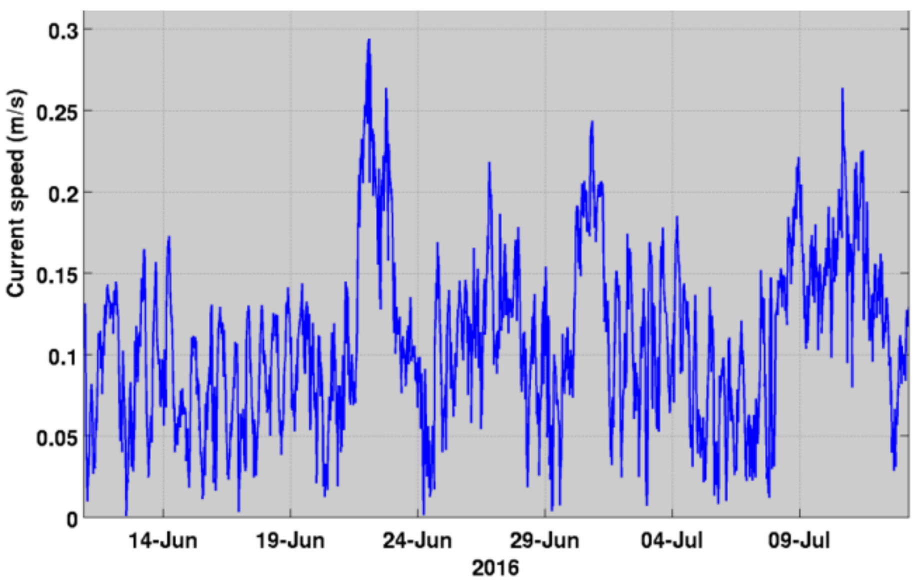


Figure 3.22: Measured depth-average current speed at ADCP4 (source: (MOS, 2016)).

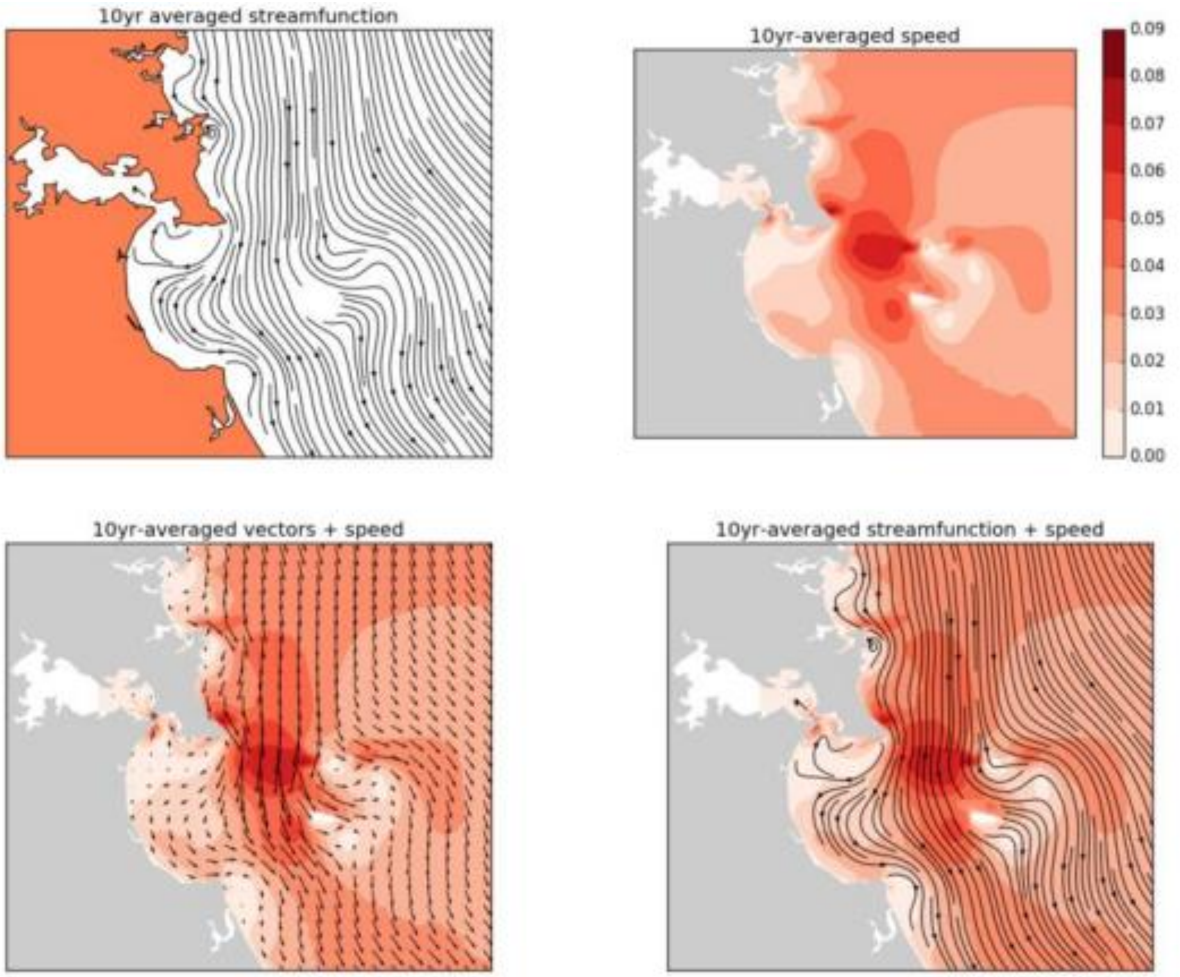


Figure 3.23: Climatological flow patterns in Te Ākau Bream Bay based on mean current speeds from ROMS hindcast. (MOS, 2016b).

3.10 Coastal change

3.10.1 Beach profiles

Northland Regional Council have six beach profile monitoring transects along the Te Ākau Bream Bay shoreline which have been surveyed since the 1970s. The location of these profiles is shown in Figure 3.25. Based on our visual inspection of the beach profiles, the dune toe level is represented by the 2.5 mRL contour (Figure 3.24). Regression analysis was done to assess horizontal retreat distances at the dune toe (2.5 mRL contour). The profile data and linear regression plots for each beach profile are presented in Appendix C and Table 3.11 provides a summary of the linear regression rates measured at the dune toe.

An example of the profile data and analysis at RM15 is shown in Figure 3.24. This figure shows the average regression rate, and 95% confidence intervals measured at each beach profile. There was a gap in the profile dataset between approximately the mid-1980s to 2000 where no survey data were available.

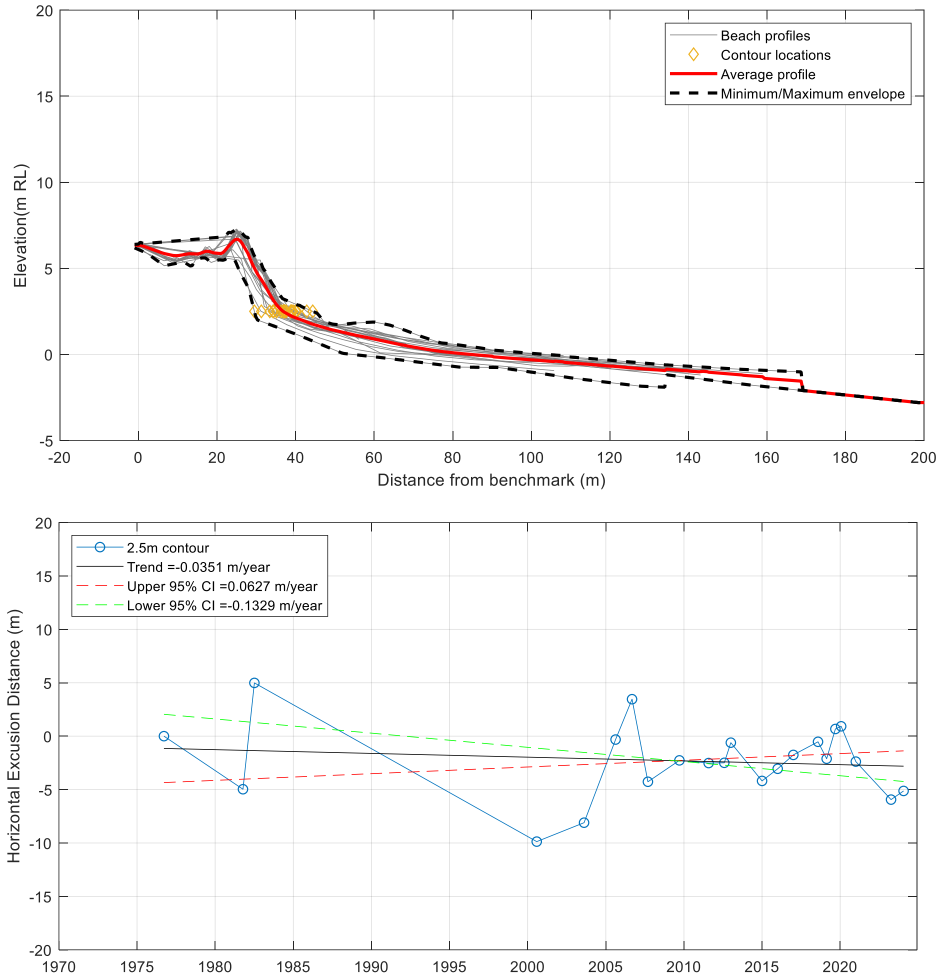


Figure 3.24: Example of profile data at RM15. (Top) Cross-shore profile surveys, (bottom) linear regression plot for horizontal movement at the 2.5 mRL contour.

Table 3.12: Summary of linear regression rates measured at the 2.5 mRL contour for each beach profile

Profile name	Location	Cell	Time period	Number of profiles	Average regression rate (m/year)	95% confidence interval (m/year)	
						Lower	Upper
RM8	Marsden Point	A	July 1976 – January 2024	31	-0.22	-0.28	-0.17
RM11	Ruakākā North	B	January 1977 – January 2024	32	0.35	0.25	0.45
RM13	Ruakākā South	B	January 1977 – January 2024	32	0.46	0.37	0.56
RM15	Uretiti North	C	September 1976 – January 2024	23	-0.04	-0.13	0.06
RM17	Uretiti South	D	September 1976 – January 2024	18	0.02	-0.06	0.10

Profile name	Location	Cell	Time period	Number of profiles	Average regression rate (m/year)	95% confidence interval (m/year)	
						Lower	Upper
RM22	Waipū Cove	E	January 1977 – January 2024	24	0.34	0.20	0.47

3.10.2 Historic shorelines

Historic shoreline changes were also assessed using shoreline data from a new national Coastal Change database (University of Auckland and Resilience to Nature Challenge). The data includes historic shorelines which have been mapped from historic aerial photographs and high-resolution satellite imagery. The Coastal Change database provides the rates of shoreline movement at 10 m intervals along the coastline. The weighted linear regression rates, provided by Coastal Change database for Te Ākau Bream Bay, are presented in Figure 3.25. Based on the alongshore variation in regression rates, the Te Ākau Bream Bay shoreline has been divided into five coastal cells (A to E). The median regression rates and 95% confidence intervals for each cell are presented in Table 3.13 and Figure 3.26.

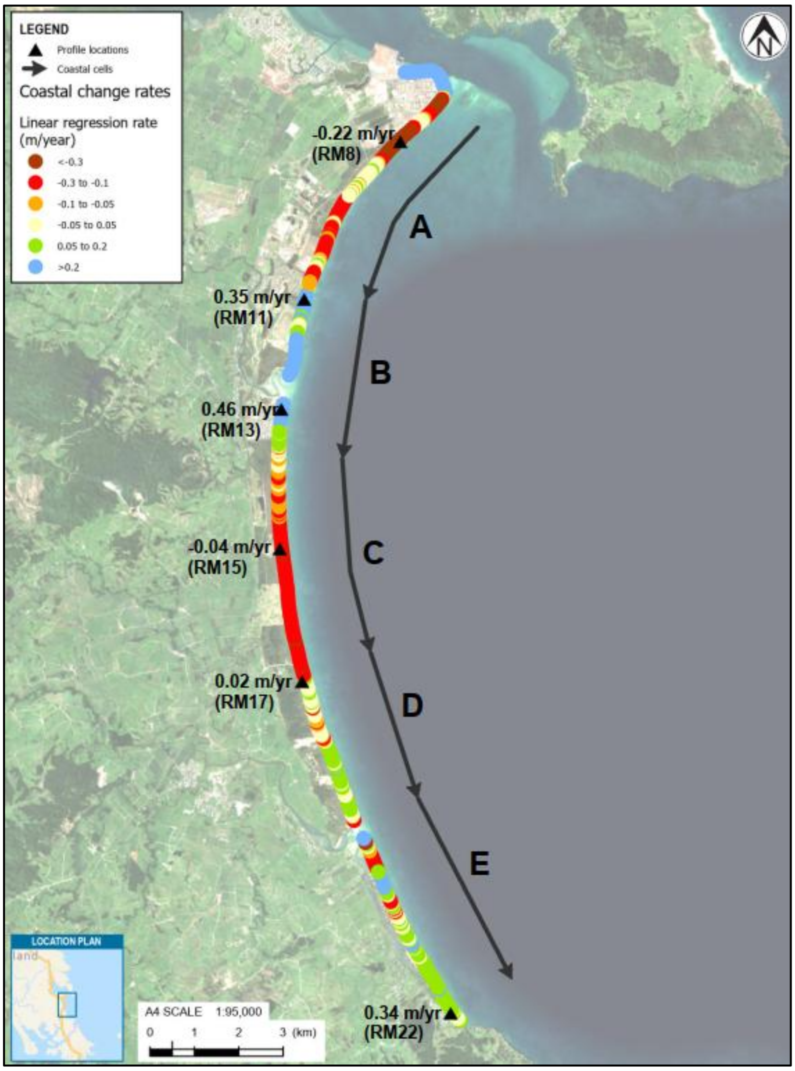


Figure 3.25: Overview of the rates of historic shoreline change along Te Ākau Bream Bay. Coastal change rates are based on Coastal Change (1942, 1966 to 2023) and beach profile data is based on NRC beach profile datasets (1977 to 2024).

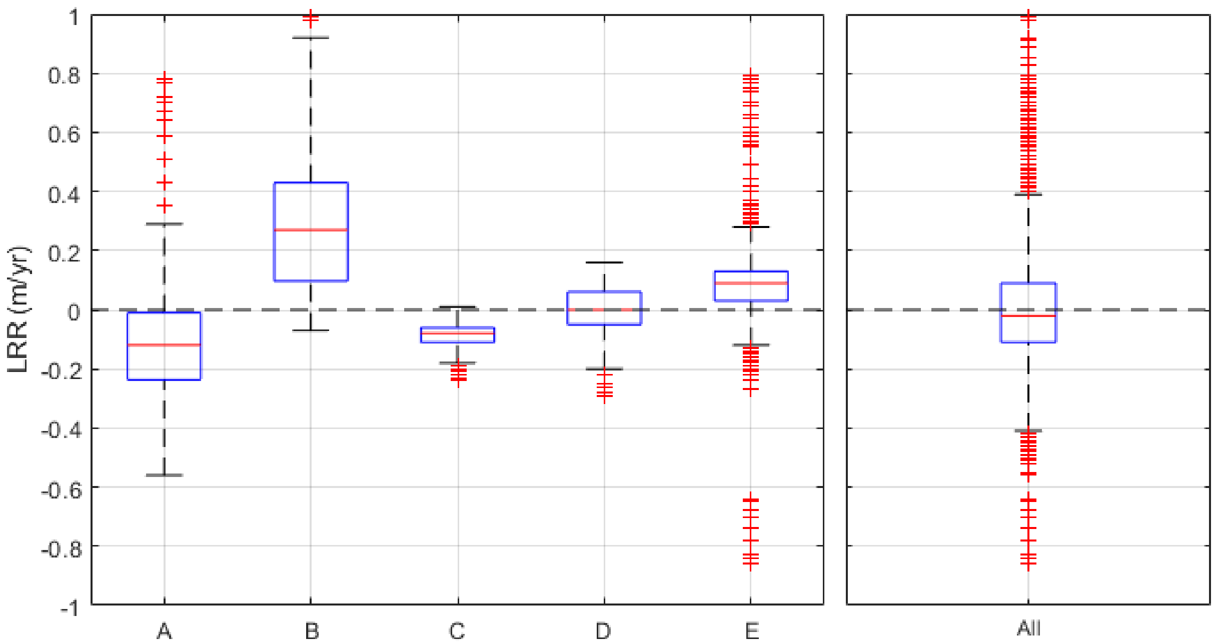


Figure 3.26: Median weighted linear regression rates and 95% confidence intervals calculated for each cell based on the historic shoreline data.

Table 3.13: Summary of historic shoreline change from Coastal Change data along Te Ākau Bream Bay

Cell	No. shorelines (median)	Shoreline length (km)	Oldest shoreline	Latest shoreline	Median regression rate (m/year)	Percentile range within cell (m/year)	
						Lower 5%	Upper 5%
A	18	4.7	28/05/1942	17/08/2023	-0.12	-0.46	0.10
B	18	3.6	28/05/1942	17/08/2023	0.27	-0.03	1.19
C	6	4.4	13/03/1950	17/08/2023	-0.08	-0.18	-0.01
D	7	3.5	11/10/1963	17/08/2023	0.00	-0.16	0.15
E	7	4.6	17/06/1966	18/02/2023	0.09	-0.19	0.38
All	7	20.8	20/05/1963	18/02/2023	-0.02	-0.37	0.42

Note: the 95% percentile is calculated based on the range of linear regression rates for different transects in each cell (it's not the average 95% CI trend for each transect).

Overall, the shoreline trend analysis shows alongshore variability, with segments of accretion balanced by segments of erosion since 1963, with the highest rates of erosion occurring at the northern end of the bay (cell A, open coast of Marsden Point) and the centre of the bay (cell C, Ruakākā to Uretiti). Areas of localised accretion are also apparent, around the Ruakākā River mouth (cell B) and the southern end of the Bay (Waipū cove, cell E). The median trend including all cells is -0.02 ± 0.4 m/yr, which at a high level suggests close to dynamic equilibrium in shoreline position through space (alongshore variability) over the last 50 years.

This analysis is consistent with independent research (Jones et al., 2025[6]) on coastal erosion at the northern end of Te Ākau Bream Bay that used the same Coastal Change data in addition to laser

[6] Jones, B. D., Dickson, M. E., Ford, M., Hikuroa, D., Ryan, E., Carrington, A., & Chetham, J. (2025). Braiding archaeology, geomorphology and indigenous knowledge to improve the understanding of local-scale coastal change. *Cambridge Prisms: Coastal Futures*, *3*, e2.

scanning of the dune, and mātauranga (Māori knowledge). Jones et al. (2025) focus on an open coast site near Marsden Point where visible erosion of the dune exposed a midden (site of discarded shells) that was dated to be deposited 224 to 270 years before present. The midden was exposed at the foredune during storms in 2023 (Gabrielle and Hale), indicating that following these storms the shoreline was in the most eroded state it has been in the last ~300 years. This location is close to beach profile site RM8 where the erosion trend is -0.22 m/yr, and is inside Cell A of this analysis where the erosion trend is -0.12 m/yr averaged over a length of 4.7 km. At the specific site, the rate of change was identified to be -0.45 m/yr (Jones et al., 2025).

Based on Coastal Change historic shorelines, the erosion trend at this northern segment is localised to a ~5 km section of coast and does not represent the conditions at other sections, as discussed above.

3.10.3 Comparison of profile and shoreline data

The profile data shows that the dune toe position can fluctuate over time with periods of accretion and erosion. The overall trends measured in the profile datasets are generally consistent with the trends measured from the historic shoreline data. Figure 3.27 shows a comparison between the beach profile survey data and historic shorelines information obtained from Coast Change database at RM8. The two data sets show similar trends, but with some variability that is not unexpected.

