APPENDIX G

PORT OF NAPIER PROPOSED WHARF AND DREDGING PROJECT: PHYSICAL COASTAL

NAPIER PORT

Port of Napier proposed wharf and dredging project: Physical coastal environment

Prepared for

Port of Napier Ltd

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Executive Summary

This report presents an overview of the physical coastal environment in the vicinity of the Napier as part of the technical information in assessing the effects of Port of Napier Limited (PoNL) proposal for capital dredging of the central fairway, outer swing basin and inner swing basin at the Port of Napier.

The effects of dredging and dredge spoil disposal on the physical coastal processes and the wider coastal environment are identified through reference and interpretation of detailed technical studies that involved field observation, measurement and data collection, and numerical and empirical modelling.

The main considerations for the effects on the physical coastal processes were:

- Potential changes to the wave environment as a result of deepening the entrance channel and disposal of sediment,
- Changes to patterns of sedimentation in the wider coastal area, and
- The dispersal of fine sediments due to the dredging and disposal operation.

Studies carried out to investigate these effects have shown that they are mostly negligible, and of magnitudes within the variability of the natural environment.

1. Introduction

1.1 Background

This report provides an overview of the coastal processes and physical coastal environment in the vicinity of Napier. The report also addresses the effects of progressing Port of Napier Limited (PoNL) operations in deepening and making wider the shipping channel to provide for larger ships.

A broad range of work exists regarding the physical coastal environment around Napier. There is also a long history to this work, with early studies by Marshall identifying the distinct character of the shore prior to the 1931 Napier earthquake (Marshall 1927, 1929), and describing the effects of the earthquake soon after (Marshall 1933). More recently, Komar (2005, 2007, 2010; Komar and Harris 2014) synthesised a wealth of information, in describing coastal evolution, erosion and coastal management issues in southern Hawke Bay from Tongoio south to Cape Kidnappers.

Appendix 1 has been included as an addition to the references used in this report, and presents a bibliography of published papers, reports and unpublished research studies and technical information on the physical coastal environment of the area. This work has been referred to in providing an understanding of the coastal processes of the area with regard to assessing the effects of the PoNL proposal. The earlier work, in particular Komar (2010), Kirk and Single (1999) and Single (1985) in describing the general coastal environment, provides an appropriate basis for the overview presented in this report. Recent findings from investigations carried out for PoNL will be presented in relation to aspects of the assessment of the effects of dredging and dredge spoil disposal.

With regard to Appendix 1, shoreline evolution has been a major focus of studies due to the effects of the 1931 Hawke's Bay earthquake. However the nature of the sediment composition of the beaches and how this is a significant factor in the response of the shore to changes in the wave environment, response to storms and changes in the sediment budget has also resulted in much research, subsequent reports and management guidelines. Erosion of sections of the shore, such as Haumoana and Westshore has also resulted in a number of specific studies and reports. Recent coastal management focus has been on addressing coastal hazards and planning for the effects of climate change.

The local territorial authorities (Hawke's Bay Catchment Board – up until 1989, Hawke's Bay Regional Council and Napier City Council) have carried out coastal monitoring for over 40 years. Beach profile monitoring sites have been surveyed in some cases since the 1940s, but more regularly since 1974. In addition, other monitoring has included measurements of beach change over short periods of time, observations and measurements of sediment sizes and distributions across and along the shore, observations and measurement of wave parameters and currents in the nearshore, and measurements of winds. PoNL has measured wave and wind parameters offshore of the port and from the harbour breakwater respectively since 2004.

Data collection has also been carried out for research on different projects, such as long-term shoreline change, enhancement of surf breaks, gravel movement along and across the shore, long-term shoreline development, and the assessment of sediment budgets for different sections of the shore.

PoNL proposes to deepen and widen the existing approach channel to accommodate deeper draft and wider ships, and to establish a new berth (No. 6 berth) on the northern face of the main port reclamation. The layout of the work is shown in Figure 1.1. The dredging work will involve widening the current dredged channel, extending it seaward by about 1.3 km, and deepening it in stages to a depth of 14.5 m below chart datum. The project will result in the dredging and disposal of approximately 3.2 million m^3 of material. It is proposed that the dredge spoil will be deposited in a new 346 ha disposal area located approximately 3.3 km southeast of Pania Reef, approximately 5 km offshore of Town reef in water depths of about 20 to 23 m. The relative locations of the dredged footprint, the disposal area and the reefs are shown in Figure 1.2.

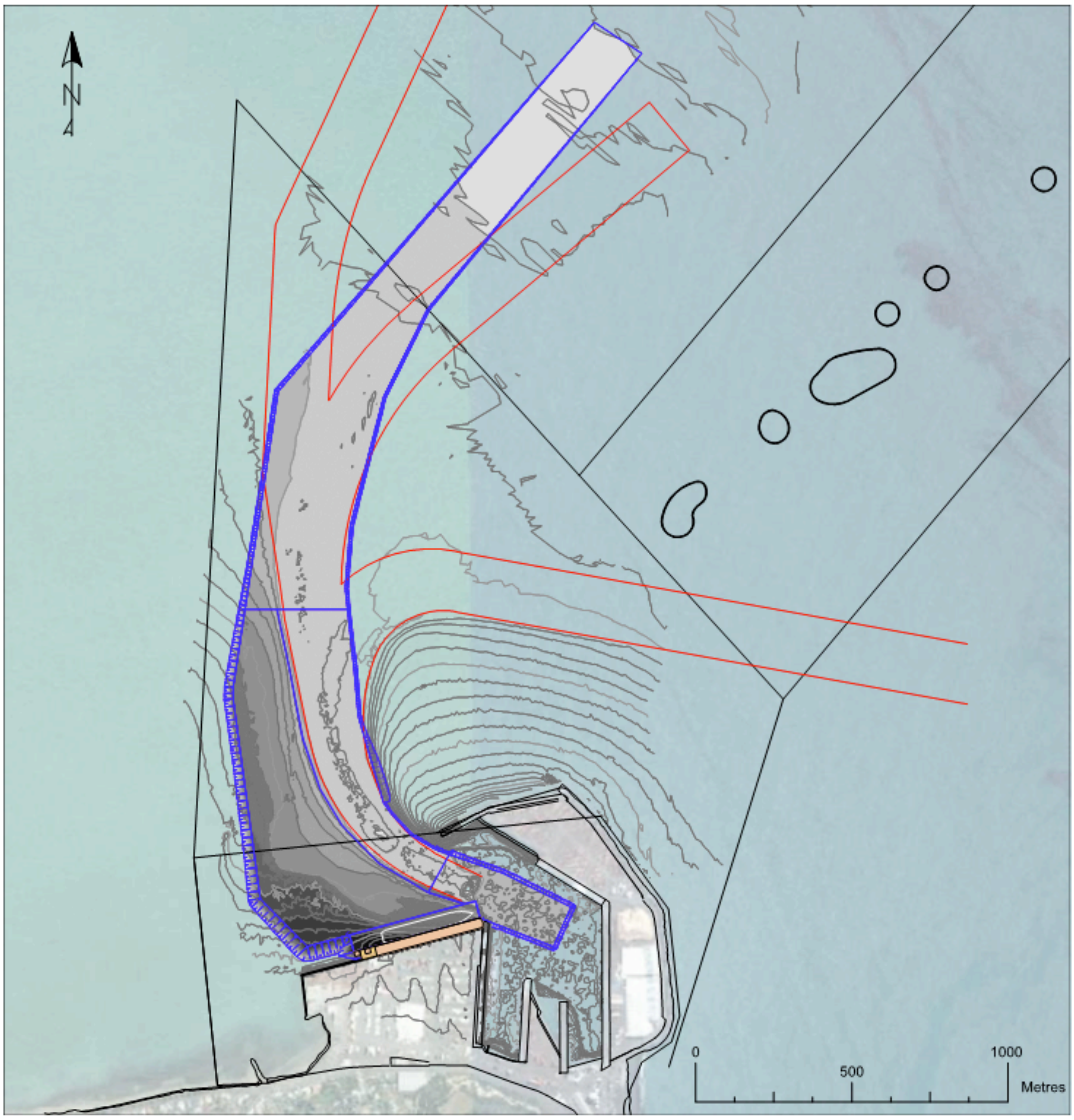

Figure 1.1 Footprint of proposed dredging works by Port of Napier Ltd

A number of studies have been carried out to augment the knowledge base of the coastal environment and to investigate specific aspects of coastal processes in the area including studies on:

- Hydrodynamic factors in the vicinity of the harbour and along the wave corridor landward of the shipping channel.

  Measurements of waves and currents offshore of the channel, inshore off Westshore and the Beacons, and offshore of Marine Parade were carried out to assess the wider coastal environment. The results are reported in Advisian reports (2017b, 2017c).

  Empirical and numerical modelling of the currents and wave processes was carried out by Advisian to assess the wider coastal environment for plume dispersal and receiving dredged material. The results are reported in Advisian (2017a, 2017b).

Advisian assessed the wave environment in the vicinity of the channel to identify changes to the wave propagation across the deeper channel and into the nearshore and beaches. The results are reported in Advisian (2017c).

- Sediment characteristics of material to be dredged from the channel and within areas to be dredged.

  Beca Ltd carried out an investigation of the geotechnical aspects of the seabed to identify the types and quantities of different sediments that would be dredged in deepening the channel and the swing basins. The results are reported in Beca Ltd (2016, 2017). Cawthron also collected sediment samples from the seabed in their assessment of benthic ecology factors (Sneddon *et al.* 2017)

- Sedimentological factors of potential dredge spoil receiving sites, including sediment characteristics of the nearshore and adjacent beaches.

  Beca Ltd and PoNL carried out measurements of nearshore seabed and beach sediments to determine the sizes and mixtures of sediments at potential dredge spoil receiving areas and to examine the potential for beach nourishment at Westshore.

The work on the physical coastal environment was carried out in conjunction with work on ecological matters. Sneddon *et al.* (2017) present a detailed assessment of the effects of the project on benthic ecology and fisheries.

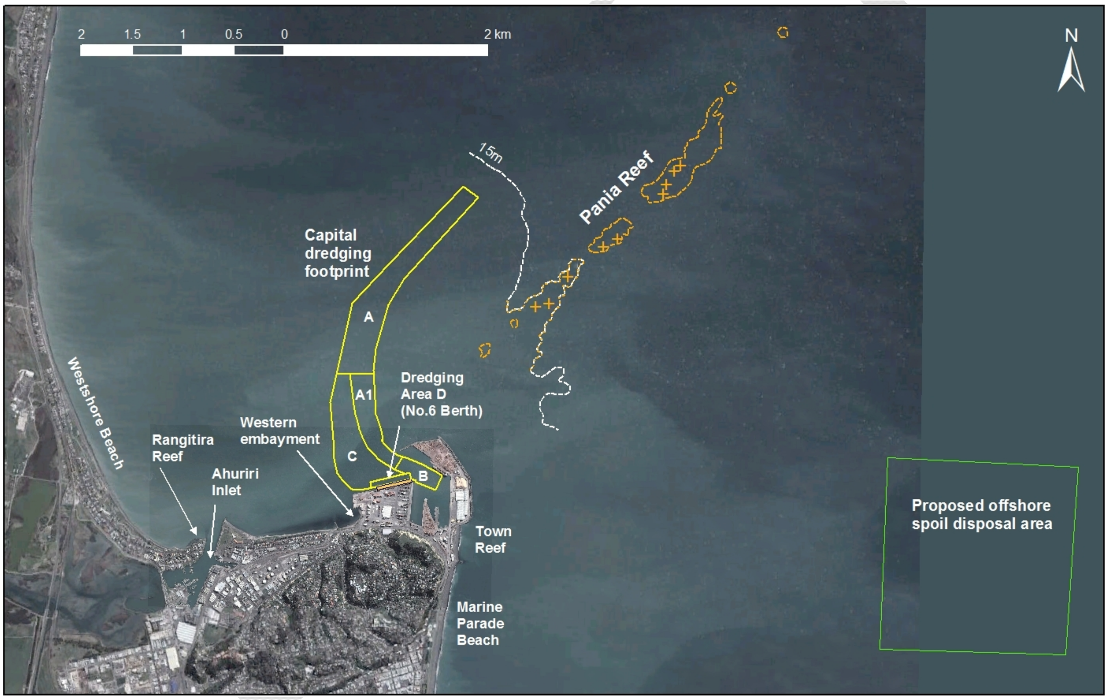

Figure 1.2 Composite aerial photograph of Port of Napier, showing the scale and layout of the proposed project elements (from Cawthron 2017).

1.2 Scope of this report

The scope of this report is to provide an overview of the physical coastal processes, and an assessment of the potential effects of the proposed dredging and disposal activities on the physical coastal environment in the vicinity of the Port of Napier. The specific objectives of the report are to:

- Describe the existing wave and current processes and the sediment transport patterns for the Napier coast.

- Summarise the changes to the coastal processes as a result of the proposed dredging and disposal and deeper channel.
- Summarise the potential effects of changes to the wave environment on the wave corridor inshore of the deeper channel and on the beaches west of the port, and to the area inshore of the proposed disposal site and the beaches of Marine Parade.
- Assess the effects of the proposed dredging operation and placement of dredged sediment on the sedimentation processes of the Napier coast. These effects include turbidity from dredging, at the dredged sediment placement site and areas in-between, and changes to wave refraction and sediment movement on the seabed as a result of placement of dredged sediment.

In particular, this report presents a synthesis of the findings of project specific studies carried out by Advisian, Worley Parsons Group Australia; Cawthron Institute; and Beca Ltd, namely:

- *6 Wharf Development - Geotechnical Factual Report*. Beca Ltd (3/9/2016)
- *6 Wharf Development: 3D Geological Model and Dredge Volumes*. Beca Ltd (23/10/2016)
- *Napier Port Proposed Wharf and Dredging Project: Dredge plume modelling.* Advisian (Unpublished draft 24/2/17)
- *Napier Port Proposed Wharf and Dredging Project: Post-disposal fate of dredged sediments.* Advisian (Unpublished draft 19/5/17)
- *Napier Port Proposed Wharf and Dredging Project: Coastal process studies.* Advisian (Unpublished draft June 2017)
- *Assessment of effects on benthic ecology and fisheries resources from proposed dredging and dredge spoil disposal for Napier Port.* Sneddon *et al*. Cawthron Institute (Unpublished draft 18/4/17)

2. The physical coastal environment of the Napier coast

2.1 Regional coastal character

The beaches of Napier exhibit the overall nature of the coastal environment. The beaches comprise a mixture of sand and gravel, and form the limit of the Heretaunga Plains. The plains are formed from deposition of silts, sands and gravels eroded from the inland Ruahine and Kaweka Ranges and from central Hawke's Bay, and carried to the coast by the Tukituki, Ngaruroro, Tutaekuri and Esk Rivers. Although the plains are a Holocene depositional feature, the barrier beach is a dynamic modern landform, and is likely to have had a similar form and character during the geological history of the area to what is present now. The beaches are a barrier between the plains and the sea in form and in the separation of the coarser sediments of the plains and fine sediments of the seabed. The crest of the barrier beach is also generally at a higher elevation than the plains to landward. The barrier beach system is a product of the delivery of sediments to the coast by fluvial processes, and reworking, sorting and alongshore distribution of these sediments by waves.

Figure 2.1 locates places referred to in the text. The arc of the shoreline is broken by Bluff Hill, once an island (Scinde Island) joined to the mainland by the extension of the barrier beaches from the south and north. The city centre of Napier lies behind the Marine Parade section of the southern barrier beach, while Ahuriri Lagoon sits behind the northern barrier beach of Westshore. The Port of Napier is an artificial harbour formed by the construction of a breakwater built out from Bluff Hill at the northern end of Marine Parade between 1897 and 1890.

A major factor in the form and character of the contemporary coastal environment is the change resulting from the 1931 Hawke's Bay earthquake. Tectonic movement resulted in uplift of the coastal block north of the Tukituki River, and subsidence to the south. The abrupt uplift of Ahuriri Lagoon resulted in reduction of the areal extent by about 12.8 km2, and major changes to the character of the Westshore shoreline. The beach at Westshore changed in form, from a narrow, gravel spit, to a broader barrier with a wide sandy expanse on the seaward side (Campbell 1975). The elevation and width of the beach along the Marine Parade also increased due to the earthquake uplift.

From Figure 2.1 it can be seen that the alignment of the beaches is generally north to south, facing east. The exceptions are the southern end of Westshore, where the shoreline curves to face northeast, the beach at East Pier, also facing northeast, and the shore between Ahuriri Lagoon inlet and the Port of Napier (Hardinge Road) that faces north to northwest.

Due to refraction within the bay, waves approach the shore from the east to east-southeast, and the beaches are generally aligned to the predominant wave approach.

In general, the mixed sand and gravel beach south of the port towards Awatoto (the Marine Parade) is stable to slightly accretional. South of Awatoto to the Tukituki River, the shore is stable to erosional, while south of the river the shore is predominantly erosional. The shore to the west of the port contains small pocket beaches, with a sandy beach adjacent to the port, and a mixed sand and gravel beach built out against the east pier of Ahuriri Lagoon inlet. Between these two beaches is a stretch of shore (adjacent to Hardinge Road and Spriggs Park) composed of natural and introduced boulder and cobble material that extends across the intertidal zone. The shore along Westshore, north of Ahuriri Lagoon inlet, is erosional and has changed in character from a mainly sandy shore up until the late 1970s to an artificially nourished mixed sand and gravel shore as a result of management measures undertaken to address erosion. The shore north of Napier Airport (also known as the Beacons, or the Airport Gap) is composed of a gravel dominant mix of sand and gravel, and is also slightly erosion in the long-term.

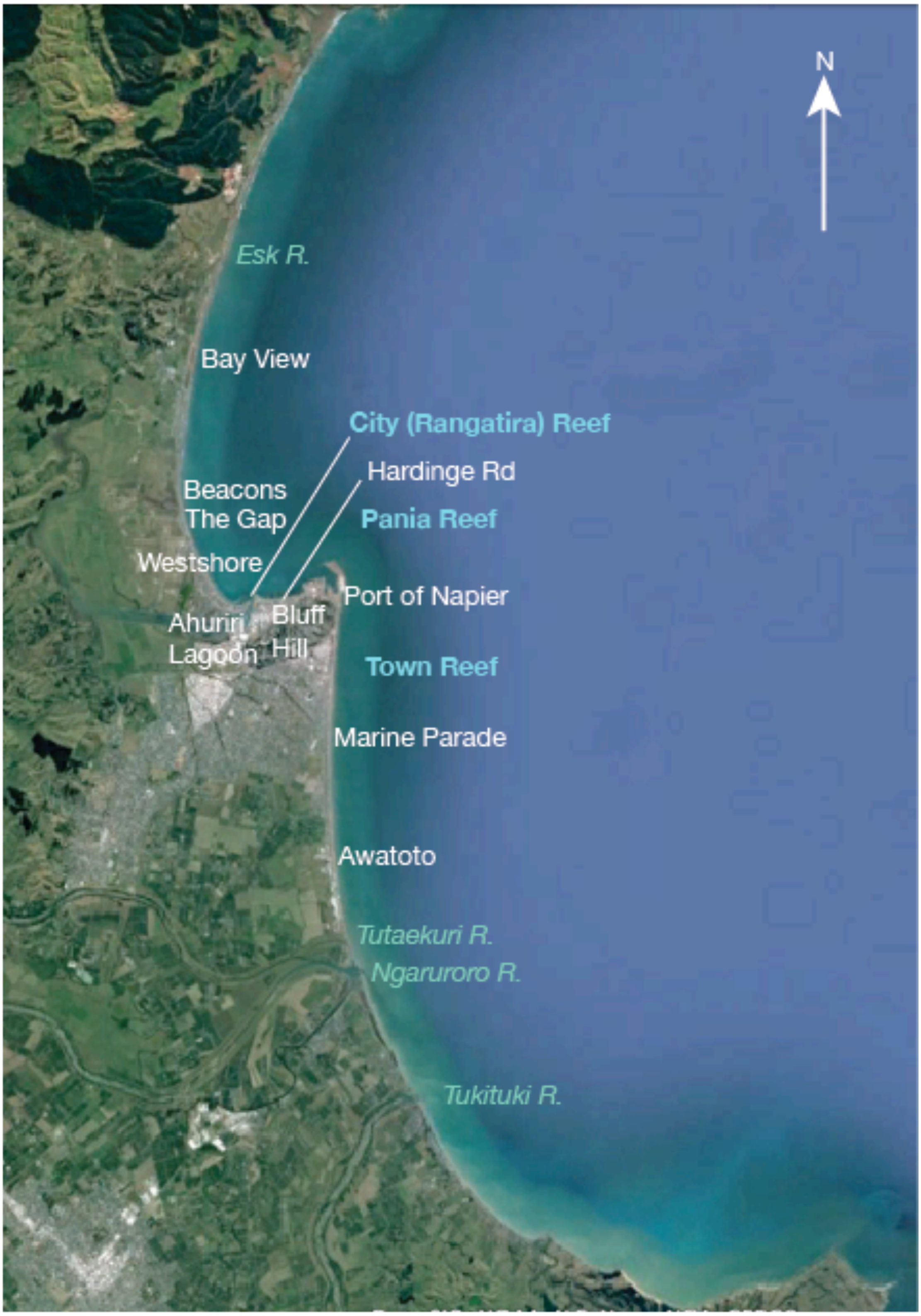

Figure 2.1 Location map of the southern portion of Hawke Bay (Satellite imagery from GoogleEarth). See also Figure 1.1 for locations near Port of Napier.

