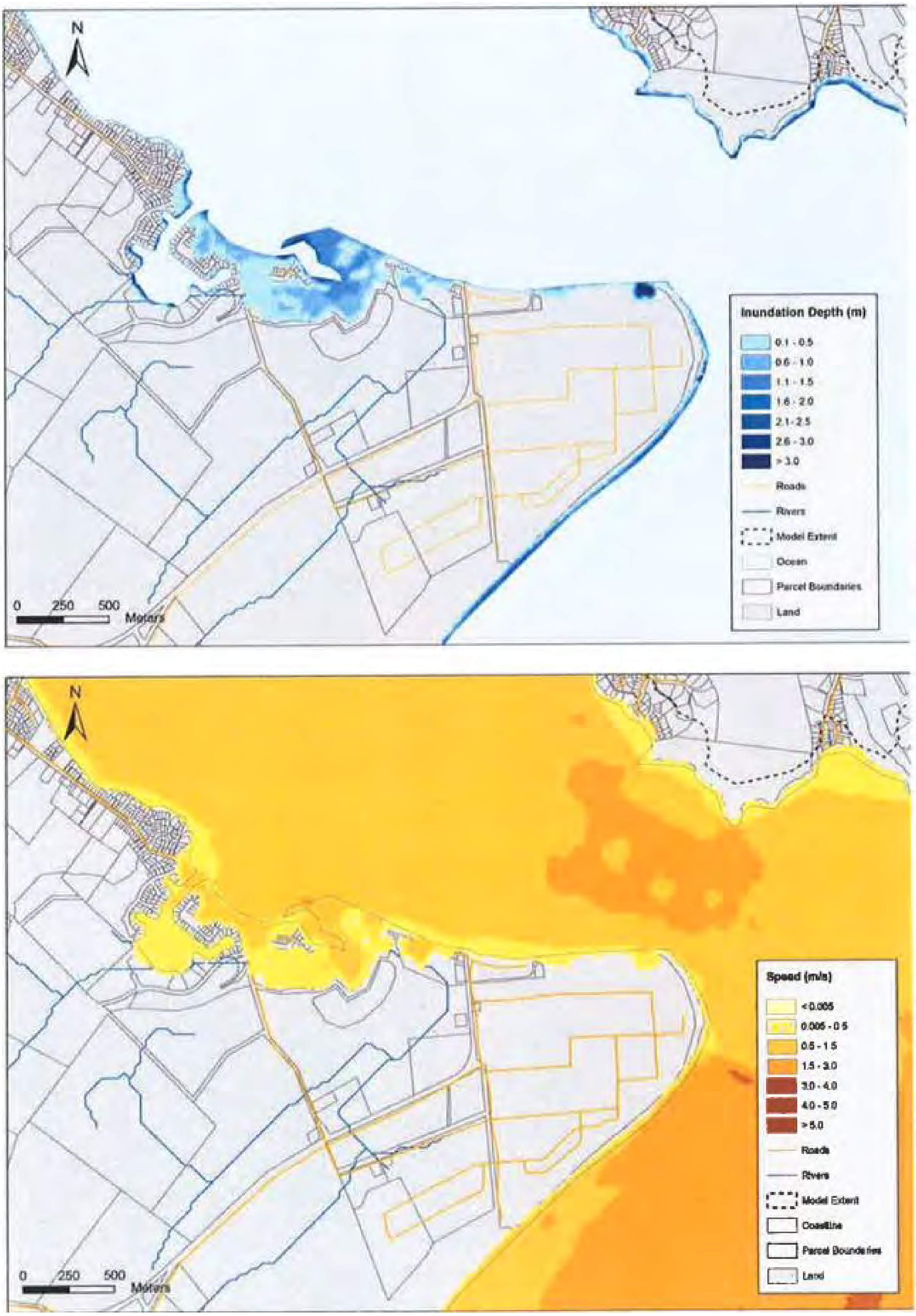


Figure 3-23: Maximum inundation depth (upper) and speed (lower) for the M_w 9.0 Tonga/Kermadec Trench tsunami scenario at MHWS (Source: Arnold et al., 2011)

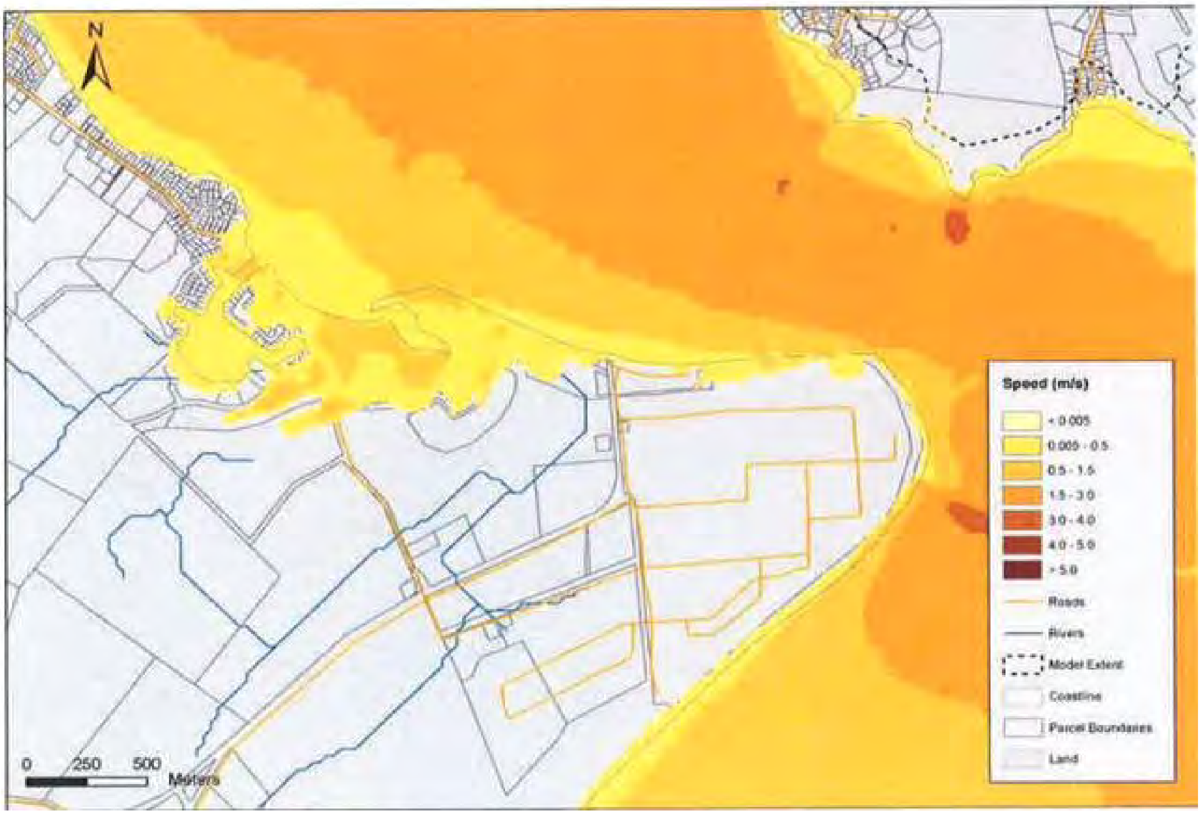


Figure 3-24: Maximum inundation depth (upper) and speed (lower) for the South American tsunami scenario at MHWS + 0.5 m Sea Level Rise (Source: Arnold et al., 2011)

3.10.1 Climate change effects

Climate change effects include changes to sea level and potential effects on storms, wind, storm-tide and wind.

3.10.1.1 Sea level rise

Historic sea level rise in New Zealand has averaged 1.7 ± 0.1 mm/year (Hannah and Bell, 2012) with Northland exhibiting a slightly higher rate of 2.2 ± 0.6 mm/year. Beavan and Litchfield (2012) found negligible vertical land movement in Northland and therefore suggest the higher rate for Northland may be due to the short record length.

Climate change is predicted to accelerate this rate of sea level rise into the future. The NZCPS (2010) requires that the identification of coastal hazards includes consideration of sea level rise over at least a 100 year planning period. Potential sea level rise over this time frame is likely to significantly alter the coastal hazard risk.

The Ministry of Environment (MfE, 2008) guideline recommends a base value sea level rise of 0.5 m by 2100 (relative to the 1980-1999 average) with consideration of the consequences of sea level rise of at least 0.8 m by 2100 with an additional sea level rise of 10 mm per year beyond 2100.

Modelling presented within the most recent IPCC report (AR5; IPCC, 2013) show predicted global sea level rise values by 2100 to range from 0.27 m, which is slightly above the current rate of rise, to 1 m depending on the emission scenario adopted. Extrapolating the RCP8.5 scenario to 2115 results in a sea level range from 0.27 to 0.47 m by 2065 and 0.62 to 1.27 m by 2115 (Figure 3-25). The RCP8.5 scenario assumes emissions continue to rise in the 21st century. Adopting this scenario is considered prudent until evidence of emission stabilising justify use of a lower projection scenario.

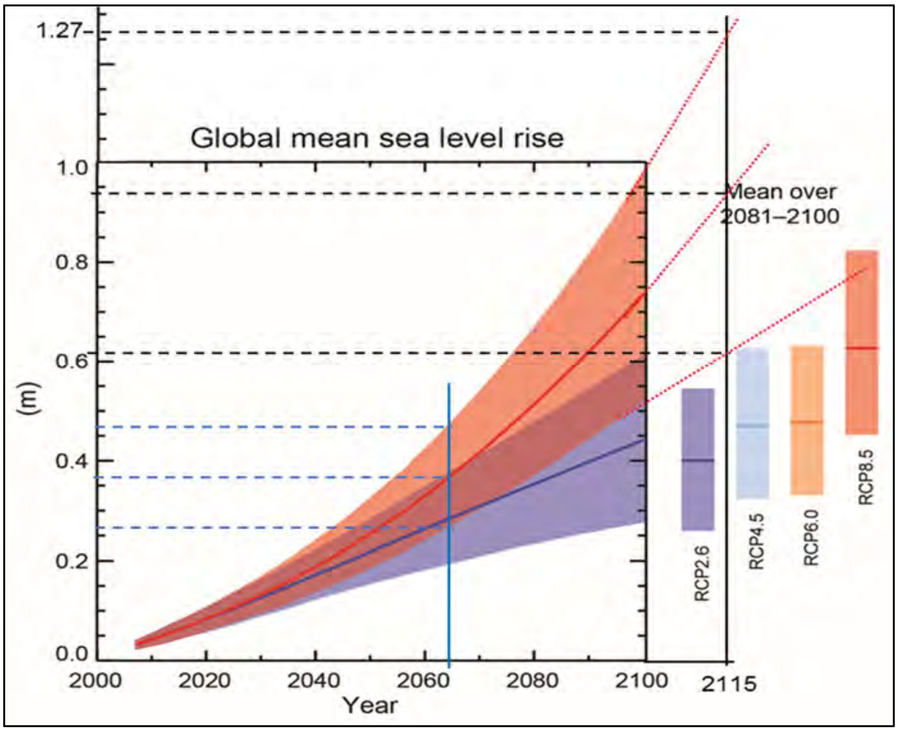


Figure 3-25: Projections of potential future sea level rise presented within IPCC AR5 (IPCC, 2013) with adopted values for this assessment at 2065 and extrapolated to 2115

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

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

4 Assessment of coastal processes

4.1 Definitions and key processes

A tidal inlet includes the narrow entrance channel together with the intertidal and submarine deltas that can form at one or both ends of the entrance channel (Hume and Herdendorf, 1987). The major morphological units are (refer Figure 4-1):

1. Ebb tidal delta – this covers the seaward part of the inlet and includes the main ebb channel, swash bars and marginal flood channels. It represents a volume of sediment stored on the seaward side of the inlet entrance. It is formed mainly by tidal currents and waves.
2. The narrow deep channel at the inlet entrance (throat/gorge)
3. Flood tide delta, typically comprising a shield of sand that develops in the tidal basin landward of the throat, including flood channels, tidal flats and ebb spits.

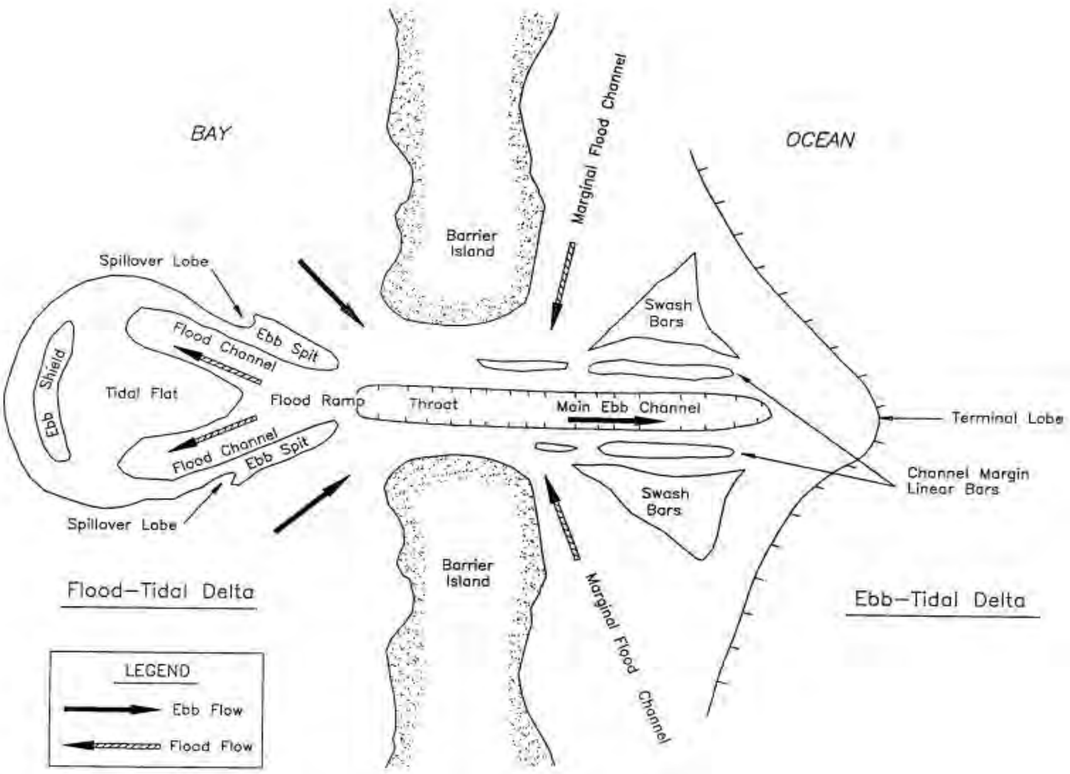


Figure 4-1: Definition of a conventional tidal inlet (USACE, 2008)

Based on the classification of Hume and Herdendorf (1985), Whangarei Harbour inlet can be classified as a single spit enclosed estuary of fluvial origins. The Mair Bank and Calliope Bank are swash bars that are formed largely within the intertidal and subaerial parts of the ebb tide delta.

4.1.1 Locational stability

Morphological stability of tidal inlets has two main components; location stability and cross-sectional stability. Locational stability describes the lateral migration of the channel, and cross-sectional stability relates to the variability of the cross-sectional area and its relation to tidal flow characteristics. The inlet to Whangarei Harbour is situated in the lee of the Tertiary volcanic rock Whangarei Heads and, as such, is reasonably stable in terms of position, with the main controls on the ebb tide delta size and shape being a function of the tidal flows into the harbour, the incident wave direction, sediment grain size and the alongshore drift rate (Figure 4-2).

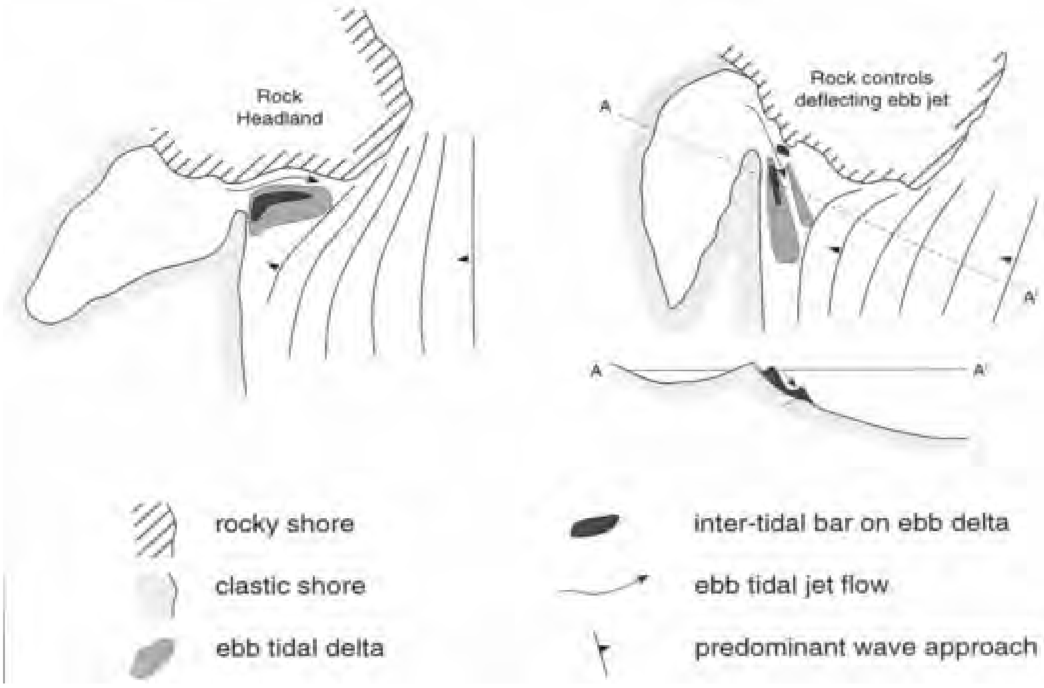


Figure 4-2: Schematic diagrams depicting controls on ebb delta size and shape for half delta inlets (Hicks and Hume, 1996)

The key characteristics of the tidal inlet and ebb delta at the entrance to Whangarei Harbour are summarised in Table 4-1.

Table 4-1: Characterisation of the Whangarei Harbour tidal inlet and the ebb delta (Hume and Herdendorf, 1988)

Ebb delta sand volume (10^6 m^3)	168
Ebb delta shape	High-angle half delta
Mean spring tidal range (m)	2.1
Mean Spring tidal prism, Ω ($10^6 m^3$)	155
Throat width at mean tide (m)	790
Throat area at mean tide (m^3)	14,600
Mean throat depth (m)	18.5
Ebb jet angle (Deg)	55
Beach slope to 10 m depth contour	0.0111
Annual net littoral drift, M_{total} (m^3/year)	20,000
Ebb delta length/breadth ratio	1.6
Average sand size, d_{50} (mm)	0.17
Wave energy factor (m^2sec^2)	22
Daily mean runoff (m^3/sec)	1
Ω/M_{total} ratio	7,750 (> 150, good flushing and little bar formation)

A study of wave refraction patterns in Bream Bay showed the Whangarei Harbour inlet entrance emerges in a zone of low energy that provides natural stability to the inlet (Duder & Christian, 1983) due to the sheltering effect of Whangarei Heads from northern and eastern wave energy. This is illustrated in Figure 3-19.

There is a large volume of sand storage and this directs tidal flows against the volcanic rocks of Whangarei Heads. Annual net littoral drift of 20,000 m^3 per annum is a relatively small value for an open coast location. However, based on observations of movement of the Ruakaka River entrance to the south, there is little evidence of pronounced trends of movement, either to the south or north, also suggesting a small net littoral transport rate. These low transport rates indicate the local wave climate effects and the influence of the sheltering effect of Whangarei Heads play a significant part in the formation of the ebb tide delta.

The ebb delta and flood tide shoals are supplied by small amounts of northerly directed alongshore transport. A key observation from Table 4-1 is that the tidal prism, is large ($155 \times 10^6 m^3$) in relation to the net littoral drift (20,000 m^3/yr). The ratio of tidal prism to net littoral drift, introduced by Bruun and Gerritsen (Bruun, 1978) relates these two important parameters that control inlet stability. The resulting ratio of 7,570 is significantly greater than the threshold of 150 that was determined by Bruun and Gerritsen to characterise good flushing and little bar formation on the ebb delta. This suggests the delta should be very stable with good flushing and little bar formation. This is confirmed by the bathymetric survey data that shows very little change in bathymetry in the outer parts of the ebb tide delta.

Based on an average suspended sediment concentration of 6 mg/L within the harbour entrance (refer Table 3-2) and the tidal prism of $155 \times 10^6 m^3$, the suspended tidal flux entering and departing the harbour is approximately 360 m^3/tide. There are around 715 tides per year, so the annual tidal flux of 257,600 m^3/yr is an order of magnitude greater than the net littoral drift, confirming the dominance of tidal effects over wave driven sediment transport at Marsden Point.

4.1.2 Inlet cross sectional stability

The inlet cross-sectional stability is often evaluated based on the relationship between the tidal prism and cross-sectional area of the inlet. Figure 4-3 shows the results of the relationship for Whangarei Harbour in relationship with other New Zealand inlets. This figure indicates that the inlet is stable with no significant trend to erosion or deposition in the inlet.

Stability of the harbour entrance has also been attributed to the presence of shell material, which provides an armour layer protecting the underlying soft sands. This was confirmed by Healy and Black (1982) who investigated sediment transport in Marsden Point and concluded the shell lag present on much of the inlet rarely moves, even in spring tide conditions, and that much of the bed have an aged appearance with the shells being covered by algae; a testimony to the stability of the sediment and the low rates of sand supply by alongshore drift. Morgan, Kench and Ford (2011) and Kerr and Associates (2016a) also identify the role of shells in the long term stability of the ebb tide delta and Mair Bank.

The Black and Healy study (1982) defined that no sediment movement occurred when tidal velocities were less than 0.3 m/s and that sand grains were moving more than 50% of the time when current speed at 1m above the seabed was between 0.3 and 0.35 m/s. The main sediment transport paths due to tidal currents are identified in Figure 4-4.

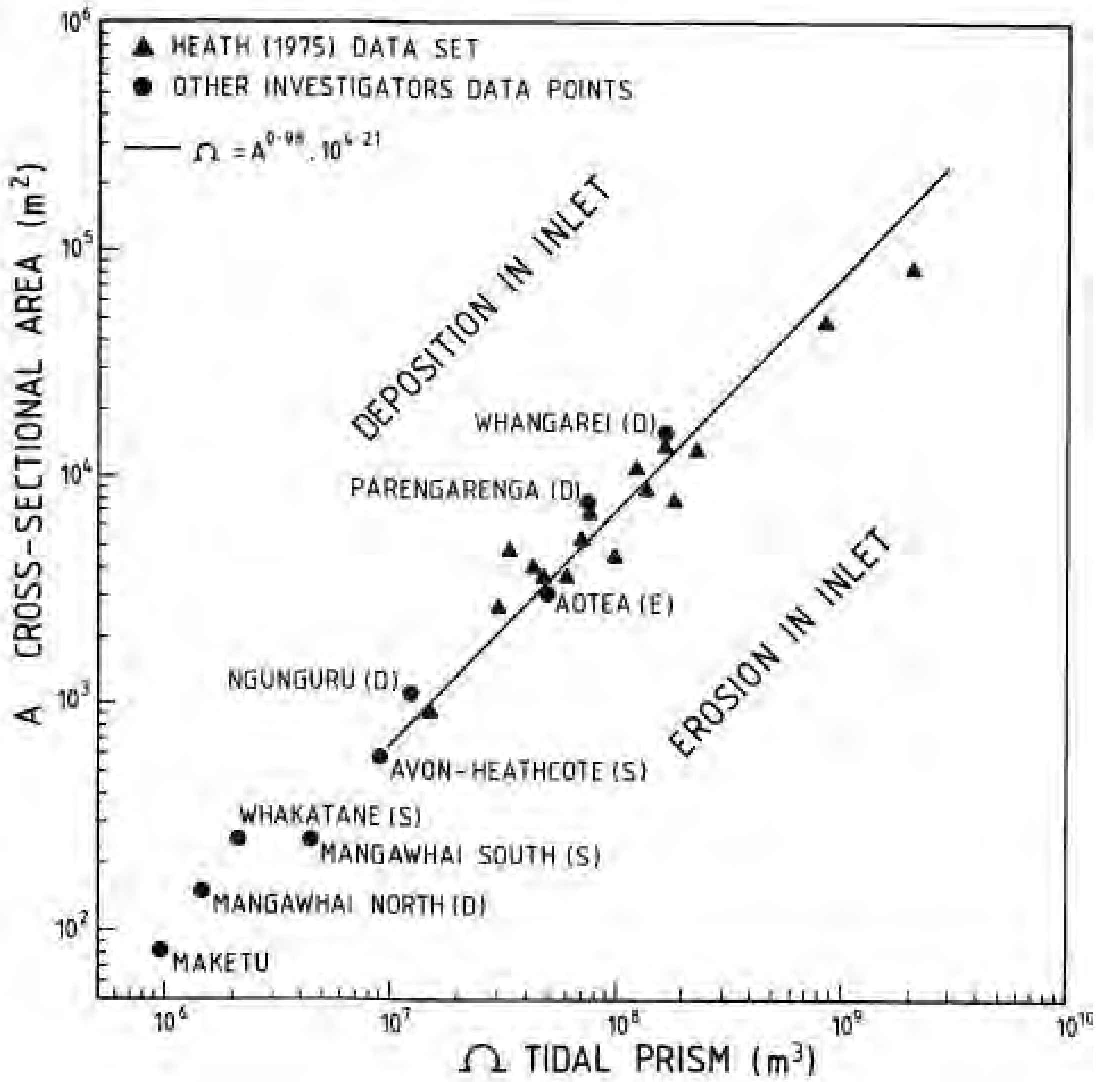


Figure 4-3: Stability of New Zealand tidal inlets using Heath (1975) relationship (Source: Hume and Herdendorf, 1985b)

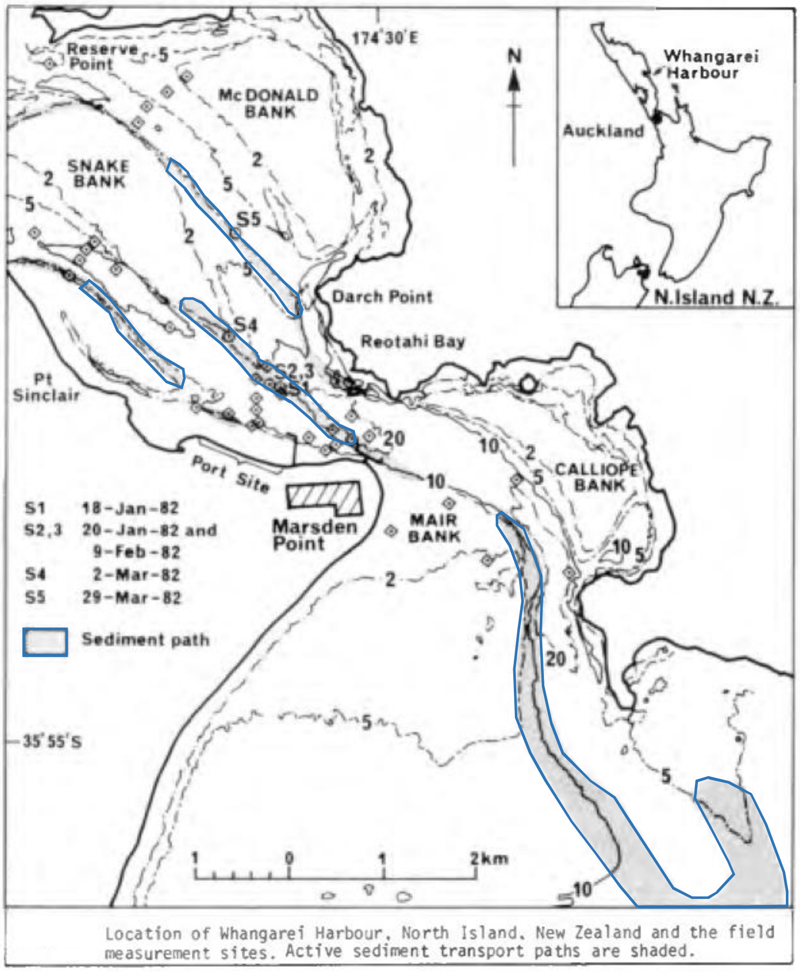


Figure 4-4: Main sediment transport paths due to tidal currents (source: Black & Healy, 1982)

MSL (2016b) sediment dynamic modelling shows very similar sediment transport pathways to those identified by Black and Healy (see Figure 4-5).

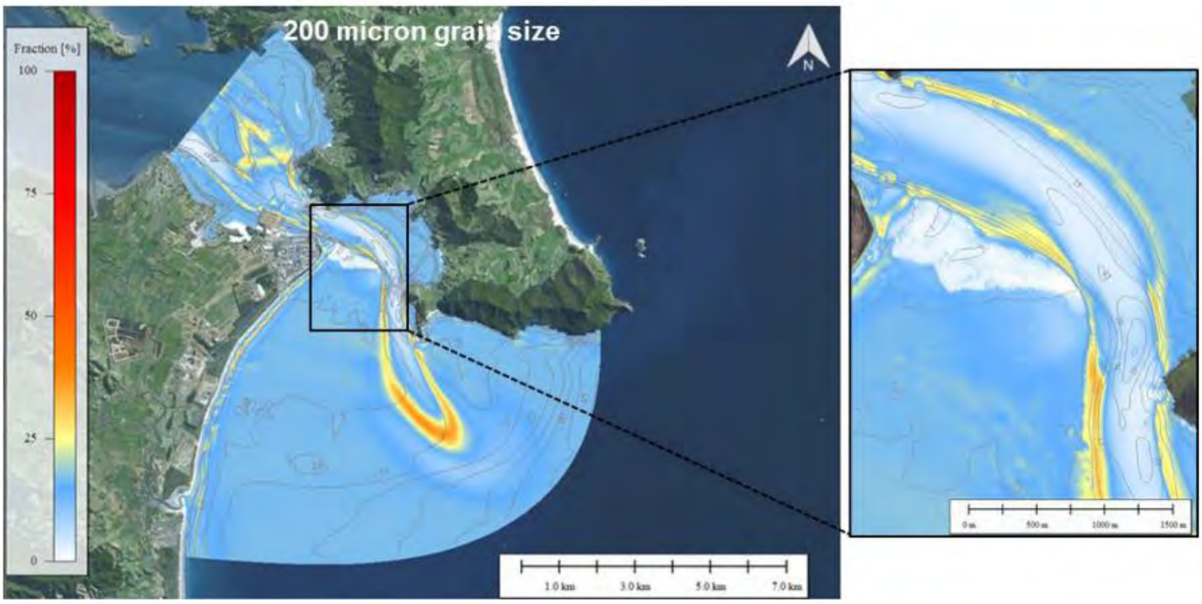


Figure 4-5: Distribution of 200 µm grain size sediments for a 6 month fair weather period (Source: MSL, 2016b)

Figure 4-6 shows a summary of the inferred sediment transport pathways for the existing situation. It shows the sediment flux that moves into and out of the harbour as suspended sediment concentrations of around 260,000 m^3/yr and the supply to this area due to alongshore drift of sands along the coastline from Ruakaka River mouth. The sediment transport pathways are complex in the vicinity of the ebb tide shoal and Mair Bank, with some overwash of sand from the delta to the channel, but also another sediment transport pathway due to tidal flows and the relatively erosion resistant surface of Mair Bank, with tidal flows moving sediment in a south easterly direction along the southern face of Mair Bank, then entering the channel to flow into the harbour. There are several return mechanisms with sand transport pathways to the various shoals both in Bream Bay and within the inlet and inner harbour.

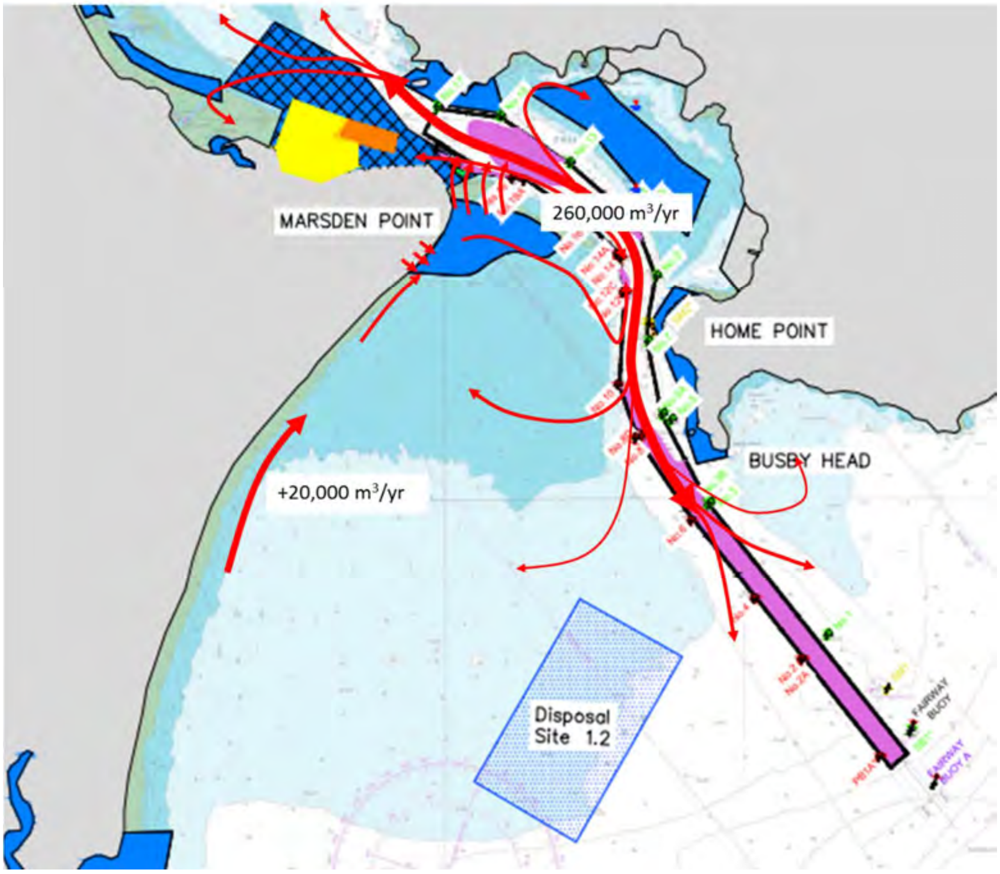


Figure 4-6: Inferred sediment transport pathways for the present day situation in the vicinity of the harbour entrance

4.1.3 Ebb tide delta stability

An assessment of the stability of the ebb tide delta has been made by comparing the 5 m, 10 m and 15 m depth contours from 1939 to 2015 (refer Figure 4-7 and Figure 4-8). More detailed surveys of the shallower areas since 2001 allow an assessment of changes to the 2 m and 0 m depth contours (refer Figure 4-9).

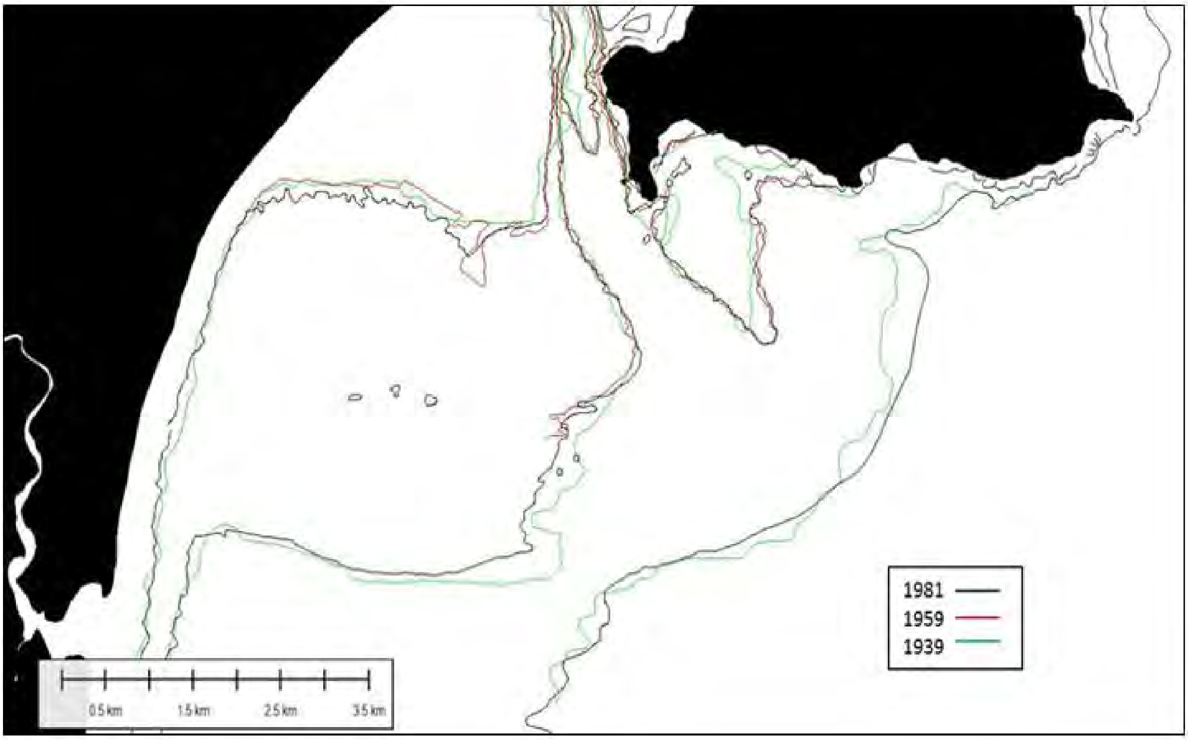


Figure 4-7: Historic changes at the 5 m, 10 m and 15 m depth contours from 1939 to 1981

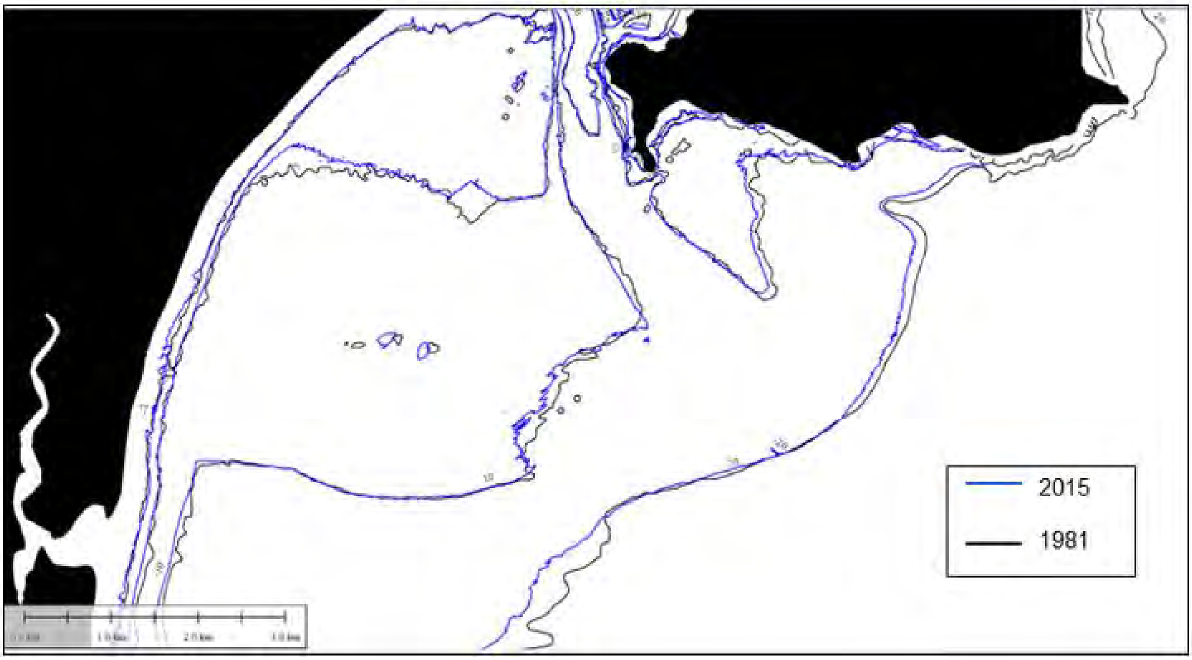


Figure 4-8: Historic changes at the 5 m, 10 m and 15 m depth contours from 1981 to 2015

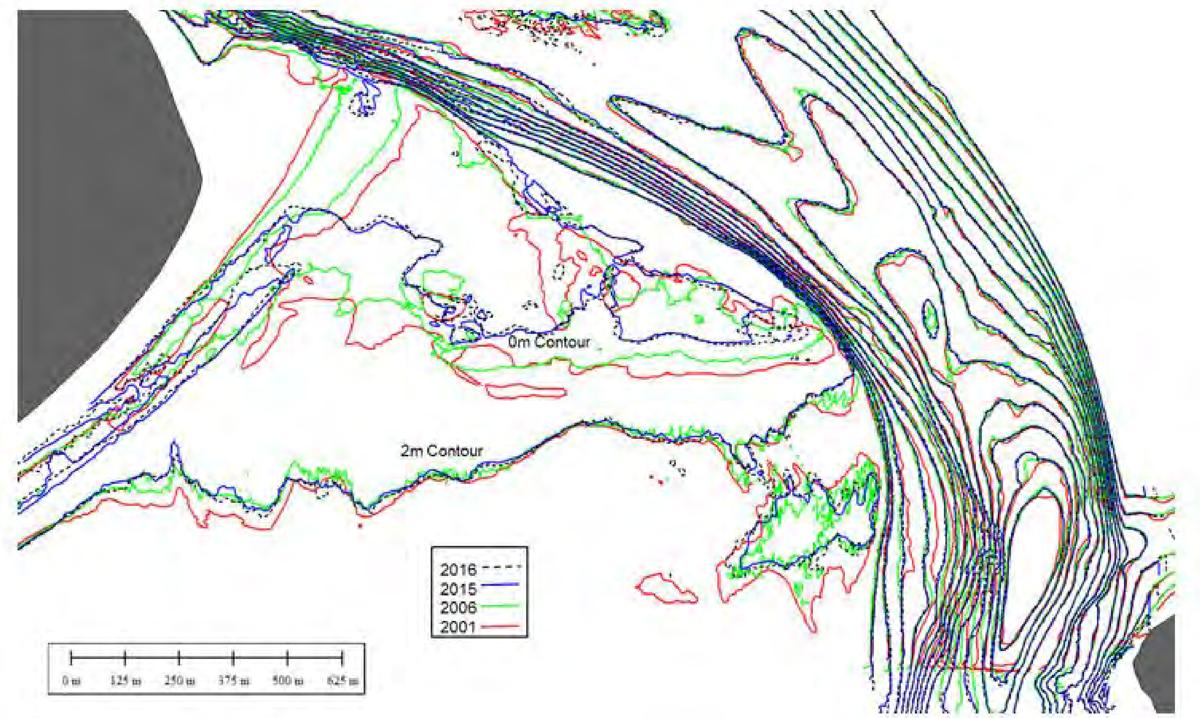


Figure 4-9: Historic changes at the 2 m and 0 m depth contour from 2001 to 2016

The resulting analysis shows that over the 76 year period there has been no significant change to the ebb tide delta or the approaches below the 5 m depth contour. This stability has remained despite both anthropogenic (human induced) and natural changes within the harbour. There appears to be more change occurring above the 5 m depth contour and this is considered in the following section.

4.1.4 Mair Bank stability

Due to a Pipi population decline on Mair Bank over recent decades (Williams and Hume, 2014), there has been a number of studies specifically looking at the stability of Mair Bank. Morgan et al. (2011) analysed digitised aerial photography of Mair Bank over 56 years to determine multi-decadal changes in the position and planform configuration of major morphological units (refer Figure 4-10). It was identified that the footprint of Mair Bank has remained constant over this time period, but significant changes in surface morphology have occurred with dynamic sediment reworking. These changes were largely above chart datum, while contours below 5 m Chart Datum were largely unchanged.

The dynamics of the surficial sediment are illustrated by western end of the seaward shell swash bar migrating landward at an average rate of 10m/yr between 1950 and 2006. Morgan et al. (2011) also calculated the largest subaerial change in sand storage volume occurred between 2003 and 2006, when volume increased from 1.107 x 10^5 m^3 to 1.690 x 10^5 m^3. The change in volume is around 60,000 m^3, or 20,000 m^3/yr and equivalent to the full amount of net littoral transport estimated by Hume and Herdendorf (1985). In terms of material accumulation over the extent of the ebb delta, this equates to a uniform bed level rise of 10 cm across Mair Bank, or a 1.3% increase in total volume of the bank.

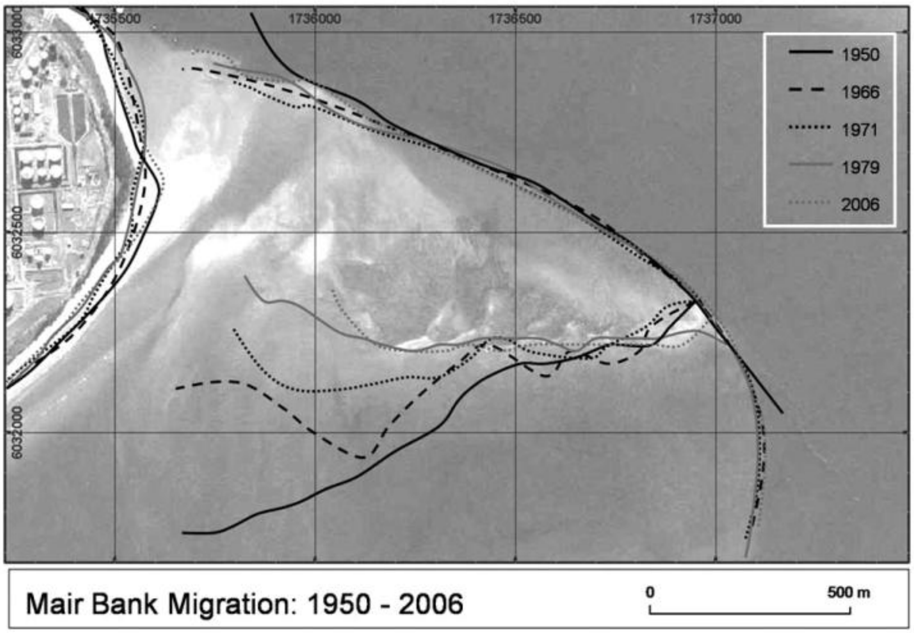


Figure 4-10: Mair Bank morphological changes from 1950 to 2006 based on interpretation of aerial photographs using the wet beach line along the coast, the northern boundary of Mair Bank and the crest of the southern seaward shell swash-bar as proxies to estimate changes over time (source: Morgan et al. 2011)

The Morgan et al. (2011) study also confirms that minor changes in delta configuration have been shown to have pronounced effects on the erosion and accretion of adjacent shorelines (Oertel, 1977), particularly if the changes result in consequential impacts to wave energy and direction arriving at the coast. Consequently the geomorphic stability of these sand bodies are important to adjacent shoreline morphodynamics, as reduction in size, a change in position or loss of sediment volume have the potential to alter physical processes acting on the coast and promote coastal change.

4.1.4.1 Annual survey trends

Annual surveys have been carried out over Mair Bank from 2000 and they provide further detailed information on changes to the ebb tide shoal and Mair Bank reported in Williams and Hume (2014). This survey data has been applied to assess spatial and temporal elevation changes. Changes in surface morphology over approximately 5 year periods are shown in Figure 4-11 to Figure 4-13 with the overall change from 2000 to 2014 shown in Figure 4-14. Additional figures that show the change of the 0m (Chart Datum) contour for the same time period are included in Appendix E. These are useful as they allow a focus on the changes to the intertidal footprint of Mair Bank and the swash channel that separates the bank from Marsden Point.

From 2000 to 2005 (Figure 4-11) the following processes were observed (Williams and Hume, 2014):

- Erosion along shoreline of Marsden Point
- Accretion on the northern shoreline of Marsden Point and along the edges of the entrance channel and around the wharf
- Movement of shoals on the surface of Mair Bank, characterised by areas of accretion adjacent to areas of erosion.

From 2005 to 2010 (Figure 4-12) the following processes were observed (Williams and Hume, 2014):

- Erosion in the nearshore along the southern refinery shore of Marsden Point

- Accretion on the northern shoreline of Marsden Point and a shoal extending north into the main channel
- Accretion in the channel separating Marsden Point and Mair Bank
- Accretion around the margins of the shallower central parts of Mair Bank
- Erosion along the southern seaward margin of Mair Bank and a migration northward of the shell ridge of some 150 m.

From 2010 to 2013 (Figure 4-13) the following processes were observed (Williams and Hume, 2014):

- Erosion in the nearshore along the southern refinery shore of Marsden Point
- Accretion on the northern shoreline of Marsden Point and a shoal extending north into the main channel
- Accretion in the channel separating Marsden Point and Mair Bank
- Accretion around the margins of the shallower central parts of Mair Bank
- Erosion along the southern seaward margin of Mair Bank and a migration northward of the shell ridge of some 150 m.

