Appendix A Site summaries

Table of contents

1 Waihī Beach

1.1 Site description

Waihī Beach is an unconsolidated, northeast-facing shoreline, located 35 km northwest of Tauranga in the Bay of Plenty (Figure 1.1). The shoreline is 9 km long and is bound by Rapatiotio Point at the northern end and Bowentown Heads at the southern end. The northern end of the shoreline is moderately developed with Waihī Beach settlement and at the southern end is the Bowentown settlement. The beach at the northern end is gentle sloping with lower dune crest elevations. In contrast, the southern end of the beach is steep with higher dune crest elevations. There are three streams which discharge onto the coast: One Mile, Two Mile and Three Mile Creeks. Historically periods of erosion have encroached private property since the 1950s and there are currently two rock revetments fronting Shaw Road and The Loop which have a total length of approximately 1 km.

The site has been split into 13 cells based on variation in long term trends and dune heights and backshore morphology. An overview of the cell splits is provided in Figure 1.2. Several photos taken during the site visit are provided in Figure 1.2.

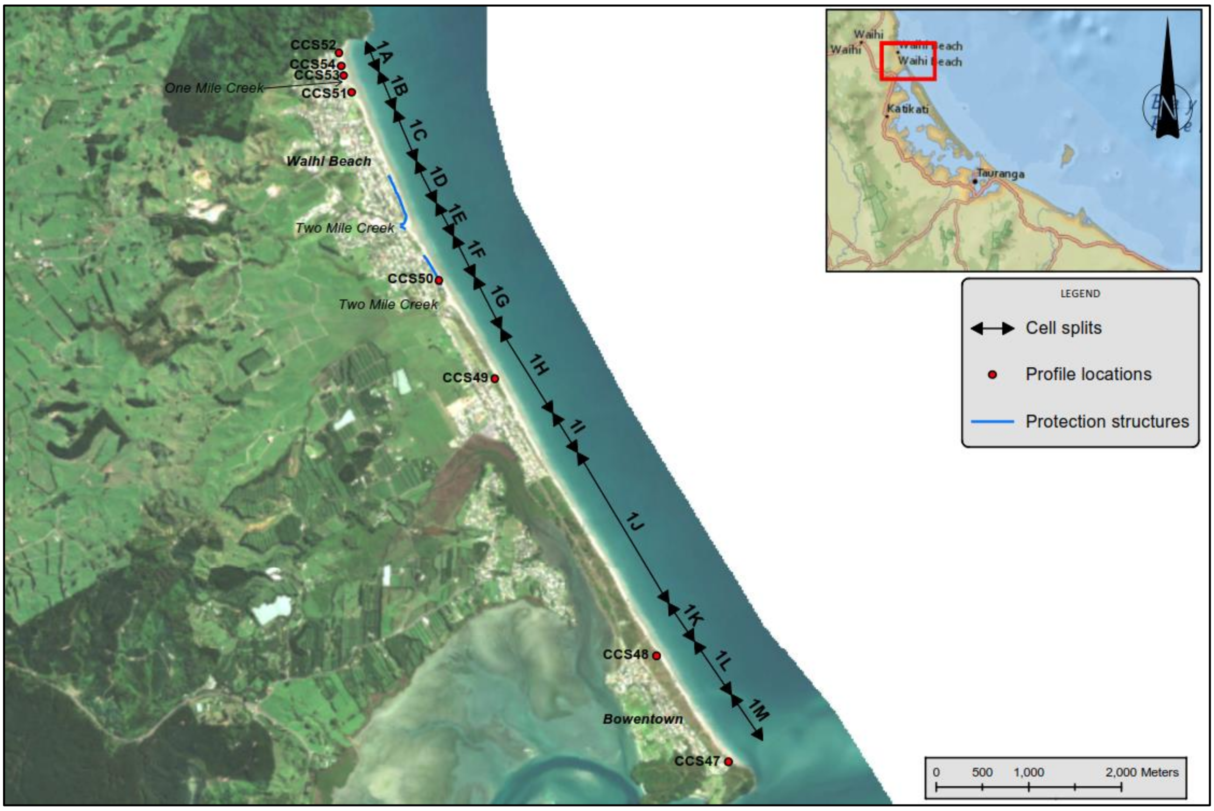


Figure 1.1: Site overview of Waihī Beach

Figure 1.2: Site photos along the Waihī Beach shoreline

1.2 Morphology

Waihī Beach is a straight barrier beach which has formed as a tombolo attached to Bowentown Head at the southern end. The shoreline comprises Holocene beach deposits with mean grain sizes ranging from medium to fine sand. There is a trend of increasing grain size towards the southern end where the shoreline is a higher energy environment with a steeper beach slope.

Dune heights range from 1 m at the northern end, up to 7 m towards the southern end. While the beach lacks parallel dune ridges, there is a set of higher paleo-frontal dunes approximately 50 to 100 m landward of the present-day dunes. Towards the centre and southern end, the paleo-frontal dunes are transected by older parabolic, transgressive dunes (Harray & Healy, 1978).

The beach is classified as a closed sedimentary system, receiving little sediment from littoral drift or rivers and subsequently the main source of sediment is from offshore exchange. The streams which discharge onto the coast provide minimal sediment however they can have localised impacts on the shoreline position.

Recently available information from the NZ SeaRise programme indicates that the Waihī Beach shoreline is relatively stable with very slight uplift at the northern end and slight subsidence at the southern end.

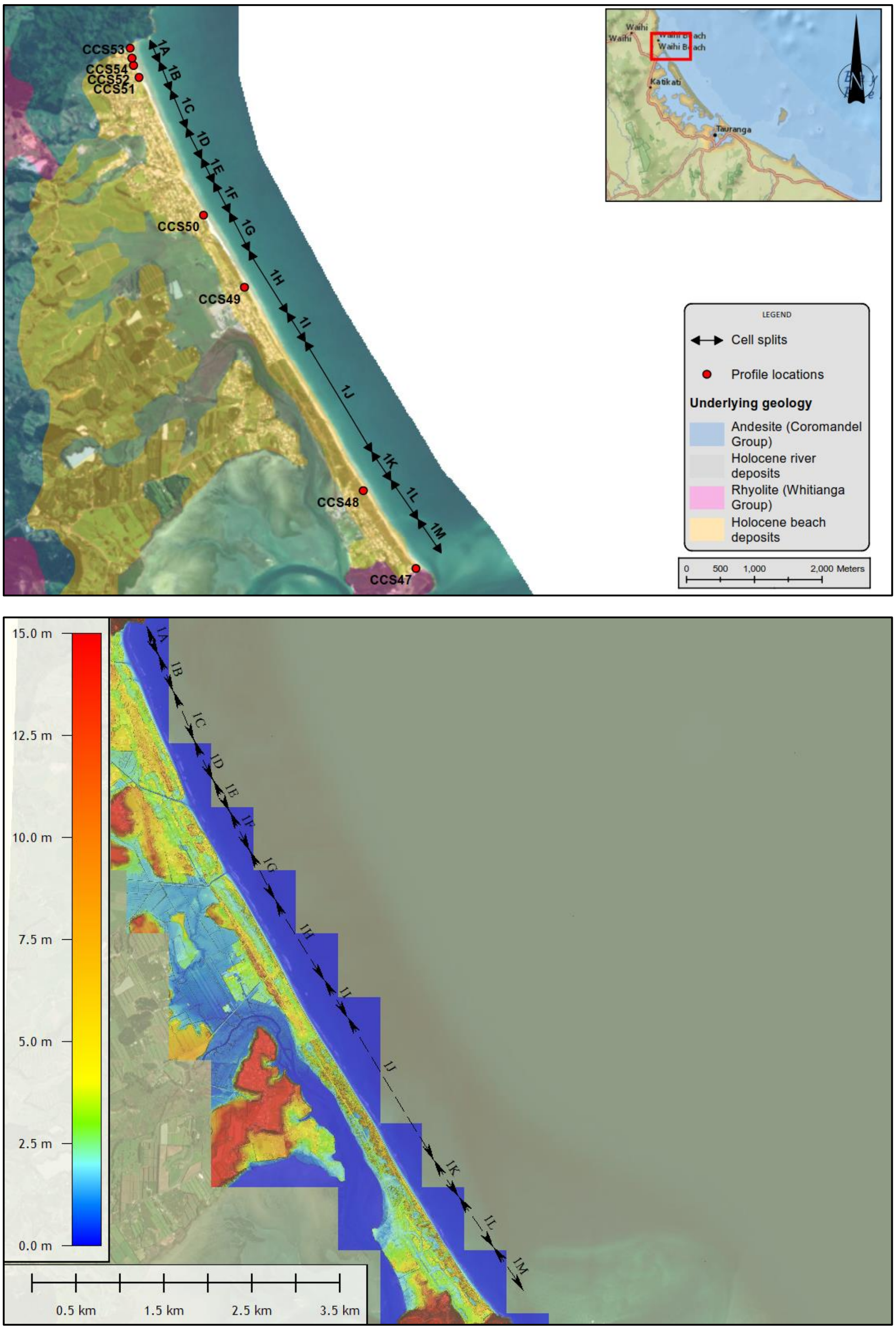


Figure 1.3: (Top) Underlying geology along the Waihī Beach shoreline. (Bottom) 2018 DEM data for Waihī Beach

1.3 Coastal processes

The Waihī Beach shoreline faces northeast and is exposed to waves from north to east. The shoreline experiences mild to moderate swell-wave energy with a moderate tidal range. Based on NIWA (2018) the 200-year ARI storm tide level is 1.53 m MVD-53 and the 200-year ARI offshore significant wave height is 5.48 m. Littoral drift is south-east towards Bowentown, where sediment tends to move along the offshore bar onto the Bowentown ebb tidal delta (Harray & Healy, 1978).

Mayor Island is approximately 36 km offshore and is understood to have some influence on the nearshore hydrodynamics as it creates a focal point for deepwater waves approaching the shelf (Bear et al., 2009).

1.3.1 Short-term

Figure 1.4 and Figure 1.5 shows an example of short-term storm cut of the dunes near profile CCS49, following the recent storm events in May-June 2021. Between January 2021 and June 2021 there was approximately 5 m erosion measured at the 2.5 m RL contour (Figure 1.5).

The short-term storm cut along Waihī Beach has been assessed based on the statistical analysis of beach profile data (see main report Section 5.4.1). All profile plots are shown in Appendix B. The minimum, mode and maximum bound values are based on the 5 year, 50 year and 200 year ARI storm cut distances. Figure 1.6 provides an example of the extreme value curve at profile CCS51.

Storm cut tends to increase from north to south along Waihī Beach with the largest storm cut occurring in cells 1J to 1M. Adopted storm cut is also in line with Eco Nomos Ltd (2003) who found maximum storm cut of 30 m for Waihī Beach.

Figure 1.4: Site photos taken near profile CCS49, Cell 1H. (Top) 12th February 2021 prior to the 2021 storm events (source T+T). (Bottom) 27th May 2021 following the first storm event (source BOPRC)

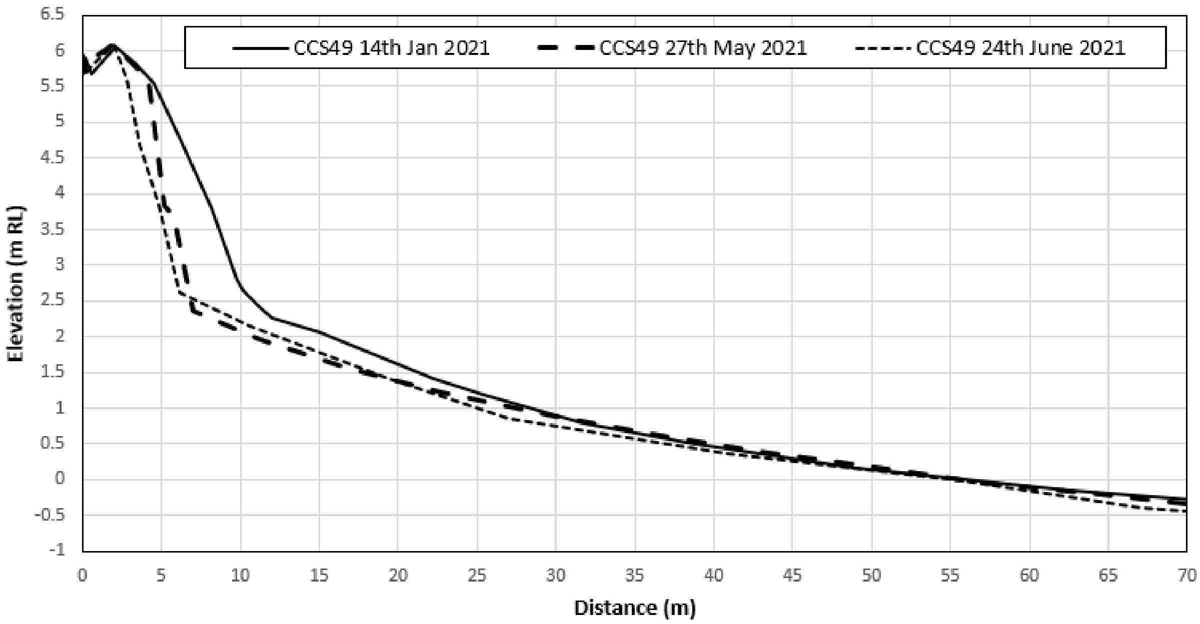


Figure 1.5: Pre and post storm profiles at CCS49 in 2021. The initial storm event occurred on 23rd May 2021, followed by another storm event on 8th June 2021

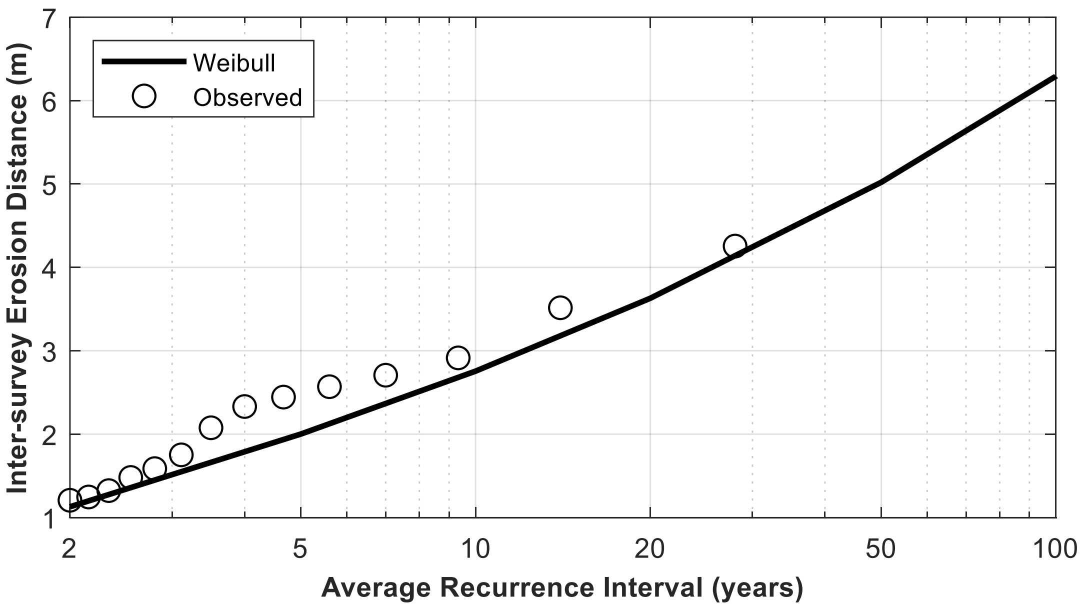


Figure 1.6: Example of extreme value curve for profile CCS51

Table 1.1: Adopted short-term storm cut values (m) for Waihī Beach

Cell	Min	Mode	Max
1A to 1C	3	7	13
1D to 1I	3	8	18
1J to 1K	5	15	25
1L to 1M	5	20	35

1.3.2 Long-term trends

Long-term trends along Waihī Beach have been based on regression analysis of historic shoreline data and beach profiles (Figure 1.7 and Figure 1.10) (see main report Section 5.6).

The profile and shoreline data shows the erosion rates tend to increase from north to south along the beach. Profile CCS50 is in front of the revetment and hence the long-term trend is near zero (Figure 1.7). Beach profiles north of the revetment tend to show accretional trends (CCS52, CCS54, CCS53, CCS51), whereas the profiles south of the revetment tend to show long term erosion (CCS47, CCS48, CCS49) (Figure 1.7).

Regression rates measured from the beach profile data are generally consistent with the regression rates measured in the historic shorelines (Figure 1.10). The accretion rates measured at profiles CCS53, CCS54 and CCS52 are higher than the regression trends measured in the shoreline data however this is due to the shorter dataset in the beach profiles. The large fluctuations apparent in Cells 1E and 1G are due to the stream mouths within these cells, which have shifted over time.

Between 1942 and 1960 the shoreline data shows that most of the beach experienced significant erosion. This erosion was particularly evident in the 1950s when a series of severe storms threatened beachfront properties. The present-day position at the northern end (cell 1A and 1B) is seaward of the 1942 shoreline, implying an overall accretion trend. Profile data at the northern end indicates that most of this accretion occurred between 1996 and 2020 which is likely to be linked with the dune planting that has occurred. Figure 1.8 shows the northern end of Waihī Beach in 1962 with minimal dune system. This area has since been planted and the low dunes now extend approximately 30 m seaward (Figure 1.9).

For the rest of Waihī Beach, the 2019 shoreline is landward of the 1942 shoreline position, indicating an overall erosion trend. Due to the presence of erosion protection structures within cells 1D and 1F the shoreline data shows relative stability; however, it is likely that in absence of the structures the shoreline within these cells would retreat at a similar rate to the adjacent shoreline. Despite the net south-easterly littoral drift the southern end of the beach shows the largest long term erosion rates, up to -0.5 m/yr within cell 1M. The high erosion rates at this end of the beach are consistent with what was previously assessed by T+T (2015).

Interestingly, Harray & Healy (1978) described erosion being the greatest at the northern end, where at the time there was no dune system. Figure 1.11 shows that in 1978 the shoreline at the southern end (cell 1J and 1M) was relatively stable with a slight erosion trend, however since 1978 significant erosion has occurred.

The shoreline regression analysis shows high accretion rates near the Two-Mile and Three-Mile Creeks (Cells 1E and 1G). The creeks were established in the 1930's to drain the backshore area, however it is understood this resulted in lowering of beach levels and erosion of the adjacent dune system. In the early 1960's training groynes were constructed at Two-Mile Creek to prevent migration of the mouth, and these were upgraded to the existing groynes in 2009.

Figure 1.12 shows significant erosion of the shoreline on the southern side of Two-Mile Creek in 1943. However, since the training works have been introduced over the years the shoreline has been recovering and hence the significant accretion rates between 1943 and 1992. Over recent years the accretion has slowed as the shoreline reaches equilibrium with the adjacent coast. It is likely that under the existing groyne configurations at Two-Mile and Three-Mile Creeks the shoreline within Cells 1E and 1G will show similar trends with the adjacent cells.

Overall, there is a deficit in the sediment supply to the Waihī Beach and subsequently there has been a trend of long-term erosion for most of the shoreline since the 1940s.

Adopted long-term trends are based on the variation in the mean regression rate measured within each cell. For cells 1D and 1F where the revetment has influenced the measured rates, the rates from the adjacent unprotected cells have been adopted. For cells 1E and 1G where the stream mouths have influenced historic trends, the adopted rates have been based on the adjacent cells. Adopted long-term rates for each cell are provided in Table 1.4.

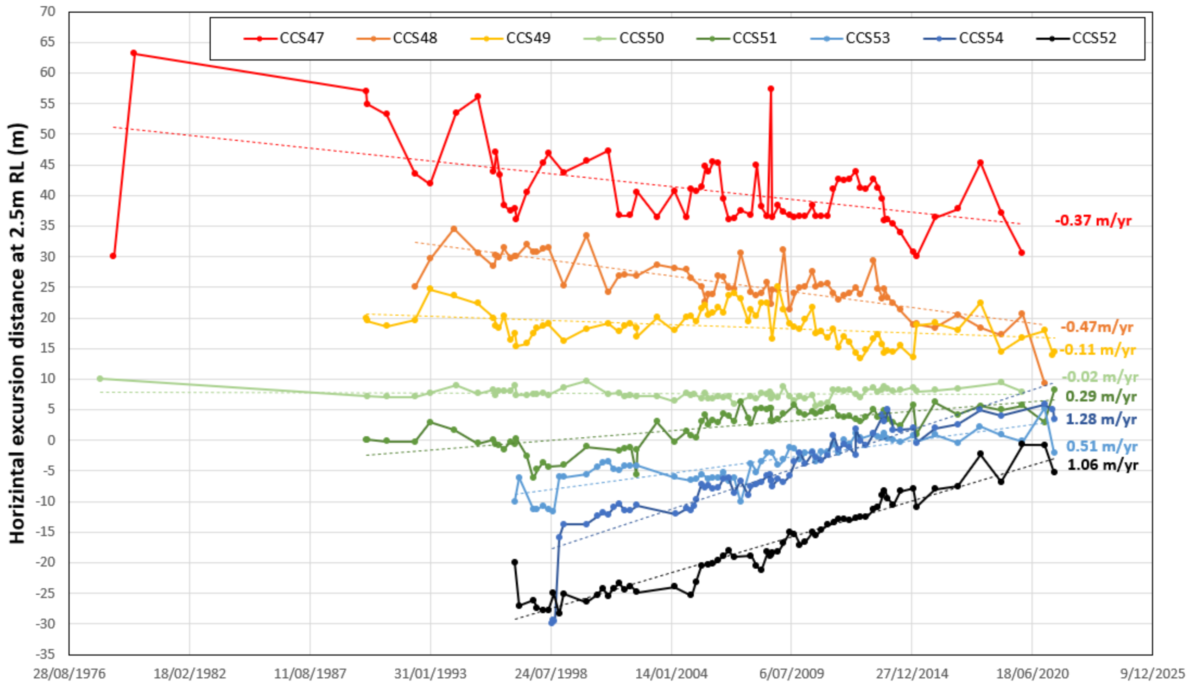


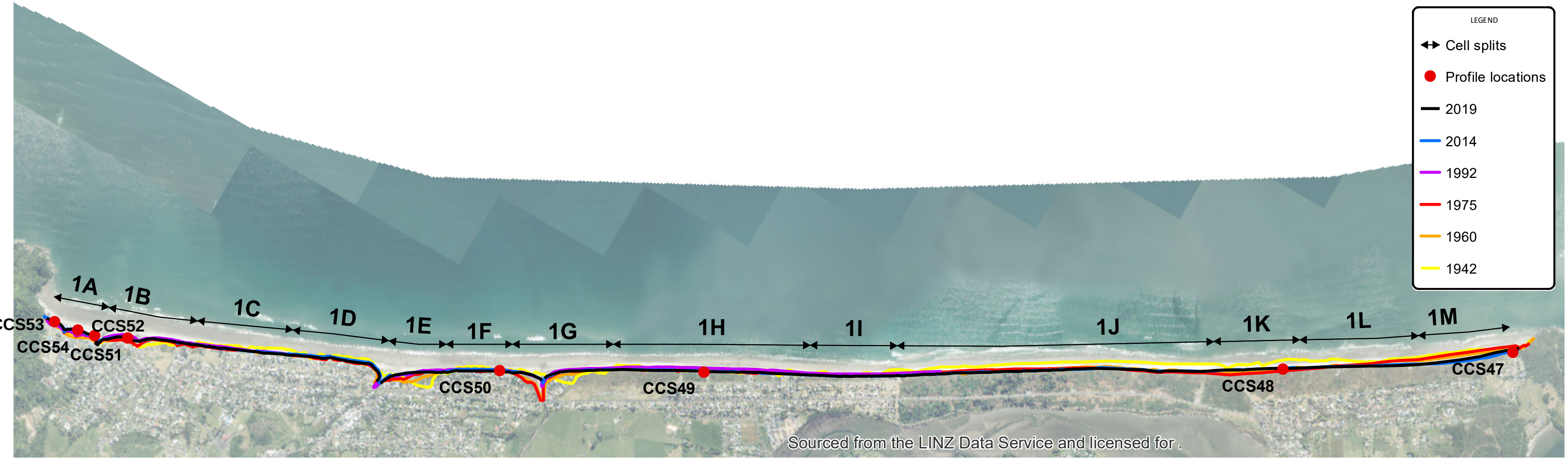
Figure 1.7: Horizontal excursion distances at the 2.5m RL (MVD-53) contour for beach profiles along Waihī Beach

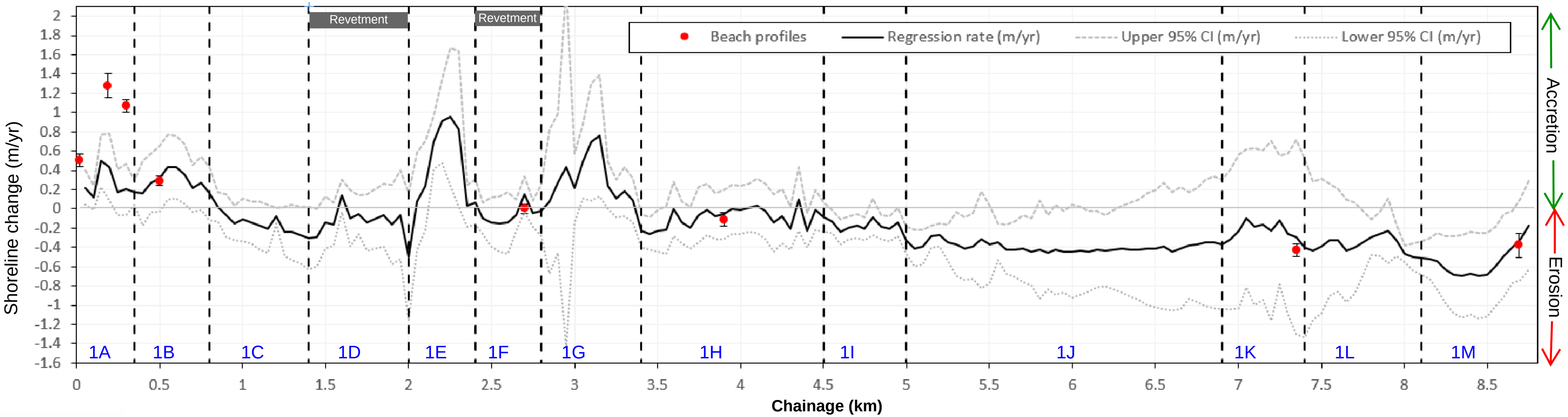
Figure 1.8: Historic photograph of Waihī Beach in 1962 (sourced from Western Bay of Plenty District Council Community Archives)

North end of Waihi Beach in 1996 - before Coast Care planting

North end of Waihi Beach in 2005 - after Coast Care planting

Figure 1.9: Dune planting at the northern end of Waihī Beach (sourced from Coastal State of the Environment Report 2014, Bay of Plenty Regional Council)





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Western Bay of Plenty Coastal Erosion
Waihi Beach
Long term trend analysis