With regard to coastal recreation, Westshore is the main beach for swimming as the Marine Parade beach is steep and dangerous in all but the most benign conditions. A number of shore-based coastal recreational activities are located at East Pier and along the Marine Parade. The New Zealand surf guide identifies four regionally important surf breaks; *The Gap* – adjacent to the eat-west runway at the airport; *Westshore* – off the Westshore surf club; *City* *(or Rangatira) Reef* – at the southern end of Westshore (also known as Whakarire Avenue); *Hardinge Road* – along Hardinge Road from the East Pier to the east. These are all west of the port. Recreational diving and fishing is also important in the Napier coastal environment, with Pania Reef and Town Reef noted areas for these activities.

2.2 Local Geology

2.2.1 Local setting

The geology of the Napier area includes a complex range of reworked sedimentary deposits. Figure 2.2 shows a section of the QHawkesBay geology map. Dominating the coastal hinterland are folded and faulted late Cretaceous and Tertiary sediments making up the fan deposits across the Heretaunga Plains and Ahuriri area, a narrow band of beach deposits along the coast, and the outcrop of Pleistocene poorly sorted greywacke gravels with interbedded sand and silt that comprise Bluff Hill and Cape Kidnappers.

Figure 2.2 Section of the 1:250,000 Geological Map of Hawkes Bay (Lee *et al.* 2011), illustrating the complex of deposits and faults in the area.

A series of hills and low ranges run parallel with the Ruahine Range, lying inland of the Heretaunga Plains. Numerous fault zones are identified in the zone seawards of the low ranges, with the Heretaunga Plains lying to the east of the Matapiro Syncline. Major faults include the Roys Hill and Napier Faults, running from southwest to northeast, to the north and west of Bluff Hill, and the active Awanui Fault, also trending in a southwest to northeast direction, across the plains to the west and north of Hastings.

The Heretaunga Plains lies across the lower reaches of three gravel bedded rivers (Ngaruroro, Tukituki, Tutaekuri). The sediments carried to the coast by the rivers form the thick beds of conglomerates, greywacke sand and gravel underlying the plains (McLintock 1966).

2.2.2 Recent tectonic history

Komar (2005, 2010) presents a detailed discussion of the tectonic history of the area. The long-term nature of tectonic change is a result of subduction of the Pacific plate along the Hikurangi Trough. This has caused uplift of much of the region, including the Ruahine and Kaweka Ranges that supply the resistant greywacke rocks that form the Heretaunga Plains and the Napier beaches. Although long-term uplift has formed the mountain ranges, nearer the coast there is a geologic trend of submergence. Gibb (1996) notes subsidence of the plains at a mean rate of between 1 and 5 metres per 1,000 years. The long-term trend was abruptly, but temporarily reversed by the uplift north of the Awanui Fault during the 1931 earthquake.

Figure 2.3 illustrates the varied tectonic response along the coast as a result of the earthquake. The stretch of coast south of Awatoto towards Cape Kidnappers dropped by up to 0.7 metres. Komar notes “subsidence along this stretch of shore remains an important factor in its erosion” (2010 p 2-21).

Elevations along the shoreline north of Awatoto were raised at the time of the 1931 earthquake, with the amount of uplift increasing with distance north from the Awanui Fault to a maximum of about 2.4 m at Tongoio. Uplift of the Napier beaches was thought to be about 0.6 to 1.5 m at Marine Parade, and 1.8 to 2.0 m along Westshore. The immediate effects of the uplift included reduction in the size of the Ahuriri Lagoon due to drainage of the tidal water body, raised elevations of the beach ridge along Westshore, and an increase in the width of the beach at Westshore and along the Marine Parade. Figure 2.4 illustrates the dramatic nature of the change to the landscape, and the change in the form of the coastal barrier. The narrow gravel spit at Westshore immediately backed by the lagoon, could be overtopped by waves during severe storms before the earthquake, afterwards there was a wider expansive shore, backed by a gravel ridge. The low level of the beach along the Marine Parade extended landward nearly up to the fronts of buildings in the Napier business area, and were occasionally flooded by seawater during storms. The increase in elevation and beach width along this stretch of shore now provides protection for the city from storm waves.

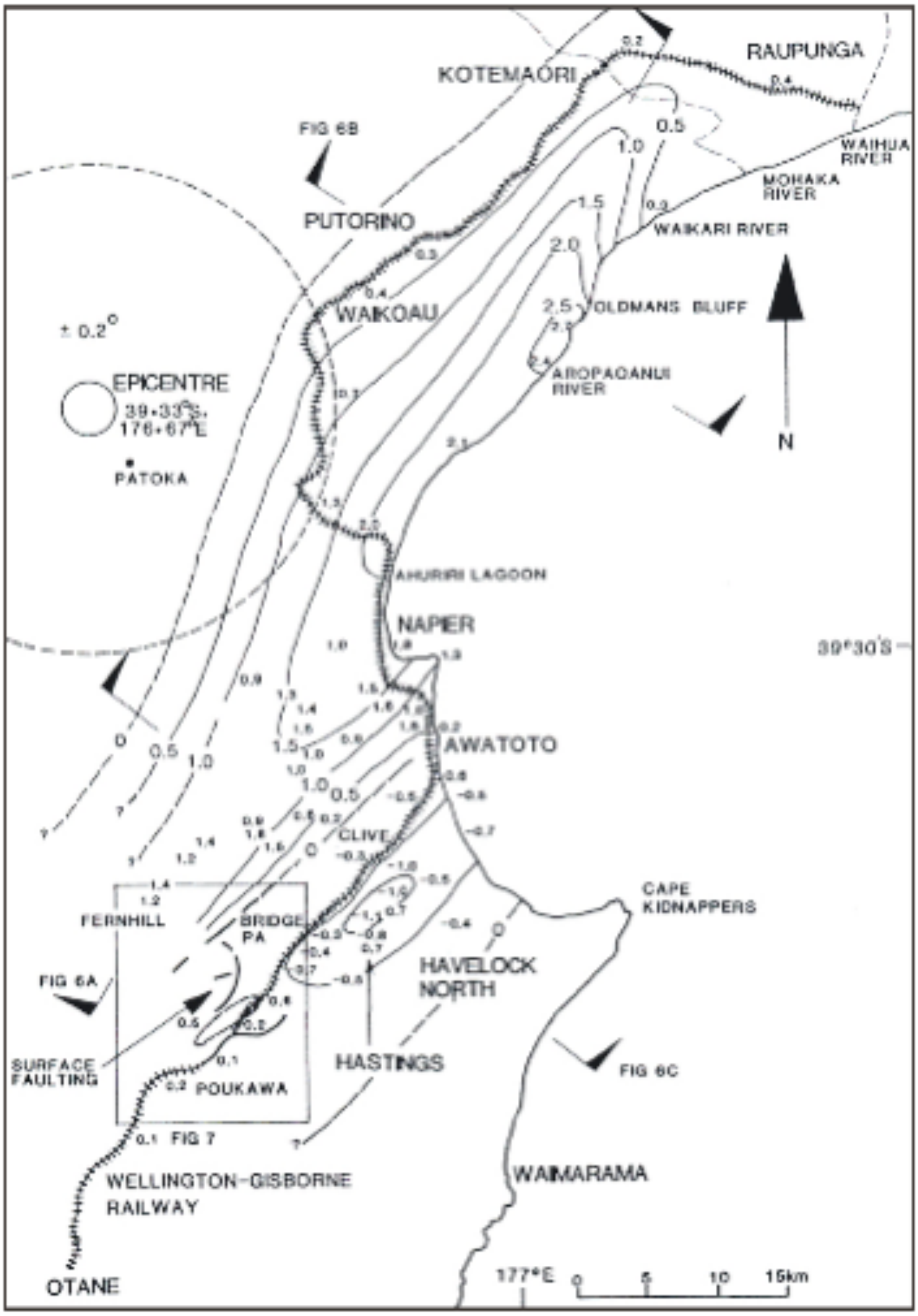

Figure 2.3 Land elevation changes produced by the 1931 Hawke's Bay earthquake. Negative values denote subsidence; positive values denote uplift (from Hull 1990).

Figure 2.4 Ahuriri Lagoon during the historic settlement period (after Stevenson 1977).

2.2.3 Seabed sediments

Figure 2.5 shows the distribution of sediments over the wider Hawke Bay area. Five main groups are evident from the work of Pantin (1966). Extending mainly in bands from shallow to deeper water, these are:

- Offshore sand belt (particle sizes 0.06 to 0.25 mm);
- Offshore gravel zones;
- Mud belt;
- Central zone; and
- Sediments associated with the Lachlan Ridge.

Sands in the offshore sand zone are generally finer than 2 mm diameter, and are sourced from fluvial injections of sediment into the coastal zone after floods, and fine material resulting from beach erosion and abrasion of beach gravels. Pantin described the spatial distribution of these sediments as being affected by different sedimentation factors, such as proximity to source area, rather than irregularities in the tidal or subsurface currents. The salient area east of Napier is a zone where Pantin found no recent, or at most slow deposition.

Gravels can be found on the seabed at depths of 18 to 30 metres, and comprise subangular to angular flattened Mesozoic greywacke pebbles and cobbles mixed with mud and sand. Further offshore, the seabed sediments possibly correspond to flood plains older than 12,000 years BP (Before Present), sitting on what is now the upper continental shelf. The mud belt and central zone comprise pebbly, muddy sand, and muddy gravel, while the sediments of the Lachlan Ridge are muddy sands, and sandy mud and gravel. Recent sedimentological surveys at Port of Napier have also found gravel deposits beneath the seabed in the vicinity of the port at depths greater than 18 m. These are possibly deposits from erosion of the Bluff Hill complex and are likely to be associated with much lower sea levels of the Holocene.

Sediments associated with the nearshore (shallower than 5 to 10 metres water depth), the port channel, and the Napier beaches are described further in sections 2.5 and 2.6.

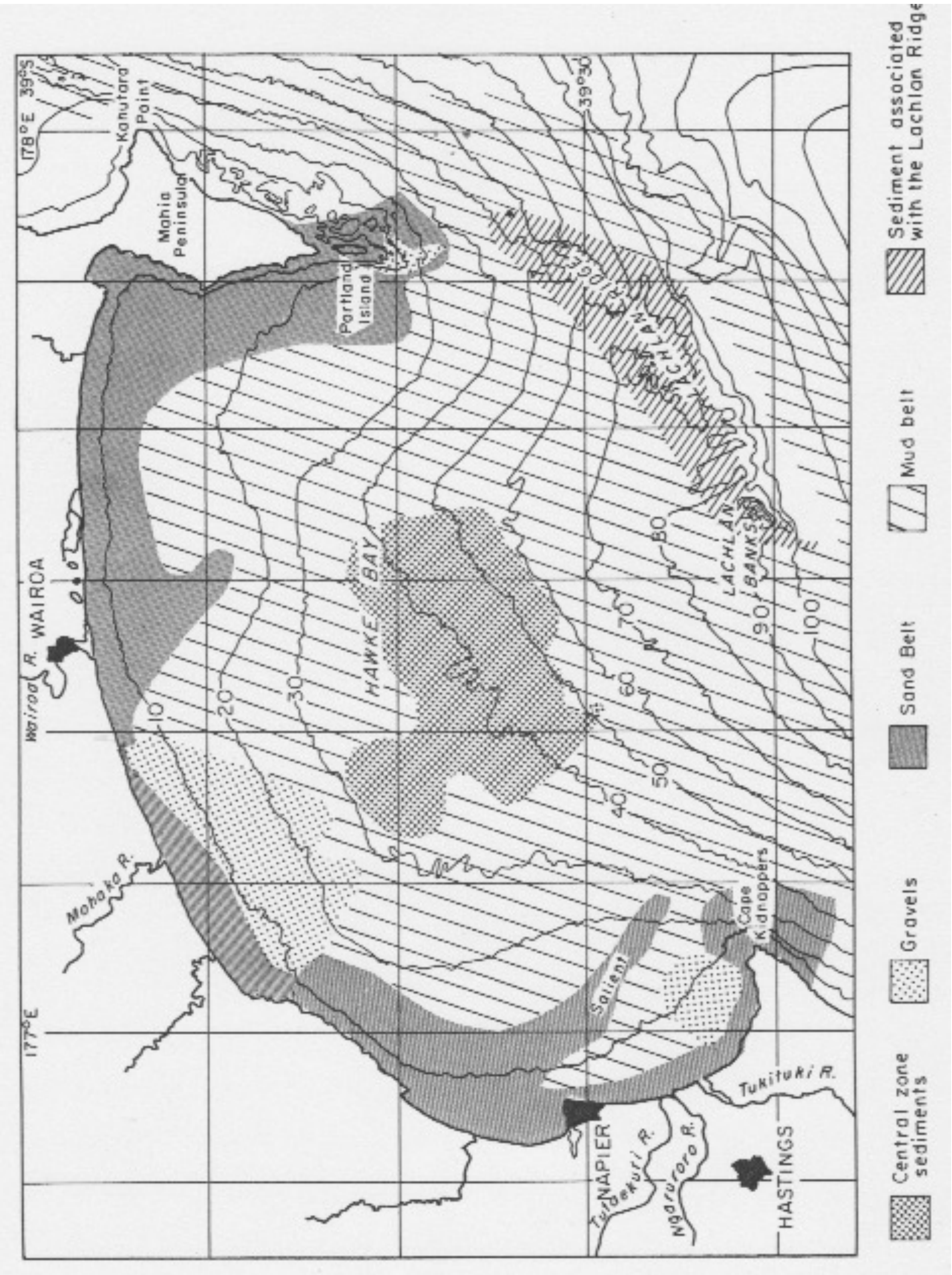

Figure 2.5 Bathymetry and distribution of offshore sediments in Hawke Bay (from Pantin 1966, Figure 7).

2.3 Process environment

2.3.1 Waves

Waves provide energy to do work in generating sediment transport on the seabed. The direction of the wave approach is important in governing the direction of sediment transport. However waves work in conjunction with other ocean currents in determining the nature and direction of coastal and inner shelf sediment movement. In water deeper than about 15 to 16 m, wave energy and the motion of water particles under the wave can act to disturb sediment particles on the seabed, initiating movement that results in entrainment of the particle by a combination of wave, tidal and oceanic currents. In shallower water, incident waves play a very important role in short and long-term beach stability, beach form and evolution, and have a direct effect on nearshore processes that include sediment transport.

In the nearshore, where depth are less than about 10 m, waves start to shoal and transform, changing shape and direction of travel. The energy of shoaling and breaking waves govern patterns of sediment transport to a considerably greater degree than tides and oceanic currents. In Napier, the shape of the waves inshore of the port channel provide for recreation through surfing at Hardinge Road and along the Westshore coast.

2.3.2 Wave environment off Napier

Wave data at Napier has been collected over various periods, including by the Ministry of Works from 1975 to 1980, PoNL in 2000 and from 2004. Additional wave data was collected for this project since April 2016. Advisian have used the wave data record (from 2004 to 2016) in calibrating wave models for assessment of the effects of the proposed dredging and disposal. Figure 2.6 shows the position of wave data collection, while Table 2.1 summarises the instrument type, wave parameters measured and the period of data coverage.

Figure 2.6 Locations of wave gauge instruments in relation to Napier Port (from Advisan 2017c).

The majority of waves approach Hawke Bay from the southeast. However they are refracted within the bay so that the approach to the shore is from the east to east-southeast. Data from the Ministry of Works show that 55% of all waves approach the beach from the east to east-southeast, and 42% approach from the east to east-northeast. Average significant wave heights (Hs) ranged from 0.1 to 3.5 metres, with 50% of all waves between 0.5 and 1.0 m (Smith 1984). These general conditions were also found in later analysis of data from the Port of Napier buoy.

The wave buoy was installed in 2004 and operates to the present day. The buoy provides directional swell wave information in roughly 15 m depth of water, seaward of the breakwater at Napier Port (Figure 2.6). Figure 2.7 shows a wave rose of the wave height and direction statistics as collected at the Port of Napier buoy. Analysis of the wave data by Worley Parsons (e.g. WorleyParsons, 2006; WorleyParsons, 2011; Advisian, 2017c) show that highest wave conditions occur generally during winter (July and August), when the Hs is in the order of 1.5 m. Highest waves generated by the stronger storms can occur from June through September, typically achieving significant wave heights in the order of 2.5 to 3.5 m. The mean peak-energy wave period is approximately 12 seconds, but storm waves with Hm0 ≥ 4m can occur with periods between 10 and 16 seconds.

Table 2.1 Locations of wave gauges (from Advisan 2017c).

Location	Instrument type	Position	Parameters	Period
Offshore	Triaxis buoy	39.457690˙ S, 176.93442˙ E	Swell wave height, period, direction	2004 to present
Channel Approaches	Triaxis buoy	39.463400˙ S, 176.907713˙ E	Swell wave height, period, direction	May - September 2016
Beacons	RBR Solo (pressure transducer)	39.459333˙ S, 176.879575˙ E	Swell wave height, period	April - September 2016
East Pier	RBR Solo (pressure transducer)	39.475750˙ S, 176.897098˙ E	Swell wave height, period	April - September 2016
Hardinge Road	RBR Solo (pressure transducer)	39.476017˙ S, 176.905400˙ E	Swell wave height, period	April - September 2016

The wave climate at the Triaxys wave buoy is highly directional, which is to be expected given that storms in the Southern Ocean are the primary source of wave energy. The largest and most frequent waves are incident from 90° to 120° relative to true north (i.e. from east–southeast), representing some 72% of the measured waves (Worley Parsons, 2006). A relatively small portion of the waves, less than about 5%, arrive from northeasterly directions from 0° to 90°.