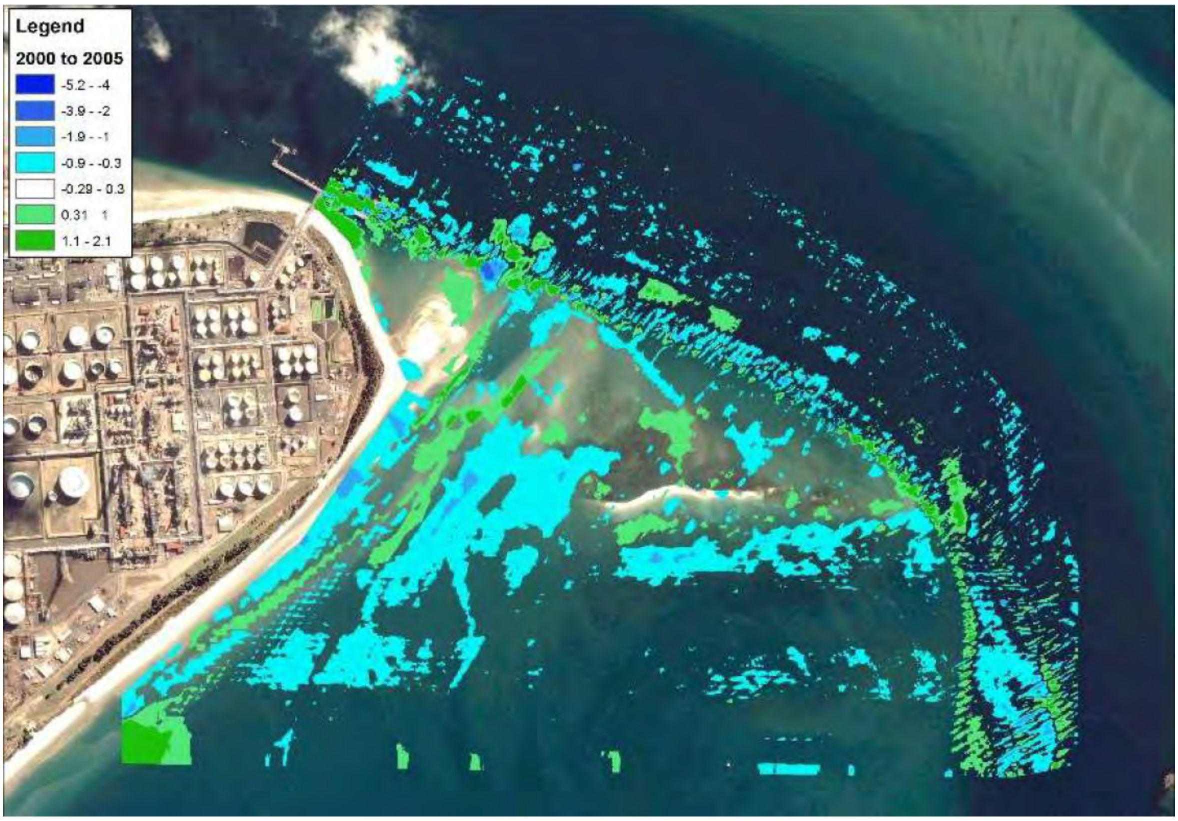


Figure 4-11: Differences in Mair Bank bathymetry from 2000 to 2005 (Source: Williams and Hume, 2014)

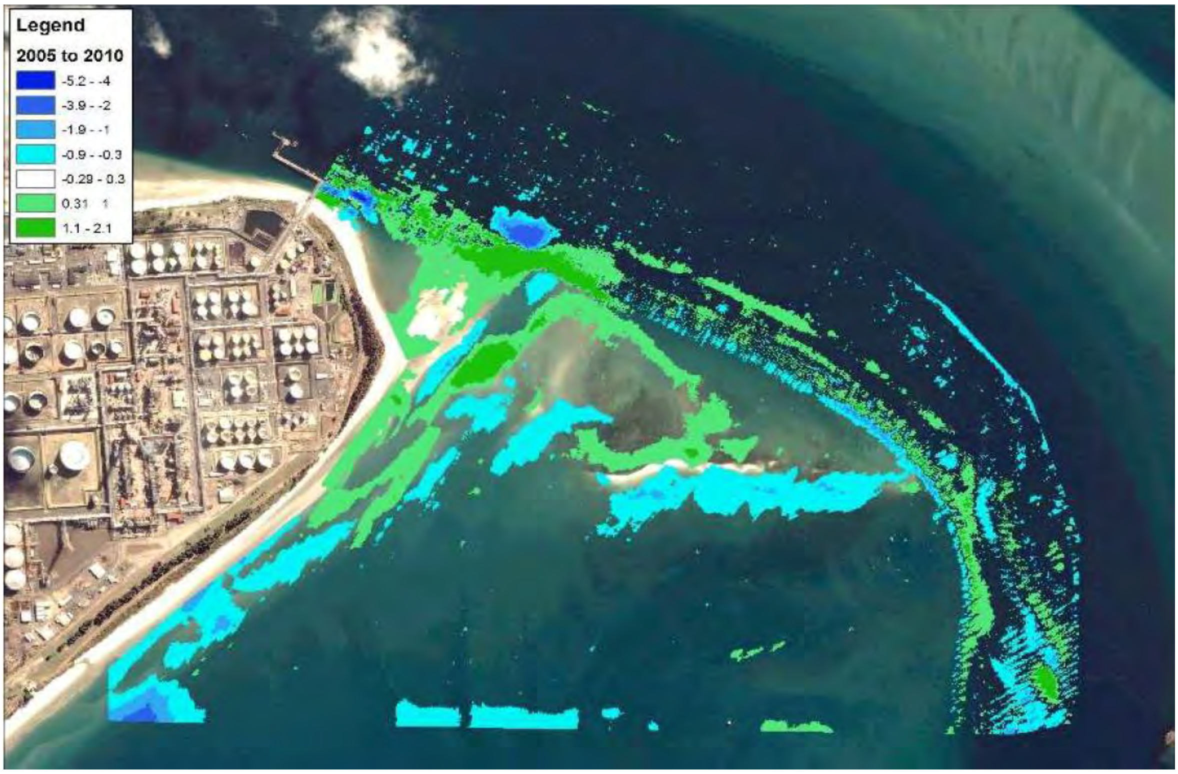


Figure 4-12: Differences in Mair Bank bathymetry from 2005 to 2010 (Source: Williams and Hume, 2014)

Figure 4-13: Differences in Mair Bank bathymetry from 2010 to 2013 (Source: Williams and Hume, 2014)

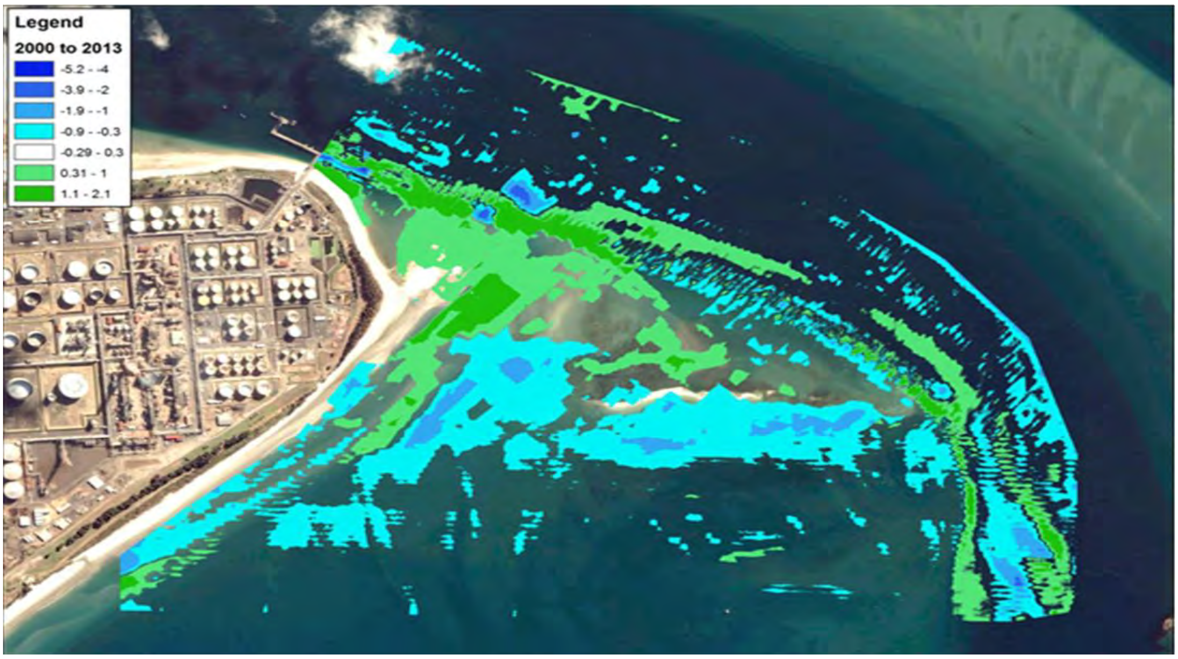


Figure 4-14: Differences in Mair Bank bathymetry from 2000 to 2013 (Source: Williams and Hume, 2014)

The simple plots of the change to the 0.5 m contour in the vicinity of Mair Bank and Marsden Point (Appendix E) shows the swash channel changes over time more explicitly. There is a wider channel in 2000 which noticeably begins to narrow in 2002 with a shore parallel nearshore beach bar evident since 2000 increasing in size and migrating to the north and welding with Mair Bank that results both a narrowing and shallowing of the swash channel in 2003. The channel deepens slightly in 2004 and 2005 but the welding of the nearshore beach bar becomes more dominant from 2005, with the channel becoming narrower and shallower from 2005. In 2013 and 2015 the swash channel is shallower than 0.5 m. The change in levels of the swash channel can also be seen in the long section plot in Appendix F. This plot shows the variation in elevation along a transect that extends from Marsden Point, through the swash channel and along Mair Bank to the channel. The location of this transect can be seen in Figure 4-15. At this location the change from the relatively deep channel to the shallower channel is evident from 2008 to 2009.

Overall these results indicate that there are natural fluctuations in the surface topography in the order of ± 1 m (vertical) and ± 2 m (horizontally) as banks and channels shift in response to storm events and tidal currents. Over the last 15 years there appears to have been a northerly migration of sand towards and extending into the main channel and a narrowing and shallowing of the swash channel that separates Mair Bank from Marsden Point. This shallowing and narrowing of the swash bar seems strongly linked to the northward migration of sand from the ebb tide shoal south of Mair Bank that is discussed in the following section.

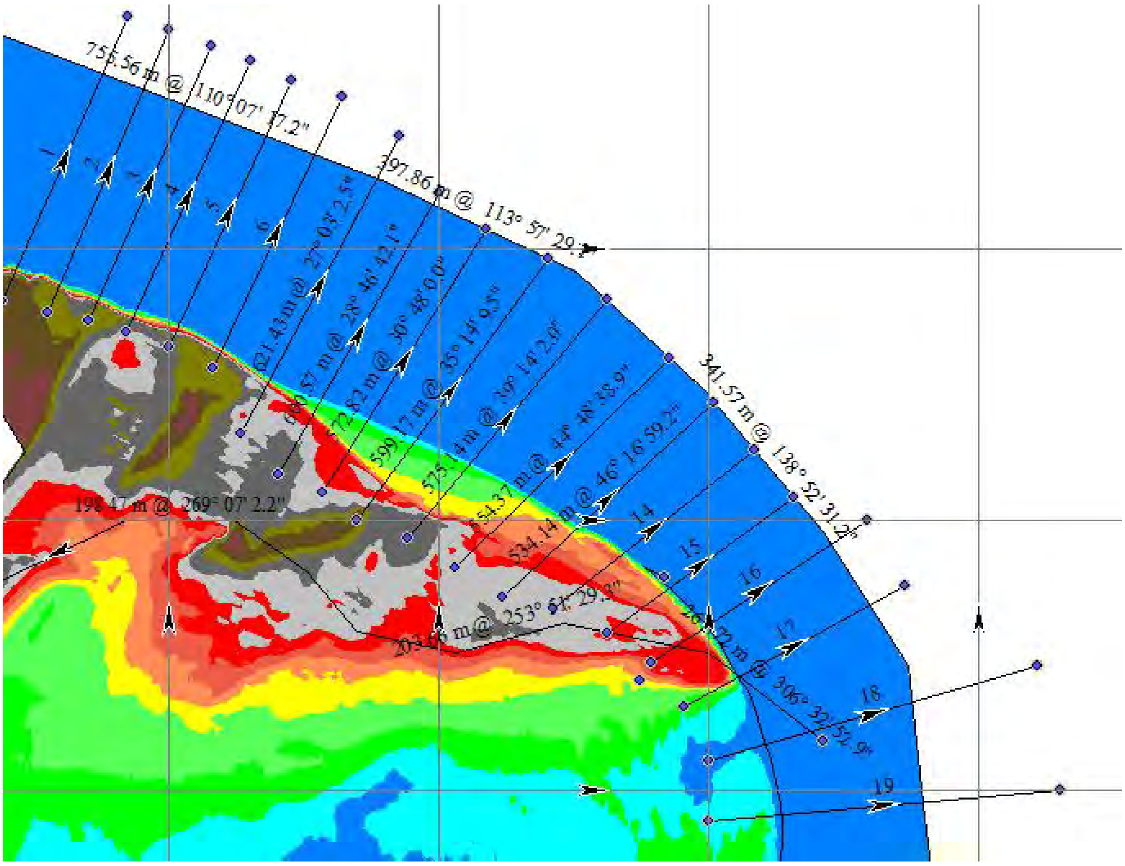


Figure 4-15: Location of sections through Mair Bank and the Ebb Tide Delta along the channel and a transect from Marsden Point through Mair Bank

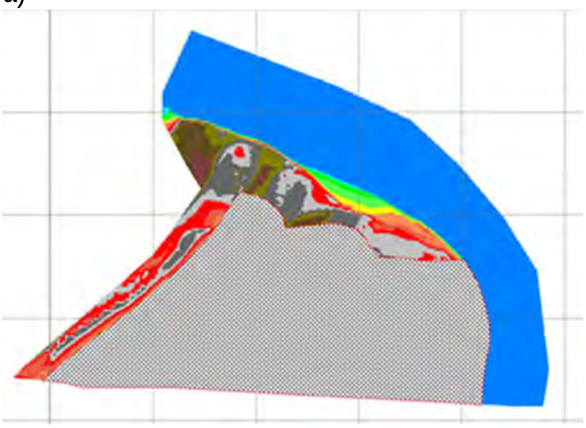
4.1.4.2 Volume and area changes

The analysis carried out by Williams and Hume (2014) has been updated in this study with total volume changes from 2000, 2005, 2010 and 2016. The amount of change has been calculated within the southern portion of the ebb tide shoal: up to the high point of Mair Bank (area 1); from the crest of Mair Bank to the edge of the channel (area 2); and within the channel (area 3) as indicated in Figure 4-16. The resulting volume changes in these areas is shown in Table 4-2 and Figure 4-17. These results show some 308,000 m^3 of sand has moved from the southern Ebb Tide Shoal since 2000 with the majority of change occurring between 2000 and 2005. There has been an increase in sand volume between the crest of Mair Bank and the edge of channel over the same time period while the volumes within the channel appear to fluctuate.

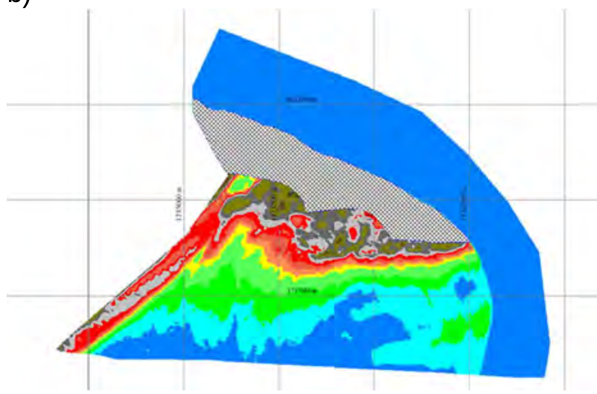
These results indicate a movement of sediment from the southern part of the ebb delta to the northern edge and along the channel with a net loss of some 210,285 m^3 over the 16 year period (around 13,150 m^3/yr). During the period of greatest change (2000 to 2005) the net loss was around 47,800 m^3/yr.

These overall changes have resulted in lowering of the seabed by up to 1 m within the southern part of the ebb tide shoal (refer Figure 4-14). This reduction in seabed level is likely to have increased wave action on the coast increasing erosion pressure along the beach and also assisted in reinforcing the northern migration of sand. Examining the wave climate between 2000 and 2005 (refer Figure 3-18) there is no obvious increase in wave energy over the long term average from 1979 to 2014 (MSL, 2016b) that might explain the changes in volume observed over that period. However, due to the still relatively short period of detailed data, these changes may be part of a longer term fluctuation driven by climatic factors.

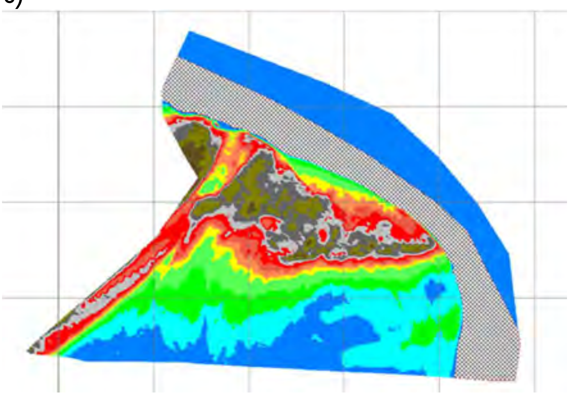
a)



b)



c)



a Southern extent of ebb tide shoal to the crest of Mair Bank

b From the crest of Mair Bank to the edge of channel

c Along the channel

Figure 4-16: Extent of volume change areas

Table 4-2: Volume change over time within three areas; southern ebb tide shoal, Mair Bank and the edge of the channel from the year 2000

Year	Southern Ebb Tide area	Mair Bank crest to channel	Left bank of channel	Total (m^3)	Annual change (m^3/yr)
2000	-	-	-	-	
2005	- 212,460	- 5,186	- 21,370	- 239,017	- 47,803
2010	- 272,151	81,839	1,261	- 189,051	9,993
2016	- 308,019	106,841	- 9,106	- 210,285	- 4,247

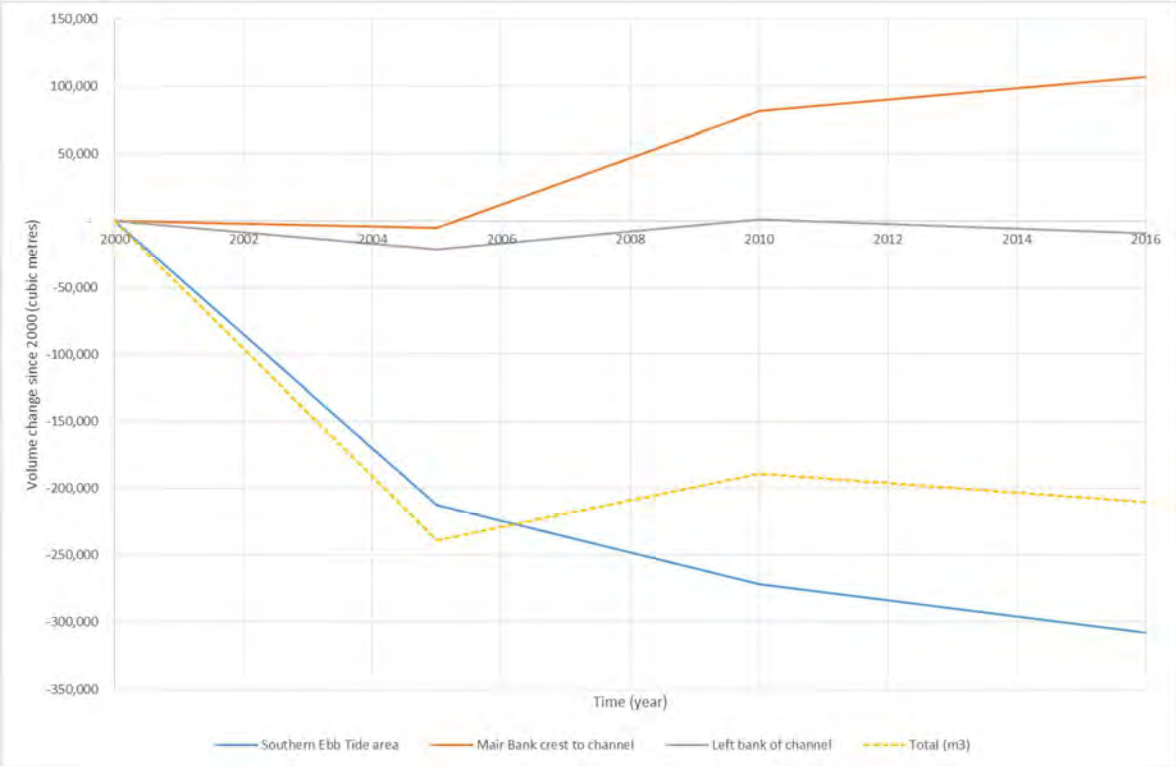


Figure 4-17: Volume change from 2000 to 2016

4.1.5 Changes to the right bank of the channel along ebb tide shoal

The annual ebb tide shoal survey data was also examined to investigate changes along the edge of the ebb tide shoal. This was done by examining 10 sections at around 150 to 200 m centres from 2000 to 2016 (refer Figure 4-15). Appendix F includes the profile comparison at 2000 and 2016 for alternate profiles from 1 to 19.

Profile 1 shows the northward accretion of the shoal with more significant accretion at the upper part of the shoal (i.e. above the -5 m depth contour). The base of the channel appears to have lowered slightly.

Profile 3 shows a similar trend of accretion of the upper part of the shoal and a steepening and lowering of the base of the channel.

Profile 5 shows a similar trend, but there is a smaller amount of change at the base of the channel.

Profile 7 shows slight accretion at the upper part of the bank and no significant changes at the lower slopes or at the base of the channel.

Profile 9 shows only small changes with some accretion on the upper part of the bank and at the base of the channel.

Profile 11 and 13 shows only small changes of both accretion and erosion.

Profile 15 shows erosion has occurred at this location at the top of the bank and at the toe. Slight accretion is evident on the upper slope of the channel.

Overall this profile analysis confirms there is northward migration of the upper part of the shoal between Profile 1 and 7, with some slight steepening of the side slopes at these locations due to scour at the lower levels. This suggests the tidal flows are seeking to maintain the inlet's cross-section area to compensate the accretion of the upper levels of the side slope.

Between Profiles 8 and 13 there is no significant change, while at Profiles 17 to 19 there is evidence of slight accretion. It is possible that sediment scoured from the lower levels of the channel between Profiles 1 and 7 has been transported around to this area and some of the sediment has settled out as a result of slightly lower tidal currents.

The net area change from 0 m CD to around 17.5 m CD was calculated and the resulting changes in cross-sectional area is shown in Table 4-3 and Figure 4-18. This figure shows the area change at each profile. Profiles 1 to 9 all show a net increase in areas (i.e. accretion along the edge of the channel) although profile 7 tends to fluctuate. Profiles 11 to 15 show net erosion and profiles 17 and 19 show accretion. The largest rate of accretion occurs at Profile 1 and 17 although the results of the profile and area analysis show accretion encroaching into the channel at the upper parts of the ebb tide delta (i.e. above -7 m CD) where the channel is the narrowest (Profiles 1 to 5) and there is an associated scouring (lowering) of the seabed effectively maintaining the cross-sectional area. Some of the eroded sand appears to migrate towards Bream Bay and may be deposited at the base of the channel in the vicinity of Profiles 17 and 19.

Table 4-3: Changes in area at profiles along the ebb tide shoal from 2000 to 2016

Section	2002	2004	2006	2008	2010	2012	2013	2016
1	4.2	-25.5	-16.6	18.5	60.4	83.2	109	52.6
3	-38.5	-21.2	-99.9	-28.3	1.6	18.9	-76.1	50.2
5	-35.5	-0.1	151.6	155.8	140.4	252.7	194.7	71.3
7	-61.3	-72.7	-28.6	-29.6	-20.1	64.9	58.6	12.9
9	48.3	44.5	31.9	35.6	40.4	45.4	38.9	14
11	-29.7	-26.6	-12.3	-45.1	15	16.5	5.1	-56.5
13	-7.2	-37	-21.2	-28	-27.1	-19	-7.2	-44.2
15	-10.6	-11.6	-42.8	-41.4	-28.3	-12.5	-13.9	-39.5
17	-22.5	34.5	96.7	124.4	107	79.7	104.4	64.3
19	27.6	-5.2	-41	16.9	-4.5	-49	12.6	26.1

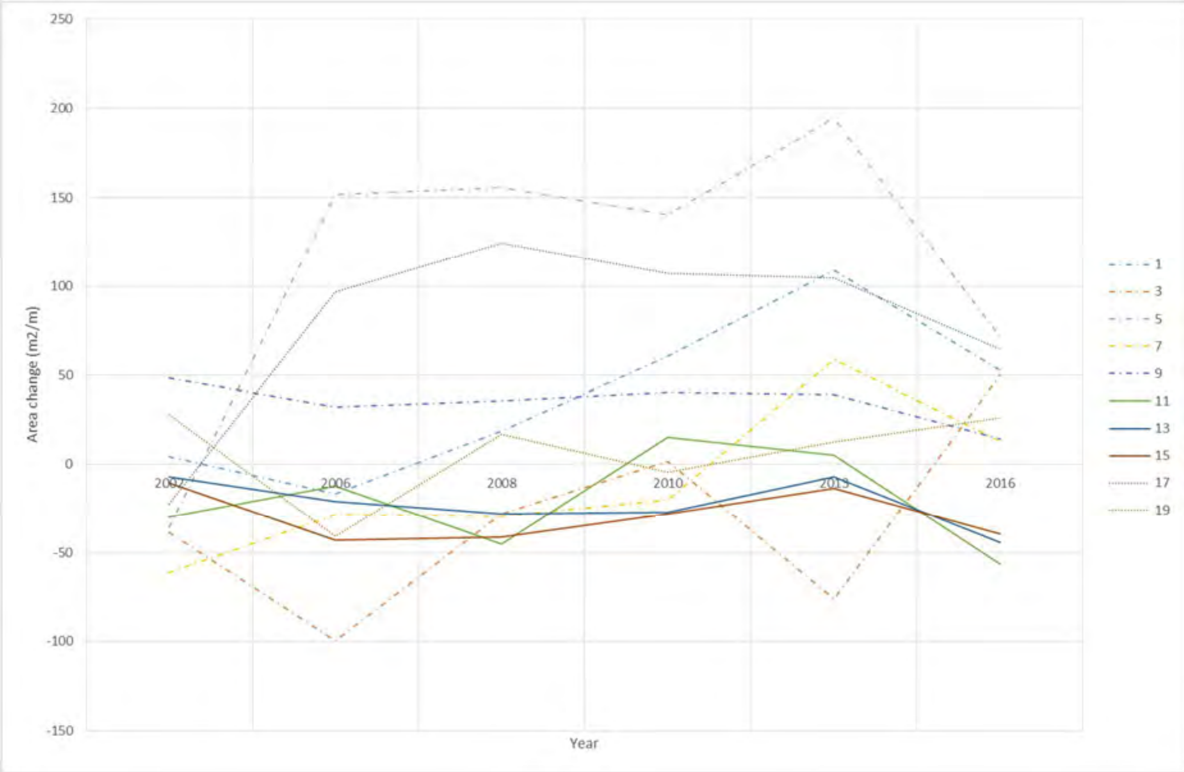


Figure 4-18: Annual change of beach area for cross-sections through Mair Bank

4.1.6 Changes to the open coast beaches from Mair Bank to Ruakaka River mouth

The open coast beaches along the shoreline of the ebb tide shoal to the Ruakaka River mouth have been experiencing low rates of erosion over the last few decades. Erosion in this location is likely to be a result of insufficient sand transported alongshore, or increases in sand transport from this area to the tidal inlet and inner harbour areas.

The assessment of existing survey data has shown that while the ebb tide delta is dynamically stable below 5 m CD, there has been a recent northward shift in sand volumes and a loss of sand from the southern part of the ebb tide shoal with an associated lowering of levels. This lowering of the seabed close to the open coast beaches results in greater wave energy (higher waves) arriving at the coast. The lowering of the seabed may change refraction processes which may result in changes to alongshore drift as well as increase storm erosion of the beaches and dunes. This process may be contributing to the observed erosion on the open coast at Marsden Point.

4.1.7 Stability of inner harbour

The lower harbour sediment dynamics are consistent with established patterns for tide-dominated inlets, with separation of the channel into areas of ebb and flood dominance, and typical transport patterns over the flood tidal delta. Broad-scale inlet geomorphology has been maintained, which is consistent with other dredged tide dominated inlets (Longdill and Healy, 2007). Concentrations of shell gravel lag were found to play an important stabilising role in determining the overall characteristics of the inlet stability and sediment dynamics (Longdill and Healy, 2007).

The comparisons of bathymetric surveys carried out by Healy and Longdill (2007) revealed that the lower harbour is very stable with essentially no change to bathymetry in many areas over a 20-year interval. Recorded tidal flows were found to be faster than the threshold speed for typical sandy sediments, but insufficient to disturb lagged shell beds (Black et al., 1989). Previous studies suggest that suspended sediment transport in the lower harbour is low and that the majority of sediment transport in the channels and channel margins occurs as bed load (Longdill and Healy 2007).

Residual distance vectors computed by Longdill and Healy (2007) in the lower harbour indicate that between 2002 and 2007 (i.e. post NorthPort developments), the large-scale pattern of sediment transport dynamics remained consistent. Minor and localised modification of transport potentials were observed immediately adjacent to the NorthPort developments. These modifications included a slight realignment of current flows near the reclamation wall and some leakage from a previously identified transport loop near the dredged basin. The potential for scour was identified by Longdill and Healy (2007) along the eastern margin of the dredged basin, and they suggested this could remove material moving downslope into the basin from its western edge. The observations were considered to be consistent with the earlier numerical model results that predicted minimal consequences resulting from the developments (Black and Healy, 1982). Since there has not been significant changes to the bathymetry since that time, the findings from the earlier studies are still valid.

Sediment transport pathways were inferred by Black et al. (1989) from observations and numerical modelling (refer Figure 4-19). According to their results, there is a net ebb imbalance in the lower harbour southern end and they suggested that deposition as a result of the NorthPort developments should be minimal, which is in general agreement with the modelling carried out by MSL (2016b).

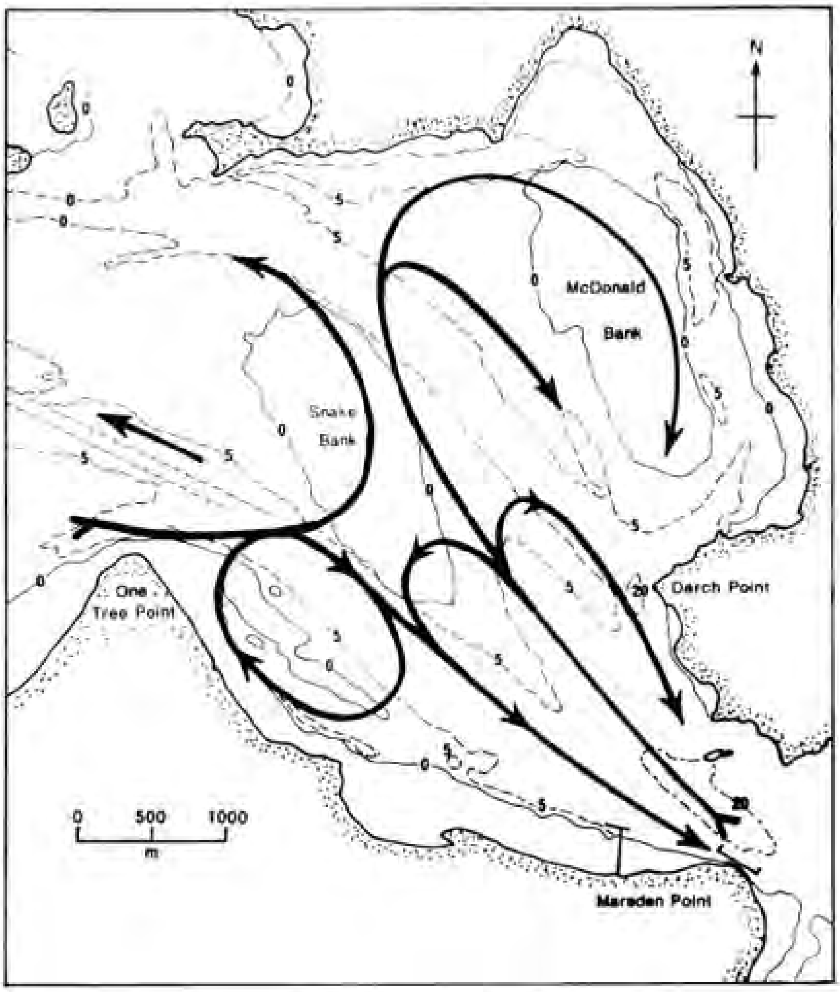


Figure 4-19: Schematic diagram showing sediment transport pathways within Whangarei Harbour based on residual velocities (Source: Black et al., 1989)

4.1.8 Summary of sediment budget for the present day

Figure 4-20 shows a summary of the existing sediment budget of the ebb tide shoal system, with variability of volume due to annual fluctuations in the order of 100,000m^3/yr, sources (alongshore drift and biological shell production) and known losses (shell removal through harvesting and overwash). The resulting budget appears largely in equilibrium which supports the observations of the overall stability of the ebb tide shoal based on long term historic survey analysis.

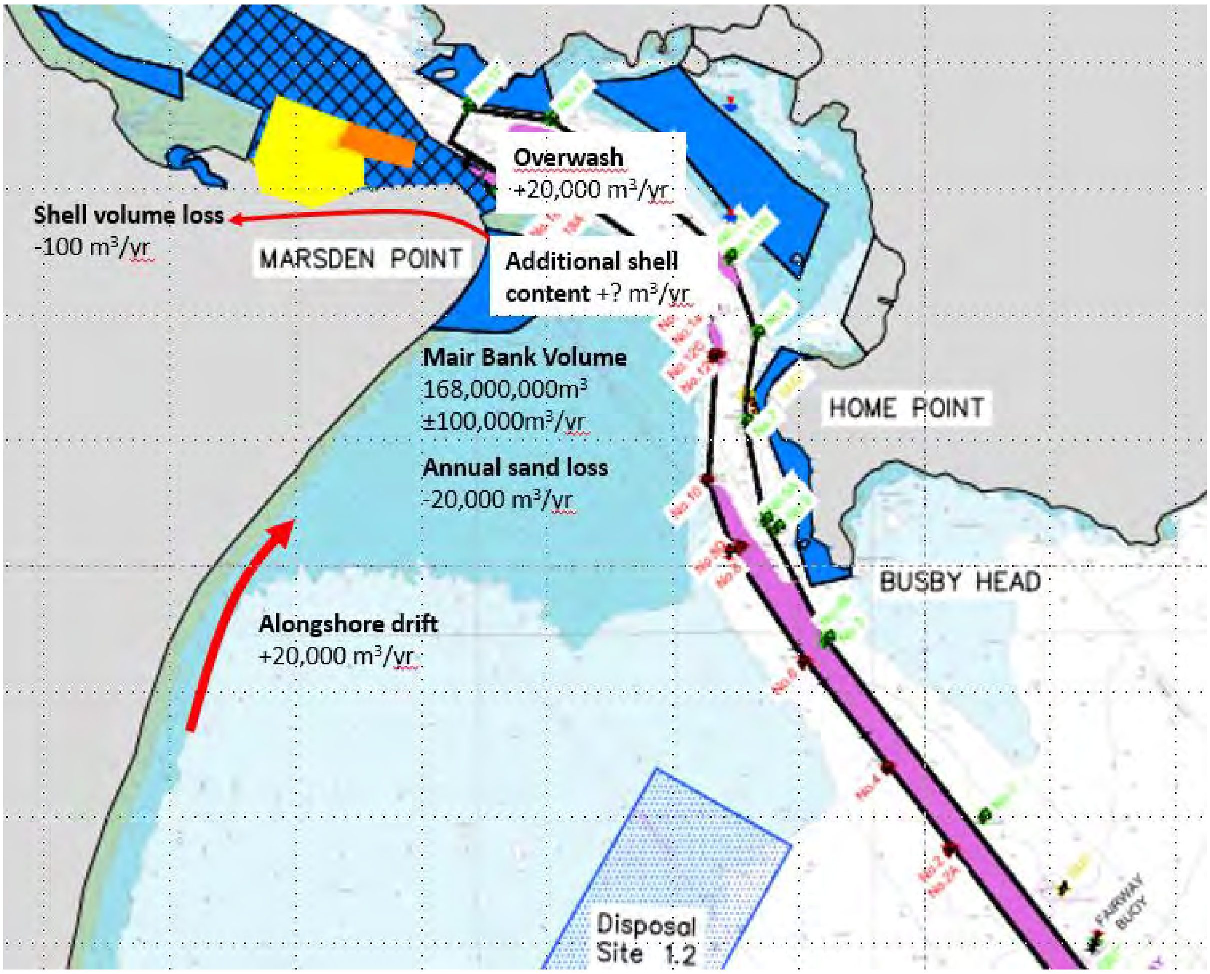


Figure 4-20: Sediment budget summary for existing situation

4.2 Potential effects of climate change on the inlet and ebb shoal

Assessing the potential effects of climate change, particularly sea level rise, on features such as the ebb shoal is complex and uncertain. No modelling of possible climate change effects has been done for this study.

With increased sea level rise there is likely to be an increase in the volume of water entering and exiting the harbour (tidal prism). Based on Figure 4-3 an increase in tidal prism is likely to result either in an increase in cross-sectional area or, if the area is confined due to structural controls, such as is present at the entrance to Whangarei Harbour, an increase in tidal velocity. This increase in tidal velocity can cause increased erosion along the channel edge and the scoured material transported to either the flood or ebb tide shoal, possibly increasing the volume of these features.

However, recent research (Van der Wegen, 2013) has identified that tidal asymmetry is a key driver of change within the estuarine area over long timescales where sea levels are increasing. Tidal asymmetry leads to small spatial gradients in tide residual sediment transport which results in morphodynamic development of the estuary.

The results of modelling carried out by Van der Wegen (2013) suggests sea level rise can change the trend of sediment transport from equilibrium/export (little or net seaward movement of sediment) to import (sand moving into the estuary) as a result of sea level rise over long time periods due to changes in tidal asymmetry. At Whangarei Heads the process of changing tidal asymmetry could result in removal of sediment from the ebb tide shoal into the harbour area over a period of decades to centuries of higher water levels. Unless replenished by alongshore transport, the loss of sediment from the ebb tide shoal could result in changes to the nearshore wave environment which could then lead to changes in the areas of accretion or erosion along the open coast shoreline adjacent to the ebb tide shoal.

Due to the existing climate variability that includes varying tide levels due to decadal and longer time cycles, as well as variations in annual wave climate, this process is unlikely to be noticeable over the next few decades when the projected increase in sea level rise is still within the range of annual fluctuations, but may become more noticeable over a longer time frame (many decades to centuries).

4.3 Summary of coastal processes

The Whangarei Harbour entrance is stable, controlled by Whangarei Heads to the north and the large ebb delta to the south. The northward directed net longshore sediment transport on the open coast of Bream Bay is very small in comparison with the sediment flux that enters and exits the harbour as a result of tidal exchange. Therefore the inlet is tide dominated, with tidal flows significantly greater than the net littoral transport which results in a stable inlet.

The analysis of historic bathymetric data shows that over the 76 year period there has been no significant change to the ebb tide delta below the 2 m depth contour. More detailed analysis of Mair Bank at the shallower part of the ebb tide delta, shows that this feature has been dynamically stable, but with natural fluctuations in the surface topography in the order of ± 1 m (vertical) and ± 2 m (horizontally) as banks and channels shift in response to storm events and tidal currents.

Over the last 16 years there appears to have been a northerly migration of sand towards and extending into the main channel, with this change largely occurring between 2000 and 2010. Surveys at 2015 and 2016 show much smaller changes. This has largely resulted in accretion of the upper part of the channel slopes with some evidences of slight steepening with some erosion of the lower slopes.

Ongoing and accelerated sea level rise may result in increased erosion pressure on the ebb tide shoal with changes in tidal asymmetry increasing sediment transport potential into the harbour that could increase erosion pressure along the open coast shoreline over a period of decades to centuries.

5 Assessment of effects of changes in physical coastal processes

This section summarises the changes to waves and currents in the nearshore environment resulting from both the dredged channel and the placement of dredged material to marine disposal areas as modelled by MSL (2016b) that may impact on coastal processes and the effect of these changes on coastal processes for both the capital (Figure 5-1) and maintenance dredging campaigns (Figure 5-2).

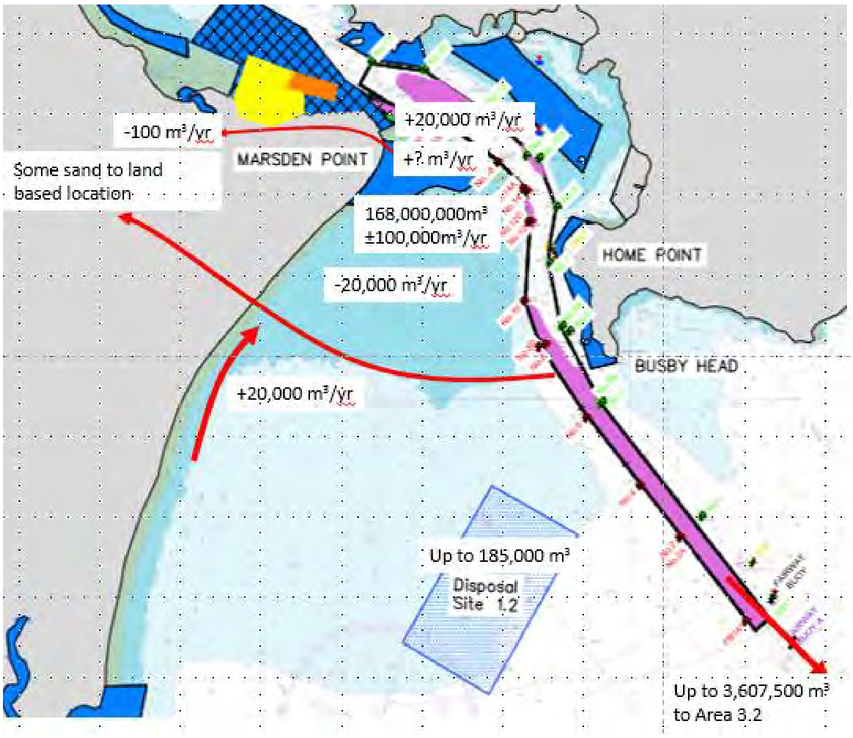


Figure 5-1: Schematic of capital dredge volume disposal options

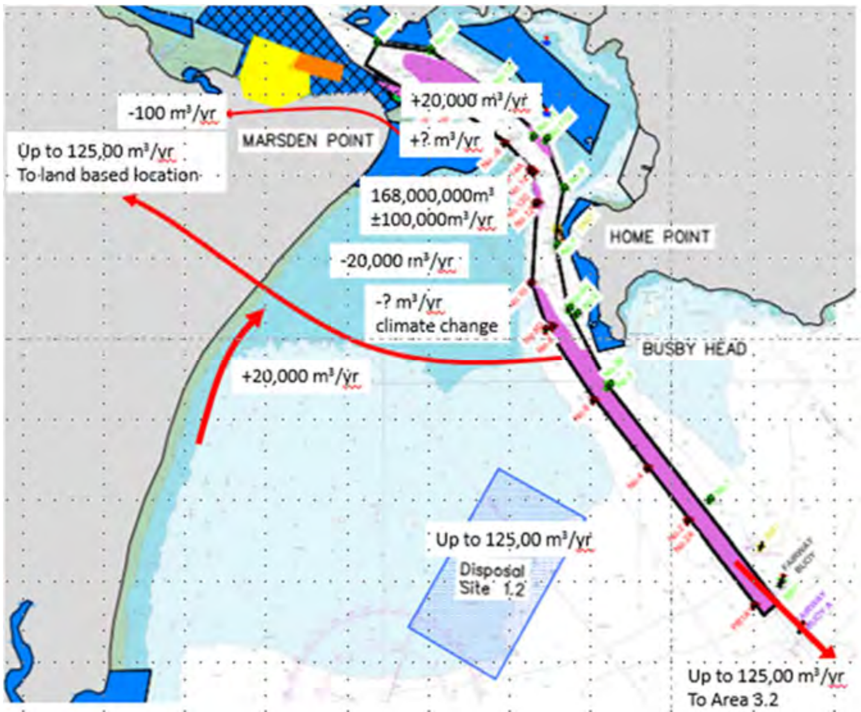


Figure 5-2: Schematic of maintenance dredge volume disposal options

Effects have been assessed based against the criteria set out in Appendix G that describes the definition of effects and the associated criteria.

5.1 Waves

The predicted change in wave height resulting from the dredged channel is shown in Figure 5-3 for average and a selection of more extreme (lower probability) events. For average and moderate wave climate conditions, the resulting changes are negligible (less than ± 0.02 m). Putting this into context, the variation in mean wave heights over the 35 year hindcast is 0.31 m. Therefore the average change is an order of magnitude less than the annual variability (refer Table 3-6).

During storm events (storms with significant wave heights offshore of 5 m or more), there may be some channel refraction effects resulting in higher waves breaking on the edge of Mair Bank and towards Busby Head. The increase in wave height at these locations is likely to be in the order of between 0.1 m and 0.3 m for storms with 5 m high waves. While there is a broader change of ±0.1 m over the majority of the ebb tide delta that can be characterised as a general reduction in wave height over the majority of the ebb tide delta, there is a slight focusing of waves along the southern flank (less than 2 cm change). Comparing the inter-annual variability on wave heights shown in Table 3-6, the relative change as a result of the dredging during high energy wave events is an order of magnitude less than the annual variability of 1.36 m for the 99% wave height (MSL, 2016b).

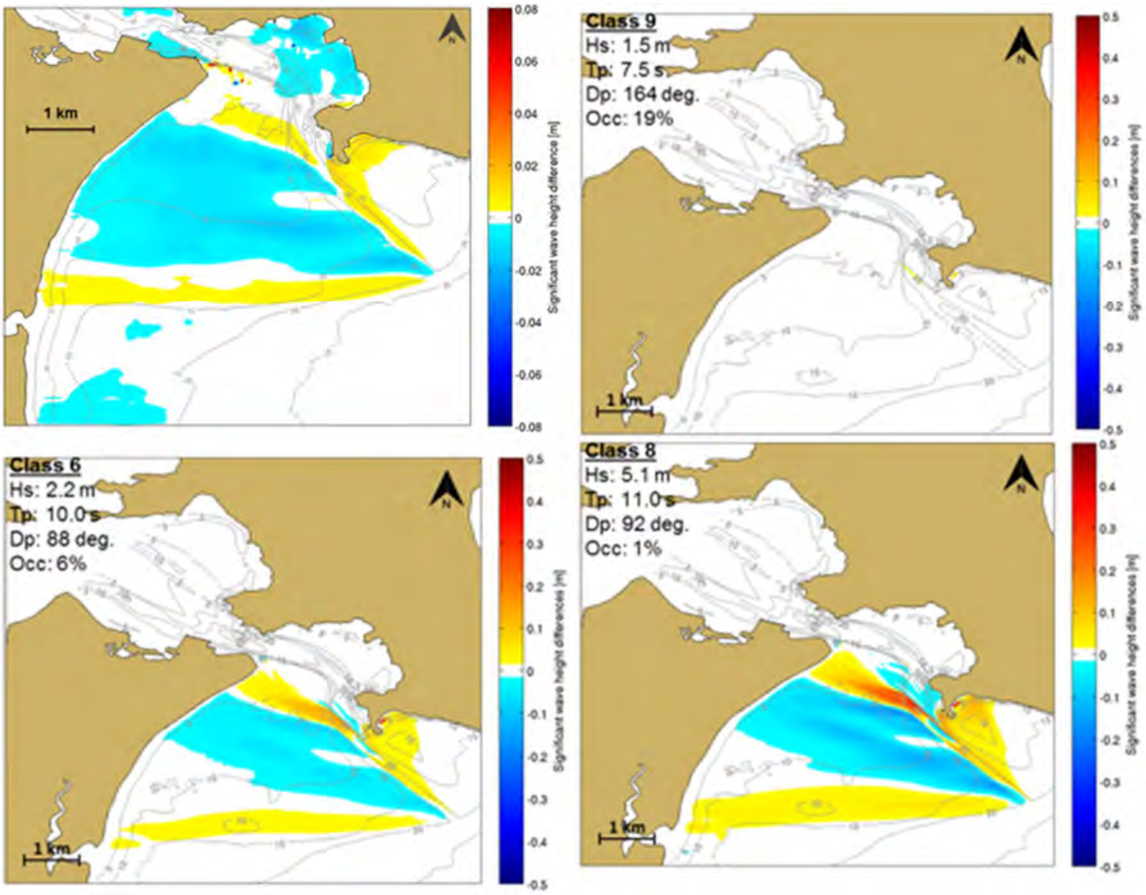


Figure 5-3: Changes in significant wave height resulting from channel dredging for average annual conditions (top left) and 19% (top right), 6% (bottom left) and 1% probability of occurrence (Source: MSL, 2016b)

Based on the existing observed variability of the upper parts of the ebb tide shoal that occurs due to the existing hydrodynamic variability on the upper parts of the shoal (±100,000 m^3/yr), these relatively small scale changes in wave heights during high energy events are unlikely to create a noticeable or measurable effect on sediment transport patterns and coastal process effects and therefore even for larger wave events will have negligible effects.

5.2 Currents

The effects on currents is limited to the harbour entrance and the ebb tide shoal as a result of the channel dredging and marine disposal. There is no change to the regional scale hydrodynamics or hydrodynamics within Bream Bay and no changes to tidal flows within Whangarei Harbour.

In the vicinity of the harbour entrance and ebb tide shoal the changes as a result of the dredging are small changes in velocity (absolute changes no more than ±0.15 m/s). Figure 5-4 shows the difference in peak flood and ebb velocities for the spring tide post channel deepening. As can be seen, there is a small reduction in tidal velocities (generally less than 0.02 m/s) except along the edges of the channel adjacent to Mair Bank, within the channel between Mair Bank and Home Point and between Home Point and Busby Head where changes can reach 0.1 m/s.

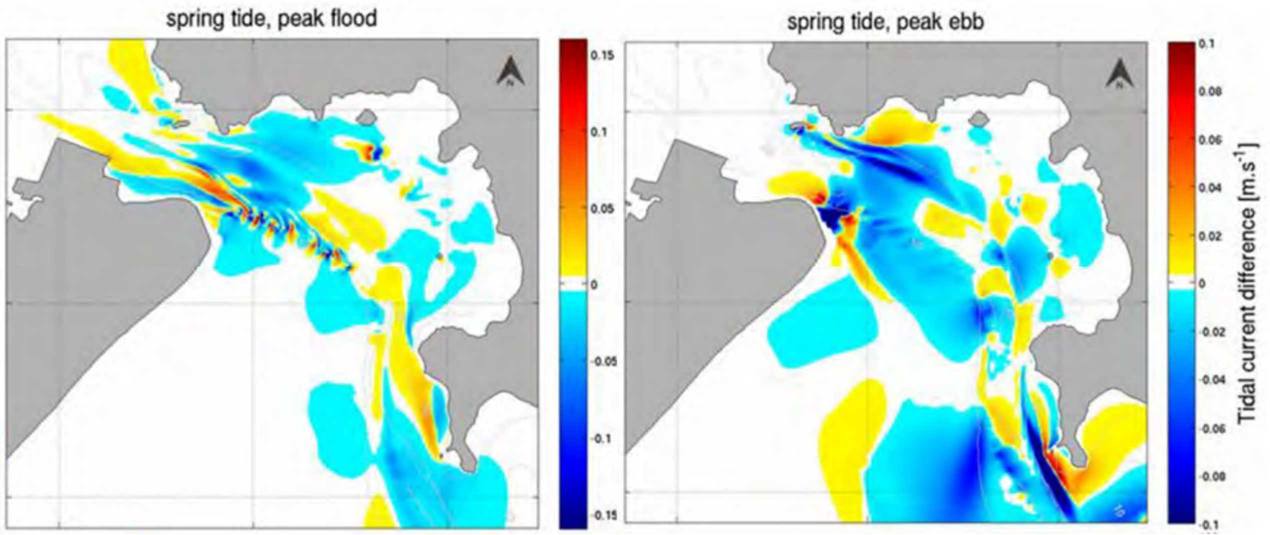


Figure 5-4: Difference in peak spring tidal flows post channel deepening for flood and ebb tides (Source: MSL, 2016b)

The materiality of these changes in peak velocity is assessed by evaluating the impact of these changes on the potential to increase, or decrease, the existing erosion potential resulting from the modelled changes to the tidal flows.

Figure 5-5 shows the total percentage change in bed shear stress post channel deepening for flood and ebb tides. As can be seen there are small reductions in bed shear stress in the outer part of the Ebb Tide Shoal and the inner bay. The reduction in shear stress indicates these areas may be areas where finer sediment can settle. The areas of slight increases in shear stress indicate areas where finer sediments are unlikely to settle.

Figure 5-6 shows percentage difference in shear stress required to mobilise 200 µm sand particles for flood and ebb tide (i.e. critical bed shear stress). A grain size of 200 µm is indicative of fine sand and representative of the typical mean grading size from field investigations carried out for this study. By only examining the critical shear stress there is a significant reduction in area potentially affected which suggests for sediments of 200 µm or coarser there will be very little change in sediment transport patterns. The figure also indicates a potential pathway for channel sedimentation, with sediment transported from the south-east of Busby Head potentially settling in the lower energy environment of the outer channel. These changes have no effect on the adjacent shoreline stability but may locally affect the seabed, principally resulting in sedimentation potential within the dredged channel and the side slopes. These effects are assessed to be negligible.