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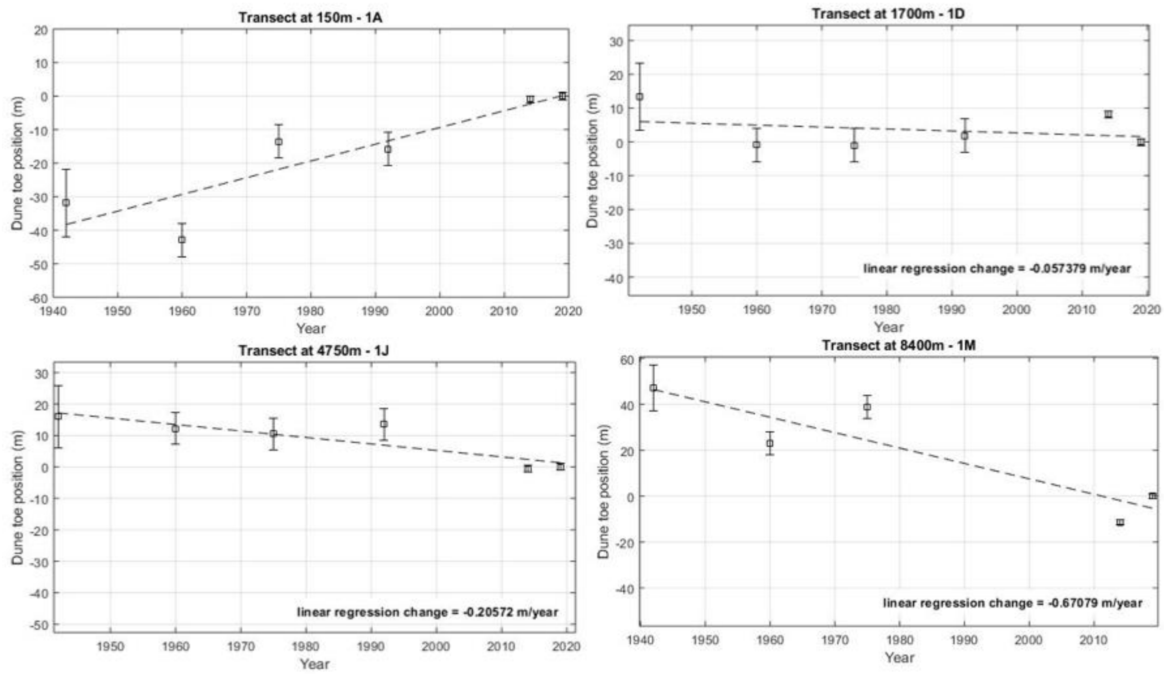


Figure 1.11: Example of regression plots from historic shoreline analysis. (Top left) Cell 1A, (top right) Cell 1D, (bottom left) Cell 1J, (bottom right) Cell 1M

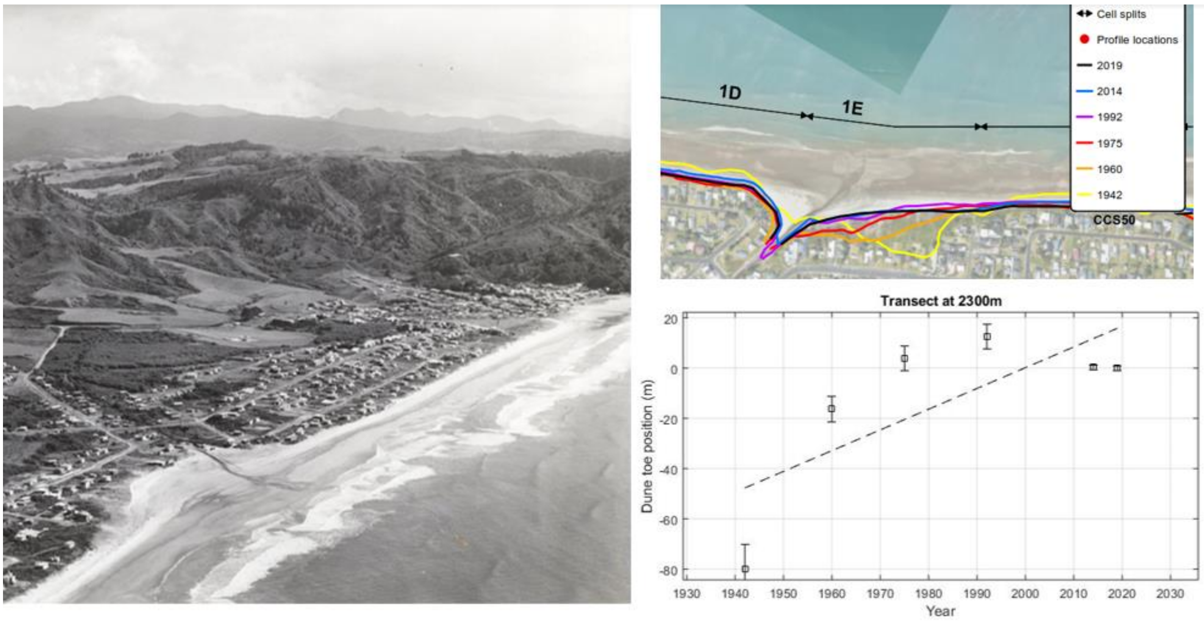


Figure 1.12: (Left) Historic photograph sourced from Waihīmuseum.co.nz showing the historic shoreline position near Two Mile Creek. (Top right) Historic shorelines around Two Mile Creek. (Bottom right) Regression analysis of shoreline positions near Two Mile Creek showing high accretion from 1942 to 1992 followed by some erosion and stability in recent years

Table 1.2: Adopted long term rates for cells along Waihī Beach (m/yr)

Cell	Min	Mode	Max
1A	0.4	0.3	0.05
1B	0.4	0.3	0
1C	0	-0.15	-0.25
1D	0	-0.1	-0.15
1E	0	-0.1	-0.15
1F	0	-0.1	-0.2
1G	-0.05	-0.1	-0.2
1H	-0.05	-0.1	-0.2
1I	-0.1	-0.15	-0.25
1J	-0.25	-0.35	-0.4
1K	-0.2	-0.25	-0.3
1L	-0.2	-0.35	-0.4
1M	-0.35	-0.4	-0.5

Since completion of the long-term shoreline analysis, additional aerial imagery was captured in 2021 following the May/June storm events. The 2021 shoreline has been adopted as the baseline; however, it has not been included in the long-term analysis. A sensitivity analysis was completed to check if the inclusion of the 2021 shoreline would influence the long-term rates. Due to the short timeframe between 2019 and 2021, the addition of the 2021 shoreline position had minimal impact on the long-term rates and therefore since the long-term analysis had already been completed, the 2021 shoreline was excluded.

1.3.3 Response to sea level rise

The shoreline response to sea level rise (SLR) along Waihī Beach has been assessed using the Bruun Response model described in Section 5.7.2 of the main report. Due to slightly differing offshore significant wave heights, estimated inner closure depth ranges from 9 m at the northern end, to 10 m at the southern end.

Response to SLR is expected to vary along the shoreline due to the differing dune heights and closure depths (Table 1.3).

Table 1.3: Contour levels used to assess the effects of SLR on extents of active profiles along the Waihī Beach shoreline

Parameter bounds	Contour levels (m RL)	Cell 1A (CCS52)	Cell 1B-1C (CCS51)	Cell 1D-1H (CCS49)	Cell 1I-1K (CCS48)	Cell 1L-1M (CCS47)
Lower bound slope	Average dune toe	2.5	2.5	2.5	2.5	2.5
	Average low water mark	-0.5	-0.5	-0.5	-0.5	-0.5
Modal slope	Average dune crest	4	5	6	5.5	7
	Zero flux depth	-4	-4	-5	-8	-6.5
Upper bound slope	Average dune crest	4	5	6	5.5	7
	Inner Hallermeier closure depth	-9.1	-9.1	-9.1	-10	-10

1.4 Local considerations

Local considerations that may influence the erosion hazard along Waihī Beach include the rock revetments within cell 1D and 1F, groynes at Three Mile Creek outlet, the various stream mouths, and the dune planting within cells 1A, 1B and 1C (Figure 1.13).

In the 1930s Two Mile and Three Mile Creeks were formed to address the stormwater drainage issues in the backshore area of Waihī Beach. In the 1950s a series of severe storm events threaten beachfront properties, and this led to the construction of various ad hoc protection structures along the shoreline between the 1960s and 1980s. In 2009 two training groynes were constructed at Three Mile Creek and between 2010 and 2011 the existing rock revetments fronting The Loop and Shaw Road were constructed.

Figure 1.13: Example of protection structures and dune planting along Waihī Beach. (Top) dune planting in cell 1A. (Bottom left) Groynes at Three Mile Creek outlet. (Bottom right) rock revetment in cell 1D

1.5 Adopted component values

Adopted component values for Waihī Beach are presented in Table 1.4.

Table 1.4: Adopted component values for coastal cells along Waihī Beach

Cell		1A	1B	1C	1D	1E	1F	1G	1H	1I	1J	1K	1L	1M
Cell centre (NZTM)	E	1860119	1860288	1860486	1860730	1860865	1861127	1861426	1861854	1862201	1862857	1863431	1863757	1864135
	N	5857075	5856668	5856176	5855681	5855268	5854831	5854310	5853551	5852892	5851844	5850857	5850323	5849757
Chainage, m (from NW)		0 to 350	350 to 800	800 to 1440	1440 to 1940	1940 to 2363	2363 to 2880	2880 to 3520	3520 to 4600	4600 to 5070	5070 to 6910	6910 to 7440	7440 to 8130	8130 to 8720
Morphology		Beach	Beach	Beach	Beach	Beach/ stream mouth	Beach	Beach/ stream mouth	Beach	Beach	Beach	Beach	Beach	Beach
Short-term (m)	Min	3	3	3	3	3	3	3	3	3	5	5	5	5
	Mode	7	7	7	8	8	8	8	8	8	15	15	20	20
	Max	13	13	13	18	18	18	18	18	18	25	25	35	35
Dune height (m above dune toe)	Min	0.8	1	1.5	2	2	3	2.2	3	2.5	3	3	4	3.5
	Mode	1	1.5	1.8	2.5	2.5	3.5	2.5	3.5	3	6	3.5	5	4
	Max	1.3	2	2	3.5	3	4	3.5	4	3.8	7	4	6.5	4.5
Stable slope (°)	Min	30	30	30	30	30	30	30	30	30	30	30	30	30
	Mode	32	32	32	32	32	32	32	32	32	32	32	32	32
	Max	34	34	34	34	34	34	34	34	34	34	34	34	34
Long-term (m/yr) -ve erosion +ve accretion	Min	0.4	0.4	0	0	0	0	-0.05	-0.05	-0.1	-0.25	-0.2	-0.2	-0.23
	Mode	0.3	0.3	-0.15	-0.1	-0.1	-0.1	-0.1	-0.1	-0.15	-0.35	-0.25	-0.35	-0.4
	Max	0.05	0	-0.25	-0.15	-0.15	-0.2	-0.2	-0.2	-0.25	-0.4	-0.3	-0.4	-0.5
Closure slope	Min	0.019	0.019	0.019	0.026	0.026	0.026	0.026	0.026	0.027	0.027	0.027	0.029	0.029
	Mode	0.018	0.018	0.018	0.018	0.022	0.022	0.022	0.020	0.020	0.020	0.016	0.016	0.012
	Max	0.009	0.009	0.009	0.012	0.012	0.012	0.012	0.012	0.011	0.011	0.011	0.009	0.009
Average VLM rate (m/yr)[1]		0	0	0	0	0	0	0	0	0	0	0	0	0

1 See main report Section 5.8

1.6 Coastal erosion hazard assessment

Coastal erosion hazard distances for Waihī Beach are presented in Table 1.5. Erosion hazard distances have been offset from the 2021 seaward edge of vegetation. $P_{50\%}$ means there is a 50% chance of an erosion distance being exceeded within that timeframe. $P_{66\%}$ can be considered a likely scenario and $P_{5\%}$ can be considered a very unlikely scenario. VLM is minimal along the Waihī Beach shoreline, with negligible impact on the erosion hazard. Therefore, unlike Maketu and Pukehina sites, an additional VLM scenario has not been included for this site.

The current CEHA is dominated by the short-term storm erosion and ranges from -6 m ($P_{66\%}$) at the northern end of beach, to -21 m ($P_{66\%}$) at the southern end where dune heights are larger and observed storm cut potential is greater. Erosion processes at the southern end of the beach are likely to be sensitive to changes in wave energy associated with the dynamics of the adjacent ebb tidal delta.

Long-term trends are a key factor influencing the variation in future CEHA along Waihī Beach. The historic long-term erosion rates have typically been larger at the southern end of the shoreline.

The impact of SLR is generally similar along the Waihī Beach shoreline, with slightly larger shoreline recession at the northern end where dune heights are lowest, and at the southern end where offshore wave heights are slightly larger. Under low SLR in 2080 (i.e. 0.4 m), the $P_{66\%}$ CEHA ranges from -16 to -70 m and under high SLR in 2130 (i.e. 1.6 m) the $P_{66\%}$ CEHA ranges from -77 to -156 m along the shoreline (Table 1.5).

Seawalls are present in cells 1D and 1F, however these structures have not been accounted for within the assessment. The CEHA represents the hazard in absence of the structures, and therefore, while these structures remain functional, the CEHA within these cells is likely to be an overprediction.

Table 1.5: Coastal erosion hazard widths (m) for Waihī Beach for current, 2080 and 2130 timeframes (shaded cells are mapped scenarios)

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Probability of Exceedance				
				Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
1A	Current	0.03	0	-4	-8	-8	-12	-14
	2080	0.4	RCP4.5	-4	-17	-20	-32	-46
		0.6	RCP8.5	-14	-29	-33	-49	-67
	2130	0.8	RCP4.5	-7	-28	-33	-57	-86
		1.25	RCP8.5	-31	-56	-62	-96	-135
		1.6	RCP8.5+	-50	-78	-84	-127	-173
1B	Current	0.03	N/A	-4	-8	-9	-12	-14
	2080	0.4	RCP4.5	-4	-18	-21	-34	-48
		0.6	RCP8.5	-14	-30	-34	-51	-69
	2130	0.8	RCP4.5	-7	-30	-35	-61	-87
		1.25	RCP8.5	-32	-58	-65	-99	-137
		1.6	RCP8.5+	-51	-80	-87	-129	-175
1C	Current	0.03	N/A	-4	-8	-9	-13	-14
	2080	0.4	RCP4.5	-29	-41	-43	-54	-67

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Probability of Exceedance				
				Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
		0.6	RCP8.5	-40	-53	-56	-72	-88
	2130	0.8	RCP4.5	-52	-72	-76	-97	-119
		1.25	RCP8.5	-76	-99	-104	-137	-168
		1.6	RCP8.5+	-95	-120	-126	-168	-206
1D	Current	0.03	N/A	-5	-10	-12	-17	-20
	2080	0.4	RCP4.5	-23	-36	-38	-48	-58
		0.6	RCP8.5	-31	-47	-49	-61	-73
	2130	0.8	RCP4.5	-41	-61	-64	-80	-96
		1.25	RCP8.5	-59	-84	-89	-111	-131
		1.6	RCP8.5+	-73	-102	-108	-135	-160
1E	Current	0.03	N/A	-5	-10	-11	-17	-20
	2080	0.4	RCP4.5	-23	-35	-37	-46	-56
		0.6	RCP8.5	-31	-44	-47	-59	-72
	2130	0.8	RCP4.5	-39	-58	-61	-77	-95
		1.25	RCP8.5	-57	-79	-83	-107	-131
		1.6	RCP8.5+	-70	-95	-100	-131	-160
1F	Current	0.03	N/A	-6	-11	-12	-18	-21
	2080	0.4	RCP4.5	-25	-36	-39	-48	-59
		0.6	RCP8.5	-33	-46	-49	-61	-76
	2130	0.8	RCP4.5	-42	-60	-64	-80	-102
		1.25	RCP8.5	-60	-82	-86	-110	-137
		1.6	RCP8.5+	-73	-98	-103	-134	-165
1G	Current	0.03	N/A	-5	-10	-12	-17	-20
	2080	0.4	RCP4.5	-26	-37	-39	-48	-61
		0.6	RCP8.5	-34	-47	-49	-61	-77
	2130	0.8	RCP4.5	-45	-62	-65	-81	-98
		1.25	RCP8.5	-62	-83	-87	-111	-135
		1.6	RCP8.5+	-76	-99	-104	-134	-164
1H	Current	0.03	N/A	-6	-11	-12	-18	-21
	2080	0.4	RCP4.5	-27	-38	-40	-50	-61
		0.6	RCP8.5	-35	-48	-51	-63	-77
	2130	0.8	RCP4.5	-47	-64	-67	-82	-103
		1.25	RCP8.5	-65	-86	-90	-113	-138
		1.6	RCP8.5+	-79	-103	-108	-137	-165
1I	Current	0.03	N/A	-5	-11	-12	-18	-21
	2080	0.4	RCP4.5	-29	-41	-43	-53	-66
		0.6	RCP8.5	-37	-51	-53	-67	-83
	2130	0.8	RCP4.5	-50	-69	-72	-90	-113

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Probability of Exceedance				
				Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
		1.25	RCP8.5	-67	-90	-95	-123	-153
		1.6	RCP8.5+	-81	-107	-113	-148	-183
1J	Current	0.03	N/A	-8	-17	-19	-26	-30
	2080	0.4	RCP4.5	-42	-58	-60	-71	-84
		0.6	RCP8.5	-50	-68	-71	-85	-100
	2130	0.8	RCP4.5	-71	-94	-98	-116	-136
		1.25	RCP8.5	-89	-116	-120	-148	-174
		1.6	RCP8.5+	-103	-133	-138	-173	-205
1K	Current	0.03	N/A	-8	-16	-18	-25	-28
	2080	0.4	RCP4.5	-38	-53	-55	-66	-77
		0.6	RCP8.5	-46	-63	-67	-81	-93
	2130	0.8	RCP4.5	-64	-86	-91	-108	-127
		1.25	RCP8.5	-81	-110	-116	-143	-168
		1.6	RCP8.5+	-94	-128	-136	-169	-199
1L	Current	0.03	N/A	-9	-21	-24	-34	-39
	2080	0.4	RCP4.5	-41	-63	-66	-81	-98
		0.6	RCP8.5	-48	-73	-78	-97	-119
	2130	0.8	RCP4.5	-69	-99	-105	-131	-161
		1.25	RCP8.5	-84	-122	-130	-169	-208
		1.6	RCP8.5+	-97	-140	-150	-199	-245
1M	Current	0.03	N/A	-8	-21	-23	-33	-38
	2080	0.4	RCP4.5	-46	-70	-74	-90	-106
		0.6	RCP8.5	-54	-81	-86	-107	-126
	2130	0.8	RCP4.5	-80	-113	-119	-146	-169
		1.25	RCP8.5	-96	-137	-147	-187	-217
		1.6	RCP8.5+	-109	-156	-169	-219	-256

2 Matakana Island

2.1 Site description

Matakana Island is a northeast-facing shoreline is approximately 24 km long and comprises unconsolidated beach sand (Figure 2.1). The northern and southern ends of the island are bound by the two deep tidal inlets, the Katikati Entrance to the north and the Tauranga Entrance to the south. The locations of the tidal inlets are largely influenced by the isolated outcrops of volcanic rock at Bowentown Heads and Mount Maunganui. Karewa Island is a small island approximately 6 km offshore from the centre of Matakana shoreline. The land on the open coast side of the Island is predominantly covered by pine forest and in many places the foredune has been altered by trees falling onto the upper beach.

The site has been split into 8 cells based on the long-term trends and morphology. An overview of the cell splits is provided in Figure 2.1.

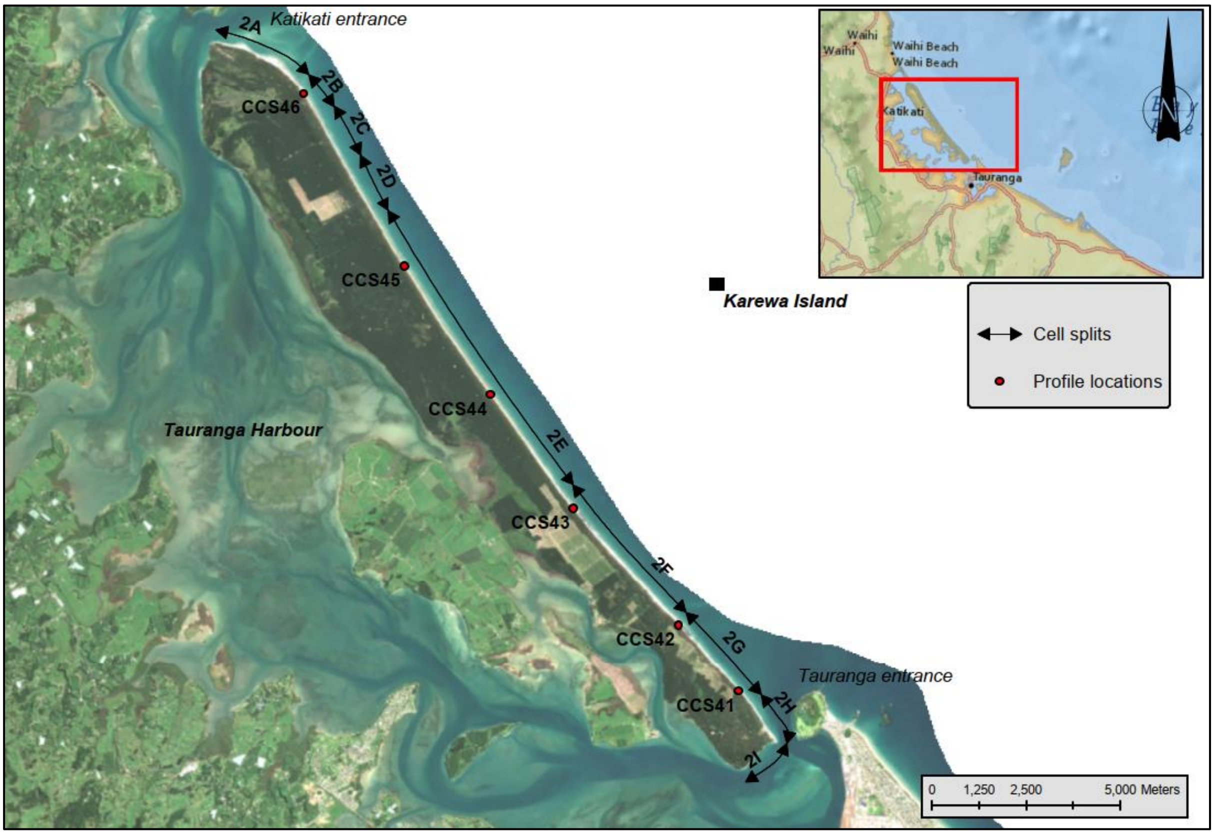


Figure 2.1: Site overview of Matakana Island

2.2 Morphology

Matakana Island is a large Holocene sand barrier that formed approximately 6000 years BP (Figure 2.2). It is understood that the barrier initially formed in at least two separate parts, separated by a tidal inlet at the present-day Blue Gum Bay (Betts, 1996). The tidal inlet eventually closed, and the barrier developed by south-easterly drift and spit extension, with accretion of successive foredune ridges along the ocean shoreline.

The north-western end is lower and contains wetlands with many ridges which reflect past changes in the harbour entrance (Figure 2.2). The southeast end is also lower than most of the barrier and is characterised by hummocky dunes and broad shoreline ridges. Beach sediment is primarily moderately well sorted medium to fine sand.

The barrier underwent considerable change following the first arrival of humans on Matakana Island sometime after the Kaharoa eruption which included widespread vegetation clearance and soil disturbance, resulting in dune instability.

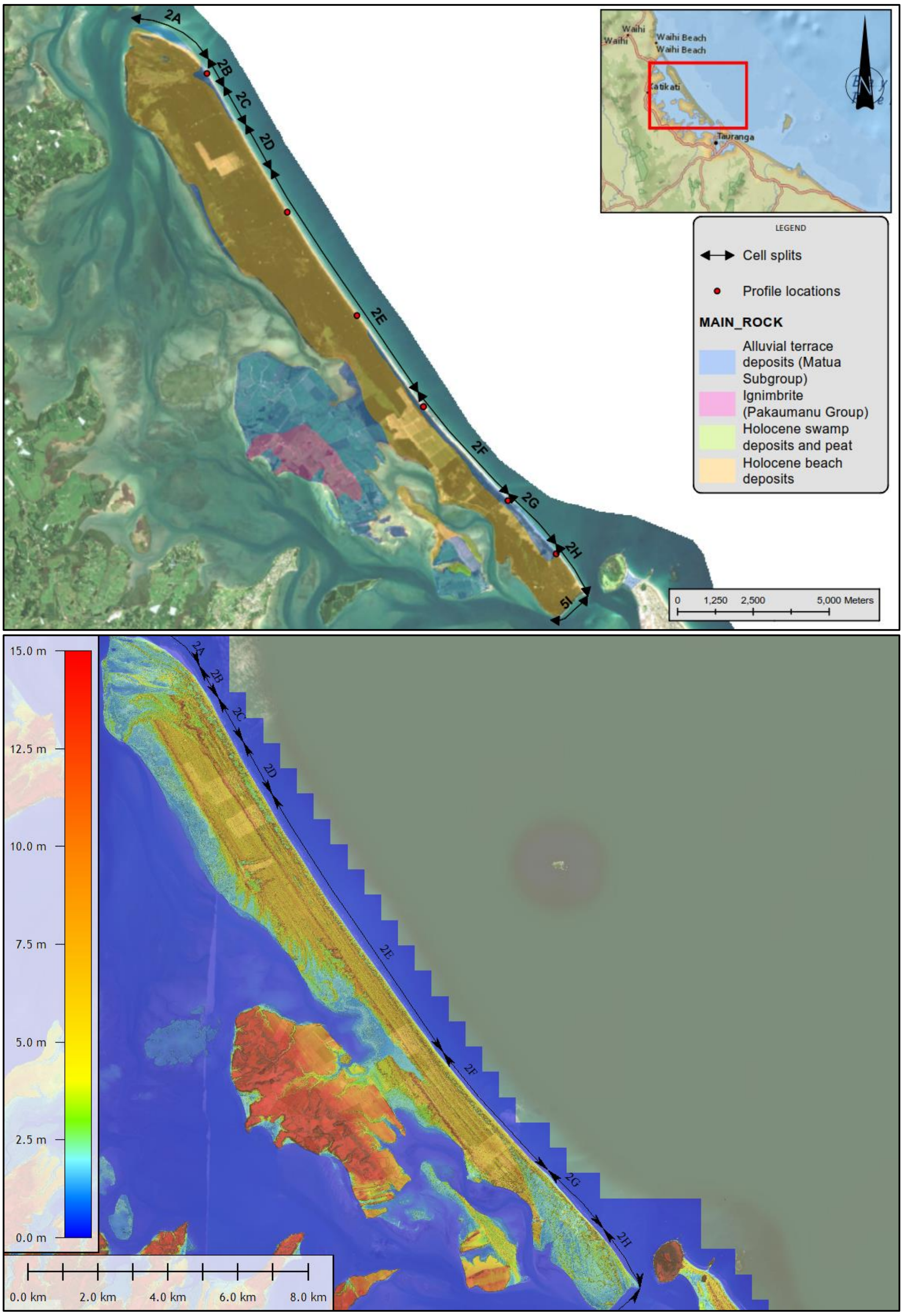


Figure 2.2: (Top) Underlying geology along Matakana Island. (Bottom) 2015 DEM data for Matakana Island

2.3 Coastal processes

The Matakana Island shoreline faces northeast and is exposed to waves from north to east. The shoreline experiences mild to moderate swell-wave energy with a moderate tidal range.

The large ebb-tidal deltas at either end of the island are major stores of sediment and provide sediment to the barrier coast at times. The deltas also modify incoming waves through refraction and energy dissipation. Karewa Island is a small offshore island, however it is likely to result in some wave refraction and a slightly lower wave climate in the lee.

NIWA (2018) do not provide offshore wave or storm tide levels specific for Matakana Island however it is expected the storm tide will be similar to the rest of the Western Bay of Plenty with the 200-year ARI storm tide level equivalent to 1.53 m MVD-53. Based on MetOcean wave hindcast data the mean significant wave heights are slightly larger at the northern end of the shoreline.

Net littoral drift is towards the southeast and Healy et al. (1977) suggests littoral drift along the island to be at least 40 000m^3 per year based on the long term progradation of Panepane Point.

2.3.1 Short-term

The short-term storm cut along the open coast of Matakana Island has been assessed based on the statistical analysis of beach profile data (see main report Section 5.4.1). All profile plots are shown in Appendix B. The minimum, mode and maximum bound values are based on the 5 year, 50 year and 200 year ARI storm cut distances. Figure 2.3 provides an example of the extreme value curve at profile CCS42.

Profile variability is largest at either ends of the barrier island and smallest in the centre at profile CCS44. The large fluctuations measured for the profiles at either end of the shoreline is due to sediment exchange and interactions with the adjacent inlet deltas. Storm cut is slightly larger at the northern end of the shoreline which may be due to a slightly higher wave exposure.