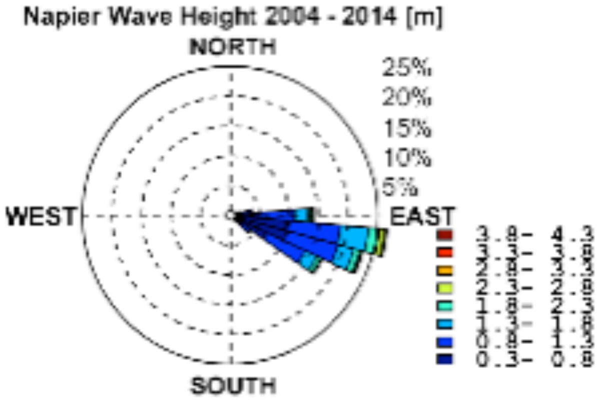

Figure 2.7 Wave statistics recorded at Triaxys wave-rider buoy NE of Napier breakwater (from Advisian 2017c)

2.3.3 Ocean and Tidal Currents

There are three types of water currents in Hawke Bay. These are ocean currents, tidal currents and wave-induced currents. Francis (1985) presents an overview of the general circulation of water that shows inflows of ocean currents north and south of the centre of the bay opening. These flows divide within the bay proper. Flows from this division go north and south, passing out of the bay close to Cape Kidnappers in the south and Mahia Peninsula in the north. Ridgway (1960) states that these flows have little effect on nearshore sediment movement.

The maximum tidal range at Napier is less than 2.0 m, and can be classified as microtidal. The spring and neap ranges are 1.9 m and 1.2 m respectively. There is a seasonal difference in the mean water level of up to 0.1 m, and due to the effects of low pressure, atmospheric systems, the highest levels are in the autumn and early winter months (March to June) with a decline to the lowest levels in September.

Analysis of tidal flows (e.g. Francis 1985; Hume *et al.* 1989; Mead *et al.* 2001; WorleyParsons 2005) concluded that the tidal currents within the bay do not have a strong reverse flow, in that although the flood tide sets to the north and the ebb sets to the southeast, the reversal in flow only accounts for up to 34% of the variance in the current speeds. The tidal component of current speeds is generally accepted at around 0.04 – 0.05 m/s. It is likely that tidal currents can cause offshore movement of suspended sediment, and can carry sediments out into the bay (Pantin 1966).

Numerical modelling (Mead *et al.* 2001, WorleyParsons 2005) strongly suggests the presence of a persistent anticyclonic gyre immediately northwest of the Port breakwater under strong winds from the southwest. During westerly and northwesterly winds, currents are directed in a southeasterly direction along the coast.

These broad-scale currents are very low velocity, and are unlikely to result in sediment transport in isolation of other forcing energy. However these currents can work in combination with wave activity that induces sediment movement through suspension and unequal distribution of energy along the shore to contribute to sediment circulation patterns.

Advisan (2017a, 2017b) present detailed analysis of current flows as derived from measurements off Napier. Site of measurement are shown in Figure 2.8. These measurements were used to calibrate models of current flows for assessment of the long-term effects on sediment transport. Figure 2.8 also shows roses of the current speeds and direction. Generally a net current of around 0.02 – 0.04 m/s is described for current meter sites between Westshore and the Port. Currents tend to flow parallel to the bathymetric contours, with a net northwest to southeast flow offshore of Westshore, and a net easterly flow adjacent to the port. To the east of the port, the net current flow is to the south and southeast.

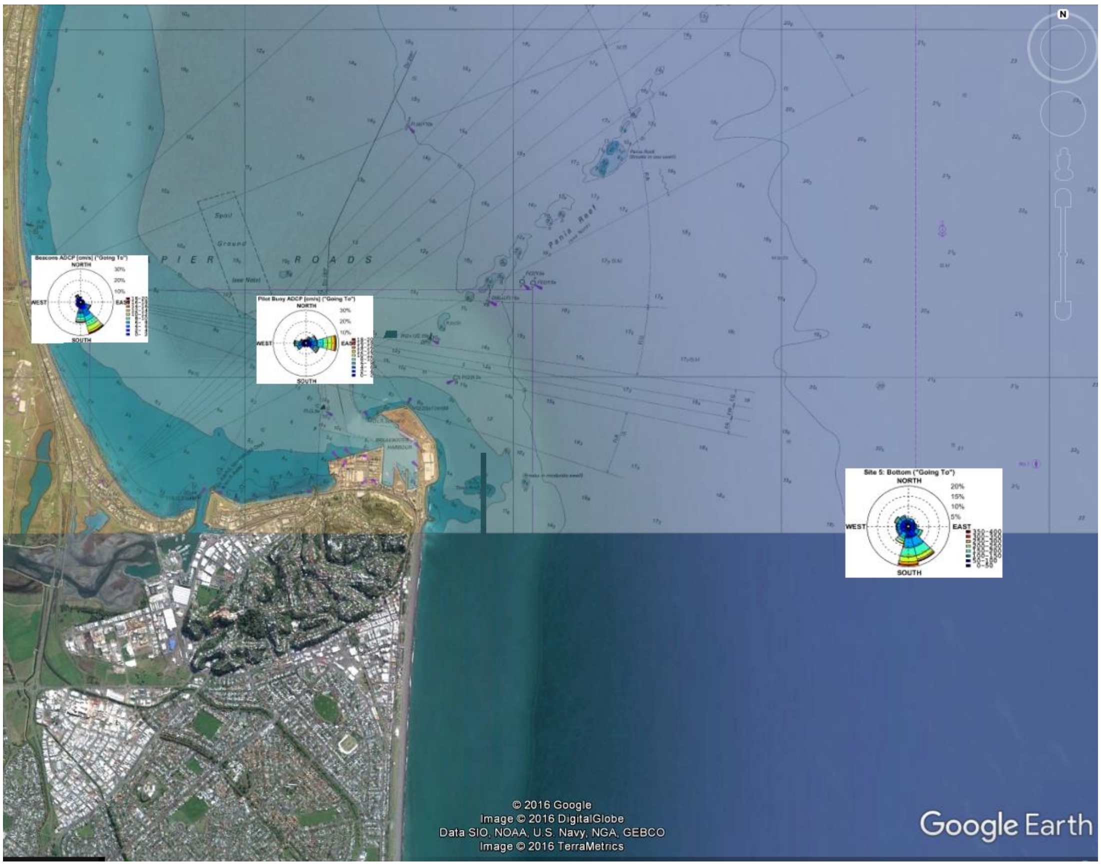

Figure 2.8 Measured current speed and direction at ADCP sites 'Beacons', 'Channel Approaches' and the proposed disposal site. Directions given as 'going to' (from Advisian 2017b).

2.4 Bathymetry

Figures 2.9 and 2.10 show the bathymetry of the area offshore of Napier. The bathymetric contours tend to lie parallel with the coast. The seabed slopes gently to depths of 150 to 200 m at the edge of the continental shelf. The 30 m depth lies about 14 km offshore of the Marine Parade and Westshore. The 10 m depth contour lies less than about 1 km offshore of the Marine Parade, but is further offshore of Westshore and Hardinge Road. This area of relatively shallower water between the port and Westshore is evident in Figure 2.10.

The port channel (dredged to about 12.4 m depth) is about 2.0 km long, heading northwest and then north from the port.

Two other features visible on Figure 2.10 are Pania and Town Reefs, located to the northeast and south of the port respectively. Both reefs run in a southwest to northeast direction. The shallowest parts of Pania Reef lie at a depth of about 8 to 10 m, with the surrounding seabed extending from a depth of about 14 m to a depth of about 18 m. Town Reef projects from the seabed within the 10 m depth contour, with the highest points on the reef about 4.5 m below chart datum.

PoNL proposes to locate the dredged sediment placement site for this project centred approximately 5 km offshore, east of the Marine Parade, and approximately 3.55 km southeast of Pania Reef, in approximately 20 to 23 m of water.

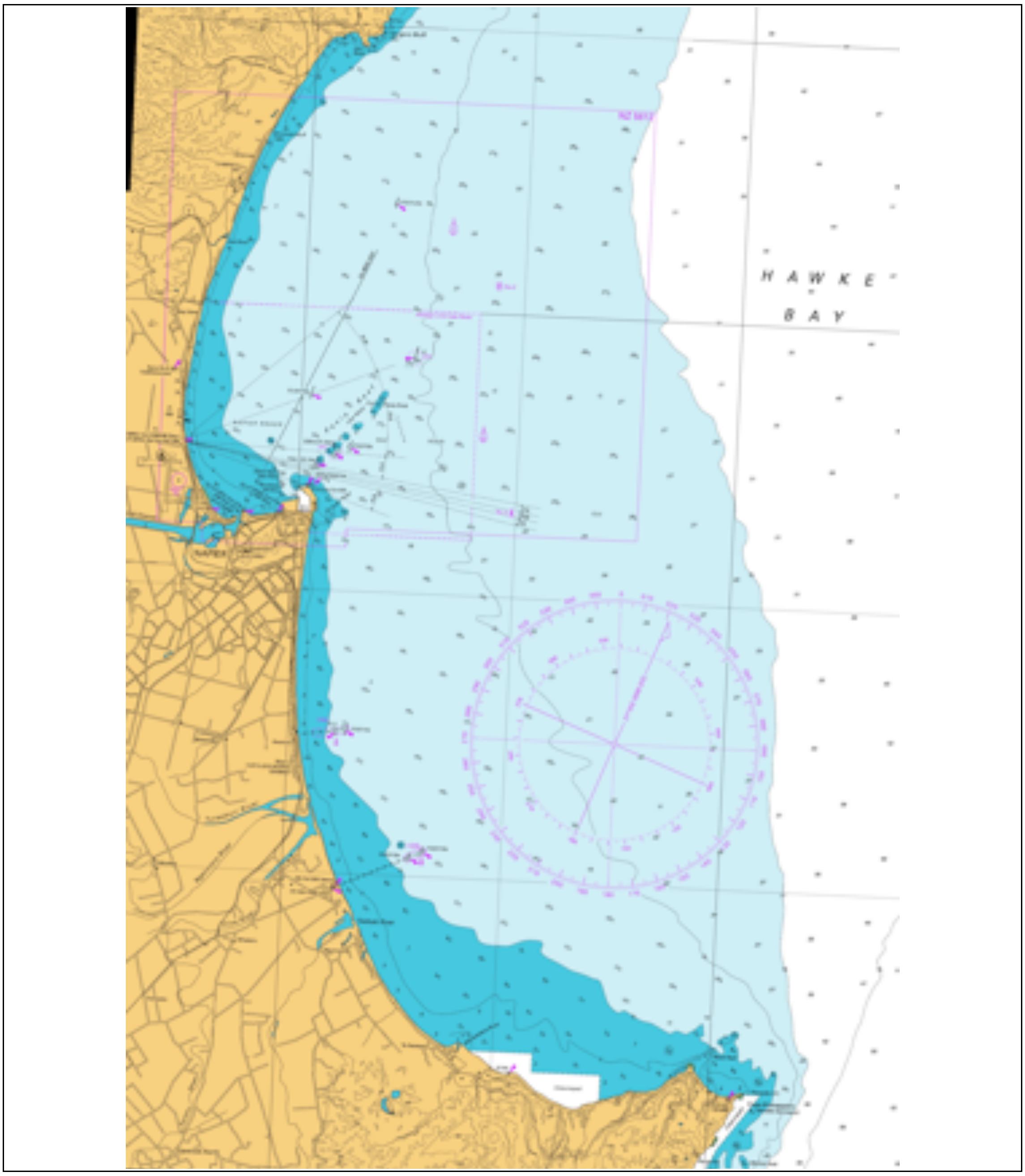

Figure 2.9 Section of New Zealand Hydrographic Chart NZ561 Approaches to Napier (Thumbnail download www.LINZ.co.nz).

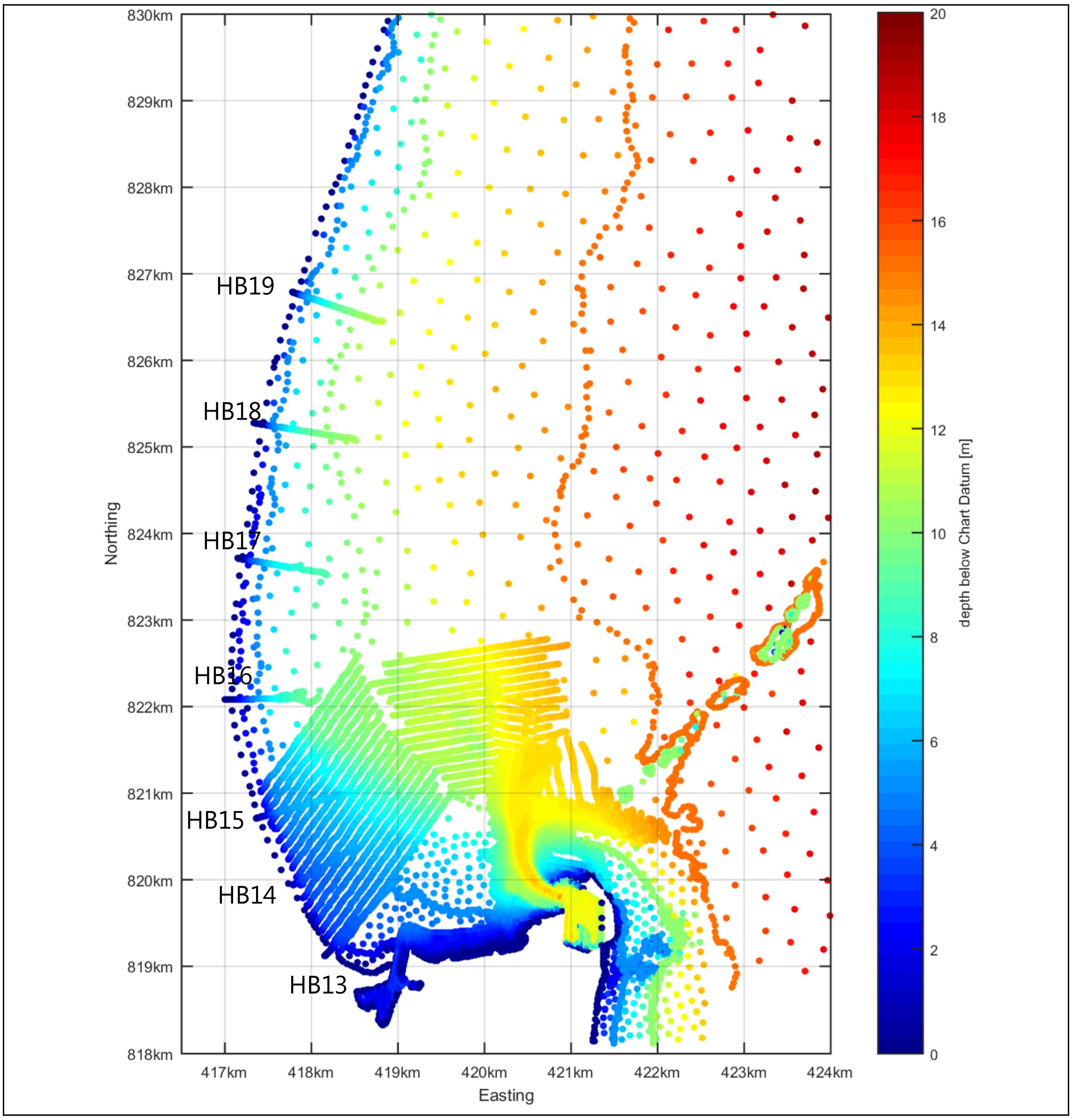

Figure 2.10 Spot depths (relative to Chart Datum) for sea floor surrounding Napier Port (from Advisian 2017c).

2.5 Beach sediment characteristics

A small number of studies have concentrated on the specific character of the beaches of Napier. However the distinct character of the coastal sediments was recognised very early (Marshall 1927). Although there are variations between the beaches to the south and north of the port, they show general characteristics of the distinct mixed nature of the sediments. Basically the beaches are comprised of a mixture of sand and gravel, derived from greywacke eroded from the mountains and transported to the coast mainly as bedload. Komar (2005) presents an extensive review of this type of beach, noting the differences from 'pure' sand or 'pure' gravel in the form and response to wave action.

The presentation of the mixture of sediments in defining the shape and appearance of the beaches depends on the day-to-day variability of the 'mix' of sizes, and whether sand, pebbles or larger sediment sizes are dominant on the beach surface. This sorting and distribution of sediments on the beach occurs in response to changes in the wave environment, the energy of the waves and supply of sediments from along the shore or across the beach, including sediment movement on and offshore.

A particular aspect of mixed sand and gravel beach processes is the across-shore zonation of sediment sizes, and the separation of the coarser component from fine sediments by a steep break in beach slope between the beach and the nearshore seabed. The crest and backshore of the barrier beach, as found at Marine Parade, is made up of coarse gravels and large disc-shaped pebbles. These are carried to the upper reaches of wave run-up and deposited as the wave swash percolates into the beach. Although storm waves reach high on the beach, they can result in deposition of sediments, such that the upper foreshore, below the crest, can have a combination of moderately sorted coarse gravels and sand particles mixed together. Lenses of sand can also be found below the crest of berms and in the bays of cusps. The lower foreshore contains sediments of all sizes, and they are usually well-sorted, so that pebbles, gravels and sand can often be seen to be separated out in bands running along the beach.

On the Marine Parade, the separation between the beach and the nearshore is readily apparent as it lies beneath the narrow surf zone, often containing a single line of breakers. Waves are usually of a plunging type, and the zone of action, where ‘work’ is carried out in movement of sediment and dissipation of wave energy occurs mostly beneath the breaker and within the swash, as the broken wave runs up the beach. There is also a distinct separation of transport of sediments, with coarser particles moving on the beach face and immediately under the breaking wave, and fine particles (fine sand and silts) moving offshore and along shore on the seabed.

There is less distinction between the lower part of the mixed beach and the nearshore at Westshore. Although the Westshore beaches can behave very much like the Marine Parade, there is usually a much larger proportion of sand in the sediment mix. This leads to a wider lower foreshore and a more gradual transition from the beach to the nearshore. There is usually a wider surf zone, and waves can break offshore and reform as they shoal inshore. Sediment transport of coarse sand along the shore will occur within the surf zone, although gravels will usually only move within the swash on the upper beach.

The nearshore to beach transition is made more complex at Hardinge Road due to the presence of a coarse cobble lag deposit along the shoreline, extending seaward of the intertidal zone. The eastern section of this shore is also relatively sheltered from waves, so sediment movement along the shore occurs mainly in the nearshore. The beach at East Pier is similar in character to the mixed sand and gravel beaches of Westshore and Marine Parade.

PoNL collected samples from the low tide level and the position of mean high water on the beach at 15 locations between the Port Beach and Esk River in January 2016 (Advisian 2017c). They found a wide range of sizes at each site. However the mixed sediments at the low tide level can be classified as fine gravel, ranging in size from medium sand to coarse gravel. Generally the sediments collected from the mean high water level showed more variability along Hardinge Road and Westshore, but showed a trend of increasing grain size with distance northward for the samples from north of Westshore.

2.6 Nearshore sediment characteristics

Although the nearshore off Napier is generally described as mantled in medium to fine sand, there is localised variability to the seabed sediment texture. Hume *et al.* (1989) and Mead *et al.* (2001) describe the spatial variability of the sediment size distribution for the area between the port and Westshore. Data from those studies and from grab samples collected by PoNL and Cawthron were combined to produce Figure 2.11, showing the spatial distribution of sediment grain size.

Mead *et al.* (2001) found for 100 grab samples, that the median grain size for sandy sediments was in the range of 0.11 to 0.31 mm, with an average of 0.15 mm. This is predominantly very fine, to fine sand. Coarser sand sized sediments are found within 2 to 5 m water depth and are more dominant along the northern section of Westshore. Hume *et al.* (1989) report that the mud fraction (<0.0625 mm) is limited to deepwater areas greater than 5 m and generally comprised 10 to 20% of the sample. The sand fraction (0.0625 to 2 mm) generally comprises up to 80 to 100% of the sample, of which the bulk of the sand fraction is fine (0.125-0.25 mm) to very fine sands (0.0625- 0.125 mm). Sediment sampling and grading analysis by the PoNL and Cawthron (2017) and by Beca (2016a) show sands within the Port area have a D50 of 0.10 to 0.12 mm and a D90 of approximately 0.90 mm.