Looking at the trends in Figure 3.25, erosion is detected at the northern end (RM8) and centre of the beach (RM15) and accretion near Ruakākā (RM11 and RM13) and the southern end of Waipū (RM22). The profiles with long-term accretion trends also show periods of erosion. For example, at RM13 there was an erosional episode (approximately 10 m retreat) between 2007 and 2016.

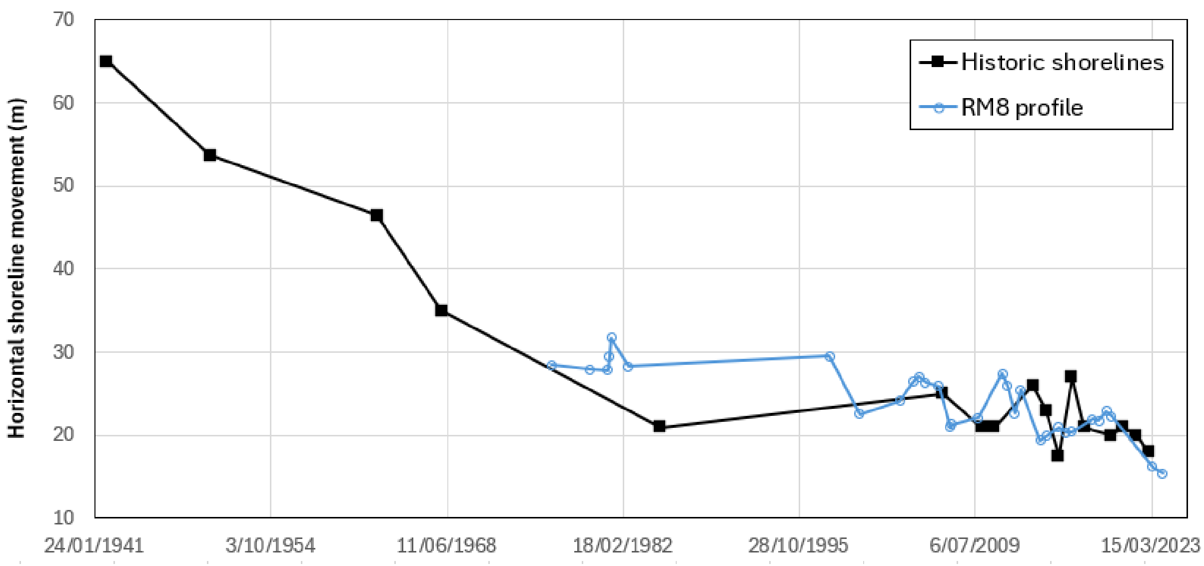


Figure 3.27: Comparison between the shoreline movement measured from the Coast Change data and the beach profile data at RM8 (Marsden Point).

The beach profile and shoreline position data both indicate that the shoreline changes dynamically in space and time at Te Ākau Bream Bay. While some locations show a net trend of accretion, others show a net trend of erosion. On balance, there is limited evidence to suggest that the beach and dune are receiving any functional source of new sand, as there is no embayment wide accretion trend. On balance, the net trend of the bay is considered to most likely be in a state of dynamic equilibrium, with variability in space and time.

4 Assessment of sediment transport potential

4.1 Depth of Closure

This section calculates the inner and outer DoC using the Hallermeier formulae and definitions. Sensitivity and the potential effect of climate change are also assessed.

4.1.1 Inner Depth of Closure

The inner DoC identifies the seaward point of measurable profile change on timescales of seasons to decades and is the landward limit of the lower shoreface. Following the shoreface definitions from Hamon-Kerivel et al. (2020), this boundary can be defined using the (Hallermeier, 1981) equation that adopts the 12 hours exceeded significant wave height and associated significant period:

$$dI = 2.28H_s - 68.5(\frac{H_s^2}{gT_s^2}) \qquad [\text{eq. 2}]$$

Where: $dI = the\ inner\ depth\ of\ closure\ and\ seaward\ limit\ of\ the\ upper\ shoreface.$

$$H_s = significant\ wave\ height\ esceeded\ for\ \frac{12h}{yr}$$

$$T_s = significant\ wave\ period\ associated\ wiht\ \frac{12h}{yr}\ exceeded\ wave\ height$$

This calculation was undertaken using wave data from the 45 year MetOcean hindcast, with the significant wave height exceeded by 12 hours a year (averaged over 45 years) being calculated and then scaled up by a factor of 1.4 to account for the hindcast under-prediction of extreme wave events (see Section 3.8.2.2).

The calculated inner DoC values are shown in Table 4.1 for each of the shoreface profiles, including the relevant wave height and period. These results are based on the multi-decadal average. The sensitivity of the inner DoC to each year in the 45 year wave climate is presented in Section 4.1.3.

The inner DoC value as output by Equation 2 was converted to a depth below MLWS (-1.25 mRL) on the profile. Calculating the DoC with reference to MLWS is consistent both with Hallermeier (1981) and Valiente et al. (2019). This results in a DoC between the -11 to -12.7 mRL contour. This corresponds approximately to the base of the steeper shoreface slope, located 700 – 800 m offshore of the beach, before the profile concaves out to the plateau described in Section 3.4.2. The location of the inner DoC at the base of the steeper section of the profile is consistent with this being a transition point from upper to lower shoreface.

Following the definitions by Hamon-Kerivel et al., (2020), the inner DoC marks the seaward boundary of the upper shoreface, identifying the seaward limit of sediment exchange with the beach face and dune on seasonal to annual timescales.

Table 4.1: Wave condition and inner DoC (dI) for each profile based on the 45 year hindcast

	$12hH_s$ [m]	$12hT_p$ [s]	dI (m)	dI (mRL)
Profile 1	5.0	10.3	9.8	-11.1
Profile 2	5.5	11.3	10.9	-12.1
Profile 3	5.7	11.4	11.2	-12.4
Profile 4	5.8	11.3	11.4	-12.6
Profile 5	5.8	11.3	11.4	-12.7
Bay average	5.6	11.1	10.9	-12.2

4.1.2 Outer Depth of Closure

The outer DoC (d_i) is a method for calculating the seaward limit of the lower shoreface that was used for evaluating sand extraction at Pākiri. The lower surface is a zone of wave induced sediment transport, with limited wave induced changes to the seabed elevation. Areas offshore of the seaward boundary of the lower shoreface have negligible sediment exchange with the upper shoreface.

The outer depth of closure for Te Ākau Bream Bay was calculated using the Hallermeier equation. The equation is calculated using the average significant wave height and period and considers the magnitude of these relative to the median grain size. For Te Ākau Bream Bay, the average D50 grain size was used for each profile based on sediment samples between the shoreline and proposed extraction area, excluding outliers. All input conditions for each profile are presented in Table 4.2, along with the resulting depth of closure values.

$$d_i = (\overline{H}_s - 0.3\sigma_s)\overline{T}_s(\frac{g}{5000D})^{0.5} \quad \text{[eq. 3]}$$

Where:

d_i is the outer depth of closure

$\overline{H}_s$ is mean significant wave height averaged over at least 1 year (m)

σ_s is the standard deviation of significant wave height (m)

$\overline{T}_s$ is the mean significant wave period (s)

D is the median grain size (m).

The average wave height and period were calculated using all hourly data in the 45 year wave hindcast. Average conditions are appropriately resolved in the wave modelled and therefore do not need scaling up as the 12 h exceeded wave height was for the inner DoC. The 45 year average wave height ranges between 0.75 m at Profile 1 to 0.9 m at Profile 4, with a mean of 0.85 m across the four profiles. The 45 year wave period was calculated using the peak period of the modelled wave hindcast and is consistently 9 seconds across the profiles. The use of peak period may result in a slightly higher value than the mean significant period and is likely conservative but consistent with how the equation was applied to Pākiri by Hilton et al., (1996). Median grain size is variable across the different profiles, with finer grains at Profile 4 (195 microns) and coarse grain values at Profile 1 (270 microns).

The DoC is presented below MLWS, which is -1.25 mRL. The combination of smaller grain size and larger wave height at Profile 4 results in the most seaward d_i value that maps to the -22.2 mRL contour. The outer DoC was shallowest at Profile 1 (-15.9 mRL) where wave height is smaller, and grain size is coarser. This profile is located south of the proposed extraction area and intercepts the southern control area. Across all profiles, the average outer DoC was calculated to be -19.1 mRL.

All of the values calculated using the 45 year mean wave conditions are located landward of the proposed extraction area, providing a robust indicator that **the proposed sand extraction is not occurring in an area that will interfere with shoreface sediment transport processes**. This is evident when comparing the average depth at the landward boundary of the extraction zone (-23.4 mRL) with the DoC values in Table 4.2. Sensitivity to annual variability in the mean wave height and period is presented in Section 4.1.3.

Table 4.2: Outer DoC (di) for each profile based on the 45 year average wave conditions

	$\overline{H}_s$ [m]	$\overline{T}_s$ [s]	$Hs\ \sigma\ (m)$	D_{50}[μm]	d_i (m)	d_i (mRL)
Profile 1	0.75	8.9	0.48	270	14.6	-15.9
Profile 2	0.83	8.9	0.52	250	16.7	-17.9
Profile 3	0.85	8.9	0.53	230	18.0	-19.2

	$\overline{H}_s$ [m]	$\overline{T}_s$ [s]	$Hs\ \sigma\ (m)$	D_{50}[µm]	d_i (m)	d_i (mRL)
Profile 4	0.90	9.0	0.55	195	20.9	-22.2
Profile 5	0.91	9.0	0.56	227	19.6	-20.8
Bay average	0.85	9.0	0.53	221	17.8	-19.1

4.1.3 Annual variability

Literature on lower shoreface morphodynamic processes identify that both the inner and outer DoC are potentially variable through space and time (e.g. Anthony, et al. 2020). The assessment above considers the spatial variability by considering 5 profiles but only considers a long-term view of the wave climate that is averaged over 45 years.

Hamon-Kerivel, et al. (2020) suggests that there can be temporal variability in the DoC over time. To understand this sensitivity, values for, d_i (outer DoC) and dI (Inner DoC) were both calculated for each year in the 45 year hindcast for all 5 profiles using annual averaged data. This provides an assessment of sensitivity to annual variation in wave conditions at Te Ākau Bream Bay. In terms of morphological response, the inner depth of closure is likely responsive at annual timescales as it is a function of extreme conditions each year. The outer depth of closure is likely less responsive to annual fluctuations, as meso-timescales dominant processes on the lower shoreface, meaning multi-decadal averaged values are likely more suitable (Hamon-Kerivel, et al. 2020). The annual variability in the outer DoC calculation is interpreted with caution when the spread in depth is converted to a location on the profile, the results are highly sensitive.

Wave parameters and the resulting closure depth values for each year in the hindcast were calculated for each profile and Figure 4.1 shows an example of the assessment for Profile 4. This figure shows the mean wave height can be variable (0.75 – 1.1 m), and the mean wave period also ranges from year to year (8.5 – 10 s).

The range of locations where the outer DoC intercepts each profile is presented in Figure 4.2. This shows that the outer DoC ranges between -14 mRL to -19 mRL on Profile 1, to -19 mRL to -27 mRL on Profile 4. Across the 5 profiles, the calculated outer DoC intercepts the profile from 1 km to 6.5 km offshore from MHWS. Across the five profiles, 91% of annual outer DoC (5 profiles times 45 years) are landward of the proposed extraction area and in all cases the mean outer DoC is landward of the proposed extraction areas.

While the average DoC position was 2.9 km seaward of the MHWS contour, the flat slope of the lower shore at Te Ākau Bream Bay means that the annual range of the outer DoC calculations can span a wide distance of 4.7 km. For the profile with the greatest number of annual events within the proposed extraction area there are 14 occurrences (31% of the time) where the outer DoC for Profile 4 is within the extraction zone. This is not expected to result in a notable geomorphic response but highlights the equations sensitivity to the gradual sloping lower shoreface. More investigation is therefore undertaken using the depth of transport method.

The annual inner DoC calculations across the 5 profiles ranged between -8 mRL and -16 mRL and are consistently located at the base of the upper shoreface slope, at the concave transition to the lower shoreface plateau which can extend, up to 1.2 km offshore of the beach with the average distance being 700 m from MHWS.

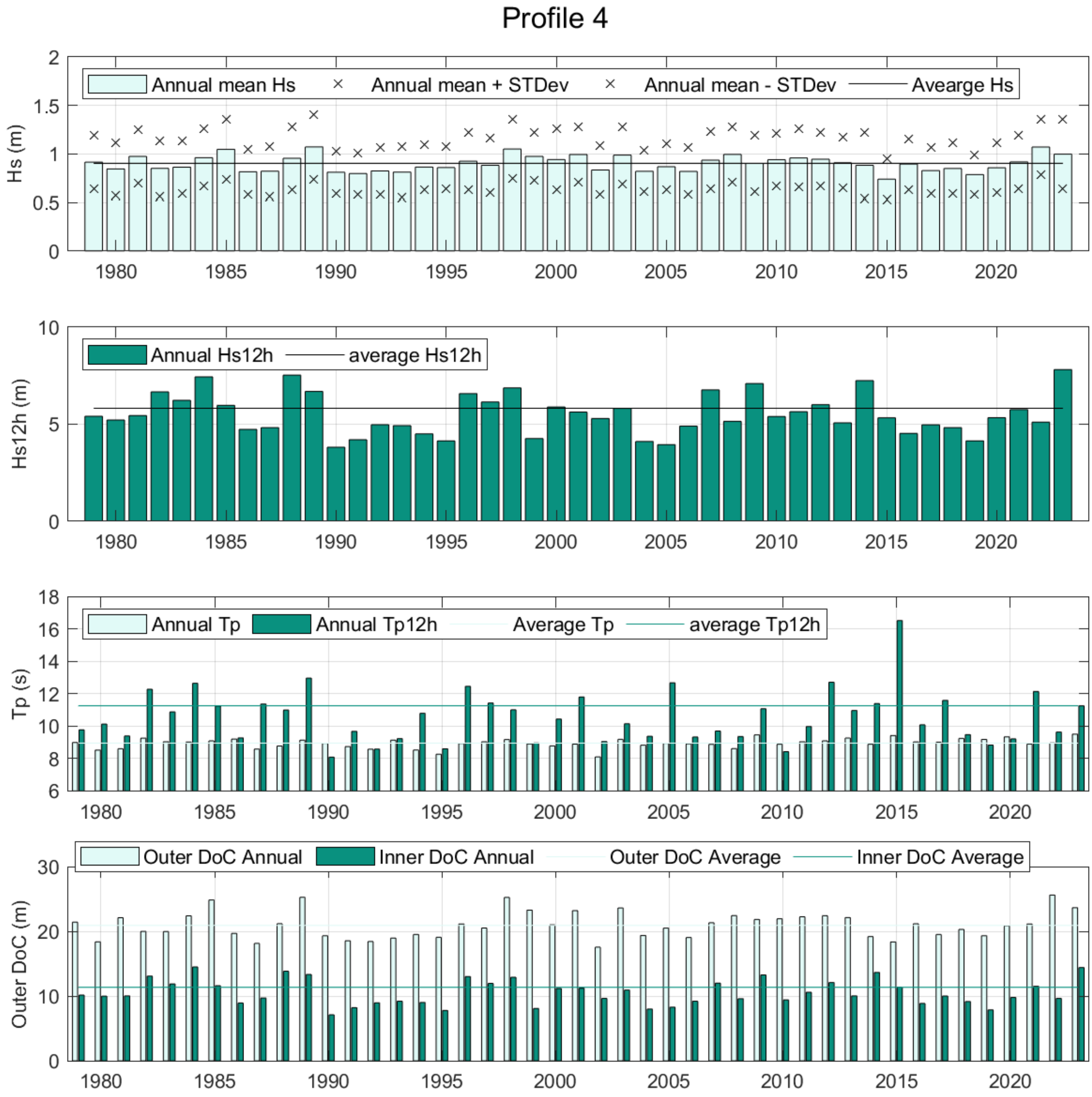


Figure 4.1: Annual range of the inner and outer DoC for and associated input wave values for Profile 4.

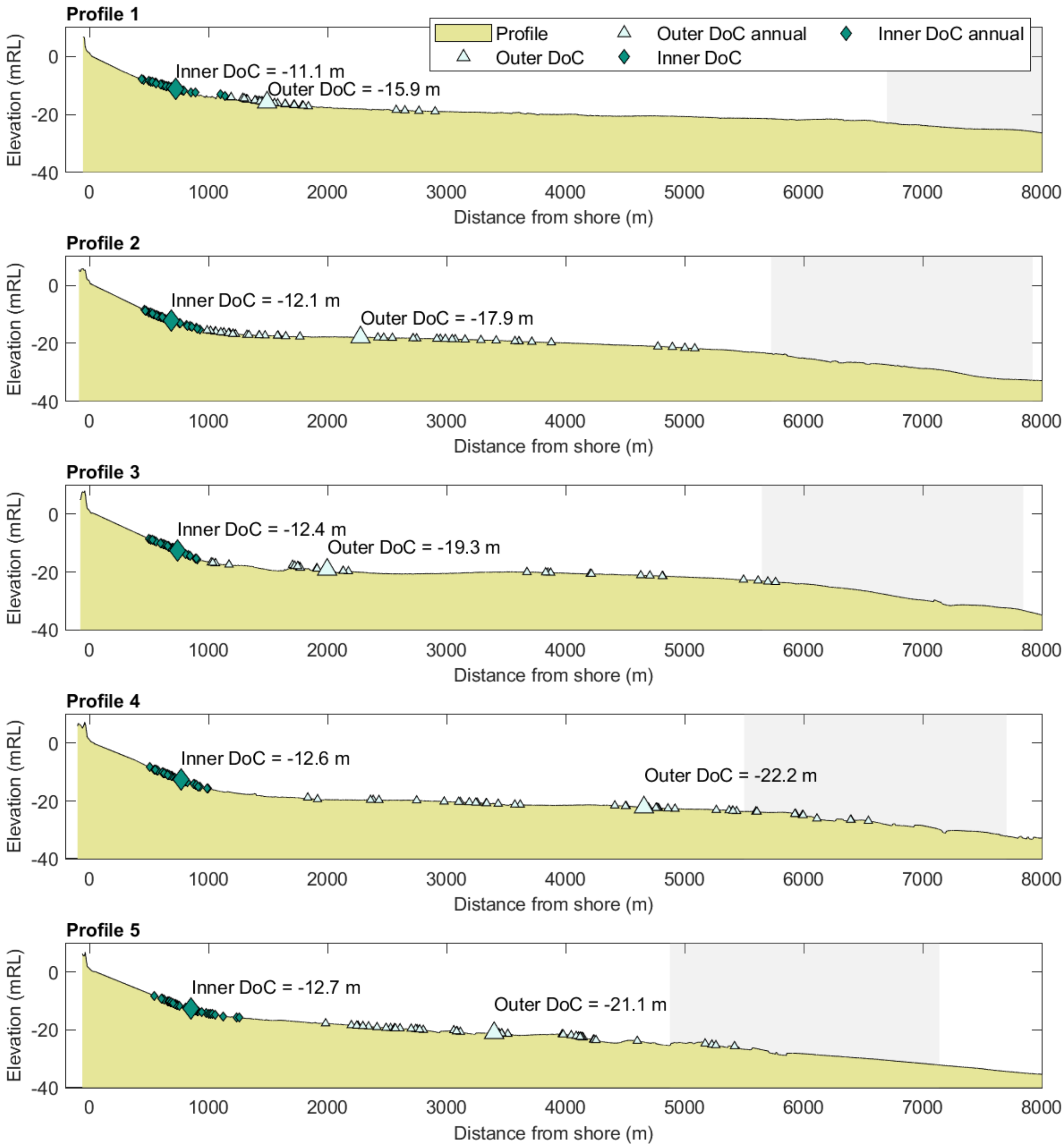


Figure 4.2: Annual range of the inner and outer DoC for each profile, as calculated for each year in the 45 year wave hindcast. Small symbols indicate the annual value, and larger values indicate the 45 year mean. Grey shading represents the proposed sand extraction area (or control area) on each profile.