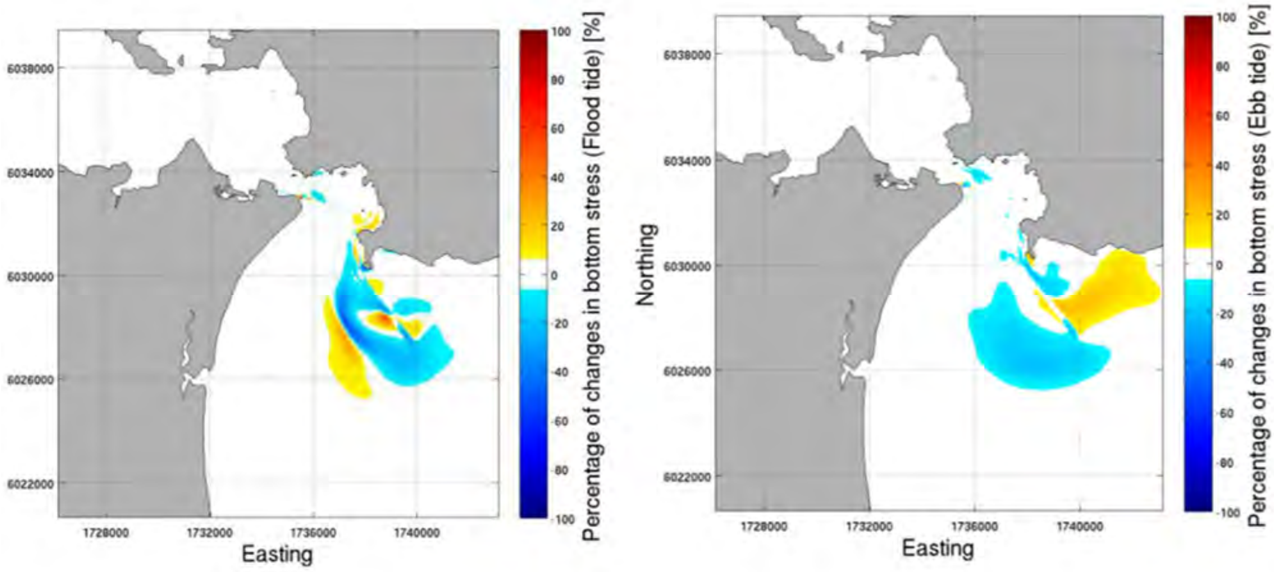


Figure 5-5: Total percentage change in bed shear stress post channel deepening for flood and ebb tides with small changes (±5%) not shown (Source: MSL, 2016b)

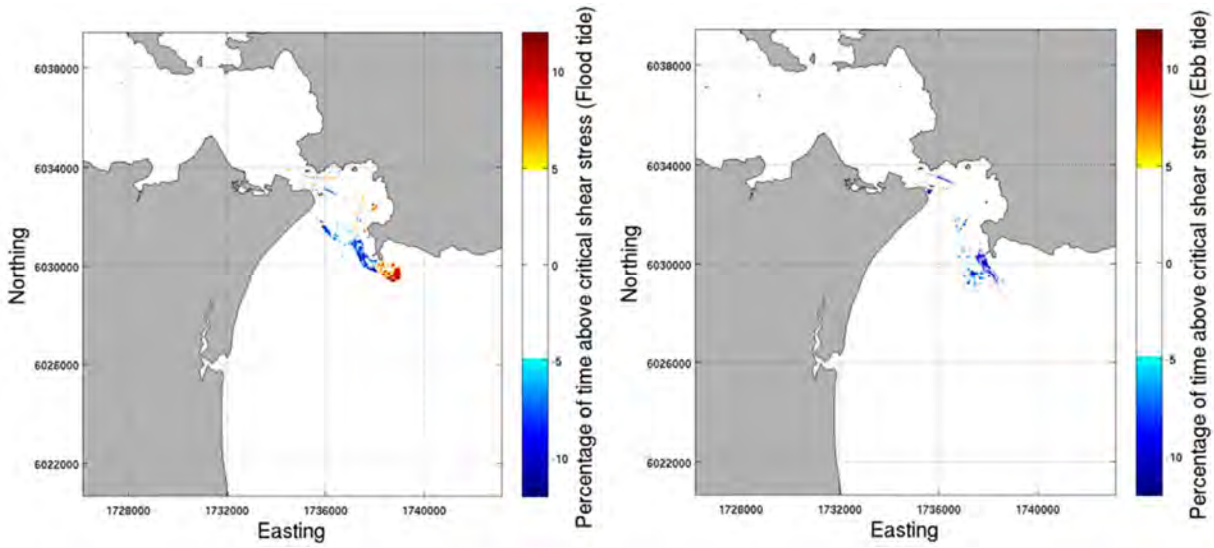


Figure 5-6: Percentage difference in shear stress required to mobilise 200 µm sand particles for flood and ebb tide (Source: MSL, 2016b)

5.3 Water level

Modelling carried out by MSL (2016b) indicate that there is no measurable change to the water levels within the harbour, although there may be some slight change to the phase of the tidal wave with mean changes in the order of ±7 minutes which may require changes to the timing of the tide arrival in the Nautical Almanac prepared by LINZ. The effect of changes to water level are considered to be negligible.

5.4 Tidal flux

Tidal flux is the rate of flow of water through a defined area. Examining the change in tidal flux as a result of the proposed channel deepening can provide another indication of the potential effects and extent of effects, particularly within the inner harbour area. Tidal flux was obtained from the tidal model at four locations as shown in Figure 5-7 extending from a transect from Marsden Point to Home Point within Bream Bay to a transect from One Tree Point to Reserve Point. The change in flux was calculated for spring and neap conditions for both flood and ebb tides. The results of this analysis is shown in Table 5-1.

Figure 5-7: Location of transects (yellow lines) to calculate tidal flux

Table 5-1: Changes in peak tidal flux

Tide phase	Transect locations	Flux (m3/s)		Difference (original-dredge)	
		Original	dredged	m3/s	%
Spring ebb	One Tree Point	9,778	9,768	10	0.10%
	NorthPort	12,773	12,757	17	0.13%
	RNZ Jetty	12,439	12,412	27	0.22%

Tide phase	Transect locations	Flux (m3/s)		Difference (original-dredge)	
		Original	dredged	m3/s	%
	Marsden Point to Home Point	16,378	16,329	49	0.30%
Spring flood	One Tree Point	8,823	8,866	-43	-0.49%
	NorthPort	11,657	11,711	-54	-0.46%
	RNZ Jetty	12,187	12,083	104	0.85%
	Marsden Point to Home Point	13,411	13,488	-76	-0.57%
Neap ebb	One Tree Point	4,614	4,621	-6	-0.14%
	NorthPort	5,876	5,852	24	0.41%
	RNZ Jetty	6,241	6,196	46	0.73%
	Marsden Point to Home Point	6,369	6,411	-43	-0.67%
Neap flood	One Tree Point	3,601	3,595	6	0.17%
	NorthPort	4,650	4,642	8	0.17%
	RNZ Jetty	4,555	4,545	10	0.23%
	Marsden Point to Home Point	6,487	6,459	29	0.44%

The results show only very small difference in tidal flux as would be expected with the small changes in velocity and water level. The largest change occurring during spring flood conditions at the RNZ Jetty (0.85% increase in peak flow at that location). The average change across all the transects during spring tide is less than 0.01% and 0.17% for ebb tide flows. This shows some small localised changes with increases and decreases in flow but only with a small net change.

The present trend of reducing tidal flux from the Jetty to One Tree Point is unchanged with the proposed works. The relative change at this location is also very small (less than 0.5% during spring tide and 0.17% ebb tide). The effect of these tidal flux changes on coastal processes are negligible.

5.5 Expected changes to the inner harbour

The inner harbour area extends into Whangarei Harbour westward of Northport. Tidal flows are low and confined to the channels and waves tend to be locally generated within the harbour.

5.5.1 Capital dredging

During the capital dredging works there are no construction activities proposed within the inner harbour area. The progressive deepening of the access channel leading to Whangarei Harbour will make small progressive changes in tidal flows over the course of the dredging activity. However, the small amounts of tidal flow changes in this area is shown in Figure 5-4 for the complete channel and are less than ±0.02 m/s. These small changes in tidal velocity do not change the forces acting on the seabed or the shoreline area. The changes in tidal flux are also very small. As a result, no change either to existing sediment transport patterns or shoreline change is predicted. Therefore during capital dredging effects on coastal processes are expected to be negligible within the inner harbour.

5.5.2 Maintenance dredging

There will be periodic maintenance dredging required in order to maintain the channel cross section and enable safe access by more heavily laden vessels. This dredging may utilise a range of different vessel types, depending on the location and volume of material to be dredged. The slight variation in tidal flows identified in the section above will not result in any ongoing change to the tide and wave forces currently acting on the seabed or shoreline. Therefore, during the period where the access channel is maintained, effects on coastal processes within the inner harbour are also expected to be negligible.

5.6 Expected changes along the entrance channel

The entrance channel is a tidal inlet to Whangarei Harbour. This area includes the small bays along the rocky coast from Mount Aubrey to Home Point including Calliope Bank, Urquarts Bay and Taurikura. This area is dominated by tidal flows following the alignment of the main channel with smaller flows along the side channels around Calliope Bank. The entrance channel area is relatively sheltered from waves generated in Bream Bay and, due to the small fetches in this area, locally wind generated waves are low.

5.6.1 Capital dredging

During construction there will be dredging vessels operating within the entrance channel area and sailing to the disposal areas. There is already marine infrastructure in place to service the vessels (berthing areas and jetties of both Northport and Refining NZ) and therefore no other infrastructure will be require as part of the construction activity.

The channel deepening will result in progressive changes to the seabed level within the channel and therefore it will also make progressive changes to tidal flows. However, as set out in Section 5.2, the resulting change of the completed works on tidal currents is small, with absolute changes of no more than ± 0.15 m/s in this location and generally less than ±0.02 m/s and the tidal flux changes are also very small. The changes in tidal currents include a reduction in tidal flows along the right bank of the channel adjacent to the ebb tide shoal and smaller increases in tidal flow along the northern flank of the inlet channel. In the outer channel area the combined effects of wave and tidal currents increase the critical bed shear stress adjacent to Busby Head during higher energy events. However, the seabed composition at this location, including shell lag and medium to fine sands increases the resistance of the seabed to change at this location. Over the majority of the channel area the effect on existing sediment transport patterns are expected to be minor during the capital dredging period.

5.6.2 Maintenance period

Over the maintenance period there will be periodic maintenance dredging using a range of different vessel types, depending on the location and volume of material to be dredged, in order to maintain the channel cross section and enable safe access by more heavily laden vessels. Sedimentation will occur in the jetty berthing pocket and the inner channel area due to:

- suspended sand transported through the tidal exchange settling out in areas where tidal flows have been reduced, and
- sand migration over the ebb tide shoal onto the side slopes of the right bank of the channel and then distributed along the channel edge, depositing in areas where there are lower tidal velocities.

A similar process of sedimentation will occur in the outer channel area, with localised areas, such as the channel adjacent to Busby Head, potentially more susceptible to sedimentation during higher energy events.

Apart from the expected sedimentation within the channel footprint, the slight variation in tidal flows and waves adjacent to the channel will not result in any change greater than the existing variation in tide and wave forces currently acting on the seabed or shoreline. Therefore during the period where the access channel is maintained there will be negligible effects on coastal processes within the channel entrance.

5.7 Expected changes to the ebb tide shoal and Mair Bank

The ebb tide shoal is a large stable medium to fine sandy feature formed by tidal currents and waves. Mair Bank is a coarse sand and shelly/gravel feature within the intertidal and sub-aerial part of the shoal that has a large biological component (pipi and mussels). The upper parts of the shoal and Mair Bank are more dynamic features that can vary in horizontal elevation by ± 0.5 m and vertical position by ± 2.0 m from year to year responding to higher energy wave events. A 2.5km^2 area along the outer part of the ebb tide shoal has been identified as Disposal Area 1-2 and is to be used as a deposition area of a portion of the capital (2.5 to 5%) and up to 100% of maintenance dredging volumes as shown in the schematics in Figure 5-1 and Figure 5-2.

5.7.1 Capital dredging

The proposed channel alignment has been developed to limit disturbance of the ebb tide shoal and Mair Bank, whilst achieving the target depth and adhering to navigational safety requirements. Dredging will be carried out within the berth pocket area and at discrete locations along the subtidal part of the ebb tide shoal. The volume of sediment removal from the more active part of the ebb tide delta (i.e. above the 10 m depth contour) is relatively small (around 150,000 m^3 or less than 0.1% of the total delta volume) with the greatest volume being taken from the deeper and less mobile parts of the delta (around 3,470,200 m^3).

The changes are predicted to increase tidal flows in the small channel present between Mair Bank and Marsden Bank (refer Figure 5-4). This slight increase in tidal flow may assist in maintaining the location of the channel between the two banks, but this will also be dependent on existing sediment transport trends and the response to storm events.

Dredging is also expected to cause slight changes to wave refraction patterns which will typically result in a slight reduction in wave heights along the ebb tide shoal (less than ±0.02 m), apart from within a narrow area along the southern flanks of Mair Bank, which may have small increases in wave height during higher energy events (0.1 to 0.3 m, refer Figure 5-3). However, as these changes are an order of magnitude less than the annual variability for large waves that already result in changes of ±100,000 m^3/yr within the upper parts of the ebb tide shoal, these small modelled effects are unlikely to manifest in measurable changes to sediment transport trends.

Capital dredging will include the placement of between 2.5 and 5% of sand from the dredging within an area on the ebb tide shoal, being Disposal Area 1-2 (i.e. between 90,500 to 181,000 m^3). These volumes are in the same order as the 150,000 m^3 proposed to be dredged in the more active part of the ebb tide delta (i.e. above the 10 m depth contour) and therefore retain the net volume of the upper part of the ebb tide delta.

Based on the analysis of surveys of the ebb tide shoal and Mair Bank from 2000 to 2016 there has been some global movement of sediment from the southern area of the ebb tide shoal with some 20,000 m^3/yr moving from the southern part of the ebb tide shoal and being deposited along the flanks of the tidal inlet over the 16 year time period where detailed surveys are available (refer Figure 4-20). These changes are attributed to the natural fluctuations that occur at this location.

The placement of a proportion of sand from maintenance dredging in the proposed nearshore placement Area 1-2 will either assist in replacing the historic loss of sand and/or assist in maintaining a supply of sand to the ebb tide delta. Modelling has shown that the mound formed will not result in changes in wave conditions that could result in changes that would affect littoral drift or storm effects on the beach environment. Modelling has also shown that sediment placed in this area will migrate shoreward at a rate dictated by the natural processes of wave and tide activity. Therefore, capital dredging and the placement of dredged material within Area 1-2 will have a beneficial effect on coastal processes operating on the ebb tide shoal.

Therefore, as a result of the capital dredging works the effects on coastal processes within the ebb tide shoal area are considered less than minor.

5.7.2 Maintenance dredging

The maintenance dredging activity will be similar to the capital dredging process, but with smaller volumes and possibly smaller dredge vessels. Maintenance dredging may also include the placement of sand within an area on the ebb tide shoal, at Disposal Area 1-2. Similar beneficial effects associated with nearshore placement of dredged material at Area 1-2 will result during maintenance dredging, as described above in Section 5.7.1.

5.7.3 Potential long term effects

The numerical modelling and analysis has shown that the proposed channel dredging has little effect on the coastal processes operating in this area. However, it is recognised that both the capital dredging and ongoing maintenance dredging may result in a net loss of sediment from the ebb tide shoal over time that may not be replenished from natural sources (refer Figure 5-1 and Figure 5-2). The net loss is a potential effect whether disposal is to land or to Site 3-2 as in both cases the dredged sediment is not within the active nearshore sediment system.

While the capital dredge volumes are small in comparison to the volume of sand stored in the ebb tide delta (around 2.2% of the estimated volume of the ebb tide shoal) and the expected maintenance dredging volumes are also small (between 0.03% and 0.07% of the estimated volume of the ebb tide delta), these net losses of sediment may result in a reduction in the total volume of the ebb tide shoal over time. Assuming full removal of both capital and maintenance dredging from the ebb tide delta over the 35 period of the consent, this would result in around 5.6M to 7.9Mm^3 of sediment removal that equates to around 3.3 to 4.7% of the existing ebb tide delta volume.

The reduction in volume could manifest in a reduction in level of the existing ebb tide shoal area (i.e. assuming the footprint of the shoal remains the same). However, it is more likely to result in both a reduction in level and a reduction in overall plan form size of the delta, as it would be expected that ongoing coastal processes would move sand towards the shoreline. An overall change in area and height would result in smaller observed changes than if only height was reduced.

The potential change in elevation over the 35 year period has been assessed based on the total area of the ebb tide delta to the 15 m contour (around 35km^2) and, conservatively, assuming the variation would manifest in the upper part of the delta above the 5 m depth contour (an area of around 6 km^2). Assuming a uniform change over the area as a result of the capital and maintenance dredging, the change in elevation (vertical change) ranges from 0.16 to 0.23 m (spread over 35 km^2) to 0.9 to 1.3 m (focussed on changes only occurring above the 5 m contour). The associated net horizontal reduction of the ebb tide shoal that currently extends around 5.6 km seaward from Marsden Point would be in the order of 70 m. We note the vertical changes are of a similar range of the measured vertical variability of levels of ±0.5 m within the upper part of the ebb tide delta (Morgan et al., 2011). The potential change in plan form area for the full ebb tide delta would be between 0.75 km^2

and 1.1 km^2 taking into account the full removal of capital and maintenance dredging from the ebb tide shoal.

However, full removal of sediment is not proposed and therefore actual effects will be less than described in the paragraphs above. The proposed replacement of sand during in the active part of the ebb tide shoal during the capital and maintenance dredging campaigns will effectively maintain the sand volume in the active part of the ebb tide delta (i.e. above the 10 m depth contour). Therefore the main loss from the ebb tide shoal will be the 3,470,000 m^3 from the deeper part of the delta during capital dredging and there will be no losses, and possibly gains, to the upper part of the ebb tide delta during the maintenance dredging period and the effect of this loss on the delta dynamics will not be measurable (that is effects will be negligible to nil). There will be no net sediment loss, and possibly sediment gains, to the upper part of the ebb tide delta during the maintenance dredging period. This will maintain and possibly enhance sediment volumes to offset other effects such as sea level rise.

5.8 Expected changes to the open coast shoreline from Marsden Point to Ruakaka

This is a dynamic area with existing coastal process trends of general stability in the vicinity of Ruakaka to some locations of erosion in the vicinity of Mair Bank.

5.8.1 Capital dredging

The capital dredging will result in small changes, both in terms of the typical wave height (less than 2 cm) and storm waves (typically less than 5 cm) that are an order of magnitude less than the annual and extreme variability in wave height. As the changes are small it is unlikely that these changes will result in any measurable change to the existing coastal processes so effects are considered less than minor.

5.8.2 Maintenance dredging

The nearshore placement of dredged material at Disposal Area 1-2 (as discussed in Section 6.4) can assist in reducing the effects observed with existing coastal processes both during the capital and maintenance dredging phases of the project so has a beneficial effect.

5.9 Expected changes to the open coast shoreline from Home Point to Smugglers Bay

The shoreline from Home Point to Smugglers Bay comprises strong volcanoclastic cliffs with narrow alluvial beaches at Home Point and Smugglers Bay (refer Figure 3-7 and Figure 3-8). These cliffs are already subject to very low rates of natural erosion processes both from weathering of the steep subaerial cliff face and, to a less degree, tidal flows at the base of the cliffs that remove cliff debris. The absence of significant wave cut platforms at the base of these cliffs shows that the existing current and wave action has minimal effect of the cliff shore that has been exposed to these processes for the last 6,500 years. Capital dredging

The proposed channel deepening results in an increase in wave height of around 0.1 m along Smugglers Bay for the most extreme cases of high energy events with offshore waves of more than 5 m (annual occurrence of less than 5%) (refer Class 8, Figure 5-3). There is also a slight increase in wave energy at Busby Head of the same order of magnitude for the same events but a reduction in energy along Home Point to Busby Head.

Changes of this order will not make a noticeable change to the coastal processes operating in this area as a result of these changes being small in relation to the annual variability in wave climate; the small changes occur during infrequent storm events and the main physical processes of erosion, including weathering and land-sliding of the cliff shores are not driven by wave energy in these relatively sheltered locations. These predicted changes in wave height as a result of the channel dredging will have negligible effects on the physical coastal processes operating on the cliff and beach coasts in this area.

Modelling of critical shear stress changes on the seabed off Busby Head suggested there may be some minor effect on the seabed at the 10 m depth contour (refer Figure 5-6). However, this theoretical effect is unlikely to manifest as the seabed condition at this location is more rocky and shelly than the sandy seabed simulated in the modelling. Therefore erosion processes resulting from the increased shear stress are likely to be negligible as they are not likely to result in measurable changes to seabed levels.

5.9.1 Maintenance dredging

The effect on the coastal processes in this area as a result of the maintenance dredging activity is expected to be negligible.

5.10 Expected changes to the seabed within Bream Bay

Bream Bay is a relatively sheltered embayment in the Hauraki Gulf. The shallower parts of the bay has a medium to fine sandy seabed, with rocky reef outcrops and a variety of seabed forms resulting from wave and current interaction.

5.10.1 Capital dredging

A 2.5 km^2 disposal area is situated at the 45 m depth contour to the south east of the channel (disposal area 3-2). This area has been designed to have the capacity to place all capital and maintenance dredged material over the period of the consent without any loss of placed sediment over time from within a slightly larger mixing area of 5.75 km^2. The seabed sediment composition within the disposal area is similar to the dredged material so it is anticipated that any sediment placed in this area will perform similarly to the in situ sediment.

The potential effect of placing a mound of sediment on the seabed on coastal processes is that it might change wave patterns that may result in changes to littoral transport along the open coast. The results of hydrodynamic modelling show that for most wave conditions the wave orbital velocity at the seabed is too small to cause sediment to move. Orbital velocities increase to potentially being able to transport sediment during storms with significant wave heights greater than 5 m. Therefore, sediment placed in this area is likely to largely remain within the disposal area, with only very small amounts of migration from the 2.5 km^2 area and all sediment remaining within the 5.75 km^2 area. Modelling of the effects on waves over a period of a year, including storm events, was conservatively carried out with a 4 m high mound over the entire disposal area as the worst case scenario with all capital and maintenance dredging over 35 years placed at this location and no loss of sediment from the system over the 35 year period. However, even with this conservative scenario, the change in maximum wave heights along the open coast were ± 5cm from the existing situation. Variations in maximum wave heights of ± 0.05 m are well within the annual variability of maximum waves height within Bream Bay of ± 1.3 m. Therefore, placing capital dredging in disposal Area 3-2 will not have a minor effect in the vicinity of the disposal area and negligible effects on the wider coastal processes operation on the open coast of Bream Bay.

5.10.2 Maintenance dredging

Area 3-2 may be required to take additional sediment from maintenance dredging. The potential effects of placing additional sediment is the modification of wave heights and the associated impact on the beaches in terms of littoral drift changes and storm effects. As discussed above, the modelling for the entire amount of maintenance dredged material being disposed at Area 3-2 over the 35 year term sought for the consent (and assuming no losses of material), indicated minor effects on the seabed adjacent to the disposal area and negligible effects coastal processes on the open coast. As the maintenance dredging volumes will be several orders of magnitude smaller than the capital dredging, effects on both adjacent and wider environment will be negligible.

5.11 Expected changes to recreational surfing

While surfing can be carried out along much of the Bream Bay coastline, surfing spots are recognised at the Ruakaka River mouth and at the Power Station sites. Wave modelling carried out by MSL show that these areas experience a slight concentration of wave energy, supporting the likelihood of these areas being favourable for surfing. Figure 5-3 shows modelled changes to the wave climate as a result of the proposal. MSL conclude the modelling shows no fundamental changes to the mean wave height and negligible changes to the maximum climate along the Ruakaka shoreline, changes to recreational surfing would be negligible.

5.12 Expected effects resulting from relocation of navigations aids

The proposal includes the relocation and addition of navigation aids to clearly mark out the navigation channel. These structures will have no effect on coastal processes.

5.13 Expected effects on public access to and along the Coastal Marine Area and to culturally significant sites

The existing coastal processes described in Section 3 and 4 results in changes and modifications of beach level and sand levels in the intertidal areas. Apart from localised limitations on access at specific locations of the CMA during the dredge campaigns, the proposal has no change to the existing public access available to and along the Coastal Marine Area or to culturally significant sites such as Mair Bank. The placement of sediment on the ebb tide shoal may have some localised beneficial effect by reducing existing erosion effects.

5.14 Expected effects on existing and future coastal hazards

The sandy shoreline along the northern part of Bream Bay and within Whangarei Harbour are currently susceptible to coastal erosion and are likely to experience greater erosion pressure as a result of sea level rise and climate change effects. The main driver for change will be increased sea levels that allow higher waves to reach the nearshore environment for all wave conditions. As identified in Section 3.10.1.2 the increase in average conditions is negligible while there is some increase in the less frequent storm events.

The increased sea level will reduce the effect of the proposed dredging on wave processes (i.e. reduced effects from the present day situation) as the greater water depth will reduce nearshore processes. The potential for increased tidal flow from the harbour will not be affected by the proposal as the throat of the inlet will not be modified and it is this area that controls the tidal flows.

The proposal has less than minor effects on coastal processes in the present day and the effect will reduce as a result of expected climate change effects. By retaining additional sand volume in the active part of the ebb tide delta it may provide a beneficial effect to assist in offsetting some of the future coastal hazard effects.

5.15 Tsunami

The existing harbour area is vulnerable both to distant and local tsunami sources. The high velocities resulting from the tsunami are likely to result in large scale movements within the sandy systems of the nearshore, ebbtide delta, coastline and inner harbour. Specifically scouring of the narrower parts of the inlet throat with deposition both in deeper water seaward and landward of the inlet in the present day situation. Even in the present day situation this is likely to require inspection of the channel and inlet to confirm the safe operability of vessels accessing the port and jetty and it is likely that some maintenance dredging may be required to maintain operability.

While tsunami wave modelling has not been carried out for this assessment, as the narrowest part of the inlet throat has not been modified and, the channel deepening is unlikely to change the large scale effects of the tsunami on the wider environment. However, it can be expected that the dredged outer channel area may be subject to rapid deposition as this is the area that some of the sand that has been scoured from the inlet throat is likely to settle. The dredge disposal areas may also experience greater rates of localised change with higher forces exerted on the seabed than typically occur from extreme storm events.

5.16 Overall cumulative effects

Overall the changes to tidal flows and wave conditions resulting from the channel dredging and marine disposal are small and typically within the existing variability of tidal currents and wave energy. Changes to existing coastal processes are anticipated to be negligible on the open coast from Marsden Point to Ruakaka River or along the rocky coast from Home Point to Smugglers Bay, on the ebb tide shoal and Mair Bank or within the inner harbour area.

6 Proposed avoidance, reduction and mitigation measures

As discussed in Section 5.7.3 the numerical modelling and analysis has shown that the proposed channel dredging has little effect on the coastal processes operating in this area. However, it is recognised that both the capital dredging and ongoing maintenance dredging may result in a net loss of sediment from the ebb tide shoal over time that may not be replenished from natural sources (refer Figure 5-1 and Figure 5-2). While the capital dredge volumes are small in comparison to the volume of sand stored in the ebb tide delta (around 2.2% of the estimated volume of the ebb tide shoal) and the expected maintenance dredging volumes are also small (between 0.03% and 0.07% of the estimated volume of the ebb tide delta), these net losses of sediment may result in a reduction in the total volume of the ebb tide shoal over the 35 year period of consent being sought. The losses in volume due to the cumulative effect of the capital and maintenance dredge volumes could result in a combination of a reduction in the footprint of the ebb delta as well as a general lowering in elevation. Broad scale estimates of change suggest average changes in elevation of between 0.15 m to 0.23 m, although there might be localised change of around 1 m if the elevation changes are restricted to the upper parts of the delta.

It is also recognised that Mair Bank and the coastline extending southward from Marsden are currently experiencing change and some net loss of sand. Future sea level rise may also result in a loss of sediment from the ebb tide shoal. Both the possible ongoing removal of sediment from the capital and maintenance dredging and future sea level rise effects may result in increased erosion pressure on Mair Bank as well as ongoing shoreline erosion along the open coast beaches adjacent to the ebb tide shoal. As such there is potential for cumulative effects of a continuous removal of sand from the ebb tide delta reducing the net volume stored in the delta that would exacerbate instability of the delta and have an associated adverse effect on the adjacent shoreline.

Placing suitable dredged sediment within the ebb tide shoal that both results in a reduction in the volume of sediment removed from the ebb tide delta and enables the placed sand to be transported within the nearshore sediment transport pathways (refer Figure 4-19) is a practical means of maintaining the volume of the ebb tide shoal and maintaining a supply of sand to both the shoal and the adjacent shoreline.

The proposed volume for placement at Area 1-2 has been derived to minimise the risk of potential adverse effect (in terms of ecological effect), to replace the capital dredge volume from the more active part of the delta (i.e. the area above the 10 m depth contour) and to protect to some degree against the potential increase in losses of material in the future resulting from sea level rise by the ongoing placement of maintenance dredging material that increased the net volume of sediment entering the more active part of the delta.

6.1 Residual effects after treatment

Table 6-1 shows the total volume loss from the ebb tide shoal both in terms of cubic metres and percentage of the total ebb tide shoal volume for three scenarios. The first is with all capital and maintenance dredging being removed, the second is with between 2.5% and 5% of the capital dredging placed in Area 1-2 and the third option includes 100% of the maintenance dredging as well as between 2.5% and 5% of the capital dredging. The table also includes an assessment of the net change that occurs above the 10 m depth contour with the return of between 2.5% and 5% of the capital dredge on the basis that 150,000 m^3 is removed from above this contour during the campaign. We have not considered the ongoing effect of replacing the maintenance dredging volume on the basis that this is effectively neutral, replacing material that is removed.

Retaining a portion of the capital dredge makes a modest reduction in the overall volume removed from the ebb tide shoal. Returning 100% of the maintenance dredging volumes effectively limits to loss of sediment to the capital dredge volume, although it is noted that due to the fluctuation in elevation and volumes of the ebb tide delta as discussed in Section 4.1.3 and 4.1.4 it may not be desirable to place all maintenance dredging volumes in ebb tide shoal. If it is combined with periods of higher elevations of the ebb tide shoal it could increase the likelihood of sand inundation over Mair Bank, therefore evaluation of the amount to be returned would need to be assessed based on ongoing monitoring. Looking at the net loss of the upper part of the delta, placing between 2.5% and 5% of the capital dredge creates a situation where there is effectively very little net loss to the active system, or potentially, a slight gain that can offset potential climate change losses.

Table 6-1: Volume of sand loss from ebb tide shoal (m^3 and %) with a range of dredge disposal scenarios

Maximum total loss with all capital and maintenance dredging placed out of ebb tide shoal system		
Minimum	-5,598,000 m^3	-3.33%
Max	-7,908,000 m^3	-4.71%
Loss returning between 2.5% and 5% during capital dredging but no maintenance dredging volume returned		
Min	-5,507,050 m^3	-3.28%
Max	-7,726,100 m^3	-4.60%
Loss returning between 2.5% and 5% during capital dredging and 100% maintenance dredging volume returned		
Min	-3,547,050 m^3 (with 56,00 m^3/yr)	-2.11%
Max	-3,456,100 m^3 (with 122,000 m^3/yr)	-2.06%
Net loss of upper part of delta (above 10 m depth contour) based on returning between 2.5% and 5% during capital dredging		
Min	-59,050 m^3	N.A.
Max	31,900 m^3 (net gain)	N.A.

Provided some portion of sand is retained within the ebb tide shoal system during both the capital and maintenance dredging operation, the residual effects on coastal processes of the proposed channel dredging and disposal regime is expected to be within the observed fluctuations currently observed and therefore the effects on the coastal environment with treatment are expected to be less than minor (i.e. negligible).

7 Proposed monitoring conditions

7.1 Capital dredging related monitoring

No specific monitoring is considered necessary for coastal processes.

7.2 Long term monitoring requirements

The areas to monitor for long term potential change are Mair Bank and the shoreline in the vicinity of the ebb tide shoal. Monitoring elevation changes (if any) in seabed and shoreline in the vicinity of Mair Bank is the most useful form of long term monitoring combined with ongoing measurement of waves and water level at the Wave Rider Buoy so that changes in shoreline and seabed elevations can be assessed together with changes in wave energy and water level fluctuations.

It is anticipated that the dredged channel will need to be regularly dredged as part of ensuring safe access to Refining NZ. We anticipate the monitoring of Mair Bank, the upper portion of the ebb tide shoal and disposal Area 1-2 would be carried out at the same time and this would be done to determine the need and the quantum of maintenance dredging that should be placed in Area 1-2.

It is recommended that annual monitoring of bathymetry of the upper part of the ebb tide shoal (above the 5 m depth contour), Disposal Area 1-2 and dredged channel be continued for a period of up to 5 years after capital dredging has been completed. At that stage an evaluation of the survey data should be carried out to confirm effects are within the range assessed by the studies carried out for this application and to determine the requirements (if any) of ongoing consent related monitoring.

Pre and post dredging surveys should be retained by the consent holder in a compatible format to augment this data set and information of the volumes and locations of deposition of both the capital and maintenance dredging recorded.

Analysis of shoreline trends can be carried out by aerial photograph and LiDAR survey analysis, with these data sets being regularly updated by Northland Regional Council (NRC) and Whangarei District Council. NRC also carry out beach surveys at 5 locations within Bream Bay with data from the mid-1970's. These surveys provide a long term record of existing shoreline fluctuations and trends and NRC should continue to carry out surveys at these locations. The initiation of additional detailed beach profile monitoring at locations different to these long term profile sites is not recommended as there is no effects-based reason to require such monitoring. Furthermore, such monitoring would be limited in its applicability, as there is no good long term data set to provide the baseline context.

8 Applicability

This report has been prepared for the exclusive use of our client Chancery Green on behalf of Refining NZ Ltd, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement. We understand and agree that Refining New Zealand will submit this report in support of an application for resource consent and that the consent authority and third parties (stakeholders, submitters and interested parties) will rely on this report for the purpose of assessing that application.

Tonkin & Taylor Ltd

Report prepared by:		Authorised for Tonkin & Taylor Ltd by:
....		....
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Appendix A: Historic and Current Hydrographic Charts

4 Hydrographic Survey 1848 – R B Graham
5 Hydrographic Survey 1849 – Captain Stokes
6 Fair sheet, 1939
7 Fair sheet, 1959
8 Hydrographic Survey 1964
9 Hydrographic Survey 1974
10 Hydrographic Survey 2004 – NZ5214
11 Hydrographic Survey 2004 – NZ5215

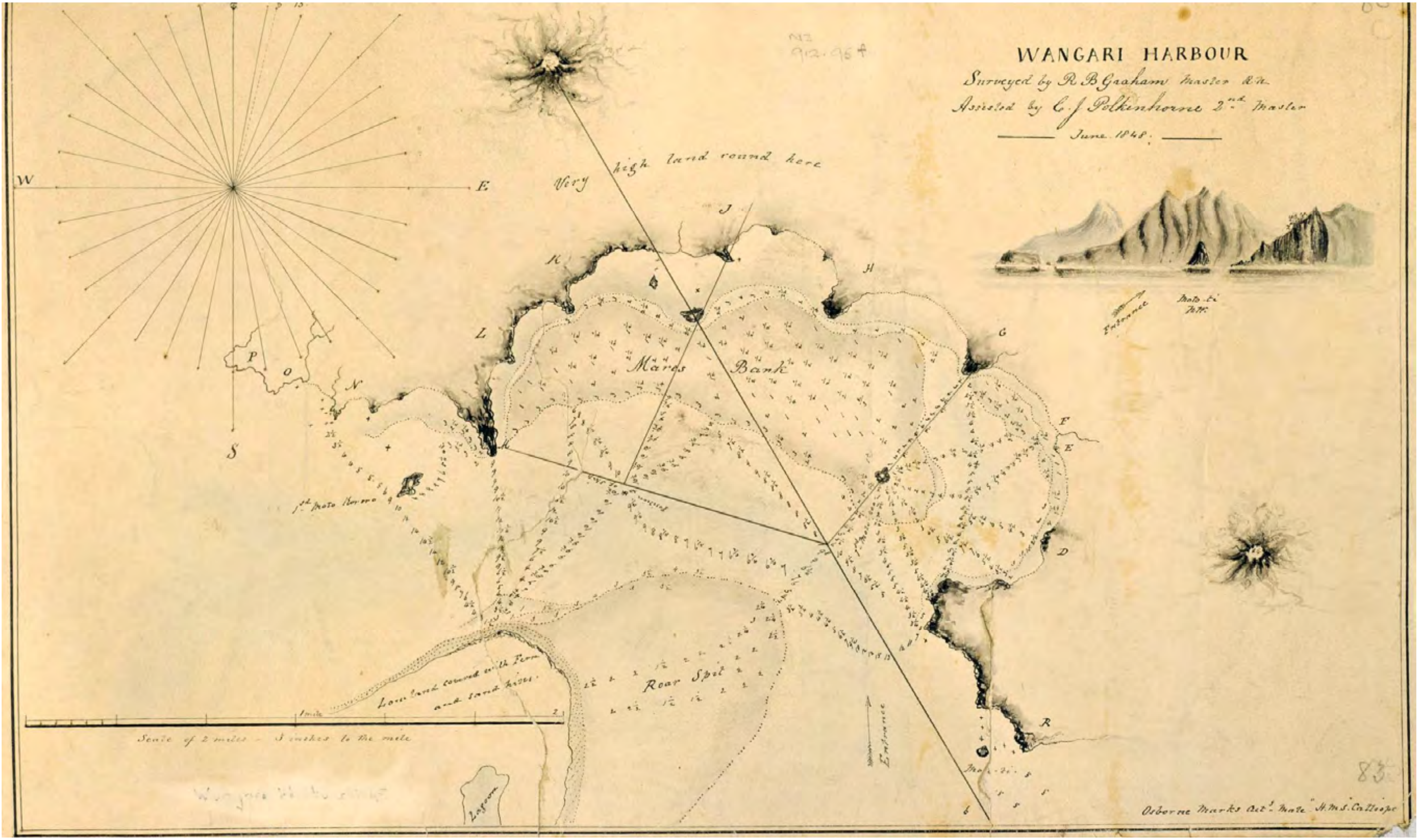

Figure A 1: 1848 Bathymetric Chart (Source: Alexander Townhall Collection

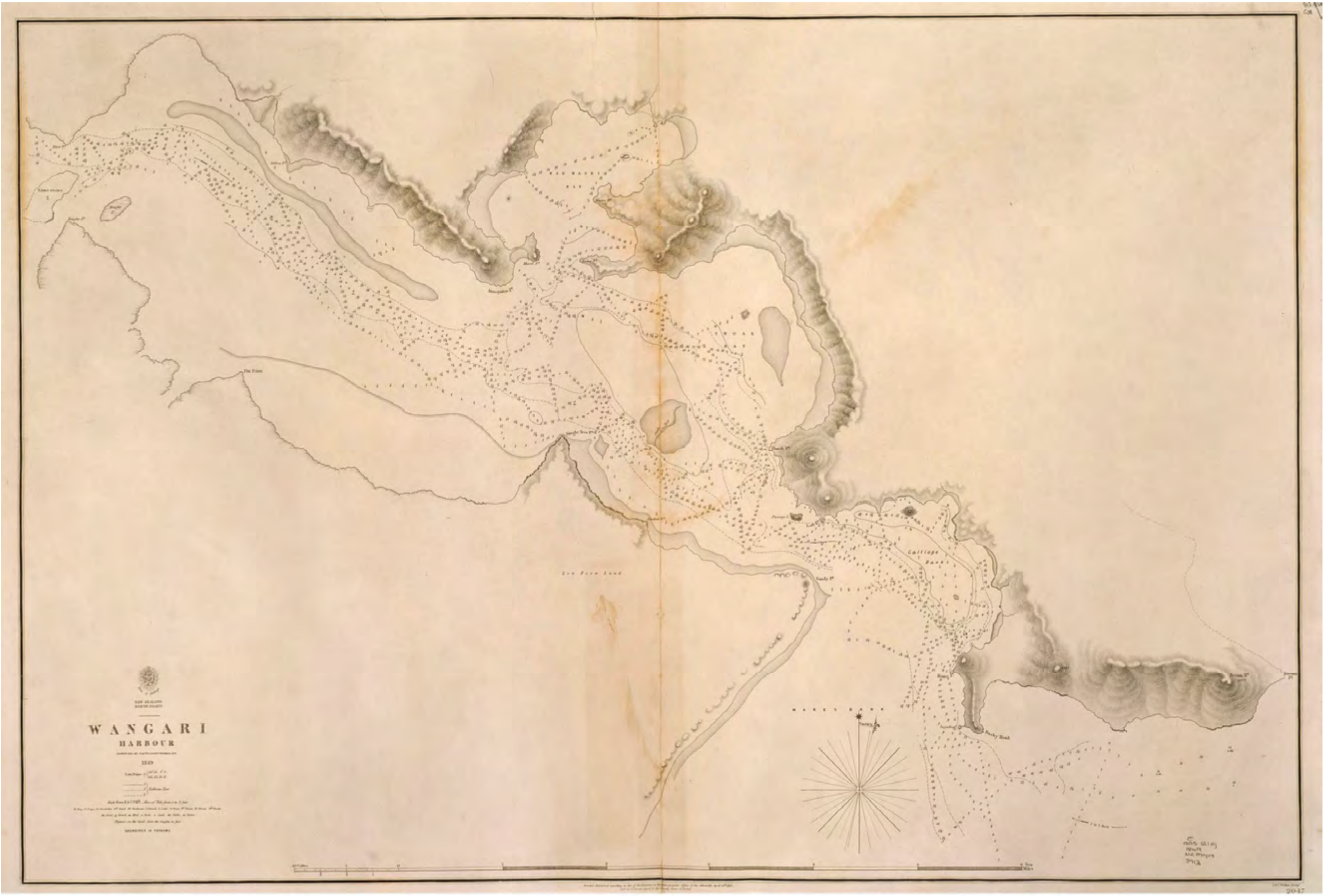

Figure A 2: 1849 Bathymetric Chart

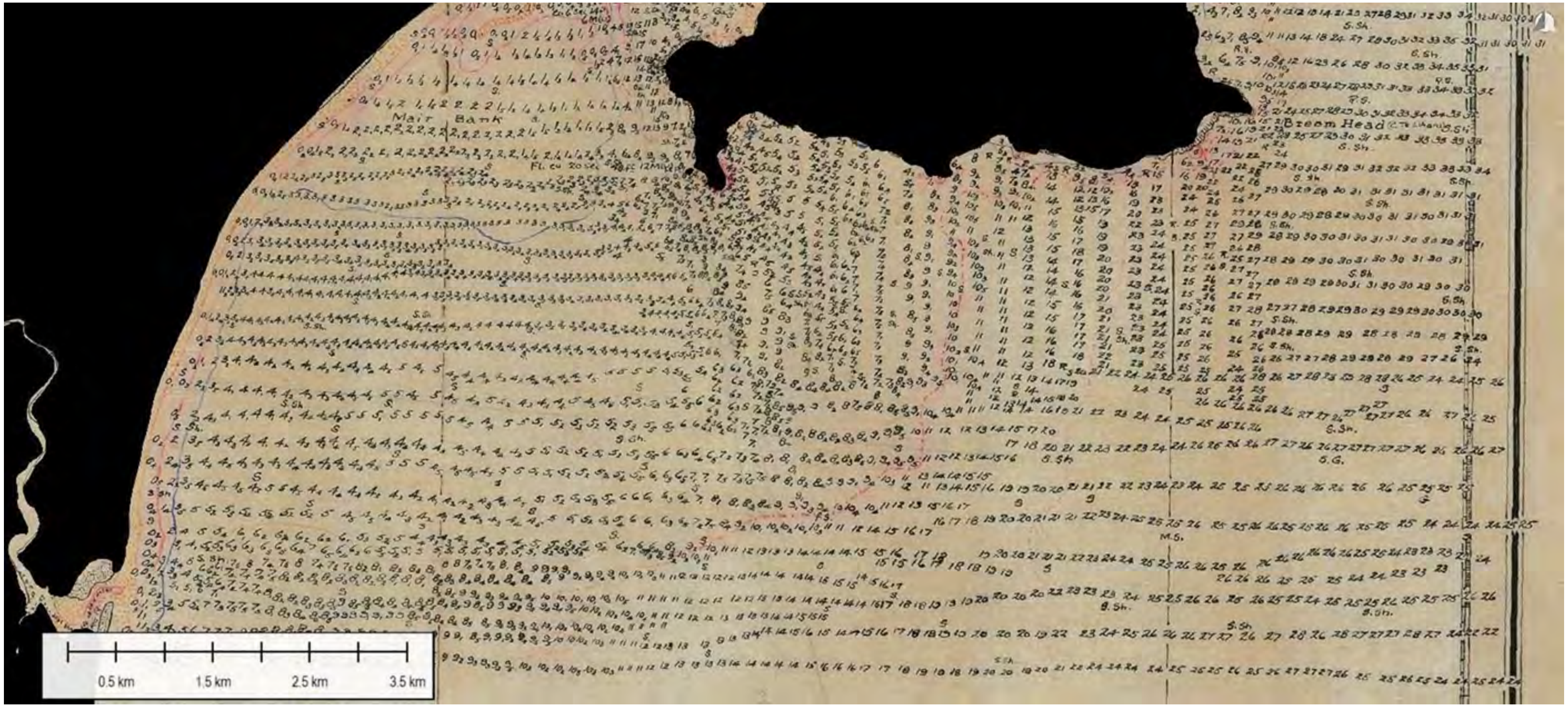

Figure A 3: Fair sheet, 1939

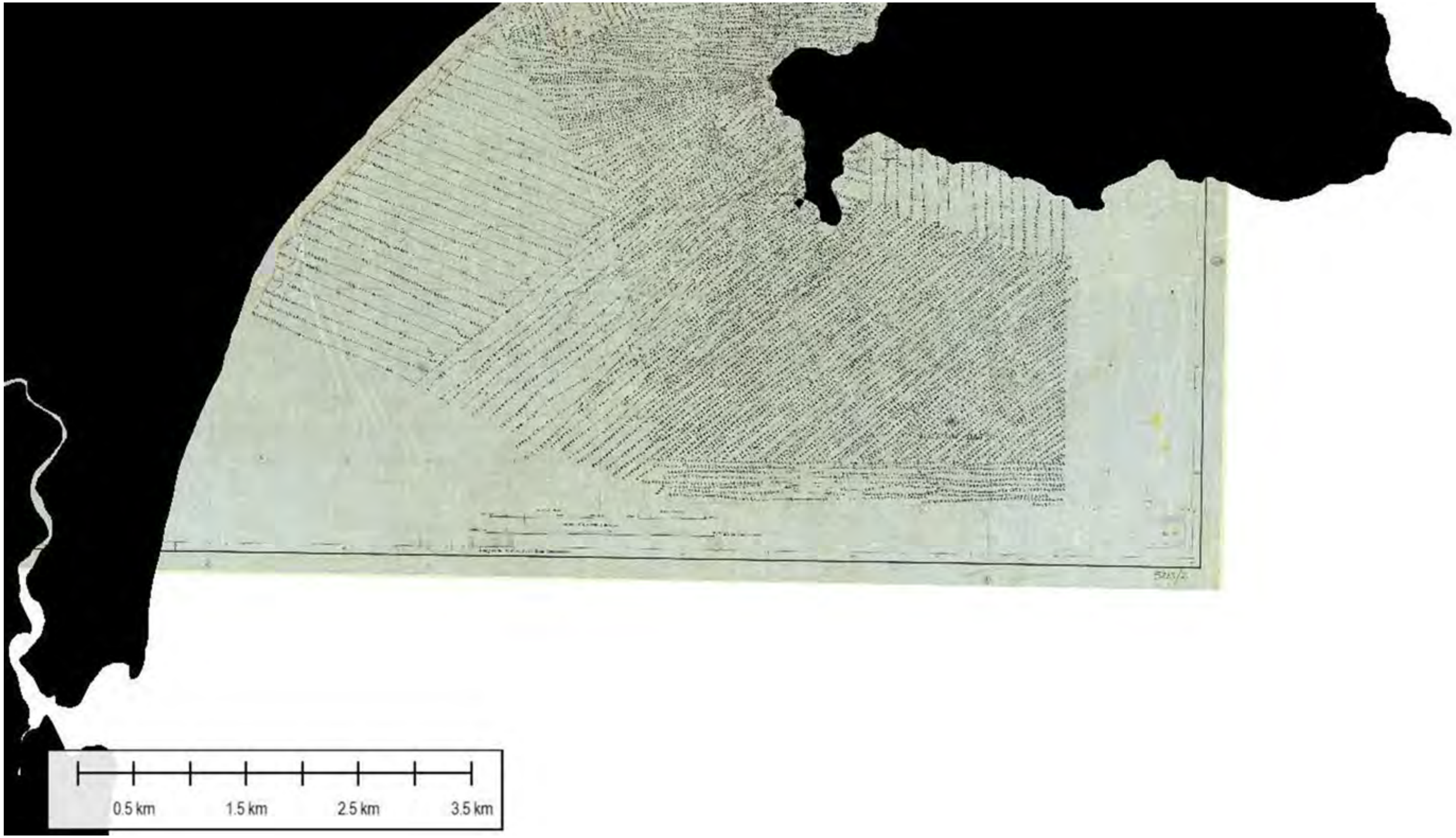

Figure A 4: Fair sheet, 1959

Figure A 5: Hydrographic survey, 1964

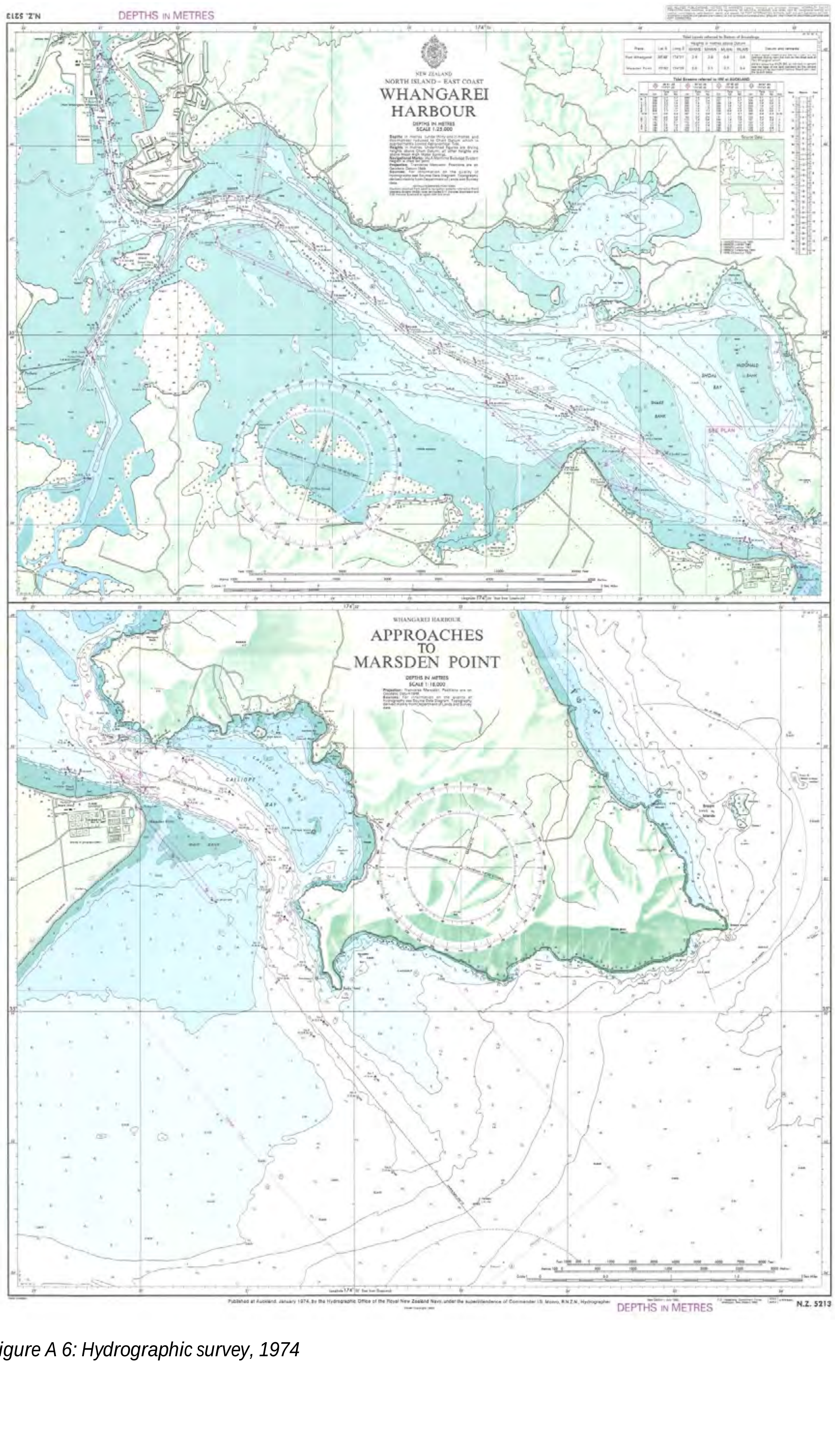

Figure A 6: Hydrographic survey, 1974

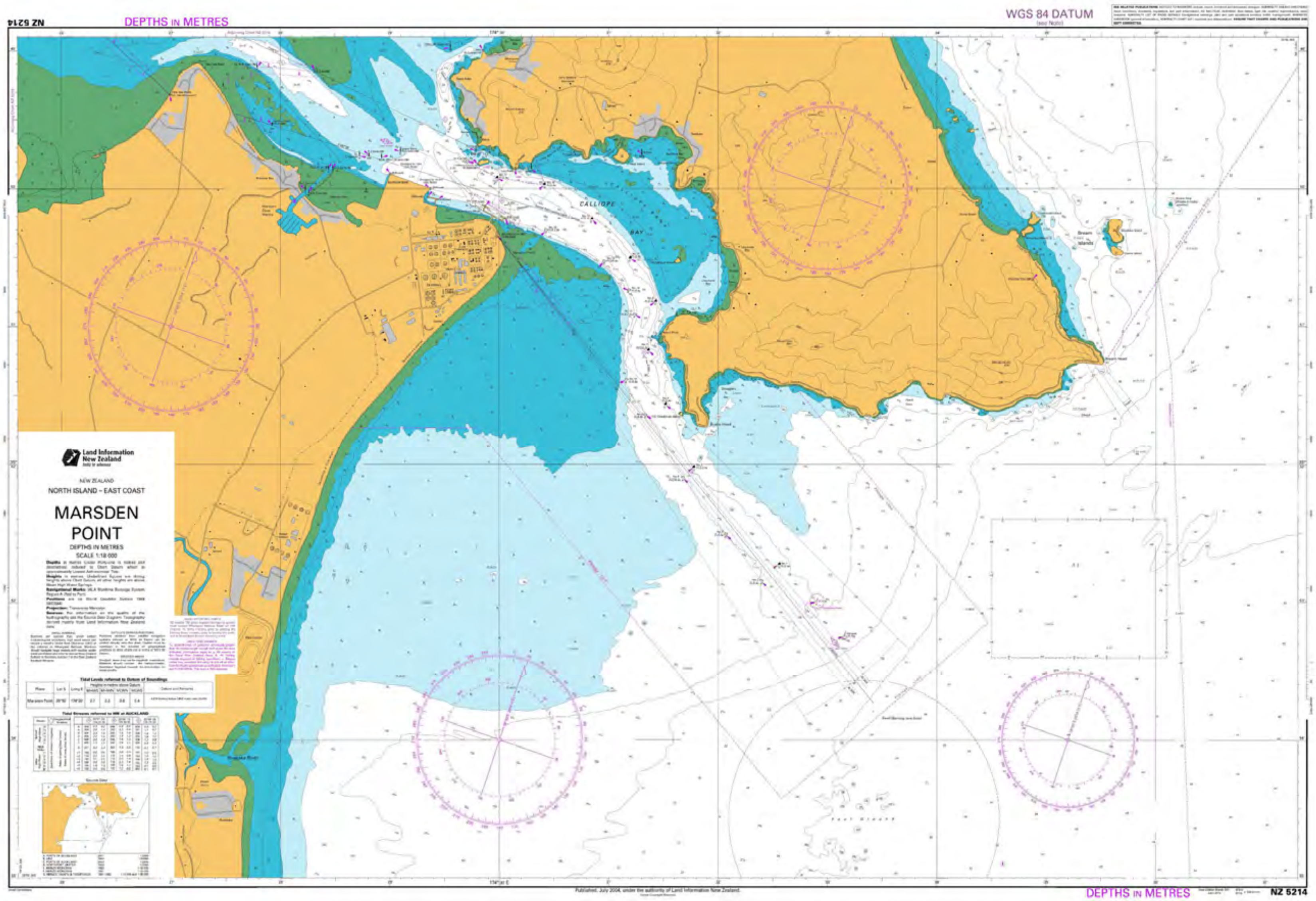

Figure A 7: NZ5214 Hydrographic Chart (Source: LINZ)