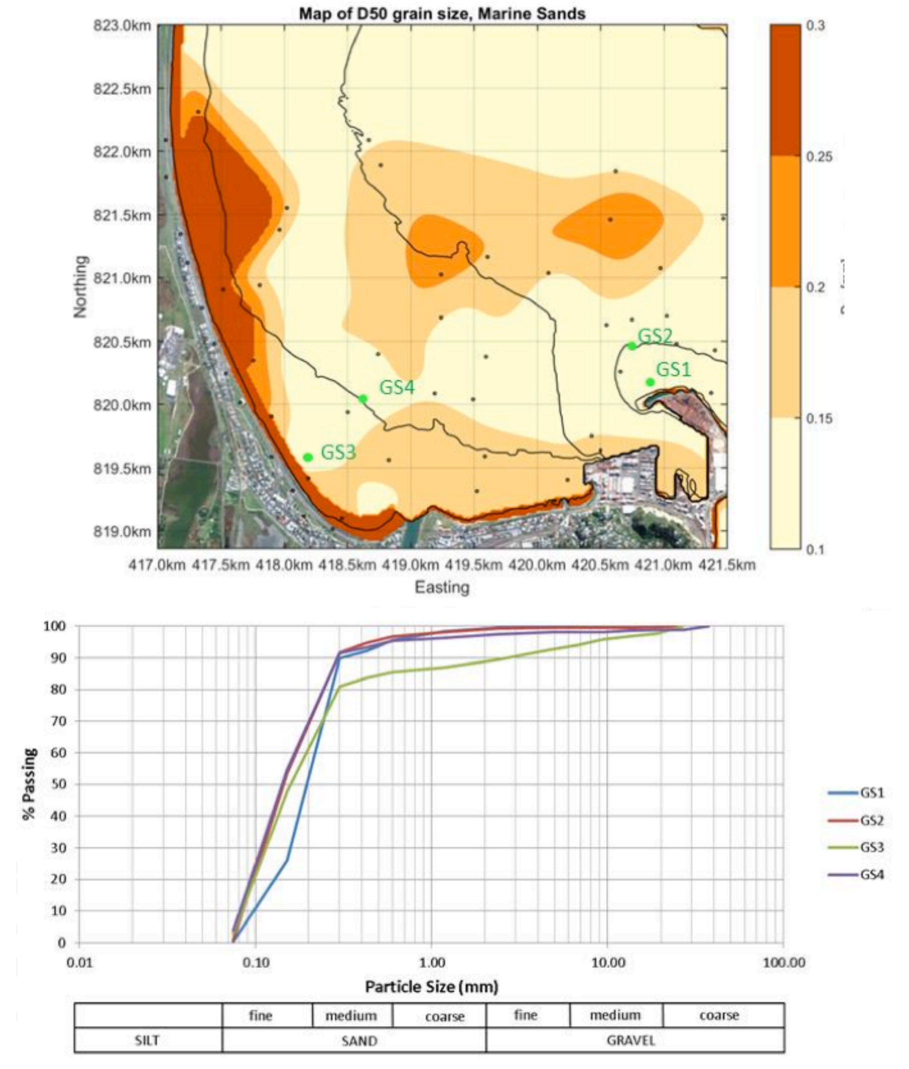

Figure 2.11 Spatial distribution of sand sizes in the sub-littoral zone north and west of Port of Napier. Lower panel shows distribution of grain size for samples taken adjacent to the port breakwater (samples GS1 and GS2) and Westshore (GS3 and GS4) (from Advisian 2017c).

An important feature of the nearshore sediment distribution apparent from Figure 2.11 is that the band of coarser sand (over 0.25 mm in diameter) is confined to a generally narrow band near the shore. This spatial distribution reflects the source of the coarser sand. It is a by-product of the sedimentary geology and the process environment. Coarser greywacke particles (pebbles and gravel) abrade under wave and swash action as sediment particles interact. The sediment particles wear down and get smaller. In effect, the coarse sand is a temporary state of the sediment particles. This is a feature of the sedimentary nature of greywacke, and is observed on other coasts of this type of sediment such as the Canterbury Bight, South Canterbury and the West Coast of the South Island. Although medium to coarse sand is produced in the abrasive beach environment of mixed sand and gravel beaches of this type, it does not persist as individual grains in the same way as quartz sand.

The abrasion results in a “source area” effect. The coarse sand will remain near to where it is produced. This is apparent along the coast south of Napier, where sediment from the Tukituki River is transported north along the coast. As the sediment moves, particles abrade. Finer particles such as fine sand and silt (smaller than 0.25 mm in diameter for example) is eventually transported offshore on the seabed or in suspension. At Awatoto, the sand fraction dominates on the lower foreshore, but is less dominant further north. This process is also evident at Taumutu and along Kaitorete barrier beach in Canterbury, and in South Bay, Kaikoura, as a result of northward sediment transport from the Rakaia River and Kowhai River sources of beach sediment. Further from the source of sediment to the beach, the more resistant (or harder) particles dominate the sediment mix of sizes, resulting in more pebbles present on the beach.

At Westshore, artificial nourishment of the beach introduces gravel and pebbles to the wave environment. These particles abrade and produce a source of sand sized particles that are transported north. Sand sized particles are also transported south along the shore from the Esk River and Bay View. This is the likely cause of the extended area of medium to coarse sand found in the area of The Gap and the Beacons.

A further sorting process occurs perpendicular to the shore. Larger particles require more energy to move, so the coarse sand is predominantly located in areas of relatively higher energy such as within the surf zone or near the shore, while finer particles are dominant further offshore. Shoaling waves also transport finer sediment particles offshore (predominantly), while the coarser particles move onshore under the same wave motion.

Offshore of the coast, the seabed surface sediments are underlain by a stiff silt/siltstone of variable depth and basement rock at depth. The stiff silt is described as a stiff, cohesive silt rather than clay with stiffness increasing with depth (Ocel, 2004). Beca (2016a, 2016b) carried out core sampling within the port channel and harbour area. Figure 2.12 shows the sediment size distribution of the near-surface samples within the existing navigation channel, and the proposed dredge footprint. This sediment is also predominantly very fine, to fine sand. All but three of the twenty-two surface samples from the navigation channel seaward of the end of the breakwater contain particles predominantly (greater than 86% of the sample) less than 200 µm (0.2 mm) in diameter. The three remaining samples are all located near the distal end of the breakwater. One contains 31% medium to coarse sand (less than 2 mm diameter), 67% sand finer than 0.2 mm and 2% silt, one contains 41% medium to coarse sand (less than 2 mm diameter), 58% sand finer than 0.2 mm and 1% gravel, and one contains 27% medium to coarse sand (less than 2 mm diameter), 73% sand finer than 0.2 mm, 1% silt and 1% gravel. A sample with up to 20% coarse sand and a small proportion of gravel was located about 750 m due north of Port Beach (Cawthron 2017), on the western edge of the capital dredging footprint.

In summary, the surface and near-surface samples show:

- Approximately 20% of sediments are finer than 0.1 mm (100 µm);
- Approximately 70% of sediments are sized between 0.1 mm and 0.2 mm (100 µm and 200 µm);
- Approximately 10% of sediments are coarser 0.2 mm, 5% coarser than 0.3 mm than 0.1 mm and 1% coarser than 0.5 mm;
- The median (d50) particle diameter is approximately 0.125 mm.

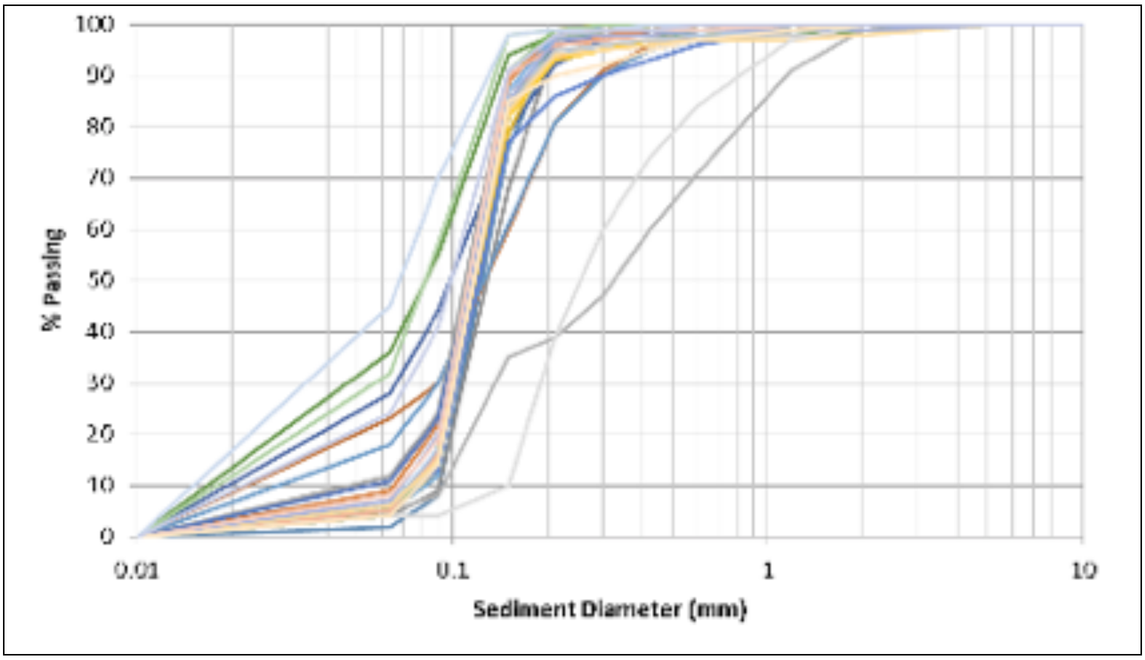

Figure 2.12 Particle size distribution of near-surface vibrocore samples taken within the proposed dredge footprint of Napier Port navigation channel (from Advisian 2017b).

2.7 Sediment transport paths

Interpretation of the potential for sediment transport based on the process and sediment relationships gives a first order description of how and where sediment might move on the seabed and in suspension. This interpretation is checked against observations in the field, such as sediment size analysis. However rates of sediment transport are difficult to predict, and so numerical modelling is undertaken using input data on the sediment properties, and derived transport capacity by currents based on wind, wave and current measurements in the field. Sediment transport modelling results show the **potential** for sediment to move due to the size of sediment in the environment and the energy vectors (magnitude and direction) relating to wave action and wave, wind and tidal currents. The amount or volume of sediment transported will depend on the amount of sediment of different sizes being 'available' for transport by the energy processes.

Figures 2.13 and 2.14 show inferred pathways of sediment transport on the beach and in the nearshore off Napier. These pathways are derived from a combination of interpretation of the seabed sediment character, interpretation of the process environment, observations and numerical modelling. Physical coastal processes distinct to mixed sand and gravel beach systems and specific to the Napier coastal environment are illustrated in the figures. In particular, Figure 2.13 shows:

- There is separation between the beach and nearshore transport system, and the nearshore and offshore transport system.
- Mixed sand and gravel is moved on the beach in the swash zone, resulting in abrasion and contributing medium and finer sand, and silt particles that are dispersed to deeper water. This occurs at all sites where these mobile sediments are present, including point sources such as the rivers, artificial nourishment sediments at Westshore, and the mixed sand and gravel beaches.
- South of the port, beach sediment transport can occur in both north and south directions, with waves often not fully refracted when breaking.

- From Ahuriri inlet to Bay View there is a net northward transport of sediment on the beach and under wave action in the littoral zone.
- Along Hardinge Road, beach sediment transport occurs to the west at East Pier, and to the east at Port Beach.
- The potential work of wind-driven currents is a factor of the wind strength and how often winds occur from a particular direction. Westerly and northwest winds are predominant and are the strongest winds. These generate the strongest currents. Southeast winds are infrequent but can generate strong currents, whereas southwest winds are more frequent but generally generate weaker currents.
- Fine sediments (generally smaller than 0.3 to 0.25 mm in diameter) are generally transported in suspension by wind-driven currents to the south during westerly and northwest winds, and to the north during southwest and infrequent southeast winds.

With regard to sediment transport on the beaches, there are periods when wave action is effectively on- and offshore, and there is no net transport of sediment along the shore. In these situations cusps form on the beach within the swash zone, and local sorting of sediments can occur. The long-term movement of sediment along the beach south of the port is from south to north. However abrasion of gravel by wave and swash action results in local generation of sand and silt particles that are removed from the beach to offshore by storm waves and return currents from the beach face. Annual net accumulation of gravel at the northern end of Marine Parade beach is relatively small. There is some accretion of gravel on the beach immediately south of the port breakwater due to sediment being transported north along the Marine Parade beach by waves approaching from the southeast. However, waves approaching from the northeast can cause erosion of gravel from this area. There has been very little gravel or coarse beach sediment arriving in the navigation channel adjacent to the distal end of the breakwater.

At Westshore, beach sediment movement occurs in a similar fashion to Marine Parade under wave action. However south of the Beacons there is a greater component of alongshore movement in the surf zone due to the greater width. Therefore the angle of wave approach at Westshore is a strong factor in determining the direction of sediment transport along the shore.

Waves also result in sorting of (mainly) sand based on size, through the onshore-offshore orbital energy beneath the wave crest and trough. Coarser sediment is transported onshore by waves while finer sediment moves offshore.

For mixed sand and gravel beach systems, current induced movement of sediment on the seabed and within the water column can be distinct from transport on the beach due to waves. Although they are linked by the wave environment energy, the resulting net transport of sediments on the beach and in the nearshore can be separate. This can result in the net transport direction being different in the different environments. Inference of uniform sediment transport on the shore and offshore that can be made on sand beach systems cannot necessarily be made for mixed sand and gravel environments.

With reference to Figure 2.13, this is the case at Napier. Wave induced currents during storms will move sediment on the beach and offshore, and when there is an incident angle of wave approach to the shore then a uniform alongshore sediment transport direction can be inferred. However during less energetic wave conditions, wave currents may initiate sediment entrainment, but wind and tide driven currents control the direction of transport.

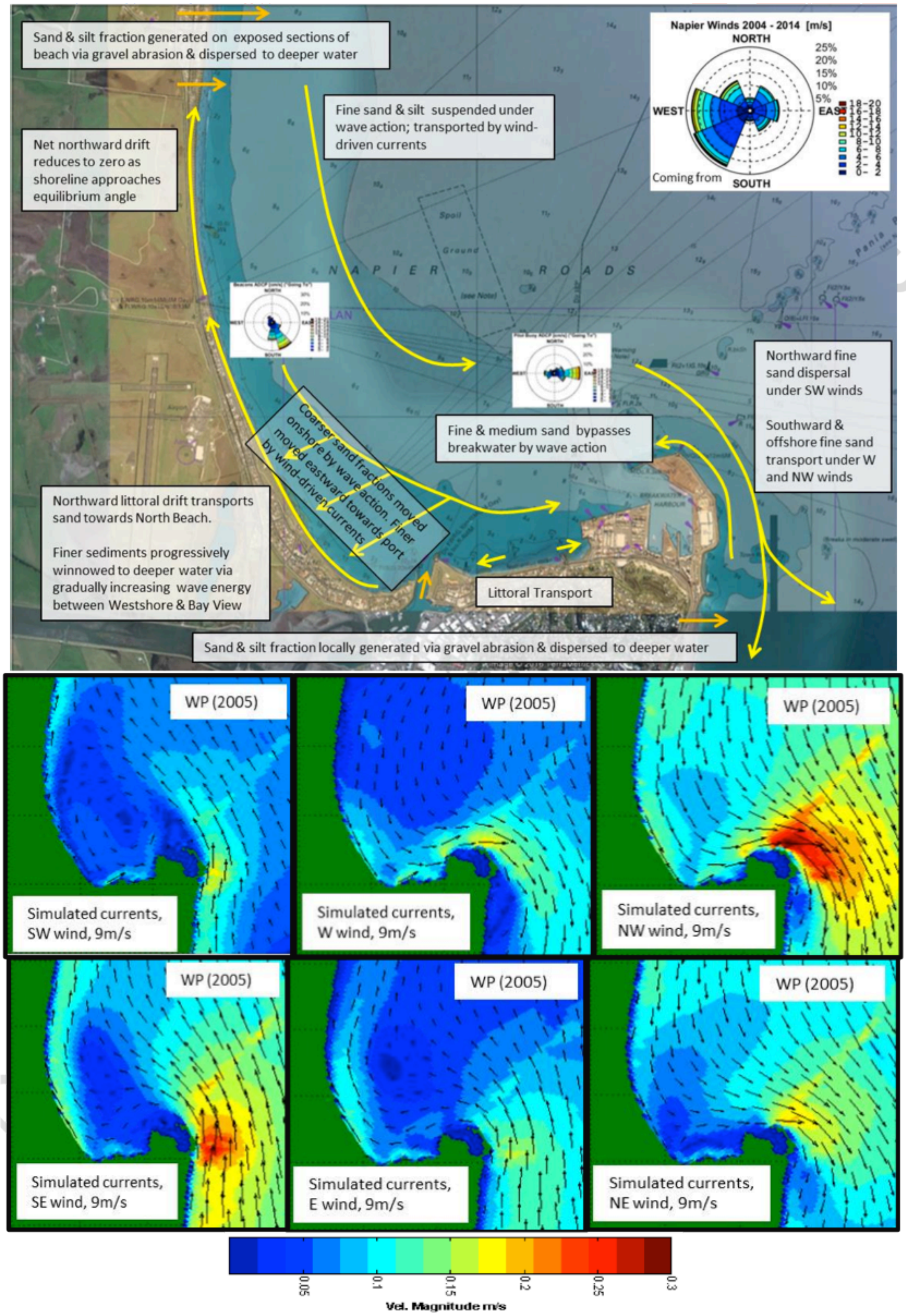

Figure 2.13 Interpretation of annual mean sediment transport pathways around Napier Port (upper panel) on basis of wind driven currents (lower panel) and known wave refraction patterns (Advisian 2017c).

Figure 2.13 shows detail of the predominant sediment transport pathways due to currents as interpreted from the model results. Data from measurements of currents at three sites off Napier (the Beacons, adjacent to the navigation channel and off Marine Parade), along with measured wind data and sediment characteristics, were used as input data to run the numerical models of sediment transport for the area. The model results are consistent with interpretations of sediment transport made from the distribution of sediments on the seabed as determined from sediment samples and particle size distribution analysis.

A significant finding from the model is the importance of wind in driving the currents that result in transport of fine sediments in depths of 2 to 10 m. Fine sand and silt, suspended by wave action is transported by the wind driven currents. Medium and coarse sand will be removed from the shore and move offshore during storms, but can move onshore during calmer conditions, and will be dispersed along the shore by beach transport and littoral currents within the surf zone.