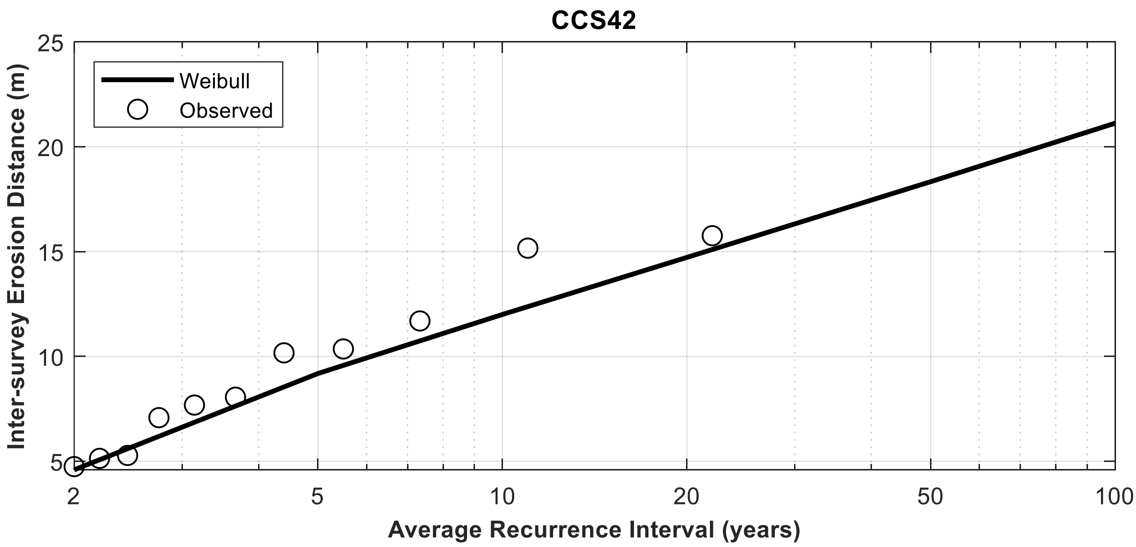


Figure 2.3: Example of extreme distribution curve at profile CCS42

For the harbour shoreline (Cell 2I) there is no beach profile data and subsequently the short-term storm cut within this cell has been assessed using SBEACH modelling (see main report Section 5.4.2). Model results indicate the storm cut at the 2.5 m RL contour along the Matakana harbour shoreline ranges from 2 to 14 m (Figure 2.4).

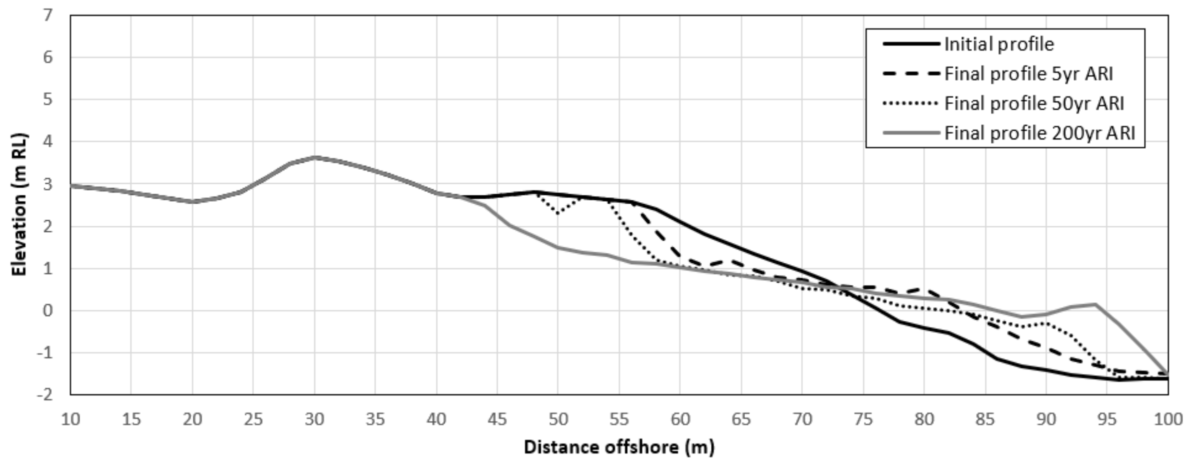


Figure 2.4: SBEACH results for the Matakana Island shoreline (cell 2I). The horizontal distance between the initial profile and the 200-year ARI profile at the 2.5 m contour is shown as 14 m

Table 2.1: Adopted short-term storm cut values (m) for Matakana Island

Cell	Min	Mode	Max
2A to 2D (CCS46)	12	25	30
2E to 2F (CCS45, CCS44, CCS43)	2	10	20
2G to 2H (CCS42, CCS41)	10	20	30
2I	2	5	14

2.3.2 Long-term trends

Long-term trends along Matakana Island have been based on regression analysis of historic shoreline data and beach profiles (Figure 2.5 and Figure 2.7) (see main report Section 5.6). Overall, the profile and shoreline data show long term erosion and fluctuations at either end of the barrier island (cells 2A, 2B, 2G and 2H), with accretion and relative stability through the centre of the island.

Based on historic shorelines, the shoreline adjacent to the Katikati inlet (Cell 2A) has eroded over 200 m since 1942. The profile data (CCS46) shows significant erosion between 1992 to 1998 (53 m). Since 1998, it appears that the erosion rate slowed (Figure 2.5). Profiles CCS45, CCS4 and CCS43 all show an overall accretion trend which is consistent with the shoreline data (Figure 2.7).

Within Cell 2G, which is approximately 1.5 km north of the Tauranga Harbour entrance, there has been over 100 m erosion since 1942. This section of shoreline is likely to be influenced by the adjacent offshore Matakana Banks (ebb tidal delta). The shoreline directly adjacent to the Tauranga entrance (Cell 2H) has generally shown stability since 1942, with over 100 m accretion at Panepane Point (Figure 2.6). The shoreline within the harbour (Cell 2H) has generally been stable with a slight erosional trend (Figure 2.6).

Trends and shoreline dynamics, at either end of Matakana Island, are largely influenced by the adjacent inlets and ebb tidal delta systems. Several studies have investigated the shoreline dynamics at the Tauranga Harbour entrance, with particular focus on dredging impacts and the stability of the Matakana Island shoreline (Ramli, 2016, de Lange & Moon, 2017). Based on pre and post capital dredging surveys, de Lange & Moon (2017) found approximately 20 m of erosion at the tip of Panepane Point following the 2015-16 capital dredging. However, they suggested that the spit is not likely to erode further under the current channel alignment. They also concluded that the observed shoreline changes were small compared with the longer term variations and natural processes are likely to dominate over the impacts of dredging in the long-term. The shoreline data shows that between 2014 and 2019 there has been approximately 40 m accretion at the tip of Panepane Point (Figure 2.6). Further discussion around the potential impacts of dredging is provided in Section 2.4.

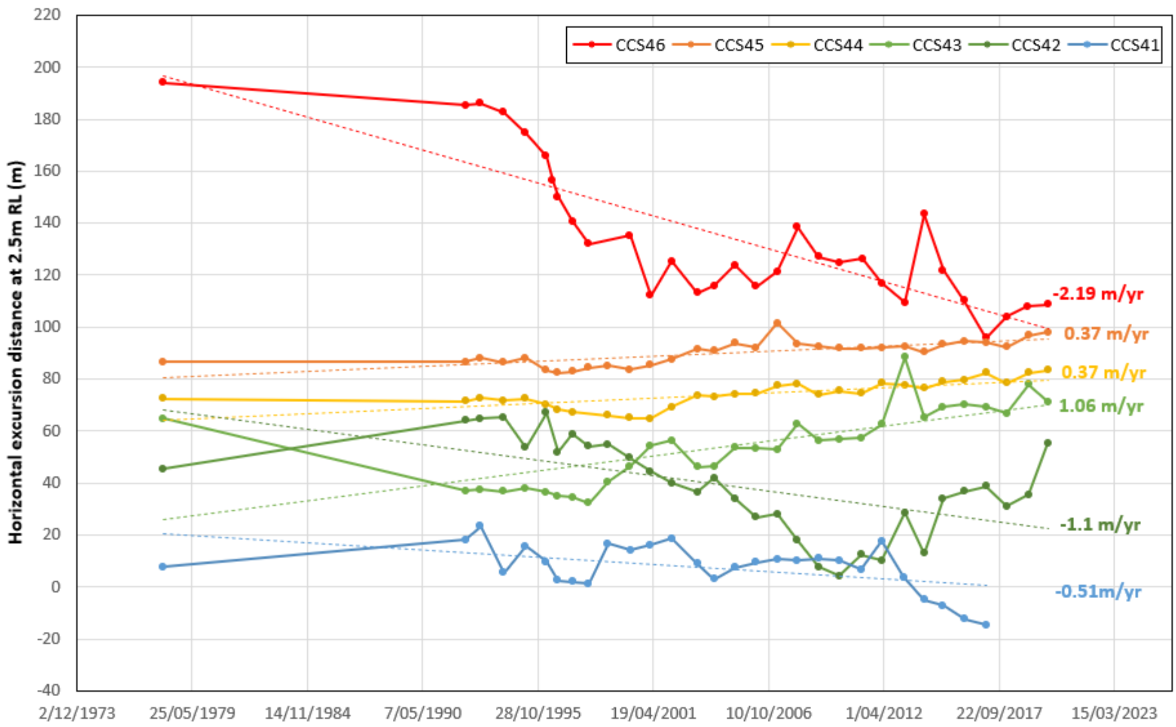


Figure 2.5: Horizontal excursion distances measured at the 2.5m RL (MVD-53) for profiles along Matakana Island

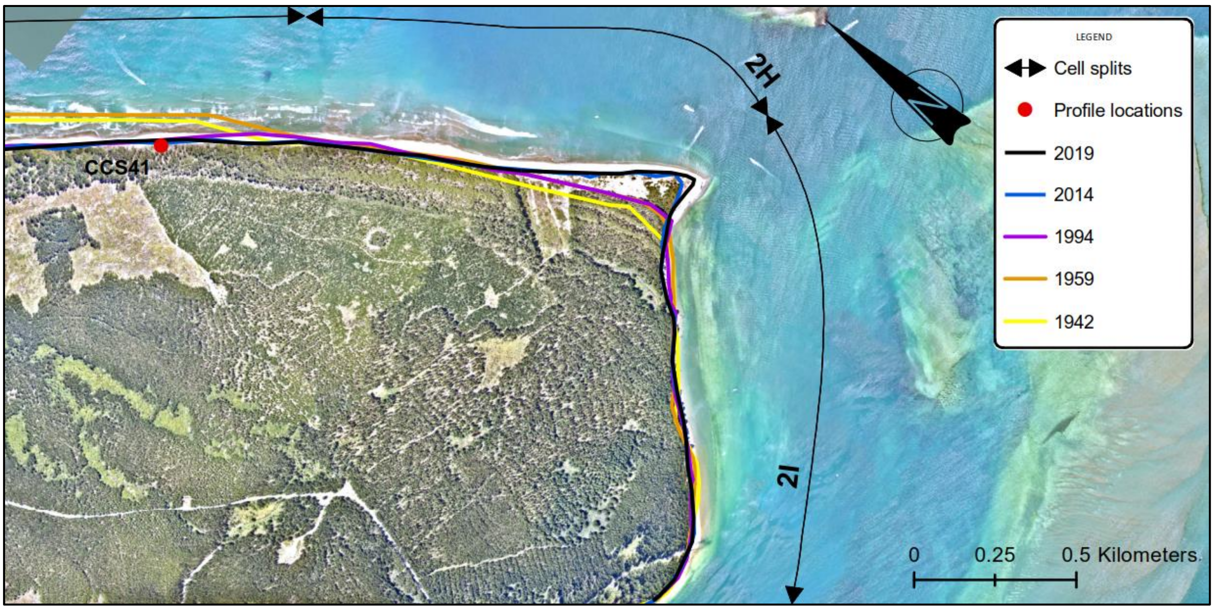
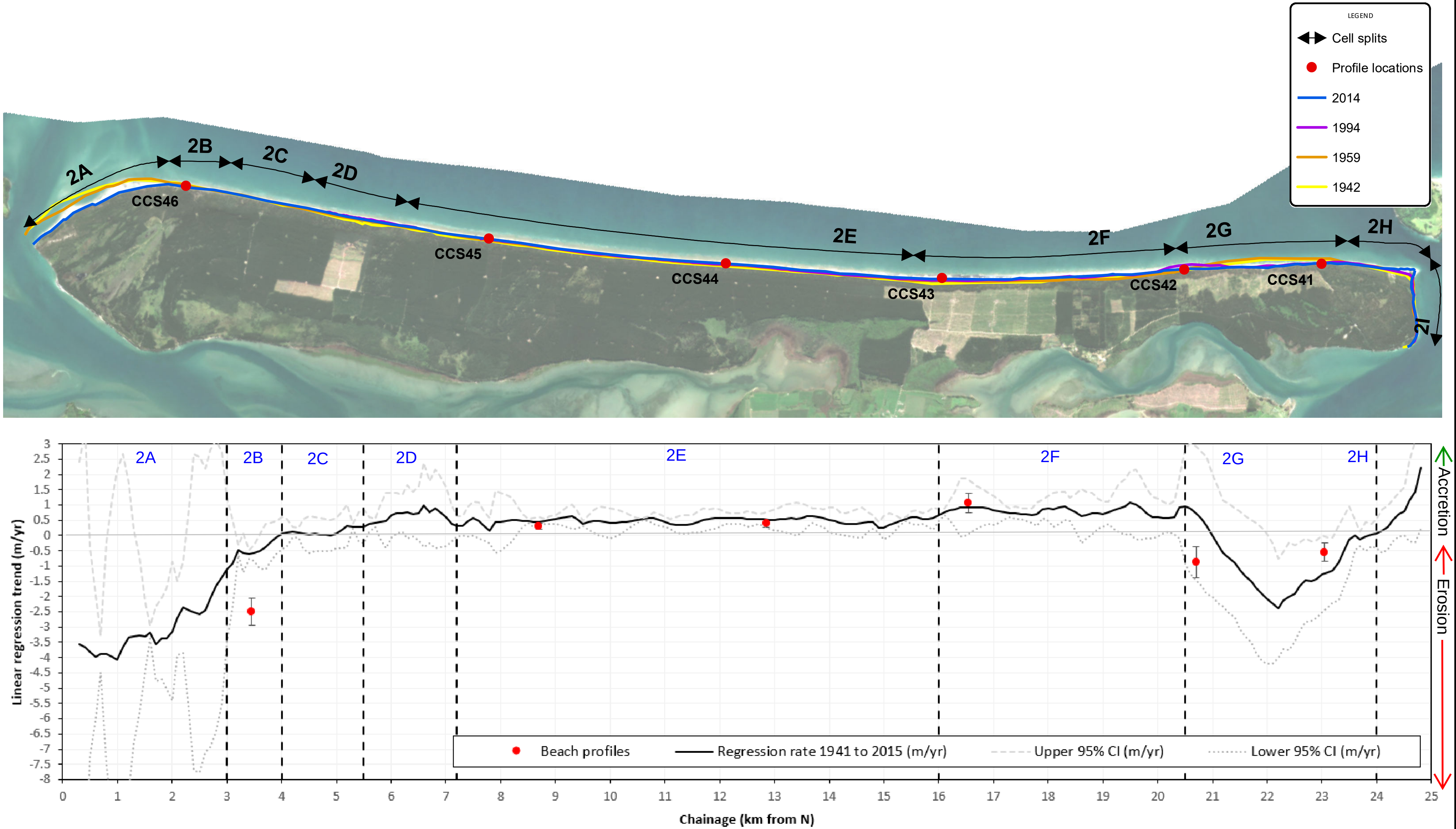


Figure 2.6: Historic shoreline changes at Panepane Point and along the harbour shoreline in Cell 2I



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PROJECT No.
1015856

Western Bay of Plenty Coastal Erosion

Matakana Island

Long term trend analysis

FIGURE No.
Figure 2.7

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Table 2.2: Adopted long-term trends for Matakana Island (m/yr)

Cell	Min	Mode	Max
2A	-0.8	-2.0	-2.5
2B	-0.8	-2.0	-2.5
2C	0.1	0.05	0
2D	0.5	0.4	0.3
2E	0.5	0.3	0.2
2F	1	0.6	0.5
2G	-0.2	-0.5	-0.8
2H	0	-0.1	-0.5
2I	0	-0.15	-0.3

Since completion of the long-term shoreline analysis, additional aerial imagery was captured in 2021 following the May/June storm events. The 2021 shoreline has been adopted as the baseline; however, it has not been included in the long-term analysis. A sensitivity analysis was completed to check if the inclusion of the 2021 shoreline would influence the long-term rates. Due to the short timeframe between 2015-2019 and 2021, the addition of the 2021 shoreline position had minimal impact on the long-term rates and therefore since the long-term analysis had already been completed, the 2021 shoreline was excluded.

2.3.3 Response to sea level rise

The shoreline response to sea level rise (SLR) along Matakana Island has been assessed using the Bruun Response model described in Section 5.7.2 of the main report. Due to slightly differing offshore significant wave heights, estimated inner closure depth ranges from 10 m at the northern end, to 8 m at the southern end.

Response to SLR is expected to vary along the shoreline due to the differing dune heights and closure depths (Table 1.3).

Table 2.3: Contour levels (m MVD-53) used to assess the effects of SLR on extents of active profiles along Matakana

Parameter bounds	Contour levels (m MVD-53)	Cells 2A – 2D (CCS46)	Cell 2E (CCS45 and CCS44)	Cell 2F (CCS43)	Cell 2G (CCS42)	Cell 2H (CCS41)
Lower bound slope	Average dune toe	2.5	2.5	2.5	2.5	2.5
	Average low water mark	-0.5	-0.5	-0.5	-0.5	-0.5
Modal slope	Average dune crest	6	4.5	4.5	4	4
	Zero flux depth	-5.5	-4.5	-4.5	-8	-10
Upper bound slope	Average dune crest	6	4.5	4.5	4	4
	Inner Hallermeier closure depth	-10.1	-10.1	-11	-8.1	-8.1

2.4 Local considerations

The key local consideration that may influence the coastal erosion hazard along Matakana Island is dredging of the Tauranga Entrance channel (Figure 2.8).

Dredging of the shipping channels within Tauranga Harbour first commenced around 1965, with the main entrance channel being dredged in 1968. Prior to dredging, the natural channel depth was approximately 7 to 8 m through the ebb-tidal delta system, and 30 m within the narrow inlet gorge (Healy et al., 1996). With further expansion of the port, another phase of capital dredging occurred in 1992 and further deepening and widening in 2015. The dredged channel now has a depth of 16 m at low water (Ramli, 2016). Dredged material has and continues to be deposited offshore at several different spoil disposal sites (Figure 2.8).

Concerns around possible destabilisation of the ebb tidal delta and erosion of the Matakana Island shoreline, in particular Panepane Point, resulted in several research studies looking at the impact of dredging.

de Lange & Moon (2015) looked at the impact of dredging on the evolution of the Matakana Island shoreline and concluded that dredging since 1968 has had two main direct effects on the morphology of the Tauranga Harbour entrance. These effects include a shallow shelf of boulders being removed with deepening of the channel along the flanks of Mauo and the creation of a deep channel through the Pleistocene ridge. In direct impacts have included further accretion of Panepane Point and an increase in the offshore extent of the ebb tidal delta. The study also concluded that due to dredging occurring within the more resistant Pleistocene sediments, the proposed capital dredging was unlikely to trigger instability of the ebb tidal delta (de Lange & Moon, 2015).

The recent study completed by de Lange & Moon (2017) concluded that under the current channel alignment, dredging impacts on the shoreline position are likely to be minimal compared with the natural processes and variation.

As part of this study the known dredging dates and volumes were compared against the horizontal excursion distances measured in the two closest beach profiles (CCS42 and CCS41) (Figure 2.9). Based on the comparison there is no apparent corelation between the beach profile trends and the dredging regime.

Overall, the current dredging regime does not appear to impact the erosion hazard along Matakana Island. However, any future changes in the dredging regime could influence the erosion on Matakana Island.

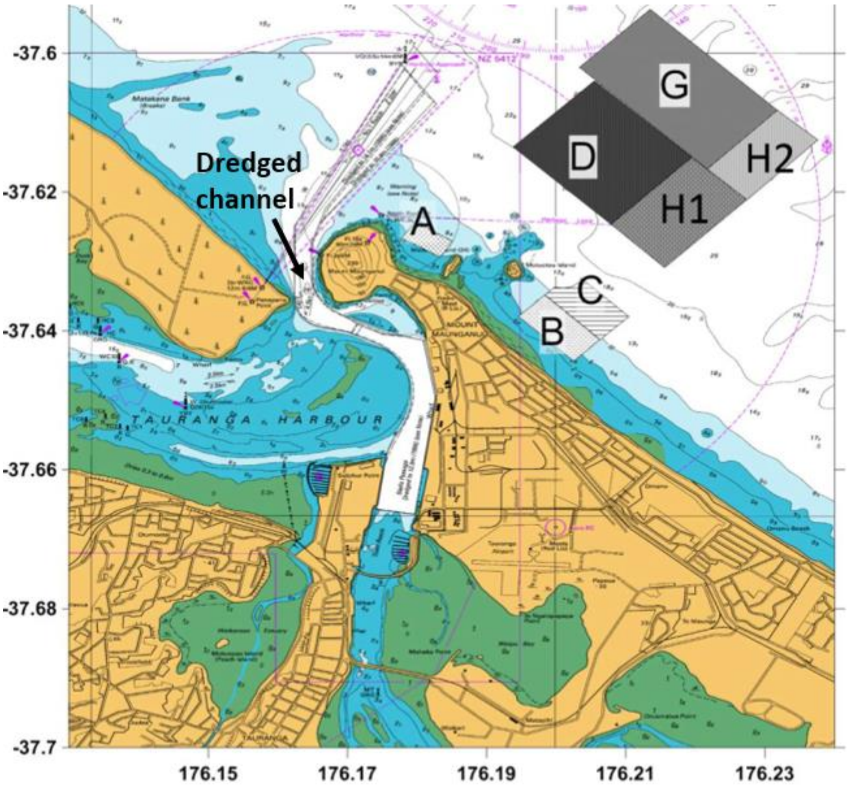


Figure 2.8: Location of main dredging channel near Matakana Island and the offshore spoil disposal sites. Sourced from Ramli (2016)

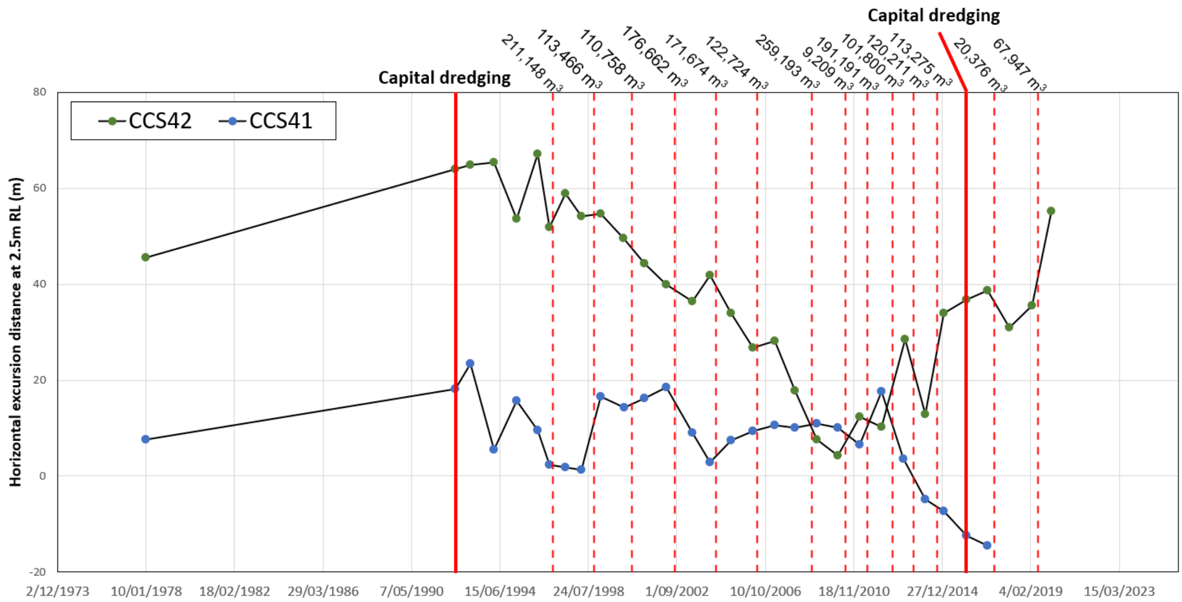


Figure 2.9: Horizontal excursion distances of the dune toe at profiles CCS42 and CCS41 on Matakana Island, overlaid with recorded dredging volumes between 1992 and 2019

2.5 Adopted component values

Adopted component values for Matakana Island are presented in Table 2.4.

Table 2.4: Adopted component values for Matakana Island

Cell		2A	2B	2C	2D	2E	2F	2G	2H	2I
Cell centre (NZTM)	E	1865238	1866554	1867110	1867903	1870675	1874710	1877369	1878612	1878374
	N	5847892	5846775	5845742	5844353	5839968	5834597	5831726	5830231	5829358
Chainage, m (from NW)		0 to 2580	2580 to 3520	3520 to 5020	5020 to 6720	6720 to 15550	15550 to 20100	20100 to 23050	23050 to 24210	24210 to 25350
Morphology		Beach	Beach	Beach	Beach	Beach	Beach	Beach	Beach	Harbour beach
Short-term (m)	Min	12	12	12	12	2	5	10	10	2
	Mode	25	25	25	25	7	20	20	20	5
	Max	30	30	30	30	15	40	25	30	14
Dune height (m above dune toe)	Min	1	2	2.5	3	3	2	4	2	1
	Mode	1.5	3	3	3.5	4	3	6	3	1.5
	Max	2	5	3.5	4	6.5	3.5	8	3.5	2
Stable slope (°)	Min	30	30	30	30	30	30	30	30	30
	Mode	32	32	32	32	32	32	32	32	32
	Max	34	34	34	34	34	34	34	34	34
Long-term (m/yr) -ve erosion +ve accretion	Min	-0.8	-0.8	0.1	0.5	0.5	1	-0.2	0	0
	Mode	-2.0	-2.0	0.05	0.4	0.3	0.6	-0.5	-0.1	-0.15
	Max	-2.5	-2.5	0	0.3	0.2	0.5	-0.8	-0.5	-0.3
Closure slope	Min	0.02	0.020	0.020	0.020	0.022	0.033	0.040	0.040	0.15
	Mode	0.013	0.013	0.013	0.013	0.020	0.020	0.020	0.010	0.10
	Max	0.009	0.009	0.009	0.009	0.012	0.014	0.016	0.009	0.06
Average VLM rate (m/yr)[1]		0	0	0	0	0	0	0	0	0

1 See main report Section 5.8

2.6 Coastal erosion hazard assessment

Coastal erosion hazard distances for Matakana Island are presented in Table 2.5. Erosion hazard distances have been offset from the 2021 seaward edge of vegetation. $P_{50\%}$ means there is a 50% chance of an erosion distance being exceeded within that timeframe. $P_{66\%}$ can be considered a likely scenario and $P_{5\%}$ can be considered a very unlikely scenario.

Based on the NZ SeaRise programme there is no VLM data available for the Matakana Island shoreline and therefore, unlike Maketu and Pukehina sites, an additional VLM scenario has not been included for this site.

The current CEHA is dominated by the short-term storm erosion and is typically larger towards the northern end of the shoreline. Along the open coast cells (cell 2A to 2H) the current $P_{66\%}$ CEHA ranges from -11 to -24 m. Along the harbour shoreline (cell 2I) the current $P_{66\%}$ is -7 m.

Long-term trends are a key factor influencing the variation in future CEHA along Matakana Island. Subsequently due to high variability in historic trends, there is high variability in the future CEHA widths. The results indicate significant erosion at either end of the barrier island. By 2130 the shoreline may potentially retreat by over 100 m within cells 2G and 2H and over 300 m within cells 2A and 2B. Erosion processes at both ends of the island are largely influenced by changes in the adjacent ebb tidal delta systems.