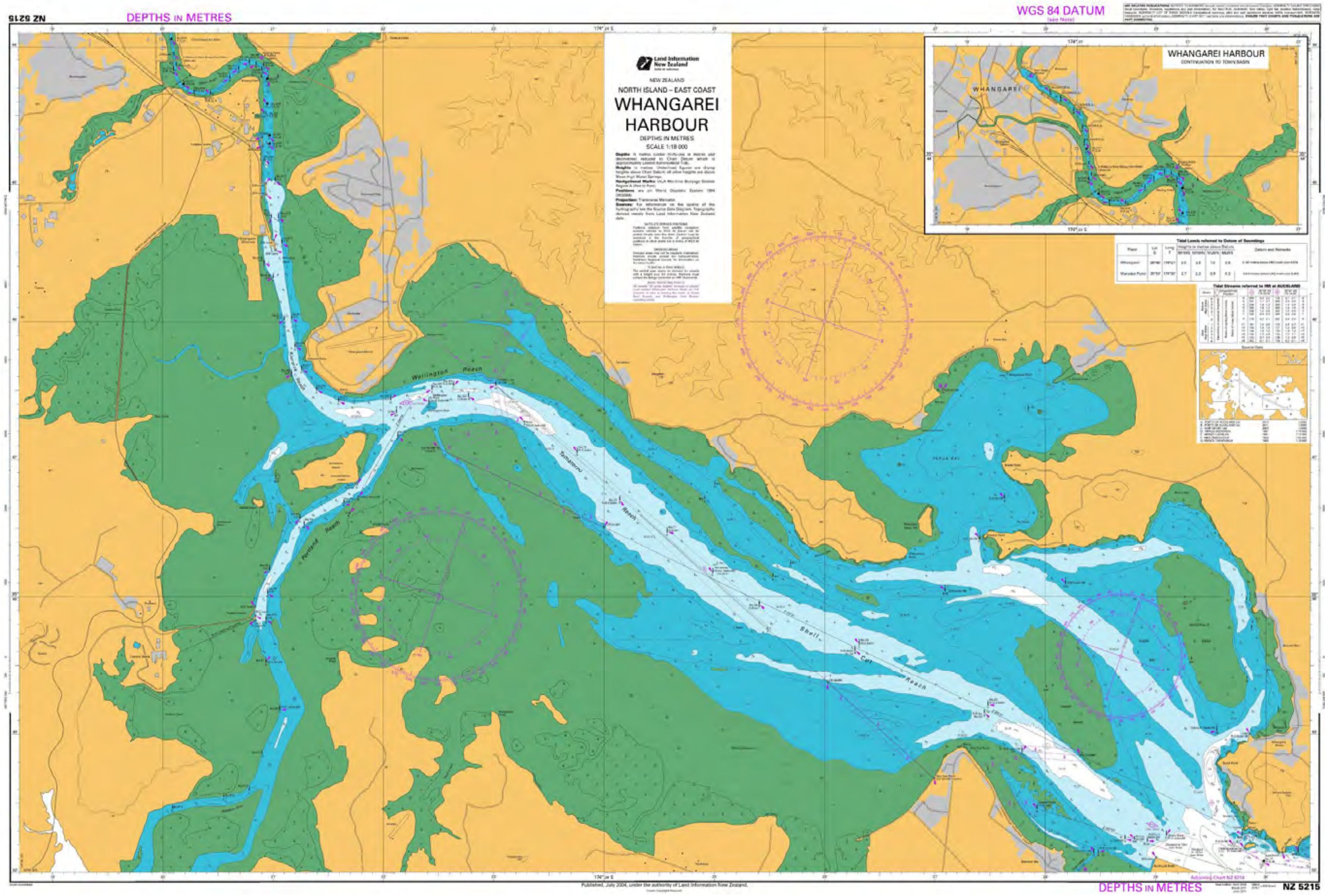

Figure A 8: NZ5214 Hydrographic Chart (Source: LINZ)

Appendix B: Historic aerial and satellite images

1	1942
2	1950
3	1958 (oblique)
4	18/04/1962 (oblique)
5	18/04/1962 (oblique)
6	06/02/1963 (oblique)
7	22/12/1965 (oblique)
8	05/04/1967 (oblique)
9	05/04/1967 (oblique)
10	20/11/1967 (oblique)
11	2/04/1976 (oblique)
12	21/02/1987 (oblique)
13	17/05/2006 (satellite)
14	2/11/2010 (satellite)
15	9/12/2012 (satellite)
16	6/03/2013 (satellite)
17	27/03/2014 (satellite)

Figure B 1: Marsden Point 1942 (Source: NZAM)

Figure B 2: Marsden Point 1950 (Source: NZAM)

Figure B 3: 1958 oblique Marsden Point (Source: NZAM)

Figure B 4: Marsden Point 18/04/1962 (Source: Whites Aviation)

Figure B 5: Marsden Point 18/04/1962 (Source: Whites Aviation)

Figure B 6: Marsden Point 06/02/1963 (Source: Whites Aviation)

Figure B 7: Marsden Point 22/12/1965 (Source: Whites Aviation)

Figure B 8: Marsden Point 05/04/1967 (Source: Whites Aviation)

Figure B 9: Marsden Point 05/04/1967 (Source: Whites Aviation)

Figure B 10: Marsden Point 20/11/1967 (Source: Whites Aviation)

Figure B 11: Marsden Point 02/04/1976 (Source: Whites Aviation)

Figure B 12: Marsden Point 21/02/1987 (Source: Whites Aviation)

Figure B 13: Marsden Point 17/05/2006 (Source: Google Earth)

Figure B 14: Marsden Point 02/11/2010 (Source: Google Earth)

Figure B 15: Marsden Point 09/12/2012 (Source: Google Earth)

Figure B 16: Marsden Point 06/03/2013 (Source: Google Earth)

Figure B 17: Marsden Point 27/03/2014 (Source: Google Earth)

Appendix C: Coastal hazard maps

Notes: Dashed CEHZ indicates greater uncertainty around stream mouths and backshore topography.

A4 SCALE 1:35,000

0 500 1,000 1,500 (m)

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DRAWN	PPK	Aug.14
CHECKED		
APPROVED		

ARCFILE 1400804.SitePlan.legendright.mxd

SCALE (AT A4 SIZE) 1:35,000

PROJECT No. 29508.002

NORTHLAND REGIONAL COUNCIL
CEHZ Assessment
Ruakaka
Site: 3

FIGURE No. Figure 3

Rev. 0

Path: P:\29508\29508.0020\WorkingMaterial\Figures\SitePlan\1400804.SitePlan.legendright.mxd Date: 8/08/2014 Time: 4:17:09 p.m.

Notes: Dashed CEHZ indicates greater uncertainty around stream mouths and backshore topography.

A4 SCALE 1:25,000

0 500 1,000 (m)

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DRAWN	PPK	Aug.14
CHECKED		
APPROVED		

ARCFILE 1400804.SitePlan.scalebar500.mxd

SCALE (AT A4 SIZE) 1:25,000

PROJECT No. 29508.002

NORTHLAND REGIONAL COUNCIL
CEHZ Assessment
Marsden Point
Site: 4

FIGURE No. Figure 4

Rev. 0

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Notes: Dashed CEHZ indicates greater uncertainty around stream mouths and backshore topography.

A4 SCALE 1:5,000

0 100 200 (m)

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DRAWN	PPK	Aug.14
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APPROVED		
ARCFILE 1400804.SitePlan.legendright.mxd		
SCALE (AT A4 SIZE) 1:5,000		
PROJECT No. 29508.002		

NORTHLAND REGIONAL COUNCIL
CEHZ Assessment
Marsden Cove
Site: 5

FIGURE No. Figure 5 Rev. 0

Appendix D: Sediment grading information

Table D- 1: Sediment size distribution within channel footprint from vibrocore and historic T+T data

Location	Sample Name	Classification (%)							
		Clay	Fine Silt	Medium Silt	Coarse Silt	Fine Sand	Medium Sand	Coarse Sand	Gravels
		<0.002 mm	0.002-0.0063	0.0063-0.02	0.02 - 0.063	0.063-0.2	0.2 - 0.63	0.63 - 2	> 2 mm
Berth	V1A 1.50-1.90m	0.0	0.2	0.9	1.1	11.4	60.7	3.8	21.9
	V1 0.3 - 0.8m	0.0	0.3	1.3	1.6	34.0	62.7	0.0	0.0
	V2 1.2 - 1.78m	0.8	0.6	1.2	1.5	11.4	55.8	10.0	18.8
Upper channel	V3 0 - 0.4m	2.3	1.8	4.6	3.5	25.6	56.6	0.4	5.2
	V4 0 - 0.5m	0.0	0.5	1.4	0.9	10.4	57.5	11.9	17.4
	V5 0 - 0.5m	0.2	0.5	1.6	1.3	5.2	60.5	4.9	25.7
	V5 1.5 - 1.8m	3.8	2.4	4.9	4.1	31.4	44.7	0.1	8.6
	TT BH 6, 8.0 m	0	0	0	7.0	43.0	49.0	1.0	0.0
	TT BH7, 3.0 m	0	0	0	3.0	47.0	50.0	0.0	0.0
	V6 0.6-1 m	1.3	1.1	2.7	2.2	15.7	56.2	10.0	10.8
	V7 0 - 0.7 m	0.2	0.7	1.9	1.3	10.8	64.5	6.9	13.6
Average		0.8	0.7	1.9	2.5	22.4	56.2	4.5	11.1
Mid Channel	V8 1.2-2 m	1.1	0.8	1.6	2.1	17.8	63.1	7.2	6.2
	V8 1.2 - 2.4 m	0.0	0.4	0.9	1.0	14.2	59.9	11.0	12.5
	V9 0.9 - 1.2 m	0.0	0.5	1.2	1.1	7.9	58.6	3.3	27.4
	V10 0 - 0.6m	0.0	0.0	0.0	0.0	4.2	72.8	21.3	1.7
	V10C 2.2 - 2.6m	0.0	0.2	1.0	1.1	6.1	61.9	8.5	21.1
	V11 0-0.6m	0.0	0.0	0.0	0.0	1.9	72.7	15.4	9.9
Outer channel to busby he	V12 0-0.6m	0.0	0.0	0.0	0.0	0.2	86.1	8.8	4.9
	V12 0.6-1.2m	1.7	1.2	2.6	2.5	18.0	57.2	7.6	9.3
	V13A 2.9-3.5m	0.0	0.0	0.0	0.0	2.2	71.8	18.8	7.2
	V13 1.7-2.1m	0.0	0.0	0.0	0.0	3.8	79.5	1.3	15.4
	V14 0.9-1.2m	0.0	0.3	1.2	1.0	2.3	51.4	22.8	21.0
	V14 1.5-1.8m	0.9	0.9	2.4	1.9	6.9	45.6	12.7	28.7
	V15 1.2-1.6m	0.1	0.3	0.7	0.7	1.9	38.1	30.9	27.4
	V15 2.4-2.8m	0.0	0.0	0.0	0.0	0.1	49.2	28.9	21.7
Outer channel	V16 1.2-1.8m	0.4	0.4	0.9	0.7	3.0	17.6	6.0	71.0
	V17 0.4-0.7m	0.0	0.0	0.0	0.0	0.0	56.8	32.8	10.4
	V17 1.8-2.2m	0.0	0.4	0.7	0.0	18.2	77.4	0.5	2.8
	V17 3.4-3.8m	0.0	0.0	0.0	0.7	7.3	55.3	19.3	17.4
	V18 0.9-1.2m	0.0	0.0	0.0	0.0	15.1	84.5	0.4	0.0
	V18 2.4-2.7m	0.3	0.6	1.0	0.0	30.0	57.5	2.3	8.2
	V19A 1.2-1.5m	0.0	0.0	0.0	0.0	19.3	79.8	0.9	0.0
	V20 0-0.5m	0.0	0.0	0.0	0.0	22.1	68.8	0.0	9.0

Table D- 2: Historic sediment grading data from T+T and Hawthorne Gedes

Reference	Depth below surface (m)	Silts	Fine Sand	Medium S	Coarse Sa	Gravels
		< 0.063	0.063-0.2	0.2 - 0.63	0.63 - 2	> 2 mm
T+TBH1	6.0 - 6.45	8.0	17.0	72.0	1.0	2.0
T+TBH4a	6.7 m	2.0	13.0	66.0	7.0	12.0
T+TBH5a	3.0 m	6.0	30.0	62.0	1.0	1.0
T+TBH6	8.0 m	2.0	33.0	58.0	5.0	2.0
T+TBH7	3.0 m	8.0	36.0	37.0	6.0	13.0
	Average	*5.2*	*25.8*	*59.0*	*4.0*	*6.0*
	Max	*8.0*	*36.0*	*72.0*	*7.0*	*13.0*
MBH1	MBH1 0.5 - 1.0 m	9.0	51.0	40.0	0.0	0.0
MBH1	MBH1 1.0 - 1.5 m	1.0	36.0	58.0	1.0	4.0
MBH2	MBH2 0.5 - 1.0 m	5.0	45.0	48.0	0.0	2.0
MBH2	MBH2 1.0 - 1.5 m	7.0	43.0	49.0	1.0	0.0
MBH3	MBH3 0.0 - 0.5 m	3.0	47.0	50.0	0.0	0.0
MBH3	MBH3 0.5 - 1.0 m	5.0	50.0	39.0	2.0	4.0
MBH3	MBH3 1.0 - 1.5 m	6.0	40.0	54.0	0.0	0.0
	Average	*5.1*	*44.6*	*48.3*	*0.6*	*1.4*
	Max	*9.0*	*51.0*	*58.0*	*2.0*	*4.0*

Table D- 3 Sediment size distribution on ebb tide shoal

Reference	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel
	< 0.0039	063 - 0.003	0.063-0.3	0.600 - 0.300	0.63 - 2	> 2.00
DA1A04	0.0	0.0	57.7	41.4	0.9	0.0
DA1A05	0.0	0.0	56.7	42.2	1.1	0.0
DA1A06	0.0	0.0	59.8	39.3	0.9	0.0
DA1A07	0.0	0.0	56.1	42.5	1.4	0.0
DA1A08	0.0	0.0	60.1	38.9	0.9	0.0
DA1A09	0.0	0.0	52.7	43.2	4.1	0.0
47	0.0	0.0	74.7	25.3	0.0	0.0
48	0.0	0.0	71.7	26.6	1.7	0.0
49	0.0	0.0	59.4	34.0	6.6	0.0
50	0.0	0.0	12.8	46.3	38.5	2.4
51	0.0	0.0	45.6	47.9	6.6	0.0
52	0.0	0.0	25.2	52.2	21.7	0.9
53	0.0	0.0	20.0	50.0	28.7	1.3
54	0.0	0.0	17.2	46.8	34.3	1.6
55	0.0	0.0	19.3	47.8	28.2	4.8
56	0.0	0.0	11.2	36.5	34.6	17.6
57	0.0	0.0	48.0	44.6	7.4	0.0
58	0.0	0.0	67.2	30.4	2.4	0.0
59	0.0	0.0	13.6	43.3	31.6	11.6
60	0.0	0.0	24.6	40.5	29.2	5.7
61	0.0	0.0	21.0	33.1	31.5	14.4
62	0.0	0.0	17.8	45.6	34.3	2.4
63	0.0	0.0	60.7	33.6	5.7	0.0
64	0.0	0.0	77.6	20.5	1.9	0.0
Minimum	*0.0*	*0.0*	*11.2*	*20.5*	*0.0*	*0.0*
Average	*0.0*	*0.0*	*42.9*	*39.7*	*14.8*	*2.6*
Max	*0.0*	*0.0*	*77.6*	*52.2*	*38.5*	*17.6*

Table D- 4 Sediment size distribution within Bream Bay

Reference	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	D50
	< 0.0039	.063 - 0.003	0.063-0.3	0.600 - 0.300	0.63 - 2	> 2.00	(mm)
DA2C	0.0	0.0	24.4	44.1	27.1	4.4	0.377
DA2D	0.0	0.0	7.1	30.0	57.2	5.7	0.602
DA2E	0.3	3.0	70.7	20.5	5.6	0.0	0.185
DA2F	0.2	1.0	5.3	7.3	28.3	58.0	2.423
DA3A	0.8	5.4	41.3	28.4	17.1	6.9	0.262
DA3B	0.0	0.6	5.5	14.3	40.6	39.0	1.111
DA3C	0.0	0.2	2.5	27.5	64.0	5.9	0.660
DA3D	1.3	6.7	49.8	29.4	12.8	0.0	0.221
DA3E	0.0	0.7	15.2	46.4	32.2	5.4	0.420
DA3F	0.0	0.0	5.7	41.9	42.2	10.3	0.517

Table D- 5 Sediment size distribution around disposal area 3-2

Reference	Silt (< 0.063 mm)	Fine to Medium Sand (0.063 to 2 mm)	Gravel (> 2 mm)	D50 (mm)
23_3.2A	3.39	89.41	7.2	0.503
24_3.2A	0	100	0	0.507
25_3.2A	0	91.4	8.6	0.514
26_3.2A	2.74	76.36	20.9	0.649
27_3.2A	0.82	75.68	23.5	0.630
28_3.2A	1.46	74.54	24	0.605
29_3.2B	10.86	89.14	0	0.244
30_3.2B	1.74	85.56	12.7	0.440
31_3.2B	10.58	89.42	0	0.203
32_3.2B	13.54	86.46	0	0.200
33_3.2B	2.32	97.68	0	0.328
34_3.2B	2.88	97.12	0	0.375
11_3.2	15.28	84.72	0	0.185
12_3.2	28.75	71.25	0	0.193
13_3.2	10.89	66.61	22.5	0.581
14_3.2	1.2	95.7	3.1	0.555
15_3.2	5.93	89.47	4.6	0.458
16_3.2	2.22	87.08	10.7	0.501
19_2.2	1.01	97.89	1.1	0.553

Table D- 6 Sediment grading properties of beach sediment along Bream Bay and Whangarei Harbour

Site		Size Range (mm)			Description	
ID	Name	$D_{10\%}$	$D_{50\%}$	$D_{90\%}$	Wentworth Size Classification	
1	Waipu	0.136	0.216	0.347	Fine	Sand
2	Ruakaka	0.146	0.246	0.428	Fine	Sand
3	Marsden Point	0.158	0.238	0.357	Fine	Sand
4	Marsden Cove	0.120	0.200	0.336	Fine	Sand
5	One Tree Point East	0.327	0.567	1.012	Coarse	Sand
6	One Tree Point West	0.315	0.448	0.639	Medium	Sand

Appendix E: Changes in the 0 m Chart Datum (CD) contour in the vicinity of Mair Bank

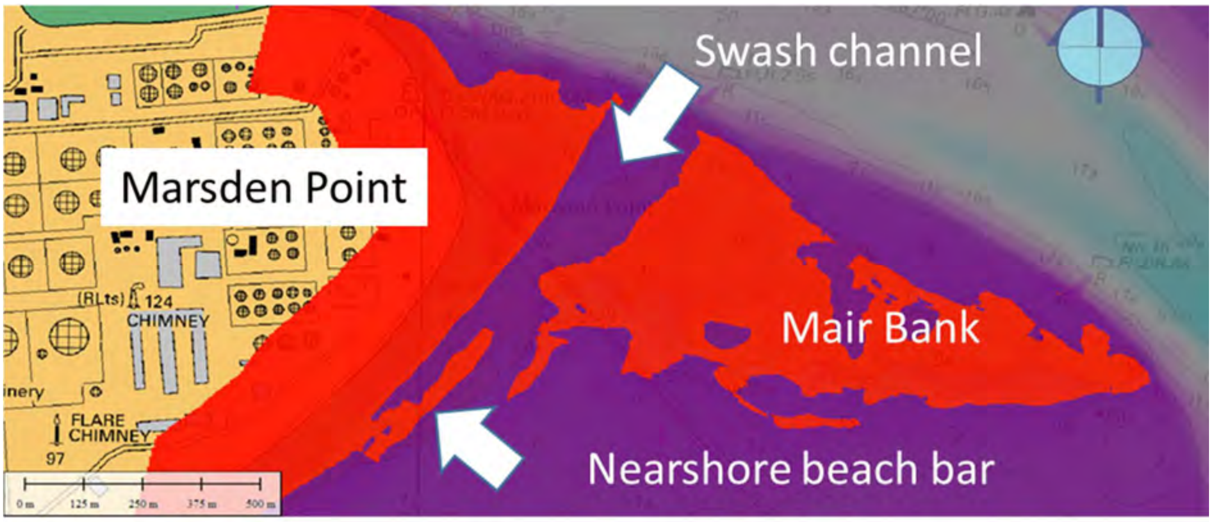


Figure E 1 Year 2000 - Area of Mair Bank above CD (red)

Figure E 2 Year 2001 - Area of Mair Bank above CD (red)

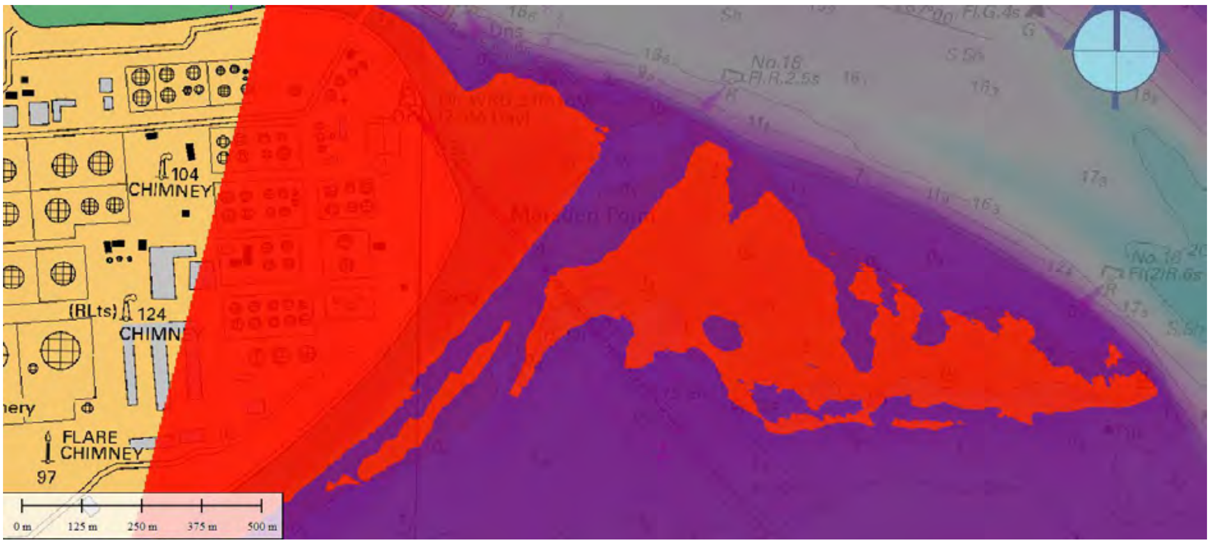


Figure E 3 Year 2002 - Area of Mair Bank above CD (red)

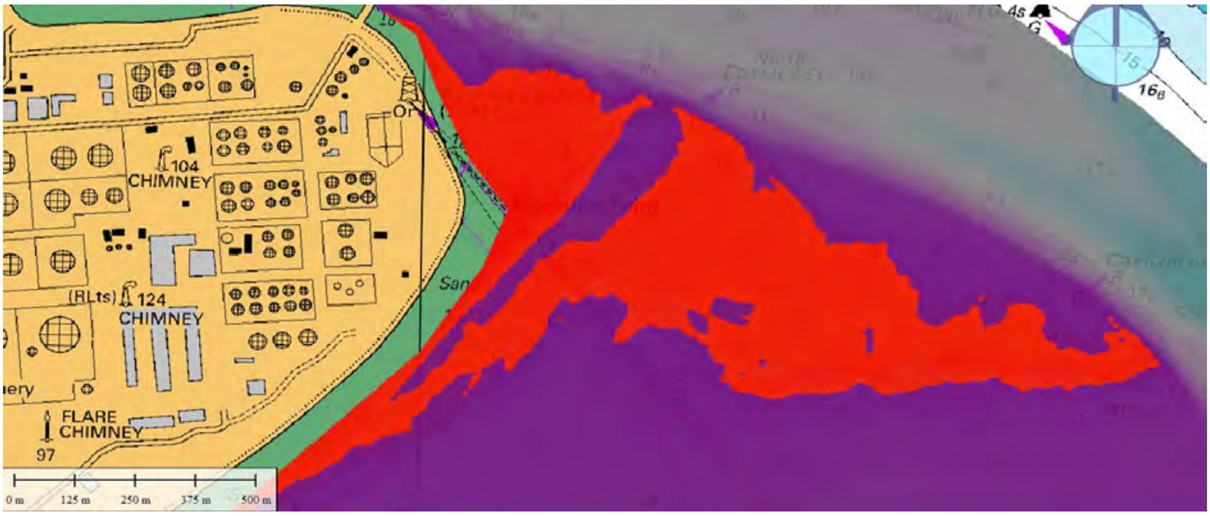


Figure E 4 Year 2003 - Area of Mair Bank above CD (red)

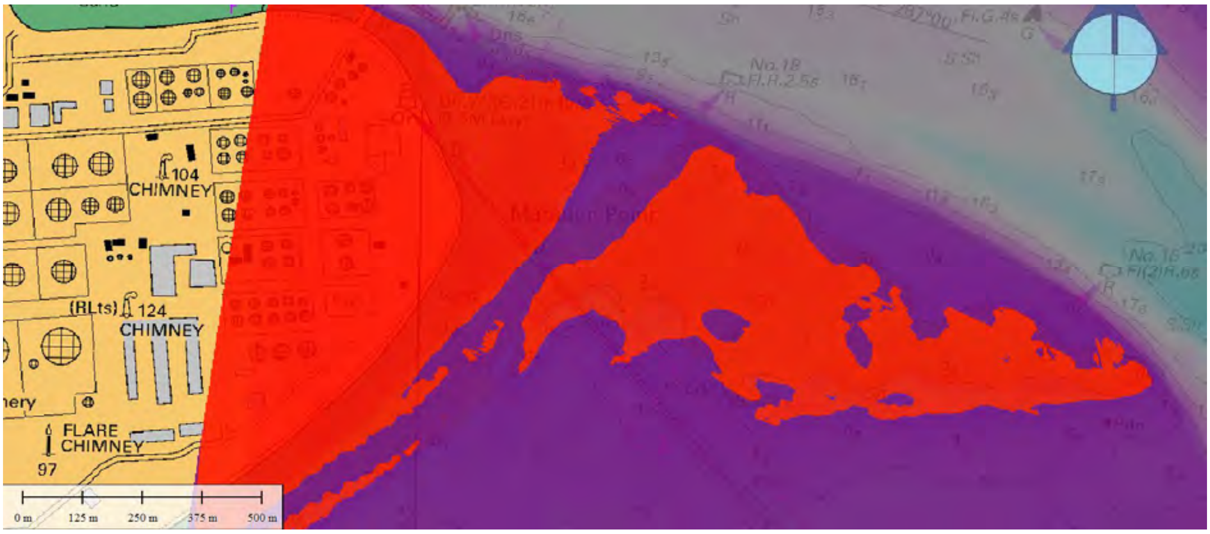


Figure E 5 Year 2004 - Area of Mair Bank above CD (red)

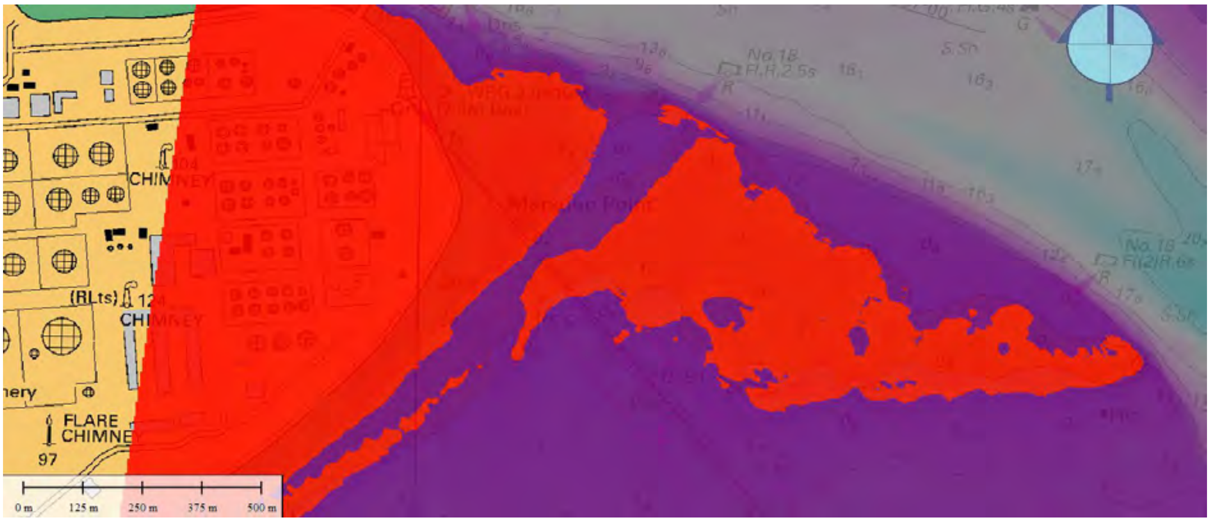


Figure E 6 Year 2005 - Area of Mair Bank above CD (red)

Figure E 7 Year 2007 - Area of Mair Bank above CD (red)

Figure E 8 Year 2008 - Area of Mair Bank above CD (red)

Figure E 9 Year 2009 - Area of Mair Bank above CD (red)

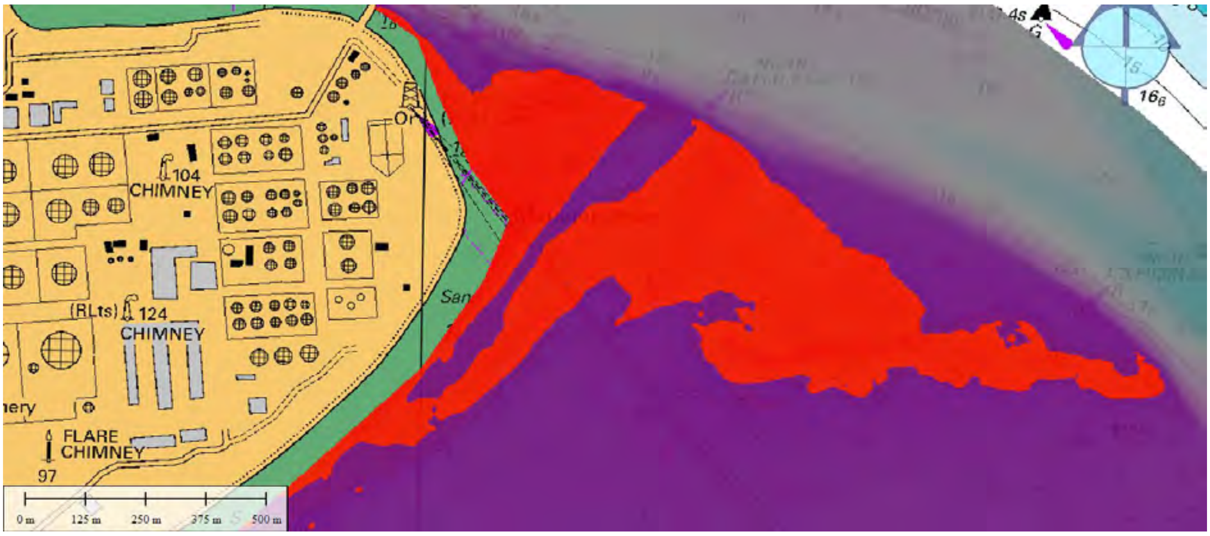


Figure E 10 Year 2010 - Area of Mair Bank above CD (red)

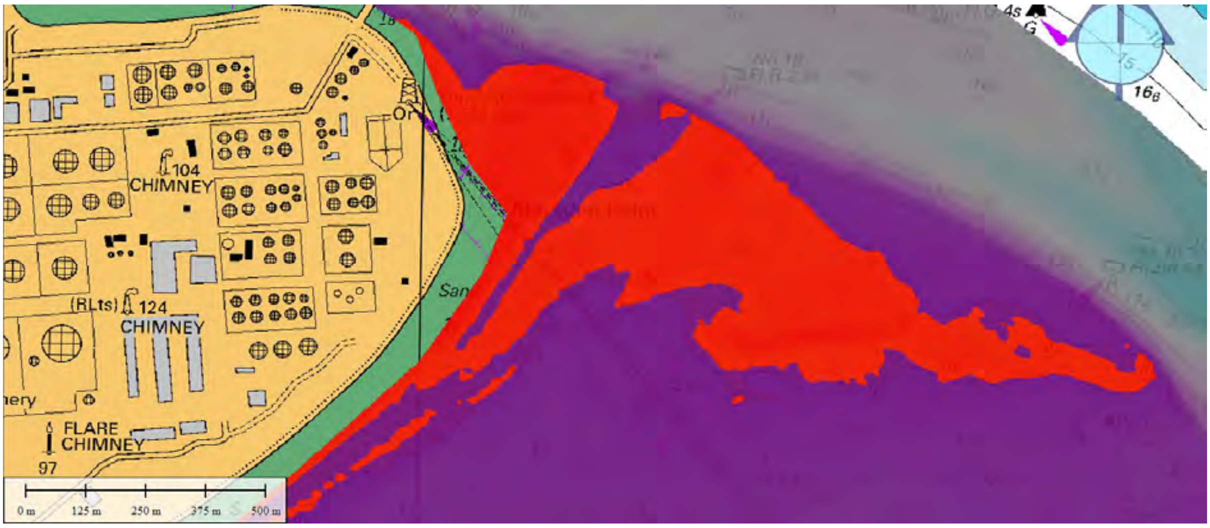


Figure E 11 Year 2011 - Area of Mair Bank above CD (red)

Figure E 12 Year 2012 - Area of Mair Bank above CD (red)

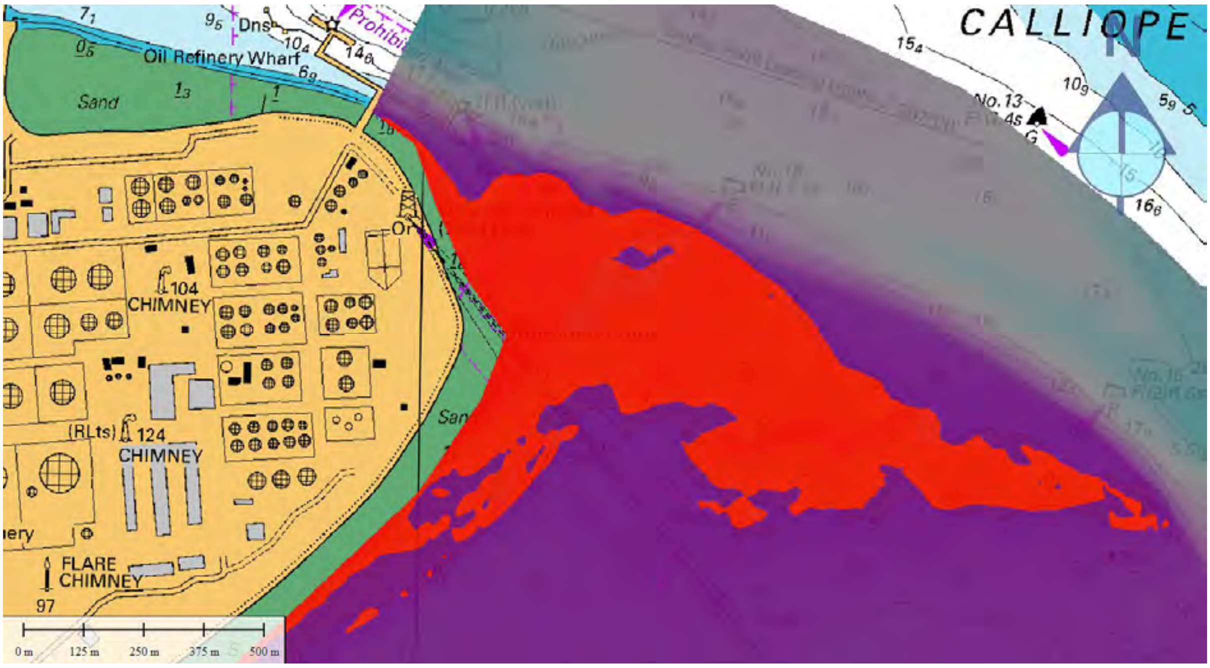


Figure E 13 Year 2013 - Area of Mair Bank above CD (red)

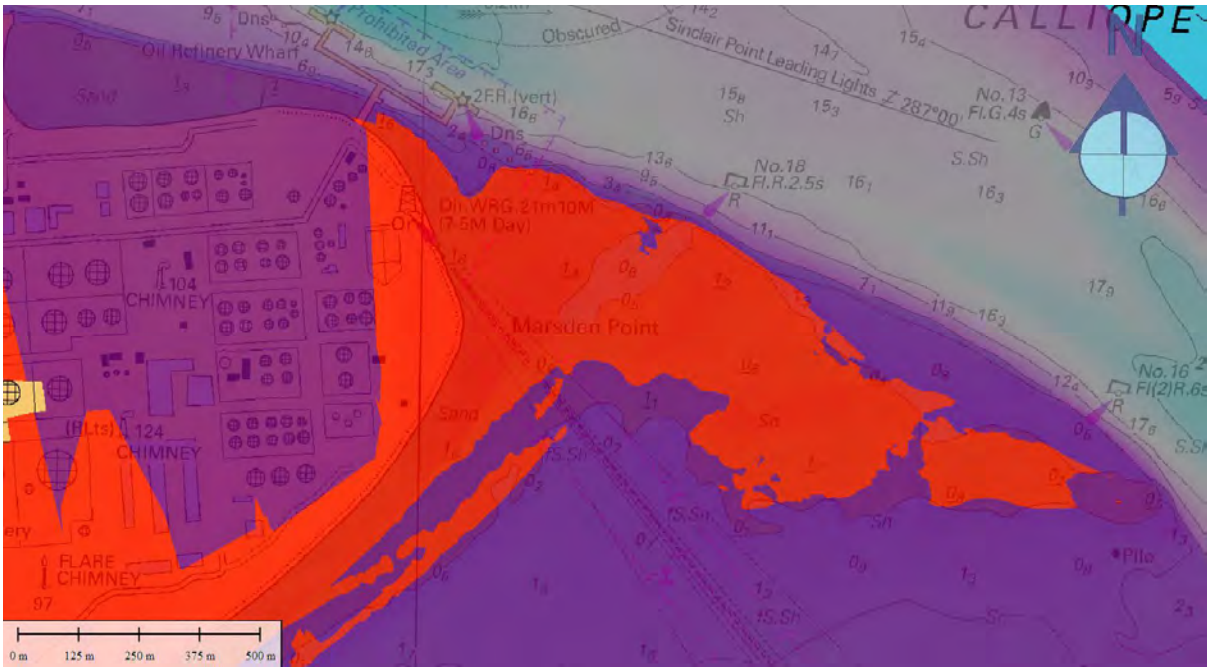


Figure E 14 Year 2015 - Area of Mair Bank above CD (red)

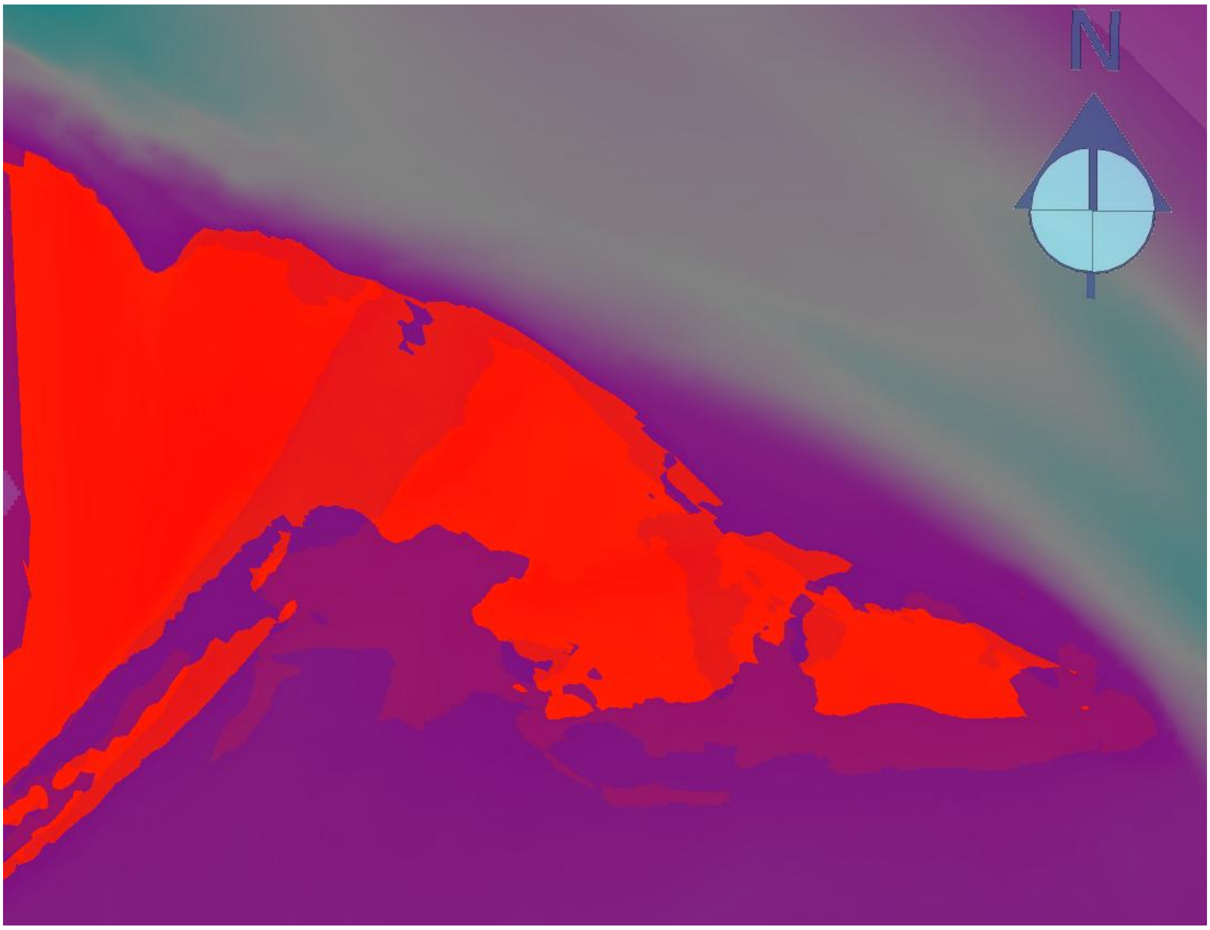
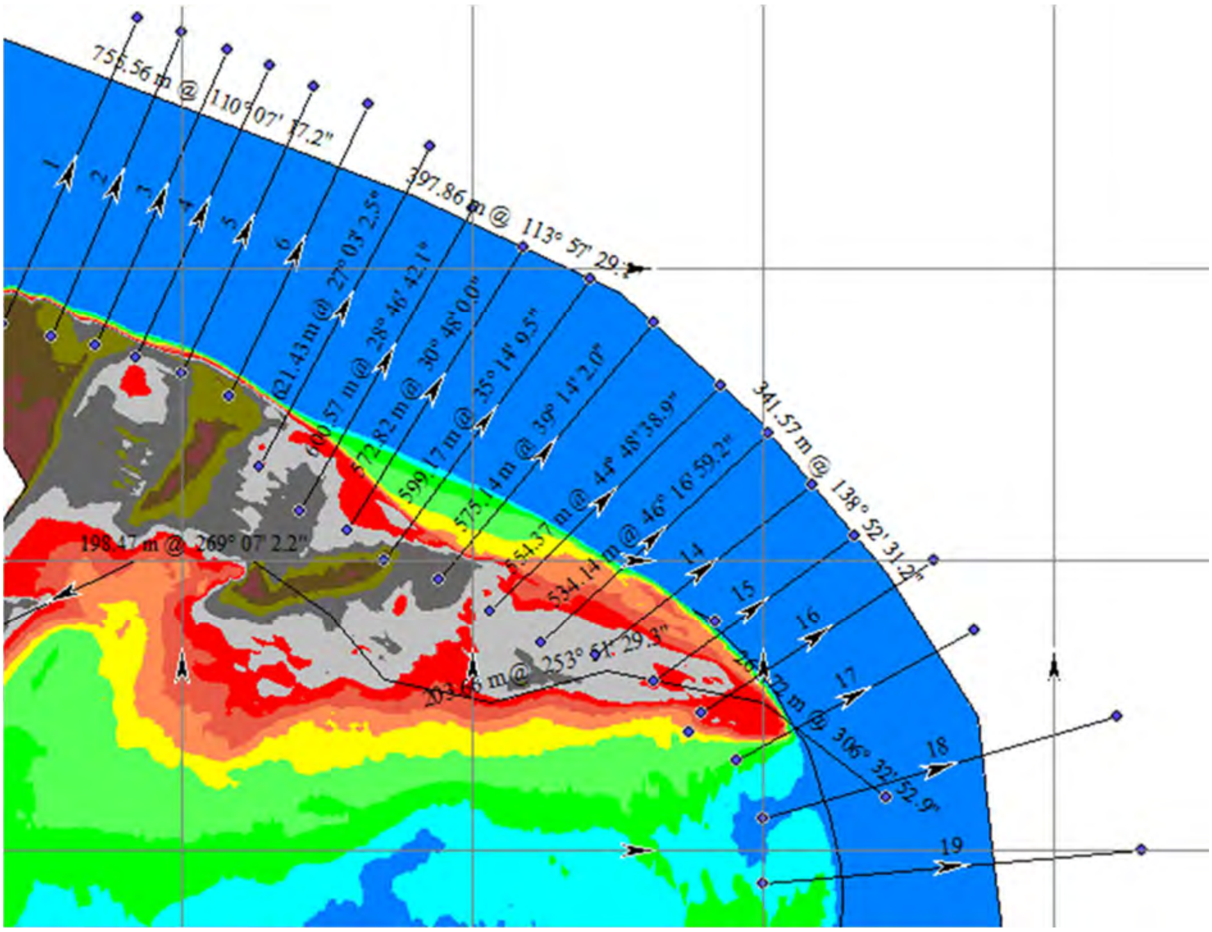
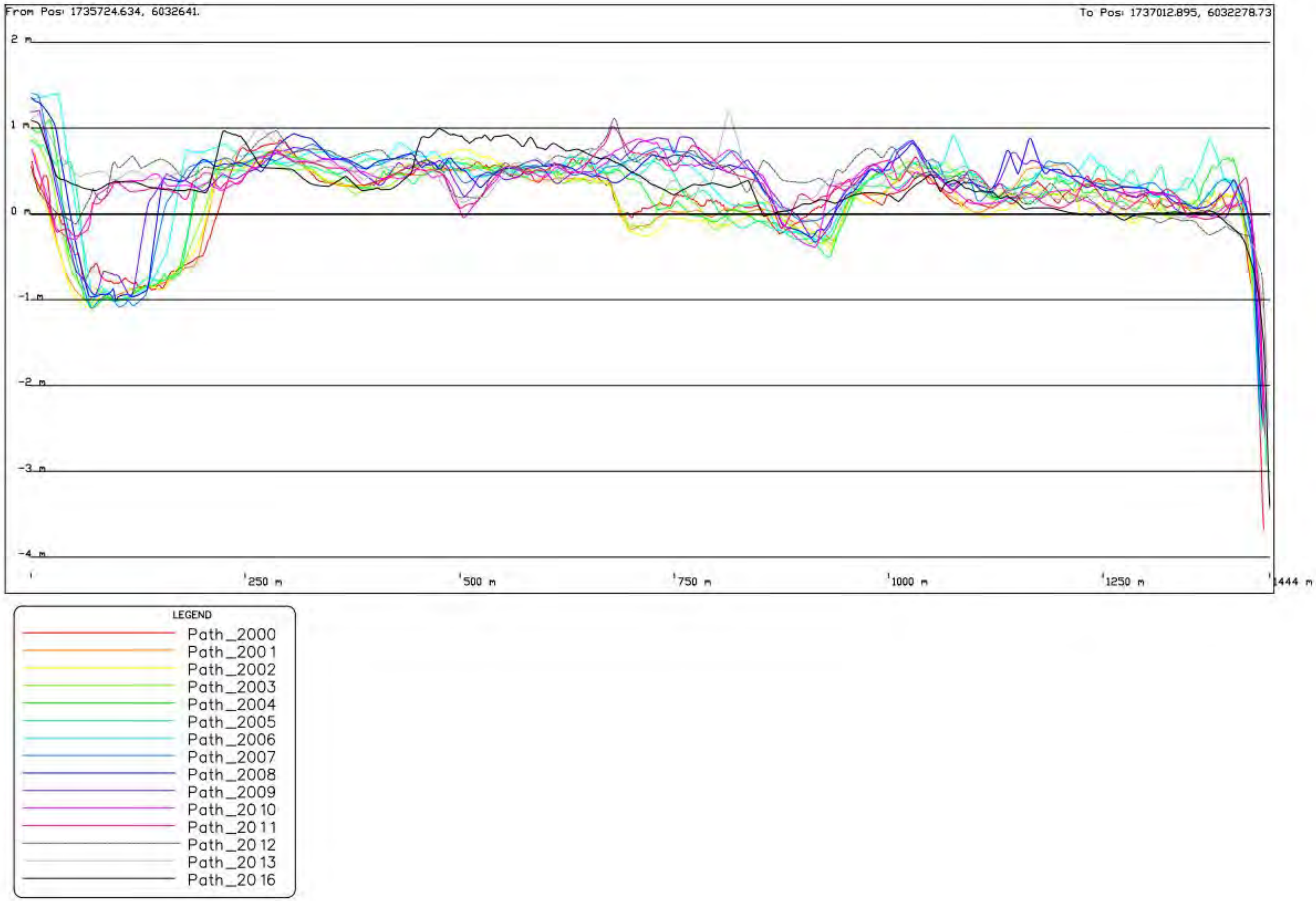