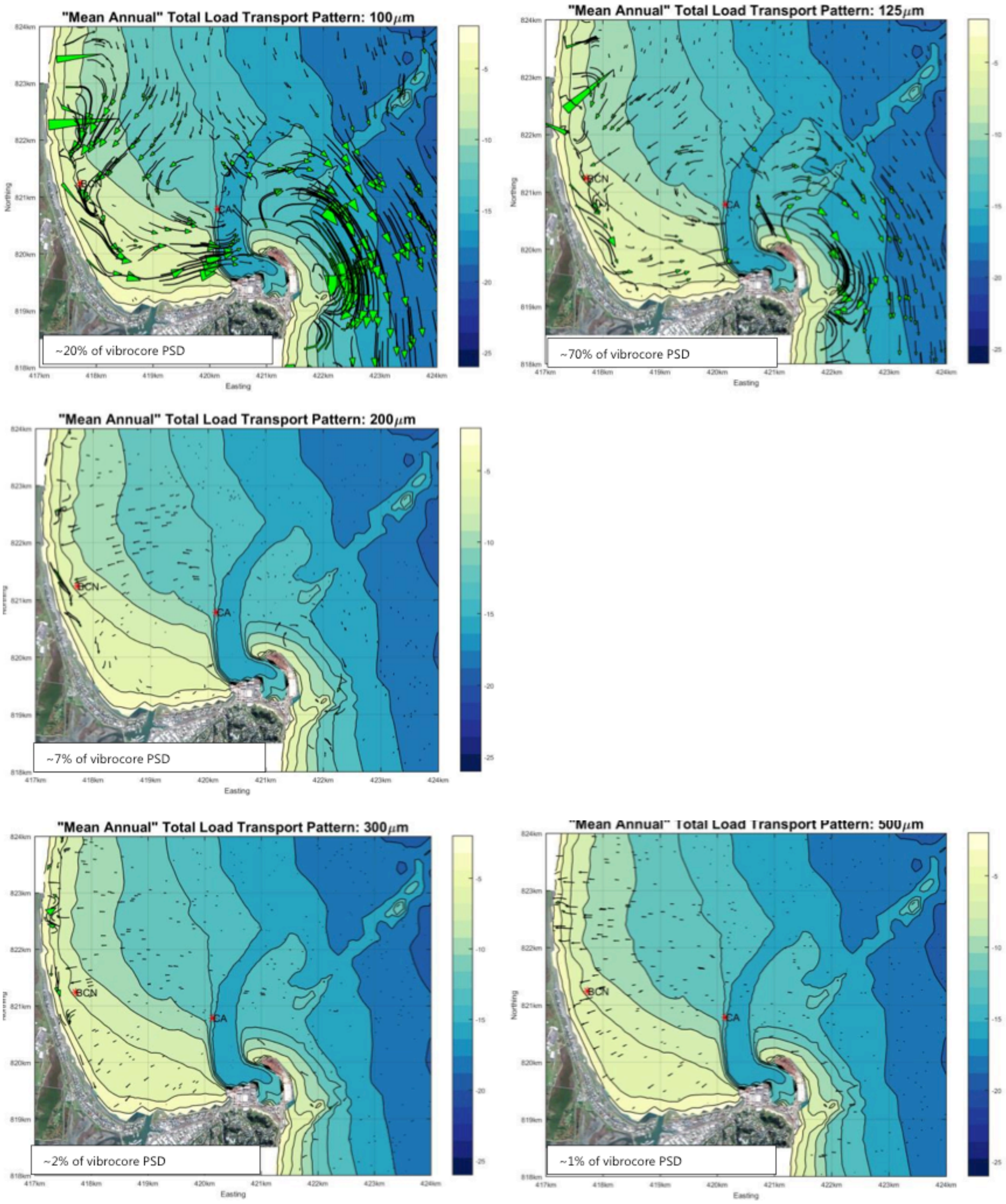

Figure 2.14 Annual average sediment transport patterns for discrete sediment diameters around Napier Port. Bathymetric contours given to Chart Datum (from Advisian 2017b).

When the seabed sediment size data is put in to the numerical transport model, the findings confirm the interpretation shown in Figure 2.13. Figure 2.14 shows the annual average sediment transport patterns for the different size fractions found on the seabed. The "total load transport" is based on the percentage of the total made up by each size class. It can be seen that the finer fractions (less than 0.125 mm or 125 μm) are transported offshore and to the south. The opposite holds for the coarser sand fractions (between 0.125 and 0.5 mm, or 125 to 500 μm).

The pattern shown is also consistent with the broader picture of sediment distribution within Hawke Bay as shown in Figure 2.5. Offshore transport of fine sand and silt is coupled with current flows predominantly to the south, resulting in transport of fines to the mud belt and offshore salient (as shown in Figure 2.5). During strong southeasterly wind and wave events (occurring for 8% of the wind record) fine sediments are transported north. Not all southeasterly wave events (up to 55% of the wave record) result in these transport conditions, as the wind and wave events are not necessarily coincident.

Sediment samples taken from or in the close vicinity of the navigation channel are consistent with the pattern of sediment transport. There is a small percentage of coarse sand at the distal end of the breakwater, indicative of bedload transport of sand particles under wave current processes, but most of the sediment is fine sand or smaller.

2.8 Human Activities

Komar (2005, 2010) presents an in-depth discussion of the history of human activities that may have modified the physical coastal environment at Napier. Komar builds on work by Kirk and Single (1999) in examining how coastal evolution and the development of the character of the coastal environment today, is a function of natural and human induced factors. Komar extends his discussion to approaches to coastal management issues including coastal erosion and inundation.

Komar (2010) notes changes to river catchments influencing sediment supply to rivers from erosion of hills, and the mining of sediment (sand and gravel) from the rivers in stabilizing channels, flood management and to fill areas across the plains to improve the area for settlement. These activities changed the sediment supply to the coast. Some actions resulted in an increase in the quantities of gravel and sand that reached the beaches, while others reduced the amount reaching the coast. Modification to the sediment budget continues through extraction of sediment from the rivers and the coast, and is noted as an area where research is required to further this aspect of coastal management (Komar 2005).

There is also a long history of direct human intervention and modification of coastal processes. Gibb (1996) notes from earlier reports by Harvey (1948) and Parsons (1995), that the chief Tu Ahuriri artificially opened the present entrance to Ahuriri Lagoon sometime between 1769 and 1824. The natural inlet was previously located to the north at Keteketerau (see Figure 2.4), or approximately at the Beacons. The new entrance has remained stable since that time and the entrance to the north closed.

Further modifications to the Ahuriri Lagoon inlet were carried out between 1876 and 1879, with the construction of inlet training walls. This resulted in localized accumulation of sediment as the shore adjusted to changes in the local pattern of wave energy and tidal flows in and out of the lagoon. Between 1879 and 1893 there was extensive modification of the beach and shoreline to the west of the lagoon inlet. Sediment dredged from the inlet entrance was placed onto or near the shore immediately west of the western training mole to create an outer beach.

The development of the Port of Napier at the present site was due to the small harbour within Ahuriri being too small for the growing settlement. Construction of the Port's breakwater was undertaken in 1887-90. The inner part of the breakwater extends shore-normal from the base of Bluff Hill, and then bends toward the north so that it is nearly parallel to the shore to its south. The breakwater has been lengthened over time to meet the needs of increased Port' functionality. Analysis of wave refraction by Worley (2002) found that the breakwater extends the natural wave shelter effect to Westshore and Hardinge Road provided by Bluff Hill from waves approaching from the south of east. Wave heights were reduced by approximately half at Westshore beach due to the sheltering effect of the breakwater.

Komar's analysis of the coastal evolution at Napier addressed local concerns that the port breakwater was a cause of erosion at Westshore due to obstruction of the supply of sand and gravel from south of the port. It was found that although more than a century has passed since its completion, the beach updrift of the breakwater (the town beach at Marine Parade) had not built out to such an extent that gravel was moving along the face of the breakwater and entering the navigation channel (Kirk and Single, 1999; Komar, 2005). Dredging records and the analysis of sediment particles from the channel and harbour entrance show that predominantly fine sand from the nearshore and offshore seabed reaches that channel, rather than coarse sediment moving along the base of the breakwater. Komar's interpretation was:

> "…that the constructed breakwater in effect behaves as a headland, an extension of Bluff Hill, accounting for the advance of the shore at the time of construction, but now the beach gravel and coarse sand arriving from the south is consumed by abrasion, as found in the experiments of Marshall (1927), converting it to the fine sand and silt component of the greywacke, which only then is able to move offshore and around the breakwater's arm" (Komar, 2010).

This interpretation is consistent with descriptions of the effects of the construction of the training walls (jetties) at Ahuriri in the 1870s, prior to construction of the breakwater. The accumulation of gravel on the beaches was at a rate, and in total reflective of local deposition of sediment from dredging of the inlet, and did not show evidence of large volumes of gravel passing from the south, around Bluff Hill and along the shore towards Westshore.

Other human modifications to the coast have been carried out along Hardinge Road. A seawall, railway lines and a gas pipeline ran along the backshore between the port and storage tanks located at what is now Perfume Point Recreation Reserve. Stevenson (1977) notes that a large storm demolished most of a stone wall, undermined railway lines and scattered cribwork boulders along the foreshore of Hardinge Road. The seawall remains along this stretch of coast, but all other work has been removed since the 1970s.

There was a slipway located at the eastern end of Hardinge Road. This was also removed in the late 1970s. Two small breakwaters were constructed to the west of the port (Battery Road reclamation) in the late 1970s and early 1980s, with a boat ramp and parking area. A small sandy beach has formed within the lee of these breakwaters. This is now known as Port Beach. The sand has accumulated here mainly naturally as a result of onshore sediment transport from the west and north, while there has also been some artificial nourishment with fine to medium sand by PoNL.

A small groyne was constructed about 500 m south of the base of the port breakwater in the late 1970s, early 1980s. The purpose of this groyne was to provide a small headland for a planned reclamation between the groyne and the breakwater. This area has not built out significantly, but does provide protection for port infrastructure sited along this section of the foreshore (Higgins Road).

Storm pipe outlets have also been located along the foreshore of both Westshore and Marine Parade. Most of these have been removed. However some are still present on Marine Parade, with one opposite the city now lying beneath a viewing platform that crosses the beach to about the position of mean sea level. This pier was constructed in 2015 (Figure 2.15), and although there has been local sediment accumulation around the structure, there is no noticeable effect on alongshore movement of sediment on the beach.

Figure 2.15 Viewing platform under construction on Marine Parade, November 2015 (photo by Zorn Surveying Ltd).

Erosion along the southern portion of Westshore Beach has resulted in a number of mitigation measures undertaken since as early as 1909. The placement of dredged material and gravel and boulders beside the Ahuriri Lagoon inlet training walls between 1882 and 1888 did not result in a permanent, stable beach. Although Whakarire Avenue is located on reclaimed land, the seaward face of the reclamation required protection works to combat erosion. The first of these works were placed in 1909, with additional stone dumped along the foreshore between 1911 and 1923. The protection work was maintained up until the 1931 earthquake (Single 1985). Consent was granted in 2016 to construct new shore protection along the Whakarire Avenue foreshore, including a rock revetment, a wave spending beach and modification to the existing seawall within the Coastal Marine Area (HBRC Consent No. CL130257C).

Erosion further north along Westshore Beach in the late 1970s and early to mid-1980s resulted in a program of beach renourishment being undertaken (Gibb 1996). Between 1987 and 1995, 163,500 m^3 of gravel and sand (and finer sediments) was placed above the mean high water line, and 105,500 m^3 of predominantly gravel was back dumped over the erosion scarp along The Esplanade (northern section of Westshore). Between 1991 and 1995 an artificial gravel ridge was constructed between Whakarire Avenue and The Esplanade. The sediment was sourced from the margin of Ahuriri Lagoon (mixture of fine gravel, silt and sands) and Pacific Beach, Marine Parade (fine gravel). In 1995, 19,000m^3 of very fine sand was dredged from the Ahuriri Lagoon entrance and pumped onto the beach near Whakarire Avenue. However the sand was gone from the beach within six to eight weeks (Gibb 1996).

Since 1995, an annual average of approximately 10 to 12,000 m^3 of fine gravel has been placed along the Westshore foreshore to nourish the beach and maintain the artificial gravel beach ridge. In addition, PoNL has also placed dredge spoil, from the maintenance dredging of the navigation channel, in shallow water off Westshore since at least 2012. The work by Advisian (2017a) shows that this material contributes a small percentage of the total placed to beach replenishment. This is due to the sediment generally being smaller in size than is effective for beach nourishment. Only the coarser sand fractions are transported onshore, where the residence time on the beach is limited due to ongoing northward net beach sediment transport. Finer sediments in the dredge spoil, including fine sand and smaller sized particles are transported offshore and to the east and southeast, and eventually contribute to infilling of the harbour channels (Ahuriri and the port) with fine sediment. Maintenance dredging records show infilling of the western edge of the port navigation channel, resulting in an asymmetrical dredge demand between the western and eastern sides of the channel.

2.9 Recent capital and maintenance dredging history

In November 1998 PoNL was granted consent to deposit up to 350,000 **m^3** of dredge spoil over any 12 month period by Hawke's Bay Regional Council. The locations for disposal are shown on Figure 2.16. The grounds (Area "I a" and Ares "R" ext.) extend the boundaries of previous disposal locations (Area "I" and Area "R"). Area R ext. allowed for deposition that may provide sand nourishment to Westshore, and as per condition 6 of the consent, can only receive material dredged from the fairway.

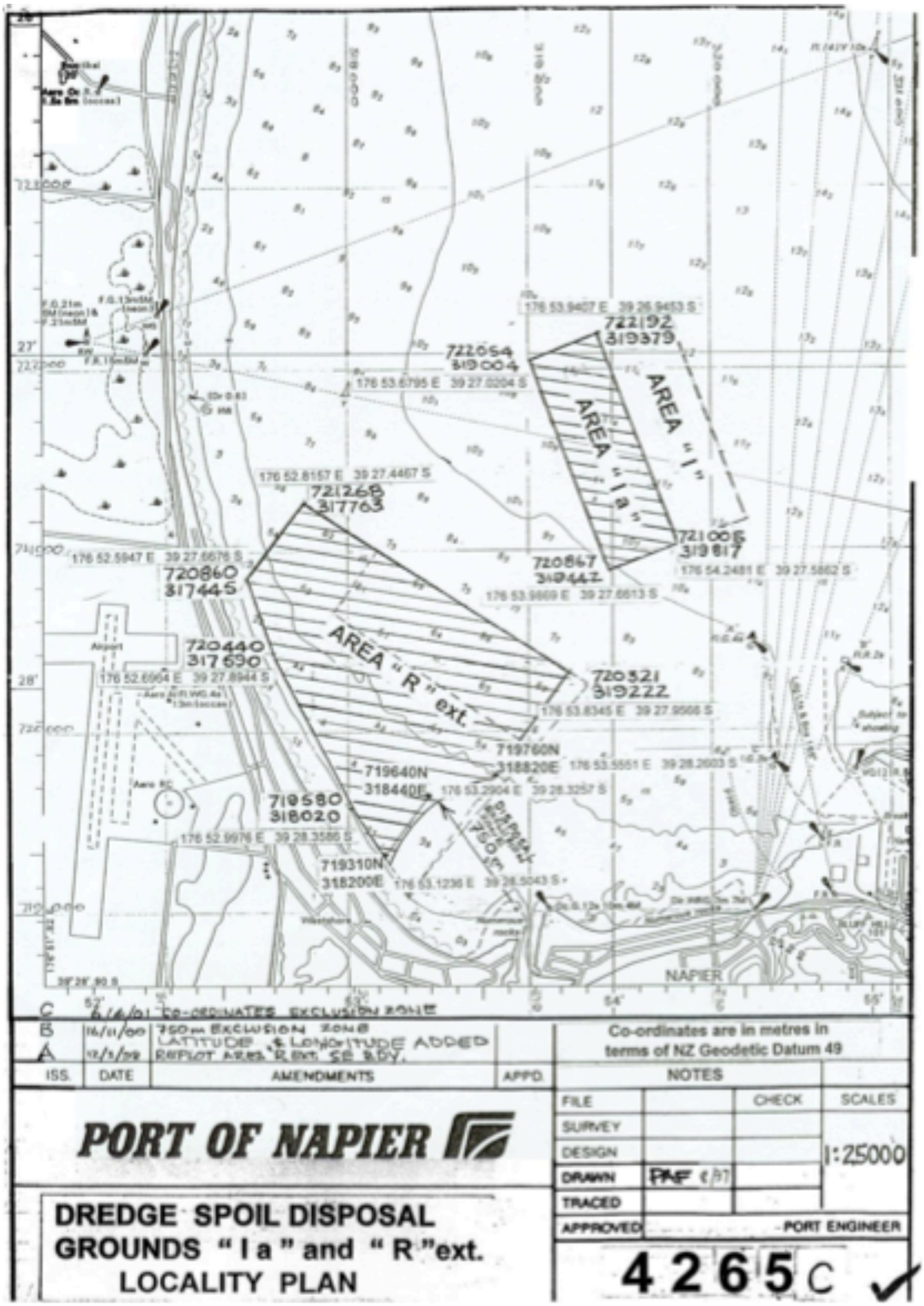

Figure 2.16 Dredge spoil disposal grounds "I a" and "R" ext. from Schedule 1 of Consent CL970159D.

Prior to 1980, dredged sediment from capital and maintenance dredging during three large programs to extend and widen the fairway (1973, 1978 and 1979) was deposited offshore of area "I" (denoted as "H" in dredge records), described as "disposed at sea" by Stevenson (1977) as a proposed reclamation area was not ready for receiving the material.

Between 1980 and 1999 dredged sediment was placed at Areas "R" and "I" and within other areas in the vicinity of area "R", including inshore of that disposal ground. Only material dredged from the fairway or in capital dredging of the approaches was placed at the inshore area "R". The sediment deposited is described in the dredging records as "fine sand and silt". Mud, clay and mixes of sediment finer than sand, dredged from the harbour berths and the swing basin, were not placed inshore. Fine sediment such as silt, mud and clay is not suitable to use for beach nourishment, and is more similar to the native sediment on the seabed in the vicinity of the offshore site ("I").

The distinction between the sediment size distributions from the different dredging areas is also evident in the record of dredge spoil disposal since 1999. Only sediment from the fairway was placed in area "R" ext., where the coarser fractions of sand sized particles (medium and coarse sand) would be available and suitable to move onshore. The finer fractions of this material are unlikely to nourish the beach due to the transport properties of the fine sediments. The recent studies have shown that the fine material moves to the east and south, potentially relocating to the harbour and navigation channel.

Table 2.2 shows volumes of sediment disposed at the different disposal areas, for the periods 1973 to 1998, and 1999 to 2015. Since 1973 there have been five large capital dredging periods (1973, 1978-79, 1994-1996, 2012, 2013-15), with a total capital dredging volume of about 1.9 M **m^3**. Maintenance dredging has totalled about 1.6 M **m^3**. The average annual maintenance dredging demand was about 37,000 **m^3** over the total period.

Table 2.2 Sediment volumes disposed at disposal areas between 1973 and 2015 (data from PoNL). All volumes in m^3.

1973 to 1998 inclusive

Dredging		**Annual Average**
Maintenance	978,280	37,626
Capital	1,494,728	57,490*
Total Dredged	2,473,008	95,116
Disposal Area		
H	1,388,000	53,385
I	720,685	27,719
R	226,777	8,722
Other Total	137,546	5,290

*Capital dredging programs 1973, 1978, 1979, 1994, 1995, 1996

1999 to 2015 inclusive

Dredging		**Annual Average**
Maintenance	616,624	36,272
Capital	402,398	23670*
Total Dredged	1,019,022	59,942
Disposal Area		
I a	631,952	37,174
R ext.	383,870	22,581
Landfill	3,200	na

*Capital dredging programs 1999, 2000, 2003, 2006, 2009, 2010, 2012, 2013-15

In 2006 3,200 m3 was deposited on land, while over the last five to ten years, about 1,200 m^3 have been placed at Port Beach. Since 1998 (under consent CL970159D) nearly 400,000 **m^3** has been placed at the inshore site (R ext.), averaging about 22,600 m^3 per year. Based on the sediment characteristics of the fairway surface sediments (Advisian 2017b), between 5% and 10% of the dredged material from the channel is sand greater than 300 mμ diameter (medium to coarse sand) that has potential to move inshore to nourish the beaches of Westshore. This equates to potentially between 1,100 and 5,600 m^3 per year of placed dredge spoil that may temporarily nourish the beach.