Throughout the centre of the island the future CEHA are less due to long-term accretion rates. The long-term accretion near the centre of the island (cell 2F) may be associated with wave sheltering in the lee of Karewa Island. Historic accretion rates are highest within cell 2F where several of the future CEHA scenarios indicate the future shoreline being seaward of the present-day position. The future CEHA extent tends to be dominated by the combined effect of long-term trends and recession due to SLR. For example, within cell 2F, by 2130 under low SLR scenarios (i.e. 0.8 m) the impact of long-term accretion is likely to counteract any potential recession due to SLR. However higher SLR by 2130 (i.e. 1.6 m) is expected to overtake the impact of accretion and result in shoreline retreat.

For future scenarios where the CEHA is seaward of the current CEHA (i.e. 2130 0.8 m $P_{66\%}$ in cell 2F), the future CEHA has been mapped equivalent to the current CEHA.

Table 2.5: Coastal erosion hazard widths (m) for Matakana Island for current, 2080 and 2130 timeframes (shaded cells are mapped scenarios)

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Probability of Exceedance				
				Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
2A	Current	0.03	N/A	-13	-22	-24	-29	-31
	2080	0.4	RCP4.5	-94	-151	-162	-192	-213
		0.6	RCP8.5	-106	-165	-176	-208	-234
	2130	0.8	RCP4.5	-158	-262	-281	-338	-376
		1.25	RCP8.5	-185	-294	-314	-374	-422
		1.6	RCP8.5+	-206	-319	-338	-404	-459
2B	Current	0.03	N/A	-14	-24	-25	-31	-33
	2080	0.4	RCP4.5	-93	-152	-163	-193	-218
		0.6	RCP8.5	-105	-166	-177	-209	-237
	2130	0.8	RCP4.5	-158	-263	-282	-339	-379
		1.25	RCP8.5	-182	-295	-315	-375	-424

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Probability of Exceedance				
				Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
		1.6	RCP8.5+	-201	-321	-340	-405	-460
2C	Current	0.03	N/A	-15	-23	-25	-30	-33
	2080	0.4	RCP4.5	-31	-48	-51	-62	-73
		0.6	RCP8.5	-42	-62	-65	-80	-94
	2130	0.8	RCP4.5	-51	-73	-77	-97	-113
		1.25	RCP8.5	-75	-103	-110	-139	-162
		1.6	RCP8.5+	-93	-126	-135	-173	-200
2D	Current	0.03	N/A	-15	-24	-26	-31	-33
	2080	0.4	RCP4.5	-10	-28	-30	-42	-52
		0.6	RCP8.5	-21	-41	-45	-60	-74
	2130	0.8	RCP4.5	-7	-35	-39	-60	-80
		1.25	RCP8.5	-32	-65	-72	-102	-127
		1.6	RCP8.5+	-50	-89	-97	-135	-164
2E	Current	0.03	N/A	-5	-13	-14	-21	-24
	2080	0.4	RCP4.5	+3	-14	-17	-27	-39
		0.6	RCP8.5	-7	-25	-28	-40	-55
	2130	0.8	RCP4.5	+7	-19	-22	-39	-56
		1.25	RCP8.5	-14	-42	-47	-70	-92
		1.6	RCP8.5+	-30	-61	-66	-94	-120
2F	Current	0.03	N/A	-4	-11	-13	-19	-22
	2080	0.4	RCP4.5	+38	+14	+10	-2	-16
		0.6	RCP8.5	+31	+5	+1	-13	-30
	2130	0.8	RCP4.5	+74	+32	+26	+5	-13
		1.25	RCP8.5	+59	+13	+5	-20	-43
		1.6	RCP8.5+	+48	-3	-10	-40	-67
2G	Current	0.03	N/A	-14	-23	-25	-32	-36
	2080	0.4	RCP4.5	-42	-67	-71	-86	-102
		0.6	RCP8.5	-48	-75	-79	-96	-113
	2130	0.8	RCP4.5	-65	-106	-113	-138	-162
		1.25	RCP8.5	-77	-124	-132	-160	-188
		1.6	RCP8.5+	-86	-137	-146	-178	-208
2H	Current	0.03	N/A	-12	-21	-22	-29	-32
	2080	0.4	RCP4.5	-27	-52	-57	-77	-98
		0.6	RCP8.5	-33	-62	-68	-96	-119
	2130	0.8	RCP4.5	-42	-80	-89	-128	-165
		1.25	RCP8.5	-54	-102	-114	-169	-213
		1.6	RCP8.5+	-64	-117	-132	-202	-250
2I	Current	0.03	N/A	-3	-7	-8	-13	-15
	2080	0.4	RCP4.5	-8	-19	-21	-29	-38

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Probability of Exceedance				
				Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
		0.6	RCP8.5	-10	-21	-23	-31	-41
	2130	0.8	RCP4.5	-10	-29	-33	-45	-56
		1.25	RCP8.5	-13	-34	-37	-50	-62
		1.6	RCP8.5+	-16	-37	-40	-54	-68

3 Maketū

3.1 Site description

The Maketū Peninsula is approximately 30 km southeast of Tauranga. The shoreline includes the eastern margin of the Maketū Estuary, Ōkurei Point (Town Point) and Newdicks Beach (Figure 3.1). The shoreline within Maketū Estuary is characterised by low, estuarine banks. Erosion protection structures (in varying condition) exist in sections along the estuary shoreline. Ōkurei Point forms a 67 m high headland, fronted with rocky shore platform on the western side and sandy beach on the eastern side (Newdicks Beach). The site has been split into 11 cells based on the morphology, elevation and long-term trends. An overview of the cell splits is provided in Figure 3.1. Several photos taken during the site visits are provided in Figure 3.2.

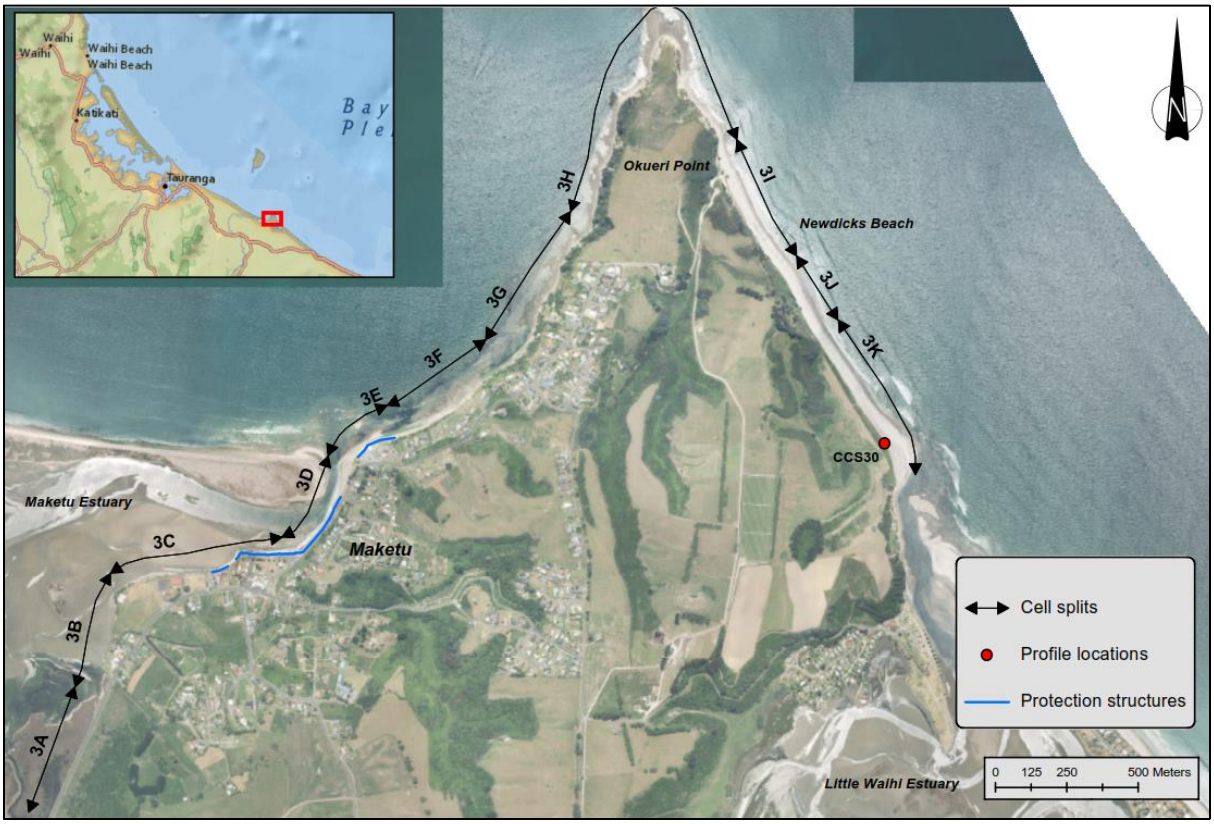


Figure 3.1: Site overview of Maketū

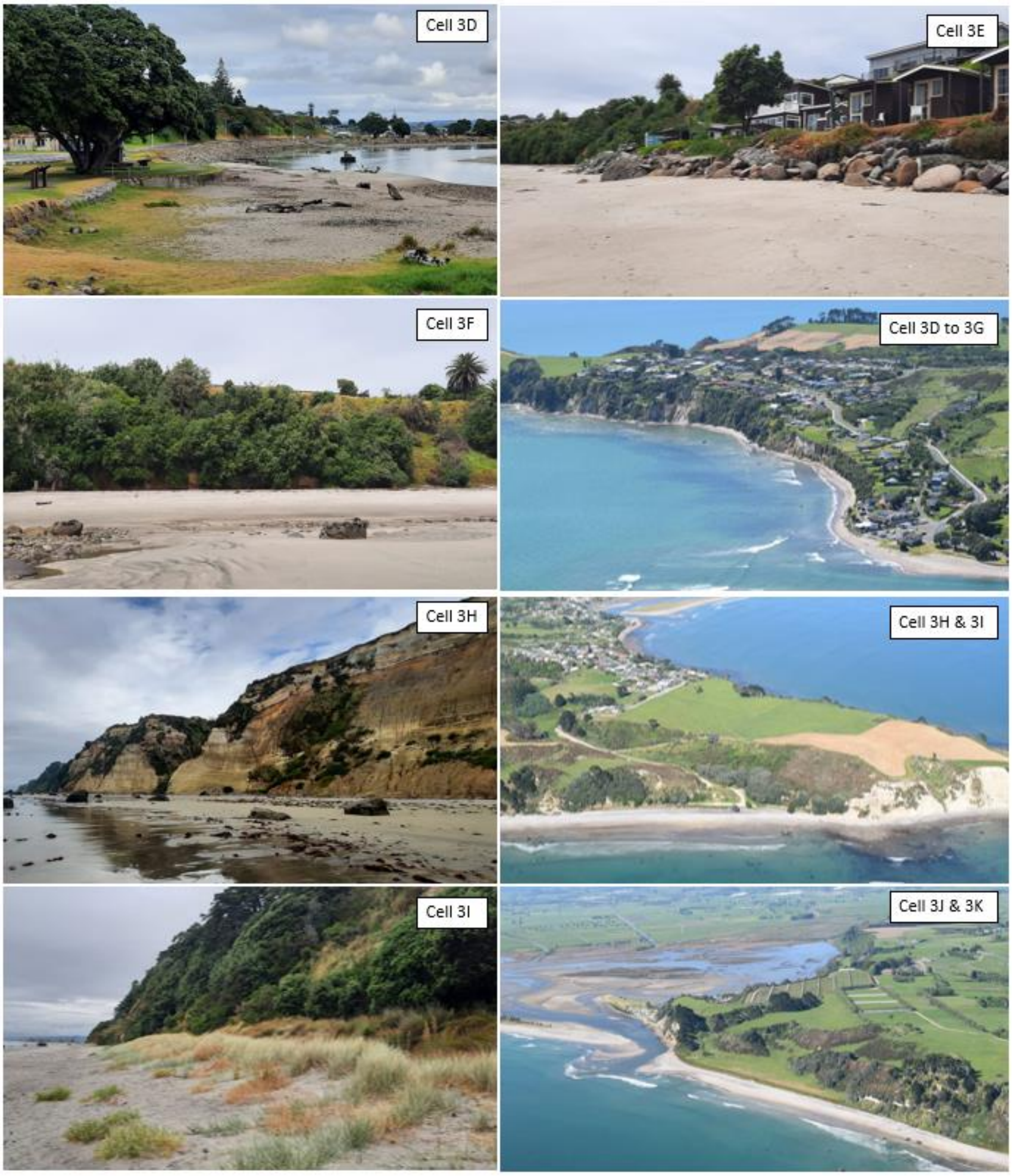


Figure 3.2: Site photos taken along the Maketū shoreline

3.2 Morphology

The Maketū Peninsula is a horst structure constrained by north east striking normal faults on the eastern and western extents of the elevated landform feature. Middle to late Pleistocene fluvial and aeolian volcaniclastic sediments along with interbedded pyroclastic deposits form the foundations of the peninsula. The majority of these sediments are a part of the Matua Subgroup which has been defined as comprising fluviatile sands, silts, gravels, dune sands, loess and lahar deposits (Briggs, et al., 2006).

Briggs et al. (2006) also notes that there are numerous smaller normal faults across the peninsula that have offsets ranging from centimetres to a few metres. These smaller fault features were observed during the site visit to the Maketū Peninsula. These normal faults have resulted in a spatially variable geological stratigraphy of the peninsula. As a result of the fault offsets, different geological layers within the Matua Subgroup which have different weathering resistances are exposed along the base of the sea cliffs bounding the peninsula.

Along the northern extent of the Maketū Peninsula, geological layers within the Matua Subgroup that are more resistant to erosion result in steep slopes ranging between 50° - 70°. The slopes along the southern extent of the peninsula generally have geological layers exposed within the base of the coastal cliffs that are less resistant to erosion, resulting in slope angles between 40° - 50°.

The shoreline within the Maketū Estuary is characterised by weakly consolidated banks comprising Holocene swamp deposits. The estuary itself formed following Quarternary uplift of the Maketū Basin and it has since infilled with sediment from both coastal and land-based sources.

The most recently available information from the NZ SeaRise programme indicates the Maketū shoreline is uplifting at an average rate of 3.1 mm/yr.

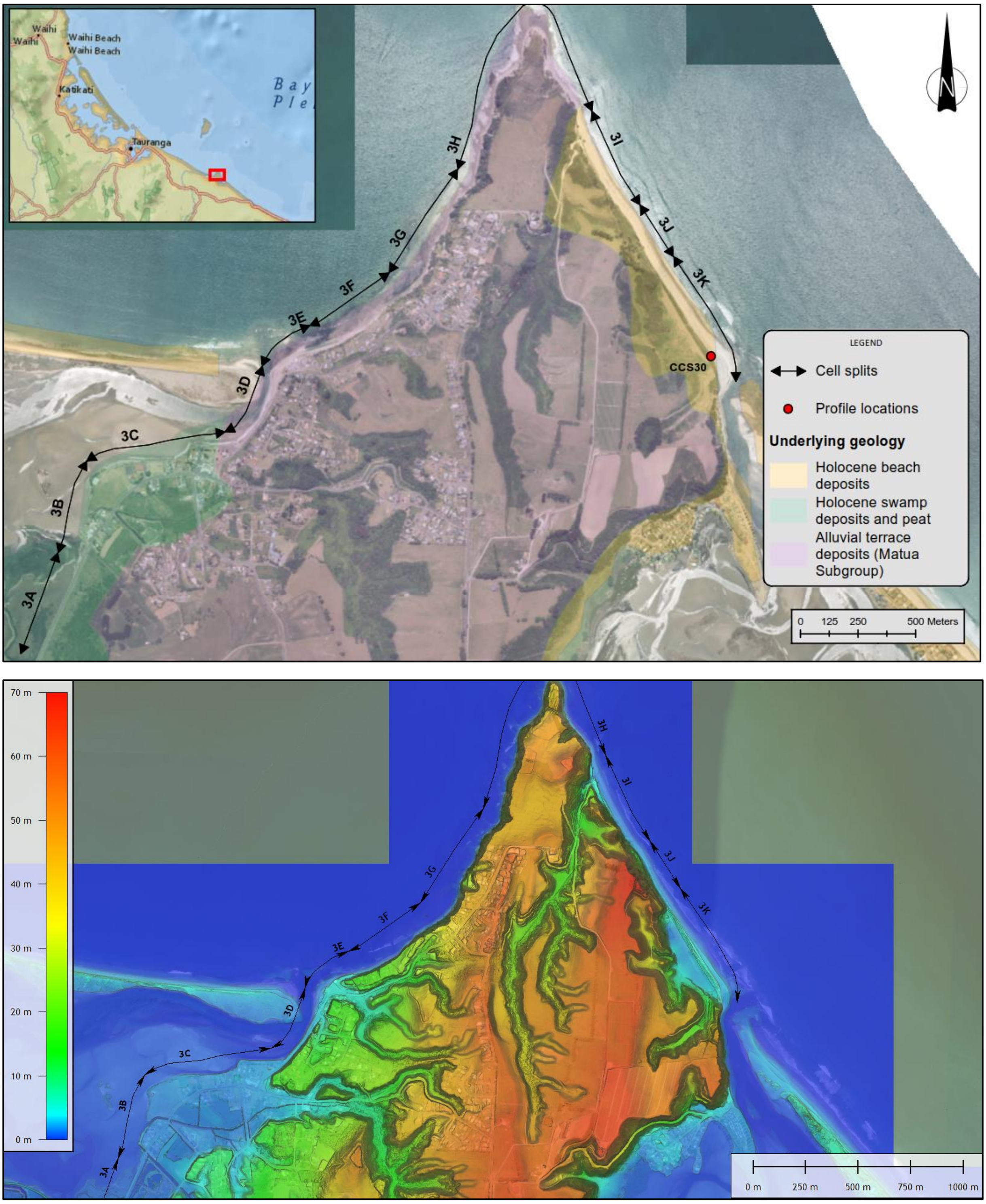


Figure 3.3: (Top) Underlying geology across the Maketū Peninsula. (Bottom) 2020 DEM data for Maketū

3.3 Coastal processes

The Maketū Estuary is a low mesotidal estuarine lagoon with numerous tidal channels and is enclosed by a barrier spit. Historically the Kaituna River flowed into the Maketū Estuary but has been diverted both naturally and artificially at various times. The recent Kaituna River Re-diversion project has resulted in 20 percent of the Kaituna River flows being returned to the estuary every tidal cycle.

The cliffs at Ōkurei Point are exposed to waves from the north to east. The shore platform on the western side and the sand beach on the eastern side are likely to provide some protection to the toe of the cliff under present-day sea level. Based on NIWA (2018) the 200-year ARI storm tide level is 1.54 m MVD-53 and the 200-year ARI offshore significant wave height is 7.22 m.

Net littoral drift is predominantly southeast with potentially some northwest drift on the eastern side of Ōkurei Point.

3.3.1 Short-term

The short term storm cut is only applicable to the unconsolidated beach shoreline in Cell 3K. The short-term storm cut within Cell 3K has been assessed based on the statistical analysis of beach profile data at CCS30 (see main report Section 5.4.1). The profile plot is provide Appendix B. The minimum, mode and maximum bound values are based on the 5 year, 50 year and 200 year ARI storm cut distances. Figure 3.4 shows the extreme value curve at profile CCS30.

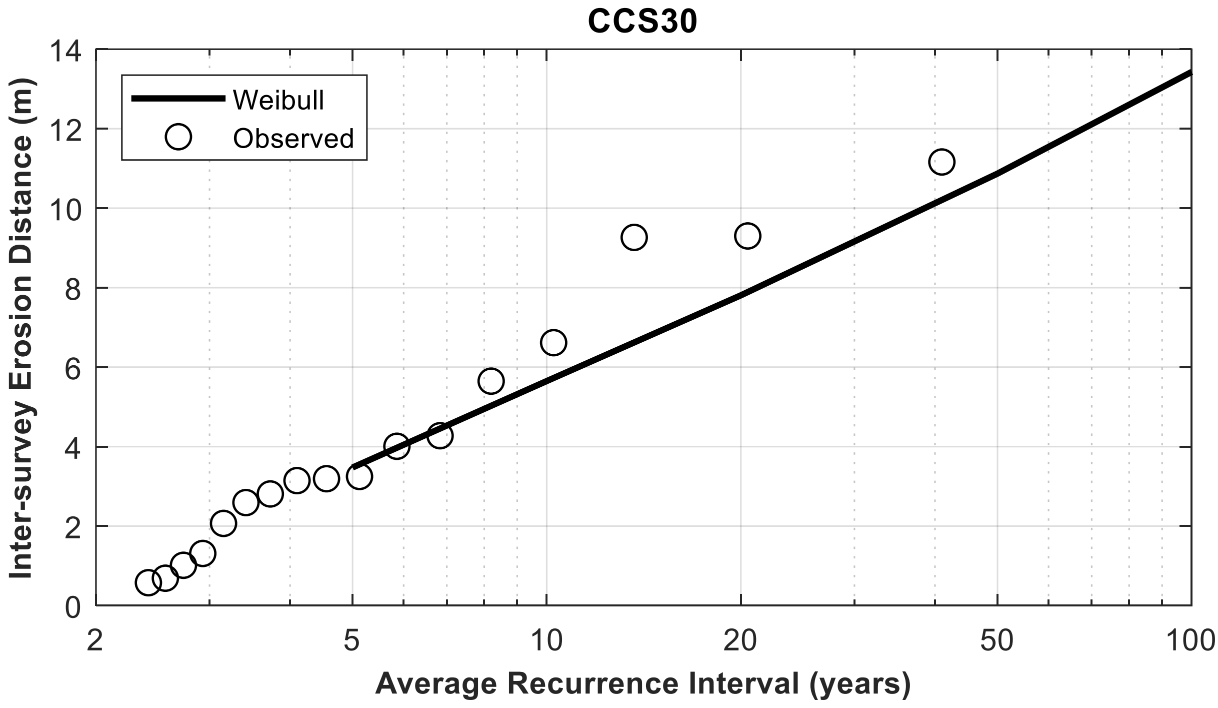


Figure 3.4: Example of extreme distribution curve at profile CCS30

Table 3.1: Adopted short term component values (m) for Cell 3K

Cell	Min	Mode	Max
3K	3	10	15

3.3.2 Long-term trends

Long-term trends around Maketū have mostly been based on regression analysis of historic shoreline data with consideration of the trends measured at beach profile CCS30 (see main report Section 5.6). Due to inaccuracies in defining the cliff toe, long-term rates have been measured based on historic shoreline position along selected transects (Figure 3.5).

The shoreline within Maketū Estuary, in particular Cell 3C, has undergone changes as tidal channels have shifted and adjacent Maketū spit has changed. Figure 3.6 highlights some of the changes that have occurred since 1942. The shoreline within Cell 3C has shown accretion in some sections, particularly west of the marae. However, towards the east, rock has been placed along sections and the present-day tidal channel runs adjacent to the shoreline, which suggests erosion is occurring. To account for this variability, we have assumed long-term rates ranging from 0 to -0.1 m/yr.

Another apparent change is within Cell 3B, where the 1942 aerial shows salt marsh vegetation fronting the estuarine bank whereas the 2020 aerial shows this vegetation is absent. Cell 3A is still fronted with salt marsh vegetation and the shoreline along this section appears to still be stable. Due to the presence of protection structures within cell 3D it is difficult to measure long-term trends, however it is assumed the erosion rates will be similar to the estuarine bank within cell 3C.

The partial re-diversion of the Kaituna River into the Maketū Estuary, which was recently completed in 2020, may have implications on the long-term trends along the estuary shoreline. However, there is limited shoreline data to infer what these implications might be.

For the exposed cliffs around the peninsula, the regression analysis suggests toe erosion rates range from -0.02 to -0.15 m/yr (Figure 3.5).

Beach profile data at CCS30 shows shoreline fluctuations since 1970, with a slight accretional trend of 0.1 m/yr (Figure 3.7). The accretion within cell 3K is also apparent in the historic shoreline data (Figure 3.5). This accretion within cell 3K is possibly due to combined effects of Ōkurei Point acting as a natural groyne causing accretion on the updrift side, as well as with changes in the ebb-tidal delta system at the mouth of the Little Waihī estuary.

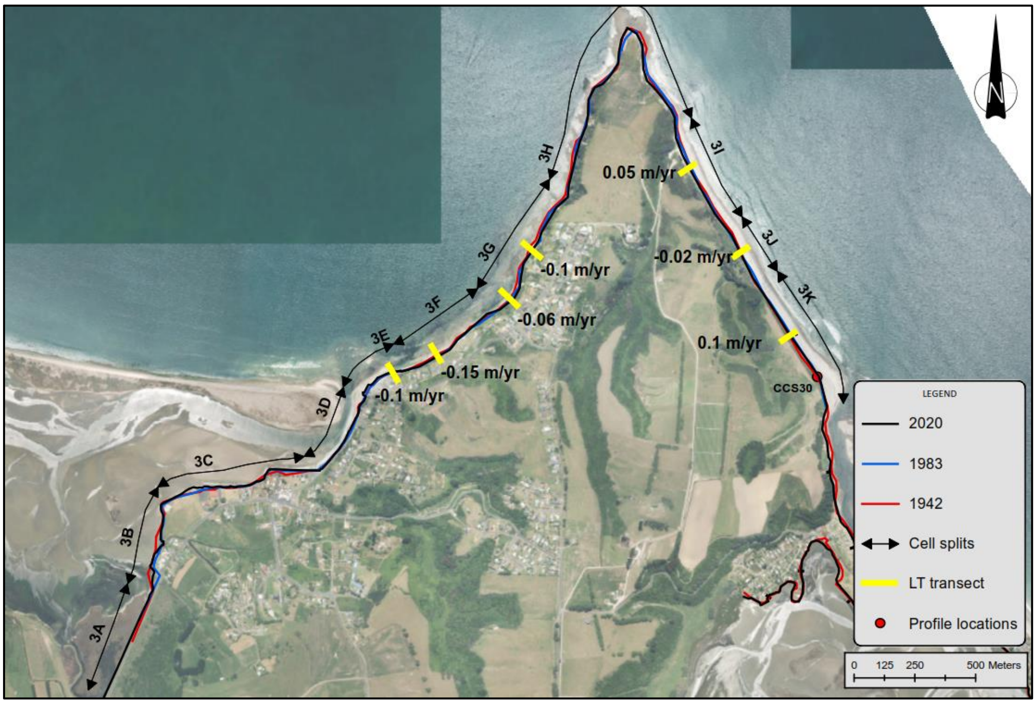


Figure 3.5: Historic shorelines around the Maketū shoreline with long term (LT) transects where regression rates have been calculated

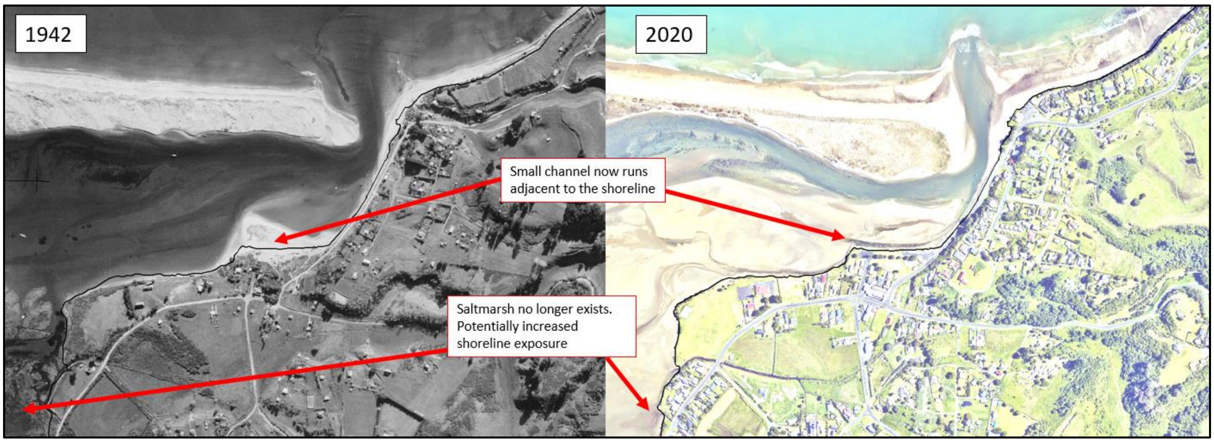


Figure 3.6: Shoreline changes within the Maketū Estuary between 1942 and 2020. Black line shows the location of the 2020 shoreline

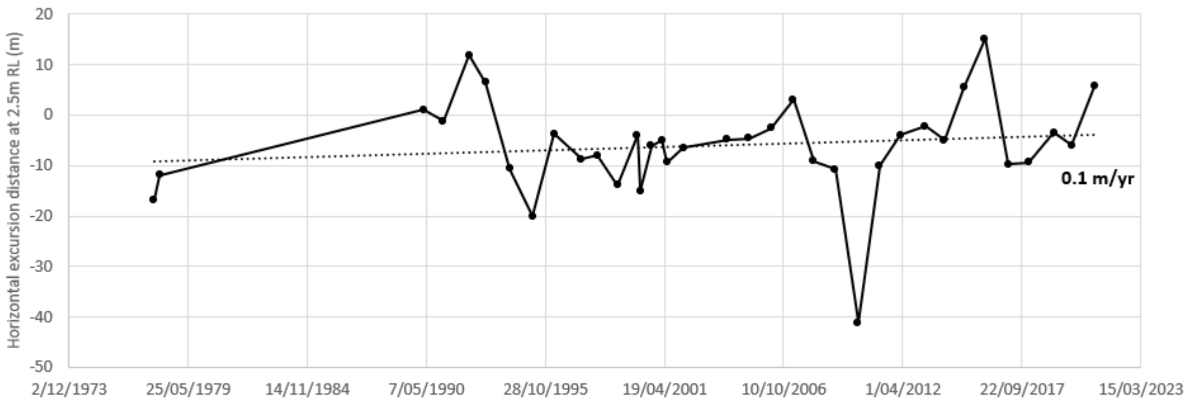


Figure 3.7: Horizontal excursion distances measured at the 2.5m RL contour at profile CCS30

Table 3.2: Adopted long-term trends along the Maketū shoreline (m/yr)

Cell	Min	Mode	Max
3A	0	-0.02	-0.05
3B	0	-0.02	-0.05
3C	0	-0.05	-0.1
3D	0	-0.05	-0.1
3E	-0.05	-0.08	-0.1
3F	-0.05	-0.1	-0.15
3G	-0.05	-0.1	-0.15
3H	-0.05	-0.1	-0.15
3I	0.05	0	-0.05
3J	0	-0.02	-0.05
3K	0.1	0	-0.02

3.3.3 Response to sea level rise

Consolidated cliff and bank response to sea level rise (SLR) has been assessed based on the model proposed by Ashton et al. (2011) (see main report Section 5.7.3). As the sea level rises there is likely to be increased wave energy propagating over the fronting platform and beach to reach the cliff toe and remove talus material more effectively and increase the potential for wave action and currents to affect cliff recession. However, there is also potential for talus material to provide self-armouring and subsequently slow recession of the cliff toe.