Figure E 15 Comparison of 2000 and 2015 bathymetric data

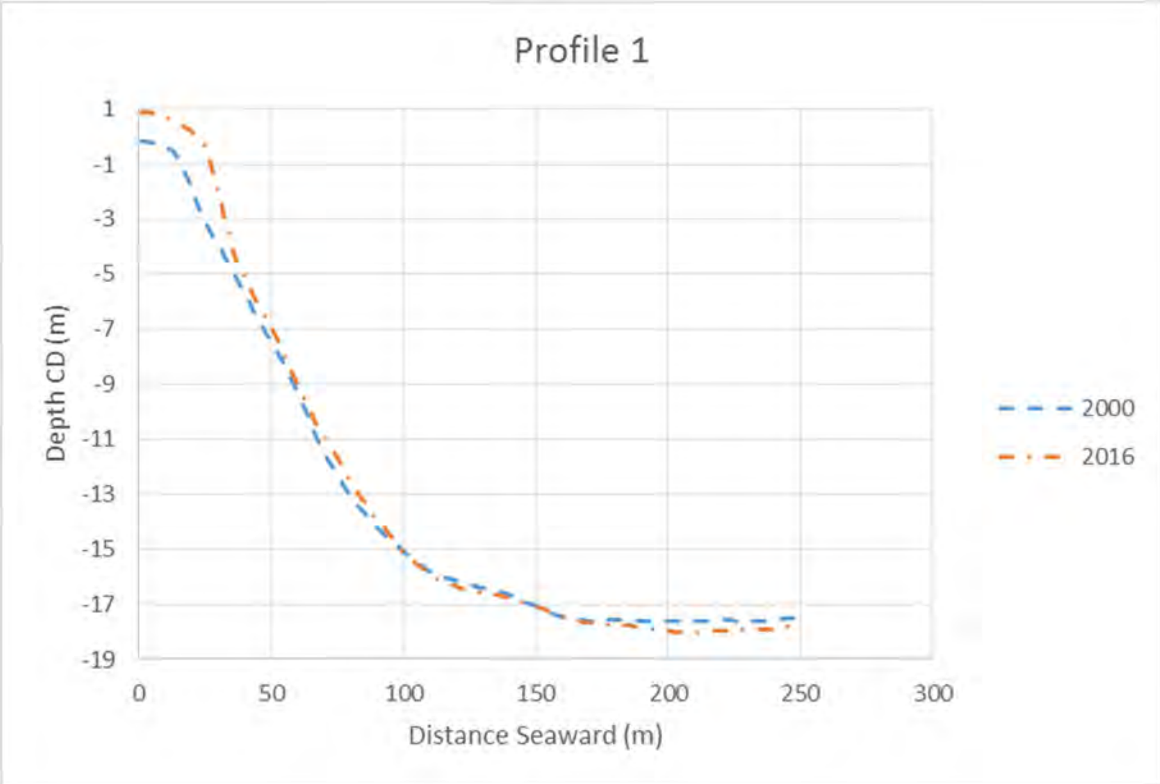
Appendix F: Profiles along the ebb tide shoal

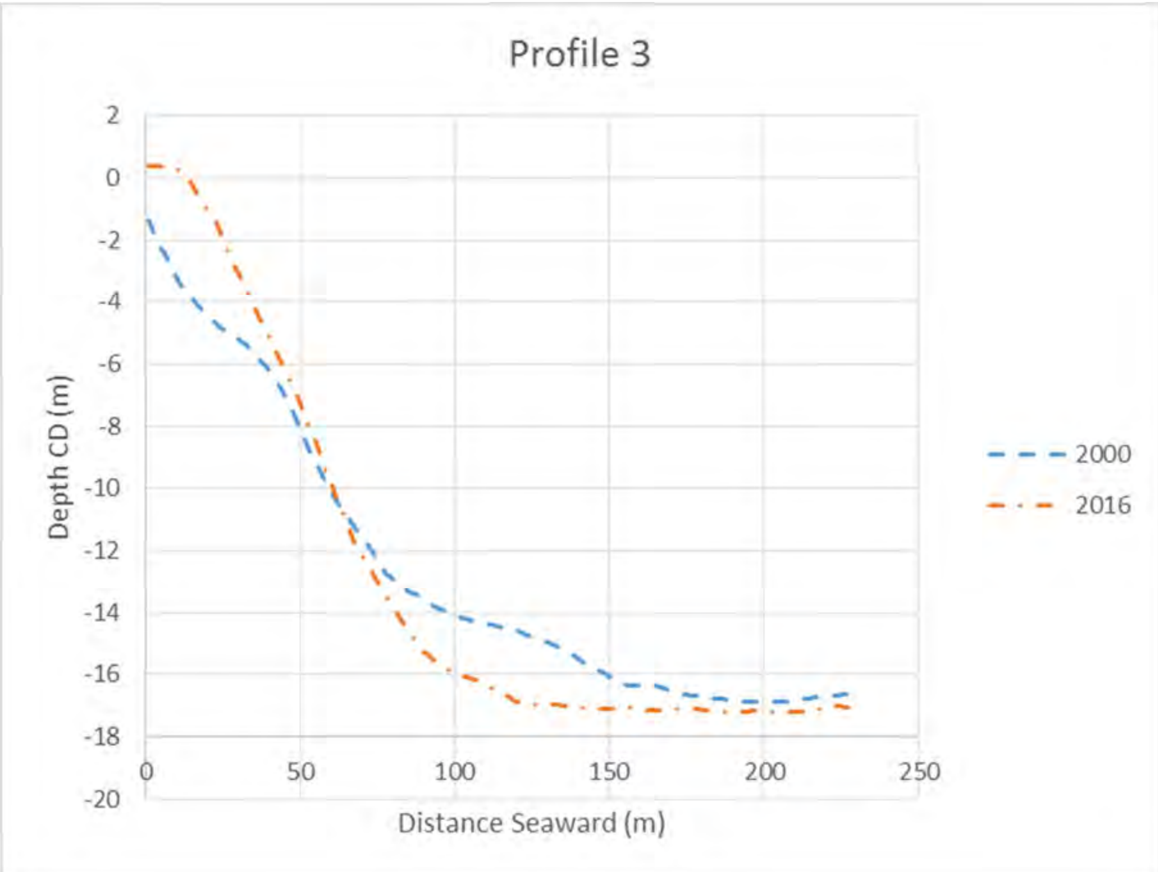


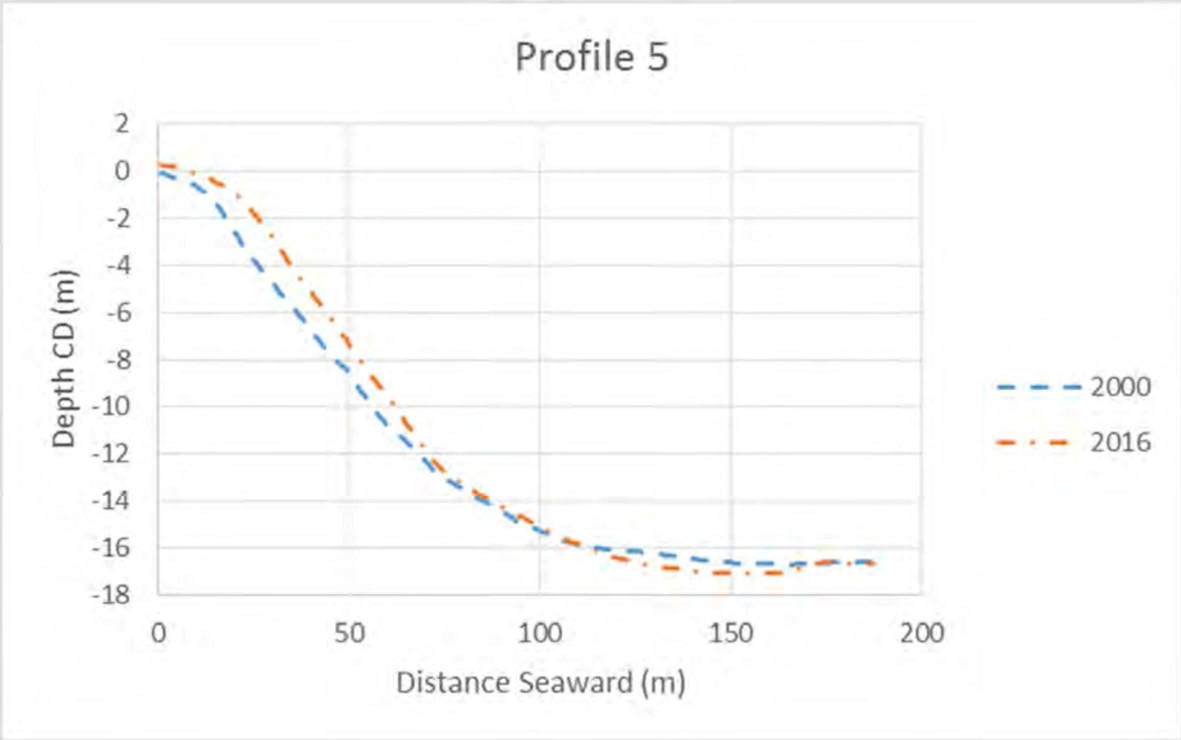
755.56 m @ 110° 07' 17.2"
397.86 m @ 113° 57' 29.1"
341.57 m @ 138° 52' 31.2"
198.47 m @ 269° 07' 2.2"
203.66 m @ 253° 51' 29.3"
1
2
3
4
5
6
14
15
16
17
18
19



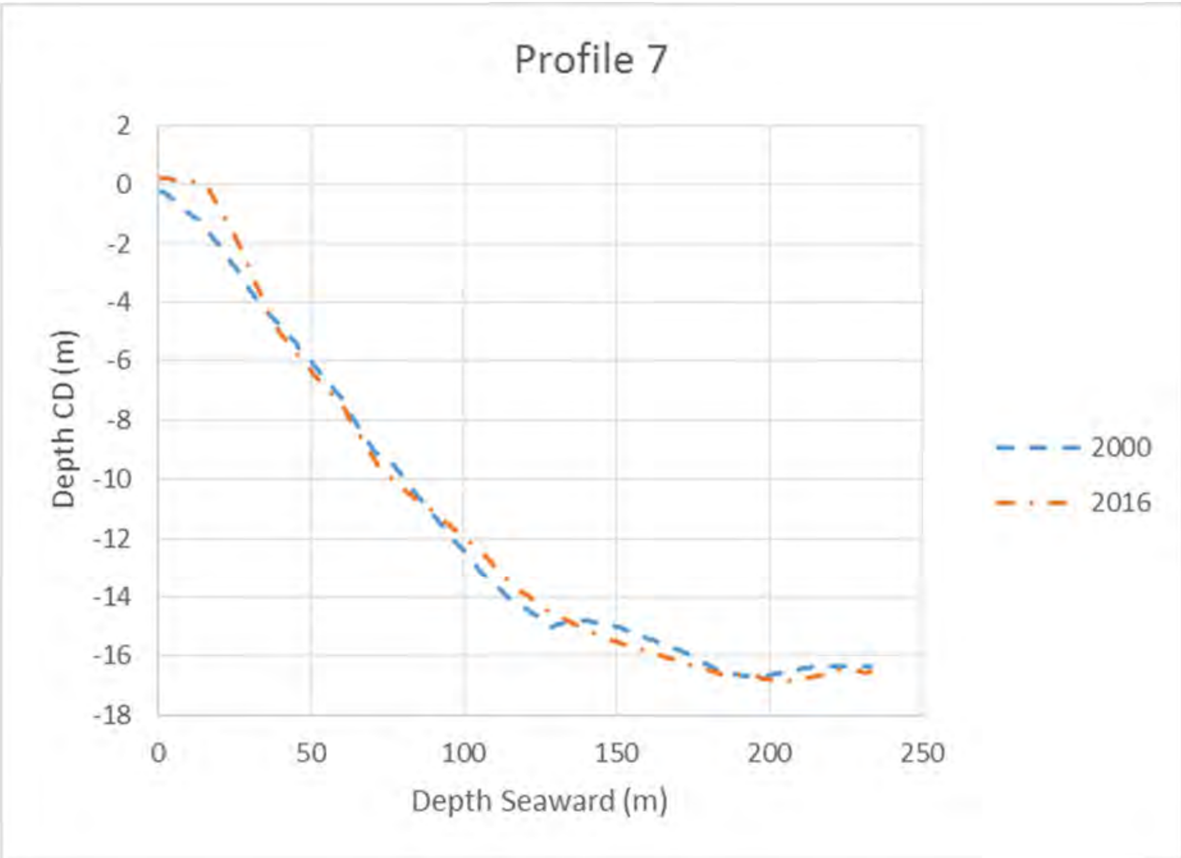
Long section along the crest of Mair Bank


Profile 1
1
-1
-3
-5
-7
-9
-11
-13
-15
-17
-19
Depth CD (m)
0
50
100
150
200
250
300
Distance Seaward (m)
2000
2016


Profile 3
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
Depth CD (m)
0
50
100
150
200
250
Distance Seaward (m)
2000
2016



Profile 5
Depth CD (m)
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
50
100
150
200
Distance Seaward (m)
2000
2016



Profile 7
Depth CD (m)
2
0
-2
-4
-6
-8
-10
-12
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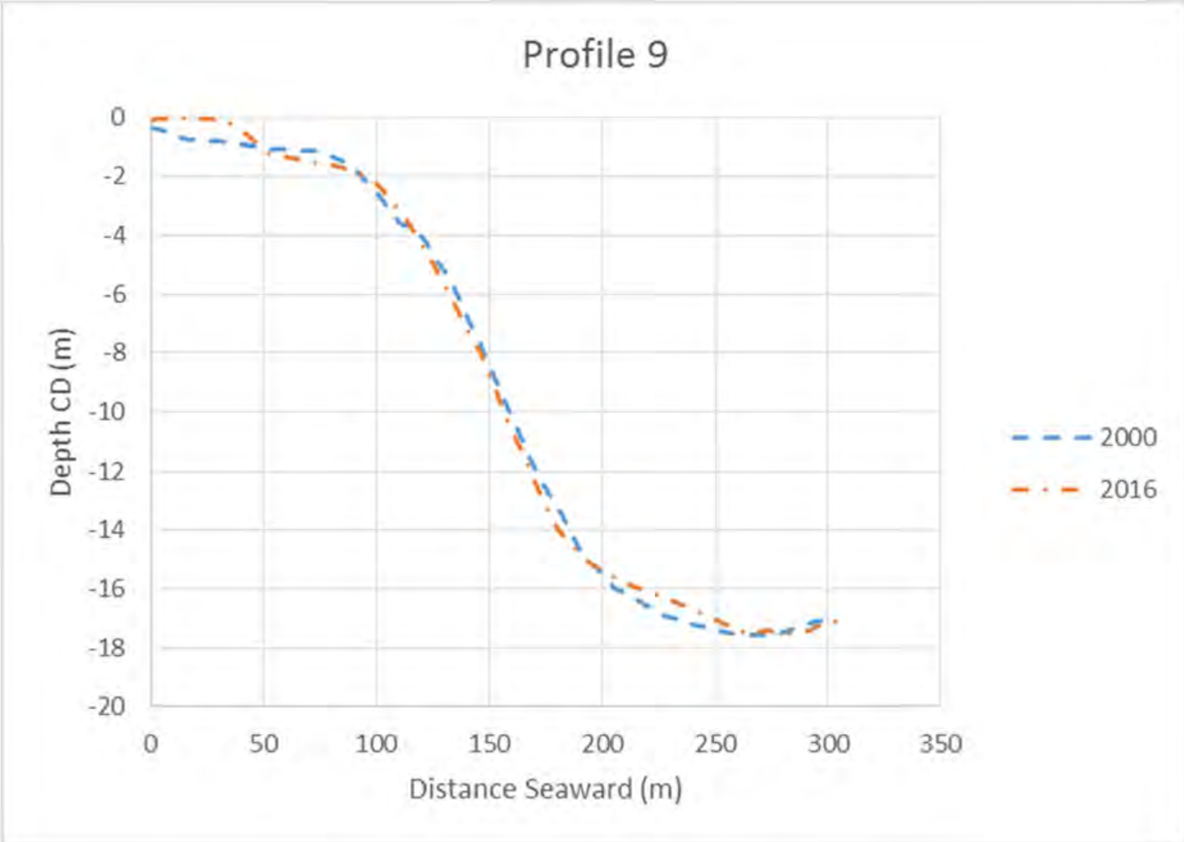

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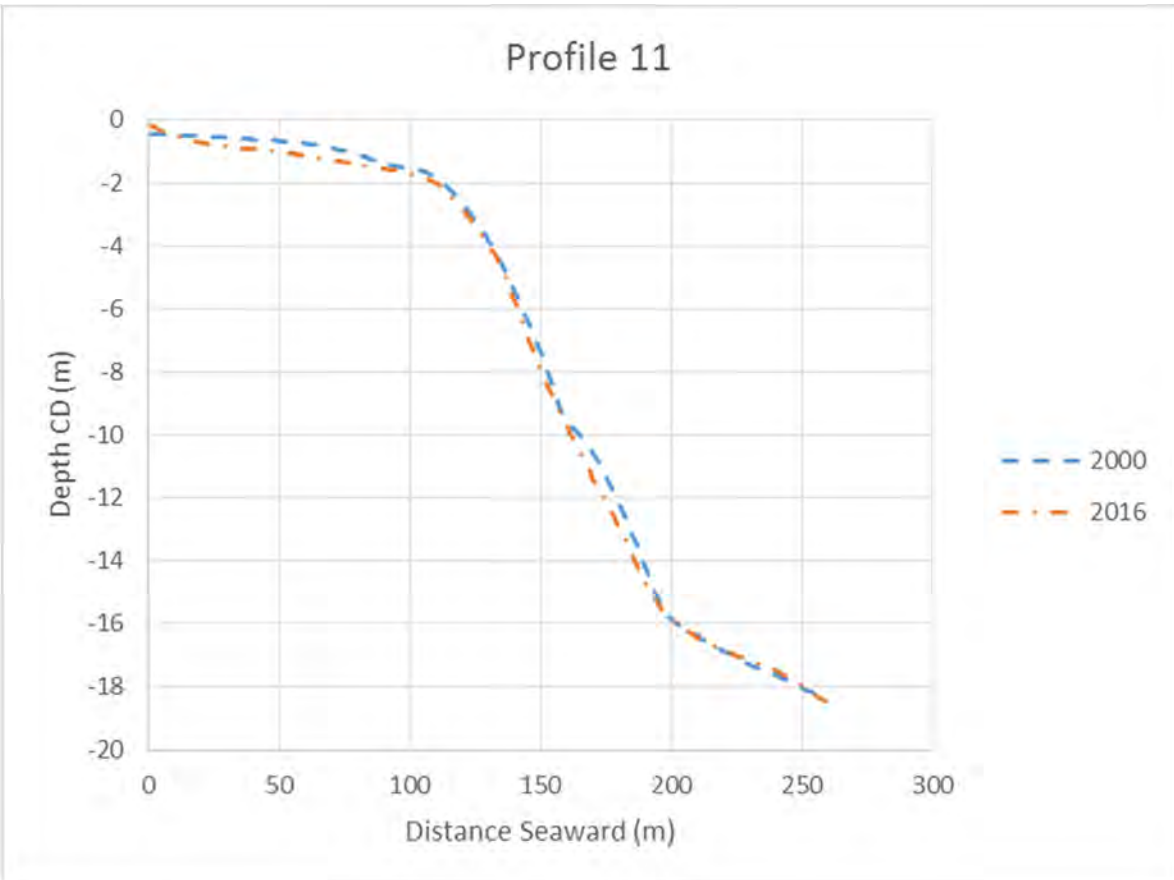

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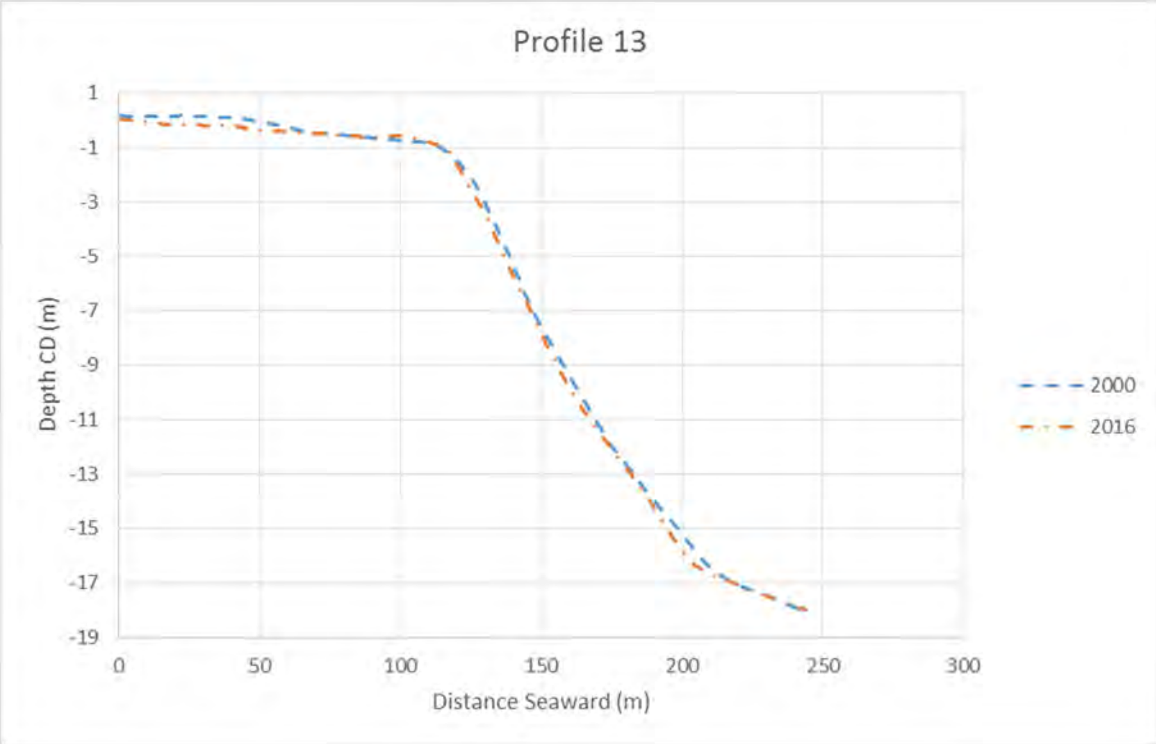
Distance Seaward (m)
2000
2016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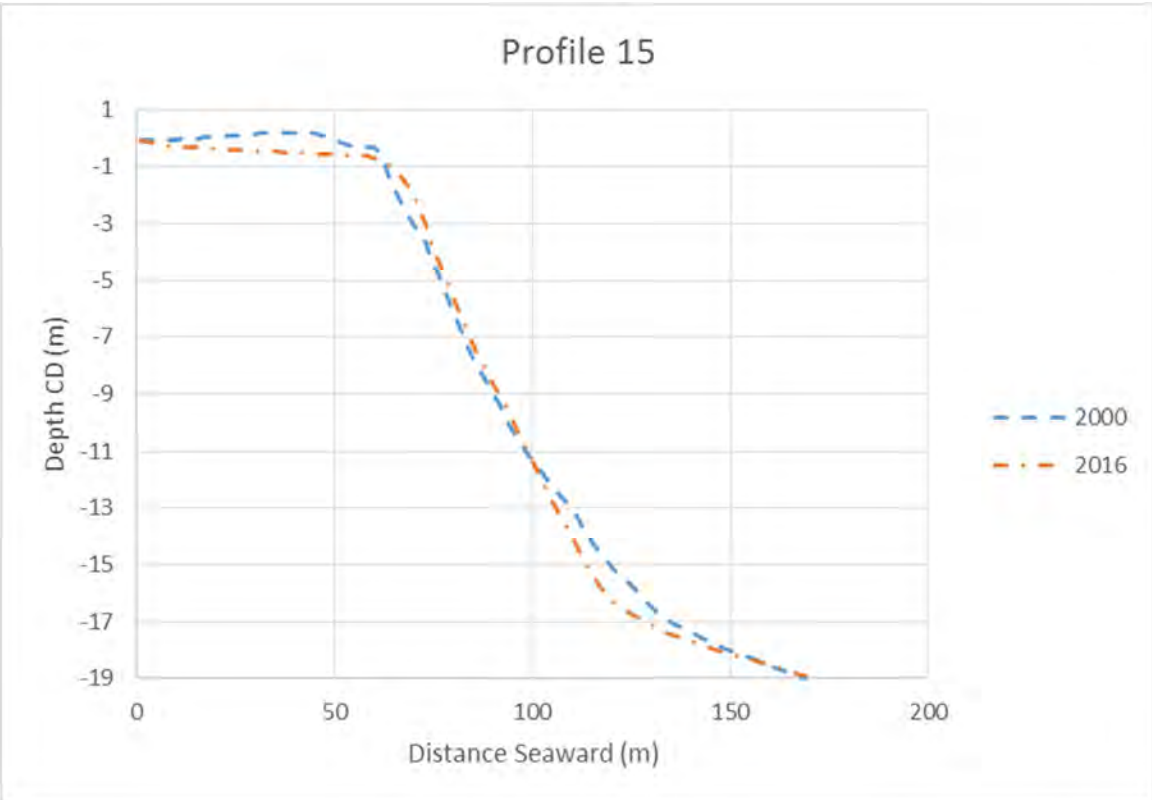
Distance Seaward (m)
2000
2016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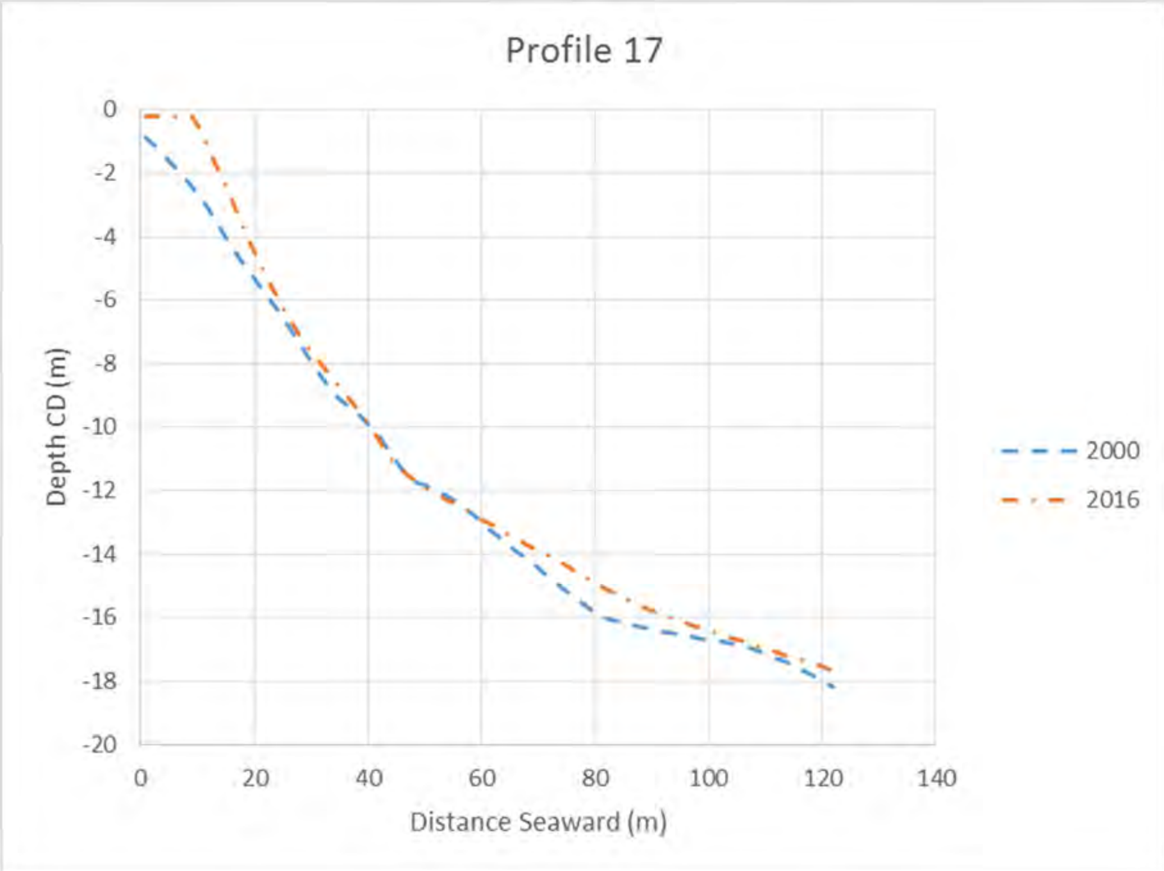
Distance Seaward (m)
2000
2016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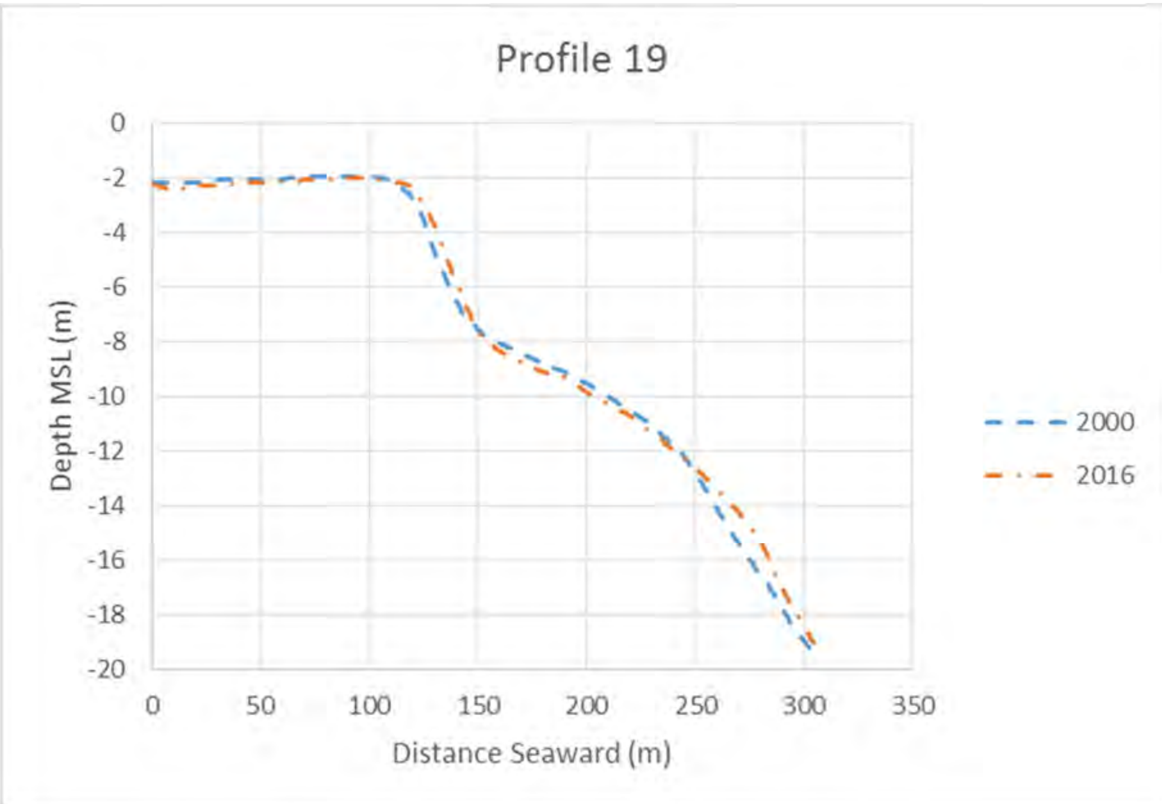
Distance Seaward (m)
2000
2016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150
200
250
300
350
Distance Seaward (m)
2000
2016

Appendix G: Summary of the criteria for describing the magnitude of effects on coastal processes

Significance	Criteria: Coastal Processes
Very High /severe	Total loss of, or very major alteration to, key elements/features of the existing baseline condition such that the post-development character, composition and/or attributes will be fundamentally lost. This includes irreversible changes to tides, currents, waves and/or sand transport causing adverse impacts on significant parts of the shorelines of Bream Bay or Whangarei Harbour, causing increased erosion and/or significant environmental habitat values. Substantial changes to the seabed morphology such that: the majority of the regional distribution of a habitat type for nationally protected ecological communities is lost or substantially depleted; or such that the sediment pathway for sand flow to other areas is permanently intercepted.
High (Significant)	Major loss or alteration to key elements/features of the existing baseline condition such that the post-development character, composition and/or attributes will be fundamentally changed. In particular, extensive or acute disturbance (major impact) occurring to the shorelines bordering Marsden Point and Mair Bank, causing increased erosion and/or significant environmental habitat values. Also, substantial changes to the seabed morphology such that: the majority of the regional distribution of a habitat type for regionally protected ecological communities is lost or substantially depleted; or such that the sediment pathway for sand flow to other areas is temporarily intercepted.
Moderate /medium (More than minor)	Loss or alternation to one or more key features of the existing baseline conditions such that the post-development character, composition and/or attributes will be fundamentally changed. Changes to tides, currents, waves and/or sand transport affecting parts of the shorelines bordering Bream Bay or Whangarei Harbour, causing short term increased erosion that would affect communities or habitat values, such that natural recovery or mitigation measures would alleviate adverse impacts. Also, substantial changes to the seabed morphology such that the local distribution of a locally valued seabed habitat type is permanently lost or substantially depleted.
Low/minor	Minor shift away from existing baseline conditions. Changes arising will be discernible, but attributes of the existing baseline condition will be similar to pre-development circumstances or patterns. Changes to tide levels, currents, waves and/or sand transport processes causing changes in shoreline stability of limited or temporary nature. Changes to the seabed morphology would be of local spatial extent with no impacts elsewhere.
Negligible (Less than minor)	Very slight changes from the existing baseline conditions. No perceptible impacts on regional hydrodynamics beyond the immediate works area. Local hydrodynamic changes that have no consequent adverse impacts elsewhere. Little or no changes to water level, current, wave or sand transport processes at shorelines such that any impacts to shoreline stability would be imperceptible. Changes to the seabed morphology would be temporary with only local spatial extents and no impact elsewhere.
No effect	No detectable change in physical parameters.
Beneficial	Any effects or measures that are expected to result in reduced shoreline erosion where that is presently a problem, or design features or management activities that would make a positive contribution to shoreline amenity or coastal environmental values.

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CRUDE SHIPPING PROJECT

PROPOSED DEEPENING AND REALIGNING OF THE WHANGAREI HARBOUR ENTRANCE AND APPROACHES

VOLUME FOUR:

ANNEXURE TWO (e) TO ANNEXURE TWO (I)

Prepared for:

ChanceryGreen on behalf of the New Zealand Refinery Company Limited **August 2017**

Prepared by:

Ryder

Crude Shipping Project

Proposed Deepening and Realigning of the Whangarei Harbour Entrance and Approaches

Prepared for: New Zealand Refining Company Limited

Prepared by: Gavin Kemble, *Managing Director and Environmental Planner*
Cole Burmester, *Associate and Environmental Planner*
Myaan Bengosi, *Environmental Planner*

Date Finalised: August 2017

Annexure Two: Technical Reports

e) Crude Shipping Project – Mid-point multi-criteria alternatives assessment. T & T. Monique Cornish. Dated March 2017
f) Report in Support of an Assessment of Effects on the Environment – Navigational Risk Assessment of Engineered Channel Designs. Navigatus. Geraint Bermingham and Paul Dickinson. Dated 15 August 2017
g) Environmental Spill Risk Assessment for Proposed Tanker Operations Associated with Engineered Channel. Navigatus. Kevin Oldham, Matt Bilderbeck and Geraint Bermingham. Dated 14 August 2017
h) Whangarei Harbour Entrance and Marsden Point Channel Realignment and Deepening: Assessment of Environmental (Airborne) Noise Effects. Styles Group. Jon Styles. Dated 31 July 2017
i) Assessment of effects on marine mammals from proposed deepening and realignment of the Whangarei Harbour entrance and approaches ('Marine Mammals Assessment'). Cawthron Institute. Deanna Clement and Deanna Elvines. Dated August 2017
j) AEE Report – Coastal Birds – Final. Bioresearches Group Limited. Graham Don. Dated 09 August 2017
k) Assessment of Marine Ecological Effects excluding Seabirds and Marine Mammals. Brian T Coffey and Associates. Brian Coffey. Dated 10 August 2017
l) Recreation and Tourism Effects Assessment. Rob Greenaway and Associates. Rob Greenaway. Dated August 2017

Annexure Two: Technical Reports

e) Crude Shipping Project – Mid-point multi-criteria alternatives assessment. T & T. Monique Cornish. Dated March 2017

REPORT

Tonkin+Taylor

Crude Shipping Project

Mid-point multi-criteria alternatives assessment

Prepared for
ChanceryGreen for Refining NZ

Prepared by
Tonkin & Taylor Ltd

Date
March 2017

Job Number
30488.3000.v2.5

Exceptional thinking together

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Table of contents

1 Executive summary

Tonkin + Taylor was engaged by ChanceryGreen on behalf of Refining NZ (RNZ) to undertake a mid-point review of the potentially viable options to expand the depth and improve the navigability of the shipping channel (both at the entrance and outside of Whangarei Harbour) into the refinery at Marsden Point (the Crude Shipping project). The scope of the engagement was to document the process to-date and to consolidate the findings to support confirmation of a set of preferred options to be taken forward for more detailed assessment as part of a formal Assessment of Environmental Effects (AEE).

Clients of Refining NZ currently import crude oil using Aframax and Suezmax tankers. The harbour has a draught restriction of 14.7 meters Chart Datum (CD). These restrictions mean that only fully laden Aframax tankers (carrying 80,000 to 100,000 tons of crude oil) or partially loaded Suezmax tankers (with 100,000 to 120,000 tons cargo size) can access Refining NZ's discharge terminal. In order to reduce freight costs and impact per tonne transported, the Marsden Point facility could be upgraded to allow fully laden Suezmax tankers to deliver crude oil.

Initially there were three feasible approaches to enable the use of larger tankers explored[1]:

a) dredge the access channel and the RNZ berth
b) install a Single Point Mooring (SPM) system in deeper water offshore connected by an underwater pipeline to the refinery
c) use Ship to Ship transfer in deep water to transfer cargo into smaller tankers for final discharge at the refinery.

The work initially undertaken by Poten & Partners[1] (see Appendix A) found that the dredging alternative (Option A) is preferred from a financial perspective, as the initial the investment can be recovered over a relatively short timeframe, while the added operating costs are relatively small. While all three alternatives have good environmental records, the dredging of the harbour channel allows the continued use of the existing terminal and provides access for more efficient, fully laden Suezmax tankers. This potentially reduces the number of port calls compared to the other options using larger vessels, while having the advantage of discharging in a location that is sheltered from seas and swells, and allows for the most effective emergency response in case of an incident.

In order to understand the feasibility of dredging the access to the channel and the RNZ berth and disposal of dredged material (Option A above), RNZ established an expert team to characterise the existing environment, develop and refine options, and to consider the potential effects associated with the proposal in the context of natural, social, cultural and economic costs and benefits.

Five channel alignment options were considered:

- *Option 1:* alignment keeps within the existing buoyed navigation area ("fairway") and closely follows the current shipping channel centreline, resulting in five heading changes.
- *Option 2:* aimed to increase the distance between changes in channel alignment through the Home Point stretch and follows the existing channel route, resulting in five heading changes.
- *Option 3:* provides a further increase in the distance between changes in channel alignment through the Home Point stretch and reduces the total number of changes in heading to four.

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1 Poten & Partners (August, 2016), Crude Shipping Alternatives Marsden Point, NZ. 28 pp.

- *Option 4:* characterised by a straight mid-section, this was a refinement to Option 3 resulting from the Channel Design Workshop. The channel route is simplified to three main headings, two bends and further increasing the distance between changes in channel alignment through Home Point stretch.
- *Option 5:* developed as an alternative to Option 4 which aimed to avoid any dredging adjacent to Buoy 12/14 by moving the alignment to the east. The alignment therefore extends closer to, and requires dredging at, Home Point.

Option 4, was refined twice (Options 4.1 and 4.2) to further improve navigability. Options 2, 4.2 and 5 were considered the most appropriate to be carried forward for further refinement and this analysis.

Six options were initially considered for assessment as potential dredge disposal sites:

- *Option 1:* ebb delta
- *Option 2:* nearshore water depth (around 25 m CD)
- *Option 3:* intermediate water depth (around 45 m CD)
- *Option 4:* Land based options such as reclamation where possible and consented
- *Option 5:* local beach nourishment
- *Option 6:* deep water off Ocean Beach (around 70 m CD)
- *Option 7:* unspecified location outside the EEZ.

The locations of Options 1, 2 and 3 were refined twice (to Options 1.2, 2.2 & 3.2 respectively) as part of the ongoing investigations. The disposal options sites can be broadly split into three categories: land-based disposal or beach nourishment (Options 4 & 5); inner sites (Options 1.2, 2.2 & 3.2); and offshore sites (Options 6 & 7).

The refined options for channel alignment, dredge disposal and dredge methodology considered in this assessment are summarised in Table 1 below.

Table 1: Summary of options assessed as part of the mid-point multi criteria assessment

Channel options	
Option 2: existing mid-section	Maintains the current channel alignment.
Option 4.2: straight mid-section (west)	Removes the s-bend from the current alignment meaning significant improvement in navigation for arriving ships.
Option 5: straight mid-section (east)	Straightens the alignment by moving the channel closer to Home Point to the east.
Disposal options	
Area 1.2: ebb delta	Situated on the south-eastern edge of the ebb delta to the south of the inner harbour entrance.
Area 2.2: nearshore	Situated in 20-30m of water off the mid-coast of Bream Bay to the west of the channel.
Area 3.2: intermediate	Situated in moderately deep water to the south-east of the channel.
Area 4: land based reclamation	Land based options such as reclamation where possible and consented.
Area 5: beach nourishment	Beach nourishment options.
Area 6: deep water	A broadly defined location in 60-80m water depth off Ocean Beach and north of Lady Alice Island.
Area 7: outside the EEZ	An undefined location outside New Zealand's Exclusive Economic Zone (EEZ).
Dredge methodology	
1a: trailer hopper suction dredge, THSD (with controlled overflow via central weir)	A long suction pipe that is 'trailed' along behind the dredge vessel, dragging and sucking up sediment into its hopper. Overflow via a central weir (or 'green valve') reduces the air entrainment so any dredge material in the overflow falls to the seabed, minimising discharge plumes.
1b: trailer hopper suction dredge, THSD (actual overflow)	A long suction pipe that is 'trailed' along behind the dredge vessel, dragging and sucking up sediment into its hopper. As the ship hopper fills, it "spills over" the side.
2: cutter suction dredge (CSD)	A long cutter head breaks up the sea bed substrate before pumping the sediment into the hopper.
3: backhoe	An excavator is mounted to a vessel, barge, or pontoon. The boom and bucket goes into the water to scoop sediment up from the bottom then brings it to the surface for removal.
i: ebb tide dredging	Restricts dredging to the ebb tide which reduces disturbed sediment accumulating in the harbour. Extends the duration of operations.
ii: all tide dredging	No restriction on dredging operations. Duration of dredging would be shorter.

A multi criteria assessment (MCA) approach was used to provide a systematic and transparent way to evaluate options in the context of potential impacts on natural, social, cultural and economic aspects to derive the best practicable options.

Initial input as to the aspects which may be impacted, weightings for each aspect and potential magnitude and duration of impact was provided by the appropriate expert team members(s) based on their work to-date. Interim results were presented back to the expert team for discussion and agreement at an initial findings workshop in June 2016. As a result of the workshop, further input was provided by the expert team and the results of ongoing research and modelling were incorporated into the assessment.

As a result of the process, and based on the information available as at October 2016, the following are recommended:

Channel Alignment: the key consideration in the selection of the channel alignment is the outcome from a navigational safety perspective. Option 4.2 has been found to perform the best from a navigational safety perspective due to the reduction in the number of headings required, and notably ensuring no course changes around the rocky outcrop at Home Point, which is reflected in the economic sphere of the MCA. The 4.2 alignment is also the furthest from the known areas of high conservation value and hard shore biological diversity, which is reflected in the natural sphere of the assessment, especially when compared with Option 5. Avoiding Home Point also means that Option 4.2 is also likely to result in fewer temporary amenity impacts (light, noise and visual) on the local community. The combination of reduced impact on marine ecology and the headland also mean that this option performs well from a cultural perspective, but concerns remain with regards to the impact on taonga species. As this is perceived by iwi as a new alignment (as opposed to deepening the existing channel as characterised by Option 2), they have concerns as to their ability to perform their role as kaitiaki / stewards of the area.

Dredge Disposal Options: the land based disposal and beneficial reuse option (Options 4 & 5) were assessed as preferential overall, and it is therefore recommended that they are progressed where practicable. However, it is noted that as there are no specific land based disposal or beneficial reuse options defined at present, there will likely be a range of additional costs and benefits associated with these options when specific locations are identified. It is also unlikely to be practicable or economic to dispose of the entire capital dredge volume to land, therefore additional marine disposal sites need to be considered.

Overall, the inner sites (Options 1.2, 2.2 & 3.2) are better characterised than the offshore sites (Options 6 & 7), and the granularity of the information available for these two groups influenced the results of the MCA.

Overall, the offshore options are less feasible than the inner sites from a time, cost and environmental risk perspective, and it is therefore recommended that the inner sites are considered for consenting. Of the three sites, Option 3.2 performed the best in the MCA assessment and is designed to be able to take the full volume of the capital dredge. Option 3.2 is preferred due to a smaller footprint and less potential impact on sea-floor flora and fauna. Being further offshore, there is less potential impact on birdlife and known areas of conservation value. The site is also more removed from known areas of importance to recreational and commercial fishers, although there are still concerns about impacts on mahinga mataitai. Key aspects for assessment include the potential interaction with marine mammals and impacts on taonga species. It is also recommended that limited volumes of dredged material are placed in the ebb delta (Option 1.2) to provide resilience to the geomorphological system and Mair Bank, which is reflected in the MCA assessment of natural aspects.

Dredge Methodology: until a channel option is confirmed it is not possible to determine which of the available dredge methodologies are the most appropriate along the different parts of the transect (berth, inner-harbour and outer harbour). Controlling overflow via the central weir (also referred to as green valve technology) and / or ebb tide dredging should be considered where it is assessed that environmental and cultural effects warrant the use of these methods. However, as the sediment along the channel alignment is likely to settle quickly due to its generally sandy nature, these technologies may not be necessary during dredging and disposal as turbidity levels will already be low. There are also potential commercial, natural environment and social trade-offs due to the increase in dredge duration which come with the use of these dredge methodologies which should be taken into consideration in terms of cost and benefit.

Overall it is recommended that RNZ continues to engage with iwi to fully understand cultural effects and options for mitigation, as cultural aspects were consistently assessed by iwi representatives as being potentially significant both in terms of the weightings allocated to these aspects, as well as the perceived potential impact.

2 Introduction

2.1 Report structure

This report is structured as follows:

- Section 1: provides the background to the project and the purpose and scope of the mid-point review
- Section 2: details methodology used in the mid-point review, including weightings, impact assessment and normalisation
- Section 3: provides a high level summary of the impacts most material to each aspect based on the research and professional option of the expert panel
- Section 4: summarises the preferred options in the context of the multi-criteria assessment
- Section 5: applicability
- Appendix A: report on the feasibility of approaches to allow fully laden Suezmax tankers to deliver crude oil by Poten & Partners
- Appendix B: schematics of the channel alignment options considered as part of the min-point review
- Appendix C: list of contributors from the expert panel
- Appendix D: key literature to support the opinions in Sections 3 and results in Section 4
- Appendix E: complete tabularised MCA results.

2.2 Business need

RNZ is seeking to reduce crude product transportation costs through economies of scale to support RNZ's competitive position and long term business sustainability. As a result, a review of crude oil shipping efficiency was undertaken by RNZ. Clients of Refining NZ currently import crude oil using Aframax and Suezmax tankers. The harbour has a draught restriction of 14.7 meters Chart Datum (CD). These restrictions mean that only fully laden Aframax tankers (carrying 80,000 to 100,000 tons of crude oil) or partially loaded Suezmax tankers (with 100,000 to 120,000 tons cargo size) can access Refining NZ's discharge terminal. For clarity, the intention of the proposed dredging project is not to bring any larger vessels to the Refinery. In order to reduce freight costs and impact per tonne transported, the Marsden Point facility could be upgraded to allow fully laden Suezmax tankers to deliver crude oil.