The inner DoC has some sensitivity in level but is not very sensitive to annual variation in terms of distance from the shoreline, due to the location at the seaward section of the steeper slope. However, the outer DoC is very sensitive in terms of distance from the shore, due to the low gradient lower shoreface and transition to offshore. This sensitivity is further investigated below using the shear stress calculated DoT.

When interpreting the calculated outer DoC in the context of the profile geometry and changes in sediment grain size, the long-term average outer DoC appears suitable for informing the seaward limit of the lower surface in the context of a sand extraction effects assessment, as the average value is consistent with changes in profile shape and sediment texture, whereas the annual values are highly sensitive to the extended plateau. Adopting a long-term average is also consistent with the lower shoreface being a zone of mesoscale dynamics, which occur on timescales of at least decades (Hamon-Kerivel et al., 2020). Figure 4.3 shows an example from Profile 2, where a general increase in sediment grain size is noted moving seaward towards the calculated mean outer DoC point. This indicates that lighter grains are more prone to being swept away, with coarser sediments being stranded until extreme events. A coarse band of sediment is also present at the transition to the lower shoreface on Profile 4. The coarse sediments indicate a limiting wave energy for inducing sediment transport, which is consistent with the DoC theory. On profile 4, sediment grain sizes inside the proposed extraction are generally coarser than on the lower shoreface defined by 45 year mean Outer DoC. There also appear to be undulations in the profile within the extraction area that indicate relict bedforms which are not smoothed out by wave action. Referring to the annual variability with the profile geometry and sediment texture across the profiles (Figure 3.7) indicates that the 45 year average values are potentially suitable for informing the DoC at Te Ākau Bream Bay. However, the improved physics associated with the DoT methods (presented below) provides additional check on the suitability of the extraction area being seaward of the lower shoreface.

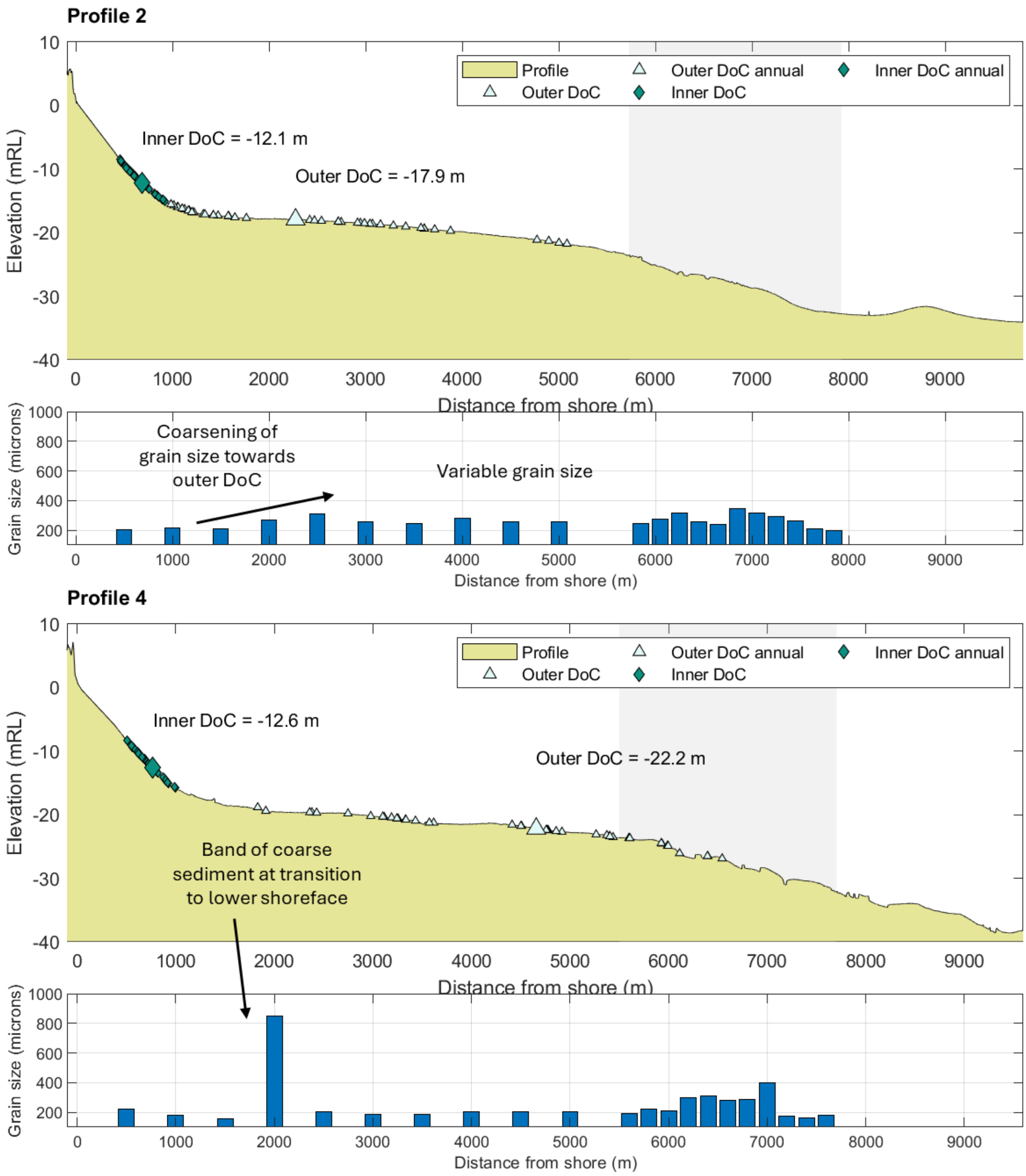


Figure 4.3: Interpretation of profile geometry, sediment grain size and DoC calculations for Profiles 2 and 4.

4.1.4 Effect of climate change

Climate change will result in higher sea levels, which has an influence on where the DoC is located with regards to mean low water spring. Climate change will also have an uncertain influence on wave climate, with the potential for increasing mean waves. The effect of climate change on the DoC was assessed by considering an increase in mean sea level of 0.35 m during the consent duration, and an increase in mean wave height by 5%.

If the only impact of climate change is a rise in mean sea level, then the influence on the outer DoC will be to move the DoC landward due to the greater water depth. However, the outer DoC is also sensitive to mean wave climate and even a 5% increase can affect the location of the outer DoC.

Table 4.3 below shows that a 5% increase in wave climate associated with climate change results in a $\boldsymbol{d_i}$ value that is on average 1.1 m greater than the baseline present day value, even though the actual change in wave height is only 4 – 5 cm. The combined effect of rising sea level and increasing mean wave height is an increase in depth of the outer DoC by 0.7 m.

Table 4.3: Potential effect of climate change on the outer DoC

	$\bar{H}_s$ [m]	$\Delta\ \bar{H}_s$ [m] *	d_i (m)	$\Delta\ d_i$ (m)*	d_i (mRL)	Increase in depth (m)
Profile 1	0.79	+0.04	15.5	+0.9	-16.4	0.6
Profile 2	0.87	+0.04	17.7	+1.0	-18.6	0.7
Profile 3	0.89	+0.04	19.1	+1.1	-20.0	0.8
Profile 4	0.95	+0.05	22.2	+1.3	-23.1	0.9
Profile 5	0.95	+0.05	20.8	+1.2	-21.7	0.8
Bay average	0.89	+0.04	18.9	+1.1	-19.8	0.7

*The Δ symbol indicates the amount of change compared to the present-day values presented in Table 4.2.

4.2 Depth of Transport

This section calculated the DoT based on bed shear stress. Sensitivity to the potential effect of wave variability, tidal currents and climate change is also assessed.

4.2.1 Bed shear stress equations

The limit of significant sediment transport for each of the five profiles was calculated based on the bed shear stress approach developed by Valiente, et al. (2019). This approach is based on the calculation of the combined wave and current induced bed shear stress along the cross-shore profile, and the comparison of this maximum bed shear stress to a critical bed shear stress for transport. With this approach, it is possible to analyse whether different types of bedform activity can be expected along the cross-shore profile under different wave and tidal current conditions.

As per Valiente, et al. (2019), the combined wave and current-induced bed shear stress was computed following Soulsby (1997) and the different thresholds for initiation of motion and bedform activity were taken from Nielsen (1981). The formulas that were adopted for the calculation of both the maximum combined bed shear stress τ_{max} and the critical bed shear stress $\tau_{critical}$ are given below.

The maximum wave bed shear stress is calculated using equation 4.

$$\tau_w = \frac{1}{2}\rho f_w U_w^2 \text{ [eq. 4]}$$

Where ρ is the density of seawater (taken as 1,027 kg/m^3), f_w is the wave friction factor, and U_w is the wave orbital velocity. Following the methodology as suggested by Soulsby (1997), the wave orbital velocity U_w was calculated using the JONSWAP formulas described in Soulsby, et al. (1986) and is based on the significant wave height and period. The wave condition can represent a point in time, or can be a statistically relevant event such as an event that is exceeded for 12 hours within the investigated timeframe H_{s12h}, the corresponding peak wave period T_{p12h}, and the water depth h. Both point in time events and the 12h exceeded events are considered in sections below. The wave friction factor f_w was calculated using equation 5.

$$f_w = 1.39 \left(\frac{A}{z_0}\right)^{-0.52} \text{ [eq. 5]}$$

Where A is the semi-orbital excursion and z_0 is the bottom roughness parameter, these are calculated using equations 6 and 7 respectively.

$$A = \frac{U_w T_{p12h}}{2\pi} \text{ [eq. 6]}$$

$$z_0 = \frac{D_{50}}{12} \text{ [eq. 7]}$$

Where D_{50} is the median sediment diameter along the cross-shore profile. To be able to compare the results of the shear stress model to the results using the Hallermeier equations, the cross-shore averaged median sediment diameters as listed in Table 3.2 were used.

Consistent with the formula for wave-induced bottom shear stress, the current-induced bottom shear stress is calculated separately using equation 8.

$$\tau_{cb} = \rho C_d \bar{U}_{cb}^2 \text{ [eq. 8]}$$

Where C_d is the drag coefficient and $\bar{U}_{cb}$ is the maximum near bottom depth-averaged flow velocity. The drag coefficient C_d is calculated using equation 9.

$$C_d = max\left[\left(\frac{\kappa}{1 + \ln\left(\frac{h}{z_0}\right)}\right)^2, 0.0025\right] \text{ [eq. 9]}$$

Where κ is the Von Karman constant (κ = 0.4). Subsequently, the individually calculated wave- and current-induced bed shear stresses are combined to calculate the combined mean wave- and current-induced bed shear stress is calculated using equation 10.

$$\tau_m = \tau_{cb}\left[1 + 1.2\left(\frac{\tau_w}{\tau_{cb} + \tau_w}\right)^{3.2}\right] \text{ [eq. 10]}$$

The maximum combined wave- and current-induced bed shear stress is calculated using equation 11 which can account for flow direction (here assumed to be aligned towards coast).

$$\tau_{max} = [(\tau_m + \tau_w|cos\theta|)^2 + (\tau_w|sin\theta|)^2]^{1/2} \text{ [eq. 11]}$$

Lastly, the critical bed shear stress is calculated using equation 12.

$$\tau_{cr} = \psi_{cr} g(\rho_s - \rho) D_{50} \text{ [eq. 12]}$$

Where ρ_s is the sediment density (here taken as **2,550** kg/m^3) and ψ_{cr} is the critical Shields parameter. The value of the critical Shields parameter depends on the bedform activity that is considered. Different values for the critical Shields parameter are listed in Table 4.4.

Table 4.4: Values for the critical Shields parameter linked to different bedform activities

Bedform activity	Critical Shields parameter (ψ_{cr})	Description
Initiation of motion	0.048	Some individual grains become agitated on the seabed and start rocking.
Formation of sharp-crested vortex ripples	0.1	Localized back and forth motion on the seabed with sand grains organising into small and closely spaced ripple formations.
Transformation from vortex to post-vortex ripples	0.2	Ripples becoming larger and spaced out.
Transition into a plane bed	1	Sand entrained near bed and ripples smoothed out.

Note: Values are adopted from (Grant, et al., 1982).

4.2.2 45 year wave induced bed shear stress hindcast

To calculate the average amount of days per year during which different types of bedform activity take place at each of the profiles, the following steps were applied:

- For each profile, the critical threshold for bed shear stress $\tau_{critical}$ associated with different types of bedform activity was calculated. The bed shear stress thresholds at each profile at Te Ākau Bream Bay vary depending on the grain size D_{50}; the thresholds for different bedform activities are presented in Table 4.5.

Table 4.5: Bed shear stress values for different motion thresholds

		Critical shear stress (N/m^2) for different morphology thresholds			
Profile	**D_{50} (microns)**	**Start of motion**	**Vortex ripples**	**Post vortex ripples**	**Transition to plane bed**
P1	**270**	0.19	0.40	0.81	4.03
P2	**250**	0.18	0.37	0.75	3.74
P3	**230**	0.16	0.34	0.69	3.44
P4	**195**	0.14	0.29	0.58	2.91
P5	**227**	0.16	0.34	0.68	3.39
P6	**221**	0.16	0.33	0.66	3.30

- For each of the profiles, the 45 year modelled wave climate across the profile was used to reconstruct a hindcast of wave induced bed shear stress (wave locations are in Figure 3.13). This is based on the un-calibrated hindcast, which is a suitable representation of typical conditions may under-predict extreme events. Further analysis of extreme events based on hindcast calibration are presented in Section 4.2.2.
- For each MetOcean Solutions output point, hourly values of the significant wave height H_s, peak wave period T_p and water depth h over the entire 45 year hindcast were used to calculate the maximum wave-induced bed shear stress τ_{max}, using the formulas as described in Section 4.2.1. This was undertaken at five water depth points across for each bathymetric profile. The results are visualized in Figure 4.4 for water depths at the seaward boundary of the extraction area.

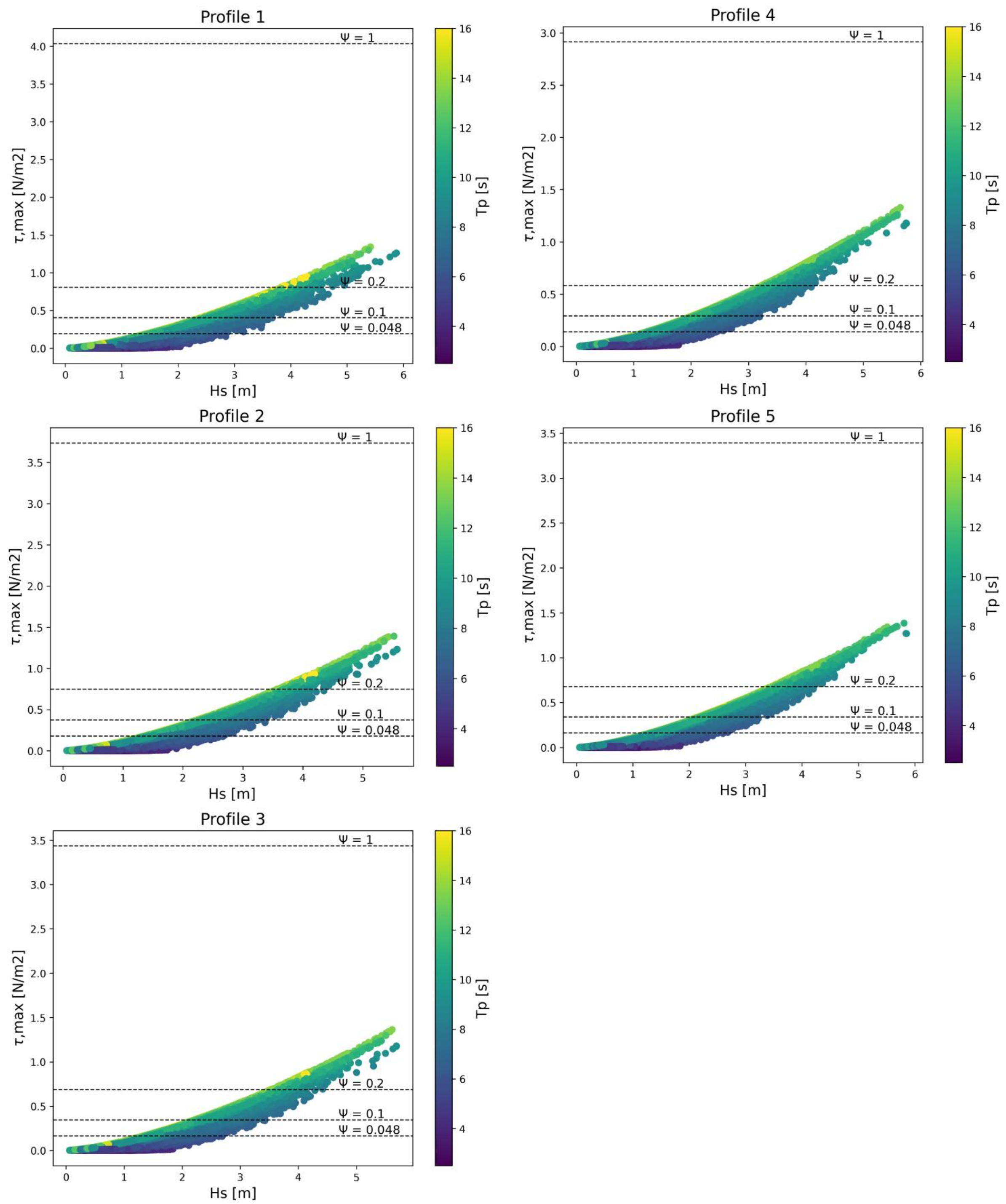


Figure 4.4: Relationship between hourly values of the significant wave height (H_s), maximum wave-induced bed shear stress (τ_{max}), and peak wave period (T_p) from the uncalibrated 45 year MetOcean Solutions hindcast, at the seaward boundary of the proposed extraction area for profile 1 to 5. The dotted black lines indicate the different shear stress thresholds linked to different forms of bed activity (see Table 4.4).

- For each profile, the calculated maximum wave-induced bed shear stresses τ_{max} were compared to the critical threshold for bed shear stress $\tau_{critical}$ associated with different types of bedform activity. This was undertaken at five locations spanning the shoreface. Based on this comparison, the average amount of days/year during which transport linked to the different bedform activity types (Table 4.5) takes place was calculated for each of the profiles.

The results of this analysis are shown in Figure 4.5. Sediment transport associated with the start of motion (ψ=0.048) takes place for ~1/3 of the year at the most shoreward output location for each of the profiles. At the extraction location, this has decreased below two months a year (ranging from 36 days/year at profile 1 to 51 days/year at profile 4). This type of sediment transport can be induced by either low waves (~1 m) with a relatively long peak period, or by slightly higher waves (up to ~2.8 m) with a shorter peak period. The initiation of motion thresholds indicates that sand grains can be agitated but are not transported functional distances (Grant, et al., 1982).

Types of bedform activity associated with higher Shields values (0.1, 0.2 and 1) lead to an increasingly smaller amount of days/year of transport at each of the output locations. Wave motions capable of creating bed ripples inside the proposed extraction area are calculated to occur for 1 – 2 weeks per year. Sediment transport associated with a transition to a plane bed (ψ=1), which indicates significant transport, does not occur at any of the profiles over the 45 year hindcast, when extreme events are not scaled up through calibration to the wave buoy.