3. Changes to the process environment as a result of the project

3.1 Introduction

Results from numerical models and field studies have provided an assessment of the changes to the hydrodynamics and sedimentation processes as a result of the proposed dredging and dredge spoil disposal (Advisian 2017a, 2017b, 2017c; Cawthron 2017). The findings drawn from that work are presented in the following sections.

3.2 Modelling

A series of numerical models were used to simulate the coastal process systems around Napier. Wave, current and sediment transport processes were modelled using the Delft3D suite of models. Sediment transport in the littoral zone (near to shore and under breaking waves) was simulated using Unibest. Wave refraction and shoaling were modelled using MIKE21BW. These models are described in detail by Advisian (2017b, 2017c), and are appropriate for the nearshore and offshore coastal process environment in the area.

Numerical models for sediment transport on mixed sand and gravel beaches are not quantitatively precise due to the complex mix of the sediment sizes. Therefore numerical models of littoral and beach transport were used to determine relative changes in the process energy from the existing channel situation to the conditions at completion of the proposed work, and the potential to change the coastal environment, rather than to determine quantitative changes to shore geometry and sediment transport.

The models were calibrated against field data collected from long-term deployments and for this project. The data included wave characteristics from the Triaxys buoy maintained by PoNL, other short term wave buoy deployments at the Channel Approaches, Beacons, East Pier and Hardinge Road, current meter deployments at Beacons, Channel Approaches and the proposed site for disposal east of the port, wind data from the port and tidal information derived from published tidal constituents for the area.

The calibrated 3d flow model was verified against Acoustic Doppler Current Profiler (ADCP) data. The calibration period was relatively stormy in comparison to the long-term wind record. However measured and simulated currents correlated closely to wind speed. This is consistent with findings from earlier studies at Napier (WorleyParsons 2005). Validation of the model showed that high current velocities during the storm events and the overall changes in magnitude during storms were reproduced.

Wave heights and periods of the model were also calibrated to measured data, and verified against further storm events. The model performed at 'excellent' level in reproducing wave heights, periods and direction (Advisian 2017b).

Data-driven and model-driven approaches were used to assess sediment transport processes around the port and the disposal areas. This resulted in the identification of sediment transport potential, transport pathways, and with reference to the sediment sizes present on the wider seabed and within the proposed dredge area, the relative transport of different sediment size fractions could be determined.

Overall, the model results allowed for good calibration, with consistent findings between models, field measurements and observations. This meant that the models provided a dependable platform whereby the assessment of changes to the wave environment, and assessment of sediment transport (suspended-sediment plume, bedload, and resuspension of placed sediment at disposal sites) can be achieved with reasonable confidence.

The findings of the model studies, combined with field observations were used to assess options for design of the channel configuration and options for the location of dredged sediment disposal.

3.3 Waves

A detailed analysis of the wave climate was undertaken to determine the effect of the deeper channel on waves passing across the channel and into shore. This provided for identification and assessment of potential changes to the shore geomorphology, and the 'surfability' of waves in the lee of the channel. Wave refraction and shoaling over the proposed area of dredge spoil disposal were also examined to determine changes to the wave properties and potential effects inshore.

Analysis of the wave climate was carried out for the existing or 'baseline' situation and for the dredged channel bathymetry. The difference between the baseline and dredged channel results gives the change to wave height and direction. The method used gave weight to the importance of each wave condition by the contribution to total wave energy. Therefore relatively rare waves, such as found in large storms, that are important to sediment transport and geomorphic 'work' are not neglected, and the contribution of frequently occurring but small waves is not exaggerated.

3.3.1 Effects of deeper channel on the wave climate

Seven different alternative dredge footprints were assessed before settling on a final design. Figure 3.1 shows the energy-weighted mean wave height and direction for the baseline condition and for the fully dredged channel (-14.5 m CD). The general finding is that there is very little change in the vectors of wave height and wave approach to the shore. There is some minor modification to wave height and direction along Hardinge Road due to refraction by the navigation channel approaches and swing basin of waves approaching from the east and southeast.

The change in energy-weighted wave height and direction are plotted in Figure 3.2. The effect of the channel is shown, as is the reduction in the change in wave parameters with distance from the channel. Wave height and energy is reduced in the immediate lee of the port at Port Beach and the southern section of Westshore, but increased at East Pier and along The Esplanade. Changes in mean wave height are small, with a decrease in mean wave height of about 5 cm at Port Beach, an increase of about 6 cm at East Pier, a decrease of less than 2 cm along Westshore, and an increase of about 2 cm at The Gap.

The deeper channel causes the wave approach to be less refracted as it passes the channel, and so there is slightly more angle to the wave approach to the shore. Influence of the channel dredging decreases to the west and north along Westshore. The resulting change is from about 4 degrees, near to the port, to less than 1 degree at Westshore, with the angle of the wave crest rotated clockwise, such that the resultant angle with the shore is to the west and north. There is no change in direction of wave approach to the shore due to the deeper channel, from The Esplanade to the north.

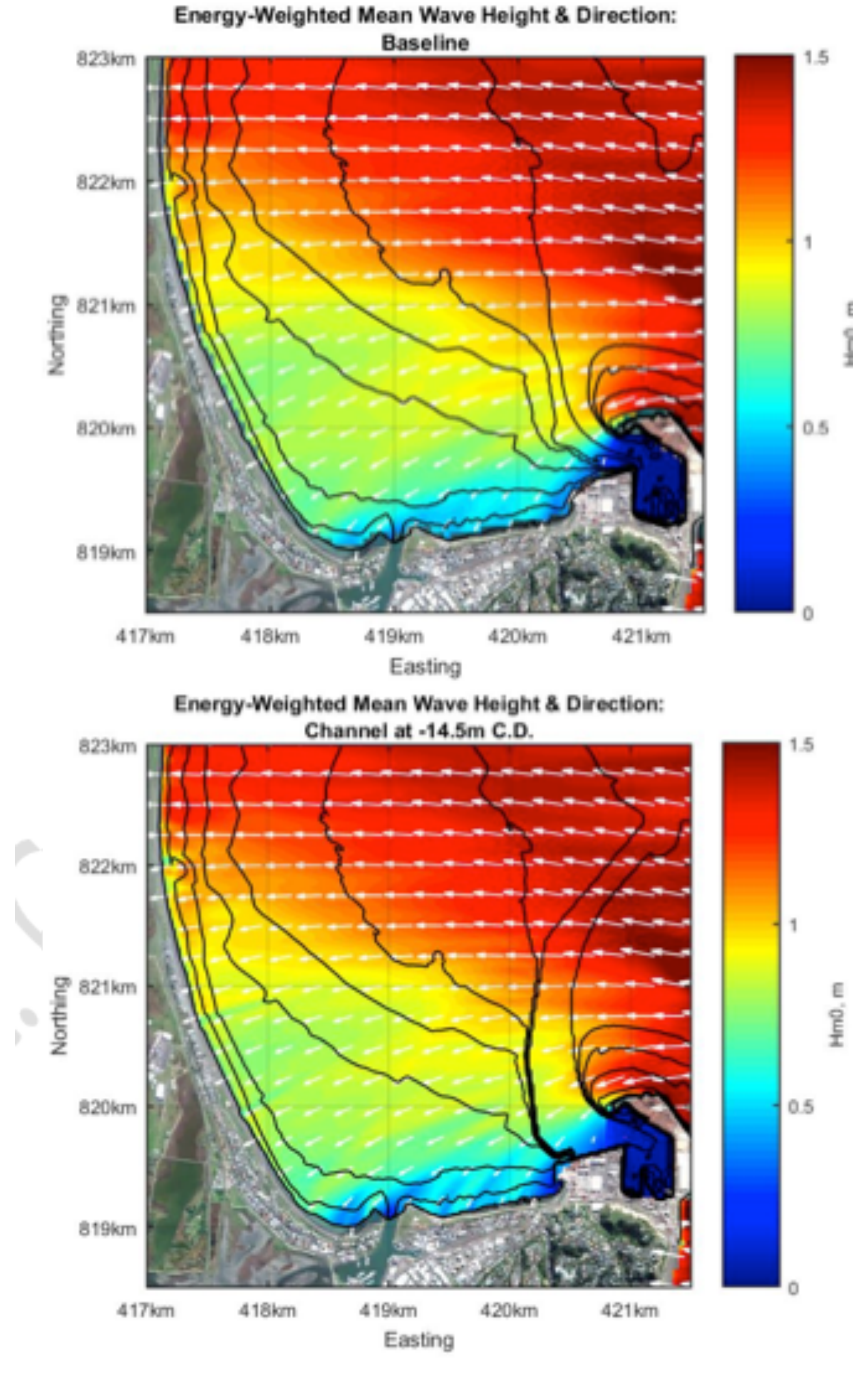

Figure 3.1 ‘Energy-weighted’ patterns of wave refraction around Napier Port. Upper panel: ‘Baseline’ conditions represent how waves refract today. Lower Panel: Simulated wave refraction patterns for optimal design of navigation channel and turning basin, dredged to a depth of -14.5 m CD (from Advisian 2017c).

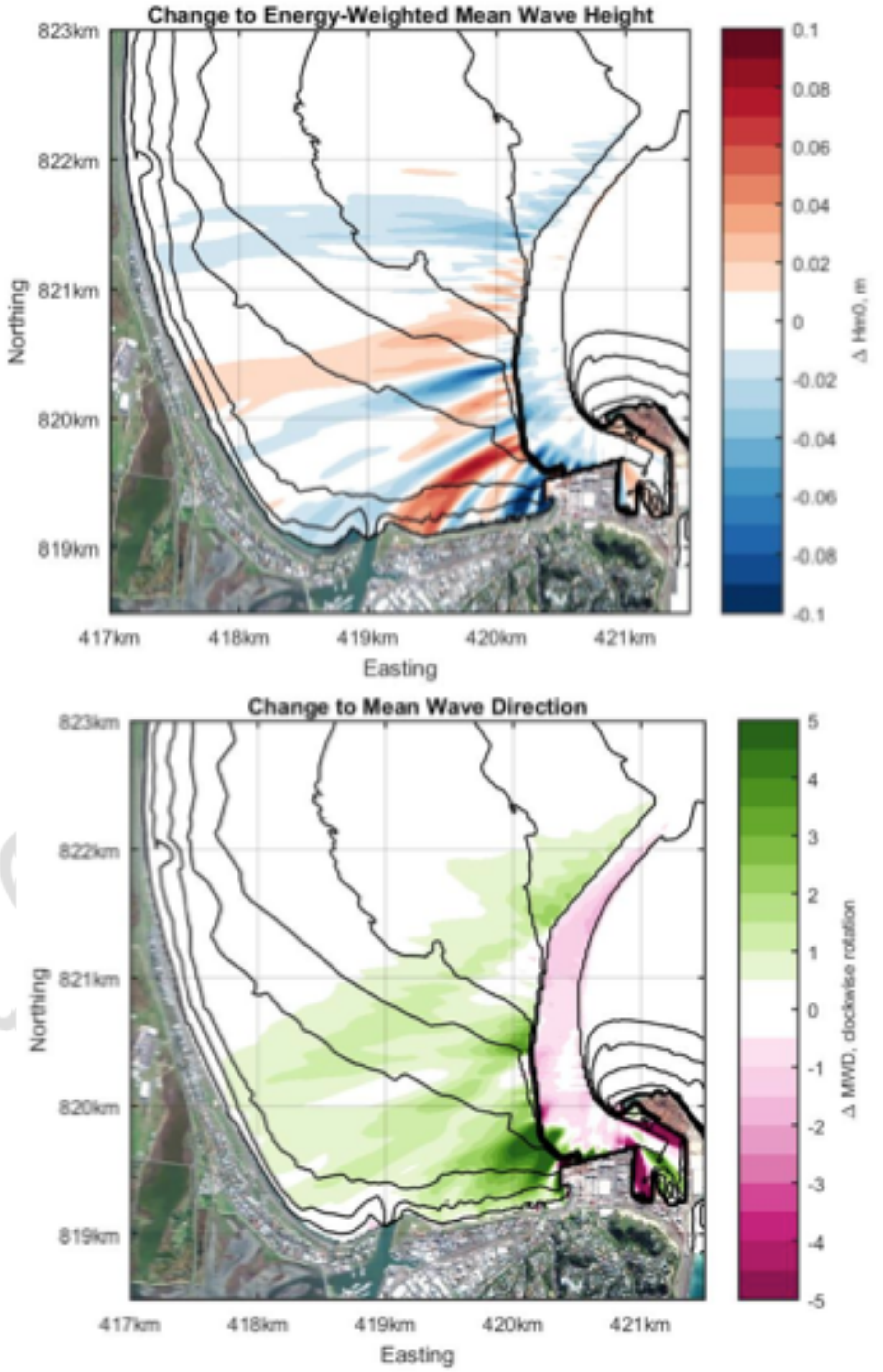

Figure 3.2 Changes in pattern of wave refraction around Napier Port due to deepening of navigation channel to -14.5 m CD. Upper Panel: Change in mean wave height. Lower Panel: Change in mean wave direction (Advisian 2017c).

3.3.2 Effects on surfability of waves

The New Zealand Coastal Policy Statement (NZCPS, Department of Conservation 2010), Policy 16 recognises the need to protect surf breaks of national importance. Although the local breaks are not nationally significant as per Schedule 1 of the NZCPS, they are regionally important, and recognised as such by PoNL. Local breaks are identified in the New Zealand Surf Guide. Four breaks are located west of the port. These breaks are located as followed, with descriptions from the NZ Surf Guide:

- The Gap – the shore adjacent to the east-west runway at the airport. Beach break, skill level – beginner, several peaks along the beach, both left and right handers, optimal swell direction NE, optimal wind W, Quality Rating: 4/10;
- Westshore – near the Westshore surf club. Beach break, skill level - beginner, several peaks along the beach, both left and right handers, optimal swell direction NE, optimal wind W, Quality Rating: 4/10;
- City Reef (aka Rangatira Reef) – southern end of Westshore adjacent to Whakarire Avenue. Beach break, skill level - beginner, one main peak with both left and right handers, optimal swell direction NE, optimal wind SW, Quality Rating: 6/10;
- Hardinge Road – Along Hardinge Road from Port Beach west to the East Pier. Right point break, skill level - beginner, very sheltered from port, when working has nice, long wally wave, optimal swell direction E, optimal wind SW, Quality Rating: 2/10.

Model simulations to assess the surf breaks considered wave refraction, diffraction, non-linear wave interaction, wave asymmetry and skewness, and depth induced wave breaking (Advisian 2017c). The models showed negligible effects at The Gap and Westshore. However the closer breaks at City Reef and Hardinge Road were examined in more detail.

Figure 3.3 shows change in significant wave height (Hs, approximately the average of the highest 1/3 of waves) for an easterly storm occurring at low water. There is a small increase in the significant wave height along Hardinge Road, although a decrease in significant wave height at Port Beach. There is also a small increase in wave height at the City Reef break. There are also increases of about up to 0.4 m to the maximum wave height as shown in Figure 3.4.

Figure 3.5 shows the simulated wave crests for the baseline and dredged channel situations. For the model storm conditions, the wave crests are predicted to remain broadly unchanged by the deeper channel. However the increase in wave height suggests that wave scattering from the swing basin will enhance the potential for a long ride along Hardinge Road.

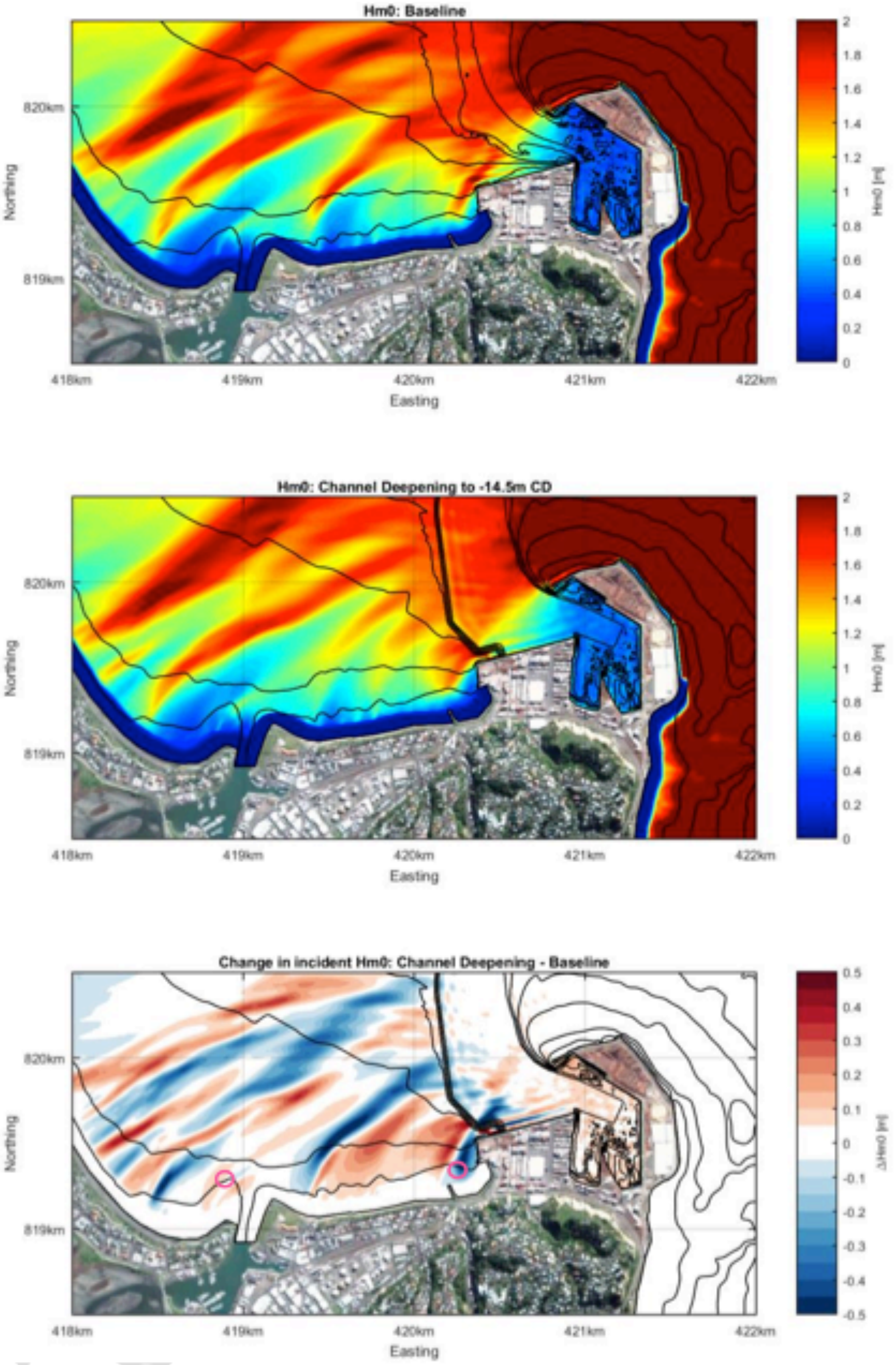

Figure 3.3 Changes in significant wave height for easterly storm occurring at Low Water. Offshore wave height 3.0 m, Wave Period 11.0 sec, incidence angle 90˚ (due east). Circles show locations of surf breaks at Hardinge Road and City Reef (from Advisian 2017c).