Initially there were three feasible approaches explored[2]:

a) dredge the access channel and the RNZ berth
b) install a Single Point Mooring (SPM) system in deeper water offshore connected by an underwater pipeline to the refinery
c) use Ship to Ship transfer in deep water to transfer the cargo into smaller tankers for final discharge at the refinery.

2 Poten & Partners (August, 2016), Crude Shipping Alternatives Marsden Point, NZ. 28 pp.

The work initially undertaken by Poten & Partners (see Appendix A) found that the dredging alternative (Option A) is preferred from a financial perspective, as the initial the investment can be recovered over a relatively short time frame while the added operating costs are relatively small. The other alternatives have either very high operating costs or involve high upfront investment costs which require Refining NZ to move to Very Large Crude Carriers (VLCC) – about 3 times the current delivery size – in order to offset these additional costs. While all three alternatives have good environmental records, the dredging of the harbour channel allows the continued use of the existing terminal but provides access to more efficient, fully laden Suezmax tankers. This potentially reduces the number of port calls while having the advantage of discharging in a location that is sheltered from seas and swells, and allows for the most effective emergency response in case of an incident.

2.3 Initial options assessment

In order to understand the likely effects associated with the proposal, RNZ assembled a team of appropriately qualified and experienced and well respected experts to:

- characterise the existing environment, including natural, social, cultural and economic aspects
- identify possible dredge channel configurations, dredge methodologies and disposal options
- consider the potential effects of these various options in the context of costs and benefits.

From November 2014 to December 2015 a comprehensive range of high level studies and investigations were carried out by the team to better understand and characterise the existing natural, social and cultural environments, and to identify possible channel alignment and disposal options. As a result of these investigations a number of options were not progressed due to potential natural and social impacts, navigational safety, project risks and / or economic viability, while other options were further refined. We outline that characterisation and refinement process below.

2.3.1 Channel options

Five channel alignment options were considered which fulfilled the requirements of increased depth and were in accordance with PIANC (World Association for Waterborne Transport Infrastructure) design principles (Royal HaskoningDHV, June 2016):

- *Option 1:* alignment keeps within the existing buoyed navigation area (“fairway”) and closely follows the current shipping channel centreline, resulting in five heading changes.
- *Option 2:* aimed to increase the distance between changes in channel alignment through the Home Point stretch and follows the existing channel route, resulting in five heading changes.
- *Option 3:* provides a further increase in the distance between changes in channel alignment through the Home Point stretch and reduces the total number of changes in heading to four.
- *Option 4:* characterised by a straight mid-section, this was a refinement to Option 3 resulting from the Channel Design Workshop. The channel route is simplified to three main headings, two bends and further increasing the distance between changes in channel alignment through Home Point stretch.
- *Option 5:* developed as an alternative to Option 4 which aimed to avoid any dredging adjacent to Buoy 12/14 by moving the alignment to the east. The alignment therefore extends closer to, and requires dredging at, Home Point.

Option 4, was refined twice (Options 4.1 & 4.2) to further improve navigability. Options 2, 4.2 & 5 were considered the most appropriate to be carried forward for further refinement and analysis (see Appendix B).

2.3.2 Disposal options

Six options were initially considered for assessment as potential dredge disposal sites (see Figure 1-1):

- *Option 1:* ebb delta
- *Option 2:* nearshore water depth (around 25 m CD)
- *Option 3:* intermediate water depth (around 45 m CD)
- *Option 4:* Land based options such as reclamation where possible and consented (not shown on map)
- *Option 5:* local beach nourishment (not shown on map)
- *Option 6:* deep water (60-80 m CD)
- *Option 7:* unspecified location outside the EEZ (not shown on map).

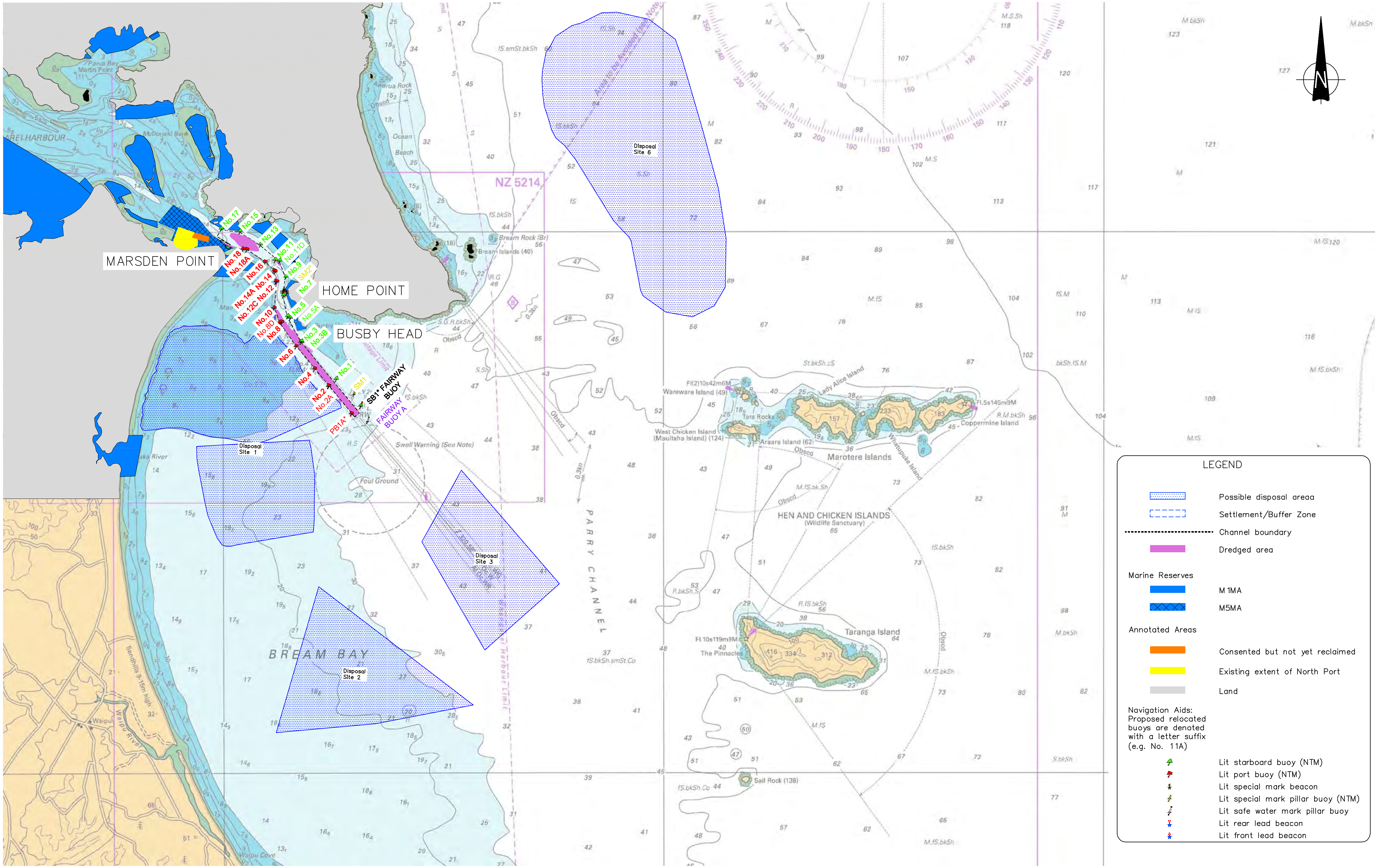
The location of Options 1, 2 & 3 were refined twice (to 1.2, 2.2 & 3.2 respectively) as part of the ongoing investigations. These locations (except Options 4, 5 and 7) are shown on Figure 1-2 below.

2.4 Mid-point options assessment

More detailed studies, investigations and analyses were undertaken on the refined options to further the understanding as to how they could affect the environment, as well as the cost and feasibility of implementation.

In April 2016, ChanceryGreen on behalf of Refining NZ commissioned Tonkin & Taylor Ltd ("Tonkin + Taylor" or "T+T") undertake a mid-point review of the options for dredging and disposal which were considered feasible at that time, which included three channel options, seven disposal sites and six aspects of dredge methodology (see Table 1-1).

The assessment aimed to consolidate the information generated for each of the options to-date, and provide a transparent process for agreeing the preferred options to be taken forward for further, more detailed assessment, as part of a formal Assessment of Environmental Effects. The assessment process also aimed to highlight where the most important potential impacts lie for each of the options, so that effort can be placed in the right areas in terms of finalising the preferred options, and if necessary, the development of mitigation strategies in order to ensure that any adverse effects are acceptable.



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NOTES :

1. Hydrographic chart sourced from Linz Data Service (NZ 5214/5219)
2. Navigation aids and relocation placements from Royal HaskoningDHV drawing PA1028/MA/1121 rev K.

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Initial Disposal Sites

FIG. No. Figure 1-1

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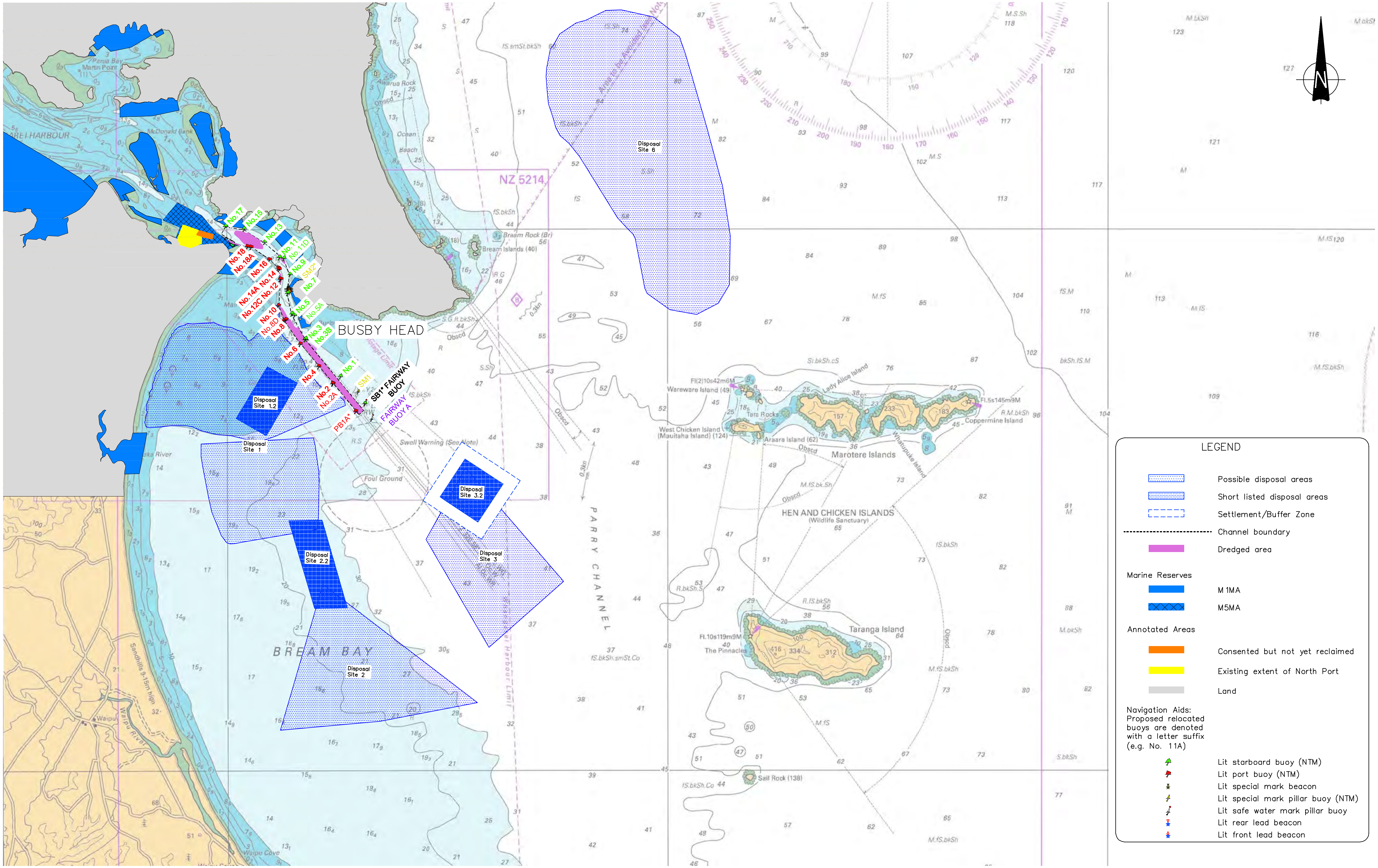

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NOTES :

1. Hydrographic chart sourced from Linz Data Service (NZ 5214/5219)
2. Navigation aids and relocation placements from Royal HaskoningDHV drawing PA1028/MA/1121 rev K.

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MARSDEN POINT NORTHLAND

Midpoint Refine

FIG. No. Figure 1–2

REV. 0

Table 1-1: Summary of options assessed as part of the mid-point multi criteria assessment

Channel options[3]	
Option 2: existing mid-section	Maintains the current channel alignment.
Option 4.2: straight mid-section (west)	Removes the s-bend from the current alignment meaning significant improvement in navigation for arriving ships.
Option 5: straight mid-section (east)	Straightens the alignment by moving the channel closer to Home Point to the east.
Disposal options	
Area 1.2: ebb delta	Situated on the south-eastern edge of the ebb delta to the south of the inner harbour entrance.
Area 2.2: nearshore	Situated in around 25m of water off the mid-coast of Bream Bay to the west of the channel.
Area 3.2: intermediate	Situated in moderately deep water (around 45m) to the south-east of the channel.
Area 4: land based reclamation	Land based options such as reclamation where possible and consented.
Area 5: beach nourishment	Beach nourishment options.
Area 6: deep water	A broadly defined location 60-80m water depth off Ocean Beach and north of Lady Alice Island.
Area 7: outside the EEZ	An undefined location outside New Zealand's Exclusive Economic Zone (EEZ).
Dredge methodology	
1a: trailer hopper suction dredge, TSHD (with controlled overflow via central weir)	A long suction pipe that is 'trailed' along behind the dredge vessel, dragging and sucking up sediment into its hopper. Overflow via a central weir (or 'green valve') reduces the air entrainment so any dredge material in the overflow falls to the seabed, minimising discharge plumes.
1b: trailer hopper suction dredge, TSHD (actual overflow)	A long suction pipe that is 'trailed' along behind the dredge vessel, dragging and sucking up sediment into its hopper. As the ship hopper fills, it "spills over" the side.
2: cutter suction dredge (CSD)	A long cutter head breaks up the sea bed substrate before pumping the sediment into the hopper.
3: backhoe	An excavator is mounted to a vessel, barge, or pontoon. The boom and bucket goes into the water to scoop sediment up from the bottom then brings it to the surface for removal.
i: ebb tide dredging	Restricts dredging to the ebb tide which reduces disturbed sediment accumulating in the harbour. Extends the duration of operations.
ii: all tide dredging	No restriction on dredging operations. Duration of dredging would be shorter.

3 See Appendix B for schematics of channel alignment options.

3 Assessment methodology

A multi criteria assessment (MCA) methodology was used to provide a systematic and transparent approach for evaluating shortlisted options in the context of potential impacts on various natural, social, cultural and economic aspects to robustly test those options, and to derive the preferred (best practicable) option. An initial MCA matrix was developed to:

- capture all important aspects from an natural, social, cultural and economic perspective which could be impacted by the channel, disposal or dredge methodology options,
- agree weightings for each of the aspects based on stakeholder and expert opinion, and
- agree potential impacts (positive and negative) on each of the aspects for each of the options based on stakeholder and expert opinion.

The assessment is based on the research and findings of the expert team working collectively on behalf of RNZ (see Appendix C for a list of contributors).

Initial feedback on the aspects, weightings and impacts was solicited from the expert team via a formal written information request and one-on-one interviews. Subsequently, interim results were presented back to the expert team at an initial findings workshop in June 2016. As a result of the workshop, further input was provided by the expert team, and the results of ongoing research and modelling were incorporated into the assessment (see Appendix D for details of key reports contribution to the findings of this assessment).

3.1 Aspects and weightings

The aspects included in the assessment are provided in Table 2-2. Particular attention was placed on ensuring that impacts were not double counted, as well as accurately reflecting interdependencies and feedback loops.

Weightings are used as a multiplier to reflect the importance of each of the aspects to communities of interest which include local residents, businesses and iwi, as well as the potential to impact ecosystem services. Weightings were initially proposed by the member(s) of the expert panel who were best placed to assess the perceived criticality of each of the aspects to stakeholders. Weightings were discussed and agreed or revised as part of the initial findings workshop as summarised in Table 2-1.

Table 2-1: Weighting descriptions

0.5	1	2	3
Minor importance to a small number of stakeholders OR Aspect does not impact or have an interdependency with other aspects	Minor importance to a wide range of stakeholders OR Interdependency with other aspect. Does not impact the functioning of the community or ecosystem	Moderate importance to stakeholders OR Interdependency with other number of other aspects. Impacts the functioning of the community or ecosystem	Major importance to stakeholders OR Significant interdependency with other aspects. Aspect is critical to the health or welbeing of communities (human or ecological)

Table 2-2: Summary of aspects and weightings

Aspect	Description	Weighting
Natural		
Direct impacts		
Impact on benthic flora & fauna at site	Direct impacts on ecological communities removed or smothered	2
Impact on local fish stocks	Direct impacts on species due to changes at the dredge / disposal site (habitat, resources, movement paths)	2
Impact on marine mammals	Direct impacts on species due to changes at the dredge / disposal site (habitat, resources, movement paths)	2
Impact on shore birds & pelagic birds	Direct impact on feeding and nesting sites and indirect impacts on mating due to noise, light and general activity in the area	2
Sediment matching	Degree to which the deposit would match the existing substrate	2
Contamination	Potential for any existing contaminants to be spread	3
Impact on intertidal and subtidal flora and fauna	Impact on sensitive coastal flora (e.g. seagrass beds) and sensitive soft bottomed communities	2
Impact on significant ecological habitats or species of flora and fauna within those habitats	Potential to impact areas with important conservation value	3
Impact on reef	Potential to impact known area of hard shore biological diversity	2
Turbidity (dredge location)	Potential for movement of sand from site and impacts on water quality (colour and clarity) and associated impacts on phyto / zooplankton	2
Turbidity (disposal location)	Potential for movement of sand from site and impacts on water quality (colour and clarity) and associated impacts on phyto / zooplankton	2
Indirect impacts		
Coastline formation	Potential for deposition to occur to a level greater than normal coastal processes	1
Natural Character & underwater seascape (biophysical)	Significance of the impact on the natural character values & 'landscape' of the sea floor	1
Coastal erosion	Potential for erosion to occur to a level greater than normal coastal processes	2
Resilience	Impact on resilience of the coastal system based on volume of sand removed / deposited	3
Social		
Permanent impacts		
Fishing	Impact on recreational fishing (access or stocks) by boat, from shore or diving. Includes fin and shellfish	3
Hunting	Impact on duck hunting on- or near-shore	3
Watercraft sports	Impact on on-water sports (e.g. yachting, rowing, waka ama, windsurfing, canoeing, jet skiing, boating)	3
Watercraft sports	Impact on boating communities associated with relocation of the navigation buoys	0.5
Wave sports	Impact on wave sports (e.g. kite surfing, wind surfing and surfing) due to changes in surf breaks	3
In-water activities	Impact on in-water activates (e.g. diving, swimming) due to changes in turbidity, currents, wave profile	3
Beach access and use	Changes to beach access	3
Natural Character & underwater seascape (perceptual)	Significance of the impact on the natural character values & 'landscape' of the sea floor	1
Permanent effects of navigation lights	Impact on local and visitor communities associated with new Navaid structures	1
Temporary impacts		
Temporary amenity effects (light spill & noise emissions above water)	Impact on local community from light and noise associated with dredge operations	2
Temporary visual amenity & landscape	Aesthetic impacts on local community associated with dredging operations	2

Cultural		
Kaimoana at Mair Bank	Impact on the ability to collect kaimoana from Mair Bank (based on erosion of Mair Bank) which may impact the ability to collect kaimoana (particularly pipi) sustainability	3
Kaimoana at Marsden Bank	Impact on the ability to collect kaimoana from Marsden Bank (based on erosion of Marsden Bank) which may impact the ability to collect kaimoana sustainability	3
Taonga species	Impact on native birds, plants and animals of special cultural significance and importance to tangata whenua	3
Mahinga Mataitai	Impacts on other key traditional mahinga mataitai and fishing grounds	3
Mauri of Harbour	Impact on the mauri of the harbour, including the potential impact of sand removal from system	3
Cultural Landscapes and Seascapes	Impacts on important markers including Manaia, Matariki, Te Whara, the Takahiwai and Pukekauri Ranges and islands including Tatanga	3
Kaitiakitanga	Impact on the ability of tangata whenua to fulfil their duties as kaitiaki and on matauranga and tikanga in regard to resources	3
Subsurface Archaeological Sites	Impact on subsurface archaeological sites, including shipwrecks	3
Land-based Archaeological sites	Impact on natural and physical resources that contribute to an understanding and appreciation of New Zealand's history and cultures	3
Economic		
Indirect impacts		
Impact on intakes and outfalls	Potential impact on intakes and/or outfalls (blocking) excluding NIWA operations	0.5
NIWA Operations	Potential impact on NIWA aquaculture operations (Abalone)	2
Commercial Fishing	Shellfish and fish	3
Navigation	Potential effects on navigational safety due to channel alignment	3
Project Safety	Risk associated with undertaking the option [environmental and workplace health and safety (WHS)] linked to methodology and programme duration	3
Direct impacts		
Legal	Jurisdictional and practical issues associated with consenting each option	2
Maintenance	Degree to which deposition site or channel alignment impacts cost of maintenance	2
Revenue	The amount of revenue generated via beneficial reuse	0.5
Cost	Total cost of option	3

3.2 Impact assessment

The expert team provided an impact assessment across each of the aspects, for each of the channel alignment, dredge disposal site and dredge methodology options based on the categories summarised in Table 2.3. Impacts were discussed and agreed or revised as part of the initial findings workshop.

Table 2-3: Summary of impact categories

-1	0	1	2	3
Positive impact on the aspect being considered	Neutral or no impact on the aspect being considered	Minor impact on the aspect being considered Impact is can be avoided or remediated. Recovery expected to occur in less 1-2 years	Moderate impact of the aspect being considered Impact is difficult to avoid or remediate. Recovery expected to occur over up to 5-years	Major negative impact on the aspect being considered Impact is very difficult to avoid or remediate. Impact permanent or recovery expected to take longer than 5-years

Impact scores are combined with the weighting to provide an overall score for each aspect. The weighted impact assessment scores are reported in the following sections. Results can be interpreted as a lower number being more favourable.

3.3 Normalisation

Results are normalised so that natural, social, cultural and economic criteria are treated equally within the assessment, regardless of the number of aspects identified within each of the four environments.

Results are also provided excluding direct costs to RNZ linked to consenting (legal), project and maintenance costs, as well as any revenue (if any) which could be derived from the beneficial reuse of dredge material. This allows a view of the project as perceived by external stakeholders, who are less sensitive to RNZ costs / benefits, and potentially more interested in the balance of broader costs and benefits.

3.4 Sensitivity assessment

Three aspects of data treatment were explored with regards to the impact on results:

- weighted versus unweighted results
- normalised versus normalised results
- inclusion versus exclusion of direct project costs.

The overall ranking of the options was not impacted by weightings or normalisation. There is an impact of excluding direct costs on the relative difference between the options for channel alignment, which is due to project and navigational safety being better expressed when direct costs are removed. As there is an impact, results are presented including and excluding direct costs for full transparency.

4 Summary of key issues

The following section summarises the key issues for each aspect as determined by the relevant expert team member(s), and agreed with the full group at the findings workshop. The complete tabularised MCA results are provided in Appendix E

The following aspects were raised across the expert team as key potential impacts, and were weighted highly:

Mair Bank: the importance of retaining sediment within the system, and in particular the impact on the stability of Mair Bank. Mair Bank has been an important location for the collection of pipi by iwi and local residents. Over recent years the pipi population has been in decline, and the mussel population has been increasing. It is important to recognise that this system is going through a period of change in advance of the commencement of this project, which has heighted iwi and community concerns regarding any impact of the project on Mair Bank. Disposal of dredge material at the inner locations (Option 1.2, 2.2 & 3.2), and in particular disposal Option 1.2, allows for the retention of material within the system to potentially replenish Mair Bank (see section 3.5).

Areas with special ecological or conservation value: there are four areas designated as having particular conservation value within the Regional Coastal Plan (i.e. M1MA) which extend from Home Point to Busby Head. Of particular note are the hard-bottomed communities, comprising sponge gardens and kelp beds[4], which are subject to smothering by disturbed sediment. When compared to channel alignment options 2.2 and 5, option 4.2 has the widest clearance of these communities. The nature of the sandy substrate means that disturbed material will likely settle quickly and not travel to the point it will interact with these communities. The proposed dredge and disposal sites are soft bottomed areas of seabed that support a benthic community that is considered typical of the coastal environment off the north east coast of the North Island, which is not of regional or national significance[4].

Cultural values: a range of potential impacts have been identified as part of the Cultural Values Assessment and engagement with Patuharakeke Te Iwi Trust Board), including impacts on traditional fishing areas (Mahinga Mataitai) and access to kaimoana, taonga species and the mauri of the harbour. It is recommended that RNZ continue to engage with iwi to fully understand perceived impacts and options for mitigation.

Navigational and project safety: a key consideration in the selection of the channel alignment is the outcome from a navigational safety perspective. Option 4.2 has been found to perform the best from a navigational safety perspective due to the reduction in the number of headings required, and notably ensuring no course changes around the rocky outcrop at Home Point. From a project safety perspective the offshore disposal options present increased environmental risk, as well as increased cost, and hence inner options are considered preferable for the majority of the capital dredge disposal.

4 Brian T. Coffey and Associates Limited (October, 2016), AEE: RNZ Marine Ecology 3. 67 pp.

4.1 Marine mammals

Expert input on weightings and potential impacts on marine mammals was provided by Cawthron Institute. Impacts on marine mammal navigation and feeding were considered the most material. Baleen Whales are likely to be the most impacts based on the frequency of nose predicted to be associated with the project. Overall, key aspects identified from a marine mammals perspective included:

- increased noise may lead to a permanent or temporary threshold shift or auditory masking which may impact behaviour of marine mammals
- the physical presence of dredge vessels presents the risk of entanglement or strike
- turbidity plumes may impact behaviour and feeding patterns due to the changes in prey distribution.

The options assessment (summarised in Table 3-1) concluded that from a marine mammal perspective:

Disposal: beach nourishment is preferred, with the nearshore option the next best alternative due to limited likely interaction with marine mammals. Ebb Delta and Intermediate sites are the least preferred options due to the potential for physical interaction with marine mammals.

Alignment: limited difference in the impacts associated with channel alignment.

Methodology: operational noise levels are fairly similar across the methods, with backhoe dredges sometimes 'noisier' due to their use in excavating fractured rock and coarser gravels[5]. Any reduction in sediment in the water column is considered important. Ebb tide preferable to all tide dredging, due to the respite in operations; however, it is recognised that this may be offset by the overall duration of the project.

Table 4-1: Summary of potential effects on marine mammals

Category			Natural
			Direct impacts
Aspect			Impact on marine mammals
Description			Direct impacts on species due to changes at the dredge / disposal site (habitat, resources, movement paths)
Dredge Disposal	1.2	Ebb Delta	4
	2.2	Nearshore	2
	3.2	Intermediate	4
	4	Land based disposal	0
	5	Beach nourishment	0
	6	Deep water	2
	7	Outside EEZ	2
Channel	2	Existing mid-section	2
	4.2	Straight mid-section (west)	2
	5	Straight mid-section (east)	4
Dredge Methodology	1a	Trailer (with central weir)	4
	1b	Trailer (actual overflow)	4
	2	Cutter	4
	3	Backhoe	4
	i	Ebb Tide Dredging	0
	ii	All Tide Dredging	2

[5] Central Dredging Association, CEDA, (2011) Underwater Sound in Relation to Dredging, CEDA Position Paper 7 November 2011. 6 pp.

4.2 Shore and pelagic birds

Table 4-2: Summary of potential effects on Shore and pelagic birds

Category			Natural
Aspect			Direct impacts
			Impact on shore birds & pelagic birds
Description			Direct impact on feeding and nesting sites and indirect impacts on mating due to noise, light and general activity in the area
Dredge Disposal	1.2	Ebb Delta	4
	2.2	Nearshore	4
	3.2	Intermediate	2
	4	Land based disposal	0
	5	Beach nourishment	4
	6	Deep water	2
	7	Outside EEZ	2
Channel	2	Existing mid-section	2
	4.2	Straight mid-section (west)	2
	5	Straight mid-section (east)	4
Dredge Methodology	1a	Trailer (with central weir)	2
	1b	Trailer (actual overflow)	4
	2	Cutter	2
	3	Backhoe	2
	i	Ebb Tide Dredging	2
	ii	All Tide Dredging	4

Expert input on weightings and potential impacts on shore and pelagic birds (including species which are targeted by recreational hunters) was provided by Bioresearches based on research undertaken over numerous breeding seasons.

Impacts on habitat (feeding and roosting) were considered, as well as potential collision with dredge operations. Key issues identified included:

- proximity of dredge disposal sites to nesting and feeding sites (e.g. Bream Bay Beach, Ruakaka and Waipu Estuaries, Marsden Bay)
- impact of beach nourishment on areas of potential high ecological value
- proximity to Home Point Shag nesting colony which is home to the Pied Shag which is nationally threatened
- an illuminated dredger off Busby Head may present a collision risk for (juvenile) Grey Faced Petrels.

The options assessment (summarised in Table 3-2) concluded that from a shore and pelagic birds' perspective:

Disposal: land based disposal (not beach nourishment) preferred, with the Intermediate and Deep Water options the next best alternatives.

Alignment: limited difference in the impacts associated with channel alignment. Option 5 least preferred due to the proximity to Home Point.

Methodology: all tide dredging least preferred due to overall greater risk of disturbance of shore and pelagic birds' habitat and behaviour.

4.3 Marine ecology (excluding marine mammals and avifauna)

Table 4-3: Summary of potential effects on marine ecology (excluding marine mammals and avifauna)

Category			Natural						
			Direct impacts						
Aspect			Impact on benthic flora & fauna at site	Impact on local fish stocks	Sediment matching	Contamination	Impact on intertidal and subtidal flora and fauna	Impact on significant ecological habitats or species of flora and fauna within those habitats	Impact on reef
Description			Impact on ecological communities removed or smothered	Direct impacts on species due to changes at the dredge / disposal site (habitat, resources, movement paths)	Degree to which the deposit would match the existing substrate	Potential for any existing contaminats to be spread	Potential to impact areas with important conservation value	Potential to impact areas with important conservation value	Potential to impact known area of hard shore biological diversity
Dredge Disposal	1.2	Ebb Delta	4	2	2	0	-2	6	4
	2.2	Nearshore	4	2	0	0	2	3	2
	3.2	Intermediate	2	2	0	0	2	3	2
	4	Land based disposal	0	0	0	0	0	0	0
	5	Beach nourishment	0	0	0	0	0	0	0
	6	Deep water	4	2	4	0	2	0	0
	7	Outside EEZ	2	2	4	0	2	0	0
Channel	2	Existing mid-section	2	2		0	2	6	4
	4.2	Straight mid-section (west)	2	2		0	2	6	4
	5	Straight mid-section (east)	4	4		0	4	9	6
Dredge Methodology	1a	Trailer (with central weir)	2	2		0	2	3	0
	1b	Trailer (actual overflow)	4	4		0	4	9	4
	2	Cutter	2	2	0	0	4	3	0
	3	Backhoe	4	4	0	0	4	3	0
	i	Ebb Tide Dredging	2	2	0	0	2	3	2
	ii	All Tide Dredging	4	4	0	0	4	9	4

Expert input on weightings and potential impacts on marine and coastal ecology was provided by Brian Coffey & Associates. Potential impact on the areas of important conservation value is of particular concern. Key Issues from an ecological perspective included:

- potential impact on the four areas of important conservation value set out in the Operative Northland Coastal Management Plan, including the high value hard-bottomed communities from Home Point to Busby Head which are vulnerable to smothering
- potential impact on Three Mile Reef from increased turbidity
- sand supply to Mair Bank and flow-on impacts on biodiversity on the bank.

Contamination is an important aspect considered within the assessment (note a weighting of 3 in Table 2-2). A number of different sampling exercises were undertaken by members of the expert panel as part of characterising the existing environment including sampling of the proposed channel alignment area: Bioresearches identified 107 sampling points to characterise the seabed sediment quality and biota present in or near the area to be dredged, with an additional five sites up-harbour from the dredge area, and five sites beyond the dredge area offshore[6].

[6] Bioresearches (September, 2016) Existing Environment Assessment: Ecology of the Dredge Area, Whangarei Heads. 210 pp.

Sediment chemistry and particle size were assessed at all sites to ascertain the risk associated with the disturbance of this material during dredging. The chemistry results were compared against the ANZECC interim sediment quality guidelines (where available). None of the surface sediment samples exceeded the ANZECC ISQG Low values with exception of Fluoranthene, Phenanthrene and Pyrene at site C26S (located 250 m seawards of the Refining NZ wharf along the slope of the channel edge). This minor exceedance was not considered material and the study concluded that no adverse effects are expected to occur from the redistribution of sediments during dredging or from the disposal of the dredge spoil at a nearby marine disposal site[7].

In a separate sampling exercise, a suite of 26 Vibrocore samples were taken from the dredging area to characterise the existing environment[8]. Interpretation of the contamination results by Brian T. Coffey and Associates[9] included that the thresholds of potential concern for heavy metals (as defined by ANZECC guidelines) were approached for Nickel in sample V19A and exceeded for sample V20 (both samples were taken in the outer reaches of the dredge footprint on approach to the harbour). Sample V20 also exceeded the *Effects Range-Low*. The analysis of back-up samples for both cores were submitted for additional elutriate testing and a full range of organic analyses, the results of which support the conclusion there are no issues with the potential contamination status of material to be disposed of from the proposed dredging footprint[9].

The options assessment (summarised in Table 3-3) concluded that from an ecology perspective:

- Disposal: onshore disposal is preferred with Intermediate option the next best alternative. Outside the EEZ is also considered a preferable option due to no potential impact on areas of important conservation value. For the same reason the ebb delta option is the least preferred option. Overall there is the need to balance the overall footprint of the disposal area with avoiding the complete smothering of benthic communities.
- Alignment: channel option 5 is the least preferred due to the proximity to Home Point, and option 4.2 is preferred due to overall reduction of risk during operation.
- Methodology: consideration should be given to using methods which reduce turbidity when this is an issue based on substrate density, particularly when in proximity of the areas of important conservation value and Home Point.

7 Bioresearches (September, 2016) Existing Environment Assessment: Ecology of the Dredge Area, Whangarei Heads. 210 pp.

8 Tonkin & Taylor (April, 2016) Marsden Point Refinery – Crude Freight Project. Geotechnical Factual Report. 255 pp.

9 Brian T. Coffey and Associates Limited (October, 2016) AEE: RNZ Marine Ecology 3. 67 pp.

4.4 Turbidity

Table 4-4: Summary of potential turbidity impacts

Category			Natural	
			Direct impacts	
Aspect			Turbidity (dredge location)	Turbidity (disposal location)
Description			Potential for movement of sand from site and impacts on water quality (colour and clarity)	Potential for movement of sand from site and impacts on water quality (colour and clarity)
Dredge Disposal	1.2	Ebb Delta		2
	2.2	Nearshore		2
	3.2	Intermediate		2
	4	Land based disposal		0
	5	Beach nourishment		0
	6	Deep water		2
	7	Outside EEZ		2
Channel	2	Existing mid-section	2	
	4.2	Straight mid-section (west)	2	
	5	Straight mid-section (east)	2	
Dredge Methodology	1a	Trailer (with central weir)	2	4
	1b	Trailer (actual overflow)	4	4
	2	Cutter	4	4
	3	Backhoe	4	2
	i	Ebb Tide Dredging	2	0
	ii	All Tide Dredging	4	0

Expert input on weightings and potential turbidity impacts were provided by Royal HaskoningDHV[10] and Tonkin + Taylor (using data modelled by MetOcean).

Impacts are split to reflect different potential turbidity impacts from dredging and disposal. While it is recognised that turbidity is a key issue for all marine flora and fauna, and the local community from ecological, recreational, cultural and aesthetic perspectives, the predominance of coarser, heavier sediments across the dredge area indicate that disturbed sediment will generally fall out of the plume quickly causing minimal impact (see MetOcean, 2016).

The options assessment (summarised in Table 3-4) concluded that:

Disposal: minimal turbidity changes are anticipated at all ocean disposal sites, although beach nourishment and land based disposal options are preferred, as there are potentially very limited turbidity impacts associated with these options.

Alignment: minimal turbidity changes are anticipated at all dredge locations.

Methodology: it is recognised that all tide dredging could create more turbidity than ebb tide dredging, although this is dependent on the substrate type. Equally, as a general methodology, controlling overflow via a central weir reduces turbidity plumes, but this is unlikely to be an issue across the project site due to sediment composition.

CSD and backhoe both have potential to affect turbidity in particular ways; however, these methodologies are not necessarily interchangeable or mutually exclusive and may have to be used at different points along the alignment for different purposes.

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10 Royal HaskoningDHV (May, 2016) Technical Memo: Dredging Assessment Methodology. Reference M&APA1028N006D04. 42 pp.

4.5 Physical environment

Table 4-5: Summary of potential impacts on the physical environment

Category			Natural				
Aspect			Direct impacts	Indirect impacts			
			Sediment matching	Coastline formation	Natural character and underwater seascape (biophysical)	Coastal erosion	Resilience
Description			Degree to which the deposit would match the existing substrate	Potential for deposition to occur to a level greater than normal coastal processes	Significance of the impact on the natural character values & 'landscape' of the sea floor	Potential for erosion to occur to a level greater than normal coastal processes	Impact on resilience of the coastal system based on volume of sand removed / deposited
Dredge Disposal	1.2	Ebb Delta	2	-2	1	-2	-3
	2.2	Nearshore	0	0	1	2	6
	3.2	Intermediate	0	0	2	2	6
	4	Land based disposal	0	-2	0	0	0
	5	Beach nourishment	0	-2	0	-2	-3
	6	Deep water	4	0	1	2	6
	7	Outside EEZ	4	0	1	2	6
Channel	2	Existing mid-section		0	1	0	
	4.2	Straight mid-section (west)		0	1	0	
	5	Straight mid-section (east)		0	2	0	
Dredge Methodology	1a	Trailer (with central weir)					
	1b	Trailer (actual overflow)					
	2	Cutter	0				
	3	Backhoe	0				
	i	Ebb Tide Dredging	0				
	ii	All Tide Dredging	0				

Expert input on weightings and potential impacts on coastal geomorphology was provided by Tonkin + Taylor using data provided by MetOcean. Information on changes to natural character was also provided by Brown Ltd.

Overall, the potential impacts are driven by the location of dredge disposal site(s). Key findings from a physical environment perspective included:

- the benefits of keeping sediment within the system including:
  - aiding the long term stability of Mair Bank
  - creating long term resilience to storms and climate change effects
  - conserving the sediment budget on the ebb delta.
- matching 'like with like' minimises biological and geomorphological effects

- negligible impact on natural character and the underwater seascape (biophysical)[11].

The options assessment (summarised in Table 3-5) concluded that from a resilience perspective there is merit in utilising the ebb delta site (Option 1-2) for disposal of at least some small proportion of the capital dredge material (recognising that the site is not suitable to take the entire volume of the capital dredge), and for disposal of ongoing maintenance dredging[12]. The Nearshore option is the next best alternative for the remaining capital volume. Offshore options are the least preferred due to sediment matching and the dredged material leaving the system.

4.6 Social impact

It is recognised that the area is significant recreation area, particularly with regards to boating and fishing. Expert input on issues of importance to the community and weightings was provided by Rob Greenaway & Associates. Potential impact scores were provided by:

- Brian Coffey & Associates: fishing
- Bioresearches: wildfowl hunting
- Tonkin + Taylor (based on data provided by MetOcean): coastal landform and currents and subsequent impacts on recreation
- Brown Ltd: natural character, visual amenity and the impact of light and noise.

The options assessment (summarised in Table 3-6) concluded that:

- there is the potential for a temporary decrease in fish stocks in the disturbed areas, but there will be no permanent impact on fishing. It is noted that the disturbance will cause fish to relocate, as opposed to reducing overall fish numbers.
- there is the possibility of improved beach access in the longer term if ebb delta and / or beach nourishment options are utilised.
- impact on natural character (perceptual) is likely to be limited.
- all channel options will result in the addition of new navigational aids, which may be considered a change in amenity value by some; however, these will be dwarfed by the existing character. There will also be temporary amenity impacts (light and noise) associated with dredge activities. For this reason channel alignment option 5 is the least preferred due to its proximity to shore and required dredging of hard rocky material at Home Point.
- there is a preference for all tide dredging over ebb tide dredging due to the decreased duration of temporary impacts on amenity values.

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11 Brown and Associates (October, 2016) Landscape & Natural Character Effects – Key Findings. 3 pp.

12 Tonkin & Taylor (November, 2016). Crude Freight Shilling Project, Whangarei Harbour: Coastal Processes Assessment – Consultation Draft. Version 6. 160 pp.

Table 4-6: Summary of potential social impacts

Category			Social										
			Longer-Term Impacts									Temporary Impacts	
Aspect			Fishing	Hunting	Watercraft sports	Watercraft sports	Wave sports	In-water activities	Beach access	Natural Character & underwater seascape (perceptual)	Permanent effects of navigation lights	Temporary amenity effects (light spill & noise emissions above water)	Temporary visual amenity & landscape
Description			Impact on recreational fishing (access or stocks) by boat, from shore or diving. Includes fin and shellfish	Impact on duck hunting on- or near-shore	Impact on on-water sports (e.g. yachting, rowing, waka ama, windsurfing, canoeing, jet skiing, boating)	Impact on boating communities associated with relocation of the navigation buoys	Impact on wave sports (e.g. kite surfing, wind surfing and surfing) due to changes in surf breaks	Impact on in-water activates (e.g. diving, swimming) due to changes in turbidity, currents, wave profile	Changes to beach access	Significance of the impact on the natural character values & 'landscape' of the sea floor	Impact on local and visitor communities associated with new Navaid structures	Impact on local community from light and noise associated with dredge operations	Aesthetic impacts on local community associated with dredge operations
Dredge Disposal	1.2	Ebb Delta	3	0	3		3	0	-3			0	0
	2.2	Nearshore	3	0	0		3	0	0			0	0
	3.2	Intermediate	3	0	0		0	0	0			0	0
	4	Land based disposal	0	0	0		0	0	0			0	0
	5	Beach nourishment	0	0	0		0	0	-3			0	2
	6	Deep water	3	0	0		3	0	0			0	0
	7	Outside EEZ	3	0	0		0	0	0			0	0
Channel	2	Existing mid-section	3	0	0		0	0	0	1	1	2	2
	4.2	Straight mid-section (west)	3	0	0		0	0	0	1	1	2	2
	5	Straight mid-section (east)	6	0	0		0	3	0	1	1	4	4
Dredge Methodology	1a	Trailer (with central weir)	3	0	0		0	0	0			2	2
	1b	Trailer (actual overflow)	6	0	0		0	0	0			4	4
	2	Cutter	3	0	0		0	0	0			2	4
	3	Backhoe	6	0	0		0	0	0			4	4
	i	Ebb Tide Dredging	6	0	0		0	0	0			4	4
	ii	All Tide Dredging	3	0	0		0	0	0			2	2

4.7 Tangata whenua

There have been eight hui held since 2014, resulting in the publication of the Cultural Values Assessment[13] which considers short and longer term potential impacts across the four wellbeing's (natural, social, cultural and economic). This report formed the basis of the MCA assessment, with additional input from the report's co-author, Juliane Chetham on behalf of the hapu represented by the Patuharakeke Te Iwi Trust Board. There are real concerns from tangata whenua that the project may impact:

- their ability to collect kaimoana from Mair Bank[14], Marsden Bank and from other key traditional mahinga mataitai and fishing grounds
- taonga species
- the mauri of the harbour, and in particular the impact of sand removal from system
- important markers including Manaia, Matariki, Te Whara, the Takahiwai and Pukekauri Ranges and islands including Tatanga
- the ability of tangata whenua to fulfil their duties as kaitiaki and on matauranga and tikanga in regard to resources.

As Table 3-7 shows, potential impacts are perceived to be generally high for all dredge disposal and channel options:

- Disposal: there is concern that fishing areas (other than Mair Bank) may be affected to a greater extent by ebb delta (Option 1.2) and nearshore disposal (Option 3.2). Overall, land based disposal (Option 4) or disposal outside the EEZ (Option 7) are preferred.
- Alignment: Option 5 is the least preferred, and Options 2 and 4.2 are perceived to have similar impacts. Option 2 slightly preferable based on impacts on taonga species and the ability of iwi to perform their role as kaitiaki (i.e. because there will be benthic communities removed (even if they will recover) iwi do not consider that they are able to fulfil their role as kaitiaki / stewards). There may be options to mitigate and monitor direct impacts of the project and restore iwi role as kaitiaki.
- Methodology: ebb tide dredging is preferred to all tide dredging, as is controlling overflow via a central weir, due to the potential decrease in turbidity generated.

13 Patuharakeke Te Iwi Trust Board Inc (January, 2015) Cultural Values Assessment Report: Refining NZ Ltd – Crude Freight Proposal. 23 pp.

14 It has been reported that the population of pipis on Mair Bank has been decreasing for some time, and that the mussel population has been subsequently increasing. While the cause of these changes is not fully documented, the fact that the ecosystem is in change needs to be noted in the context of future expectations of collecting pipi from Mair Bank, with or without this dredging project.

Table 4-7: Summary of potential cultural impacts from a tangata whenua perspective

Category			Cultural								
Aspect			Kaimoana at Mair Bank	Kaimoana at Marsden Bank	Taonga species	Impact on Mahinga Mataitai	Mauri of Harbour	Cultural Landscapes and Seascapes	Kaitiakitanga	Subsurface Archaeological Sites	Land-based Archaeological Sites
Description			Impact on the ability to collect kaimoana from Mair Bank (based on erosion of Mair Bank) which may impact the ability to collect kaimoana (particularly pipi) sustainability	Impact on the ability to collect kaimoana from Marsden Bank (based on erosion of Marsden Bank) which may impact the ability to collect kaimoana sustainability	Impact on native birds, plants and animals of special cultural significance and importance to tangata whenua	Impacts on other key traditional mahinga mataitai and fishing grounds	Impact on the mauri of the harbour, and in particular the potential impact of sand removal from system	Impacts on important markers including Manaia, Matariki, Te Whara, the Takahiwai and Pukekauri Ranges and islands including Tatanga	Impact on the ability of tangata whenua to fulfil their duties as kaitiaki and on matauranga and tikanga in regard to resources	Impact on subsurface archaeological sites, including shipwrecks	Impact on natural and physical resources that contribute to an understanding and appreciation of New Zealand's history and cultures
Dredge Disposal	1.2	Ebb Delta	3	6	6	6	6	3	3	0	0
	2.2	Nearshore	3	3	6	6	3	3	3	0	0
	3.2	Intermediate	3	3	3	6	3	3	3	0	0
	4	Land based disposal	0	0	0	0	3	0	0	0	0
	5	Beach nourishment	0	0	3	3	3	3	3	0	0
	6	Deep water	0	0	3	3	3	0	3	0	0
	7	Outside EEZ	0	0	0	0	3	0	0	0	0
Channel	2	Existing mid-section	6	6	3	6	6	3	3	0	0
	4.2	Straight mid-section (west)	6	6	6	6	6	3	6	0	0
	5	Straight mid-section (east)	6	6	9	9	9	6	9	0	0
Dredge Methodology	1a	Trailer (with central weir)	6	6	6	3	3	3	3		
	1b	Trailer (actual overflow)	9	9	9	9	9	6	6		
	2	Cutter	6	6	6	6	6	3	3		
	3	Backhoe	6	6	6	3	6	3	3		
	i	Ebb Tide Dredging	6	6	3	3	3	3	3		
	ii	All Tide Dredging	9	9	6	6	6	6	6		

4.8 Archaeology

Information on potential impacts on archaeological sites was provided by Clough & Associates.

There is not perceived to be any likely direct impact to either subsurface or land-based archaeological sites as a result of any of the proposed options (see Table 3-8). This finding is based on a study completed for Northland Regional Council in 2015[15] as well as additional desktop research undertaken on behalf of RNZ.

Consideration of indirect impacts of changes to currents and wave heights as a result of the project was also considered to be minimal[16].

Table 4-8: Summary of potential impacts on archaeological sites or other areas of cultural significance

Category			Cultural	
Aspect			Subsurface Archaeological Sites	Land-based Archaeological Sites
Description			Impact on subsurface archaeological sites, including shipwrecks	Impact on natural and physical resources that contribute to an understanding and appreciation of New Zealand's history and cultures
Dredge Disposal	1.2	Ebb Delta	0	0
	2.2	Nearshore	0	0
	3.2	Intermediate	0	0
	4	Land based disposal	0	0
	5	Beach nourishment	0	0
	6	Deep water	0	0
	7	Outside EEZ	0	0
Channel	2	Existing mid-section	0	0
	4.2	Straight mid-section (west)	0	0
	5	Straight mid-section (east)	0	0
Dredge Methodology	1a	Trailer (with central weir)		
	1b	Trailer (actual overflow)		
	2	Cutter		
	3	Backhoe		
	i	Ebb Tide Dredging		
	ii	All Tide Dredging		

[15] Brown, A., R. Clough with S. Bickler. 2015. Northland Coastal and Freshwater Heritage Survey: Identification of Historic Heritage Resources (Draft report for Northland Regional Council) cited in Clough & Associates (April, 2016). Marsden Refinery Whangarei Harbour Dredging: Archaeological Assessment. Draft. 25 pp.

[16] Clough & Associates (April, 2016). Marsden Refinery Whangarei Harbour Dredging: Archaeological Assessment. Draft. 25 pp.

4.9 Indirect economic impacts

Table 4-9: Summary of potential broader economic impacts

Category			Economic		
			Indirect Impacts		
Aspect			Impact on intakes and outfalls	NIWA Operations	Commercial Fishing
Description			Potential impact on intakes and/or outfalls (blocking). Excluding NIWA operations.	Potential impact on NIWA aquaculture operations (Abalone)	Shellfish and fish
Dredge Disposal	1.2	Ebb Delta	1	2	0
	2.2	Nearshore	0	0	6
	3.2	Intermediate	0	0	3
	4	Land based disposal	0	0	0
	5	Beach nourishment	0	0	0
	6	Deep water	0	0	0
	7	Outside EEZ	0	0	0
Channel	2	Existing mid-section	0	0	0
	4.2	Straight mid-section (west)	0	0	0
	5	Straight mid-section (east)	0	0	3
Dredge Methodology	1a	Trailer (with central weir)	0	0	0
	1b	Trailer (actual overflow)	0	0	0
	2	Cutter	0	0	0
	3	Backhoe	0	0	0
	i	Ebb Tide Dredging	0	0	0
	ii	All Tide Dredging	0	0	0

These aspects are intended to cover the impacts on broader economic activity in the area. Expert input on weightings and potential impacts was provided by:

- Tonkin + Taylor: impact on commercial intakes and outfalls, including those that are connected to NIWA's commercial abalone production facility, with input from RNZ.
- Brian Coffey & Associates: impact on commercial fishing, with input from Rob Greenaway & Associates, Juliane Chetham (Patuharakeke Te Iwi Trust Board) and RNZ.