Due to the sheltered environment within the Maketū Estuary, the SLR response factor along the estuarine banks is estimated to range from 0.1 to 0.3. The cliffs around the peninsula are exposed to swell from the open ocean and subsequently the SLR response factors are estimated to range from 0.3 to 0.5. However, for Cell 3J, the SLR response factors are estimated to be slightly less, ranging from 0.2 to 0.4. This is due to the sandy beach in front of the cliff toe which is likely to provide some protection against increased wave action at the cliff toe with SLR.

For the unconsolidated dunes within Cell 3I and 3K (Newdicks Beach), the SLR response has been assessed based on the Bruun Model (see main report Section 5.7.2).

3.4 Cliff instability

Cliff instability due to coastal erosion around Maketū Peninsula has been assessed based on the cliff heights and assumed stable slopes (see main report Section 5.5.3). Based on site observations and previous literature, slope failures around the Maketū Peninsula are typically shallow, translational landslips. Adopted stable slopes have been based on the existing slopes which range from 45° to 60° (Figure 3.8).

Cliff heights are largest at the tip of the peninsula and along the eastern side (Cells 3H and 3J) where heights range from 40 to 70 m high.

Figure 3.8: Example of existing slopes around the Maketū Peninsula

3.5 Local considerations

Local considerations which may influence the erosion hazard around Maketū include the presence of protection structures and potential impacts from the Kaituna re-division.

The Kaituna River historically flow into the Maketū Estuary but has been diverted both naturally and artificially at various times. The low-lying Kaituna swampland surrounding the Maketū Estuary was historically prone to flooding. In 1922 Ford’s Cut was constructed as an attempt to reduce flooding. In 1954 Ford’s Cut was blocked with a stopbank and the river was subsequently diverted along a canal to the coast in Feb 1958, bypassing the Maketū Estuary. The diversion resulted in sedimentation within the estuary and enlargement of the flood tide delta (Burton & Healy, 1985). The recent Kaituna River Re-diversion project has resulted in 20 percent of the Kaituna River flows being returned to the estuary every tidal cycle which may influence the tidal deltas and subsequently shoreline erosion within the estuary (Figure 3.9).

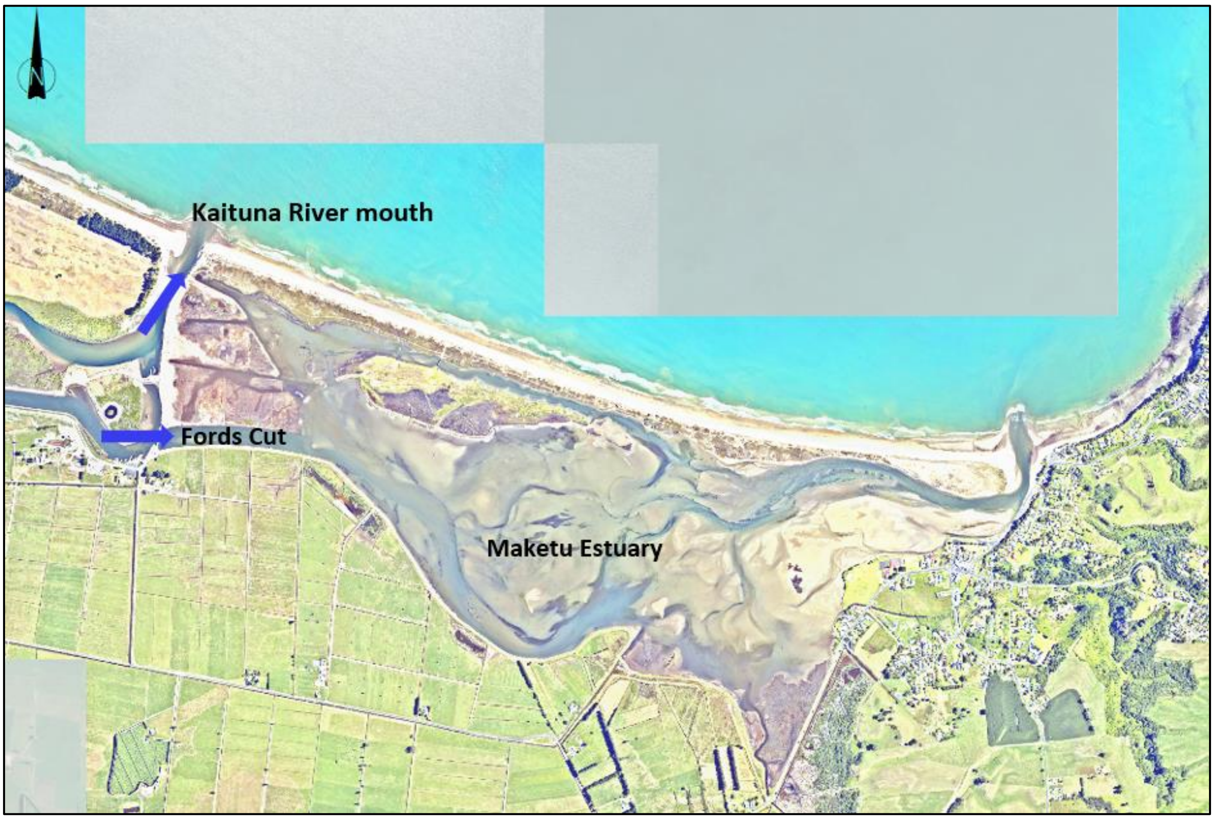


Figure 3.9: Map of Maketū Estuary showing the recent re-diversion of river flow through Fords Cut

3.6 Adopted component values

Adopted component values for Maketū are presented in Table 3.3.

Table 3.3: Adopted component values for Maketū

Cell		3A	3B	3C	3D	3E	3F	3G	3H	3I		3J	3K
Cell centre (NZTM)	**E**	1903436	19003557	1903922	1904340	1904478	1904777	1905096	1905442	1905930		1906110	1906354
	N	5814792	5815189	5815469	5815639	5815915	5816093	5816446	5817254	5816691		5816395	5816028
Chainage, m (from W)		0 to 470	470 to 885	885 to 1500	1500 to 1850	1850 to 2100	2100 to 2500	2500 to 3000	3000 to 4400	4400 to 4800		4800 to 5100	5100 to 5800
Morphology		Estuarine bank	Estuarine bank	Estuarine bank	Estuarine bank	Estuarine bank	Cliff	Cliff	Cliff	Beach	Cliff	Cliff	Beach
Short-term (m)	**Min**	0	0	0	0	0	0	0	0	3	0	0	3
	Mode	0	0	0	0	0	0	0	0	10	0	0	10
	Max	0	0	0	0	0	0	0	0	15	0	0	15
Cliff/dune height (m above toe)	**Min**	0.5	1.0	1.5	2.0	3.0	15	40	40	2	15	65	2
	Mode	0.8	1.5	2.0	2.5	3.5	18	41	47	3	30	68	3
	Max	1.0	1.8	2.5	3.5	4.0	20	42	50	4	45	70	5
Slope stability (°)	**Min**	18	18	18	18	18	45	45	45	30	45	45	30
	Mode	25	25	25	25	25	50	50	50	32	50	50	32
	Max	30	30	30	30	30	60	60	60	34	60	60	34
Long-term (m/yr) -ve erosion +ve accretion	**Min**	0	0	0	0	-0.05	-0.05	-0.05	-0.05	0.05	0	0	0.1
	Mode	-0.02	-0.02	-0.05	-0.05	-0.08	-0.10	-0.10	-0.10	0	-0.02	-0.02	0
	Max	-0.05	-0.05	-0.10	-0.10	-0.10	-0.15	-0.15	-0.15	-0.05	-0.05	-0.05	-0.02
[1]SLR factor (cliffs) [2]Closure slope (beaches)	**Min**	0.1[1]	0.1[1]	0.1[1]	0.1[1]	0.3[1]	0.3[1]	0.3[1]	0.3[1]	0.033[2]	0.2[1]	0.2[1]	0.033[2]
	Mode	0.2[1]	0.2[1]	0.2[1]	0.2[1]	0.4[1]	0.4[1]	0.4[1]	0.4[1]	0.020[2]	0.3[1]	0.3[1]	0.020[2]
	Max	0.3[1]	0.3[1]	0.3[1]	0.3[1]	0.5[1]	0.5[1]	0.5[1]	0.5[1]	0.015[2]	0.4[1]	0.4[1]	0.015[2]
Average VLM rate (m/yr)[1]		0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031

1 See main report Section 5.8

3.7 Coastal erosion hazard assessment

The coastal erosion hazard around Maketū has been assessed both with and without the impacts of VLM. Table 3.4 presents the erosion distances based on no future VLM and Table 3.5 presents the erosion distances accounting for future VLM. Erosion hazard distances have been offset from the 2021 seaward edge of vegetation along the estuary shoreline and the cliff toe along the cliff shoreline. $P_{50\%}$ means there is a 50% chance of an erosion distance being exceeded within that timeframe. $P_{66\%}$ can be considered a likely scenario and $P_{5\%}$ can be considered a very unlikely scenario.

For most of the shoreline, the current CEHA is dominated by the slope stability component and therefore is a function of cliff/bank height and the stable angle of repose. As a result, the current CEHA is largest for areas of high cliffs. For the unconsolidated dunes in cells Cell 3I and 3K, the current CEHA is dominated by the short-term storm cut.

The future CEHA are smallest within Maketū Estuary, particularly within cells 3A and 3B where the estuarine bank is relatively sheltered and has shown minimal long-term erosion. The CEHA increases within cells 3C and 3D where the estuary channel influences shoreline dynamics and is expected to increase the long-term erosion. Under 1.6 m SLR by 2130 the $P_{5\%}$ CEHA indicates potential for up to -20 m of erosion. Cell 3E is also influenced by the estuary channel position as well as ocean coast dynamics. Future erosion within cell 3E is estimated to be up to -32 m by 2130 with 1.6 m SLR. Future shoreline trends along the estuarine shoreline may be sensitive to changes in the sand bank positions within the estuary. A shift in the position of the sand banks could potentially alter the wave energy at the shoreline and change the patterns of erosion and accretion.

Erosion protection structures of varying condition are present within cells 3C, 3D and 3E, however these have not been accounted for within the assessment. The CEHA represents the hazard in absence of the structures, and therefore, while these structures remain functional, the CEHA within these cells is likely to be an overprediction.

For the cliff cells the slope instability component contributes almost 50% of the total CEHA width for the future scenarios. The long-term trends and response to SLR along cells 3F to 3H are expected to be relatively similar. For the 2130 1.6 m SLR scenario the $P_{5\%}$ CEHA ranges from -50 to -77 m along the cliffs in cells 3F to 3H.

On the eastern side of Ōkurei Point, the future erosion differs slightly due to the presence of Newdicks Beach and the cliff/bank morphology within the backshore of cell 3I. The width of dunes varies from 10 to 20 m wide and is backed by cliff ranging from 15 to 45 m high. It has been assumed that once the dune erodes beyond an average distance of 15 m landward, the cliff toe will be undermined and become susceptible to instability. The current $P_{66\%}$ within this cell is -11 m and represents potential storm cut and instability of the dune. The current $P_{5\%}$ is -38 m and represents an unlikely scenario where short-term storm cut may exceed the dune and result in undermining and instability of the cliff/bank further landward. Towards the northern end of the cell where the dune is wider than 15 m, the current $P_{5\%}$ is likely to be an overestimate. For the future CEHA within cell 3I, long-term erosion and storm cut has potential to completely erode the dunes and therefore the future CEHA reflect cliff response to SLR rather than dune response.

The future CEHA is largest along the unconsolidated dunes within cell 3K. This is because the dunes are expected to experience greater shoreline retreat with SLR compared to the consolidated cliffs.

The impact of vertical land movement (VLM) has potential to alter the erosion distances through changing the relative sea level rise along the coast. For the cliff shoreline the impact of VLM (uplift) is expected to reduce the erosion hazard distance 1 to 6 m. As the unconsolidated cell (3K), is more sensitive to changes in relative SLR and the impact of VLM could reduce the erosion distance by 8 to 20 m.

Table 3.4: Coastal erosion hazard widths (m) for Maketū for current, 2080 and 2130 timeframes, excluding the impact of VLM (shaded cells are mapped scenarios)

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Probability of Exceedance				
				Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
3A	Current	0.03	N/A	-1	-2	-2	-2	-3
	2080	0.4	RCP4.5	-1	-3	-3	-5	-6
		0.6	RCP8.5	-1	-3	-4	-5	-7
	2130	0.8	RCP4.5	-1	-4	-5	-8	-10
		1.25	RCP8.5	-1	-5	-5	-8	-11
		1.6	RCP8.5+	-1	-5	-5	-9	-11
3B	Current	0.03	N/A	-2	-3	-3	-4	-5
	2080	0.4	RCP4.5	-2	-5	-5	-7	-8
		0.6	RCP8.5	-2	-5	-5	-7	-9
	2130	0.8	RCP4.5	-2	-6	-6	-9	-12
		1.25	RCP8.5	-2	-6	-7	-10	-13
		1.6	RCP8.5+	-2	-6	-7	-10	-14
3C	Current	0.03	N/A	-3	-4	-4	-6	-7
	2080	0.4	RCP4.5	-3	-8	-8	-11	-14
		0.6	RCP8.5	-3	-8	-9	-12	-15
	2130	0.8	RCP4.5	-4	-10	-12	-17	-21
		1.25	RCP8.5	-4	-11	-12	-18	-23
		1.6	RCP8.5+	-4	-11	-13	-19	-24
3D	Current	0.03	N/A	-4	-5	-6	-8	-10
	2080	0.4	RCP4.5	-4	-9	-10	-13	-16
		0.6	RCP8.5	-4	-9	-10	-13	-17
	2130	0.8	RCP4.5	-5	-12	-13	-18	-23
		1.25	RCP8.5	-5	-12	-14	-19	-24
		1.6	RCP8.5+	-5	-13	-14	-20	-25
3E	Current	0.03	N/A	-5	-7	-8	-10	-12
	2080	0.4	RCP4.5	-11	-15	-15	-18	-21
		0.6	RCP8.5	-12	-16	-17	-20	-23
	2130	0.8	RCP4.5	-15	-21	-22	-26	-30
		1.25	RCP8.5	-16	-24	-25	-30	-35
		1.6	RCP8.5+	-17	-25	-27	-32	-38
3F	Current	0.03	N/A	-9	-13	-14	-17	-19
	2080	0.4	RCP4.5	-15	-22	-24	-28	-34
		0.6	RCP8.5	-16	-24	-25	-31	-37
	2130	0.8	RCP4.5	-19	-31	-32	-40	-48
		1.25	RCP8.5	-21	-34	-36	-45	-55
		1.6	RCP8.5+	-22	-36	-38	-48	-59

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Probability of Exceedance				
				Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
3G	Current	0.03	N/A	-24	-30	-32	-38	-41
	2080	0.4	RCP4.5	-29	-40	-42	-49	-54
		0.6	RCP8.5	-30	-41	-43	-51	-57
	2130	0.8	RCP4.5	-35	-48	-51	-60	-71
		1.25	RCP8.5	-37	-52	-54	-65	-78
		1.6	RCP8.5+	-38	-54	-57	-68	-83
3H	Current	0.03	N/A	-24	-33	-35	-43	-49
	2080	0.4	RCP4.5	-30	-43	-45	-54	-62
		0.6	RCP8.5	-31	-45	-47	-56	-65
	2130	0.8	RCP4.5	-36	-52	-54	-64	-74
		1.25	RCP8.5	-38	-55	-58	-69	-80
		1.6	RCP8.5+	-39	-57	-60	-72	-83
3I	Current	0.03	N/A	-5	-11	-12	-38	-55
	2080	0.4	RCP4.5	-25	-38	-40	-50	-60
		0.6	RCP8.5	-24	-38	-40	-50	-60
	2130	0.8	RCP4.5	-26	-39	-42	-52	-65
		1.25	RCP8.5	-26	-40	-42	-53	-65
		1.6	RCP8.5+	-26	-40	-43	-53	-65
3J	Current	0.03	N/A	-38	-50	-53	-63	-69
	2080	0.4	RCP4.5	-39	-51	-55	-65	-72
		0.6	RCP8.5	-40	-52	-55	-65	-72
	2130	0.8	RCP4.5	-40	-53	-56	-67	-75
		1.25	RCP8.5	-40	-54	-57	-67	-77
		1.6	RCP8.5+	-40	-54	-57	-68	-77
3K	Current	0.03	N/A	-5	-11	-12	-16	-18
	2080	0.4	RCP4.5	-15	-27	-28	-36	-42
		0.6	RCP8.5	-21	-35	-37	-47	-55
	2130	0.8	RCP4.5	-23	-42	-45	-57	-71
		1.25	RCP8.5	-37	-61	-65	-83	-101
		1.6	RCP8.5+	-48	-75	-81	-103	-124

Table 3.5: Coastal erosion hazard widths (m) for Maketū for current, 2080 and 2130 timeframes, accounting for the impacts of VLM (shaded cells are mapped scenarios)

Cell	Timeframe	SLR (m)	Approximate RCP Scenario	Relative SLR (m)[1]	Probability of Exceedance				
					Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
3A	Current	0.03	N/A	0.03	-1	-2	-2	-2	-3
	2080	0.4	RCP4.5	0.2	-1	-3	-3	-5	-6
		0.6	RCP8.5	0.4	-1	-3	-3	-5	-6
	2130	0.8	RCP4.5	0.5	-1	-4	-5	-7	-9
		1.25	RCP8.5	0.9	-1	-4	-5	-8	-10
		1.6	RCP8.5+	1.3	-1	-5	-5	-8	-11
3B	Current	0.03	N/A	0.03	-2	-3	-3	-4	-5
	2080	0.4	RCP4.5	0.2	-2	-4	-5	-6	-8
		0.6	RCP8.5	0.4	-2	-5	-5	-7	-8
	2130	0.8	RCP4.5	0.5	-2	-6	-6	-9	-11
		1.25	RCP8.5	0.9	-2	-6	-7	-9	-12
		1.6	RCP8.5+	1.3	-2	-6	-7	-10	-13
3C	Current	0.03	N/A	0.03	-3	-4	-4	-6	-7
	2080	0.4	RCP4.5	0.2	-3	-7	-8	-10	-13
		0.6	RCP8.5	0.4	-3	-8	-8	-11	-14
	2130	0.8	RCP4.5	0.5	-4	-10	-11	-16	-19
		1.25	RCP8.5	0.9	-4	-10	-12	-17	-21
		1.6	RCP8.5+	1.3	-4	-11	-12	-18	-23
3D	Current	0.03	N/A	0.03	-4	-5	-6	-8	-10
	2080	0.4	RCP4.5	0.2	-4	-8	-9	-12	-15
		0.6	RCP8.5	0.4	-4	-9	-10	-13	-16
	2130	0.8	RCP4.5	0.5	-5	-11	-12	-17	-21
		1.25	RCP8.5	0.9	-5	-12	-13	-19	-23
		1.6	RCP8.5+	1.3	-5	-12	-14	-20	-24
3E	Current	0.03	N/A	0.03	-2	-3	-3	-4	-5
	2080	0.4	RCP4.5	0.2	-10	-13	-14	-16	-18
		0.6	RCP8.5	0.4	-11	-15	-15	-18	-21
	2130	0.8	RCP4.5	0.5	-14	-19	-20	-23	-26
		1.25	RCP8.5	0.9	-15	-22	-23	-27	-31
		1.6	RCP8.5+	1.3	-16	-24	-25	-30	-35
3F	Current	0.03	N/A	0.03	-9	-14	-15	-19	-23
	2080	0.4	RCP4.5	0.2	-14	-20	-21	-25	-30
		0.6	RCP8.5	0.4	-15	-22	-24	-28	-34
	2130	0.8	RCP4.5	0.5	-18	-28	-29	-35	-43
		1.25	RCP8.5	0.9	-20	-31	-33	-41	-50

Cell	Timeframe	SLR (m)	Approximate RCP Scenario	Relative SLR (m)[1]	Probability of Exceedance				
					Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
		1.6	RCP8.5+	1.3	-21	-34	-36	-46	-55
3G	Current	0.03	N/A	0.03	-24	-32	-34	-43	-49
	2080	0.4	RCP4.5	0.2	-28	-37	-39	-46	-51
		0.6	RCP8.5	0.4	-29	-40	-42	-49	-54
	2130	0.8	RCP4.5	0.5	-34	-45	-47	-56	-65
		1.25	RCP8.5	0.9	-36	-49	-51	-61	-73
		1.6	RCP8.5+	1.3	-37	-52	-55	-65	-79
3H	Current	0.03	N/A	0.03	-24	-35	-38	-49	-58
	2080	0.4	RCP4.5	0.2	-28	-41	-43	-51	-58
		0.6	RCP8.5	0.4	-30	-43	-45	-54	-62
	2130	0.8	RCP4.5	0.5	-35	-49	-51	-60	-69
		1.25	RCP8.5	0.9	-37	-52	-55	-65	-75
		1.6	RCP8.5+	1.3	-38	-55	-58	-69	-80
3I	Current	0.03	N/A	0.03	-5	-11	-12	-38	-55
	2080	0.4	RCP4.5	0.2	-25	-38	-40	-50	-60
		0.6	RCP8.5	0.4	-24	-38	-40	-50	-60
	2130	0.8	RCP4.5	0.5	-26	-39	-42	-52	-65
		1.25	RCP8.5	0.9	-26	-40	-42	-53	-65
		1.6	RCP8.5+	1.3	-26	-40	-43	-53	-65
3J	Current	0.03	N/A	0.03	-38	-52	-56	-71	-83
	2080	0.4	RCP4.5	0.2	-39	-51	-54	-64	-71
		0.6	RCP8.5	0.4	-39	-51	-55	-65	-72
	2130	0.8	RCP4.5	0.5	-40	-53	-56	-66	-74
		1.25	RCP8.5	0.9	-40	-53	-56	-67	-76
		1.6	RCP8.5+	1.3	-40	-54	-57	-67	-77
3K	Current	0.03	N/A	0.03	-5	-11	-12	-16	-19
	2080	0.4	RCP4.5	0.2	-8	-18	-19	-25	-30
		0.6	RCP8.5	0.4	-15	-27	-28	-36	-42
	2130	0.8	RCP4.5	0.5	-13	-30	-32	-40	-52
		1.25	RCP8.5	0.9	-26	-46	-50	-63	-78
		1.6	RCP8.5+	1.3	-38	-63	-68	-86	-105

1 Accounting for average rate of VLM

4 Waihī Estuary

4.1 Site description

The Waihī Estuary is located on the southern side of the Maketū Peninsula and is enclosed by the Pukehina Spit. The site extent includes the shoreline along the Waihī Estuary shoreline as well as the shoreline along the estuary side of Pukehina Spit. The shoreline at the estuary mouth is characterised by consolidated cliffs while the rest of the shoreline is characterised by low unconsolidated estuary shoreline. Four fluvial systems drain into the system at the southern end of the estuary, including the Pukehina Canal, Pongakawa, Wharere and Kaikokopu streams. Ad-hoc erosion protection structures are present in several locations, particularly in front of the houses at the northern margin.

The site has been split into 7 cells based on the morphology, elevation and long-term trends. An overview of the cells splits is provided in Figure 4.1. Several photos taken during the site visit are provided in Figure 4.2.

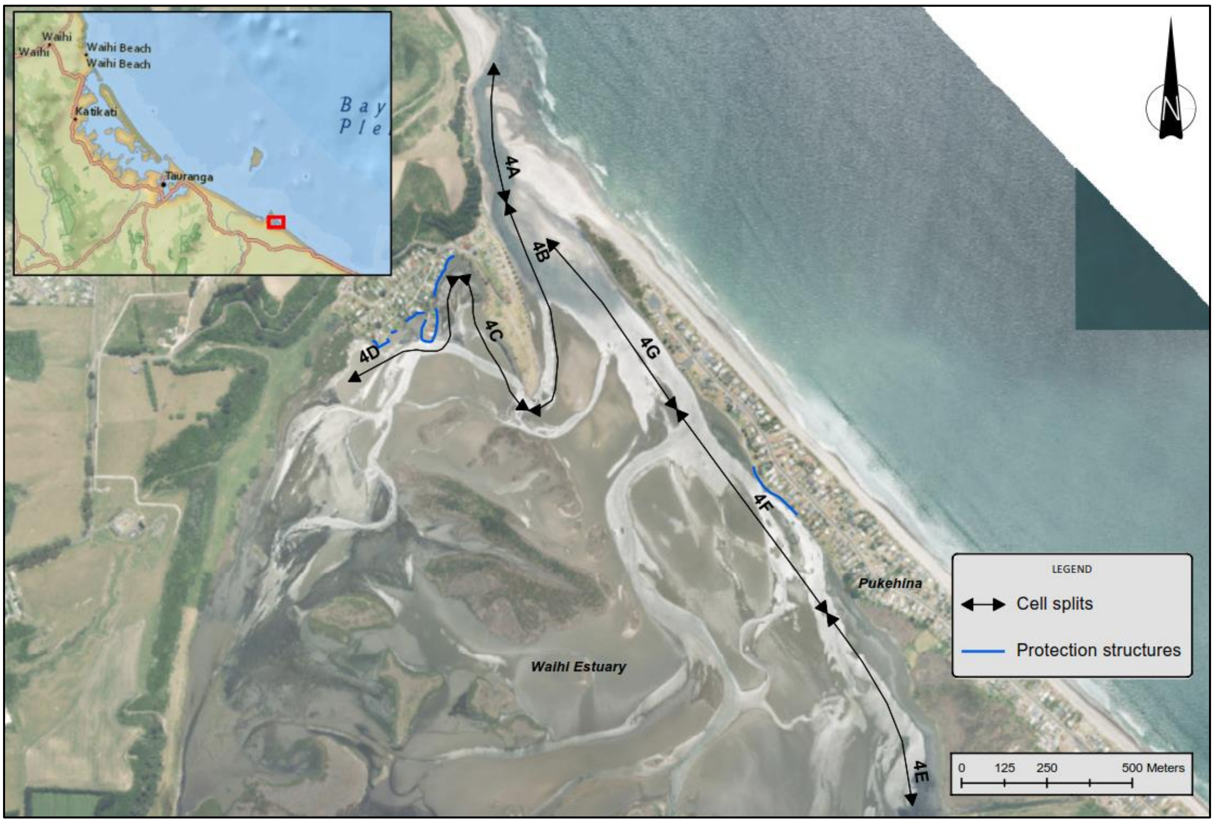


Figure 4.1: Site overview of the Waihī Estuary shoreline

Figure 4.2: Site photos along the Waihī Estuary shoreline

4.2 Morphology

The shoreline around the Waihī Estuary is predominantly characterised by narrow sandy beach fronted with shallow intertidal flats. The backshore typically comprises low-lying, unconsolidated Holocene beach deposits, except within Cell 4A where the shoreline is characterised by high consolidated cliffs comprising the Matua Subgroup (Figure 3.3). Sediments within the estuary vary from very coarse sand to fine sand.