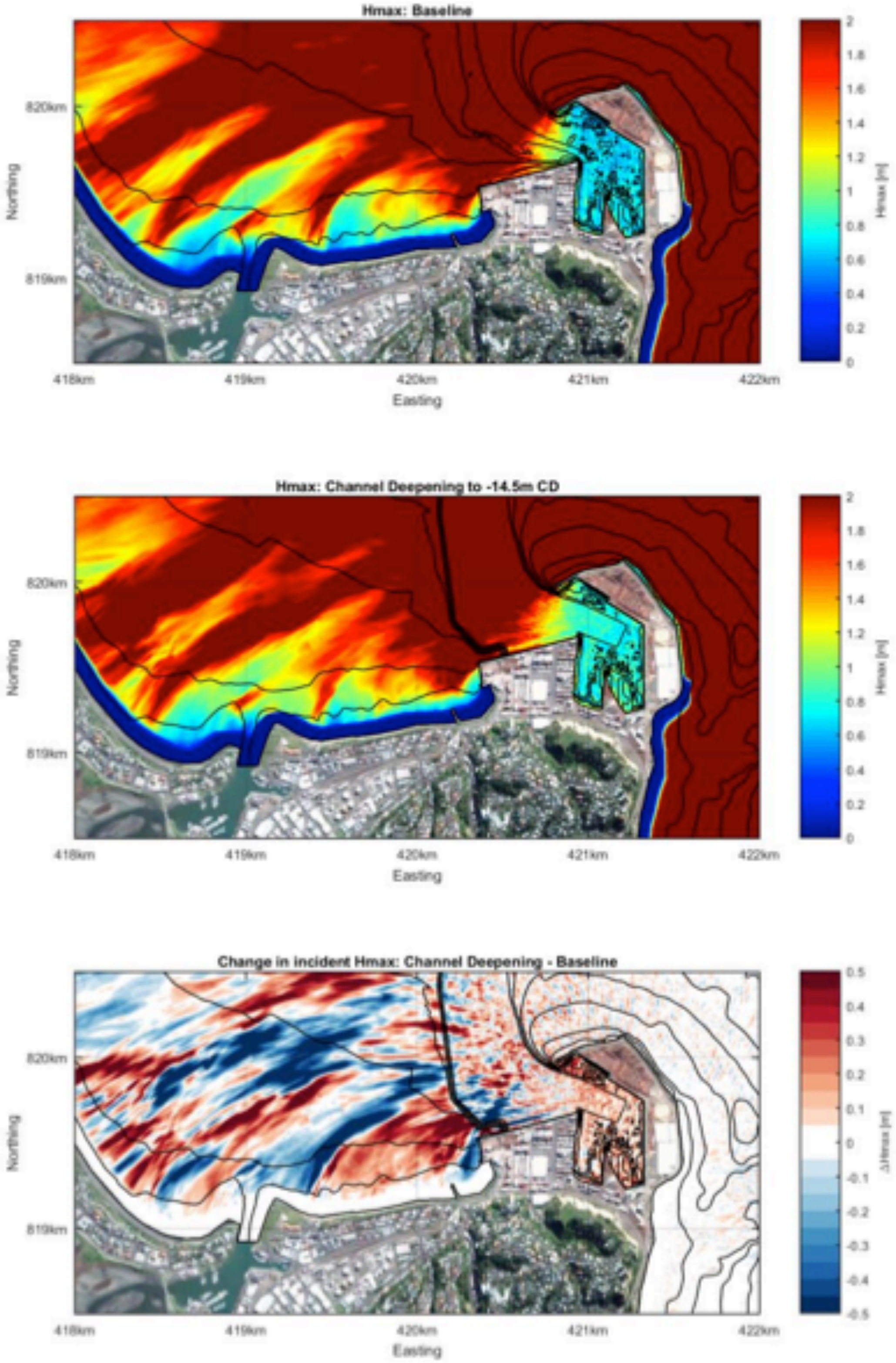

Figure 3.4 Changes in maximum wave height for easterly storm occurring at Low Water. Offshore wave height 3.0 m, Wave Period 11.0 sec, incidence angle 90˚ (due east) (from Advisian 2017c).

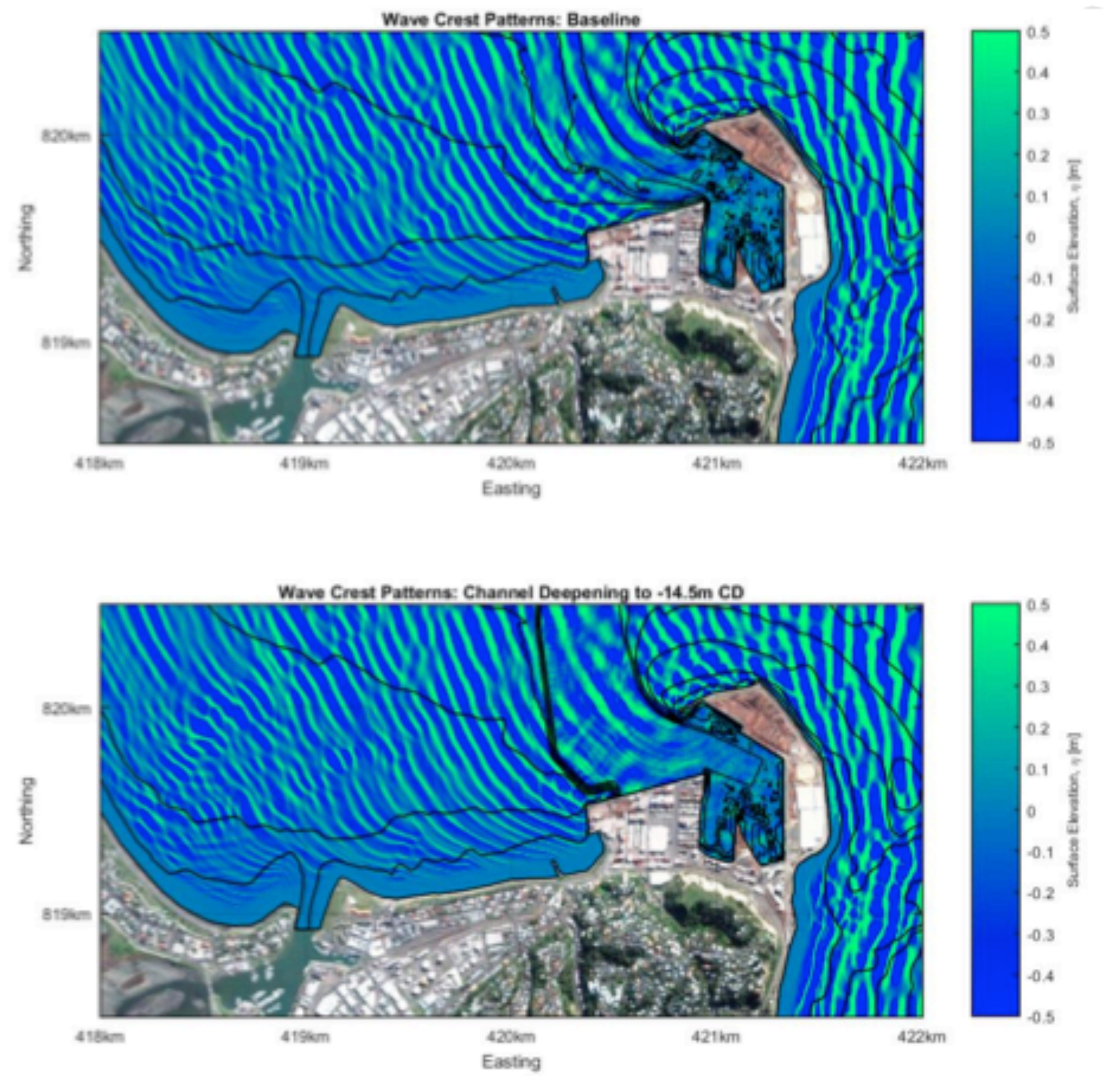

Figure 3.5 Wave crest patterns for ‘baseline’ and ‘dredge channel’ bathymetry. Easterly storm occurring at Low Water, Offshore wave height 3.0 m, Wave Period 11.0 sec, incidence angle 90˚ (due east) (from Advisian 2017c).

Discrete points within the surf breaks were further analysed for 280 different scenarios of a range of wave direction, height and period, using a calibrated and validated SWAN spectral wave model (Advisian 2017c). The scenarios were drawn from the wave data from the PoNL Triaxys wave buoy for the period 2004 to 2014. Quantification of the surfing amenity was assessed using methods described by Lewis *et al*. (2015) and Mead (2003). Descriptive parameters of wave peel angle (from the method of Mead 2003), breaker intensity and breaking wave height were also determined.

Nomograms illustrating classification of surfer ability and amenity developed by Walker (1974) and Hutt *et al.* (2001) were used to show the effects of changes in peel angle and breaker height. For both the right and left hand breaks at City Reef (Whakarire Avenue), the peel angle and surfing amenity classification did not change significantly as a result of the dredging. At Hardinge Road, there was little change to the breaker type as a result of the dredging. The peel angle increases slightly following dredging and there is slight improvement to the surfing amenity classification, with a greater proportion of waves at the break plotting on the Walker (1974) and Hutt *et al.* (2001) nomograms within areas that indicate the waves are suitable for surfing (Advisian 2017c).

3.3.3 Effects of disposal mound on the wave climate

Placement of approximately 3.2M m^3 of dredge spoil at the proposed disposal ground will result in an increase in the elevation of the seabed. PoNL estimate the increase over the disposal area will be in the order of about 1 m. The effective shallower depth can result in changes to wave propagation and refraction over the area, the amount of energy that reaches the beach and the angle of wave breaking at the shore.

Advisian (2017c) presents the results of simulated wave refraction across the existing bathymetry and the modified bathymetry of the disposal area east of the port. To replicate a worst-case scenario, a modified bathymetry of +2 m above the existing seabed was used to assess the change in energy-weighted mean wave conditions. Figures 3.6 and 3.7 show the changes to energy-weighted mean wave height and energy-weighted mean wave direction as a result of an increase in the seabed across the disposal ground.

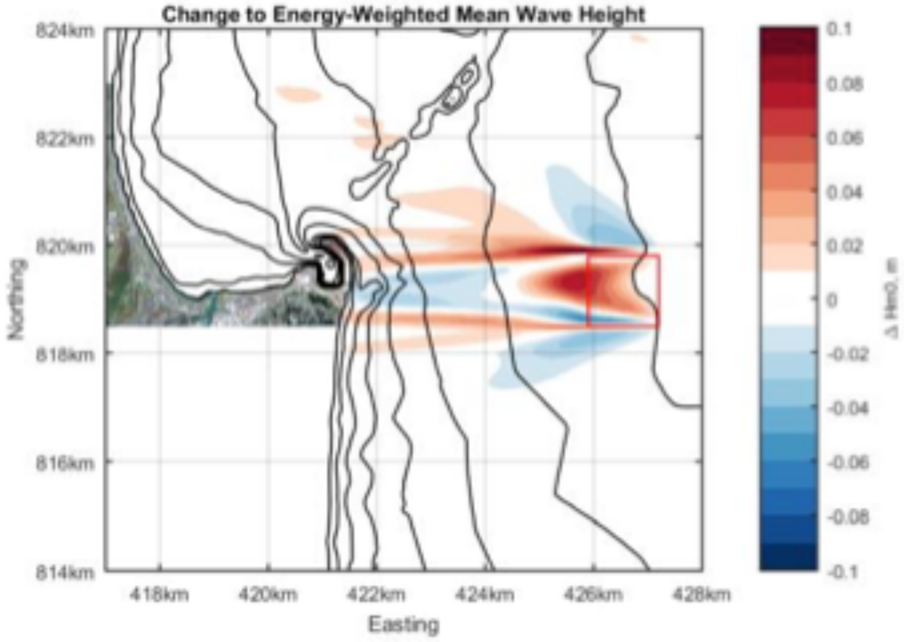

Figure 3.6 Change to energy-weighted mean wave height due to 2 m accumulation of sediment within the proposed disposal area boundaries (from Advisian 2017b).

The effect of the spoil placement on wave refraction is limited to changes in wave energy in the area immediately west of the disposal ground. Wave height is modified due to wave refraction across the disposal ground, but it is limited to a maximum change in energy-weighted wave height of ±4 cm at the shore. This is less than 4% of the incident wave height. There is no change to the energy-weighted wave direction at the shoreline.

These small changes in predicted wave energy will not result in measureable changes to the geomorphological work the waves will do at the shore.

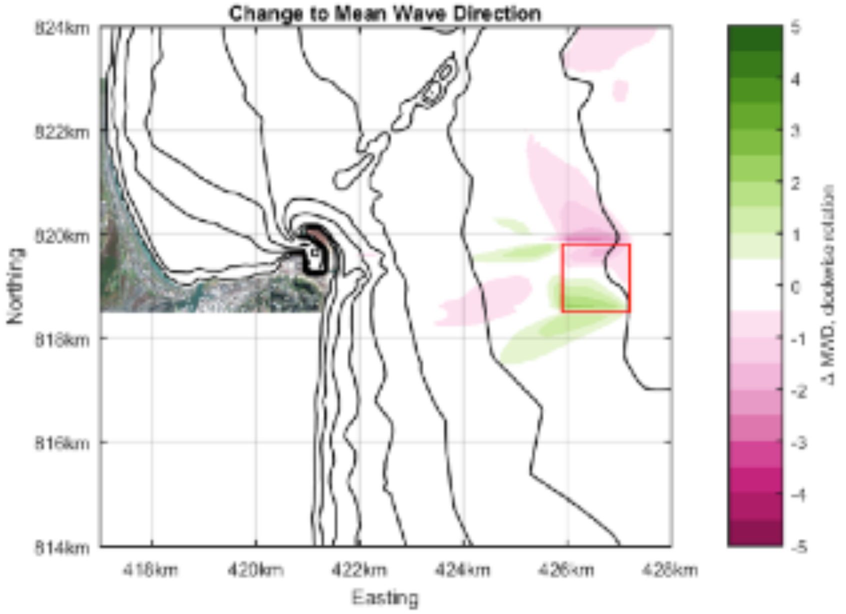

Figure 3.7 Change in energy-weighted mean wave direction due to 2 m accumulation of sediment within the proposed disposal area boundaries (from Advisian 2017b).

3.4 Sedimentation

It is expected that the proposed dredging programme will result in changes to patterns and processes of sedimentation in the immediate vicinity of the port and the proposed disposal area(s). Changes will result from:

- Addition of fine sediment into the water column and environment during the dredging activity (excavation in the channel and swing basin, and deposition at the disposal ground);
- Changes to the margins of the dredged area as the sides of the channel and margin of the swing basin "relax" into an equilibrium condition; and
- The addition of the dredged sediment onto the offshore seabed.

Advisian (2017a) presents the results of detailed dredge plume modelling based on the validated hydrodynamic model of wind and tidal currents, coupled with a wave model and particle tracking model. The investigations included predicting the suspended sediment generated from trailer suction hopper (TSHD) and backhoe (BHD) dredging activities in the navigation channel and swing basin, and movement and deposition of the suspended sediment plume. The models were also used to predict plume dispersion during deposition, and the fate of placed dredge spoil at the existing and inshore disposal grounds to the west of the port, and the proposed disposal ground east of the port.

The DELFT3D-FLOW module was used to calculate non-steady flow and sediment transport resulting from tidal and wind-driven currents. The model was calibrated and validated against measured currents at a location in approximately 10 m water depth, west of the channel. A water quality model (D-WAQ PART) was used to describe the dredge plume behaviour. This model is part of the DELFT3D suite and is coupled to the hydrodynamic model.

Sediment characteristics were based on data from Beca (2017a). Volumes of sediment to be dredged were based on the staged dredge programme and a three-dimensional model of the sub-surface sediments in the proposed dredging area (from Beca 2016b).

Modelling of the first and last dredge campaigns was carried out as they were considered to be a conservative representation of the potential effects of dredging on suspended sediment concentrations and sedimentation at sensitive sites such as Pania Reef. Campaign 1 involves BHD dredging of the area near Berth 6 to the design depth of -14.5 m CD; BHD dredging the swing basin to -12.5 m CD; and TSHD dredging of the navigation channel to -12.5 m CD. Campaign 5 is the final capital dredging to ultimate design depth using TSHD for the channel and BHD for other areas.

The relatively stormy period of July 2016 was used as the basis of the water quality modelling, as this provides a conservative assessment and was selected for the following reasons:

- July 2016 included major wind events when compared to measured wind data between 2005 and 2015, with strong westerly winds that were considered to have the potential to blow any generated sediment plumes from the dredge area toward Pania Reef;
- A range of representative wind directions occurred over the month, including south-easterly winds that were considered to have the potential to blow sediment plumes from the proposed disposal area toward Pania Reef;
- Stormy periods have been shown by the preliminary dredge plume modelling to result in larger sediment plumes;
- A full month of simulation time encompasses a full neap and spring tidal cycle; and
- TSHD durations for all campaigns are likely to be approximately two weeks, with backhoe dredging occurring over the entire month. This allows the higher relative impact of TSHD carried out in conjunction with the backhoe dredging to be fully captured in the model simulations, with the impact of backhoe dredging carried out in isolation in the second half of the month being lower (Advisian 2017a).

Multiple sediment sources within the channel and swing basin were introduced into the model to indicate the likely sequence of dredging in the different areas. Two main sediment disposal locations at the proposed disposal ground were selected as the point sources for disposal location, as indicated in Figure 3.8, as they are closest to the sensitive Pania Reef environment.

During the disposal operation, when the dredge hopper is emptied at the proposed disposal ground, the following processes would occur (as shown in Figure 3.9):

- A major portion of the released sediment load descends rapidly en masse to the seabed and deposits itself there;
- A minor portion of the sediment load goes directly into suspension (especially finer size fractions), increasing the concentration of suspended material in the water column and drifts off with the current, dispersing and gradually settling with time;
- Finer material (e.g., silts) within the mass that falls directly to the seabed will spread out radially along the seabed away from the impact zone;
- Deposited material can be subsequently re-suspended when wave conditions are sufficient strength to mobilise the seabed surface sediments and transported by currents before settling again when conditions allow.

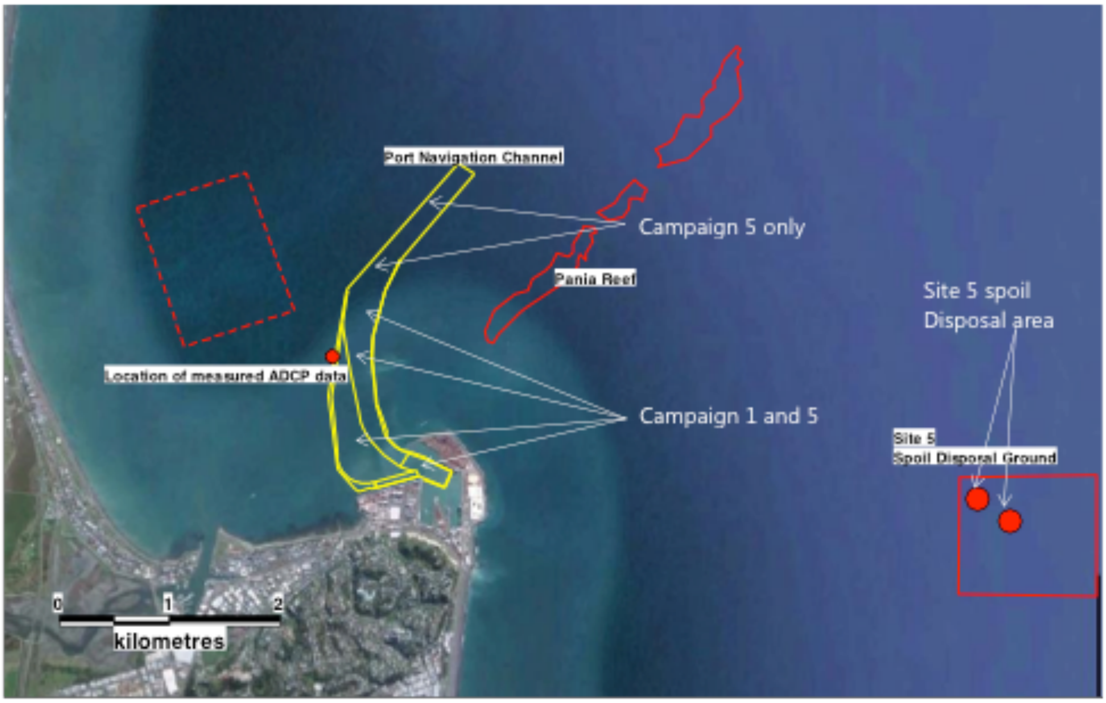

Figure 3.8 Schematic representing source areas for sediment in the plume dispersal model (from Advisian 2017a).