Potential impacts are limited to:

- impacts on intakes and outfalls, which will be minimised by further refinements in the location of disposal sites
- impacts on commercial fish / shellfish stocks. A range of species are taken by commercial fisheries, including scallops as well as fin fish. While there may be a decrease of catch in the dredging and disposal areas, fin fish will move, as opposed to being depleted, and the impact of smothering may be minimised at the disposal site(s) by controlling the depth of the dredge material deposited and harvesting prior to dredging.

In addition, broader economic cost / benefit assessment undertaken by NZIER confirmed a positive impact on the regional economy as a result of the continued operation of the refinery.

4.10 Navigational and programme safety

Impacts on programme and long-term navigational safety were provided by Royal HaskoningDHV.

Navigational safety is a project non-negotiable.

Navigational and project safety both have been allocated a weighting of three to reflect the environmental, social and cultural values at stake.

As summarised in Table 3-10, and by Royal HaskoningDHV in their channel design report (June 2016), channel alignment option 4.2 has significant advantages over Options 2 and 5. It is important to note it that it has been determined that Option 4.2 is the only option which significantly improves navigational safety from the status quo.

Equally, programme safety is a non-negotiable, as this covers the safety of the crew and vessels involved in dredge operations, as well as potential interaction with other vessels and their crews.

Programme duration is also included as an aspect of programme safety, as the likelihood of an incident occurring naturally increases with time at sea. As noted in previous sections, aspects of methodology, such as ebb tide dredging, impact the duration of the programme. The distance of the disposal site from the dredge location also has the potential to significantly influence the programme.

The assessment in Table 3-10, excludes the direct costs associated with programme duration, such as vessel hire and crew time, as these are accounted for in Section 3.11 (direct economic impacts).

Table 4-10: Summary of potential broader safety issues

Category			Economic	
			Indirect Impacts	
Aspect			Navigation	Project Safety
Description			Potential effects on navigational safety due to channel alignment	Risk associated with undertaking the option (environmental and WHS) linked to methodology and programme duration
Dredge Disposal	1.2	Ebb Delta		6
	2.2	Nearshore		3
	3.2	Intermediate		3
	4	Land based disposal		6
	5	Beach nourishment		6
	6	Deep water		6
	7	Outside EEZ		9
Channel	2	Existing mid-section	0	3
	4.2	Straight mid-section (west)	-3	3
	5	Straight mid-section (east)	9	9
Dredge Methodology	1a	Trailer (with central weir)	0	3
	1b	Trailer (actual overflow)	0	3
	2	Cutter	0	9
	3	Backhoe	0	6
	i	Ebb Tide Dredging	0	6
	ii	All Tide Dredging	0	3

The options assessment (summarised in Table 3-10) concluded that from a programme safety perspective:

Disposal: Nearshore and Intermediate disposal sites are preferred due to the reduced time and costs (as well as risk) associated with shorter transit distances. The EEZ is the least favoured disposal site due to extra time and cost (and risk) associated with transport of dredge material.

Alignment: Options 2 and 4.2 result in similar project safety and programme outcomes. Option 5 raises some technical difficulties with regards to the potential for requiring either removal of boulders and/or drill and blasting.

Methodology: methodologies which speed up operations and improve mobility result in better programme outcomes, due to reduced risk exposure time. Therefore all tide dredging is preferred and the CSD and backhoe don't score as well.

4.11 Direct economic impacts

Impacts on costs and other direct project elements, including legal and planning considerations, were provided by Royal HaskoningDHV (cost), ChanceryGreen (legal) and RNZ.

Legal, revenue and cost aspects (Figure 3-11) cover potential impacts associated with the capital dredging programme only. The maintenance aspect covers how channel alignment and capital dredge disposal may impact the need for maintenance dredging in the future.

The options assessment (summarised in Table 3-11) shows that for:

Disposal: overall Nearshore and Intermediate disposal sites are preferable.

Alignment: channel alignment options 2 and 4.2 result in similar impacts, and Option 5 is least preferred overall.

Methodology: the more complex methodologies (CSD and backhoe) increase time and cost in this case. All tide dredging is most effective from a time and cost perspective.

Table 4-11: Summary of potential direct economic impacts as a result of the project

Category			Economic			
Aspect			Direct Impacts			
			Legal	Maintenance	Revenue	Cost
Description			Potential effort associated with consenting each option	Degree to which deposition site or channel alignment impacts cost of maintenance	The amount of revenue generated via beneficial reuse	Total cost of option
Dredge Disposal	1.2	Ebb Delta	2	-2	0	6
	2.2	Nearshore	0	0	0	3
	3.2	Intermediate	0	0	0	3
	4	Land based disposal	4	0	-0.5	6
	5	Beach nourishment	4	0	-0.5	6
	6	Deep water	2	0	0	6
	7	Outside EEZ	6	0	0	9
Channel	2	Existing mid-section	2	2		3
	4.2	Straight mid-section (west)	2	2		3
	5	Straight mid-section (east)	4	2		9
Dredge Methodology	1a	Trailer (with central weir)				3
	1b	Trailer (actual overflow)				3
	2	Cutter				6
	3	Backhoe				9
	i	Ebb Tide Dredging				6
	ii	All Tide Dredging				3

5 Results

5.1 Preferred channel alignment

Options 2 and 4.2 performed very similarly in the assessment overall (Table 4-1), while Option 5 is the least preferred option. The key consideration in the selection of the channel alignment is the outcome from a navigational safety perspective. As Option 4.2 has been found to perform the best from a navigational safety perspective due to the reduction in the number of headings required, and notably ensuring no course changes around the rocky outcrop at Home Point, it is recommended that this option is progressed over Option 2.

Table 4-1: Channel alignment options (weighted)

Options	Natural	Social	Cultural	Economic	Total normalised	Total (excluding RNZ direct economic impacts)
2	1.9	0.9	3.7	1.3	7.7	7.1
4.2	1.9	0.9	4.3	0.9	8.0	7.2
5	3.3	1.9	6.0	4.5	15.7	15.4
* direct economic impacts include legal, revenue and cost and implications for ongoing maintenance						

From a natural and social perspective, Options 2 and 4.2 are identical in terms of scoring and potential impacts. Option 4.2 is the furthest away from the known areas of high conservation value and hard shore biological diversity. Avoiding Home Point also means that Option 4.2 is also likely to result in fewer temporary amenity impacts (light, noise and visual) on the local community.

From an economic perspective, the impacts are also perceived to be the same for all aspects, other than navigational safety.

From a cultural perspective Option 2 did raise fewer concerns for taonga species and the ability of tangata whenua to fulfil their duties as kaitiaki and on matauranga and tikanga, with regards to resources due to the perception that channel Option 2 follows the existing alignment more closely than Option 4.2.

In progressing channel Option 4.2, the most material issues to address are:

- potential impacts on areas of important conservation value and taonga species
- impact on the ability of tangata whenua to fulfil their duties as kaitiaki and on matauranga and tikanga with regards to resources.

As shown in Figure 4-1, there is particular concern about the potential cultural impacts. It is recommended that RNZ continue to work proactively with tangata whenua when defining both the potential and actual effects, and the measures that are advanced to ensure that any adverse effects are appropriately avoided, remedied or mitigated.

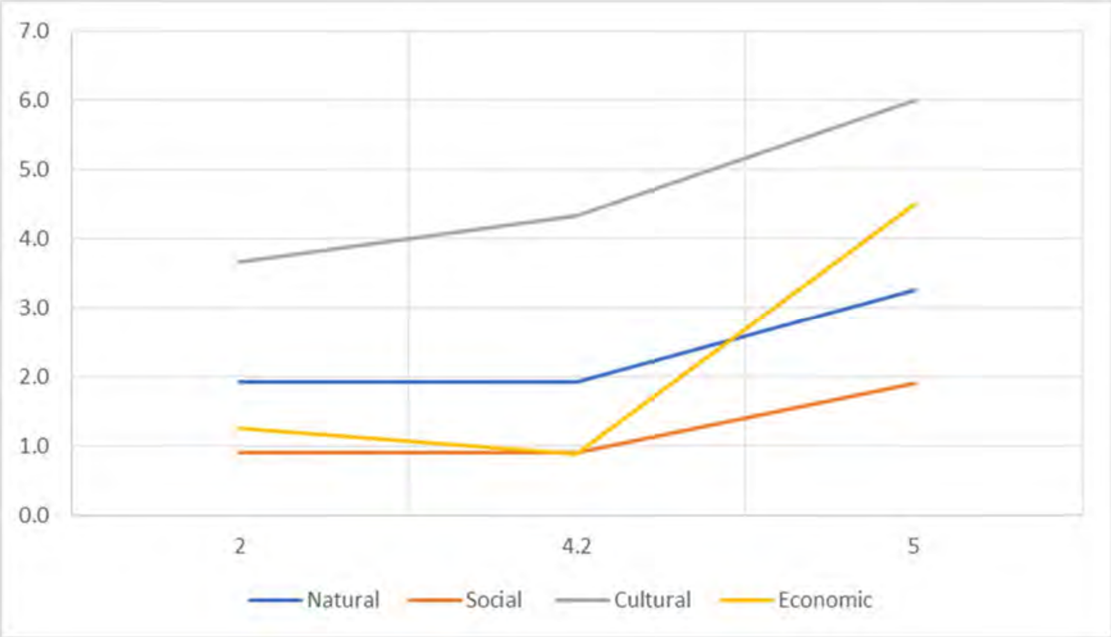


Figure 5-1: Channel alignment options (weighted)

Recommendations: progress channel alignment Option 4.2 paying particular attention to effects and mitigation options for impacts on areas of important conservation value, taonga species and the role of iwi as kaitiaki. Continue to engage with iwi to fully understand impacts and options for mitigation.

5.2 Preferred disposal options

Land based disposal options (Options 4 & 5) are preferred overall (Table 4-2), and it is therefore recommended that they are progressed where practicable. However, as there are no specific land based disposal or beneficial reuse options defined at present, there will likely be a range of additional costs and benefits associated with these options if and when specific locations are identified. Further, at this the stage of the proposal, the aspects identified as part of the MCA are necessarily focused on the marine area being studied. If and when sites for land based disposal are identified, and subject to detailed assessment, there will likely be additional aspects identified which would not apply to marine based disposal sites. Therefore the differential between land based and marine disposal sites may be reduced in subsequent assessments. It is also not possible to dispose of the entire capital dredge to land, therefore marine disposal sites need to be considered.

Overall, the offshore options (Option 6: deep water & Option 7: outside the EEZ) performed well in the assessment (Table 4-2); however, at the initial findings workshop it was agreed that these options are not feasible as that they would add significant time, cost and environmental risk. Option 6, 60-80m water depth off Ocean Beach, requires slightly greater travel time/distance to access than the inner sites and is adjacent to the main shipping channel, which increases the risk associated with disposal at this site. It would also result in a greater mismatch of sediment properties, and is subject to higher south-easterly tidal flows and wave energy, which would increase the risk of sediment plumes impacting sensitive areas. Option 7 has the greatest amount of uncertainty, as there is no specific area identified, but all areas are likely to result in a sediment mismatch, more complex (and possibly unfeasible) monitoring, as well as longer and higher risk sail times. Therefore it is recommended that the inner sites are considered for consenting.

Of the three inner sites, Option 3.2 (the Intermediate site) performed the best in the assessment across all four wellbeing's (Table 4-2), and is designed to be able to take the full volume of the capital dredge. It is therefore recommended that Option 3.2 is progressed for consenting to receive the full capital dredge. Option 3.2 is particularly preferred due to a smaller footprint and less potential impact on sea-floor flora and fauna. Being further offshore, there is less potential impact on birdlife and known areas of conservation value. The site is also more removed from known areas of importance to recreational and commercial fisheries.

The Nearshore option (Option 2.2) does not perform as well as Option 3.2 (Table 4-2) from a social, cultural or economic perspective due to closer proximity to recreational areas and traditional and commercial fishing areas.

While the ebb delta disposal option (Option 1.2) does not perform as well as Option 3.2, it performs comparatively well from an environmental perspective because of the benefits identified in disposing a proportion of dredged material at this site. Retaining that material within the system, and in particular, supporting the resilience of Mair Bank (Figure 4-2) is seen as important from a coastal process perspective. For this reason it is recommended that provision for some capital- and maintenance-dredge material be made at the ebb delta site.

Table 4-2: Disposal options (weighted)

Options		Natural	Social	Cultural	Economic	Total normalised	Total (excluding RNZ direct economic impacts)
Ebb Delta	1.2	1.4	0.8	3.7	1.9	7.7	8.1
Nearshore	2.2	2.1	0.8	3.0	1.5	7.4	8.1
Intermediate	3.2	2.1	0.4	2.7	1.1	6.2	6.6
Land based disposal	4	-0.1	0.0	0.3	1.9	2.1	1.7
Beach nourishment	5	-0.2	-0.1	1.7	1.9	3.3	2.8
Deep water	6	1.9	0.8	1.3	1.8	5.8	5.5
Outside EEZ	7	1.8	0.4	0.3	3.0	5.5	4.7

In progressing Option 3.2, the most important issues identified through the MCA assessment are:

- the potential impact on areas of important conservation value and taonga species
- the impact on resilience of sediment leaving the system on geomorphology
- the impact on mahinga mataitai and commercial fisheries.
- the potential interaction with or impact on marine mammals

It is recommended that these aspects are expressly explored as part of the AEE process.

Of the inner site options, Option 3.2 also raises the fewest concerns from tangata whenua stakeholders (Figure 4-2). Concerns about impacts on sites of cultural value (including mahinga mataitai) remain generally high. This supports the recommendation in Section 4.1 for RNZ to continue to engage with iwi to ensure that perceptions about impacts are accurate, and that options for mitigating impacts are well understood.

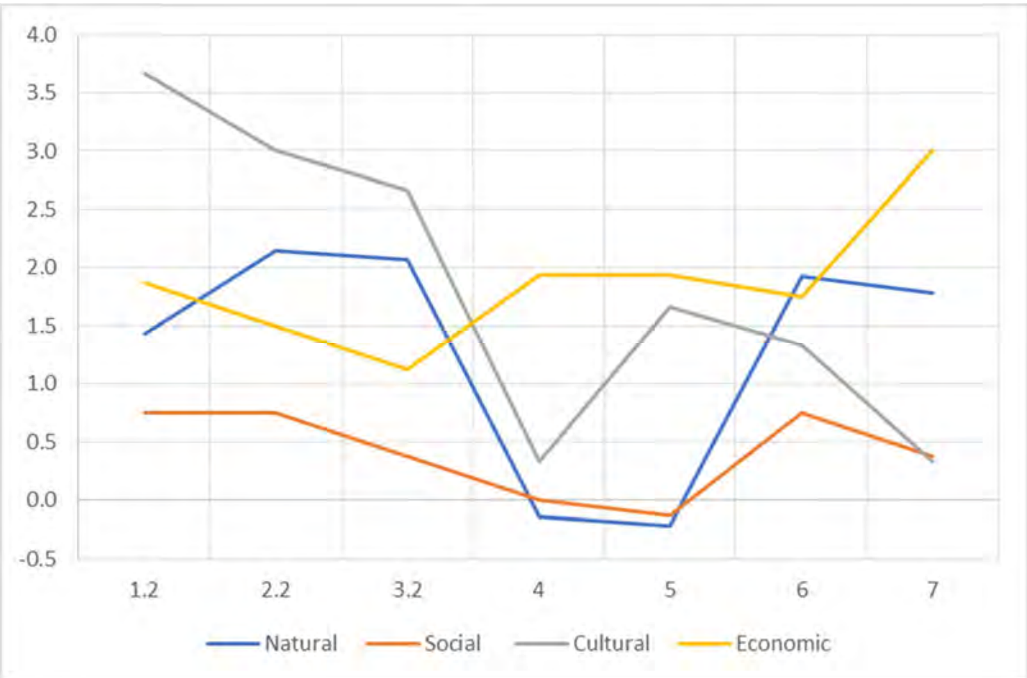


Figure 5-2: Disposal options (weighted)

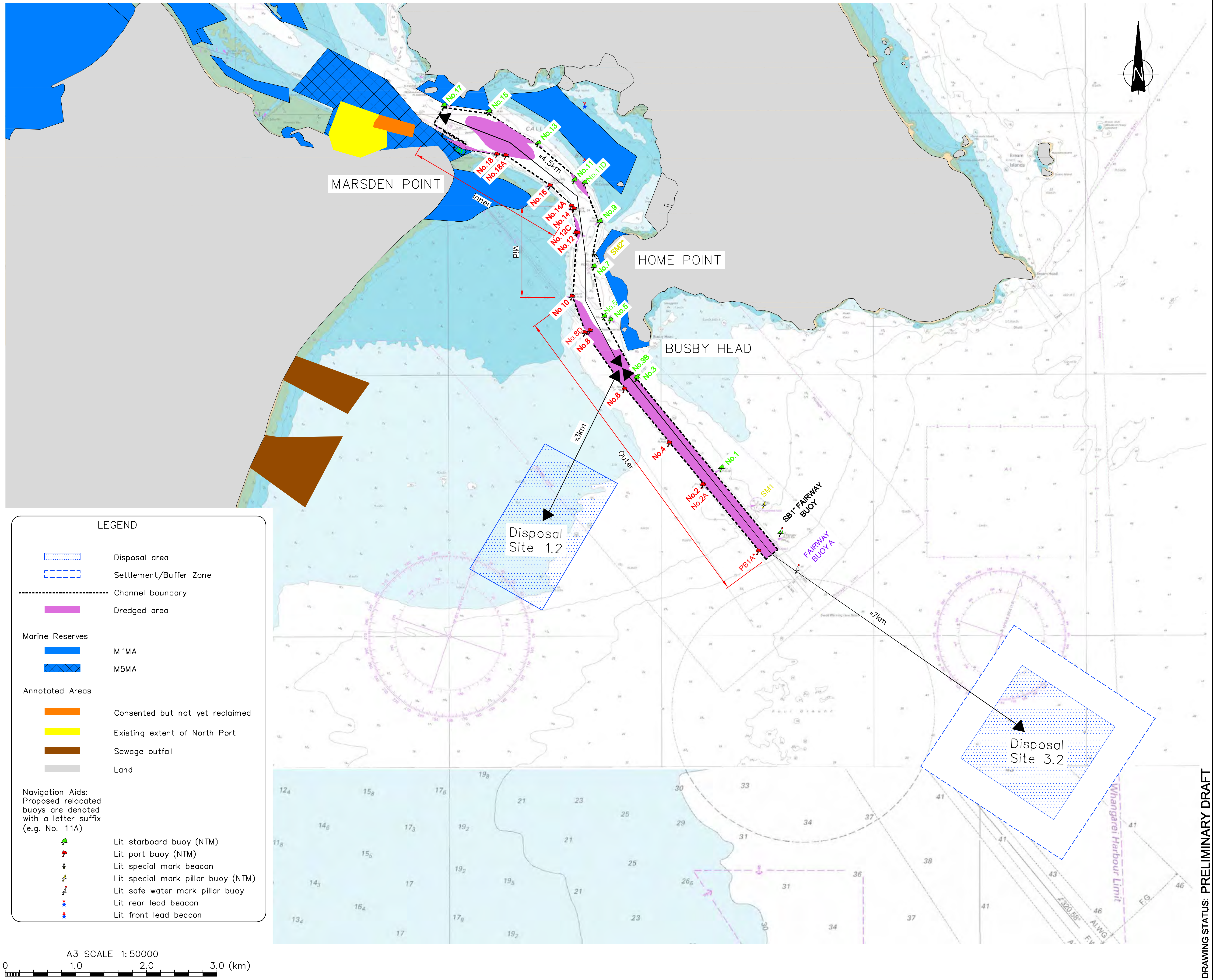
In progressing Option 1.2 (ebb delta) the following potential impacts should be considered within the AEE:

- impact on areas of important conservation value in close proximity and impact on taonga species
- impacts on the the mauri of the harbour
- impact of the ability to access to kaimoana at Marsden Bank and in other mahinga mataitai
- interaction with marine mammals
- impact on pelagic and shore bird nesting and roosting habitat
- temporary changes in access to recreational areas
- impacts on intakes and outfalls (noting that these issues have already largely been designed out)
- dredge disposal safety risks.

A plan of the recommended disposal sites is provided in Figure 4-3.

Recommendations:

- progress land based for beneficial reuse options (Options 4 & 5) where practicable.
- progress consenting for the bulk of the capital dredge to be deposited at the Intermediate site (Option 3.2) paying particular attention to mitigating or avoiding the potential interaction with marine mammals, impact on areas of important conservation value and taonga species, and impact on Mahinga Mataitai and commercial fisheries.
- progress the option for a limited volume of capital dredge and maintenance dredge disposal in the ebb delta (Option 1.2) to provide resilience to the geomorphological system and Mair Bank in particular.



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NOTES :

1. Hydrographic chart sourced from Linz Data Service (NZ 5214/5219)
2. Navigation aids and relocation placements from Royal HaskoningDHV drawing PA1028/MA/1121 rev K.

REVISION DESCRIPTION	BY	DATE
0 First Issue		
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DRAWING STATUS: PRELIMINARY DRAFT

NZ REFINING COMPANY LTD

CRUDE FREIGHT PROJECT

MARSDEN POINT NORTHLAND

Proposed Works Plan

SCALES (AT A3 SIZE) 1:50,000

Figure 3

REV. 0

5.3 Preferred dredge methodology

This study provided the expert panel with a better understanding of the options for dredge methodology, and how these might be used across the options for the project:

- the key finding with regards to dredge methodology is that the nature of the dredge material is such that turbidity is unlikely to be a significant issue[17]. The sandy substrate will likely settle quickly both along the channel alignment and at the disposal site(s). This means that the technologies and methodologies used to control turbidity (such as the THSD green valve and ebb tide dredging) may not actually deliver any significant environmental benefit from a turbidity perspective, but would increase the duration of the project overall. Controlling overflow via a green valve, ebb tide dredging or other measures should be considered where it is assessed that environmental and cultural effects warrant the use of these methods along the transect.
- the cutter suction dredge (CSD) and backhoe perform similarly overall (Table 4-3), but have different characteristics with regards to noise, vibration, turbidity and impacts on benthic flora and fauna. It is recognised that these dredge types perform different functions so are not mutually exclusive, and it is anticipated that a mix of dredge types would be used for a project of this type and scale. There may still be some need to use a CSD in in some locations, such as in the inner channel area, although less likely to be a preferred option. It may also be necessary to use a backhoe in place of the TSHD around the berth area given proximity to marine structures. It is recommended that when channel alignment is confirmed, the dredge methodologies most appropriate along the different reaches of the transect (from berth to inner-harbour and outer-harbour) are finalised.
- ebb tide dredging is preferred from an environmental and cultural perspective because of perceptions that this will help reduce turbidity. All tide dredging is preferable from a social and economic perspective because it will reduce the duration of project overall. Increased duration is not favourable from a cost perspective, and often communities prefer for projects to proceed as quickly as possible from an aesthetic and amenity perspective. However, ebb tide dredging in particular areas identified as potentially sensitive (for example, around Home Point), may be a potential mitigation strategy.

Recommendations:

- finalise the preferred dredge methodology based on the final channel design
- Examine whether ebb tide dredging and/or other measures are necessary at particular locations along the Option 4.2 transect to reduce natural, social or cultural impacts from turbidity.

[17] Bioresearches (September, 2016) Existing Environment Assessment: Ecology of the Dredge Area, Whangarei Heads. 210 pp.
Tonkin & Taylor (November, 2016). Crude Freight Shilling Project, Whangarei Harbour: Coastal Processes Assessment – Consultation Draft. Version 6. 160 pp.

Table 4-3: Dredge methodology (weighted)

Category			Natural	Social	Cultural	Economic	Total normalised	Total (excluding RNZ direct economic impacts)
Description							Total normalised to give equal weighting to four impacts	Total normalised (excluding costs to RNZ)
Dredge Methodology	1a	Trailer (with central weir)	2.1	0.9	4.3	1.0	8.3	7.9
	1b	Trailer (actual overflow)	4.1	1.8	8.1	1.0	15.0	14.6
	2	Cutter	2.3	1.1	5.1	2.5	11.0	10.3
	3	Backhoe	2.5	1.8	4.7	2.5	11.4	10.1
	i	Ebb Tide Dredging	1.4	1.8	3.9	2.0	9.0	8.2
	ii	All Tide Dredging	3.2	0.9	6.9	1.0	11.9	11.5

6 Applicability

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

We understand and agree that Refining New Zealand may use this report in support of an application for resource consent and that the consenting authority will rely on this report for the purpose of assessing that application.

Tonkin & Taylor Ltd

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Appendix A: Poten & Partners | Crude Shipping Alternatives

Crude Shipping Alternatives

Marsden Point, NZ

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Table of Contents

Executive Summary

Refining NZ, a refinery located at Marsden Point, in the northern part of New Zealand operates as a tolling refinery for oil companies which deliver crude oil and receive refined petroleum products for marketing in New Zealand. The refining fee is based on the spread between delivered crude oil and the landed cost of imported petroleum products. The refinery competes with imported products and efficiency is critical for its profitability.

New Zealand is far from most oil producing regions and transportation costs affect the refining margins. Therefore, the ability to use larger tankers is an important lever in generating freight cost savings. Larger tankers offer significant freight cost savings on a per barrel basis compared to smaller tankers.

The clients of Refining NZ currently import crude oil using Aframax and light loaded Suezmax tankers. The harbor currently has a draught restriction of 14.7 meters Chart Datum (CD), which means that only fully laden Aframax tankers (carrying 80,000 to 100,000 tons of crude oil) or partially loaded Suezmax tankers (with 100,000 to 120,000 tons cargo size) can access Refining NZ's discharge terminal. In order to reduce freight cost, the Marsden Point facility could be upgraded to allow fully laden Suezmax tankers to deliver crude oil.

There are three feasible alternative approaches to enable the use of larger tankers:

- Dredge the access channel and the Refining NZ berth
- Install a Single Point Mooring (SPM) system in deeper water offshore connected by an underwater pipeline to the refinery
- Use Ship to Ship transfer in deep water to transfer the cargo into smaller tankers for final discharge at the refinery

In Poten's view, the dredging alternative is the preferred option as the initial investment of about US$ 20-US$ 25 million can be recovered over a relatively short time frame while the added operating costs are relatively small. The other alternatives have either very high operating costs or involve high upfront investment costs which require Refining NZ to move to VLCC size cargoes (about 3 times the current delivery size) in order to offset these additional costs. Such large cargo sizes create issues for the refinery operations and require a significantly higher level of coordination between Refining NZ's customers, as well as investment in additional shore tankage.

While all three alternatives have good environmental records, the dredging of the harbor channel allows the continued use of the existing terminal but provide access to more efficient, fully laden Suezmax tankers. This reduces the number of port calls while also having the advantage of discharging in a location that is sheltered from seas and swells and allows for the most effective emergency response in case of an incident.

The flowing table ranks the alternatives according to their suitability for Refining NZ (1 being most preferred):

	Conventional Terminal (Dredging)	Single Point Mooring	Ship To Ship	Comments
Environmental Risk	1	2	3	Conventional Terminal best sheltered from seas and swell
Refining Operational Considerations	1	2	3	Large parcels delivered via SPM and STS create size mismatch with refinery
Discharge Operations	1	2	3	More communication and coordination required for SPM and STS
Capital Investment	2	3	1	Initial investment costs highest for SPM
Ongoing Operational Costs	1	2	3	Conventional Terminal only requires periodic dredging
Customer Coordination	1	2	2	VLCC cargoes (SPM & STS) requires co-loading by customers
Weather Dependency	1	2	3	STS and to a lesser extent SPM operations can be disrupted by adverse weather

Introduction

Refining NZ, a refinery based at Marsden Point / Whangarei, in the north of New Zealand, operates as a tolling refinery for several oil companies: BP, ExxonMobil and Z-Energy. These oil companies provide the crude oil and Refining NZ processes the oil and returns refined products such as gasoline, diesel, jet fuel, etc. to the oil companies, who then market these products in New Zealand. Depending on the product type, Refining NZ supplies between 65 and 100% of the petroleum products consumed in New Zealand. Therefore, Refining NZ competes directly with imported petroleum products and maximizing operational efficiencies is critical.

As refiners have little influence on crude oil pricing, they need to minimize other costs to remain competitive. Transportation costs represent a significant factor influencing Refining NZ and its customers’ profitability. Optimizing crude oil transportation costs includes providing efficient discharge port facilities and allowing large tankers to call at the port, in order to take advantage of freight savings from "economies of scale". Refining NZ’s profitability is partially based on the freight cost differential between shipping crude oil on large tankers and the higher cost of shipping refined products on smaller tankers.

The larger the oil carrying capacity of a tanker, the lower the cost per transported barrel, especially for long haul crude oil supply routes. Large oil tankers offer significant economy of scale advantages as the operating expenses (crewing, stores, spares, maintenance, insurance, etc.) of larger vessels are relatively much lower than those of smaller vessels. The crew size of smaller tankers is similar to the one of larger vessels and as a result, the crew costs, which are the largest component of vessel operating expenses (expenses not directly related to a voyage), are also comparable. Bunker fuel expenses and vessel construction costs are other large cost factors, and both provide significant advantages for larger tankers over smaller ones. However, not all ports can accommodate large vessels. Load and discharge port restrictions and local logistical constraints, such as storage capacities, are also important factors that determine the optimal tanker size for a particular trade.

Marsden Point Refinery

Like other competitive refineries in the world, Refining NZ has been evaluating ways to utilize the economies of scale advantages of larger crude oil tankers.

The primary limitations of the existing discharge terminal at the Marsden Point refinery are the water depth at the berth and in the approach channel to the harbor. Currently, customers of Refining NZ are limited to fully laden Aframax size tankers (cargo capacity: 80,000-100,000 tons) or partially loaded Suezmax tankers (capacity: 100,000-120,000 tons). A fully laden Suezmax tanker cannot enter the harbor, due to the existing draught restrictions of 14.70 meters (CD).

The following three alternatives are commonly employed to overcome draught limitations:

1. Dredging the seabed to provide a deeper access channel and berth
2. Installing a Single Point Mooring (SPM) system off the coast in deeper water
3. Lightering the vessel by discharging the cargo fully or partially from a larger vessel into smaller tankers while at sea in deeper waters

At the request of Refining NZ Poten & Partners has made a high level assessment of the safety, environmental, economical, and operational aspects of these alternatives.

The report uses the following criteria to evaluate these alternatives:

- **Environmental Risk:** The risk of harming the environment during the implementation phase and during the operational phase
- **Refinery Operations:** The impact of the shipping solution on the refinery operations. For example: Using Very Large Crude Carriers (VLCCs) would affect the refinery operations and requires increased storage capacity.
- **Discharge Operations:** Includes aspects such as ship to shore communications, vessel access in case of an emergency, etc.
- **Capital Investment:** A large upfront investment would require a longer period to recover the investment or require other offsetting cost savings.
- **Ongoing Operational Costs:** The day to day costs involved in the maintenance and discharge operations
- **Customer Coordination:** Refining NZ refines crude for multiple customers who supply their own crude to the refinery. The use of VLCCs requires a significantly higher level of coordination among the customers.
- **Weather Dependency:** Unfavorable wind conditions can affect the mooring operations and create delays, and thus add shipping costs. Additionally, the refinery needs to maintain inventory to deal with such delays.

1. Deepen Access Channel and Berth Area

The Refining NZ refinery at Marsden Point currently imports crude oil using a berth that can accommodate Aframax tankers and partially laden Suezmax tankers.

A shore connected pier with load and/or discharge equipment is typically the default solution for oil importers, unless there are specific reasons why such a configuration is impractical or uneconomic. In the case of Refining NZ, much of the required infrastructure is already in place but, in order to accommodate larger tankers, dredging will be required.

In a study performed in May 2015, Poten & Partners estimated that the use of fully laden Suezmax tankers (1 million – 1.05 million barrels) would reduce freight costs by up to US$ 0.44 per barrel.

Environmental Risk

The use of larger vessels reduces the number of required port calls. By using a conventional pier, the vessel is sheltered from seas and swells inside the harbor during discharge operations. The vessel and the refinery are connected through an over-land pipeline, which is easy to maintain and inspect. Potential issues with the pipeline can be easily identified and quickly repaired, reducing the environmental impact in case of a leakage.

A potential risk of dredging is that the seabed is disturbed and that potential pollutants that may have settled into the soil are released, causing them to be distributed by the water. This risk is higher in industrial areas where environmental regulations were historically less strict than they are today. In the case of Refining NZ, this risk is very limited. The company has already performed extensive analyses of surficial sediment and core samples within the channel area. The sediment was generally free of contaminants.

Refining Operational Considerations

Using a conventional terminal provides maximum flexibility of tonnage up to the dimensions of the terminal. Due to the relatively low capital investment costs for dredging the approach channel and dredging around the existing berth, with ongoing operational costs and refining processes remaining the same, the terminal can be upgraded for fully laden Suezmax sized tankers. The delivery reliability would remain similar to current levels.

Currently Refining NZ receives mainly Aframax cargoes of about 700,000 barrels as well as some light-loaded Suezmax cargoes, which require one delivery about every 6 days. After switching to Suezmax cargoes of 1 million barrels, the refinery would require a cargo delivery approximately every 8 days, assuming they use 120,000 bbl/day. However, it is important to note that Refining NZ will only switch a proportion of its imports to Suezmax size tankers, because some crude oil imports from South East Asia require Aframax tonnage due to load port restrictions.

Discharge Operations

In case of an emergency while discharging, the ship would be readily accessible from land. In the event of a spill, it would be easier to implement emergency response measures including, for example containment. In case of a spill, the escaped oil would be contained in a more protected area and would be less affected by wind and wave action than in an exposed open sea area, facilitating the cleanup process.

Refining NZ has existing protocols and procedures in place to quickly and effectively respond to a potential spill during discharge operations.

Capital Investment

Dredging has upfront costs involved in initially deepening the access channel. Refining NZ received initial estimates for the dredging work in the region of US$20 to US$25 million. Additionally, the use of fully laden Suezmax tankers would require a modification to the refinery's storage facilities.

Ongoing Operational Costs

Ongoing operational costs for the terminal would remain very similar to the current costs. There would be some additional costs in maintenance dredging in the future as a deepened channel often gradually fills with sediment that needs to be removed occasionally.

Customer Coordination

Upgrading import volumes from Aframax tankers to fully laden Suezmax tankers requires the least adjustment for Refining NZ customers. Several customers already use Suezmaxes on a regular basis (albeit light-loaded). Fully laden Suezmax tankers carry about 1 million barrel cargo lots (40% more than the current typical cargo size), reducing the overall number of port calls. The other two alternatives would require the use of VLCCs to optimize the higher investment (SPM) and operating costs (lightering). VLCCs carry about 2 million barrels, almost three times the current cargo size. These cargo sizes would likely be too large for an individual customer and would require the sharing of a vessel between multiple customers.

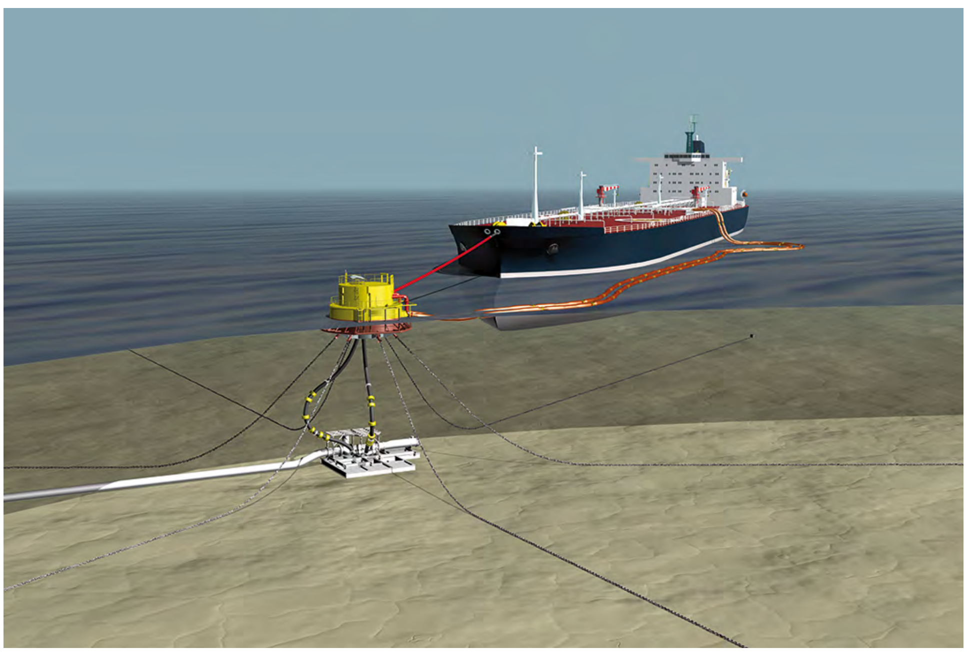
Weather Dependency

The Marsden Point terminal is located at the head of the Whangarei Harbour at the northern tip of Bream Bay. The location within the bay gives the jetty berths at Marsden Point protection from adverse weather conditions and therefore Poten considers discharging tankers at the Marsden Point terminal as the least weather dependent option. As is the case with the other alternatives, waves and swells can affect the timing of mooring and, in this case, entering the approach channel.

2. Single Point Mooring oil discharge systems

Installing a Single Point Mooring (SPM) system off the coast in deeper water is the second alternative that is also commonly employed to overcome draught limitations.

Single Point Mooring ("SPM") systems (also referred to as Single Buoy Mooring or SBM systems) can be used to import or export crude oil or petroleum products. They are manufactured and installed by well-established and specialized companies such as SBM Offshore, Bluewater and others. SPM systems consist of a buoy that is attached to the seabed and outfitted with a mooring facility for a tanker. In the case of an import facility, the buoy is equipped with an oil transfer system consisting of a pipeline between the buoy and the receiving terminal and hawsers to connect the tanker to the buoy. The system is designed so that the tanker can weathervane around the buoy while discharging.



SPM (Image Credit: Bluewater)

SPM systems are commonly employed; between the 1960's and 2012, SBM Offshore, one of the market leaders in SPM installations, built and delivered more than 450 SPMs to customers at locations worldwide. SPM systems are a cost effective option in shallow coastal areas where the construction of a marine terminal is expensive or unfeasible. However, in the case of Refining NZ, much of the required terminal infrastructure is already in place. SPMs are also commonly employed as loading terminals in offshore oil development projects.

The most common SPM design is the "Catenary Anchor Leg Mooring (CALM) system.

CALM SPM (Image credit: SOFEC)

A CALM SPM system consists of a floating buoy, which is anchored to the seabed by catenary chain legs that are secured to anchors or piles. The loading or offloading tanker is moored by one or two mooring hawsers to a turntable mounted on top of the buoy using a slewing bearing. The slewing bearing allows the tanker to freely weathervane around the SPM, always keeping the bow into wind and waves and thus keeping the windage area and wave exposure to a minimum.

In 1999, Refining NZ commissioned a study examining the feasibility of installing an SPM for the delivery of crude oil. The report investigated the installation of a CALM SPM in the Bream Bay with a 10 km underwater pipeline and a 3.5 km land based pipeline using existing right of way. The SPM would be anchored in water with a depth of about 30 m and would be suitable for tankers up to VLCC size. Two different pipeline scenarios were evaluated: a single 48" diameter pipeline and a dual 34" diameter pipeline. For cost reasons, the underwater pipeline would be built on shore in two 5 km sections and towed into position.

Refining NZ indicated that they did not further pursue the project due to the high cost estimates resulting from the initial feasibility study and due to the operational considerations discussed in this report.

Environmental Risk

A pipeline running over the seabed for several miles to connect the SPM to the refinery always creates some incremental risk. Indeed, ships mooring and offloading cargo off the coast of New Zealand represents a higher risk than tankers discharging in the more protected environment of a harbor, although entering and exiting the port also presents some risk.

Crude oil from the SPM flows through a submerged sea line. The tanker and the SPM are connected via two floating hoses which are attached to the manifold of the tanker. Although these components can be managed and are generally safe, they introduce a potential for problems.

SPMs are generally safe and efficient loading and off-loading systems. A 2010 risk assessment study by the International Organization of Oil and Gas Producers estimates that 1 event (tanker breakout or surge event) occurs for every 5,621 operating days. The mean volume of oil spilled in such incidents is estimated at 946 barrels.

Refining Operational Considerations

Single Point Mooring systems can be designed to accept all common types of crude oil tankers, including VLCCs. Due to the high initial investment of installing an SPM, VLCCs would be the optimal vessel size to minimize the transportation costs and offset the higher investment. However, regular use of VLCCs, which carry typically about 2 million barrels of crude oil, would require significant adjustments to the storage capacity of the refinery and the large cargo size would affect deliveries for the customers of the refinery. Presently, Aframax tankers typically carry a cargo of about 700,000 barrels for an individual customer.

Discharge Operations

Vessels secured to an SPM are generally able to continue load and discharge operations even under unfavorable weather and swell conditions. Mooring and unmooring operations normally do not require tugboat assistance. Some SPM discharge locations, such as buoys moored at sites with inadequate under keel clearance or unfavorable current condition, require "Stand by" tow back tugs to prevent the tanker from drifting into the SPM.

Capital Investment

The 1999 study investigated the cost of positioning an SPM into the Bream Bay, which at that time was estimated at about A$ 77.3 million (~US$ 50 million). This included the SPM and its installation connected to 10 km of underwater pipeline plus about 3.5 km of shore side pipeline, including the pipeline installation.

These costs did not include the required addition of crude storage tanks at the refinery. Deliveries of such large volumes will require significant modifications to the storage capacity, which will add to the initial investment.

Refining NZ has reviewed SPM cost estimates at a high level on a number of occasions, with the last review in 2013 suggesting costs of around US$150 million, including storage modifications.

Ongoing Operational Costs

Single Point Mooring maintenance and operating guidelines must be strictly enforced in accordance to the "Single Point Mooring Maintenance and Operations Guide" published by the "Oil Companies International Marine Forum"(OCIMF). OCIMF's mission is to be the foremost authority on safe and environmentally responsible operations of oil tankers and terminals, promoting continuous improvement of standards of design and operations.

SPM mooring systems are robust, generally maintenance friendly and do not experience excessive down time. However, safe and efficient operations of the system require a team of trained mooring masters, cargo coordination personnel, hose handling, mooring and maintenance crews, including divers. Suitable workboats are required as well, adding to the operating expenses of the system. The actual costs of these arrangements depend on the location and the prevailing weather and swell conditions as well as on the regulatory requirements in place once the SPM is operational.

The overall operating cost of an SPM is likely higher than the cost of maintaining a conventional terminal, but less expensive than maintaining a lightering operation. Refining NZ will need to maintain the existing infrastructure as a backup for the SPM and for loading products onto coastal vessels, in which case the SBM maintenance costs would be incremental.

Customer Coordination

As stated above, the high capital costs of the SPM would require customers to take advantage of the economies of scale provided by VLCC tankers. However, a two million barrel VLCC cargo would likely exceed the requirements of individual customers, and as a result, it would require them to co-load.

Weather Dependency

The SPM system is designed to operate safely in a wide range of weather conditions. As mentioned before, the offloading tanker can freely weathervane around the SPM, always keeping the bow into wind and waves and thus keeping the windage area and wave exposure to a minimum. However, there are weather circumstances, combining heavy winds with long-wave period swells and tidal currents, where SPM operations may need to be suspended.

3. Ship to Ship Transfer Operations (Lightering)

Another way of supplying long haul crude oil to refineries at locations with insufficient water depth and draught restrictions, while still benefiting from the economies of scale of VLCCs or Suezmaxes, is the employment of Ship to Ship Transfers, also known as lightering. This operation allows larger, deep drafted tankers to remain in offshore areas with sufficient water depth as close as permissible to the receiving refinery, where they offload their cargo into smaller, draft suitable tankers (typically Aframax size) which deliver the crude oil to the refinery.

Source: Overseas Shipholding Group

The following map, produced by DYNAMARINe's Online STS, an organization that collects operational information from Ship to Ship (STS) transfer operators shows the worldwide locations where STS transfers occurred between 2011 and 2015. As the map clearly illustrates, STS operations are common in many locations.

Source: DYNAMARINe Online STS

Ship to ship transfer or lightering of crude oil from a Very Large Crude Carrier (VLCC) with a carrying capacity of about 280,000 tons onto a draft suitable Aframax size tanker of about 80,000 deadweight tons was successfully introduced by a major U.S. oil company at an offshore location in the U.S. Gulf around 1976.

The U.S. Gulf region has a huge amount of refining capacity in Texas and Louisiana. Prior to the introduction of lightering, crude oil supply to those refineries was restricted to smaller Aframax tankers, as only those vessels were able to meet the draft restrictions at U.S. Gulf ports of 40 feet. This made long haul transportation cost very high and uneconomical, especially for crude oil from the Arabian Gulf.

After the successful introduction of lightering, instead of shipping 80,000 tons of crude oil from the Arabian Gulf in Aframax tankers, VLCCs' were able to deliver about 280,000 tons to designated lightering positions, some 50 to 60 miles off the U.S. Gulf coast. Here they are lightered to completion by suitable Aframax tankers which make the final crude oil delivery to the refineries. It normally takes four Aframax loads to complete a VLCC discharge and, subject to weather conditions and availability of Aframax tonnage, the operation requires between 10 to 30 days to complete.

Since then, lightering operations have improved and are tightly regulated. Lightering is now a common way to provide long haul crude oil to refineries at draft restricted locations around the world.

Ship to ship oil transfer operations usually take place at designated, open, unrestricted sea areas with sufficient water depth (allowing adequate under keel clearance) to keep the interactive forces exerted during the approach of two vessels, to a minimum. Inadequate under keel clearance has a negative effect on a ship's maneuverability as well as the rudder and steering performance during the vessel's approach. About half of the lightering operations worldwide occur while the vessels are at anchor while about 30% occur by connecting the vessels while underway and anchoring for discharging. About 19% of the lightering operation are performed while the vessels continue to move at slow speed.

Typically, lightering operations can only be conducted in designated lightering areas, approved by respective National Authorities. Designated lightering areas must provide ample, unrestricted sea room to allow safe approach and maneuverability between off taker and mother ship (VLCC). Refining NZ would have to go through an approval process to obtain a designated lightering area.

Environmental Risk

Even though transshipment operations involve higher risk due to the increased number of cargo handling operations, lightering enjoys a good safety and spill record. According to the online STS quality assessment (OSIS), 3.3% of all STS operations experience an incident, while the remaining 96.7% are incident free.

By far the most frequently occurring incident is the breakdown of the mooring lines between the vessels. The following table, covering the period from April 2011 to December 2015, shows the frequency of different types of incidents as a percentage of the operations with incidents.

Incident	Frequency
Mooring Lines Breakdown	62%
Vessel Collision	13%
Fender Breakdown	9%
Oil Spill on Deck	5%
Hose Breakdown	3%
Fail of Communications	3%
Main Engine Failure	3%
Damage by tug or Service boats	1%
Vessel Blackout	1%

Source: Online STS

Refining Operational Considerations

In order to offset the relatively high operational costs of lightering, Refining NZ would have to use VLCC sized tankers. This has the same disadvantages as the use of an SPM: larger storage requirement and coordination between customers.

Additionally, due to the weather dependence of lightering, there is an increased risk of refinery supply disruptions, though weather conditions in the area of Marsden Point are generally favorable. According to a NIWA study on the weather conditions in Northland, 40% of the time swells are less than 1 meter while only 8% of the time they exceed 2 meters along the East Coast of Northland. Average wind speeds at the airport of Whangarei are generally around 10-13 km/h.

The refinery needs to maintain additional storage to manage the possibility that ships cannot offload the cargo due to weather conditions. Deliveries will be affected if either the ship-to-ship transfer is not possible or if the lightering Aframaxes cannot enter or exit the harbor.

Discharge Operations

Lightering operations require a higher level of oversight from the refinery and shore based organization. The parties involved in a lightering operation are normally the tanker to be lightered (mother vessel) typically a VLCC, the vessels to receive the oil (Off taker) typically an Aframax size tanker and the lightering service company who provides the lightering equipment such as a suitable work boat and fenders.

Either Refining NZ engages a lightering service provider who arranges an off taker for the lightering operation or Refining NZ needs to charter-in a vessel. It can be expected that not many Aframax tankers are trading in the New Zealand area, as Marsden Point is the only refinery in the country and petroleum product imports and local distribution are performed with smaller tankers due to the required volumes. Additionally, these tankers would not be suitable as the cleaning operations to switch between crude oil and clean petroleum product cargoes would be expensive and in some cases impossible. Therefore it will be difficult (or expensive) to arrange for a suitable Aframax tanker to be available when the VLCC arrives.

Capital Investment

The initial investment can be very low, as almost all the lightering costs are operational costs, especially if an outside lightering service is employed, as they typically charge an all-in fee per lightering operation. If Refining NZ decides to set up an in-house lightering operation, they would need to buy or charter in a workboat and acquire fenders, hoses, etc.

Ongoing Operational Costs

The operating expenses of lightering are higher than the alternatives discussed. Additional storage capacity would be required as well. Chartering in an Aframax to perform the lightering operation will be expensive as Aframax tankers will likely not be readily available, once most of the New Zealand bound crude oil is moved on larger tankers. It will be extremely difficult and costly to coordinate the use of Aframaxes that still discharge at Whangarei for lightering services. The following map shows the positioning of Aframax tankers on the 13th of July 2016. The map illustrates the limited availability of tonnage in the area. (The vessel heading for New Zealand is a BP owned tanker heading to the Refining NZ refinery)

The lightering operations require the use of a workboat to handle the required fenders and a mooring master who is experienced in mooring the ships. One of the existing lightering companies could establish a presence in New Zealand and manage the lightering operations or Refining NZ could decide to manage this in house.

Source: Lloyds List Intelligence

The lightering operations will be relatively inefficient unless more than one off-taker is used, as the VLCC is lying idle while the lightering vessel sails between the mother ship and the terminal. This results in higher costs for the Aframax tanker and demurrage for the VLCC. As a reference, on the U.S. West Coast, where Aframax tonnage is less common than in the U.S. Gulf area, lightering operations cost about US$200,000 per voyage for the off taker while VLCC demurrage typically costs around US$50,000 per day, depending on the freight market conditions. If only one off-taker is used, the optimum lightering time is about 11 days, this would add about US$450,000 – US$550,000 of demurrage cost per VLCC cargo, depending on the duration of the VLCC loading operations.

Customer Coordination

Operating costs involved in the lightering operation are very high. To offset these costs, the other transportation costs need to be reduced by using the largest possible vessels. However, VLCC carries about 2 million barrels of crude oil, which most likely exceeds the amount that can be managed by an individual customer. Therefore, two or more customers need to pool their crude to fill a VLCC. This complicates the logistics for the customers.

Weather Dependency

To perform safe lightering operations, operating parameters do not necessarily require dead calm seas with no wind. Although there is no fixed maximum wind speed and wave height limit established, lightering can be safely conducted by experienced mooring masters with wind speeds up to 20 knots and short period wave heights of up to six feet. However, if swell waves with long wave periods are experienced from one direction, and wind and wind waves come from another direction, on top of prevailing tidal currents, lightering operations are difficult to be conducted safely and should be suspended.

Conclusion

The following section summarizes the pros and cons of the various alternatives:

Dredge Existing Channel

Marsden Point approach channel realignment and berth dredging to a safe water depth, allowing fully laden Suezmax tankers to provide crude oil supply to the RNZ Whangarei refinery.

- Dredging costs are lower than installation of an SPM with a pipeline.
- Using fully laden Suezmax tankers is sufficiently comparable to current crude oil delivery volumes that refinery operations and storage facilities require less modification than for the alternative solutions.
- The expectation is that Refining NZ customers can easily deliver Suezmax cargoes (approximately 1 million barrels), typically without having to share tonnage, facilitating scheduling for the customers of the refinery.
- Dredging provides the best balance of costs and benefits; a limited investment combined with improved freight costs and requiring only minor operational modifications.

SPM Discharge System

Install an SPM and an underwater pipeline to connect the SPM to the refinery.