The estuary formed following the Quaternary uplift of the Maketū Basin and has partially infilled overtime with sediment from both coastal and land-based sources. Sedimentation is minor in some areas due to potential downfaulting of the estuary along an inferred fault which runs next to the estuary and Ōkurei Point (Phizacklea, 1993). The estuary contains a number of low-lying islands, with 9.5 km of coastal perimeter and an overall area of 2.4 km^2.

Between 1943 and 1981 the southern margins of the estuary experienced accretion due to increased drainage of the Pukehina swamp area and sediment inputs from the streams. The spit on which the motor camp is located, has also accreted towards the south however there has been no apparent accretion on the northern margins of the estuary.

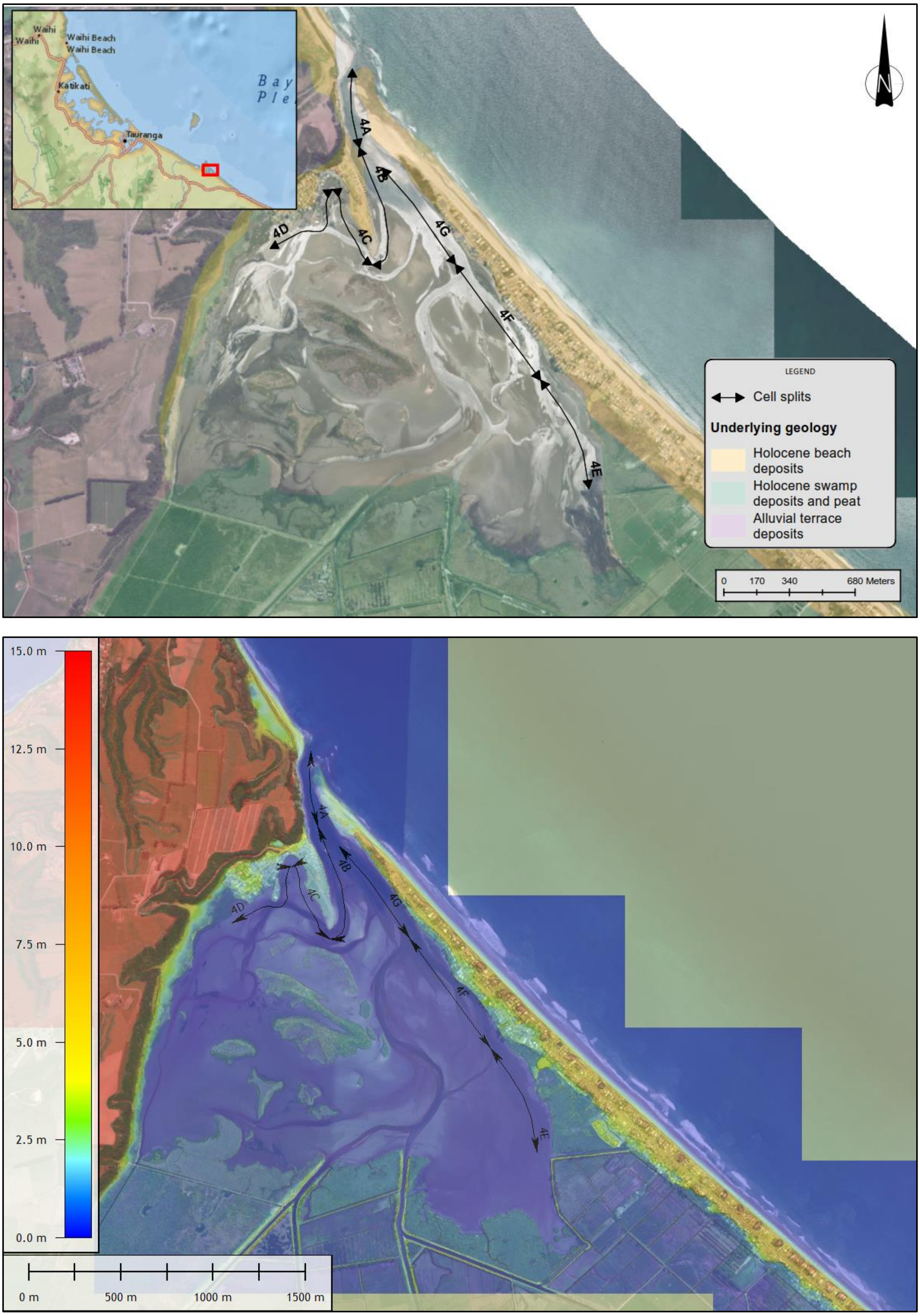


Figure 4.3: (Top) Underlying geology around the Waihī estuary. (Bottom) 2020 DEM data for Waihī estuary

4.3 Coastal processes

The Waihī Estuary covers around 2.4 square kilometres, which is almost completely exposed at low tide. The Pukehina Spit encloses most of the estuary and freshwater is supplied by the Pongakawa Stream. Based on NIWA (2019) the 200-year ARI storm tide level outside of the estuary is 1.54 m MVD-53. The shoreline is exposed to wind waves generated across the 1 to 2 km fetch from the southwest to southeast. In some locations the main tidal channel runs adjacent to the shoreline and has potential to scour the bank during peak tidal currents. Geomorphic evidence suggests there is southwards sediment transport along the estuary spit where the campground is located.

4.3.1 Short-term

Due to lack of profile data, short term storm cut along the estuary shoreline has been assessed based on SBEACH modelling (see main report, Section 5.4.2). Model results indicate the short-term storm cut along the Waihī Estuary may range from 2 to 6 m (Figure 4.4).

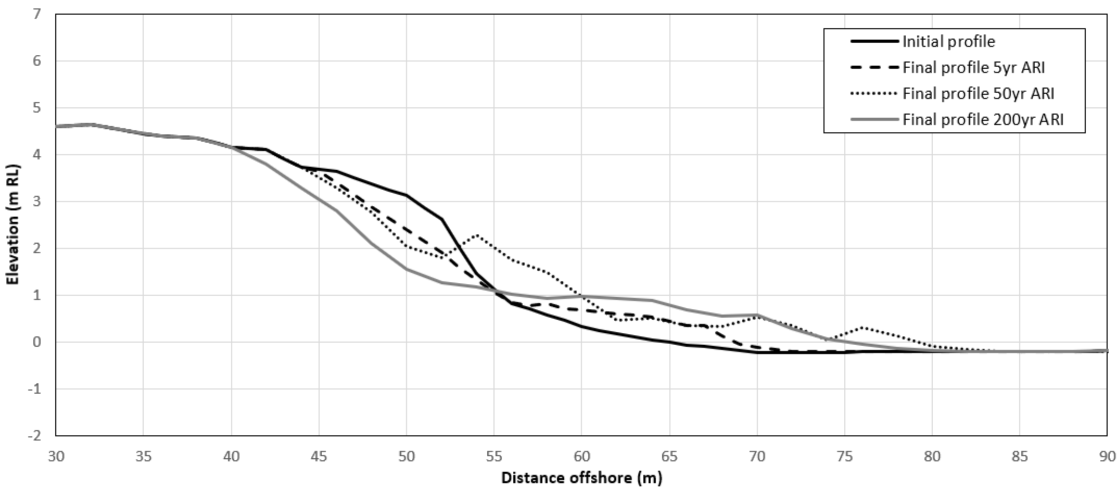


Figure 4.4: SBEACH results for a representative profile within the Waihī Estuary. The horizontal distance between the initial profile and the 200-year ARI profile at the 2.5 m RL (MVD-53) contour is shown as 6 m

Table 4.1: Adopted short-term storm cut values (m) around Waihī Estuary

Cell	Min	Mode	Max
4B to 4G	2	4	6

4.3.2 Long-term trends

Long-term trends around the Waihī Estuary have been assessed based on the historic shoreline data (Figure 4.5). The data indicates erosion of -0.12 m/yr along the cliff toe within Cell 4A at the entrance of the estuary.

The spit within Cells 4B and 4C has shown accretion at the tip towards the south, however the eastern side (Cell 4B) has shown significant erosion since 1943. This is likely to be associated with the proximity of the main tidal channel. A variety of ad-hoc protection structures have been placed along the shoreline within Cell 4C which influences the natural long-term trends, however based on the unprotected sections of shoreline the erosion rates are up to -0.08 m/yr.

For the shoreline along the western side of Pukehina Spit, the data shows long-term erosion rates ranging from 0 to -0.18 m/yr which is consistent with findings from Eco Nomos Ltd (2021).

Cell 4G is very dynamic due to its proximity to the estuary mouth. Eco Nomos Ltd (2021) suggests erosion rates range from -0.1 to -0.15m/yr. Within Cell 4F, rock protection has been placed along sections of the shoreline and Eco Nomos Ltd (2021) suggest LT -0.1 to -0.5 m/yr. Cell 4E characterised by salt marsh vegetation with minimal erosion.

Table 4.2: Adopted long-term trends (m/yr) around the Waihī Estuary shoreline

Cell	Min	Mode	Max
4A	-0.05	-0.12	-0.15
4B	-0.05	-0.1	-0.25
4C	0	-0.01	-0.05
4D	0	-0.05	-0.08
4E	0	-0.01	-0.05
4F	-0.1	-0.18	-0.25
4G	-0.1	-0.15	0.06

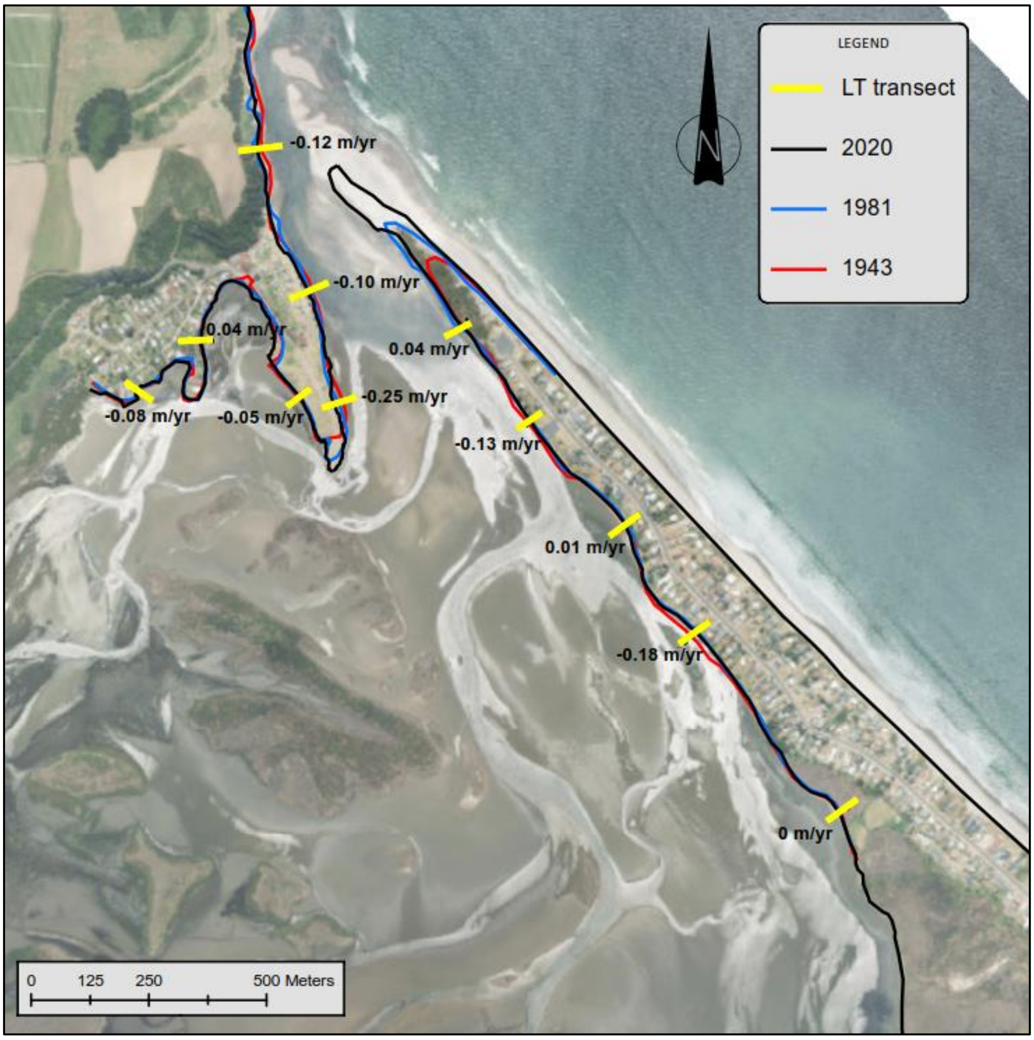


Figure 4.5: Historic shorelines along the Waihī Estuary with long term (LT) transects where regression rates have been calculated

4.3.3 Response to sea level rise

The estuary shoreline response to sea level rise (SLR) has been assessed based on the modified Bruun principle described in the main report Section 5.7.2. Based on the 2020 LiDAR, beach face slopes within Cells 4B to 4G range from 0.04 to 0.15. Due to partial sheltering from the tidal delta, the m SLR response factor for the cliffs within Cell 4A is estimated to range from 0.2 to 0.4.

4.4 Local considerations

Local considerations that may influence the coastal erosion around the Waihī Estuary include the ad-hoc protection structures which exist with Cells 4D and 4F.

4.5 Adopted component values

Adopted component values for the Waihī Estuary shoreline are presented in Table 4.2.

Table 4.3: Adopted component values for the Waihī Estuary shoreline

Cell		**4A**	**4B**	**4C**	**4D**	**4E**	**4F**	**4G**
Cell centre (NZTM)	**E**	1906391	1906534	1906438	1906270	1907690	1907251	1906896
	N	5815543	5815066	5814990	5814926	5813880	5814498	5815000
Chainage, m		0 to 400	400 to 990	990 to 1470	1470 to 2130	2130 to 2820	2820 to 3580	3580 to 4180
Morphology		Cliff	Estuary beach	Estuary beach	Estuary beach	Estuary beach	Estuary beach	Estuary beach
Short-term (m)	**Min**	N/A	2	2	2	2	2	2
	Mode		4	4	4	4	4	4
	Max		6	6	6	6	6	6
Cliff/bank height (m above toe)	**Min**	45	1.5	0.8	0.8	0.5	1	2
	Mode	50	2	0.9	1	0.8	2	4
	Max	60	2.5	1	1.5	1	2.5	7
Stable slope (°)	**Min**	45	30	30	30	30	30	30
	Mode	50	32	32	32	32	32	32
	Max	60	34	34	34	34	34	34
Long-term (m/yr) -ve erosion +ve accretion	**Min**	-0.05	-0.05	0	0	0	-0.1	0
	Mode	-0.12	-0.10	-0.01	-0.05	-0.01	-0.18	-0.1
	Max	-0.15	-0.25	-0.05	-0.08	-0.05	-0.25	-0.15
[1]SLR factor (cliffs) [2]Closure slope (beaches)	**Min**	0.2[1]	0.08[2]	0.04[2]	0.04[2]	0.04[2]	0.04[2]	0.06[2]
	Mode	0.3[1]	0.09[2]	0.06[2]	0.06[2]	0.06[2]	0.06[2]	0.10[2]
	Max	0.4[1]	0.11[2]	0.11[2]	0.11[2]	0.11[2]	0.11[2]	0.15[2]
Average VLM rate (m/yr)[1]		0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033

1 See main report Section 5.8

4.6 Coastal erosion hazard assessment

The coastal erosion hazard around Waihī Estuary has been assessed both with and without the impacts of VLM. Table 4.4 presents the erosion distances based on no future VLM and Table 4.5 presents the erosion distances accounting for future VLM. Erosion hazard distances have been offset from the 2021 seaward edge of vegetation along the estuary shoreline and the cliff toe along the cliff shoreline. $P_{50\%}$ means there is a 50% chance of an erosion distance being exceeded within that timeframe. $P_{66\%}$ can be considered a likely scenario and $P_{5\%}$ can be considered a very unlikely scenario.

The current CEHA is largest within cell 4A, and this is because it accounts for potential instability of the high cliff. The current $P_{5\%}$ CEHA width within cell 4A is -49 m. For the rest of the site the current CEHA around the estuary is between -6 to -9 m for the $P_{5\%.}$

Erosion protection structures of varying condition are present within cells 4D and 4F, however these have not been accounted for within the assessment. The CEHA represents the hazard in absence of the structures, and therefore, while these structures remain functional, the CEHA within these cells is likely to be an overprediction.

For the estuary shoreline (cells 4B to 4G), the future CEHA is dominated by the long-term trends and shoreline response to SLR. The future CEHA are largest within cells 4B and 4F where the long-term erosion rates have been highest. For the 2130 1.6 m SLR scenario the $P_{5\%}$ CEHA is up to -46 and -59 m within cells 4B and 4F, respectively. Future shoreline trends along the estuarine shoreline may be sensitive to changes in the sand bank positions within the estuary. A shift in the position of the sand banks could potentially alter the wave energy at the shoreline and change the patterns of erosion and accretion.

For the cliff within cell 4A, the sensitivity to SLR is less compared with the estuary shoreline. The slope stability component contributes almost half of the total CEHA distance, which is on average 71 m wide for the 2130 1.6m SLR $P_{5\%}$ scenario.

The impact of vertical land movement (VLM) has potential to alter the erosion distances through changing the relative sea level rise along the coast. For the Waihī Estuary shoreline the impact of VLM (uplift) has potential to reduce the erosion hazard distances by 1 to 7 m.

Table 4.4: Coastal erosion hazard widths (m) for the Waihī Estuary shoreline for current, 2080 and 2130 timeframes, excluding the impacts of VLM (shaded cells are mapped scenarios)

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Probability of Exceedance				
				Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
4A	Current	0.03	0	-27	-37	-40	-49	-58
	2080	0.4	RCP4.5	-33	-47	-49	-59	-68
		0.6	RCP8.5	-34	-48	-50	-60	-70
	2130	0.8	RCP4.5	-37	-55	-58	-68	-81
		1.25	RCP8.5	-38	-57	-60	-71	-85
		1.6	RCP8.5+	-38	-59	-62	-73	-88
4B	Current	0.03	N/A	-3	-5	-6	-7	-8
	2080	0.4	RCP4.5	-11	-16	-18	-23	-26
		0.6	RCP8.5	-13	-19	-20	-25	-28
	2130	0.8	RCP4.5	-18	-26	-28	-38	-43

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Probability of Exceedance				
				Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
		1.25	RCP8.5	-22	-31	-33	-43	-49
		1.6	RCP8.5+	-25	-35	-37	-46	-53
4C	Current	0.03	N/A	-3	-4	-5	-6	-7
	2080	0.4	RCP4.5	-7	-11	-12	-15	-19
		0.6	RCP8.5	-9	-14	-15	-19	-23
	2130	0.8	RCP4.5	-12	-18	-19	-24	-29
		1.25	RCP8.5	-16	-23	-25	-33	-39
		1.6	RCP8.5+	-19	-28	-30	-40	-47
4D	Current	0.03	N/A	-3	-5	-5	-6	-7
	2080	0.4	RCP4.5	-8	-13	-13	-17	-20
		0.6	RCP8.5	-10	-15	-16	-20	-25
	2130	0.8	RCP4.5	-12	-20	-22	-27	-33
		1.25	RCP8.5	-16	-26	-28	-36	-43
		1.6	RCP8.5+	-19	-31	-33	-43	-52
4E	Current	0.03	N/A	-3	-4	-5	-6	-7
	2080	0.4	RCP4.5	-7	-11	-12	-15	-18
		0.6	RCP8.5	-9	-14	-15	-18	-22
	2130	0.8	RCP4.5	-11	-17	-19	-24	-30
		1.25	RCP8.5	-15	-23	-25	-33	-41
		1.6	RCP8.5+	-19	-28	-30	-40	-50
4F	Current	0.03	N/A	-3	-5	-5	-7	-8
	2080	0.4	RCP4.5	-15	-21	-22	-26	-31
		0.6	RCP8.5	-17	-24	-25	-30	-36
	2130	0.8	RCP4.5	-24	-35	-37	-44	-51
		1.25	RCP8.5	-28	-41	-43	-53	-61
		1.6	RCP8.5+	-31	-46	-48	-59	-70
4G	Current	0.03	N/A	-4	-7	-7	-9	-11
	2080	0.4	RCP4.5	-9	-16	-17	-20	-24
		0.6	RCP8.5	-11	-17	-19	-23	-26
	2130	0.8	RCP4.5	-12	-23	-25	-31	-36
		1.25	RCP8.5	-15	-27	-29	-36	-43
		1.6	RCP8.5+	-18	-31	-33	-40	-49

Table 4.5: Coastal erosion hazard widths (m) for the Waihī Estuary shoreline for current, 2080 and 2130 timeframes, accounting for the impacts of VLM (shaded cells are mapped scenarios)

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Relative SLR (m)[1]	Probability of Exceedance				
					Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
4A	Current	0.03	N/A	0.03	-27	-37	-40	-49	-58
	2080	0.4	RCP4.5	0.2	-32	-45	-47	-57	-65
		0.6	RCP8.5	0.4	-33	-47	-49	-59	-68
	2130	0.8	RCP4.5	0.5	-36	-53	-55	-66	-77
		1.25	RCP8.5	0.95	-37	-56	-58	-69	-82
		1.6	RCP8.5+	1.3	-38	-58	-60	-72	-86
4B	Current	0.03	N/A	0.03	-3	-5	-6	-7	-8
	2080	0.4	RCP4.5	0.2	-9	-14	-15	-21	-24
		0.6	RCP8.5	0.4	-11	-16	-18	-23	-26
	2130	0.8	RCP4.5	0.5	-15	-23	-25	-34	-40
		1.25	RCP8.5	0.95	-19	-27	-29	-39	-44
		1.6	RCP8.5+	1.3	-22	-32	-34	-43	-49
4C	Current	0.03	N/A	0.03	-3	-4	-5	-6	-7
	2080	0.4	RCP4.5	0.2	-5	-8	-9	-11	-14
		0.6	RCP8.5	0.4	-7	-11	-12	-15	-19
	2130	0.8	RCP4.5	0.5	-9	-13	-14	-18	-22
		1.25	RCP8.5	0.95	-13	-19	-20	-26	-31
		1.6	RCP8.5+	1.3	-16	-24	-26	-34	-40
4D	Current	0.03	N/A	0.03	-3	-5	-5	-6	-7
	2080	0.4	RCP4.5	0.2	-6	-10	-10	-13	-16
		0.6	RCP8.5	0.4	-8	-13	-13	-17	-20
	2130	0.8	RCP4.5	0.5	-9	-16	-17	-21	-26
		1.25	RCP8.5	0.95	-13	-22	-23	-29	-35
		1.6	RCP8.5+	1.3	-17	-27	-29	-37	-45
4E	Current	0.03	N/A	0.03	-3	-4	-5	-6	-7
	2080	0.4	RCP4.5	0.2	-5	-8	-9	-11	-13
		0.6	RCP8.5	0.4	-7	-11	-12	-15	-18
	2130	0.8	RCP4.5	0.5	-8	-13	-14	-18	-23
		1.25	RCP8.5	0.95	-12	-19	-20	-26	-33
		1.6	RCP8.5+	1.3	-16	-24	-26	-34	-42
4F	Current	0.03	N/A	0.03	-3	-5	-5	-7	-8
	2080	0.4	RCP4.5	0.2	-12	-18	-19	-22	-26
		0.6	RCP8.5	0.4	-15	-21	-22	-26	-31
	2130	0.8	RCP4.5	0.5	-21	-31	-32	-39	-44

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Relative SLR (m)[1]	Probability of Exceedance				
					Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
		1.25	RCP8.5	0.95	-25	-36	-38	-46	-53
		1.6	RCP8.5+	1.3	-28	-42	-44	-53	-63
4G	Current	0.03	N/A	0.03	-4	-7	-7	-9	-11
	2080	0.4	RCP4.5	0.2	-7	-14	-15	-18	-21
		0.6	RCP8.5	0.4	-9	-16	-17	-20	-24
	2130	0.8	RCP4.5	0.5	-10	-20	-22	-27	-32
		1.25	RCP8.5	0.95	-13	-24	-26	-32	-38
		1.6	RCP8.5+	1.3	-16	-28	-30	-37	-44

1 Accounting for average rate of VLM

5 Pukehina

5.1 Site description

Pukehina Beach includes approximately 13 km of northeast-facing shoreline between the Waihī Estuary mouth and Ōtamarākau. The estuary side of Pukehina Spit has been included within the Waihī Estuary site (see Section 4). The northern end of the Pukehina shoreline is predominantly unconsolidated sand dunes, including the Pukehina Spit. The spit has undergone substantial residential development over the past two decades. South of the Pukehina development there are several sections of consolidated cliffs fronted with narrow beach. The Waitahanui Stream discharges at the southernmost extent of the site, near Ōtamarākau.

The site has been split into 16 cells based on variation in long term trends and dune heights and backshore morphology. A summary of the cell splits is provided in Figure 5.1. Several site photos are provided in Figure 5.2.