The approach and results described in this section provide good insights into sediment transport at each of the profiles for the annual wave climate conditions. However, it is unlikely to represent sediment transport associated with the very highest waves, which seem to be underpredicted in the 45 year wave hindcast (see Section 3.8.2.1). Given the wave climate shows generally small waves with only very infrequent extreme waves, the representative conditions are expected to be reasonable but there would be an under-representation of annual extremes where more sand would be mobilised. Therefore, sediment transport calculations associated with calibrated 12h/yr extreme wave conditions have been factored in the next section to establish the DoT used to inform the application.

The shear stress calculations are consistent with previous observations of currents and sediment transport at Pākiri measured during the sand study. Past measurements of wave driven orbital currents near the seabed at Pākiri peaked at 1.30 m/s, 0.60 m/s and 0.45 m/s in 6.5, 15, and 35 m water depths during a storm that occurred on 24 - 25 November 1995 (Source: Mangawhai – Pākiri Sand Study). For the shallowest depth sediment movement on the seabed occurred 95% of the time, while at 15 m water depth sediment movement occurred with significant wave heights of 1 m and at 35 m water depth coarse sands were only moved by the storms which occurred every one to two months.

At 35 m water depth, sediments at Pākiri were moderately sorted slightly gravelly coarse sand with distinctive mega ripples (H = 10 cm, L = 65 cm). At 15 m water depth, sediments were moderately sorted medium sands with small wave ripples (H = 5 - 10 cm and L = 15 - 20 cm). At 6.5 m two distinctive sediment types were present: i) moderately well-sorted gravelly medium sand with small wave ripples (H = 6 cm, L = 7 cm) and ii) a poorly sorted slightly gravelly coarse sand with large mega ripples (H = 10 - 15 cm and L = 100 - 150 cm). Bed movement changes observed over a two-month period were 5.5 cm, 25 cm and 33+ cm at 35 m, 15 m and 6.5 m depths respectively.

Suspended sediment concentrations at 15 m water depth were observed particularly during the 24 - 25 November storm event at 0.56 m and 1.15 m above the seabed.

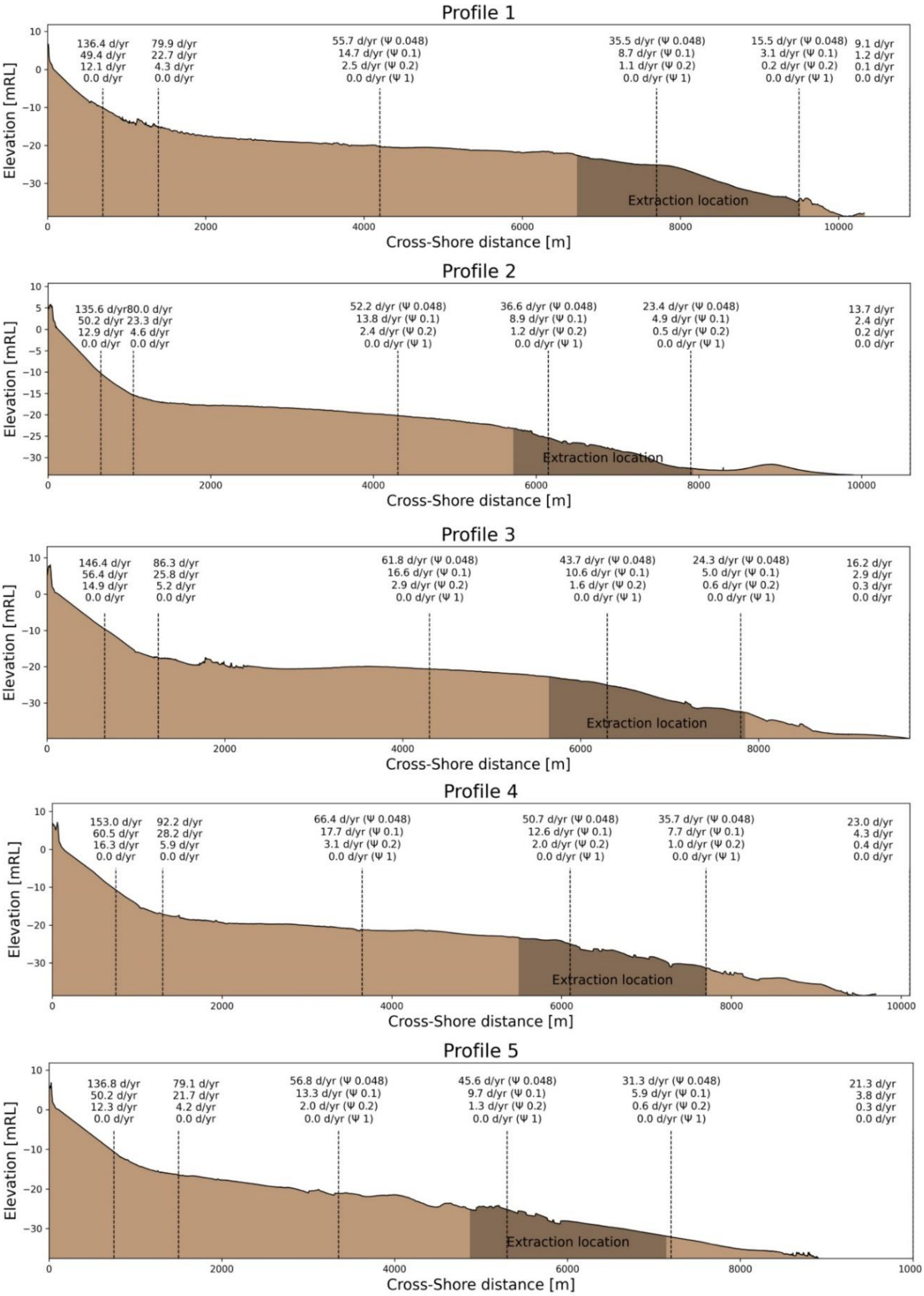


Figure 4.5: Average amount of days/year during which transport (linked to different types of bedform activity) takes place at each of the output locations along the 5 profiles.

4.2.3 Depth of Transport assessment

The DoT was calculated for each profile at Te Ākau Bream Bay using the method outlined by Valiente, et al. (2019) and in section 4.2.1 above. This is based on calculating the maximum wave-induced bed shear stress associated with the 12 h/yr exceeded significant wave height H_{s12t} and associated peak period T_{p12t} and identifying the most seaward depth at which the bed shear stress associated with these wave conditions exceeds the critical bed shear stress for transitioning from ripples to a plane bed (i.e., the bed shear stress associated with a Shields value ψ of 1 (Table 4.4). This assessment is based on the calibrated 12h/yr wave height as outlined in Table 3.11. Valiente et al. (2019) adopted the critical bed shear stress value associated with a transition to a plane bed as being the best interpretation for defining the seaward limit of the lower shoreface on beaches influenced by headlands at either end. The bed shear stress thresholds at each profile at Te Ākau Bream Bay vary depending on the grain size D_{50}; the thresholds for different bedform activities are presented in Table 4.5.

To identify the DoT for each profile (i.e. the depth at which the wave-induced bed shear stress exceeds the threshold for 'plane bed transition'), the following steps were applied:

- The averaged 12h/yr exceeded significant wave height data and the associated peak period were calculated for the 45 year MetOcean Solutions hindcast (Table 4.1), using the same representative grain size form each profile as the outer DoC (see Table 4.5). The 12 h/yr exceeded significant wave height data was upscaled by a factor of 1.4 to correct for a potential wave hindcast under prediction (see Section 3.8.2.2). The wave parameters were obtained from the MetOcean Solutions wave climate output point at the seaward end of each profile (see Figure 3.13).
- A wave transformation model 'XBeach' was used (surf beat mode) to simulate the wave height transformation across each profile, allowing the wave height to be calculated at 10 m horizontal increments across the profile. An example of the significant wave height transformation along profile 5 is shown in Figure 4.6.

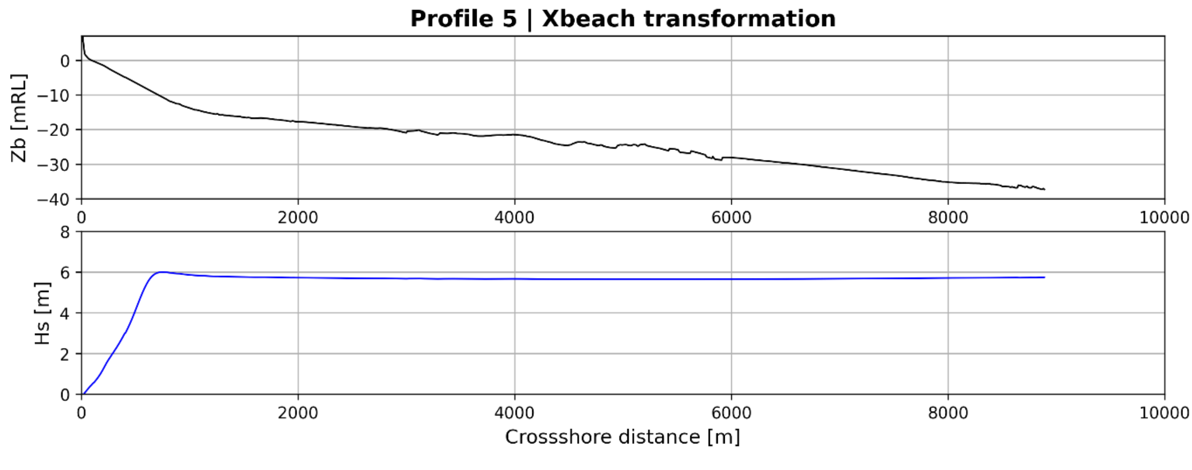


Figure 4.6: Example of the XBeach model showing significant wave height transformation across profile 4.

- For each profile, the maximum wave-induced bed shear stress τ_{max} was calculated at each point along the profile using the local significant wave height, water depth and peak period following the equations outlined in Section 4.2.1 and Valiente et al. (2019).
- The bed level at the location along each of the profiles where the calculated maximum wave-induced bed shear τ_{max} first exceeds the threshold for bed plane transition $\tau_{critical}$ was identified as the DoT.

- Lastly, the sensitivity to annual variability in the 12 h/yr significant wave height and peak period was assessed. The procedure as described in the previous 4 steps was repeated for every individual year in the 45 year hindcast, resulting in a DoT for every year.
- The influence of tidal currents and climate change was also assessed as a sensitivity test to the average year by including a current of 0.15 m/s. This is discussed further in Section 4.2.4.
- On review of the results for the annual DoT, long term average DoT and sensitivity to currents and climate change and annual variability, a representative DoT based on the 90 percentile over the 45 years was adopted to inform the likely limit of the lower shoreface (Figure 4.7).

Statistics for the distance from the shore of the DoT are shown in Table 4.6. As can be seen from Figure 4.7, the mean DoT over the 45 year hindcast varies between -10.3 mRL (profile 1) to -14.7 mRL (profile 4).

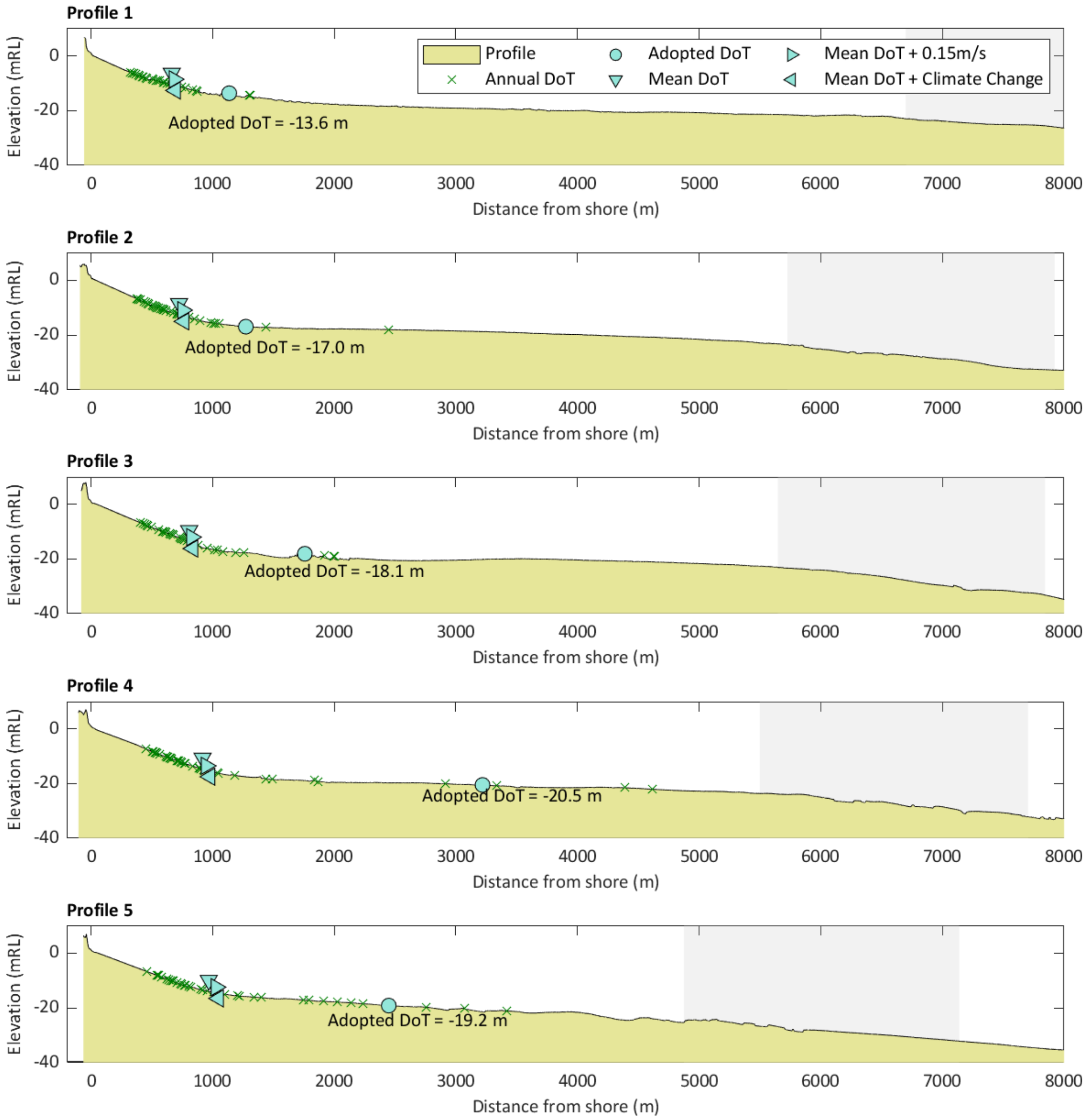


Figure 4.7: Annual range of the DoT for each profile, as calculated for each year in the 45 year wave hindcast. The green dot marks show adopted 90 percentile DoT for each profile.

It can be seen from Figure 4.7 and Table 4.6 that the variability in the location of the DoT is moderate, particularly for profiles 4 and 5. However, the DoT is more consistently located compared to the outer DoC as calculated by Hallermeier, and is also consistently landward of the outer DoC. The maximum DoT on profiles 4 and 5 extends farther seaward compared to profiles 1, 2 and 3, which is consistent with the DoC calculations. This difference in variability is related to the location of the different profile lines within Te Ākau Bream Bay (see Figure 3.13). As shown in the wave roses in Figure 3.15, the largest waves in Te Ākau Bream Bay generally originate from the northeast. For these types of waves, profiles 1, 2, and 3 are more sheltered behind the Hen and Chicken Islands/Taranga-Marotere Islands than profiles 4 and 5, resulting in lower values for the H_{s12t} for these profiles. Incidental high waves coming in from the northeast can therefore cause a large seaward shift of the DoT on profiles 4 and 5, but less so on profiles 1, 2, and 3.

Table 4.6: The distance from shore associated depth for the annual DoT for each profile

Profile	Distance of DoT from MHWS-line [m]				DoT [mRL]			
	Mean	Max	Min	Std	Mean	Max	Min	Std
Profile 1	664	1,308	322	259	-10.3	-14.4	-5.8	2.3
Profile 2	724	2,446	374	435	-12.6	-18.0	-6.7	3.1
Profile 3	807	1,999	407	371	-13.6	-19.1	-6.6	3.4
Profile 4	917	4,617	455	927	-14.7	-22.0	-7.2	3.9
Profile 5	968	3,418	458	699	-14.0	-21.1	-6.7	3.6

4.2.4 Influence of tidal currents

In addition to the DoT assessment as described in the previous section, where only wave-induced bed shear stress was considered, the DoT under combined wave and current-action was calculated. As was described in Section 3.9, the measured currents around the proposed extraction didn’t exceed 0.15 m/s and were typically between 0.05 to 0.1 m/s. The calculation of the DoT as described in Section 4.2.3 was therefore repeated for current velocities of 0.05, 0.1 and 0.15 m/s. The results are listed in Table 4.7 and Table 4.8.

Table 4.7: DoT at each of the 5 profiles under combined wave- and current-action, for different current velocities

	DoT [mRL], (difference influenced by currents)			
Profile	Waves only	Uc = 0.05 m/s	Uc = 0.10 m/s	Uc = 0.15 m/s
P1	-10.3	-10.3 (0)	-10.4 (-0.1)	-10.5 (-0.2)
P2	-12.6	-12.6 (0)	-12.7 (-0.1)	-13.0 (-0.4)
P3	-13.6	-13.6 (0)	-13.8 (-0.2)	-14.0 (-0.4)
P4	-14.7	-14.9 (-0.2)	-14.9 (0)	-15.5 (-0.8)
P5	-14.0	-14.0 (0)	-14.2 (-0.2)	-14.5 (-0.5)

Table 4.8: Distance from shore of the DoT at each of the 5 profiles under combined wave- and current-action, for different current velocities

Profile	Distance from MHWS-line of mean annual DoT [m], (difference influenced by currents)			
	Waves only	Uc = 0.05 m/s	Uc = 0.10 m/s	Uc = 0.15 m/s
P1	664	664 (0)	674 (+10)	684 (+20)
P2	724	724 (0)	734 (+10)	754 (+30)
P3	807	807(0)	817 (+10)	827 (+20)
P4	917	927 (+10)	927 (+10)	947 (+30)
P5	968	968 (0)	988 (+20)	1028 (+60)

As can be seen from Table 4.7 and Table 4.8, the current velocities have an effect on the calculated DoT. The largest effect is calculated for profile 4, where the difference in DoT between a situation with a current of 0.15 m/s and no current is -0.8 m, leading to a seaward shift of the DoT location of 30 meters.

4.2.5 Effects of climate change on DoT

Climate change results in higher sea levels, which has an influence on where the DoT is located with regard to the MHWS-line. Climate change will also have an uncertain influence on wave climate, with the potential for increasing extreme wave heights. The effect of climate change on the DoT was assessed by considering an increase in mean sea level of 0.35 m, and an increase in the 12h/yr wave height by 5%.

Both the distance of the DoT from the MHWS-line and the DoT level were calculated following the same methodology as described in Section 4.2.3. The results are shown in Table 4.9.

The results show that a combination of 0.35 m increase in mean sea level and a 5% increase in annual extreme wave height leads to a seaward shift of the DoT in the range of 30-80 m (depending on the profile) and an increase in the DoT in the range of 0.3 to 0.8 m.

Table 4.9: Potential effect of climate change on DoT

Profile	Distance from MHWS-line of DoT [m]		Mean annual DoT [m]	
	Present day	With Climate Change	Present day	With climate change
P1	664	694 (30)	-10.3	-10.6 (-0.3)
P2	724	764 (40)	-12.6	-13.1 (-0.5)
P3	807	837 (30)	-13.6	-14.2 (-0.6)
P4	917	977 (60)	-14.7	-15.5 (-0.8)
P5	968	1048 (80)	-14.0	-14.6 (-0.6)

Where CC is climate change. Difference between the baseline and the CC scenario is presented in brackets.