- The installation of an SPM, including the related pipeline system and infrastructure requires the highest upfront capital investment of all options.
- Once installed, the offshore SPM discharge system would provide cost effective crude oil deliveries without incurring excessive delays due to weather.
- VLCCs and Suezmax tonnage can be employed, taking advantage of economies of scale in freight costs.
- To meet larger cargo size deliveries, Refining NZ has to significantly increase its shore tank storage capacity.
- It is unlikely that Refining NZ's customers can individually supply crude oil by VLCCs on a consistent basis. Cooperation and closely coordinated co-loads among customers will likely be required.
- Even if an SPM discharge system is utilized, Refining NZ will need to maintain its existing jetty at Whangarei, in order to have an oil reception facility in the event the SPM system experiences any down time and to accommodate product loading onto coastal vessels.

- If not drained after discharge operations, the submerged sea line from the SPM to the shore tanks would contain crude oil. If the sea line integrity is compromised for unexpected reasons, oil seepage could occur.
- Refining NZ would have to train and maintain a team of mooring masters and discharge coordinators, hose handling, and maintenance crew including divers, as well as hire or acquire work boats and possibly pull back tugs.

Ship to Ship Transfer (Lightering)

Discharge the cargo at a designated lightering area from a larger mother vessel into smaller tankers that can transport the cargo to the refinery.

- Designated lightering areas have to be established and approved.
- To recover the higher cost involved in lightering, Refining NZ customers might have to use larger VLCC tankers. This would require significant additional storage capacity.
- Long term contracts with reputable Lightering companies have to be negotiated if possible, or in-house lightering operation has to be established.
- Lightering operations require a team of trained mooring masters and cargo coordinators as well as workboats, adequate and approved fender systems, cargo discharge hoses and hose handling crews.
- The utilization of Ship to Ship transfer operations, to provide crude oil to the Refining NZ refinery, will not reduce the number of tankers calling Marsden Point. The equipment has to be stored and properly maintained when not in use.
- Difficulties to obtain cost effective off takers due to lack of suitable tonnage in the Whangarei trading region.
- Refining NZs' customers have to coordinate co-load agreements for VLCC cargoes.
- An important disadvantage of lightering operations is the weather dependency. Long delays could be very costly and quickly eliminate the "economy of scale" gains. It could also create severe inventory problems for the refinery

In Poten’s view, of all the possible alternatives, the dredging option provides the best balance based on the evaluation criteria: The combination of limited initial investment and the modest on-going operating costs makes this a very cost competitive solution. As a result, the refinery can use fully laden Suezmax tonnage, which does not require significant changes to the refinery operations or for the customers, while still providing significant transportation cost savings. Incremental transportation cost savings of using VLCCs would be offset by higher initial investments or operating costs, as well as requiring significant additional coordination among Refining NZ's customers.

The following table shows Poten's ranking of the alternatives:

	Conventional Terminal (Dredging)	Single Point Mooring	Ship To Ship	Comments
Environmental Risk	1	2	3	Conventional Terminal best sheltered from seas and swell
Refining Operational Considerations	1	2	3	Large parcels delivered via SPM and STS create size mismatch with refinery
Discharge Operations	1	2	3	More communication and coordination required for SPM and STS
Capital Investment	2	3	1	Initial investment costs highest for SPM
Ongoing Operational Costs	1	2	3	Conventional Terminal only requires periodic dredging
Customer Coordination	1	2	2	VLCC cargoes (SPM & STS) requires co-loading by customers
Weather Dependency	1	2	3	STS and to a lesser extent SPM operations can be disrupted by adverse weather

References

International Association of Oil & Gas Producers: *Water Transport Accident Statistics*; March 2010

DYNAMARINe Online STS: OSIS STS Statistics Report 2011 – 2015

NIWA: *The climate and weather of Northland*, P.R. Chapell, 2013

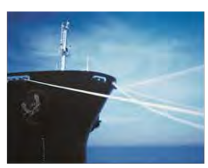
Poten and Partners Overview

Poten & Partners has been in business for more than 70 years, and while it originated as a ship brokerage firm it has expanded into providing a range of commercial and advisory services related to supply, cargo trading, and transportation of crude oil, petroleum products, condensates, naphtha, LPG, natural gas, and LNG. The company currently employs 170 staff members and has offices in New York, London, Athens, Houston, Perth, Singapore and Guangzhou.

Complementary businesses across the energy value chain

UPSTREAM

MIDSTREAM



MARINE

INFRASTRUCTURE

DOWNSTREAM

Our brokers continuously pursue business opportunities, which link us to the realities of energy transactions and provides primary source information. As brokers for ships and commodities, we arrange more than a thousand transactions every year.

Poten & Partners consulting and project development staff provides strategic guidance and understanding of longer-range economic horizons.

Our economists monitor and analyze energy developments in key countries, and advise companies on strategy, objectives, and implementation. Our focus is on energy supply and transportation issues and strategies that can benefit our clients. Balance and synergy between these disciplines make us effective and unique. Our people are diverse, with planning, marketing, engineering, and executive backgrounds in oil and gas companies, banks, shipping companies, academia, and government service. These talented people have conceived and brought many projects to fruition.

We serve organizations of every size, industry leaders and smaller companies alike. Doing this right means we must — and we do — adhere to the highest standards of professionalism, business ethics, and discretion. Our assets are our people, their skills, and our valued relationships with an impressive list of clients and customers.

Tanker Research & Consulting

Poten's Tanker consulting team is comprised of senior marine logistics, petroleum, upstream and downstream experts who have been involved in advising on all stages of the petroleum supply chain.

In addition, our team is frequently called upon to prepare pricing analyses, global supply and demand projections, and tailored market analyses for leading energy companies and major world governments.

Crude Oil

With decades of combined experience, we are a leading provider of consulting services to the crude oil industry. Our staff combines years of experience in trading, brokerage, shipping and refining to assist our clients with the challenges and opportunities of commerce in the crude oil industry. Clients include oil companies, traders, financial institutions, pipeline owners, terminal operators and government agencies.

Our services include:

• Market analysis, long and short term forecasting and special studies in industry trends

• Analysis of trade regions, supply and demand, pricing and contracts

• Valuation of new crude oil production

• Plant-by-plant evaluations, competitor analysis and strategic planning

• Investor and lender due diligence

Fuel Oil

Poten is available to discuss and prepare single-client research reports on fuel oil related topics. Our consultants possess a wide range of experience and resources to assist clients in meeting essential business objectives associated with crude oil and refined products. Our consulting group combines experience in fuel oil trading, brokerage, shipping, refining and reporting.

Clients include oil companies, traders, financial institutions, pipeline owners, terminal operators and government agencies.

Clean Refined Petroleum Products

Poten & Partners offers comprehensive consulting and advisory services to the transportation fuels and condensates industries, including:

- Trade regions supply and demand analysis
- Price outlooks

Asphalt

We are leading advisors to companies and countries seeking assistance in the worldwide asphalt industry. Our consultants combine years of experience, decision tools, and organizational strategies to provide a comprehensive overview of the asphalt markets.

Our services and publications include:

- Comprehensive asphalt market information services
- Commercial intelligence and advice on pricing and marketing
- Assessments and forecasts spot prices, supply and demand, and global trends
- Analysis of global production and consumption
- Lender and investor due diligence
- Litigation support
- Customized training sessions

Clients include oil companies, government agencies, refiners, paving contractors, terminal operators, as well as financial institutions.

Asphalt Weekly Monitor®: The leading asphalt market price reference publication. Weekly analysis of the US and Canadian asphalt industry, including prices, market development and alternate values

Naphtha

With over thirty years of experience, we are a leading provider of consulting services to both naphtha producers and consumers. Our staff combines years of experience in trading, brokerage, shipping and refining to assist our clients with the challenges and opportunities of commerce in the naphtha market. Clients include oil companies, traders, LNG companies, GTL companies and petrochemical companies.

Our services include:

• Market analysis, long and short term forecasting and special studies in industry trends

• Analysis of trade regions, supply and demand, pricing and contracts, quality trends

• Investor and lender due diligence

Natural Gas Liquids

Poten & Partners has over thirty years of experience and recognition as consultants and commercial brokers to the international LPG business. During this period, we have been retained by LPG producers including Saudi Arabia, Kuwait, Abu Dhabi, Venezuela, and Indonesia. Our assignments have ranged from analyzing long-term demand/supply to recommending short-term marketing strategies. We have also provided assistance to shipowners, traders, petrochemical end-users and other buyers around the world.

The Poten Project Team is staffed by individuals with substantial NGL and LPG, petrochemical, shipping and management knowledge and experience. All the consultants in the team have advised senior decision makers in international energy companies on strategy and corporate positioning. The advisors to the project include former industry executives with responsibility for taking significant LPG related business decisions.

Our LPG consulting activities include the publication of multi-client studies such as:

• LPG in World Trade (an annual publication)

• LPG in World Markets (a monthly publication)

Poten is a leading provider of commercial advisory and brokerage services to the energy and ocean transportation industries, including:

• Consulting services for LNG, shipping and natural gas, LPG, NGLs, condensates, light petroleum products, crude oil, petrochemicals, fuel oil and asphalt

• Capital services for financing of shipping and energy infrastructure projects

• Project development services for marine transportation and energy infrastructure transactions.

• Ship brokerage for crude oil, petroleum products, LNG and LPG

• Commodity brokerage for LPG, LNG, naphtha and condensates

LNG and Natural Gas

Available consulting services and publications include:

• Gas international trade

• Analysis and forecasts of:

  • Regional and worldwide gas supplies and markets,

  • International short- and long-term LNG/natural gas trades,

  • Regional and worldwide LNG, natural gas, and energy values,

  • Short- and long-term pricing for LNG/natural gas and competing fuels for the end-user markets (e.g., power generation),

• Evaluation of gas project cost-of-service, facilities, legal and regulatory activities, political considerations, and technological developments,

• Evaluation and forecasts of LNG terminals and LNG shipping,

• Corporate business strategies for entry and growth in the LNG business and international LNG trade.

Project Development & Finance and Capital Services

Ship and commodity brokerage transactions most often stem from short to medium-term market dynamics. Our Project Development professionals understand market fundamentals and have the expertise to structure and create innovative and practical solutions. We typically pursue long-range objectives that require time to mature. Our creativity, experience, preparation and perseverance contribute to the success of these projects.

Shipping Asset Projects

Poten has initiated shipping projects by taking a concept to a client, helping develop the component parts, and guiding the project to a conclusion. These projects include shipyard contracts for new construction and conversions, sale of existing ships and fleets, and various kinds of long-term transportation agreements.

Energy Projects

Poten has participated in many large energy asset-related projects. We have assisted clients in identifying and evaluating opportunities for investment in refineries, petrochemical plants, oil, gas, and gas liquids pipelines, petroleum products terminals, and retail distribution companies. We have acted as marketing advisor for new export projects involving LPG, LNG, condensates, refined fuels and petrochemicals. Some examples are:

Project Finance

Poten has assisted in the financing of energy and shipping ventures. Our staff is experienced in evaluating the earning potential of assets, preparing finance proposals, and negotiating with lenders and investors. In order to obtain optimum financing for our clients, we sometimes find supplementary equity capital. For ship financing, Poten can advise on foreign exchange hedging, alternative flags of registry, tax consequences of domiciling companies in particular countries, and the provision of surety through mortgages or assignment of revenues.

Brokerage Services

Ship and Commodity Brokerage

Crude Oil & Refined Products

Shipbrokers arrange marine transportation of crude and refined oil products on a spot and term charter basis. Our proprietary Internet portal provides our clients access to many of the same databases used by our brokers and analysts, including real-time vessel positions and information on fixtures.

Our brokers have extensive experience in tanker sale and purchase, including fleet sales, lease and charter-back transactions and transportation finance. Our real-time market information gives our clients timely advice on short and long-term trends, critical for vessel acquisition decisions.

LPG

Our LPG shipbrokers and commodity brokers are active throughout all vessel segments ranging from VLCCs to smaller semi-refrigerated vessels. We retain a team of professionals canvassing the market and providing clients with global intelligence on the ocean transportation of LPG, ammonia, and petrochemical gases. We routinely arrange spot and term charters and develop contracts of affreightment to suit clients' specific requirements. In addition, we are active in the sale and purchase of LPG carriers and offer project development and consulting services to our clients.

LNG

Members of Poten's commercial group have decades of LNG experience allowing them to understand short-term market dynamics and identify future trends. Our brokers are involved in all aspects of the midstream and downstream LNG delivery chain including supply, transportation and regasification.

Poten's client relationships and industry contacts build upon our experience in the sale and purchase of LNG carriers and in spot and term chartering arrangements.

Contact Details:

If you have any questions, please contact:

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Email: ebroekhuizen@poten.com

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New York, New York 10022

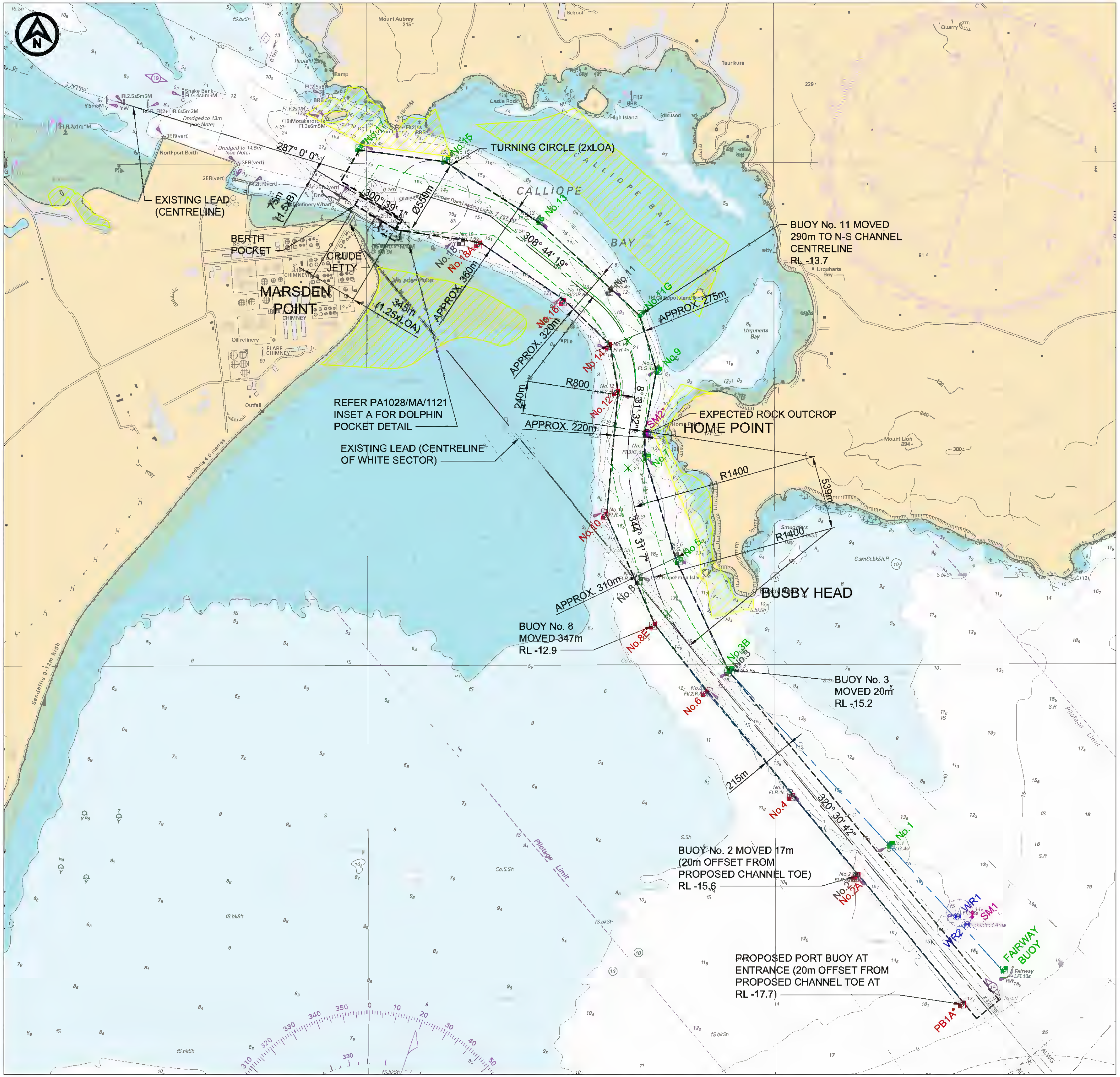
www.poten.com

Appendix B: Channel alignment options

The following schematics detail channel alignment options 2, 4.2 and 5 as at the mid-point review in June 2016 (from RHDHV, 2016b).

DRAWING No. PA1028/MA/1201

DO NOT SCALE



LEGEND:

------	DESIGN TOE LINE
—·—·—	DESIGN CHANNEL CENTRELINE
- - - (green)	THEORETICAL TOE LINE
—·— (green)	THEORETICAL CHANNEL CENTRELINE
—·— (blue)	BUOY BOUNDARY (15m MINIMUM OFFSET FROM BUOY)
	PROPOSED RELOCATED BUOYS (e.g. No. 11A)
	STARBOARD BUOYS
	PORTSIDE BUOYS
	WAVERIDER BUOYS
	SPECIAL MARK BUOYS
	EXISTING BUOYS TO BE RELOCATED
	MM1 BOUNDARY

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. GEOMETRY OF DESIGN CHANNEL AND BERTHING AREA BASED ON SUEZMAX VESSEL WITH LENGTH OF VESSEL (LOA) = 276m AND BEAM (B) = 50m.

REV	DATE	DESCRIPTION	BY	CHK	APPD
D	02.12.15	BUOY No.8 MOVED	BAM	RM	
C	02.11.15	CHANGES CARRIED OVER FROM OPTION 4-2	BAM	RM	
B	22.07.15	RELOCATED BUOYS ADDED	BAM	MP	
A	20.07.15	DRAFT FOR REVIEW	BAM	MP	

REVISIONS

CLIENT: CHANCERYGREEN ON BEHALF OF: REFINING NZ Your Energy Hive

PROJECT: REFINING NEW ZEALAND CRUDE FREIGHT PROJECT

DRAWING TITLE: CHANNEL DESIGN OPTION 2 CHANNEL ALIGNMENT

CHART DATUM

NOT FOR CONSTRUCTION

300 0 300 600 900 1200 1500m

1:15000 (A1) 1:30000 (A3)

HASKONING AUSTRALIA PTY LTD SYDNEY

Royal HaskoningDHV Enhancing Society Together

DRAWN BAM | DATE 02/12/2015 | JOB No. PA1028

AUTOCAD REF. PA1028-MA-OP2D-95%

SCALE AT A1 1:15000

DRAWING No. PA1028/MA/1201 | REVISION D

\\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1028 REFINING NZ CAD\E11 WORKING DRAWINGS\PA1028-MA-OP2D-95%.DWG 12/2/2015 4:37 PM

DRAWING No. PA1028/MA/1121

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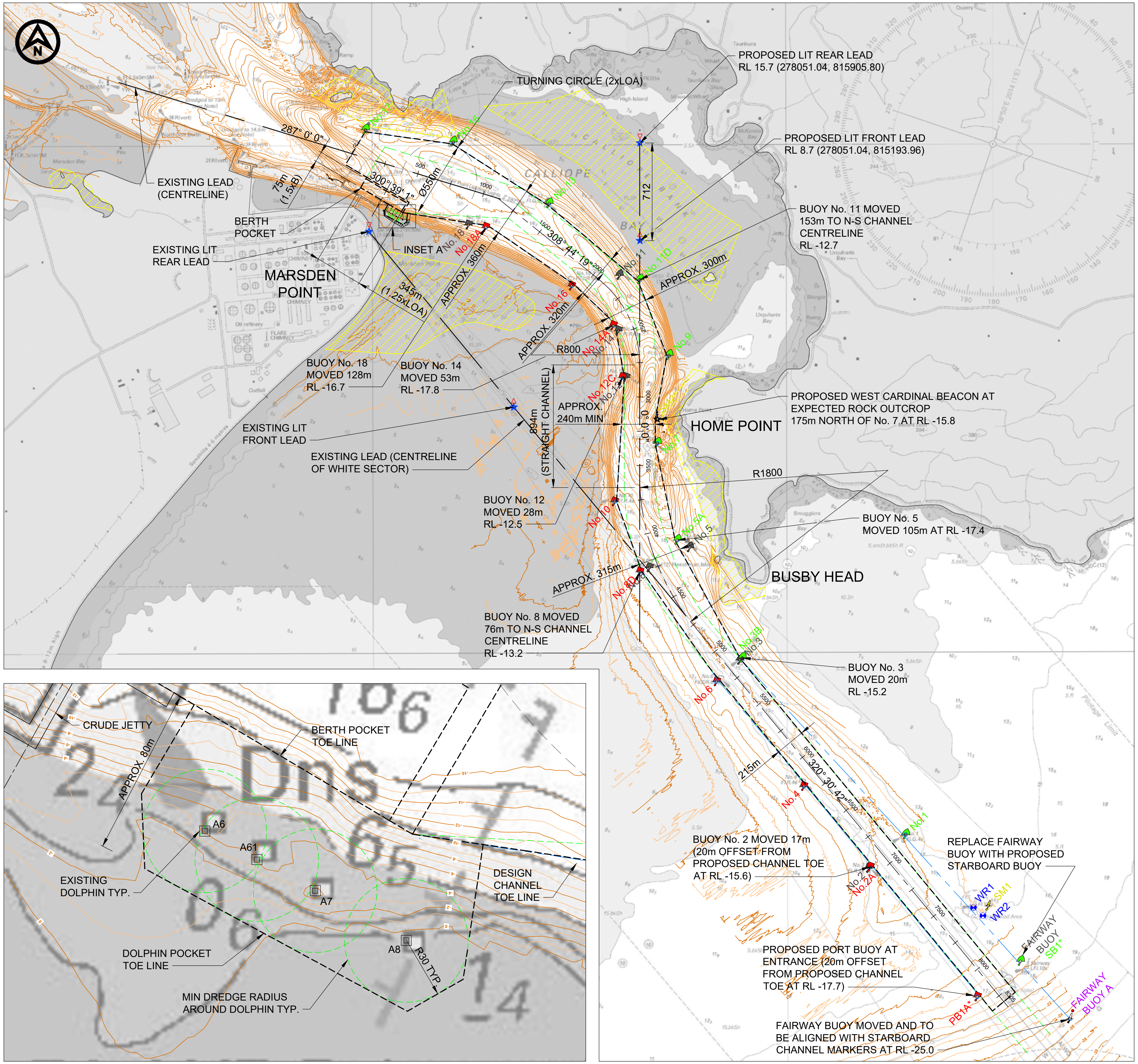


INSET A - DOLPHIN POCKET
1:1,000 (A1)

PLAN - CHANNEL ALIGNMENT
1:15,000 (A1)

LEGEND:

- DESIGN TOE LINE
- DESIGN CHANNEL CENTRELINE
- THEORETICAL TOE LINE
- THEORETICAL CHANNEL CENTRELINE
- BUOY BOUNDARY (15m MINIMUM OFFSET FROM BUOY)

NAVIGATION AIDS:
PROPOSED RELOCATED BUOYS ARE DENOTED WITH A LETTER SUFFIX (e.g. No. 11A)

- LIT STARBOARD BUOY (NTM)
- LIT PORT BUOY (NTM)
- LIT WEST CARDINAL BEACON
- LIT SPECIAL MARK PILLAR BUOY (NTM)
- LIT SAFE WATER MARK PILLAR BUOY
- EXISTING BUOY TO BE RELOCATED
- WAVERIDER BUOY
- LIT REAR LEAD BEACON
- LIT FRONT LEAD BEACON
- LEAD LINE

CONSTRAINTS:

- MM1 BOUNDARY

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. GEOMETRY OF DESIGN CHANNEL AND BERTHING AREA BASED ON SUEZMAX VESSEL WITH LENGTH OF VESSEL (LOA) = 276m AND BEAM (B) = 50m.
5. THE DAYLIGHT LEADS ON THE OFFSHORE APPROACH CHANNEL BETWEEN THE FAIRWAY BUOY AND BUOYS 3/6 SHOULD BE MADE MORE SENSITIVE TO ADEQUATELY SHOW THE NAVIGATION LIMITS OF THE NEW CHANNEL AND BE BRIGHT ENOUGH TO SUPPORT OPERATIONS IN ADVERSE ENVIRONMENTAL CONDITIONS. AN ADDITIONAL FRONT LEAD SHOULD BE ESTABLISHED WITH DAY AND NIGHT LIGHTS IN THE CURRENT FRONT LEAD POSITION. THE EXISTING FRONT LEAD SHOULD BE REPLACED WITH A SIMPLE DAY\NIGHT LIGHT LEAD WITH NO DAY SHAPE.
6. NORTHPORT TO REMOVE THE DAY SHAPE TOP STRUCTURE FROM THE EXISTING FORE LEAD STRUCTURE AND PLACE A NEW 1.2m HIGH STRUCTURE (ON TOP) TO HOLD THE PROPOSED LIGHT. LIGHT COLOUR TO BE CONFIRMED.

REV	DATE	DESCRIPTION	BY	CHK	APPD
M	22.09.16	WEST CARDINAL MARK ADDED	BAM	JGC	
L	24.08.16	LEADS AND FAIRWAY BUOY MOVED	BAM	JGC	
K	23.06.16	LEADS MOVED	BAM	RM	
J	22.06.16	FAIRWAY BUOY MOVED	BAM	RM	
H	02.12.15	REISSUED FOR REVIEW	BAM	RM	
G	27.10.15	DREDGING AROUND DOLPHINS ADDED	BAM	RM	
F	23.10.15	LABELS REMOVED	BAM	RM	
E	22.10.15	REVISED SUEZMAX VESSEL	BAM	RM	
D	16.10.15	BUOYS No.2 AND PB1 SHIFTED	BAM	RM	
C	13.10.15	CHANNEL CENTRELINE ADDED	BAM	MP	
B	12.10.15	PROPOSED N–S LEAD ADDED	BAM	MP	
A	10.09.15	REVISED FROM OPTION 4–1	BAM	MP	

REVISIONS

CLIENT
CHANCERYGREEN ON BEHALF OF:
REFINING NZ
Your Energy Hive

PROJECT:
REFINING NEW ZEALAND CRUDE FREIGHT PROJECT

CHART DATUM

NOT FOR CONSTRUCTION

300 0 300 600 900 1200 1500m
1:15000 (A1) 1:30000 (A3)

20 0 20 40 60 80 100m
1:1000 (A1) 1:2000 (A3)

DRAWING TITLE:
CHANNEL DESIGN OPTION 4–2 CHANNEL ALIGNMENT

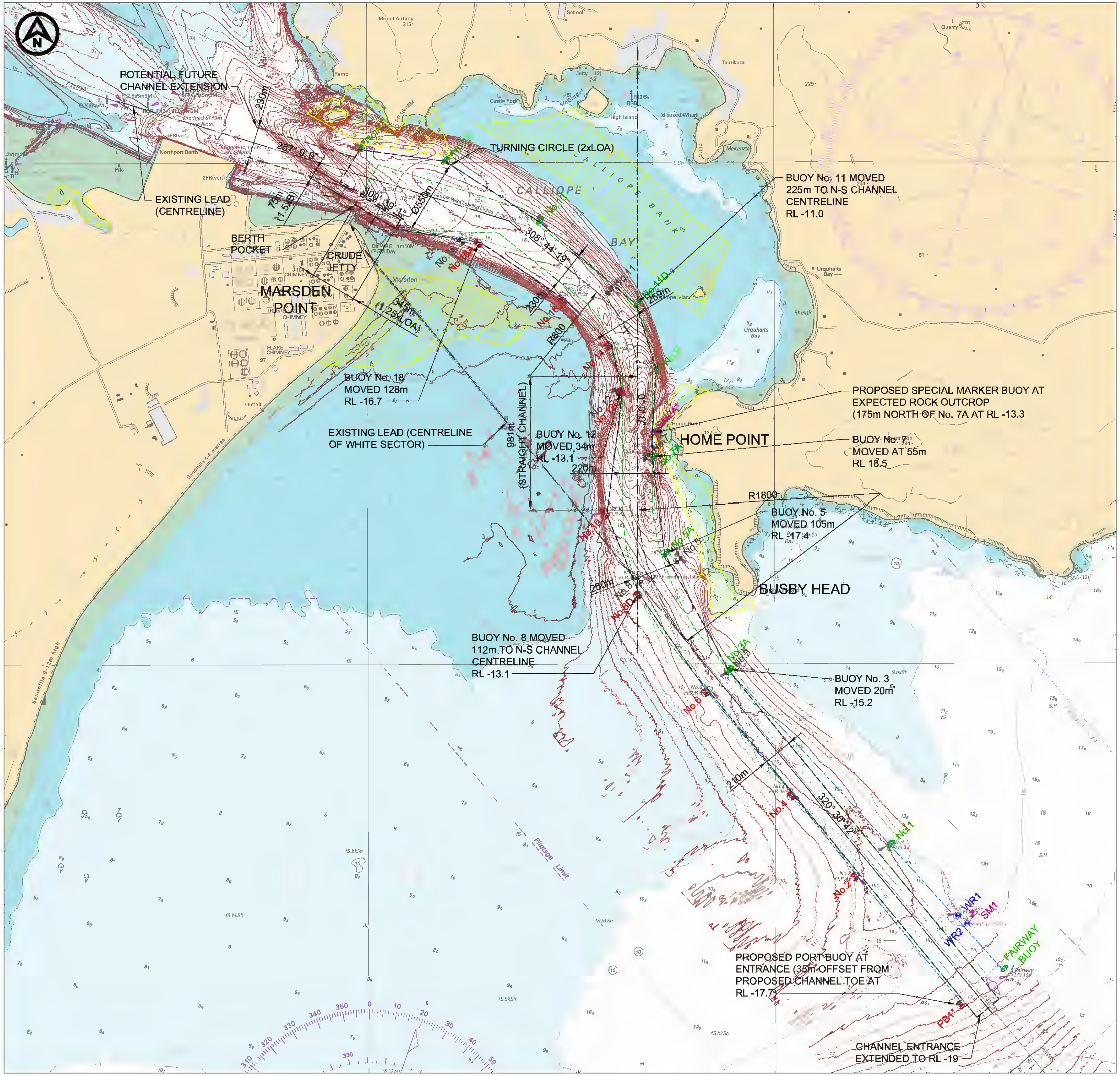
HASKONING AUSTRALIA PTY LTD
SYDNEY
Royal HaskoningDHV
Enhancing Society Together

DRAWN BAM | DATE 26/08/2016 | JOB No. PA1028
AUTOCAD REF. PA1028–MA–OP4–2L–98%
SCALE AT A1 AS SHOWN
DRAWING No. PA1028/MA/1121 | REVISION M

\\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1028 REFINING NZ CAD\E11 WORKING DRAWINGS\PA1028-MA-OP4-2L-98%.DWG 9/22/2016 10:20 AM

DRAWING No. PA1028/MA/1301

DO NOT SCALE



LEGEND:

– – –	PROPOSED CHANNEL TOE LINE
– – –	DESIGN CHANNEL TOE LINE
– · –	BUOY BOUNDARY (15m MINIMUM OFFSET FROM BUOY)
– · –	OPTION 4-2 REV A DESIGN CHANNEL CENTRELINE
	STARBOARD BUOYS
	PORTSIDE BUOYS
	WAVERIDER BUOYS
	SPECIAL MARK BUOYS
	EXISTING BUOYS TO BE RELOCATED AND PREVIOUS REVISIONS
	RELOCATED BUOYS (e.g. No. 11A)
	MM1 BOUNDARY

NOTES:

1. SURVEY UNDERTAKEN BY DML, DATED APRIL 2015. INCLUDES BATHYMETRIC SURVEY SHOWN AT 1m CONTOURS, COASTAL OUTLINE, MARSDEN POINT JETTY STRUCTURES AND LOCATION OF NAVIGATION AIDS.
2. HORIZONTAL DATUM MOUNT EDEN CIRCUIT, NZGD1949.
3. ALL LEVELS REDUCED TO CHART DATUM.
4. GEOMETRY OF DESIGN CHANNEL AND BERTHING AREA BASED ON SUEZMAX VESSEL WITH LENGTH OF VESSEL (LOA) = 274m AND BEAM (B) = 48m.
5. PROPOSED CHANNEL TOE FOLLOWS DESIGN CHANNEL TOE SOUTH OF BUOY No. 3, AND FOLLOWS BUOY BOUNDARY NORTH OF BUOY No. 3.

CHART DATUM

NOT FOR CONSTRUCTION

300 0 300 600 900 1200 1500m

1:15000 (A1) 1:30000 (A3)

REV	DATE	DESCRIPTION	BY	CHK	APPD
A	10.09.15	DRAFT FOR REVIEW	BAM	MP	

REVISIONS

CLIENT: CHANCERYGREEN ON BEHALF OF: REFINING NZ Your Energy Hive

PROJECT: REFINING NEW ZEALAND CRUDE FREIGHT PROJECT

DRAWING TITLE: CHANNEL DESIGN REALIGNMENT OPTION 5 CHANNEL ALIGNMENT

HASKONING AUSTRALIA PTY LTD SYDNEY

Royal HaskoningDHV Enhancing Society Together

DRAWN BAM | DATE 10/09/2015 | JOB No. PA1028

AUTOCAD REF. PA1028-MA-OP5A-DESIGN LEVEL

SCALE AT A1 1:15000

DRAWING No. PA1028/MA/1301 | REVISION A

\\HKA-SERVER\PUBLIC\CURRENT JOBS\~PA1028 REFINING NZ CAD\E11 WORKING DRAWINGS\PA1028-MA-OP5A-DESIGN LEVEL.DWG 9/10/2015 5:13 PM

Appendix C: Expert panel

The following table records the participants in the four phases of the assessment:

- initial development of the MCA
- findings workshop
- MCA refinement
- peer review.

The asterisk (*) denotes the key contributor from each organisation (where applicable).

Table C-1: Contributors to the mid-point options assessment

Organisation	Specialist Area	Name	MCA development	Workshop	MCA refinement	Peer review
Refining NZ		Dave Martin* Greg McNeill Riaan Elliot	✓	✓	✓	
Chancery Green	Legal	Chris Simmons	✓	✓	✓	
Patuharakeke Te Iwi Trust Board	Cultural Values	Juliane Chetham	✓	✓	✓	
Ryder Consulting	Ecology Peer Review	Brian Stewart				
Tonkin + Taylor	Geomorphology MCA Assessment	Richard Reinen-Hamill Monique Cornish	✓	✓	✓	
MetOcean Solutions	Geomorphology modelling	Sarah Gardiner* Peter McComb		✓		
Royal HaskoningDHV	Channel alignment & dredging methodology	Richard Mocke* Justin Cross	✓	✓	✓	
Cawthron Institute	Ecology: marine mammals	Deanna Clement	✓	✓	✓	
Brian T Coffey & Associates	Ecology	Brian Coffey	✓	✓	✓	
Rob Greenaway & Associates	Recreation	Rob Greenaway	✓	✓	✓	
The University of Auckland	Geomorphology peer review	Paul Kench				
Bioresearches	Ecology: shore and pelagic birds	Graham Don			✓	
Brown Ltd	Landscape, visual and natural character matters	Stephen Brown			✓	
Clough & Associates	Heritage	Rod Clough			✓	

Appendix D: Key literature

Bioresearches (September, 2016) Existing Environment Assessment: Ecology of the Dredge Area, Whangarei Heads. pp 210.

Brown and Associates (October, 2016) Landscape & Natural Character Effects – Key Findings. 3 pp.

Brian T. Coffey and Associates Limited (October, 2016) AEE: RNZ Marine Ecology 3. 67 pp.

Central Dredging Association, CEDA, (2011) Underwater Sound in Relation to Dredging, CEDA Position Paper 7 November 2011. 6 pp.

Clough & Associates (April, 2016). Marsden Refinery Whangarei Harbour Dredging: Archaeological Assessmnet. Draft. 25 pp.

Patuharakeke Te Iwi Trust Board Inc (January, 2015) Cultural Values Assessment Report: Refining NZ Ltd – Crude Freight Proposal. 23 pp.

Poten & Partners (August, 2016), Crude Shipping Alternatives Marsden Point, NZ. 28 pp.

Royal HaskoningDHV, RHDHV (May, 2016a) Technical Memo: Dredging Assessment Methodology. Reference M&APA1028N006D04. 42 pp.

Royal HaskoningDHV, RHDVH (June, 2016b) Refining NZ Crude Freight Project: RNZ Channel Design. Revision 5. 237 pp.

Tonkin & Taylor (April, 2016) Marsden Point Refinery – Crude Freight Project. Geotechnical Factual Report. 255 pp

Tonkin & Taylor (November, 2016). Crude Freight Shilling Project, Whangarei Harbour: Coastal Processes Assessment – Consultation Draft. Version 6. 160 pp.

Appendix E: MCA summary

Table E-1: MCA results (weighted) for natural aspects considered

Category			Natural														
			Direct impacts											Indirect impacts			
Aspect			Impact on benthic flora & fauna at site	Impact on local fish stocks	Impact on marine mammals	Impact on shore birds & pelagic birds	Sediment matching	Contamination	Impact on intertidal and subtidal flora and fauna	Impact on significant ecological habitats or species of flora and fauna within those habitats	Impact on reef	Turbidity (dredge location)	Turbidity (disposal location)	Coastline formation	Natural character and underwater seascape (biophysical)	Coastal erosion	Resilience
Description			Impact on ecological communities removed or smothered	Direct impacts on species due to changes at the dredge / disposal site (habitat, resources, movement paths)	Direct impacts on species due to changes at the dredge / disposal site (habitat, resources, movement paths)	Direct impact on feeding and nesting sites and indirect impacts on mating due to noise, light and general activity in the area	Degree to which the deposit would match the existing substrate	Potential for any existing contaminats to be spread	Potential to impact areas with important conservation value	Potential to impact areas with important conservation value	Potential to impact known area of hard shore biological diversity	Potential for movement of sand from site and impacts on water quality (colour and clarity)	Potential for movement of sand from site and impacts on water quality (colour and clarity)	Potential for deposition to occur to a level greater than normal coastal processes	Significance of the impact on the natural character values & 'landscape' of the sea floor	Potential for erosion to occur to a level greater than normal coastal processes	Impact on resilience of the coastal system based on volume of sand removed / deposited
Dredge Disposal	1.2	Ebb Delta	4	2	4	4	2	0	-2	6	4		2	-2	1	-2	-3
	2.2	Nearshore	4	2	2	4	0	0	2	3	2		2	0	1	2	6
	3.2	Intermediate	2	2	4	2	0	0	2	3	2		2	0	2	2	6
	4	Land based disposal	0	0	0	0	0	0	0	0	0		0	-2	0	0	0
	5	Beach nourishment	0	0	0	4	0	0	0	0	0		0	-2	0	-2	-3
	6	Deep water	4	2	2	2	4	0	2	0	0		2	0	1	2	6
	7	Outside EEZ	2	2	2	2	4	0	2	0	0		2	0	1	2	6
Channel	2	Existing mid-section	2	2	2	2		0	2	6	4	2		0	1	0	
	4.2	Straight mid-section (west)	2	2	2	2		0	2	6	4	2		0	1	0	
	5	Straight mid-section (east)	4	4	4	4		0	4	9	6	2		0	2	0	
Dredge Methodology	1a	Trailer (with central weir)	2	2	4	2		0	2	3	0	2	4				
	1b	Trailer (actual overflow)	4	4	4	4		0	4	9	4	4	4				
	2	CSD	2	2	4	2	0	0	4	3	0	4	4				
	3	Backhoe	4	4	4	2	0	0	4	3	0	4	2				
	i	Ebb Tide Dredging	2	2	0	2	0	0	2	3	2	2	0				
	ii	All Tide Dredging	4	4	2	4	0	0	4	9	4	4	0				

Table E-2: MCA results (weighted) for social aspects considered

Category			Social										
Aspect			Longer-Term Impacts									Temporary Impacts	
			Fishing	Hunting	Watercraft sports	Watercraft sports	Wave sports	In-water activities	Beach access	Natural Character & underwater seascape (perceptual)	Permanent effects of navigation lights	Temporary amenity effects (light spill & noise emissions above water)	Temporary visual amenity & landscape
Description			Impact on recreational fishing (access or stocks) by boat, from shore or diving. Includes fin and shellfish	Impact on duck hunting on- or near-shore	Impact on on-water sports (e.g. yachting, rowing, waka ama, windsurfing, canoeing, jet skiing, boating)	Impact on boating communities associated with relocation of the navigation buoys	Impact on wave sports (e.g. kite surfing, wind surfing and surfing) due to changes in surf breaks	Impact on in-water activates (e.g. diving, swimming) due to changes in turbidity, currents, wave profile	Changes to beach access	Significance of the impact on the natural character values & 'landscape' of the sea floor	Impact on local and visitor communities associated with new Navaid structures	Impact on local community from light and noise associated with dredge operations	Aesthetic impacts on local community associated with dredge operations
Dredge Disposal	1.2	Ebb Delta	3	0	3		3	0	-3			0	0
	2.2	Nearshore	3	0	0		3	0	0			0	0
	3.2	Intermediate	3	0	0		0	0	0			0	0
	4	Land based disposal	0	0	0		0	0	0			0	0
	5	Beach nourishment	0	0	0		0	0	-3			0	2
	6	Deep water	3	0	0		3	0	0			0	0
	7	Outside EEZ	3	0	0		0	0	0			0	0
Channel	2	Existing mid-section	3	0	0		0	0	0	1	1	2	2
	4.2	Straight mid-section (west)	3	0	0		0	0	0	1	1	2	2
	5	Straight mid-section (east)	6	0	0		0	3	0	1	1	4	4
Dredge Methodology	1a	Trailer (with central weir)	3	0	0		0	0	0			2	2
	1b	Trailer (actual overflow)	6	0	0		0	0	0			4	4
	2	CSD	3	0	0		0	0	0			2	4
	3	Backhoe	6	0	0		0	0	0			4	4
	i	Ebb Tide Dredging	6	0	0		0	0	0			4	4
	ii	All Tide Dredging	3	0	0		0	0	0			2	2

Table E-3: MCA results (weighted) for cultural aspects considered

Category			Cultural								
Aspect			Kaimoana at Mair Bank	Kaimoana at Marsden Bank	Taonga species	Impact on Mahinga Mataitai	Mauri of Harbour	Cultural Landscapes and Seascapes	Kaitiakitanga	Subsurface Archaeological Sites	Land-based Archaeological Sites
Description			Impact on the ability to collect kaimoana from Mair Bank (based on erosion of Mair Bank) which may impact the ability to collect kaimoana (particularly pipi) sustainability	Impact on the ability to collect kaimoana from Marsden Bank (based on erosion of Marsden Bank) which may impact the ability to collect kaimoana sustainability	Impact on native birds, plants and animals of special cultural significance and importance to tangata whenua	Impacts on other key traditional mahinga mataitai and fishing grounds	Impact on the mauri of the harbour, and in particular the potential impact of sand removal from system	Impacts on important markers including Manaia, Matariki, Te Whara, the Takahiwai and Pukekauri Ranges and islands including Tatanga	Impact on the ability of tangata whenua to fulfil their duties as kaitiaki and on matauranga and tikanga in regard to resources	Impact on subsurface archaeological sites, including shipwrecks	Impact on natural and physical resources that contribute to an understanding and appreciation of New Zealand's history and cultures
Dredge Disposal	1.2	Ebb Delta	3	6	6	6	6	3	3	0	0
	2.2	Nearshore	3	3	6	6	3	3	3	0	0
	3.2	Intermediate	3	3	3	6	3	3	3	0	0
	4	Land based disposal	0	0	0	0	3	0	0	0	0
	5	Beach nourishment	0	0	3	3	3	3	3	0	0
	6	Deep water	0	0	3	3	3	0	3	0	0
	7	Outside EEZ	0	0	0	0	3	0	0	0	0
Channel	2	Existing mid-section	6	6	3	6	6	3	3	0	0
	4.2	Straight mid-section (west)	6	6	6	6	6	3	6	0	0
	5	Straight mid-section (east)	6	6	9	9	9	6	9	0	0
Dredge Methodology	1a	Trailer (with central weir)	6	6	6	3	3	3	3		
	1b	Trailer (actual overflow)	9	9	9	9	9	6	6		
	2	CSD	6	6	6	6	6	3	3		
	3	Backhoe	6	6	6	3	6	3	3		
	i	Ebb Tide Dredging	6	6	3	3	3	3	3		
	ii	All Tide Dredging	9	9	6	6	6	6	6		

Table E-4: MCA results (weighted) for economic aspects considered

Category			Economic								
			Indirect Impacts					Direct Impacts			
Aspect			Impact on intakes and outfalls	NIWA Operations	Commercial Fishing	Navigation	Project Safety	Legal	Maintenance	Revenue	Cost
Description			Potential impact on intakes and/or outfalls (blocking). Excluding NIWA operations.	Potential impact on NIWA aquaculture operations (Abalone)	Shellfish and fish	Potential effects on navigational safety due to channel alignment	Risk associated with undertaking the option (environmental and WHS) linked to methodology and programme duration	Jurisdictional and practical issues associated with consenting each option	Degree to which deposition site or channel alignment impacts cost of maintenance	The amount of revenue generated via beneficial reuse	Total cost of option
Dredge Disposal	1.2	Ebb Delta	1	2	0		6	2	-2	0	6
Dredge Disposal	2.2	Nearshore	0	0	6		3	0	0	0	3
Dredge Disposal	3.2	Intermediate	0	0	3		3	0	0	0	3
Dredge Disposal	4	Land based disposal	0	0	0		6	4	0	-0.5	6
Dredge Disposal	5	Beach nourishment	0	0	0		6	4	0	-0.5	6
Dredge Disposal	6	Deep water	0	0	0		6	2	0	0	6
Dredge Disposal	7	Outside EEZ	0	0	0		9	6	0	0	9
Channel	2	Existing mid-section	0	0	0	0	3	2	2		3
Channel	4.2	Straight mid-section (west)	0	0	0	-3	3	2	2		3
Channel	5	Straight mid-section (east)	0	0	3	9	9	4	2		9
Dredge Methodology	1a	Trailer (with central weir)	0	0	0	0	3				3
Dredge Methodology	1b	Trailer (actual overflow)	0	0	0	0	3				3
Dredge Methodology	2	CSD	0	0	0	0	9				6
Dredge Methodology	3	Backhoe	0	0	0	0	6				9
Dredge Methodology	i	Ebb Tide Dredging	0	0	0	0	6				6
Dredge Methodology	ii	All Tide Dredging	0	0	0	0	3				3

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Annexure Two: Technical Reports

f) **Report in Support of an Assessment of Effects on the Environment – Navigational Risk Assessment of Engineered Channel Designs. Navigatus. Geraint Bermingham and Paul Dickinson. Dated 15 August 2017**

Report in Support of an Assessment of Effects on the Environment

Navigational Risk Assessment of Engineered Channel Designs

Prepared for Chancery Green on behalf of Refining NZ
by
Navigatus Consulting

Post Consultation Report Rev 0

15 August 2017

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Prepared by Navigatus Consulting Ltd for:

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Revision	Date	Authorised By	
		Name	Signature
Draft A	11 October 2016	G. Bermingham	
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Draft for Client review	2 November 2016	G. Bermingham	
Revised Draft	2 December 2106	G. Bermingham	
Public Consultation Draft	14 December 2016	G. Bermingham	p.p.
Post Consultation Report Rev 0 Improved explanations in places. Includes consideration of navigational effect of disposal areas	15 August 2017	G. Bermingham	

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Table of Contents

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Glossary

Term	Meaning
Aft	Towards the stern, or back, of a ship.
Aframax Tanker	A medium-sized crude oil tanker with a dead weight tonnage between 80,000 and 120,000.
ALARP	As Low As Reasonably Practicable. An internationally recognised term used within the context of managing risk.
Bow	The forward part of a ship.
Breasting Dolphin	A man made structure that extends above the water level that is not connected to shore, against which a ship may berth.
Chart	A nautical map showing the maritime area including depths, navigation marks and selected tidal current flows.
Chart plotter	An electronic device that displays a chart and superimposes the GPS-derived position of a ship. The device can also display data such as ship speed and course.
Conn	To direct the steerage of a ship. An office performing this duty is said to 'have the conn'.
Currency	The extent to which an individual is recently practiced in undertaking an operation and up to date with procedures. Often to be considered 'current' an individual is expected to have carried out the procedure within a specified time period.
Deadweight Tonnage	A measure of how much weight a ship is carrying or can safely carry. It is the sum of the weights of cargo, fuel, fresh water, ballast water, provisions, passengers and crew.
Displacement	A measure of the weight of a ship. The displacement is the weight of the body of water that would otherwise be occupied by a ship.
Fore	Towards the bow, or front, of a ship.
Forepeak	The part of the hold of a ship within the angle of the bow.
Freeboard	The height of a ship's side between the actual waterline and the deck.
Grounding	The act of a ship coming into firm contact with the bed of the sea.
Heading	A direction or bearing.
Headway	The forward progress made by a vessel.
Human Factors	The factors that influence human performance in a given operational environment and situation.

Term	Meaning
Keel	The lengthwise steel structure that runs along the centre of the hull of a ship from the bow to the stern. Typically the lowest part of the hull of a ship.
Knot	A measure of speed. One nautical mile per hour.
Making fast	To attach a line securely.
Making way	Moving through the water.
Lateral mark	A post or buoy marking the side of a navigable channel. Usually accompanied by a 'Port' or 'Starboard' indicating which side of the channel is being marked for a ship entering port.
LOA	Length Overall. The total length of a ship including all fixtures and fittings.
Lead (ing) marks	Navigation marks (usually with lights and/or sight boards) permanently located so that when they align they indicate a defined path or bearing.
Master	The officer in charge (captain) of a commercial vessel.
Nautical Mile (nm)	A nautical unit used for measuring distances at sea, defined in the metric system as 1,852 metres (Historically, defined as one minute of latitude and traditionally approximated to 2,000 yards).
PEL	Port Entry Light. A fixed light has defined sectors. These sectors being coloured to act to indicate to a bridge crew the vessel bearing relative to the light. This to indicate by the colour of light seen, that the vessel is on the correct path, to port or starboard of the path, and unsafe areas so mariners can determine if they are on a defined path or at the correct position.
PIANC	The World Association for Waterborne Transport Infrastructure.
Pilot	A pilot (also referred to as a 'Marine Pilot' or 'Maritime Pilot') is a mariner knowledgeable of a given local area, who is employed to manoeuvre ships through local waters such as harbours or river mouths.
Pilotage	The act of piloting a ship.
Pilotage Plan	A plan of how the pilot will take a ship into, or out of, a port, typically including headings and speeds at a range of points along the way.
Port (side)	Left hand side of a ship (when facing forward on a ship). ALSO Left side of a channel when facing in the direction of the flood tide (usually up a channel), or otherwise as defined by the local maritime authorities.
PPU	Personal Pilotage Unit. A specialist portable chart plotter independent of the ship's own navigation system. Used by pilots.

Term	Meaning
Reach	A defined open or straight portion of water or channel.
Starboard (side)	Right hand side of a ship (when facing forward on a ship). ALSO Right side of a channel when facing in the direction of the flood tide (usually up a channel), or otherwise as defined by the local maritime authorities.
SOPs	Standard Operating Procedures
Stern	Back or rear end of a ship.
Steerage	Effective directional control of the ship by means of the action of water over the rudder.
Suezmax Tanker	A crude oil tanker, which is the maximum size that can transit the Suez Canal. Typical dead weight tonnage is between 120,000 and 200,000.
Waterline	The level of the water on the side of a ship. Or, the designed line that the water will be at with the ship in a known condition.
Way	As in “taking way off”. See Headway and Making way.
Windage	The effect of the wind on the surface of a ship (hull and superstructure) above the water line.