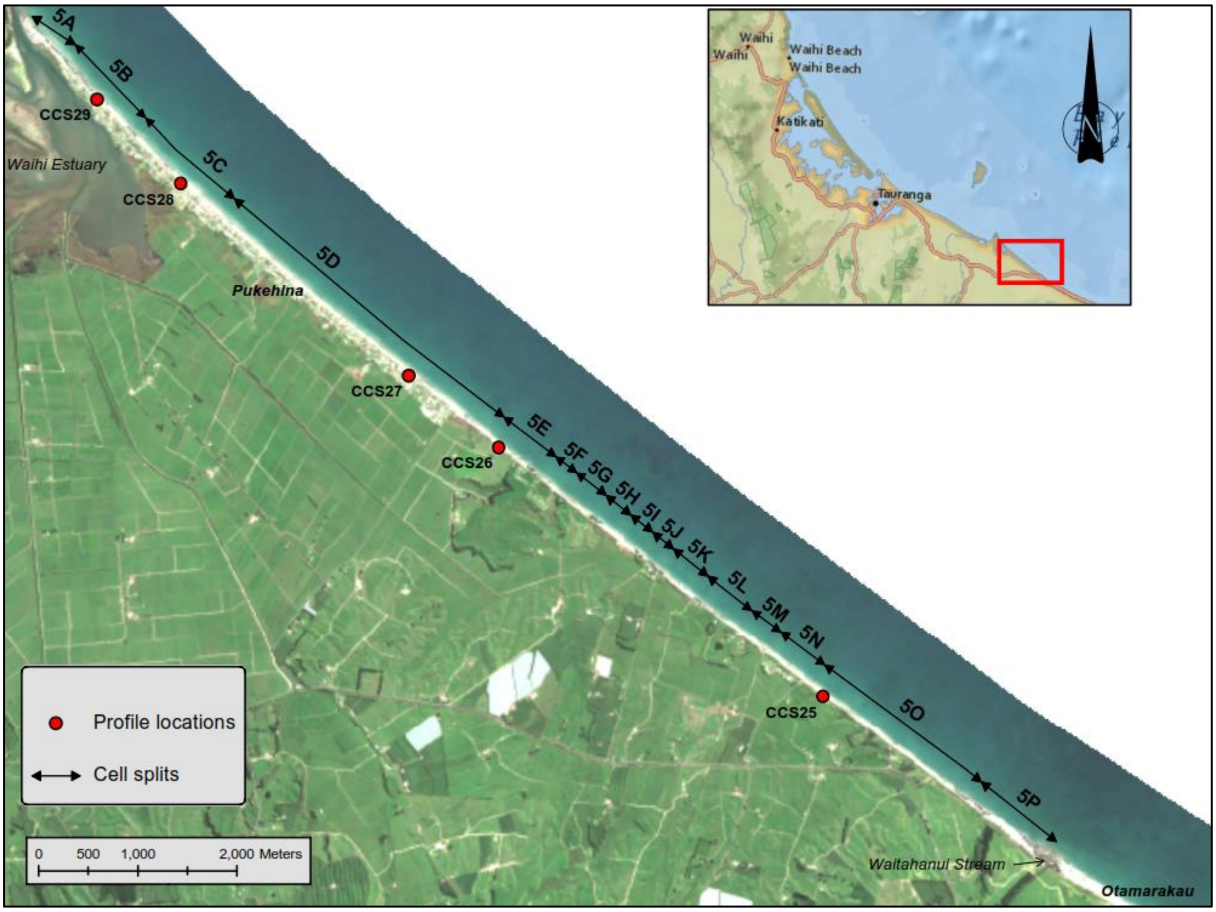


Figure 5.1: Site overview for Pukehina

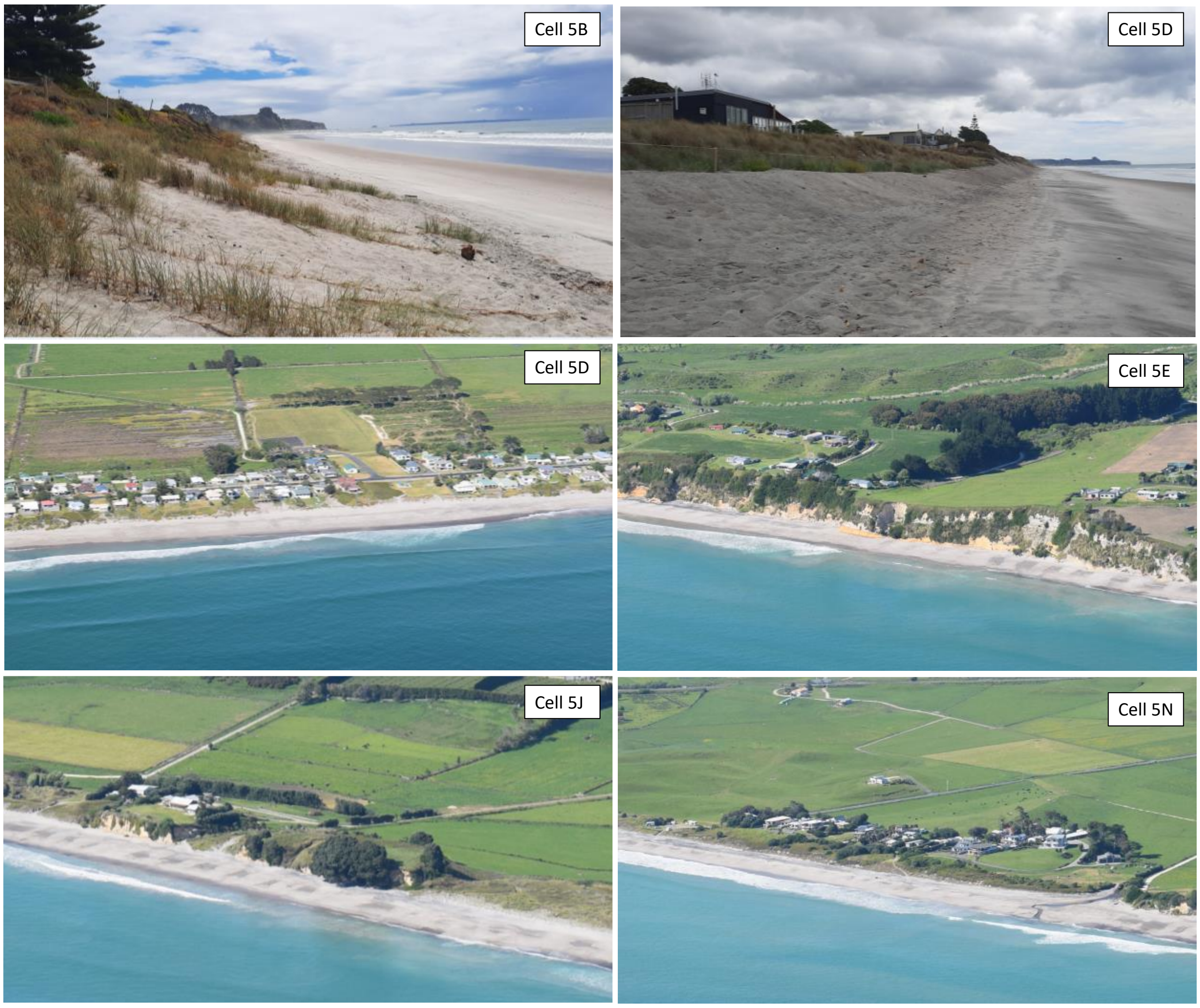


Figure 5.2: Site photos for Pukehina

5.2 Morphology

Pukehina is a narrow barrier spit consisting of late Holocene sands, which enclose the Waihī Estuary at the northern end (Figure 5.3). The barrier spit developed soon after the recent post-glacial transgression, as a result of the rapid onshore flux of sediment associated with sea level rise (SLR). Downwrapping of the Maketū Basin during the Pleistocene, faulting and collapse of the Whakatane Graben, and glacio-eustatic sea level fluctuations has led to the formation of coastal terraces within the region. Sections of the coast can be considered a veneer sand beach over a shore platform cut into a cliffed Pleistocene terrace (Phizacklea, 1993). The numerous rock outcrops contribute to the slightly coarser sands along the coast. The sections of cliff towards the southern end of the Pukehina site (Cells 5E, 5G, 5J, 5L,5M) comprise the Matua Subgroup and due to faulting different sedimentary units with different weathering resistance have become exposed at the base of the coastal cliffs.

Sediment is predominantly from fluvial sources including the Waitahanui Stream and the Waihī Estuary, as well as erosion of local submarine rock outcrops.

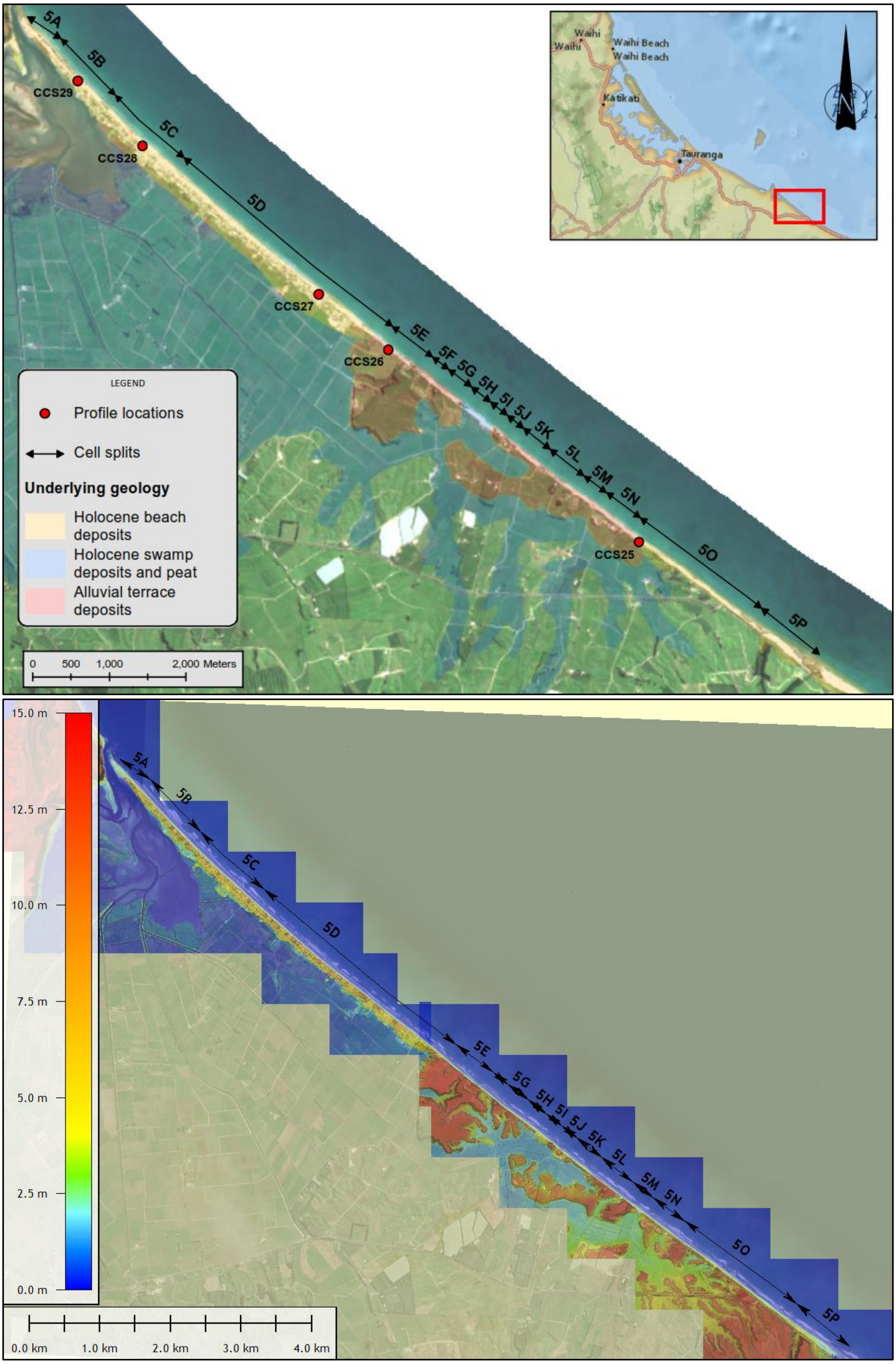


Figure 5.3: (Top) Underlying geology along Pukehina. (Bottom) 2015 (south) and 2020 (north) DEM data for Pukehina shoreline

5.3 Coastal processes

The Pukehina shoreline faces northeast and is exposed to waves from north to east. The shoreline experiences mild to moderate swell-wave energy with a moderate tidal range. Based on NIWA (2019) the 200-year ARI storm tide level is 1.54 m MVD-53 and the 200-year ARI offshore significant wave height is 7.22 m. Waves heights tend to be slightly larger towards the southern end of the site.

Some studies suggest the net littoral drift is bi-directional. The regional net littoral drift is southeasterly, however the geomorphology of the Pukehina Spit suggests that net drift in this area is northwest with a potential centre point at Ōkurei Point and another centre point near Ōtamarākau. Although, Phizacklea (1993) also highlights that spit orientation is determined by a combination of factors, including inlet channel geometry, wave energy, wave refraction and tidal flow and consequently spit orientation may sometimes be contrary to dominant littoral drift.

5.3.1 Short-term

Figure 5.4 shows recent storm cut of the dunes near profile CCS27 (Cell 5D). The short-term storm cut along Pukehina has been assessed based on the statistical analysis of beach profile data (see main report Section 5.4.1). All profile plots are shown in Appendix B. The adopted minimum, mode and maximum values are based on the 5 year, 50 year and 200 year ARI storm cut distances (Table 5.1). Figure 5.5 provides an example of the extreme value curve at profile CCS42. Storm cut is estimated to range from 5 to 20 m at the northern end (Cells 5A to 5D) and 10 to 30 m at the southern end (Cells 5F to 5P). This trend and magnitude of storm cut along the shoreline is also consistent with the findings from Eco Nomos Ltd (2003).

Figure 5.4: Example of recent storm erosion (21 August 2020) along Pukehina Beach near CCS27 (Cell 5D). Photo sourced from westernbay.govt.nz

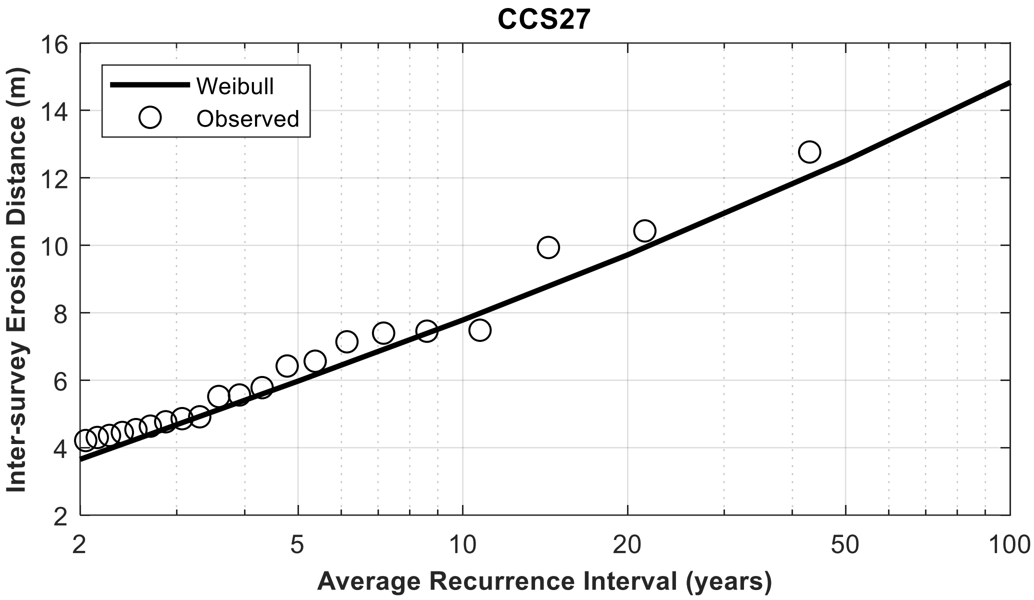


Figure 5.5: Example of extreme distribution curve at profile CCS27

Table 5.1: Adopted short-term storm cut values (m) for the cells along Pukehina

Cells	Min	Mode	Max
5A to 5D	5	10	20
5F, 5H to 5I, 5K, 5N to 5P	10	20	30

5.3.2 Long-term trends

Long-term trends have been assessed based on regression analysis of historic shorelines and beach profile data. There are differences in the trends measured from shorelines and profile data and this is largely due to the different lengths of datasets. Profiles CCS29, CCS27 and CCS26 all show long-term erosion since at least 1990 whereas the shoreline data within these locations' suggestion overall accretion since 1943 (Figure 5.6). Figure 5.7 shows the shoreline positions in comparison with the horizontal excursion distances measured from the profiles at the same locations.

At the northern end of the spit (Cells 5A and 5B), there appears to have been overall accretion between 1943 and 1992 (Figure 5.6 and Figure 5.7). This apparent in the aerial photographs which show the spit developing and vegetation growth expanding (Figure 5.8). However, following 1992 there appears to be a trend of erosion, and this is also shown in the profile data.

Further east within Cells 5C to 5D, the shoreline data shows erosion between 1943 and 1986, which includes the 1970s storm events that resulted in significant erosion along the coast. It appears that between 1986 and 1992 there was some dune recovery. However, since 1992 both the profile data and shorelines show an erosional trend.

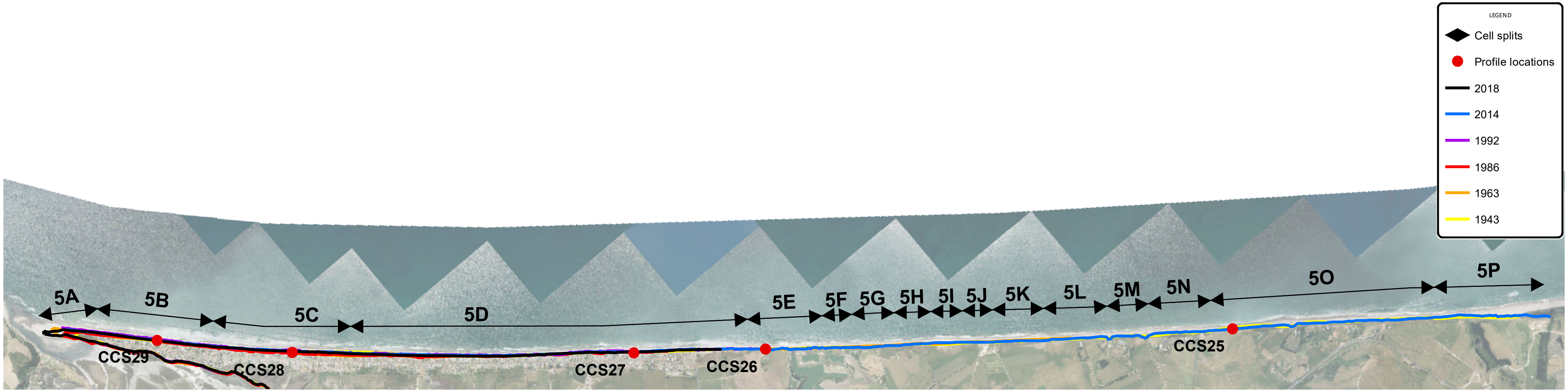
The shoreline regression analysis east of Cell 5E shows large fluctuations which are likely to be associated with the differing morphologies including, stream mouths, as well as alternating sections of cliff and dune. The data generally suggests long-term erosion along the cliff sections and sediment accumulation around historic and existing stream mouths. Historic photos from Phizacklea (1993) show erosion of the sand material along the toe of the cliff between 1977 and 1992 near profile CCS26 (Cell 5E) (Figure 5.9). The beach profile data and oblique aerials also indicate loss of beach material.

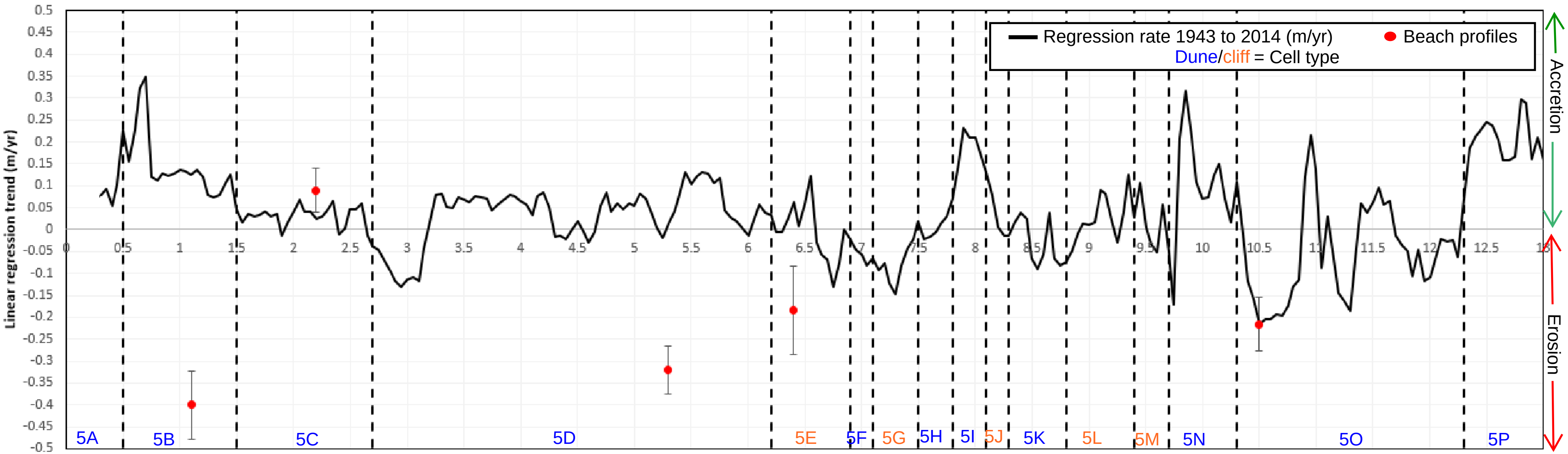
The cliff sections typically show stability or long-term erosion and this is because cliffs do not have the ability to rebuild following erosion. In contrast, where there are sections of unconsolidated dune, the shoreline has ability to rebuild and accrete.

Previous studies generally describe the beach as being stable or towards an erosive state. Healy et al. (1977) also described long-term erosion along the Pukehina shoreline and attributed it to several factors including absence of an offshore bar, Okueri Point blocking any southerly littoral drift and the Waihī estuary acting as a sediment sink. Phizacklea (1993) described the Pukehina shoreline as being stable, tending towards an erosive state with historic erosion rates ranging from 0 to -0.2 m/yr. Eco Nomos Ltd (2003) attributes most of the shoreline changes to duneline fluctuations related with storm cut and recovery instead of long-term trends. Although the significant erosion over the last 40 years and lack of full dune recovery could suggest that there is a long-term recession trend.

Overall, the long-term trends along the Pukehina coast are difficult to establish, particularly at the northern end where there have been dynamic fluctuations associated with storm erosion and beach recovery. Adopted long-term trends have been based on both the analysis of shoreline and beach profile data, recognising historic fluctuations and a general trend of long-term erosion over the last 30 years. Adopted long-term trends for each cell are presented in Table 5.2.

Since completion of the long-term shoreline analysis, additional aerial imagery was captured in 2021 following the May/June storm events. The 2021 shoreline has been adopted as the baseline; however, it has not been included in the long-term analysis. A sensitivity analysis was completed to check if the inclusion of the 2021 shoreline would influence the long-term rates. Due to the short timeframe between 2018 and 2021, the addition of the 2021 shoreline position had minimal impact on the long-term rates and therefore since the long-term analysis had already been completed, the 2021 shoreline was excluded.





Notes:

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Tonkin+Taylor

105 Carlton Gore Rd, Newmarket, Auckland
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CHECKED	TDS	Jul.21
APPROVED	RCH	Jul.21

ARCFILE
ShorelinePlotPukehina.mxd

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Western Bay of Plenty Coastal Erosion

Pukehina

Long term trend analysis

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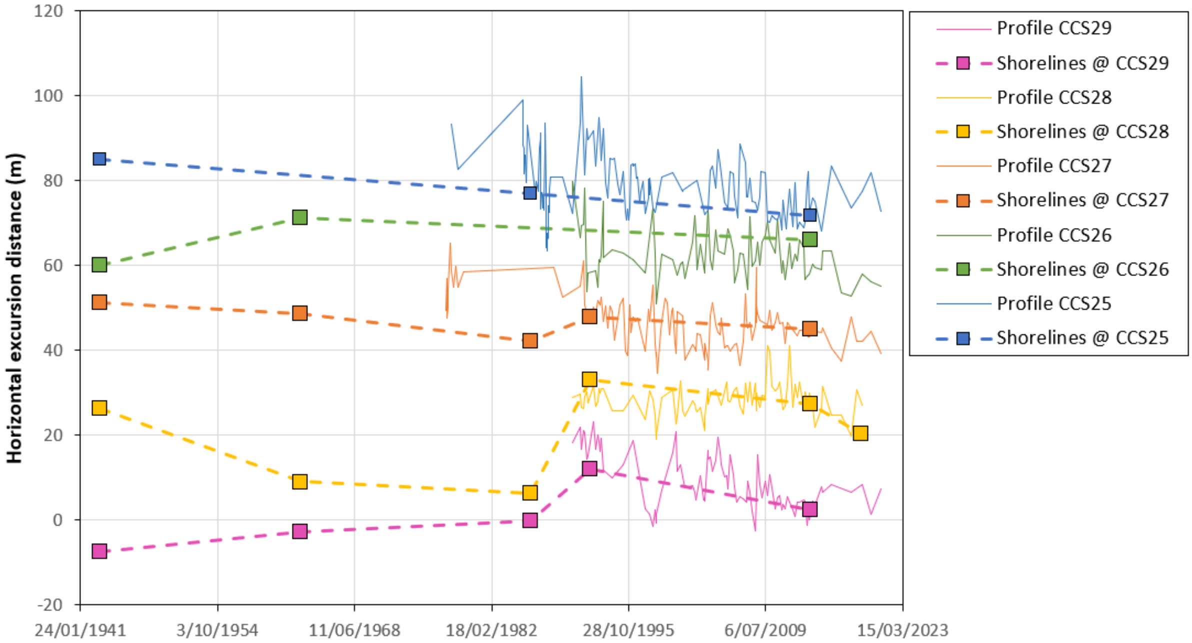

Figure 5.7: Horizontal excursion distances measured from the profile data (at the 2.5m RL MVD-53 contour) and the historic shorelines derived from aerial photographs at equivalent locations

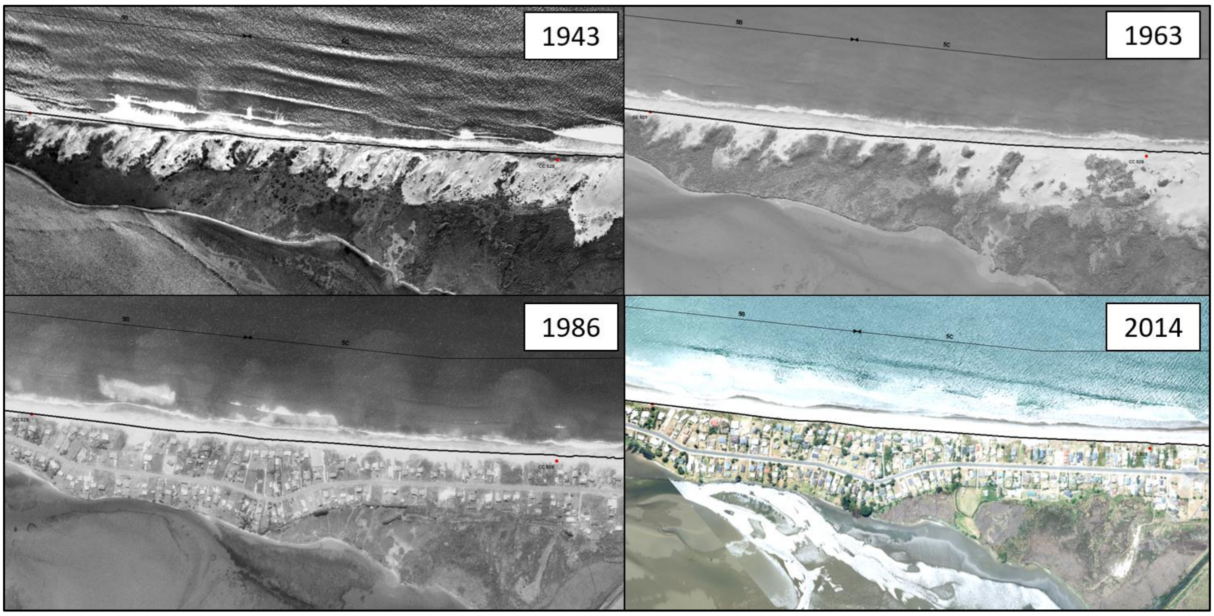

Figure 5.8: Historic aerial photographs for the Pukehina Spit overlaid with the 2018 shoreline position (black line)

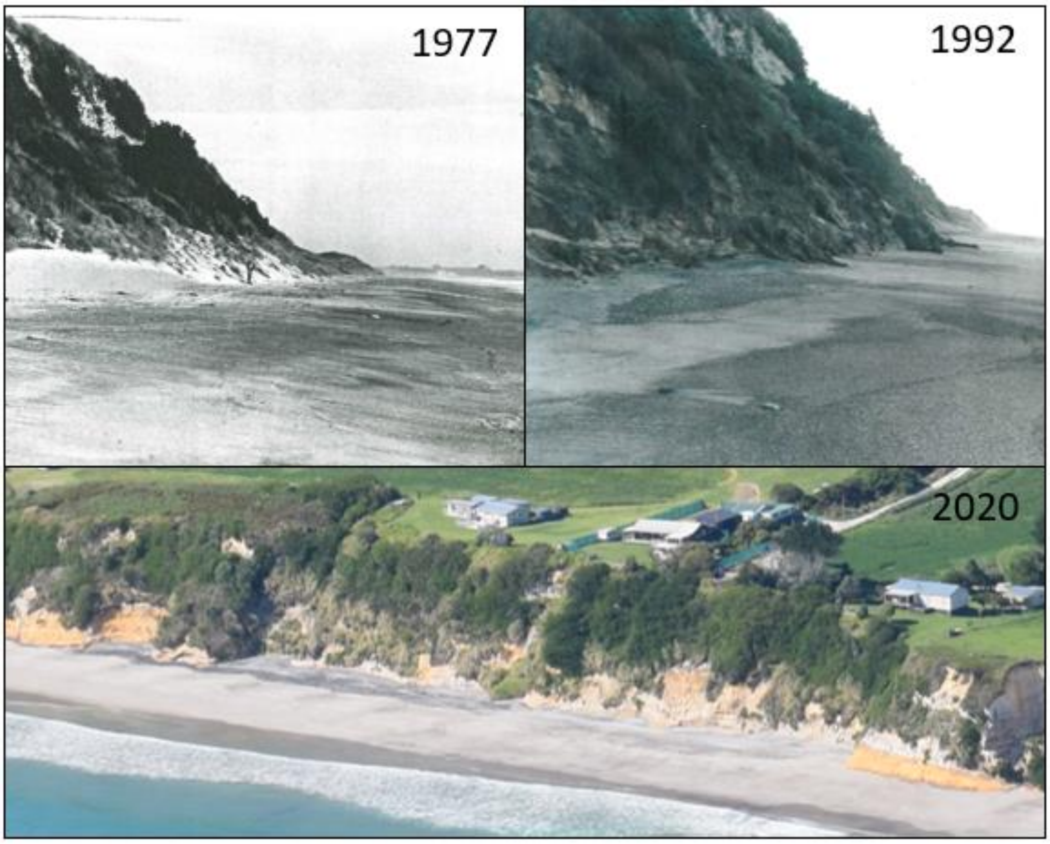

Figure 5.9: Historic photos showing erosion of dune material along the toe of the Pukehina cliffs (Cell 5E). 1977 and 1992 photographs sourced from Phizacklea (1993). 2020 photograph taken by T+T

Table 5.2: Adopted long-term trends for the cells along Pukehina (m/yr)

Cell	Min	Mode	Max
5A	0.1	-0.15	-0.3
5B	0.1	-0.15	-0.3
5C	0.05	0.02	-0.05
5D	0.08	-0.1	-0.3
5E	0	-0.1	-0.22
5F	0	-0.05	-0.08
5G	0	-0.05	-0.1
5H	0.05	0	-0.05
5I	0.05	0	-0.05
5J	0	-0.05	-0.1
5K	0.05	-0.05	-0.1
5L	0	-0.05	-0.1
5M	0	-0.05	-0.1
5N	0.1	0	-0.05
5O	0	-0.1	-0.22
5P	0.1	0	-0.1

5.3.3 Response to sea level rise

For the unconsolidated dunes along Pukehina, the shoreline response to SLR has been assessed using the Bruun Response model described in Section 5.7.2 of the main report.