4.3 Summary and conclusion

The above assessments of sediment transport consider three initial lines of evidence for assessing boundaries of the upper and lower shoreface, including the profile geometry, the Hallermeier calculations, and the influence of grain size. A fourth method was also applied by calculating the DoT, identifying the zone on the shore profile where significant sediment transport occurs based on bed shear stress.

The four methods all converge to suggest that the upper shoreface is located on the steeper sloping section that transitions to a concave base at an average depth of -12.5 mRL, located 700 m offshore of MHWS on average. This boundary fluctuates with depths of -16 mRL located up to 1,200 m offshore of MHWS. The start of the lower shoreface is characterised by a concave slope towards a gradually sloping or in some locations bulging upward lower shoreface that extends an average of 2.9 km offshore from the MHWS contour. The Hallermeier equations for the outer DoC are sensitive to minor variations in wave height and period and the resulting small change in depth can result in major changes in distance from the shore at Bream Bay due to the gradual slope of the lower shoreface. The outer DoC as calculated using Hallermeier can range from 1.0 to 6.5 km from MHWS, which indicates that annual sensitivity is not suitable for this equation. However, the 45 year average outer DoC aligns well with the most seaward annual DoT point, with this alignment indicating the lower shoreface could extend to this location on extreme years.

The DoT method provides a more robust assessment of profile zonation based on the formula being based on sediment transport equations. The two methods for calculating the seaward extent of the lower shoreface are both useful for assessing the extraction area, although more confidence is given to the DoT method. To account for the range in results, two definitions for the lower shoreface are proposed for Te Ākau Bream Bay. The first is based on the 90 percentile DoT (to account for annual variability) as a lower shoreface area of frequent and significant sediment transport (Zone 2). The second is based on the 45 year mean DoC which is also consistent with the most extreme DoT year and is interpreted as being a lower shoreface zone of infrequent sediment transport.

All these boundaries are landward of the proposed extraction area and generally make sense when interpreted on the profile features and sediment characters. The convex sections of the lower shoreface and the ridge and swale features along the extraction area boundary are most now likely relict landforms that were formed during times of lower sea level Based on the sediment transport thresholds undertaken to inform the DoC, there is insufficient sediment transport to maintain functional shaping of ridge and swales. The undulations in the extraction area (e.g. 0.5 m trough over 100 m span) further indicate this area is not actively shaped by wave action. In contrast, the mostly smooth appearance of the lower shoreface indicates an area wave planing does occur and some onshore transport may be occurring across the lower transport to shape the convex bulge on Profile 3. Given the wide nature of the lower shoreface, this does not indicate transport from the offshore area to the lower shoreface.

Figure 4.8 and Figure 4.9 show the calculated inner and outer DoC and the p90 DoT with regard to the profiles and the DoC calculations. This summary figure is used to interpret the following zones:

- The upper shoreface zone of significant morphological change (**Zone 1**) as defined by the inner Hallermeier, averaged over 45 years is -12.5 mRL, located 700 – 1,000 m offshore of MHWS and does vary on annual timescales.
- The lower shoreface zone of frequent sediment transport (**Zone 2**), defined by the p90 DoT. This averages to be -17.5 mRL (1,880 m offshore of MHWS) and ranges between -13 mRL and -20.5 mRL (900 to 3,200 m offshore of MHWS).
- The lower shoreface zone of infrequent sediment transport (**Zone 3**), as defined by the 45 year outer Hallermeier equation. This averages to be -21 mRL (2.9 km offshore) but does extend to -22 mRL at Profile 4, located 4.6 km offshore.
- The offshore area (**Zone 4**) where wave induced sediment transport does not functional exchange with the shoreface at decadal timescales, being seaward of the 90 percentile DoT and for additional conservatism also being seaward of the 45 year average outer DoC.

The seaward limit of the lower shoreface is most seaward at Profile 4. At this profile, the lower shoreface as informed by the p90 DoT is 3.2 km landward of the proposed extraction area, and if defined by the 45 year outer DoC is 850 m landward of the proposed extraction area. This allows sufficient separation distance between the activity and definition of the lower shoreface boundary to account for some uncertainty with climate change.

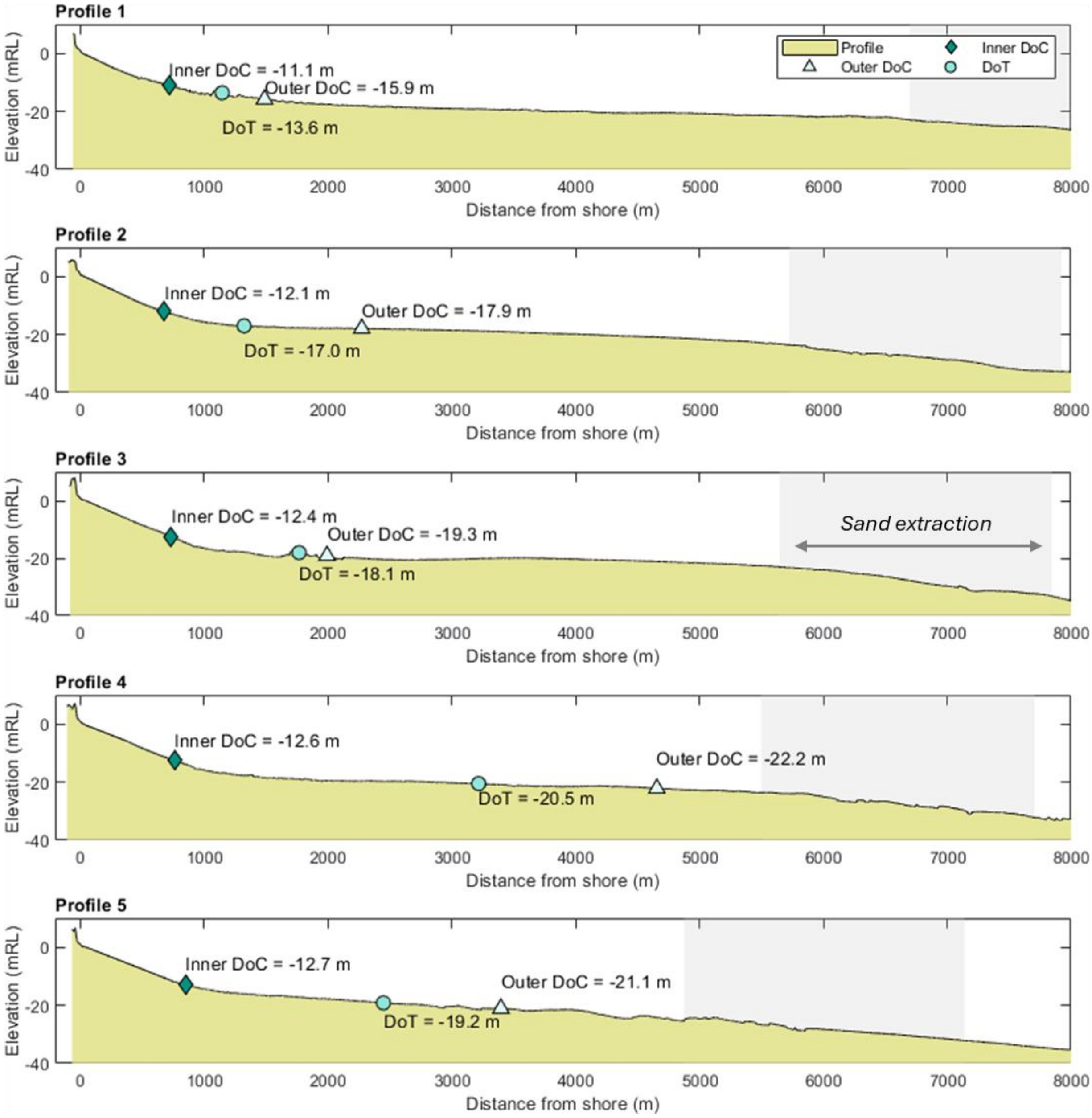


Figure 4.8: Summary of the inner and outer DoC and the DoT at all profiles.

The location of the proposed extraction area regarding the three above shoreface zones is presented in Figure 4.9. The areas were defined by initially joining the points associated with each profile. When overlayed on the map, the inner DoC points were all located on the existing 10 m depth contour from the LINZ chart, so this was used to define a spatial upper shoreface. The zone of frequent sediment transport was then defined by the p90 DoT values, with a minimum distance of 1,000 m from the upper shoreface boundary. The zone of infrequent sediment transport was defined by the 45 year outer DoC value, with a minimum distance of 3.5 km from the upper shoreface (Figure 4.9). These minimum distances were adopted to give more weight to the zonation identified at Profile 4, which is conservative.

Adopting the modern definition for the lower shoreface boundary as recommended by Hamon-Kerivel et al. (2020) means that the extraction area would be over 2 km seaward of the boundary at the closest point. While the outer DoC method is considered less robust and conservative at Bream Bay, it provides a useful check for interpreting the potential effect of the activity.

The plan shows that using either definition of the seaward limit of the lower shoreface, there is no overlap between the proposed extraction area and the lower shoreface at Te Ākau Bream Bay, with a minimum separation distance of 880 m between the conservative definition of the lower shoreface and the proposed extraction area.

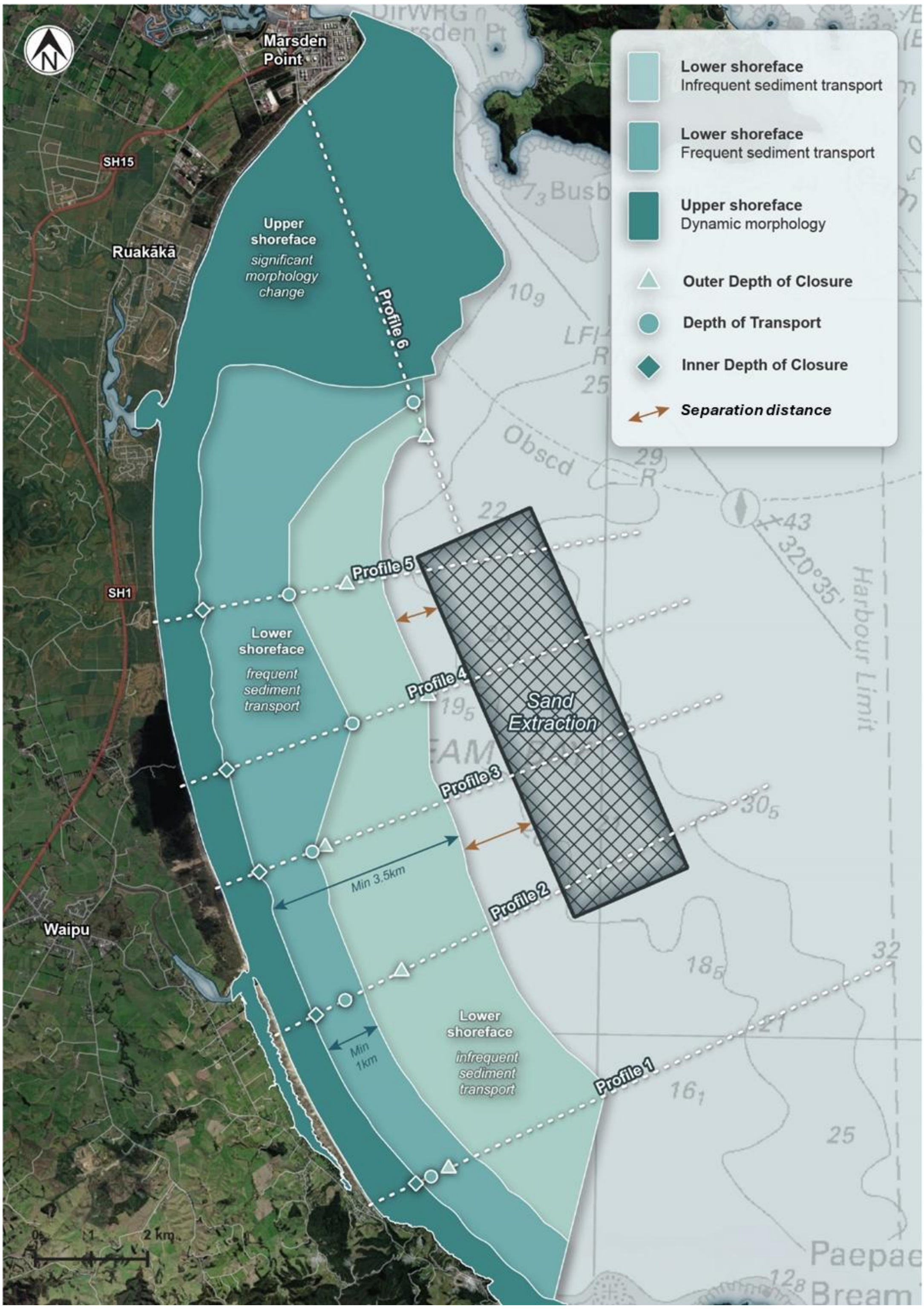


Figure 4.9: Site plan showing the shoreface zones in relation to the sand proposed extraction area.

5 Assessment effects on coastal processes

5.1 Potential effects

Based on an overview of recent research and current industry practice regarding aggregate extraction in the marine environment in UK coastal waters (BMAPA/Crown Estate, 2013) for the Crown Estate and the Marine Environment Protection Fund Steering Group, aggregate extraction could potentially exert an influence on three principal receptors:

- The seabed and its sediments.
- The sediments suspended within the water column.
- The coastline.

This influence could arise through direct physical change associated with the extraction process itself (covering both extraction and screening of sediments) or through indirect consequences of the extraction, causing changes to wave, tide, and sediment regimes operating across and beyond the extraction area.

The main direct impacts caused by marine aggregate extraction are due to disturbance of the seabed, arising from the passage of the drag head over the seabed and changes in bathymetry directly resulting from removal of deposits.

Indirect impacts on the physical coastal process environment can potentially result from:

- Changes in wave transformation processes due to the altered seabed bathymetry.
- Reduced shelter afforded to adjacent shorelines by extracted banks and bars.
- Drawdown of sediment from the shoreface or seabed to infill extracted areas.
- Changes in tidal currents.
- Alteration of regional sediment transport pathways and the supply of sediment to adjacent sandbanks or beaches.
- Formation and dispersal of a sediment plume in the water column, and subsequent deposition of the entrained sediment particles.

Physical impacts from marine aggregate extraction can also arise cumulatively with other seabed activities, such as offshore wind turbine construction, cable or pipeline laying, or fish trawling.

Figure 5.1 shows that marine sand extraction can occur if the location is suitable offshore to prevent a drawdown of sediment on the beach (BMAPA/Crown Estate, 2013).

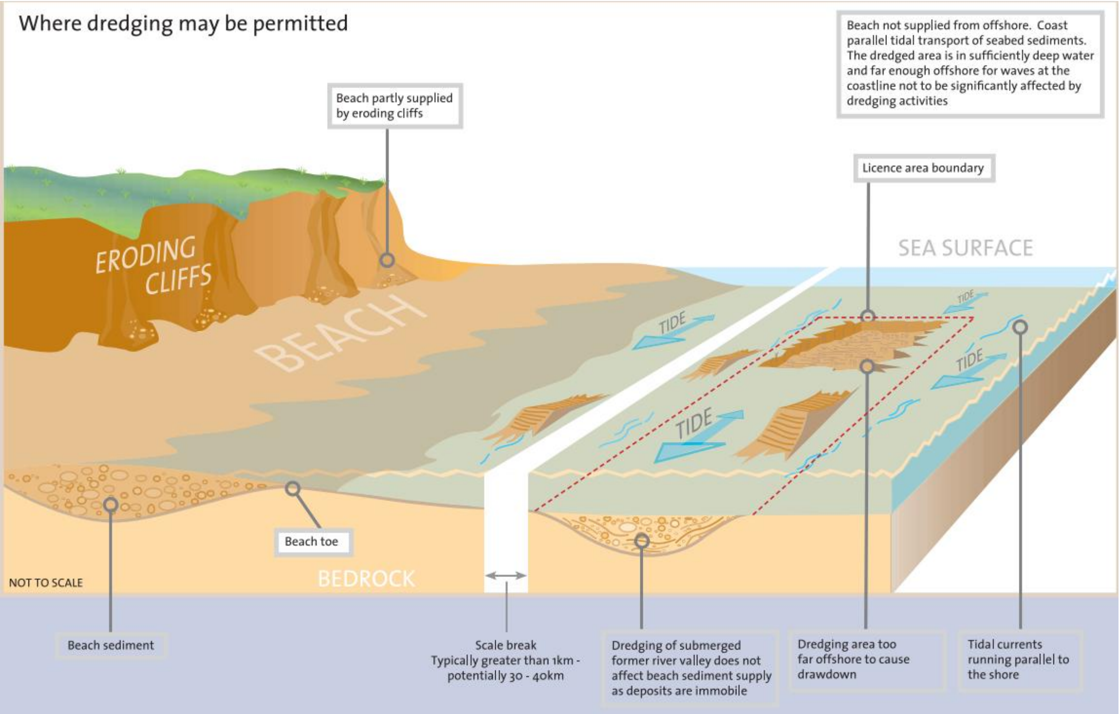


Figure 5.1: Schematic showing key variables for minimising risk of marine extraction at the coast. Source: UK Best Guidance (BMAPA/Crown Estate, 2013).

5.2 Defining levels of effects

The level of effect for different coastal elements is assessed using the definitions in Table 5.1, informed by the data and analysis presented above for the proposed extraction area, the lower shoreface, the upper shoreface and the beach considering wave and hydrodynamic processes and sediment transport and associated morphological changes.

Table 5.1: Qualitative definition for levels of effect on the physical coastal environment

Significance	Criteria: Coastal Processes
Very High /severe	Total loss of, or very major alteration to, key elements/features of the existing baseline condition such that the post-development character, composition and/or attributes will be fundamentally lost. This includes irreversible changes to tides, currents, waves and/or sand transport causing adverse impacts on significant parts of the shorelines of Te Ākau Bream Bay, causing increased erosion and/or significant environmental habitat values. Substantial changes to the seabed morphology such that: • The majority of the regional distribution of a habitat type for nationally protected ecological communities is lost or substantially depleted; or such that • The sediment pathway for sand flow to other areas is permanently intercepted.
High (Significant)	Major loss or alteration to key elements/features of the existing baseline condition such that the post-development character, composition and/or attributes will be fundamentally changed. In particular, extensive or acute disturbance (major impact) occurring to the shorelines, causing increased erosion and/or significant environmental habitat values. Also, substantial changes to the seabed morphology such that: • The majority of the regional distribution of a habitat type for regionally protected ecological communities is lost or substantially depleted; or such that • The sediment pathway for sand flow to other areas is temporarily intercepted.

Significance	Criteria: Coastal Processes
Moderate /medium (More than minor)	Loss or alternation to one or more key features of the existing baseline conditions such that the post-development character, composition and/or attributes will be fundamentally changed. Changes to tides, currents, waves and/or sand transport affecting parts of the shorelines bordering Te Ākau Bream Bay, causing: • Short term increased erosion that would affect communities or habitat values, such that natural recovery or mitigation measures would alleviate adverse impacts. or, • Substantial changes to the seabed morphology such that the local distribution of a locally valued seabed habitat type is permanently lost or substantially depleted.
Low (minor)	Minor shift away from existing baseline conditions. Changes arising will be discernible, but attributes of the existing baseline condition will be similar to pre-development circumstances or patterns. Changes to tide levels, currents, waves and/or sand transport processes causing changes in shoreline stability of limited or temporary nature. Changes to the seabed morphology would be of local spatial extent with no impacts elsewhere.
Negligible (Less than minor)	Very slight changes from the existing baseline conditions. No perceptible impacts on regional hydrodynamics beyond the immediate works area. Local hydrodynamic changes that have no consequent adverse impacts elsewhere. Little or no changes to water level, current, wave or sand transport processes at shorelines such that any impacts to shoreline stability would be imperceptible. Changes to the seabed morphology would be temporary with only local spatial extents and no impact elsewhere.
No effect	No detectable change in physical processes or landforms, including water levels, shoreline position, beach profile, waves and currents.
Beneficial	Any effects or measures that are expected to result in reduced shoreline erosion where that is presently a problem, or design features or management activities that would make a positive contribution to shoreline amenity or coastal environmental values.