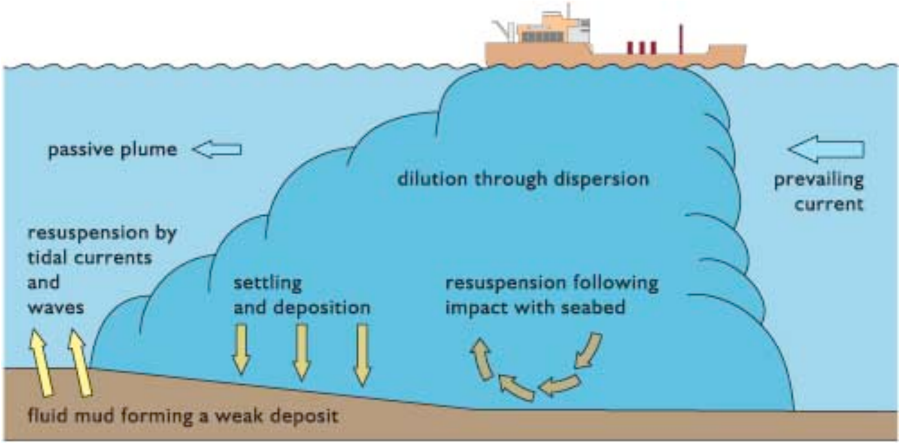

Figure 3.9 Schematic of a dynamic sediment plume discharged from a dredge hopper. [*Source: CIRIA (2000)*].

3.4.1 Plume concentrations and spatial extent

The modelling results show concentrations of suspended sediment in mg/L (equivalent to parts per million, ppm) above background levels. There is little quantitative data on background suspended sediment concentrations, for the coastal area off Napier. However work by WorleyParsons (2005) shows suspended sediment concentrations induced by wave and current re-suspension near the seabed of between 2 to 3.1 mg/L. They note that sediment concentrations in flood discharge from rivers such as the Esk and Tukituki Rivers can exceed 10,000 mg/L. Cawthron (2017) also note that there are high concentrations of background turbidity at Pania Reef as a result of large river flows, and fine material resulting from abrasion of sediment on the beach. Only the silt and finer fractions of sediment are represented in the sediment concentration as sand fractions quickly settle out of the water column and onto the seabed in the immediate vicinity of the area of disturbance (dredging and disposal).

The models produce maps of near-surface percentile exceedance of total suspended sediment concentrations (from greater than 1000 mg/L down to 10 mg/L), and silt, and sand deposition percentile exceedances (from 100 mm to 1000 mm, down to 1 mm deposition thickness).

The results allow general observations to be made:

- The plume generated at the proposed disposal ground was more extensive than that generated at the dredge site, for all scenarios tested;
- Sediment concentrations are spread relatively evenly over the water column;
- There is no potential for sedimentation to occur at Pania Reef due to re-suspension of sediments by wave-induced stirring, the distance of the ground from the reef, and the prevailing current directions;
- There is no potential for Pania Reef to be affected by suspended sediments >10 mg/L above background, with 98%ile Silt/clay fraction concentrations (exceeded for less than 1 day per month during the dredging campaigns) less than 10 mg/L above background levels over the reef area;
- The sand fraction of the discharge settles quickly and does not travel long distances from the source location. Sand fraction deposition is limited to immediate disposal and dredge areas only;
- The highest suspended sediment concentrations above background levels are in the inner port area and at the spoil ground;
- The highest concentrations occur at the beginning of the campaigns due to TSHD dredging dominating, lower concentrations result from backhoe dredging; and
- Suspended sediment concentrations at the reef, while negligible, are highest during times when the currents at the spoil ground are directed toward the northwest but are still well below 10 mg/L above background and would not be visual to a casual observer.

These results are consistent with the current modelling findings of fine sediment movement on the seabed in the general area from north of Westshore to Marine Parade. The prevailing currents are generally directed toward the east, and result in sediment plume movements from the proposed disposal site to offshore and away from Pania Reef. The proposed disposal ground is further from the navigation channel and Pania Reef than offshore and inshore sites investigated east of the port, and so there is less potential for fine sediments to be transported onto the reef or back to the port and harbour. In addition, the deeper water at the proposed disposal ground location results in less potential for re-suspension of fine sediments due to wave-induced stirring.

Based on the model findings, Advisian conclude that there is no potential for dredging to result in near-surface suspended sediment concentrations adversely affecting Pania Reef, as concentrations greater than 10 mg/L above background levels will be exceeded for less than 2% of the time during the dredging campaigns.

Deposition of fine silt fractions on Pania Reef is also not predicted to occur due to the distance from the dredging operations, and limitations to settling at Pania Reef because of natural wave action. Cawthron (2017) note that turbidity around Pania reef can be high for prolonged periods, and that sediment is re-suspended from the reef top rather than the deep layers of ‘soft’ sediment to either side (p112). The Cawthron report also notes that turbidity and sediment deposition and re-suspension on Pania reef due to the dredging programme will be of a similar order of magnitude to ambient conditions, and will not lead to adverse ecological effects at the reef.

3.5 Long term sediment transport from the disposal ground

3.5.1 Sediment mobility and potential deflation of the disposal mound

Based on currents measured at the proposed disposal site, for a depth of 20 m, Advisian calculated the percentage of time each year that sediments of different sizes could be moved as bedload and / or re-suspended (Advisian 2017b). Due to the depth, potential for re-suspension of sediment is low (much less than 1%). Only very long period or very large waves are capable of lifting sediments off the seabed into the water column where they could be transported by ambient currents. These conditions occur infrequently. Sediment mobility as bedload can be initiated more often. Sediment of a diameter of 125µm represents approximately 70% of the dredged sediment. Particles of this size would be mobile due to incipient motion or bedload for approximately 6% (about 3 weeks) of the year under the average yearly range of wave and current conditions.

With regard for potential mobility of the sediments placed at the proposed disposal ground, the Advisian assessment suggests that the site is mildly dispersive for silt, and weakly dispersive for fine and medium sand. The potential for sediment movement from the proposed disposal ground is less than for all silt and fine sand sediment size fractions than for the disposal sites west of the port in depths of 10 m (near the channel approaches) and 6 m (inshore near the Beacons and Westshore).

3.5.2 Direction of sand movement

From data measured to date, currents at the proposed disposal site are almost exclusively to the south. For the period 9th December 2016 to 16th January 2017, current direction was to SSW and SSE (away from Pania Reef) for approximately 70% of the time, and WNW to N (towards Pania reef) for approximately 10% of the time. Although the data collection period for the assessment of potential sediment transport was relatively short, the period included a good range of wave and wind conditions, and was consistent with the average annual distribution of conditions for as assessed from long-term data.

In comparison to the sites west of the port, Advisian made the following observations:

- The potential magnitude of transport at the proposed disposal site is about a third of that estimated for the shallower sites. The model results show that measureable sand transport from the proposed disposal site occurs only during strong NW winds and is directed to the south.
- Although current speeds are generally higher at the proposed disposal site, the greater water depth reduces the ability for waves to initiate or re-suspend sediment for transport by ambient currents.
- For the current data available to date, sediment will be transported away from Pania Reef over 90% of the time.

3.5.3 Potential for turbidity plume generation

Stiff, silty sandy clay deposits dredged from the navigation channel will be deposited rapidly to the seabed and may become a source of turbidity during storm events as the material is slowly eroded. Advisian investigated the potential for erosion and transport of medium and coarse silt during storm events from the six main wind directions using the 3D hydrodynamic and sediment transport model. A severe wave height and period were used to maximum wave stirring of the seabed sediments. The duration of the storm and high wind speeds were increased over what had been observed (from the data from 2004 to 2015) to over-estimate the likely spatial extent of any plume generated during storm conditions.

The results show:

- Only wind from the west produced turbidity plumes that extend over Pania Reef. Winds from other directions result in dispersion of the plume away from Pania Reef, even when wind driven currents are moving in a northerly direction.
- Using conservative assumptions about storm intensity and duration for wind events, the maximum suspended sediment concentration expected over parts of Pania Reef are 2 mg/L above ambient in the surface of the water column, and 4 – 6 mg/L above ambient levels at the bottom of the water column.
- Although fine sediments may be suspended and transported over the reef, permanent deposition will not occur due to wave action and turbulent currents at the reef inhibiting deposition (Advisian 2017b).

4. The direct and indirect effects of the proposed works

4.1 Introduction

The changes to the physical coastal environment due to the proposed dredging activity and the deeper shipping channel have been assessed within the context of the existing coastal process environment around Napier. Potential effects on the physical coastal environment have been identified. These effects are discussed with regard to the following areas:

- Potential changes to the wave environment as a result of deepening the entrance channel and disposal of sediment.
- Changes to patterns of sedimentation in the wider coastal area.
- The dispersal of fine sediments due to the dredging and disposal operation.

4.2 Effects of changes to the wave environment

Changes to the wave environment as a result of refraction across the deeper channel and over the disposal ground mound will be small in magnitude and are unlikely to have a persistent geomorphological effect at the shoreline except in the immediate lee of the channel and swing basin in the vicinity of Port Beach. There will be no noticeable effect on surfing conditions and there will be no changes to existing patterns and variability of beach response to changes in the wave environment. In particular, there will be no increase in erosion or inundation hazards at the shore.

4.2.1 Wave environment inshore of the deepened channel

Due to refraction as waves pass across the deeper channel, wave height and energy is reduced in the immediate lee of the port at Port Beach and the southern section of Westshore, but increased at East Pier and along The Esplanade. Changes in mean wave height are small, with a decrease in mean wave height of about 5 cm at Port Beach, an increase of about 6 cm at East Pier, a decrease of less than 2 cm along Westshore, and an increase of about 2 cm at The Gap.

The deeper channel causes the wave approach to be less refracted as it passes the channel. Therefore at breaking, there is potential for a slightly greater angle between the line of the wave crest and the shore. The resulting change is by about 4 degrees, near to the port, to less than 1 degree at Westshore, and no change to the angle of wave approach to the shore north of The Esplanade. The angle of the wave crest will be rotated clockwise, such that the resultant angle with the shore is to the west and north.

At Port Beach, there is potential for smaller waves (and less energy) to result in the beach being slightly more accretional than at present. There may be a small increase in sediment transport along the beach and nearshore at East Pier (Perfume Point reserve) towards the

Ahuriri inlet channel. However, adjustment of the beach shape in plan is likely to be minor, and contained within the bounds of the Ahuriri inlet eastern training wall and the rubble shore at Spriggs Park.

The slight decrease in wave energy in the southern section of Westshore and the slight rotation of the breaking wave angle to the north along the beach may result in sediment moving north on the beach face, but to the south in the littoral zone and the nearshore. However the magnitude of projected changes are small in comparison to the natural variability of conditions, and there is unlikely to be any measureable long-term adverse or beneficial change to the geomorphological beach response to the wave environment.

4.2.2 Effects on surfability of waves

Wave modelling of the change to the wave corridor with regard to the surf breaks west and north of the port showed negligible effects at The Gap and Westshore. The optimal wave approach for surfing waves at these locations is from the northeast, with a westerly wind. For those conditions, the channel does not affect the wave corridor of these sites.

Although there is a decrease in significant wave height at Port Beach, there is a small increase in the significant wave height along Hardinge Road, and an increase of up to about 0.4 m in maximum wave height. There was little change to the breaker type as a result of the dredging. The increase in wave height suggests that wave scattering from the swing basin will enhance the potential for a long ride along Hardinge Road. The peel angle increases slightly following dredging and there is slight improvement to the surfing amenity classification, with a greater proportion of waves at the break more suitable for surfing (Advisian 2017c).

There is also a small increase in wave height at the City Reef break (Whakarire Avenue) and an increase of about 0.4 m to the maximum wave height. For both the right and left hand breaks at City Reef, the peel angle and surfing amenity classification did not change significantly as a result of the dredging.

4.2.3 Wave environment inshore of proposed sediment disposal ground

The effect of the raised seabed on wave refraction at the proposed disposal ground east of the port is limited to changes in wave energy in the area immediately west of the disposal ground. Wave height is modified due to wave refraction across the disposal ground, with a maximum change in energy-weighted wave height of ±4 cm at the shore. There is no change to the energy-weighted wave direction at the shoreline. These small changes in predicted wave energy are limited to the area immediately onshore of the disposal ground, extending to less than 1 km south of the Town Reef. The changes will not result in measureable changes to the geomorphological work the waves will do at the shore.

4.3 Effects of changes to sedimentation processes

It is expected that the proposed dredging programme will result in changes to patterns and processes of sedimentation in the immediate vicinity of the port and the proposed disposal area. Changes will result from:

- Addition of fine sediment into the water column and environment during the dredging activity (excavation in the channel and swing basin, and deposition at the disposal ground);
- Changes to the margins of the dredged area as the sides of the channel and margin of the swing basin "relax" into an equilibrium condition; and
- The addition of the dredged sediment onto the offshore seabed.

Sedimentation process effects include turbidity in the harbour, at the dredged sediment placement site and areas in-between, changes to wave refraction and sediment movement on the seabed as a result of placement of dredged sediment, and possible changes to maintenance dredging operations as a result of the deeper channel.

4.3.1 Turbidity and spatial extent of plumes

The dredging activity will result in suspended sediments being added to the water column resulting in turbidity. The character of the sediments are such that sand particles will rapidly drop to the seabed, while silt and finer sediment concentrations will be relatively evenly spread through the water column.

During dredging, the plume generated will be very localised to the area worked. Sand overfill (spilling from the dredge hopper) will settle quickly. The highest concentrations occur at the beginning of the dredging campaigns due to trailer suction hopper dredge dominating. Lower suspended sediment concentrations result from backhoe dredging. Dredging along the navigation channel will have potential for plume generation, but because of the sediment character, this will have lower sediment concentrations than the plume resulting from dredging the inner harbour port area. It is unlikely that plume generation from dredging the channel will be greater than what occurs at present during maintenance dredging.

Deposition at the disposal ground will generate a more extensive plume than the dredging. As with overfill, settling of the sand fraction will occur rapidly and will not travel far from the discharge site. Modelling for a large range of wave and wind and resulting current scenarios showed that there is no potential for Pania Reef to be affected by suspended sediments >10 mg/L above background. Suspended sediment concentrations at the reef, while negligible, are highest during times when the currents at the spoil ground are directed toward the northwest. The 98%ile Silt/clay fraction concentration (exceeded for less than 1 day per month during the dredging campaigns) is less than 10 mg/L above background levels over the reef area. This would not be visible to the casual observer.

4.3.2 Deposition of sediments and turbidity plume generation from the disposal ground

The proposed offshore disposal ground east of the port has similar in situ sediment characteristics to the material to be dredged Cawthron (2017). Placement of the dredged sediment would not change the composition of the seabed sediments. The deposited sediment will result in a mound being built on the seabed, and this mound will intercept and transfer fine sediments moving on the seabed. The wave and current energy at the disposal area is not sufficient to cause mass movement of the deposited sediment away from the site, but the small volume of medium sand fraction may be winnowed from the site and move onshore.

With regard to the potential mobility of the sediments placed at the proposed disposal ground, the Advisian assessment suggests that the site is mildly dispersive for silt, and weakly dispersive for fine and medium sand. The potential for sediment movement from the proposed disposal ground is less than for all silt and fine sand sediment size fractions than for sites west of the port due to the deeper depth (about 20 to 23 m compared to depths of 10 m near the channel approaches and 6 m inshore near the Beacons and Westshore).

Although fine sediments may be suspended and transported over the Pania Reef, deposition of re-suspended fine silt fractions from the proposed disposal ground is not predicted to occur due to the distance from the ground, and limitations to settling at Pania Reef because of natural wave action. Turbidity around Pania Reef can be high for prolonged periods. Observations show that fine sediment is re-suspended from the higher levels of the reef rather than the deep layers of ‘soft’ sediment to either side.

Modelling results show that only wind from the west produced turbidity plumes that extend over Pania Reef. Winds from other directions result in dispersion of the plume away from Pania Reef, even when wind driven currents are moving in a northerly direction. The models also showed that the maximum suspended sediment concentration expected over parts of

Pania Reef are 2 mg/L above ambient in the surface of the water column, and 4 – 6 mg/L above ambient levels at the bottom of the water column.

The Cawthron report also notes that turbidity and sediment deposition and re-suspension on Pania reef due to the dredging programme will be of a similar order of magnitude to ambient conditions, and will not lead to adverse ecological effects at the reef.

4.3.3 Sand transport patterns from the proposed disposal ground

The proposed disposal ground does not result in sediment transport back into the dredged channel. This is an important consideration in determining the ideal disposal site. Sites west of the port and inshore towards Westshore will act as source areas for fine sand and silt to move to the southeast and back to the navigation channel.

From data measured to date, currents at the proposed disposal site are almost exclusively to the south. For the period 9th December 2016 to 16th January 2017, current direction was to SSW and SSE (away from Pania Reef) for approximately 70% of the time, and WNW to N (towards Pania reef) for approximately 10% of the time.

4.3.4 Effects on the present pattern of maintenance dredging

Over-dredging of the channel sides and batter slopes will allow for adjustment of the channel and margins after the capital-dredging programme is complete.

Although sediment will not move from the proposed disposal ground east of the port back towards the navigation channel, the deeper and longer channel across the seabed is likely to result in additional capture of sediment moving naturally within the area. However the quantity of this increase is unknown. Increased interception due to the increased length of the channel will possibly be offset by placement of fine sediments of the capital dredging east of the port, and relaxation of the over-dredged channel sides. It is likely that the interception rate and required maintenance dredging will be at least of the same order of magnitude as at present, at between 30,000 and 80,000 m^3 per year.

Small changes to sediment transport at East Pier may result in a small increase to the maintenance dredge demand for the channel into Ahuriri Lagoon.

5. Conclusions

The coastal area around Napier is characterised by the nature of the sediments making up the coast, and the limited nature of the wave environment in Hawke Bay. The mixed sand and gravel sediments of the beaches result in two distinct sediment transport systems, with coarser sediments (sand, gravel and cobbles) moving on the beach due to wave action, and fine sediments (fine sand, and silts) moving on the seabed due to wave and wind-driven currents.

The Napier coast is subject to variable wave energy but dominated by long-period swell waves from the east, with secondary energetic waves from the northeast. The coast was raised by the 1931 Hawke's Bay earthquake, resulting in a combination of immediate and long-term responses in change to the coastal geomorphology. The Napier Port and breakwater have also resulted in change to the coast in providing a protected harbour at Bluff Hill, and sheltering the shore to the east.

Studies were carried out on a proposal to deepen the navigation channel, and to deepen and increase the size of the swing basin at the port. Investigations included identifying the most suitable disposal site for the dredged sediments. to investigate these effects have shown that they are mostly negligible, and of magnitudes within the variability of the natural environment.

The main considerations for the effects on the physical coastal processes were:

- Potential changes to the wave environment as a result of deepening the entrance channel and disposal of sediment,
- Changes to patterns of sedimentation in the wider coastal area, and
- The dispersal of fine sediments due to the dredging and disposal operation.

Studies have shown that the effects are mostly small, and of magnitudes within the variability of the natural environment.

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7. Appendix 1

Coastal and Continental Shelf Processes of Napier and Southern Hawke Bay Bibliography

Bibliography Format

The bibliography contains both published and unpublished information. Material is arranged alphabetically by author.

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