The offshore wave heights and subsequently the closure depths, are slightly larger towards the southern end of the shoreline. Response to SLR is expected to vary along the shoreline due to the differing dune heights and closure depths (Table 5.3).

Table 5.3: Contour levels used to assess the effects of SLR on extents of active profiles along the Pukehina shoreline

Parameter bounds	Contour levels (m RL)	Cells 5A-5B (CCS29)	Cell 5C (CCS28)	Cell 5D (CCS27)	Cell 5F (CCS26)	Cells 5H, 5I, 5K, 5N, 5O (CCS25)
Lower bound slope	Average dune toe	2.5	2.5	2.5	2.5	2.5
	Average low water mark	-0.5	-0.5	-0.5	-0.5	-0.5
Modal slope	Average dune crest	8	13	9	10	8
	Zero flux depth	-5	-5	-5	-5	-5
Upper bound slope	Average dune crest	8	13	9	10	8
	Inner Hallermeier closure depth	-11	-11	-11.9	-11.9	-11.9

For the consolidated cliff cells the shoreline response to SLR has been assessed based on the model proposed by Ashton et al. (2011) (see main report Section 5.7.3). SLR response factors are estimated to range from 0.2 to 0.4 for the cliffs at the southern end of Pukehina.

5.4 Cliff instability

Cliff instability due to coastal erosion along Cells 5E, 5G, 5J, 5L and 5M has been assessed based on the cliff heights and assumed stable slopes (see main report Section 5.5.3). Based on site observations and previous literature, slope failures are typically shallow, translational landslips. Adopted stable slopes have been based on the existing slopes which range from 45° to 60° (Figure 5.10). Cliff heights are largest within Cell 5E where heights range from 20 to 27 m high.

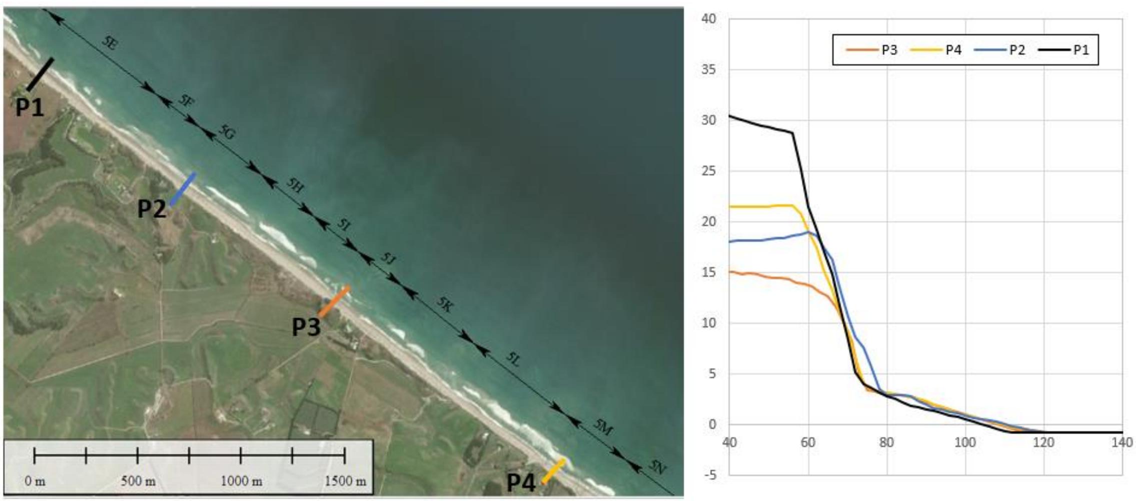

Figure 5.10: Example of cliff slopes along the Pukehina shoreline (derived from 2015 LiDAR 1 m DEM)

5.5 Local considerations

A local consideration which may influence coastal erosion along the Pukehina shoreline is the sand extraction which has occurred at Ōtamarākau. Historically sand extraction occurred on a fairly limited scale between Ōtamarākau and Hauone. Healy et al. (1977) described the extraction as having a detrimental effect on the nearshore beach-dune system with localised dune recession at Ōtamarākau. Although Phizacklea (1993) stated that apart from major destruction of the frontal dune and the only dune ridge, the beach system appears to have been able to cope with present extraction rates, with the nearby Waitahanui Stream probably helping to replenish extracted sand losses.

5.6 Adopted component values

A summary of the adopted component values for the Pukehina shoreline are provided in Table 5.4.

Table 5.4: Adopted component values for the Pukehina shoreline

Cell		5A	5B	5C	5D	5E	5F	5G	5H	5I	5J	5K	5L	5M	5N	5O	5P
Cell centre (NZTM)	**E**	1906744	1907240	1908040	1909830	1911480	1911839	1912096	1912380	1912606	1912812	1913092	1913506	1913868	1914238	1915289	1916416
	N	5815281	5814764	5813965	5812414	5811101	5810806	5810603	5810391	5810221	5810055	5809840	5809518	5809239	5808972	5808204	5807337
Chainage, m (from W)		0 to 315	315 to 1290	1290 to 2520	2520 to 6010	6010 to 6670	6670 to 6940	6940 to 7300	7300 to 7640	7640 to 7910	7910 to 8170	8170 to 8570	8570 to 9130	9130 to 9445	9445 to 9935	9935 to 11885	11885 to 12885
Morphology		Beach	Beach	Beach	Beach	Cliff	Beach	Cliff	Beach	Beach	Cliff	Beach	Cliff	Cliff	Beach	Beach	Beach
Short-term (m)	**Min**	5	5	5	5	N/A	10	N/A	10	10	N/A	10	N/A	N/A	10	10	10
	Mode	10	10	10	10		20		20	20		20			20	20	20
	Max	20	20	20	20		30		30	30		30			30	30	30
Cliff/dune height (m above toe)	**Min**	4	4	5	6	20	3	13	7	1.5	9	3	11	15	3	5	1
	Mode	4.5	5	6	7	23	4	15	8	1.8	10	5	13	18	4	7	2
	Max	5	7	10	11	27	6.5	25	9	2	11	8	15	19	5	9.5	3
Stable slope (°)	**Min**	30	30	30	30	45	30	45	30	30	45	30	45	45	30	30	30
	Mode	32	32	32	32	50	32	50	32	32	50	32	50	50	32	32	32
	Max	34	34	34	34	60	34	60	34	34	60	34	60	60	34	34	34
Long-term (m/yr) -ve erosion +ve accretion	**Min**	0.1	0.1	0.05	0.08	0	0	0	0.05	0.05	0	0.05	0	0	0.1	0	0.1
	Mode	-0.15	-0.15	0.02	-0.1	-0.1	-0.05	-0.05	0	0	-0.05	-0.05	-0.05	-0.05	0	-0.1	0
	Max	-0.3	-0.3	-0.05	-0.3	-0.22	-0.08	-0.1	-0.05	-0.05	-0.1	-0.1	-0.1	-0.1	-0.05	-0.22	-0.1
[1]SLR factor (cliffs) [2]Closure slope (beaches)	**Min**	0.050[2]	0.050[2]	0.040[2]	0.050[2]	0.2[1]	0.050[2]	0.2[1]	0.050[2]	0.050[2]	0.2[1]	0.050[2]	0.2[1]	0.2[1]	0.050[2]	0.050[2]	0.050[2]
	Mode	0.031[2]	0.031[2]	0.039[2]	0.039[2]	0.3[1]	0.039[2]	0.3[1]	0.039[2]	0.039[2]	0.3[1]	0.039[2]	0.3[1]	0.3[1]	0.039[2]	0.039[2]	0.039[2]
	Max	0.021[2]	0.021[2]	0.025[2]	0.230[2]	0.4[1]	0.022[2]	0.4[1]	0.023[2]	0.023[2]	0.4[1]	0.023[2]	0.4[1]	0.4[1]	0.023[2]	0.023[2]	0.023[2]
Average VLM rate (m/yr)[1]		0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035

1 See main report Section 5.8

5.7 Coastal erosion hazard assessment

The coastal erosion hazard along Pukehina has been assessed both with and without the impacts of VLM. Table 5.5 presents the erosion distances based on no future VLM and Table 5.6 presents the erosion distances accounting for future VLM. Erosion hazard distances have been offset from the 2021 seaward edge of vegetation. $P_{50\%}$ means there is a 50% chance of an erosion distance being exceeded within that timeframe. $P_{66\%}$ can be considered a likely scenario and $P_{5\%}$ can be considered a very unlikely scenario.

The current $P_{5\%}$ CEHA for the unconsolidated dune cells ranges from -21 to -33 m and tends to be largest at the eastern end of the beach where the storm cut is slightly higher. For the cliff cells the current $P_{5\%}$ ranges from -9 to -22 m and is highest within cell 5E where the cliff heights are largest and therefore the slope stability component is greatest.

Variations in the future CEHA are largely due to differences in long-term trends, shoreline response to SLR and backshore morphology. For the unconsolidated dunes, the 2130 1.6 m $P_{5\%}$ CEHA ranges from -68 m (cell 5D) up to -99 m (cells 5A, 5B and 5O).

For cells 5E to 5O the backshore morphology is complex with small sections of Pleistocene cliffs between unconsolidated dunes and subsequently there are significant variations in the future CEHA width along this section of coast. For the cells characterised by consolidated cliff (cell 5E, 5G, 5J, 5L and 5M), the future CEHA is smaller compared with the adjacent unconsolidated dunes. This is due to a combination of lower long-term erosion rates along the cliffs and reduced sensitivity to increases in SLR. The 2130 1.6m $P_{5\%}$ CEHA ranges from -25 to -56 m for the cliff cells and is highest within cell 5E where cliff heights are greatest.

The impact of vertical land movement (VLM) has potential to alter the erosion distances through changing the relative sea level rise along the coast. For the Pukehina shoreline the impact of VLM (uplift) has potential to reduce the erosion hazard distances by 1 to 13 m. As the unconsolidated dune cells are more sensitive to changes in relative SLR, VLM is expected to have a greater impact on the erosion distance compared with the consolidated cliff cells.

Table 5.5: Coastal erosion hazard widths (m) for the Pukehina shoreline for current, 2080 and 2130 timeframes, excluding the impacts of VLM (shaded cells are mapped scenarios)

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Probability of Exceedance				
				Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
5A	Current	0.03	0	-9	-14	-15	-21	-24
	2080	0.4	RCP4.5	-14	-32	-35	-44	-54
		0.6	RCP8.5	-18	-38	-41	-51	-62
	2130	0.8	RCP4.5	-20	-48	-53	-69	-85
		1.25	RCP8.5	-30	-61	-66	-85	-104
		1.6	RCP8.5+	-38	-71	-77	-98	-120
5B	Current	0.03	N/A	-8	-14	-16	-22	-25
	2080	0.4	RCP4.5	-15	-32	-35	-45	-55
		0.6	RCP8.5	-20	-38	-41	-52	-64
	2130	0.8	RCP4.5	-21	-49	-53	-70	-86
		1.25	RCP8.5	-31	-62	-67	-86	-106

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Probability of Exceedance				
				Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
		1.6	RCP8.5+	-38	-72	-77	-99	-122
5C	Current	0.03	N/A	-10	-16	-17	-23	-27
	2080	0.4	RCP4.5	-18	-27	-28	-35	-42
		0.6	RCP8.5	-24	-32	-34	-41	-50
	2130	0.8	RCP4.5	-26	-38	-40	-48	-58
		1.25	RCP8.5	-38	-50	-53	-63	-76
		1.6	RCP8.5+	-46	-60	-63	-75	-89
5D	Current	0.03	N/A	-10	-16	-18	-24	-28
	2080	0.4	RCP4.5	-17	-33	-35	-45	-56
		0.6	RCP8.5	-21	-38	-41	-51	-63
	2130	0.8	RCP4.5	-22	-47	-52	-68	-84
		1.25	RCP8.5	-32	-59	-64	-82	-103
		1.6	RCP8.5+	-40	-68	-73	-93	-118
5E	Current	0.03	N/A	-12	-17	-18	-22	-26
	2080	0.4	RCP4.5	-14	-25	-27	-35	-44
		0.6	RCP8.5	-14	-26	-29	-37	-48
	2130	0.8	RCP4.5	-14	-32	-35	-49	-60
		1.25	RCP8.5	-14	-34	-38	-54	-67
		1.6	RCP8.5+	-14	-35	-39	-56	-72
5F	Current	0.03	N/A	-13	-22	-24	-31	-34
	2080	0.4	RCP4.5	-24	-35	-37	-45	-54
		0.6	RCP8.5	-28	-41	-43	-52	-63
	2130	0.8	RCP4.5	-33	-48	-50	-61	-72
		1.25	RCP8.5	-43	-59	-62	-77	-91
		1.6	RCP8.5+	-50	-68	-72	-89	-106
5G	Current	0.03	N/A	-8	-12	-13	-19	-24
	2080	0.4	RCP4.5	-9	-17	-18	-24	-29
		0.6	RCP8.5	-9	-17	-19	-24	-31
	2130	0.8	RCP4.5	-10	-20	-22	-29	-38
		1.25	RCP8.5	-10	-21	-23	-31	-41
		1.6	RCP8.5+	-10	-22	-24	-32	-42
5H	Current	0.03	N/A	-16	-25	-26	-33	-37
	2080	0.4	RCP4.5	-24	-35	-37	-45	-53
		0.6	RCP8.5	-28	-41	-43	-51	-61
	2130	0.8	RCP4.5	-29	-46	-48	-58	-70
		1.25	RCP8.5	-39	-57	-60	-74	-89
		1.6	RCP8.5+	-47	-66	-70	-86	-104
5I	Current	0.03	N/A	-11	-20	-21	-28	-31
	2080	0.4	RCP4.5	-18	-30	-32	-40	-48

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Probability of Exceedance				
				Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
		0.6	RCP8.5	-22	-36	-38	-46	-55
	2130	0.8	RCP4.5	-26	-41	-43	-53	-66
		1.25	RCP8.5	-36	-52	-55	-69	-85
		1.6	RCP8.5+	-43	-61	-64	-81	-100
5J	Current	0.03	N/A	-5	-7	-8	-9	-11
	2080	0.4	RCP4.5	-6	-11	-12	-15	-19
		0.6	RCP8.5	-6	-12	-13	-16	-20
	2130	0.8	RCP4.5	-6	-14	-16	-22	-27
		1.25	RCP8.5	-6	-15	-17	-24	-31
		1.6	RCP8.5+	-6	-16	-18	-25	-33
5K	Current	0.03	N/A	-13	-23	-24	-31	-36
	2080	0.4	RCP4.5	-22	-35	-37	-45	-55
		0.6	RCP8.5	-26	-40	-43	-52	-62
	2130	0.8	RCP4.5	-29	-47	-50	-61	-74
		1.25	RCP8.5	-39	-59	-62	-76	-92
		1.6	RCP8.5+	-47	-68	-71	-88	-106
5L	Current	0.03	N/A	-7	-9	-10	-12	-14
	2080	0.4	RCP4.5	-7	-13	-14	-18	-22
		0.6	RCP8.5	-7	-14	-15	-19	-24
	2130	0.8	RCP4.5	-7	-17	-18	-24	-31
		1.25	RCP8.5	-7	-18	-19	-26	-34
		1.6	RCP8.5+	-7	-18	-20	-28	-36
5M	Current	0.03	N/A	-9	-13	-13	-16	-18
	2080	0.4	RCP4.5	-10	-17	-18	-22	-26
		0.6	RCP8.5	-10	-17	-18	-23	-27
	2130	0.8	RCP4.5	-11	-20	-22	-28	-33
		1.25	RCP8.5	-11	-21	-23	-30	-36
		1.6	RCP8.5+	-11	-22	-24	-31	-38
5N	Current	0.03	N/A	-13	-21	-23	-30	-33
	2080	0.4	RCP4.5	-18	-31	-33	-41	-50
		0.6	RCP8.5	-22	-36	-39	-47	-58
	2130	0.8	RCP4.5	-21	-41	-43	-54	-67
		1.25	RCP8.5	-30	-52	-55	-69	-85
		1.6	RCP8.5+	-37	-61	-65	-81	-99
5O	Current	0.03	N/A	-15	-24	-26	-33	-37
	2080	0.4	RCP4.5	-26	-41	-43	-52	-63
		0.6	RCP8.5	-31	-46	-49	-58	-71
	2130	0.8	RCP4.5	-37	-56	-59	-72	-90
		1.25	RCP8.5	-46	-68	-71	-87	-109

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Probability of Exceedance				
				Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
		1.6	RCP8.5+	-53	-77	-81	-98	-123
5P	Current	0.03	N/A	-11	-20	-22	-28	-32
	2080	0.4	RCP4.5	-16	-30	-33	-41	-50
		0.6	RCP8.5	-21	-36	-38	-47	-58
	2130	0.8	RCP4.5	-21	-41	-44	-56	-74
		1.25	RCP8.5	-32	-52	-56	-70	-92
		1.6	RCP8.5+	-40	-61	-65	-82	-106

Table 5.6: Coastal erosion hazard widths (m) for the Pukehina shoreline for current, 2080 and 2130 timeframes, accounting for the impacts of VLM (shaded cells are mapped scenarios)

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Relative SLR (m)[1]	Probability of Exceedance				
					Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
5A	Current	0.03	0	0.03	-9	-14	-15	-21	-24
	2080	0.4	RCP4.5	0.2	-11	-26	-28	-38	-47
		0.6	RCP8.5	0.4	-15	-32	-34	-45	-54
	2130	0.8	RCP4.5	0.5	-13	-39	-44	-59	-72
		1.25	RCP8.5	0.95	-22	-51	-56	-73	-89
		1.6	RCP8.5+	1.3	-30	-63	-68	-87	-106
5B	Current	0.03	N/A	0.03	-8	-14	-16	-22	-25
	2080	0.4	RCP4.5	0.2	-11	-26	-29	-39	-48
		0.6	RCP8.5	0.4	-16	-32	-35	-45	-55
	2130	0.8	RCP4.5	0.5	-12	-40	-45	-60	-75
		1.25	RCP8.5	0.95	-22	-52	-57	-73	-92
		1.6	RCP8.5+	1.3	-30	-63	-69	-88	-109
5C	Current	0.03	N/A	0.03	-10	-16	-17	-23	-27
	2080	0.4	RCP4.5	0.2	-14	-21	-22	-29	-35
		0.6	RCP8.5	0.4	-19	-27	-28	-35	-42
	2130	0.8	RCP4.5	0.5	-19	-29	-31	-39	-47
		1.25	RCP8.5	0.95	-29	-41	-43	-51	-63
		1.6	RCP8.5+	1.3	-40	-52	-54	-65	-79
5D	Current	0.03	N/A	0.03	-10	-16	-18	-24	-28
	2080	0.4	RCP4.5	0.2	-11	-28	-30	-40	-48
		0.6	RCP8.5	0.4	-15	-33	-36	-46	-55
	2130	0.8	RCP4.5	0.5	-14	-39	-43	-60	-74
		1.25	RCP8.5	0.95	-22	-50	-54	-71	-90
		1.6	RCP8.5+	1.3	-31	-61	-65	-84	-106
5E	Current	0.03	N/A	0.03	-12	-17	-18	-22	-26
	2080	0.4	RCP4.5	0.2	-14	-24	-26	-32	-40

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Relative SLR (m)[1]	Probability of Exceedance				
					Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
		0.6	RCP8.5	0.4	-14	-25	-27	-35	-44
	2130	0.8	RCP4.5	0.5	-14	-30	-33	-45	-54
		1.25	RCP8.5	0.95	-14	-33	-36	-50	-62
		1.6	RCP8.5+	1.3	-14	-34	-38	-54	-68
5F	Current	0.03	N/A	0.03	-13	-22	-24	-31	-34
	2080	0.4	RCP4.5	0.2	-19	-30	-32	-39	-44
		0.6	RCP8.5	0.4	-24	-35	-37	-45	-52
	2130	0.8	RCP4.5	0.5	-27	-40	-42	-51	-59
		1.25	RCP8.5	0.95	-36	-51	-53	-64	-76
		1.6	RCP8.5+	1.3	-44	-61	-64	-78	-94
5G	Current	0.03	N/A	0.03	-8	-12	-13	-19	-24
	2080	0.4	RCP4.5	0.2	-9	-16	-17	-22	-28
		0.6	RCP8.5	0.4	-9	-17	-18	-24	-29
	2130	0.8	RCP4.5	0.5	-10	-19	-21	-27	-36
		1.25	RCP8.5	0.95	-10	-20	-22	-30	-39
		1.6	RCP8.5+	1.3	-10	-21	-23	-31	-41
5H	Current	0.03	N/A	0.03	-16	-25	-26	-33	-37
	2080	0.4	RCP4.5	0.2	-19	-30	-32	-39	-46
		0.6	RCP8.5	0.4	-23	-35	-37	-45	-54
	2130	0.8	RCP4.5	0.5	-25	-38	-40	-49	-58
		1.25	RCP8.5	0.95	-33	-48	-51	-61	-75
		1.6	RCP8.5+	1.3	-41	-59	-62	-75	-91
5I	Current	0.03	N/A	0.03	-11	-20	-21	-28	-31
	2080	0.4	RCP4.5	0.2	-15	-25	-27	-34	-39
		0.6	RCP8.5	0.4	-19	-30	-32	-40	-48
	2130	0.8	RCP4.5	0.5	-20	-33	-35	-44	-52
		1.25	RCP8.5	0.95	-29	-43	-46	-57	-68
		1.6	RCP8.5+	1.3	-37	-54	-57	-70	-84
5J	Current	0.03	N/A	0.03	-5	-7	-8	-9	-11
	2080	0.4	RCP4.5	0.2	-6	-11	-11	-14	-17
		0.6	RCP8.5	0.4	-6	-11	-12	-15	-19
	2130	0.8	RCP4.5	0.5	-6	-13	-15	-20	-24
		1.25	RCP8.5	0.95	-6	-15	-16	-22	-28
		1.6	RCP8.5+	1.3	-6	-15	-17	-24	-31
5K	Current	0.03	N/A	0.03	-13	-23	-24	-31	-36
	2080	0.4	RCP4.5	0.2	-18	-30	-32	-39	-47
		0.6	RCP8.5	0.4	-23	-35	-37	-45	-55
	2130	0.8	RCP4.5	0.5	-23	-39	-42	-51	-62
		1.25	RCP8.5	0.95	-32	-50	-53	-64	-78

Cell	Timeframe	SLR (m)	Approximate RCP scenario	Relative SLR (m)[1]	Probability of Exceedance				
					Min	$P_{66\%}$	$P_{50\%}$	$P_{5\%}$	Max
		1.6	RCP8.5+	1.3	-40	-60	-63	-77	-94
5L	Current	0.03	N/A	0.03	-7	-9	-10	-12	-14
	2080	0.4	RCP4.5	0.2	-7	-13	-14	-17	-21
		0.6	RCP8.5	0.4	-7	-13	-14	-18	-22
	2130	0.8	RCP4.5	0.5	-7	-16	-17	-22	-28
		1.25	RCP8.5	0.95	-7	-17	-19	-25	-32
		1.6	RCP8.5+	1.3	-7	-18	-19	-26	-34
5M	Current	0.03	N/A	0.03	-9	-13	-13	-16	-18
	2080	0.4	RCP4.5	0.2	-10	-16	-17	-21	-24
		0.6	RCP8.5	0.4	-10	-17	-18	-22	-26
	2130	0.8	RCP4.5	0.5	-11	-19	-21	-26	-30
		1.25	RCP8.5	0.95	-11	-20	-22	-29	-34
		1.6	RCP8.5+	1.3	-11	-21	-23	-30	-36
5N	Current	0.03	N/A	0.03	-13	-21	-23	-30	-33
	2080	0.4	RCP4.5	0.2	-14	-26	-28	-35	-43
		0.6	RCP8.5	0.4	-18	-31	-33	-41	-51
	2130	0.8	RCP4.5	0.5	-17	-33	-35	-44	-56
		1.25	RCP8.5	0.95	-26	-43	-46	-57	-72
		1.6	RCP8.5+	1.3	-34	-53	-56	-71	-89
5O	Current	0.03	N/A	0.03	-15	-24	-26	-33	-37
	2080	0.4	RCP4.5	0.2	-22	-35	-38	-46	-53
		0.6	RCP8.5	0.4	-26	-41	-43	-52	-61
	2130	0.8	RCP4.5	0.5	-31	-48	-51	-63	-74
		1.25	RCP8.5	0.95	-39	-59	-62	-75	-91
		1.6	RCP8.5+	1.3	-47	-69	-73	-89	-107
5P	Current	0.03	N/A	0.03	-11	-20	-22	-28	-32
	2080	0.4	RCP4.5	0.2	-12	-25	-27	-35	-43
		0.6	RCP8.5	0.4	-17	-30	-33	-41	-52
	2130	0.8	RCP4.5	0.5	-15	-33	-35	-46	-58
		1.25	RCP8.5	0.95	-23	-43	-46	-58	-74
		1.6	RCP8.5+	1.3	-31	-53	-57	-72	-91

1 Accounting for average rate of VLM