5.3 Te Ākau Bream Bay sand resource

The sand resource at Te Ākau Bream Bay is defined as the volume of Holocene (< 12 Ka) sand of the Karioitahi Group located in an area where extraction will have **negligible direct or indirect** effects on coastal processes and landforms. This is the sediment defined as Facies 1 in the MPSS.

The landward boundary of the sand resource area is the seaward extent of the lower shoreface (defined by the 45-yr outer DoC), and the seaward boundary is the depth where practical extraction is readily achievable, and this is taken to be around the 30 m depth contour. While there are significant volumes of sand within Te Ākau Bream Bay landward of the lower shoreface, this was not deemed part of the resource, as sand removed from this area has potential to interrupt coastal processes and landforms within Te Ākau Bream Bay. This area landward of the outer depth of closure is approximately 95,000,000 m^2, which is considered unsuitable for sand extraction. The volume of sand in this area is likely very high based on the profile but is currently unknown as cores were not taken in this zone.

The extent of the potential Te Ākau Bream Bay sand resource is shown in Figure 5.2, being an area of 44,000,000 m^2 between the outer DoC and the -30m depth contour (compared to application area of 15,400,000 m^2). To determine a minimum sand resource volume at Te Ākau Bream Bay the vibracore investigation depths were used to calculate a volume apart from where evidence of the Awhitu group was observed at VB 20.01 and this depth was used. The 3D geological software programme, Leapfrog Works (version 2024.1) estimated a minimum sand resource volume of at least 124,110,000 m^3 within between the outer DoC and the -30 m contour. This is an average depth of 2.8 m below the surface. This volume and depth are likely to be a conservative assessment as no interface was seen in any of the other cores, and recovery was more limited in the more sandy and shelly samples. This means that the depth of sand resource could be greater than the depth of the vibracores obtained during the field campaign, and therefore using the depth from the vibracores is likely to represent a lower bound estimate of the potential volume. Even with this likely underestimate of the resource volume, the application is to take a total of 7% of the available volume, form a smaller area over the 35 year duration.

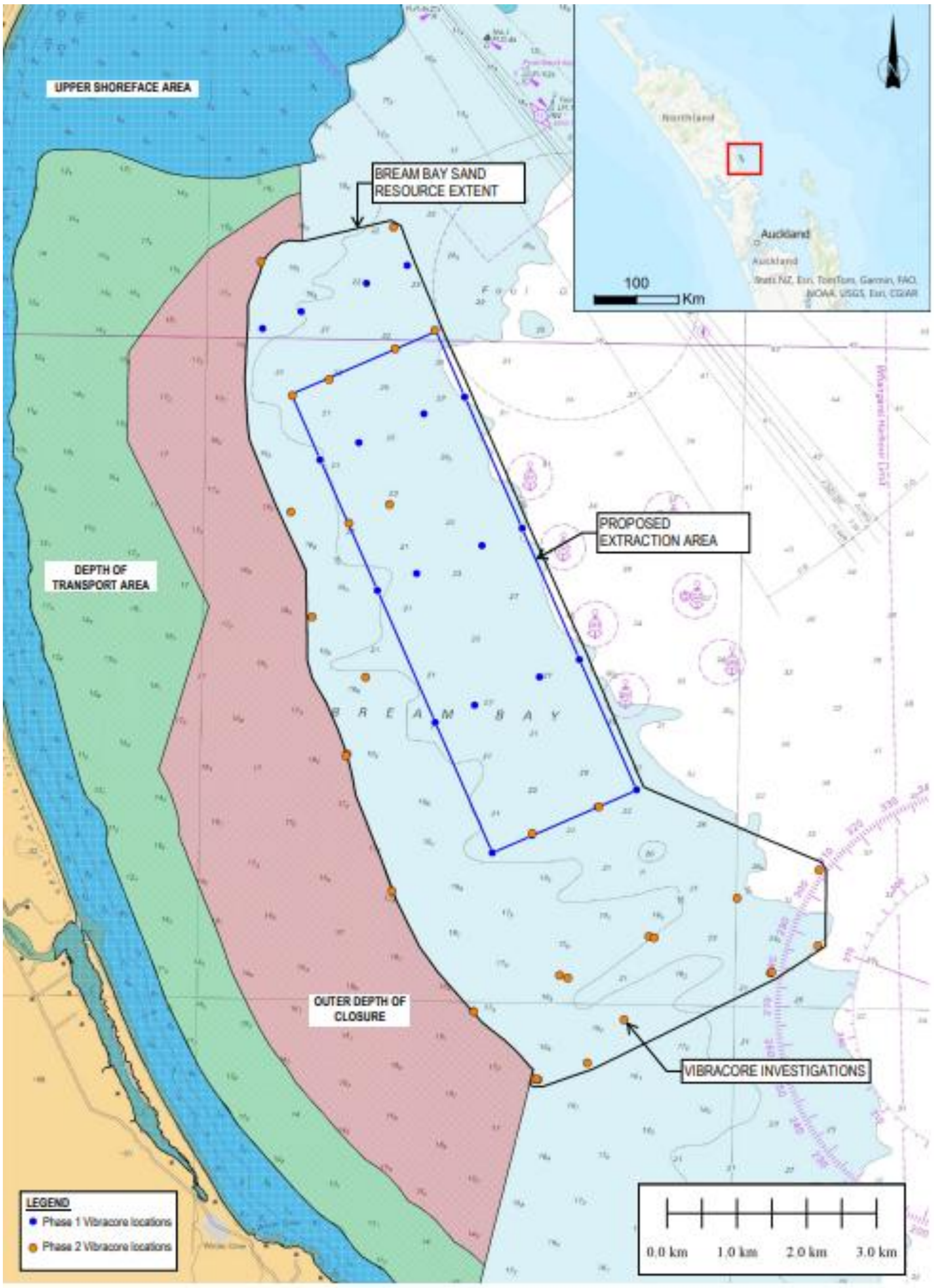


Figure 5.2: Map showing the extent of the Bream Bay sand resource used in the calculation of potential resource

5.4 Proposed extraction area

Extracting with a trailer suction hopper dredge (TSHD) will affect the direct seabed where sediment is being removed. The most direct effect will be the removal of sand, resulting in a local change to the seabed elevation. The application area is 15.4 km^2, extending 7.0 km alongshore and 2.2 km across shore comprising 77 cells 1,000 m long x 200 m wide. For the first three years of consent, MBL is seeking to extract a total of 150,000 m^3/yr with a maximum volume within any cell of 5,000 m^3.

If this is undertaken evenly across the proposed extraction area, the average change in bed level would be -0.01 m/yr and if it was limited to the maximum extraction volume per cell of 5,000 m^3/yr, only 30 of the 77 cells would be dredged and the average bed level change across these 30 cells would be -0.04 m/yr.

The rate of extraction is proposed to increase from year four onwards, to 250,000 m^3/yr, resulting in an average change in bed level of -0.016 m/yr. With the maximum extraction value remaining the same, this means that the minimum number of cells accessed would increase from 30 to 50 with the average bed level change per year in each of these cells remaining at -0.04 m/yr. The full proposal is to extract 8,450,000 m^3 of sand over 35 years, which accumulates to a change in bed level of -0.55 m averaged across the proposed extraction area.

The activity could therefore cause a progressive lowering of the seabed level over 35 years, which is a localised effect within the activity footprint. The potential for lowering of the seabed to affect waves and sediment transport processes is discussed in relevant sections below.

5.4.1 Extraction tracks

The drag head of the proposed TSHD vessel '*William Fraser*' is 1.6 m wide and the extraction depth is 0.1 m (Figure 5.3). The hopper on the *William Fraser* has a capacity of 923 m^3. MBL are proposing to extract for a maximum of 3.5 hours per trip to fill the hopper over a track length of 11-13 km (average vessel speed of 2 knots). This means that approximately two extraction lines would be traversed for each extraction operation, assuming the extraction pattern follows the full long axis of the area. Extraction activities will be undertaken 3-4 times per week for the first 3 years (max of 162 per year), then 5-6 times per week for the remaining duration of consent (max of 270 per year) although the maximum volume of sand extraction per cell not to exceed 5,000 m^3 per annum.

The coastal process assessment indicates that wave induced sediment transport infrequently occurs in the extraction zone, with the initiation of sediment motion exceeded for 20-30 days per year, and the initiation of ripple formation occurring for 4-6 days per year. Wave induced currents at the seabed of the proposed extraction area are not sufficient to transport sediment particularly far but are sufficient and frequent enough to reduce perturbations on the seabed caused by the drag head during larger wave conditions.

A potential adverse effect on the seabed within the extraction zone is the formation of unnatural larger depth variability compared to the adjacent seabed caused by repeated extraction over the same section of the seabed. Even though the activity is being undertaken in a seaward location beyond the outer DoC and DoT, the potential formation of tracks that are greater than the existing seabed variability (i.e. 2 m wide and more than 0.4 m below the surrounding seabed) could potentially interfere with sediment transport processes during the most extreme events.

MBL are proposing to manage extraction lines to avoid track repetition by both the annual limit of dredge volume of 5,000 m^3 in each cell which would result in an average depth of -0.04 m and having a Sand Extraction Operation Plan to avoid repeatedly excavation along the same track within a cell. **As tracks with a larger depth variability than observed on the existing seabed are not formed by a single extraction line** and u**sing the proposed extraction method with annual extraction limits in each cell the likelihood of repeated extraction of the same area of seabed creating changes in seabed level greater than the observed variability is avoided**.

Bathymetric monitoring will also be undertaken to understand how the activity is changing the local seabed within the proposed extraction area.

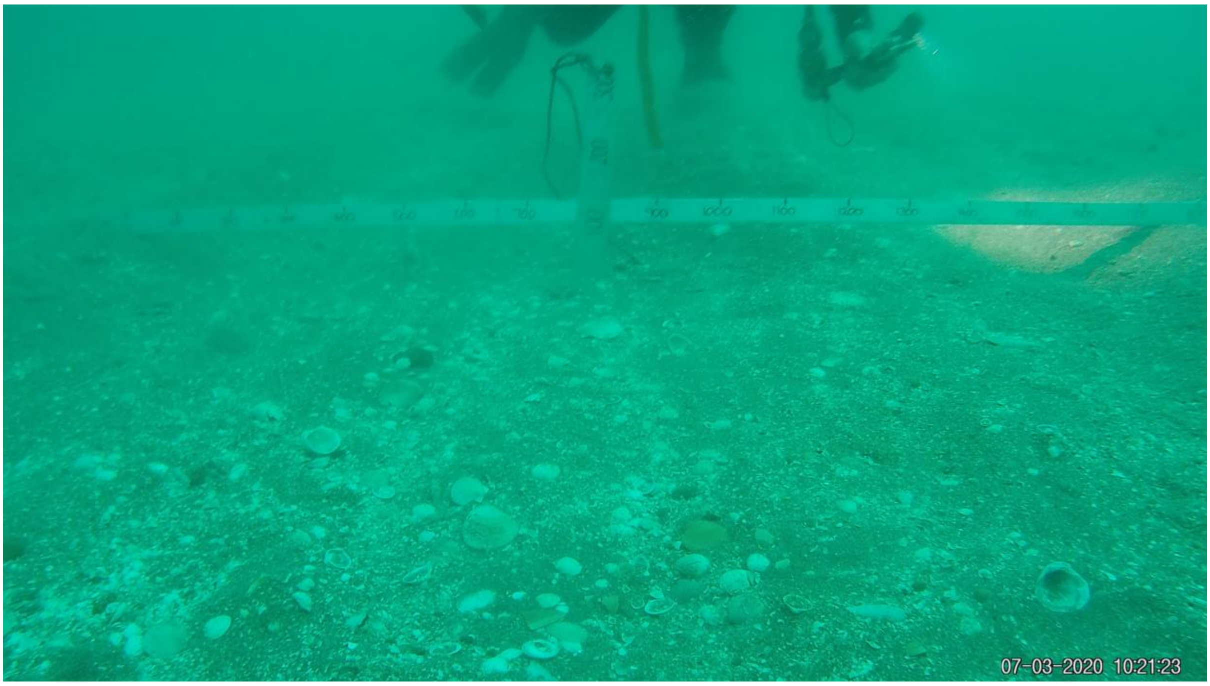


Figure 5.3: Photo from MBL showing an extraction track from the William Frasor drag head.

5.5 Waves

The activity has potential to locally alter wave processes approaching the coast of Te Ākau Bream Bay if the cumulative lowering of the seabed is sufficient to alter the height and or direction of waves passing over the proposed extraction area. A numerical modelling assessment was undertaken by MetOcean Solutions to assess the potential for the sand extraction activity to alter wave processes approaching different surf breaks along Te Ākau Bream Bay (MOS, 2024). The MetOcean Solution analysis considered a baseline scenario with the existing bathymetry, and a post extraction scenario where the full proposed extraction area was lowered by 0.55 m. This is based on the removal of the full consented volume over 35 years under the assumption of **no** sediment recharge to offset the volume removed. This is a suitable worst-case assumption because any recharge remains uncertain, and the rate of any recharge will need to be established through monitoring during the consent duration.

The modelling by MetOcean Solutions indicates that lowering the seabed in the proposed extraction area by 0.55 m can result in localised changes to wave height at different locations within Te Ākau Bream Bay. The change in wave height is generally very small (±0.01 to 0.02 m change). These changes will be difficult to measure and due to existing natural variability in the wave climate, changes of this order are not expected to alter the physical coastal process regime in any of the zones considered.

Given the small magnitude of modelled changes to wave height and direction, the results from the MetOcean Solutions model are interpreted to have a **negligible effect on wave transmission to the shoreline in a way that affects coastal processes**.

5.6 Hydrodynamics

Available information on currents in Te Ākau Bream Bay shows currents are typically low (<0.15 m/s) at the seabed. Currents can be influenced by changes in seabed elevation, if an activity creates a significantly shallower ridge, or deeper channel of dimensions significantly greater than the existing seabed variability. The extraction activity at Te Ākau Bream Bay is spread across a relatively large area, with small changes in bed level.

The average depth of the proposed extraction area is 27.5 m below NZVD, and this will change by a maximum of 0.55 m over the 35 years of the proposal. This is a change in depth of less than 2%.

Dominant currents at Te Ākau Bream Bay flow north to south according to past modelling studies (Figure 3.23), which is more favourable for sand extraction according to international guidance (Figure 5.1) as it means that tidal currents are not facilitating onshore and offshore sediment exchange.

Due to the small changes in bed level and spreading of extraction around the area, the effect of changes in bed level will have a **negligible** effect on hydrodynamics in any of the zones considered.

5.7 Sediment transport

A detailed assessment of the depth of closure and depth of transport was undertaken for Te Ākau Bream Bay to make sure the activity is occurring at a suitable seaward location to minimise the risk of interfering with sediment dynamics in the surf zone, beach and dune environment. Key findings are:

- The proposed extraction area is located greater than 4 km seaward of the inner DoC, where sediment can be exchanged between the beach and nearshore on annual timescales. This avoids any potential for a storm sand bar to be developed inside the proposed extraction area.
- The proposed extraction area is located seaward of the long-term average outer DoC and is seaward of 91% of the annual variability in the DoC. This variability is influenced by wide and gradual sloping profile offshore of Te Ākau Bream Bay and is one reason the DoT methods is more appropriate.
- The presence of a wide and very gradually sloping lower shoreface makes the application of the outer Hallermeier equation potentially unsuitable and likely conservative for identifying the seaward limit of the lower shoreface where sediment is actively exchanged with the upper shoreface.
- Recent literature developed a more suitable method for assessing the seaward limit of the upper shoreface using bed shear stress calculations termed the depth of transport (Valiente, et al., 2019). The DoT method is recommended by Hamon-Kerivel et al. (2020) as a more appropriate definition of the lower shoreface when compared to the Hallermeier method.
- The DoT was calculated for each bathymetry profile at Te Ākau Bream Bay, for each year in the wave hindcast using the method by Valiente, et al. (2019) to identify the DoT as the point where bed shear stress from a 12 h/yr wave height exceeds the grain size shear stress threshold for transitioning to a plane bed. For Te Ākau Bream Bay the DoT was informed by the 90-percentile annual DOT over 45 years. This averages to be -17.5 mRL (1,880 m offshore of MHWS) and ranges between -13 mRL and -20.5 mRL (900 to 3,200 m offshore of MHWS).
- Analysis of bed shear stress threshold and exceedance was undertaken by reconstructing a 45 year hindcast of bed shear stress in different wave output points. This analysis shows that the threshold for initiation of motion is exceeded in the proposed extraction area for an average of 1-2 months per year, and the threshold for ripple formation is exceeded for about 1-2 week per year. The shear stress threshold for a significant sediment transport (transition to plane bed) was not exceeded in the proposed extraction area for the original or calibrated hindcast.
- However, it is still reasonable that under extreme conditions (e.g. 10-to-100 year return period wave height), there is potential for some sediment to be naturally mobilised between the proposed extraction area and lower shoreface. The sand extraction activity is not expected to interfere with coastal processes during these extreme conditions, as sufficient sediment will remain in the sediment body. This is attributed to the lower shoreface having a convex profile, which indicates increased sediment abundance compared to concave profiles. Further, the geotechnical investigations show that Holocene sand is present below the extraction area to at least 2 m below current level. Therefore, the extraction does not pose a risk in terms of

transitioning from a mobile sand bed (Facies 1) to the more consolidated and less mobile sandy layers (Facies 2).

- Interpretation of geomorphic evidence, including ridges and swales, and sediment texture and the profile shape indicate there is low risk of the proposed extraction interrupting sediment flows between the offshore area and shoreface. The ridges, swales and troughs in around the extraction area are most likely relict features that are not geomorphically active at present (or future) sea levels. This is evident by sediment in the extraction area being generally coarser than the shoreface, and sediment transport calculations showing minimal exceedance of motion thresholds that would be required to move sediment within and beyond the extraction area.

The overall effect of the proposed extraction on sediment transport in the proposed extraction area is considered **low** if the activity is suitably managed to avoid the formation of tracks caused by extraction that could act as local sediment sinks.

Based on our assessment, the proposed sand extraction is in the offshore zone, seaward of the lower shoreface and therefore will have **negligible** effect on the lower shoreface and **negligible effect** on sediment transport processes on the upper shoreface and beach because the activity is taking place in an area which is generally considered morphodynamically non-active.

5.8 Lower shoreface morphology

The lower shoreface is a wave shoaling zone on the coastal profile where wave induced sediment transport occurs but is seaward of where morphology change occurs on annual timescales. During extreme events, and over timescales exceeding multiple decades, the lower shoreface can be dynamic in terms of sediment exchange with the upper shore face. Large swell waves can transport sediment from the lower to upper shoreface, and some sediment entrained in bed return flow or entrained in rips can eventually be deposited on the lower shoreface.

The seaward limit of the lower shoreface was initially assessed using the Hallermeier method. This identified that the long-term average outer DoC is landward of the proposed extraction area. However, 9% of all annual calculations identified that the outer DoC can intermittently extend into a portion of the proposed extraction area to a maximum (temporary) depth of -27 mRL, while 91% of the annual calculations identify the outer DoC as being landward of the proposed extraction area, across the profiles. The Hallermeier outer DoC method is very sensitive to the shoreface profile at Te Ākau Bream Bay, with analysis indicating a 4 km range in where the outer DoC could be located, influenced by the convex profile. The extended and very gradual seaward slope of the lower shoreface makes application of the Hallermeier method conservative for Te Ākau Bream Bay. Therefore, the 45 year average value is recommended for informing the location of the Hallermeier outer DoC, which is located landward of the proposed extraction area for all profiles.

The DoT was also calculated to identify the seaward limit of the upper shoreface, as recommended by Hamon-Kerivel (2020) and following the method of Valiente, et al. (2019). Results for Te Ākau Bream Bay show that the DoT is located approximately 900 – 3,200 m from MHWS, and the extraction zone is located 4,800 – 5,600 m from MHWS on these profiles (Table 3.1). These results show that sand extraction would be seaward of the lower shoreface zone in all conditions, and there is a low likelihood of the activities in the proposed extraction area impacting long term coastal evolution, so effects on the lower shoreface are considered **low**.

5.9 Upper shoreface morphology

The upper shoreface is an area of the coastal profile that is seaward of the surf-zone (in calm conditions) and defined by a seaward point where wave induced changes to the seabed elevation occur. During large storm events, sediment eroded from the beach can be deposited on the upper shoreface as a sandbar or sand sheets. Other mechanisms of sediment transport from the dune to the shoreface include undertow and rips. Mechanisms of onshore sediment transport are associated with wave shoaling, which is generally attributed to swell conditions with relatively low wave steepness.

Analysis of the inner DoC was undertaken using the Hallermeier method, as recommended by Hamon-Kerivel, et al. (2020) to define the seaward limit of the upper shoreface. Results for Te Ākau Bream Bay show that the inner DoC is located approximately 700 – 1,200 m from the MHWS, and the extraction zone is located 4,800 - 5,600 m from MHWS at the assessment profiles. Therefore, there is no potential for the sand extraction activity to overlap with the upper shoreface where sediment is dynamically exchanged with the beach and dunes on annual timescales, so the effect on upper shoreface morphology is considered **negligible**.

5.10 Coastal morphology

A potential adverse effect from marine sand extraction is that this can cause a ‘drawdown’ of the beach. This occurs if the extraction is undertaken on the shoreface or surf-zone area that has a morphology in dynamic equilibrium with the wave climate and sediment supply. A drawdown would occur if the extraction activity forced the sediment system to be out of equilibrium, resulting in a sediment exchange from the beach to fill the holes left by the extraction. The effect of a ‘draw down’ is erosion of the beach and or dune, resulting in a beach that has less recreational space, reduced habitat area, and reduced resilience to climate change.

The sand extraction proposal for Te Ākau Bream Bay is located sufficiently offshore, in terms of distance and depth that the activity is not expected to directly or indirectly influence the beach and dune environment. This is confirmed by analysing the inner and outer DoC and the DoT, which indicate the activity is occurring at a suitable seaward depth and location for the extraction to avoid the risk of drawdown, indicating a **negligible effect** on coastal morphology of the beach at the present time.

The **negligible** effect of the extraction on wave transmission towards the shoreline is also not expected to influence coastal processes. Therefore, the overall effect of the activity on the beach and dune environment is assessed to be **negligible**, through the design of the location being offshore of the DoC.

5.11 Cumulative effects with climate change

Sea level rise over the duration of the 35 year consent is projected to be around 0.35 m, with the actual rate depending on emission scenarios and climate-ocean feedback loops. The 0.35 m value was adopted as a suitable representative for this assessment, as higher rates of SLR associated with SSP5-RCP8.5 that are typically used in hazard assessments would be non-conservative here as higher sea levels push the lower shoreface boundary landward. Climate change could impact on the activity in the following ways:

- The DoC will move up and landward based on the magnitude of sea rise. This does not increase the risk of extraction occurring on the lower or upper shoreface, as the proposed extraction area will be deeper with climate change and the DoT will move landward.
- Beach erosion will occur in response to climate change. The response of sandy beaches to sea level rise is erosion of the beach and dune through landward translation. The erosion distance attributed to sea level rise is a function of the profile slope, measured between the foredune crest and the inner DoC. The sediment eroded from the dune is deposited on the upper-shoreface. Sediment deposition on the upper shoreface attributed to sea level rise response will not reach the proposed extraction area. Therefore, there is **negligible risk** of climate change induced sea level rise increasing the effect level from the activity.

There is uncertainty regarding the effect of climate change on the mean and extreme wave climate of Te Ākau Bream Bay. Uncertainty in future wave climates indicate that the extreme wave height may reduce or stay the same or potentially increase by up to 5% with some very low likelihood of extreme waves increasing by up to 15%. Therefore, an assessment considered the effect of climate change causing a 5% increase in the mean and annual extreme wave height. The outer DoC as calculated using the Hallermeier wave base equation was found to be sensitive to a 5% increase in wave height, resulting in an outer DoC that shifts the depth seaward by up to 0.9 m when considering the balance of higher sea level moving the point landward and larger waves moving the point seaward.

The DoT method was also assessed to consider a 0.35 m increase in sea level and a 5% increase in the extreme 12 h/yr exceeded wave height, resulting in the DoT moving seaward by an average of 48 m horizontal and increasing the depth an average of 0.56 m. This indicates that an increase in extreme or mean wave height is potentially more influential than sea level rise over the duration of the consent.

However, there is sufficient buffer distance between the proposed extraction area and the lower shoreface to allow for uncertainty in future wave climate changes and to keep the DoT and DoC boundaries landward of the proposed extraction area.

5.12 Specific location assessment

5.12.1 Outline

This section comments on specific locations within Bream Bay. The location of these sites with regards to the proposed extraction area is presented in Figure 5.4.

5.12.2 Langs Beach

Langs Beach is located 7.1 km south-south-west of the closest point of the proposed extraction area (Figure 5.1). Langs is a pocket beach approximately 1.5 km in length, bound by rocky headlands on either side. The beach is influenced by two streams that drain from a local catchment through the coastal sand, creating dynamic channels through the beach. A coastal hazard assessment by Northland Regional Council (T+T, 2020)[7] indicates that the site is prone to erosion from storm events and from future sea level rise. The shoreline position has been dynamic over the past decades, with no clear trend of net accretion or erosion to indicate sediment input or losses. The landward edge of the beach is characterised by a range of sand dune, soft cliffs, protection structures. Mapped coastal erosion hazard zones indicate potential for erosion of 12-24 m by 2080, measured from the present-day dune toe position, attributed to a combination of sea level rise and storm action[8]. Coastal erosion is likely to be an issue at Langs Beach over the coming decades, attributed to sea level rise and coastal storms.

The proposed sand extraction area is located offshore, beyond the DoC and DoT and is therefore **not expected to interfere with the natural sediment movement between the beach and shoreface at Langs Beach**. Storm events at Langs Beach would be expected to transfer sediment from the dune and beach to the upper shoreface, to a depth of approximately 10 m. The proposed extraction area is located a further 6 km from the 10 m depth contour at the closest point. Following storm events, sand deposited on the upper shoreface is expected to gradually return to the beach through wave shoaling and bar migration processes. Due to the offshore location of the sand extraction, it is **very unlikely** that proposed activity could interrupt the natural sediment dynamics at Langs Beach through a draw-down effect. The proposed sand extraction is **not expected** to increase the vulnerability of Langs Beach to erosion from coastal storms and sea level rise.

[7] https://www.nrc.govt.nz/environment/natural-hazards-portal/coastal-hazards/consultant-reports/
[8] https://www.nrc.govt.nz/media/a0db0ych/langs-site-report.pdf

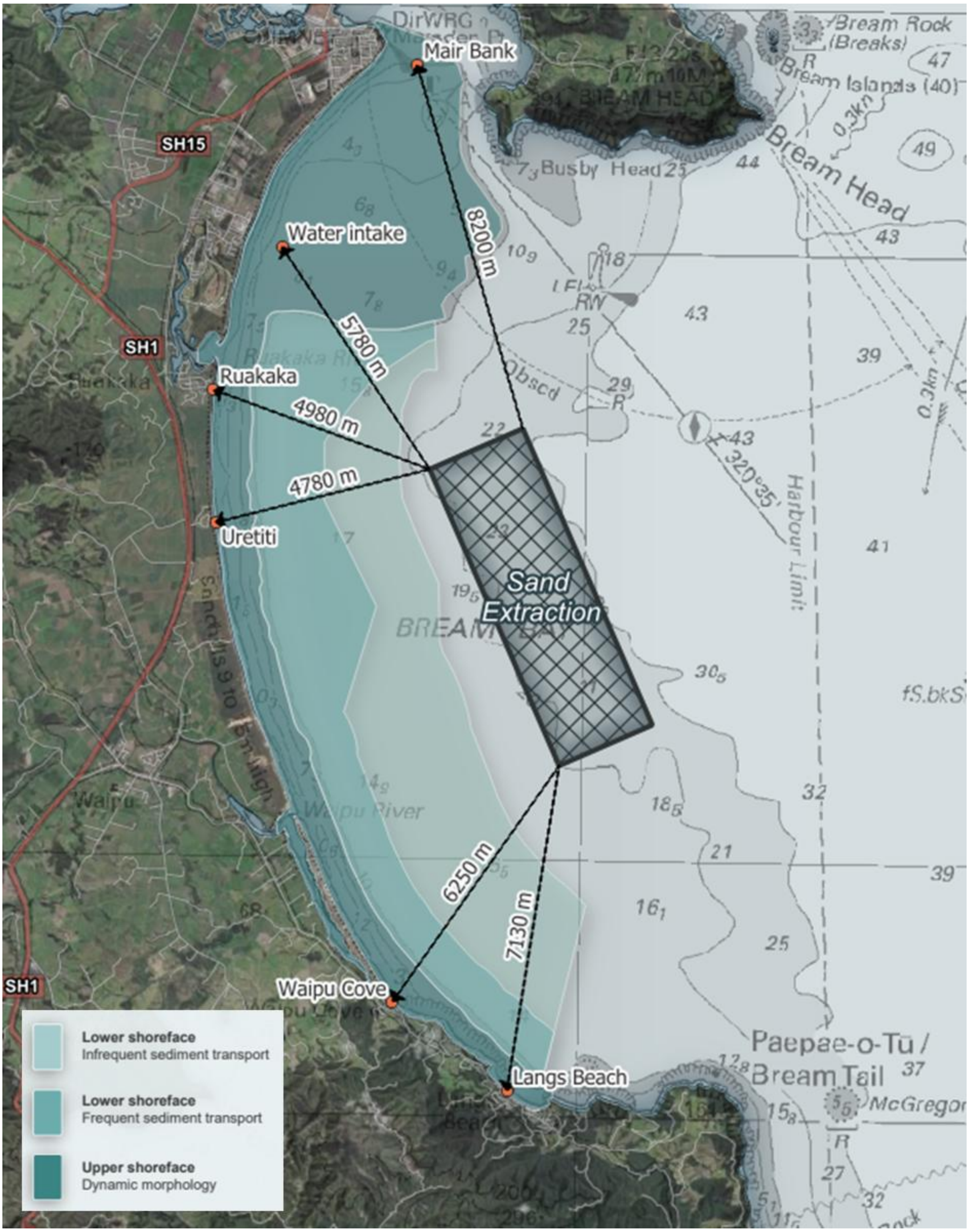


Figure 5.4: Specific assessment locations in relation to the proposed sand extraction area.

The proposed extraction area is in the swell corridor for Langs Beach which means waves pass over the extraction area before arriving at Langs Beach. If the extraction activity altered the bathymetry to a point that waves arriving at Langs Beach were altered in height or direction, this could change the natural flow of sediment at the coast. The MetOcean (2024) has assessed potential changes to wave conditions at Langs Beach based on the full proposed extraction area being lowered by 0.55 m. The results for Langs Beach identified the maximum difference in wave height is <0.01 m and the modelled change in mean wave direction is <1 degree, which will have **negligible** influence on the local coastal process regime (not discernible above natural variability).

5.12.3 Waipū Cove Beach and Estuary

Waipū Cove is a section of beach located at the southern end of Te Ākau Bream Bay. Waipū Cove is located 6.25 km south-west of the closest point of the proposed extraction area (Figure 5.1) with the estuary mouth some 5 km from the closest point. The beach is backed by sand dunes that are managed by a Coast Care dune restoration initiative. Beach profile monitoring at Waipū Cove indicates a long-term trend of accretion, at an average rate of 0.34 m/yr at the dune toe (Table 3.12), although the trend fluctuates between periods of accretion and erosion due to storm events and seasonal weather patterns. This is generally consistent with shoreline mapping from Coastal Change[9], where the typical trend is 0.1 m/yr accretion, which also shows fluctuations around this trend (Figure 3.25). A minor trend of accretion at this location is potentially attributed to erosion along the coast to the north near Uretiti (Figure 3.25).

A coastal hazard assessment by Northland Regional Council (T+T, 2020) indicates that the site is prone to erosion from storm events and from future sea level rise. Mapped coastal erosion hazard zones indicate potential for erosion of 16 - 28 m by 2080, measured from the present-day dune toe position, attributed to a combination of sea level rise and storm action[10]. Coastal erosion is likely to be an issue at Waipū Cove over the coming decades, attributed to sea level rise and coastal storms.

The proposed sand extraction area is located offshore, beyond the DoC and DoT and is therefore **not expected to interfere with the natural sediment movement between the beach and shoreface at Waipū Cove**. Storm events at Waipū Cove would be expected to transfer sediment from the dune and beach to the upper shoreface, to a depth of approximately 10 m. The proposed extraction area is located a further 5 km from the 10 m depth contour at the closest point. Following storm events, sand deposited on the upper shoreface is expected to gradually return to the beach through wave shoaling and bar migration processes. Due to the offshore location of the sand extraction, it is **very unlikely** that the proposed activity could interrupt the natural sediment dynamics at Waipū Cove through a draw-down effect. **The proposed sand extraction is not expected to increase the vulnerability of Waipū Cove to erosion from coastal storms and sea level rise.**

The proposed extraction area is in the swell corridor for Waipū Cove which means waves pass over the proposed extraction area before arriving at local beach. If the extraction activity altered the bathymetry to a point that waves arriving at Waipū Cove were altered in height or direction, this could change the natural flow of sediment at the coast. The MetOcean Solutions Ltd (2024) has assessed potential changes to wave conditions at Waipū Cove based on the full proposed extraction area being lowered by 0.55 m. The results for Waipū Cove identified the maximum difference in wave height is 0.01 m and the modelled change in mean wave direction is <1 degree, which will have **negligible** influence the local coastal process regime (not discernible above natural variability).

5.12.4 Uretiti Beach

Uretiti Beach is located centrally in Te Ākau Bream Bay, located 4.78 km east of the closest point of the proposed extraction area (Figure 5.1). The beach is backed by tall natural sand dunes. Beach profile monitoring at Uretiti indicates a long-term trend of minor erosion, at an average rate of -0.04 m/yr at the due toe (Table 3.12), although the trend fluctuated around period of accretion and erosion due to storm and seasonal events. This is generally consistent with shoreline mapping from Coastal Change, where the typical trend is -0.13 m/yr, which also shows fluctuations around this trend (Figure 3.25).

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[9] https://coastalchange.nz/

[10] 2-Waipū-cove-a1430933.pdf

A coastal hazard assessment by Northland Regional Council (T+T 2020) indicates that the site is prone to erosion from storm events and from future sea level rise. Mapped coastal erosion hazard zones indicate potential for erosion of 25 m by 2080, measured from the present-day dune toe position, attributed to a combination of sea level rise and storm action[11]. Coastal erosion is likely to be an issue at Uretiti over the coming decades, attributed to sea level rise and coastal storms.

The proposed sand extraction area is located offshore, beyond the DoC and DoT and is therefore **not expected to interfere with the natural sediment movement between beach and shoreface at Uretiti**. Storm events at Uretiti would be expected to transfer sediment from the dune and beach to the upper shoreface, to a depth of approximately 10 m. The proposed extraction area is located a further 4 km from the 10 m depth contour at the closest point. Following storm events, sand deposited on the upper shoreface is expected to gradually return to the beach through wave shoaling and bar migration processes. Due to the offshore location of the sand extraction, it is **very unlikely** that the proposed activity could interrupt the natural sediment dynamics at Uretiti through a draw-down effect. **The proposed sand extraction is not expected to increase the vulnerability of Uretiti to erosion from coastal storms and sea level rise**.

The proposed extraction area is in the swell corridor for Uretiti which means waves pass over the proposed extraction area before arriving at the local beach. If the extraction activity altered the bathymetry to a point that waves arriving at Uretiti were altered in height or direction, this could change the natural flow of sediment at the coast. The MetOcean Solutions Ltd (2024) did not assess potential changes to wave conditions specifically at Uretiti, so adjacent sites at Ruakākā and Waipū River has been reviewed. The results for identified the maximum difference in wave height is 0.01 m and the modelled change in mean wave direction is <1 degree, which will have **negligible** influence the local coastal process regime (not discernible above natural variability).

5.12.5 Ruakākā Beach and Estuary

Ruakākā Beach is located in the northern segment of Te Ākau Bream Bay, located 4.98 km northeast of the closest point of the proposed extraction area (Figure 5.1). The beach is backed by tall natural sand dunes. Beach profile monitoring at Ruakākā indicates a long-term trend of accretion, at an average rate of 0.35 - 0.46 m/yr at the dune toe (Table 3.12), although the trend fluctuates between periods of accretion and erosion due to storm and seasonal events. This is generally consistent with shoreline mapping from Coastal Change, where the typical trend is 0.2 m/yr accretion, which also shows fluctuations around this trend (Figure 3.25).

A coastal hazard assessment by Northland Regional Council (T+T, 2020) indicates that the site is prone to erosion from storm events and from future sea level rise. Mapped coastal erosion hazard zones indicate potential for erosion of 16 - 25 m by 2080, measured from the present-day dune toe position, attributed to a combination of sea level rise and storm action[12]. Coastal erosion is likely to be an issue at Ruakākā Beach over the coming decades, attributed to sea level rise and coastal storms.

The proposed sand extraction area is located offshore, beyond the DoC and DoT and is therefore **not expected to interfere with the natural sediment movement between beach and shoreface at Ruakākā Beach**. Storm events at Ruakākā Beach would be expected to transfer sediment from the dune and beach to the upper shoreface, to a depth of approximately 10 m. The proposed extraction area is located a further 4 km from the 10 m depth contour at the closest point. Following storm events, sand deposited on the upper shoreface is expected to gradually return to the beach through wave shoaling and bar migration processes. Due to the offshore location of the sand extraction, it is **very unlikely** that the proposed activity could interrupt the natural sediment dynamics at Ruakākā

[11] 3-Ruakākā-a1430946.pdf cell 3E
[12] 3-Ruakākā-a1430946.pdf

Beach through a draw-down effect. **The proposed sand extraction is not expected to increase the vulnerability of Ruakākā Beach to erosion from coastal storms and sea level rise**.

The proposed extraction area is in the swell corridor for Ruakākā Beach which means waves pass over the proposed extraction area before arriving at local beach. If the extraction activity altered the bathymetry to a point that waves arriving at Ruakākā Beach were altered in height or direction, this could change the natural flow of sediment at the coast. The MetOcean (2024) has assessed potential changes to wave conditions at Ruakākā based on the full proposed extraction area being lowered by 0.55 m. The results for identified the maximum difference in wave height is 0.01 m and the modelled change in mean wave direction is <1 degree, which will have **negligible** influence the local coastal process regime (not discernible above natural variability).

5.12.6 Aquaculture water intake

A submarine water intake pipe used for aquaculture operations at NIWA is located 5.78 km to the northwest of the proposed extraction area (Figure 5.1). The intake pipe is 2.4 m diameter, with the seaward end rising approximately 4 m above the seabed and is topped by a velocity cap. The water intake is located around 6 m below the sea surface (i.e. around 8 m CD depth contour). Turbidity is assessed by NTU in the intake riser. Based on 2023 and 2024 data, mean values are typically between 1.3 and 1.5 NTU. However, during storm events turbidity levels can rise to around 4 NTU. During Cyclone Gabrielle (12 – 15 Feb 2023) values of up to 15 NTU were recorded. Typically, the pipeline is serviced every 2 - 3 years, where divers use air lifts to suction the accumulated wedge of sand from the seaward few metres of the pipe (Andrew Forsyth, NIWA pers. comm.). The fact that maintenance clearance of sand near the intake is carried out every few years indicates that reasonable quantities of suspended sediment are present at the intake location due to wave-induced suspended sediment concentrations at this relatively shallow nearshore location within the upper shoreface.

The potential for effects from the extraction will be limited to the surface plume as any sediment disturbance around the cutter head and seabed will be too deep and distant to affect the intake. Based on an analysis of the results of field trials of the extraction plume, turbidity levels were below 1 NTU at a distance of 2 km behind the *William Fraser* and around 250 m adjacent to the vessel path which is within ambient conditions. As the distance from the closest extraction operation is nearly 3 times further than the most conservative disturbance distance from the *William Fraser*, **no effects** are expected to the sediment transport and hydrodynamics at the intake.

5.12.7 Mair Bank

Mair Bank is an intertidal and subaerial sand and shell bank at the entrance to Whangārei Harbour. A narrow channel separates Mair Bank from the coast, where Marsden Bank is attached to as a separate alongshore shoal. The proposed extraction area is located 8.2 km to the south-south-east of Mair Bank at the closest point. Mair Bank is a valued shellfish habitat that has been the subject of investigations related to shellfish mortality and geomorphic stability. Research summarised in Williams and Hume (2014)[13] indicates that the morphology of Mair Bank is dynamic, with a general northward migration of the open coast side in recent decades, and consistent position of the eastern extent (tidal channel end). The bank is an ebb tide feature influenced by the tide flowing out of Whangārei Harbour, and local wave action that constantly re-works the material that make up the bank. The general volume of sediment in Mair Bank is thought to be relatively stable, but the feature is dynamic in terms of position.

[13] https://www.nrc.govt.nz/media/suddqqjf/williams-hume-2014-investigation-into-the-decline-of-pipi-at-mair-bank-Whangārei-harbour.pdf

The physical processes and sediment dynamics that influence Mair Bank are localised at the harbour mouth location. These processes are not expected to be influenced by the proposed sand extraction which is located offshore and outside the zone of dynamic sediment exchange.

5.13 Effects summary

The overall effect of the proposed offshore sand extraction activity at Te Ākau Bream Bay on physical coastal processes within the beach, upper and lower shoreface of Te Ākau Bream Bay is **low to negligible**. The level of effect is **negligible to low within the proposed extraction area**, as summarised for each zone and element below.

Table 5.2: Summary of effects on the physical coastal environment

Zone	Element	Summary of effect	Effect level
Proposed extraction area	Waves	Very limited change in wave height and direction associated with seabed within the extraction area being 0.55 m deeper.	**Negligible**
	Hydrodynamics	The 2% change in depth within the extraction area and uniform extraction are not expected to modify oceanographic currents.	**Negligible**
	Sediment transport	Sediment mobility can occur in the extraction area during extreme conditions, with negligible net sediment transport. The activity is not expected to influence sediment transport processes unless tracks create local anomalies through repetition.	**Moderate <u>if un-managed</u>** to the point that relatively deep tracks form. **Low <u>if managed</u>** to avoid repeat tracks.
	Morphology	The activity could lower the seabed by an average depth of 0.55 m within the extraction area over 35 years if the maximum volume is removed. This is not expected to change the overall bedform characteristics within the extraction area, or waves and hydrodynamics.	**Low** within the extraction area due to the extraction method to take small track depths that are managed over the extent of the extraction area.
Lower shoreface	Waves	No notable change to wave processes on the lower shoreface.	**Negligible**
	Hydrodynamics	No change to hydrodynamics is expected on the lower shoreface which is outside of the extraction footprint.	**Negligible**
	Sediment transport	Some connectivity between the seaward lower shoreface and the proposed extraction area could be influenced during extreme	**Low**

Zone	Element	Summary of effect	Effect level
		events, but this is infrequent and unlikely to be consequential.	
	Morphology	The lower shoreface is expected to be morphological stable over annual to decadal timescales and is not expected to be altered by the offshore extraction.	**Low**
Upper shoreface	Waves	Wave processes on the upper shoreface were assessed by MetOcean to potentially be altered by a few cm if the full extraction is achieved.	**Negligible**
	Hydrodynamics	No change to hydrodynamics is expected on the upper shoreface which is outside of the extraction footprint.	**Negligible**
	Sediment transport	Sediment transport processes on the upper shoreface are dominated by local extreme conditions and are disconnected from the activity by a 4.7 km distance.	**Negligible**
	Morphology	The upper shoreface is a morphologically active zone that is disconnected from the proposed extraction area. Offshore sand is not expected to have a detectable effect in this area.	**Negligible**
Beach	All elements	No detectable change in physical parameters.	**Negligible**

5.13.1 New Zealand Coastal Policy Statement

Taking these findings into account, we have considered the proposal in the context of Objective 1[14] of the New Zealand Coastal Policy Statement in terms of physical processes in the coastal environment. It is considered that the integrity, form, functioning and resilience of the coastal environment (including both the actual extraction site and the wider area) will not be adversely affected by changes to the coastal processes resulting from the sand extraction."

[14] Objective 1 – safeguard and sustain the coastal environment

To safeguard the integrity, form, functioning and resilience of the coastal environment and sustain its ecosystems, including marine and intertidal areas, estuaries, dunes and land, by:

- maintaining or enhancing natural biological and physical processes in the coastal environment and recognising their dynamic, complex and interdependent nature.
- protecting representative or significant natural ecosystems and sites of biological importance and maintaining the diversity of New Zealand's indigenous coastal flora and fauna.
- maintaining coastal water quality, and enhancing it where it has deteriorated from what would otherwise be its natural condition, with significant adverse effects on ecology and habitat, because of discharges associated with human activity.

6 Recommended conditions and monitoring

6.1 Bathymetric monitoring

The findings of this assessment are that the level of effect on the physical coastal environment outside the area of extraction is **low to negligible**. However, bathymetric survey monitoring is still recommended to confirm and validate the findings of this assessment and to identify any unexpected effects. Key elements for bathymetry monitoring include:

- Monitoring the cumulative change in seabed level and seabed volume inside the extraction area, with reference to extraction volumes and locations.
- Identification and management of dredge track anomalies, defined as a 2 m wide track that is 0.4 m deeper than surrounding seabed in that management cell.
- Bathymetric profiles and a 100 m monitoring buffer along the northern, southern and inner boundary of the extraction area to identify and manage unexpected effects of lowering seabed level on the shoreface outside of the extraction boundary.

6.1.1 Monitoring seabed level and volume

Repeat bathymetric surveys of the of the extraction area are recommended to monitor the change in seabed level and volume. Analysis of cut and fill volumes can be undertaken to understand the change over time. Calculation of difference in seabed level since the baseline survey can be used to understand if there is progressive lowering over time. Bathymetric survey cut and fill volumes can be compared to dredge volume records. In a closed system the surveyed cut volume should be close to the recorded extraction volume. Bathymetric surveys have an error of approximately ±0.15 m and the rate of seabed lowering across the full area is approximately -0.016 m/yr based on the extraction volume, with individual tracks of -0.1 m. Therefore, it may take up to 10 years before measurable change beyond the error margin is detected in bathymetric surveys.

6.1.2 Dredge track anomalies

MBL have a Sand Extraction Operation Plan based on using equipment that extracts to a maximum depth of 0.1 m on a single pass, limiting the maximum annual volume extracted within any one cell and no repetition of the same dredge line in any 12-month period. This is to avoid dredge track anomalies, defined as a single track with a width of 2 m and a depth exceeding 0.4 m below the surrounding seabed level. Such an anomaly may create seabed features at a scale larger than observed that may potentially locally interrupt coastal processes. Bathymetric monitoring across the extraction site should be collected and analysed to identify and manage dredge track anomalies. If an anomaly is identified during the monitoring, that cell will be closed.

6.1.3 Shoreface

If an adverse effect on coastal morphology were to occur as a result of the extraction, the first location where this would be realised is the lowering of the lower shoreface close to the proposed extraction area. Monitoring of the lower shoreface is recommended in the form of:

- Bathymetric monitoring of a 100 m buffer zone on the landward (west) and northern and southern sides of the extraction area, to identify and manage any unexpected drawdown of sand from the shoreface into the extraction area.
- Bathymetric profiles from the proposed extraction area to the shoreline (as close to shore as practical) are recommended to confirm the stability of the seabed landward of the proposed extraction area.

6.2 Data collection

Bathymetric surveying of the proposed extraction area and the 100 m buffer:

- Surveys are recommended to be undertaken annually for the first 6 years, then on a 3 yearly basis. Survey collection in April – May is preferred to be consistent with baseline monitoring in 2024.
- Use of consistent (or improved as technology evolves) method to baseline monitoring which utilised a Multibeam Echosounder (MBES) with vertical error of approximately ±0.15 m. If technology improves over the consent duration, alternative methods could be adopted if the overall error is consistent or lower.
- For shoreface monitoring it is also recommended that bathymetry monitoring is extended outside the extraction area in a 100 m wide buffer zone on the west, north and south sides.

Bathymetric surveying of the six across shore profiles:

- Surveys are recommended to be undertaken annually for the first 6 years, then on a 3 yearly basis. Survey collection in April – May is preferred to be consistent with baseline monitoring in 2024.
- Use of consistent equipment to baseline monitoring which utilised a Multibeam Echosounder (MBES) with vertical error of approximately ±0.15 m. If technology improves over the consent duration, alternative methods could be adopted if the overall accuracy is consistent or lower.

A plan showing recommended bathymetry monitoring profiles and areas is presented in Figure 6.1.

6.2.1 Analysis and reporting

This coastal process effects report was informed by a bathymetry survey of a pre extracted state in 2024, which can be used as a baseline for post extraction monitoring. We recommend that shoreface morphology monitoring reports are produced at the end of each year that a bathymetric survey is undertaken. Analysis would need to:

- Identify the presence of any track anomalies that exceed the 2 m wide and 0.4 m depth threshold.
- Produce bathymetric difference maps comparing the assessment year to the 2024 baseline, and to the previous survey, with consideration of vertical survey error of ±0.15 m being greater than one dredge track depth (-0.10 m).
- Cut and fill analysis of the pre and post extraction bed level to identify:
  - Where extraction has occurred.
  - Any natural infilling and recharge can be calculated by comparing the bathymetry cut volume to the extraction volume records.
  - Consideration of survey error when comparing cut volume to extraction volume.
- Analysis of bathymetric profiles to identify the presence of any lowering of the shoreface landward of the extraction site that is above the survey error margin of ±0.15 m.
- Interpretation of the causes of any unexpected volume loss that cannot be explained by extraction volume records and tracks, taking natural processes and storm events into consideration. Metocean conditions during each monitoring period should be characterised in each monitoring report, using the best available data.

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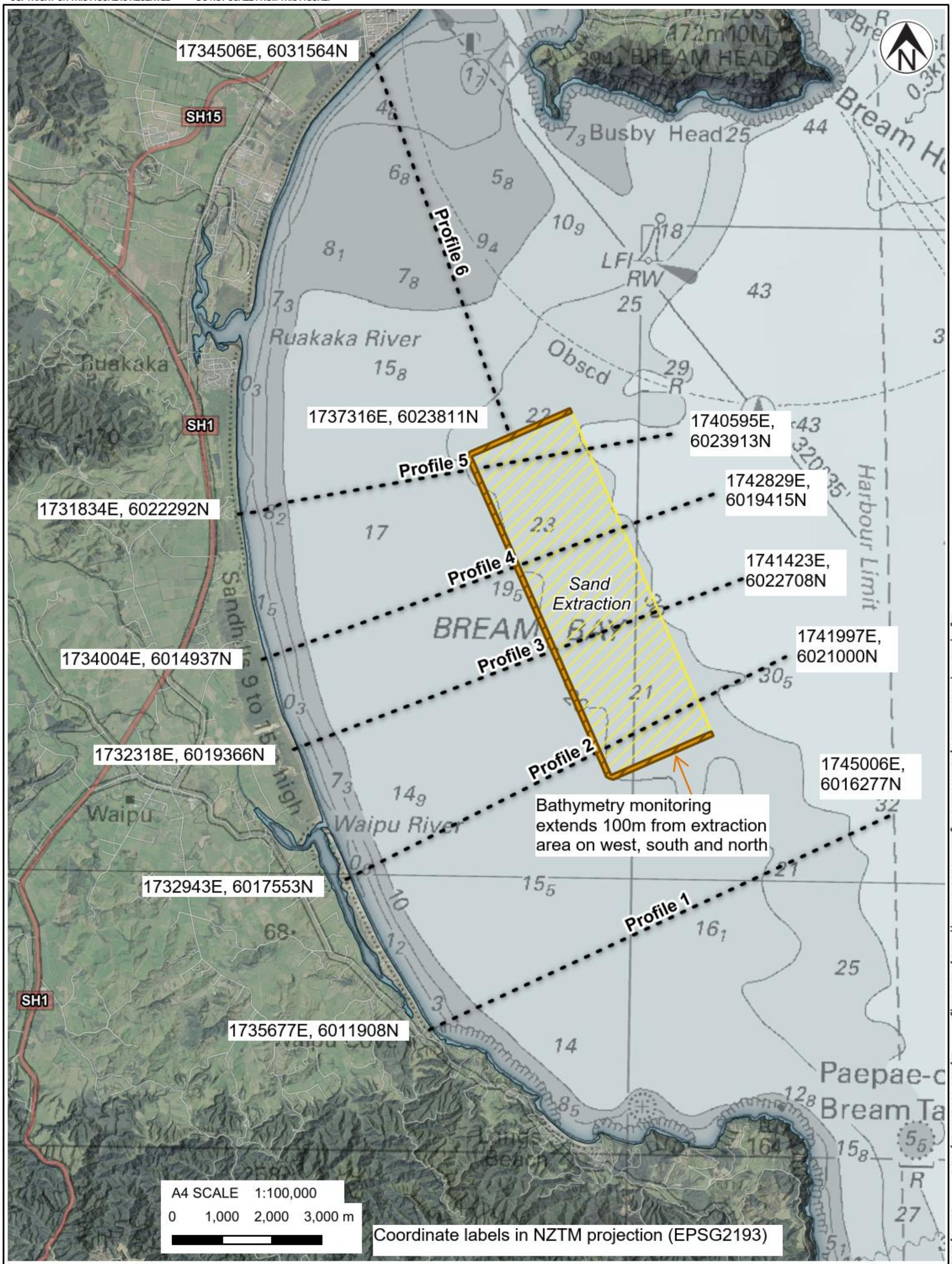

Tonkin+Taylor www.tonkintaylor.co.nz Exceptional thinking together	PROJECT No. 1093502			CLIENT McCallum Bros Ltd
	DESIGNED	EDBE	JUN.25	PROJECT Te Ākau Bream Bay Sand Extraction
	DRAWN	EDBE	JUN.25	TITLE Bathymetry Monitoring Profiles
	CHECKED			
	APPROVED	DATE		SCALE (A4) 1:100,000 FIG No. FIGURE 6.1 REV 0

Figure 6.1: Location of bathymetry monitoring area and profiles.

6.2.2 Conditions

Adaptive management is recommended if monitoring identifies that actual effects are occurring inside the extraction area or on the adjacent shoreface landward of the extraction area.

The following conditions are recommended:

a Identify the presence of track anomalies, defined as having a track width of approximately 2 m wide and a depth greater than 0.4 m below the surrounding seabed. If an anomaly is detected, stop extraction in that cell until recovery is detected in a subsequent survey.

b Identify lowering of the shoreface (or a change on convexity) landward of the extraction area as measured in the buffer zone or profiles. If lowering exceeds the survey error (±0.15 m) and cannot be explained by natural events, then extraction is limited to the seaward half of the consented area until the next annual survey is undertaken. If the lowering trend landward of the extraction zone continues after 1 year, then a review of the landward boundary is recommended.

c Identification of any immobile layers (e.g. rock) or historic facies (e.g. partly consolidated orange Pleistocene sand deposit). These are not expected based on the geotechnical assessment, but if identified by monitoring or in in operation, the cell should be closed to further extraction.

6.3 Beach monitoring

Beach monitoring is not recommended as a condition of consent. This is based on the activity occurring outside the depth of closure, where connectivity to the beach is negligible. However, we recognise the importance of coastal monitoring and the value of continuing existing beach survey monitoring transects on ideally a twice yearly basis (e.g. summer and winter) as this information is important for informing all coastal and marine activities in Te Ākau Bream Bay.

Beach profile monitoring has been undertaken at discrete profile sites by Northland Regional Council in the past, but the continuity of this program is uncertain. The evaluations carried out in this report show that MBL's proposed offshore sand extraction is not expected to influence the beach and dunes alongside Beam Bay. Therefore, specific monitoring of the beach is not considered necessary. We do not recommend consent conditions related to trends identified in the beach profile monitoring.

However, we recommend that existing beach profiles are surveyed regularly (at least annually, ideally twice annually). This could be in the form of MBL supporting Northland Regional Council to continue beach monitoring along Te Ākau Bream Bay and that this data is analysed and reported on as part of the Te Ākau Bream Bay sand extraction monitoring program.

7 Applicability

This report has been prepared for the exclusive use of our client McCallum Bros Ltd, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that our client will submit this report as part of an application under the Fast-track Approvals Act 2024 and that an Expert Panel as the consenting authority will use this report for the purpose of assessing that application. We understand and agree that this report will be used by the Expert Panel in undertaking its regulatory functions.

Compliance with the Environment Court Practice Note 2023

We confirm that, in our capacity as authors of this report, we have read and abided by the Environment Court of New Zealand's Code of Conduct for Expert Witnesses contained in the Practice Note 2023

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Richard Reinen-Hamill: I am a Technical Director: Coastal Engineering at Tonkin & Taylor Ltd (T+T). I specialise in coastal hazard risk assessments. I have worked at T+T since 1994. I have more than 35 years' experience in coastal engineering. I am a Member of Engineering New Zealand (Fellow). I hold the following qualifications – BE (hons), ME.

Tonkin & Taylor Ltd
Environmental and Engineering Consultants

Report prepared by: Authorised for Tonkin & Taylor Ltd by:

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Martine Rottink, Coastal Engineer; Rebekah Haughey, Coastal Scientist; Ben Batchelor-Cook, Coastal Engineer

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Appendix A Peer Review Letter

![Jacobs]

Challenging today.
Reinventing tomorrow.

17 December 2025

Attn: Luke Davis
Environmental Manager
McCallum Group

[redacted]

Project name: Bream Bay Sand Extraction
Project no: IZ111900

Subject: Review of Tonkin & Taylor's Te Ākau Bream Bay Sand Extraction: Coastal Processes Effects Assessment -V5- November 2025.

Dear Luke

As instructed, I have reviewed Versions 1, 3 and 5 of the Tonkin & Taylor *Coastal Processes Effects Assessment,* dated February, June and November 2025 respectively. I made a number of comments directly into Word documents of the two earlier versions reviewed, which supplied back to Tonkin & Taylor for action.

The purpose of this final review is to assess whether the changes in this later version 5 of the assessment report support my previous peer review suggestions on version 1 and version 3, and that the changes implemented in the report provide an accurate account of the methods and results of the analysis carried out in the assessment.

In general, my comments on the Version 1 report and Version 3 reports have all been satisfactorily addressed.

As a result, my review conclusions are:

1. I agree with the methods undertaken, and the finding of the assessment documented in the Version 5 report.
2. I agree with the conclusions in the Version 5 report on the scale of effects on coastal processes being negligible to low both within the proposed extraction area and within the wider Bream Bay.

Kind regards,

[redacted]

Derek Todd
Principal Coastal and Hazards Scientist

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