Gisborne Port – Twin Berths Project

Summary of Effects of the Capital & Maintenance Dredging and the reclamation & breakwater upgrade

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MetOcean SOLUTIONS

Document History

Versions

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Contents

1.Introduction

Eastland Port Ltd (EPL) is redeveloping its port infrastructure to allow for an expected increase in log exports. EPL are also required to renew their capital and future maintenance dredging and disposal consents. Currently, dredged sediment is disposed at an offshore disposal site situated in approximately 18 – 20 m water depth (Figure 1.1), with an average annual dredge volume of approximately 70,000 m^3 based on estimates obtained between 2003 and 2019 by Eastland Port (Worley, 2021).

These works include redeveloping Wharf 7 and extending Wharf 8 seaward to accommodate two vessels in the port at the same time, combined with restoring the outer breakwater back to its previous dimensions, and reclaiming the area to the south of it (Figure 1.2). The interaction of the refurbished breakwater and the reclaimed area with the incoming waves might affect the surfing conditions along Poverty Bay. In addition, fine sediments can potentially be released during the construction of the reclamation area, from fine sediments present on the rock and crushed rocks to be used for the reclamation revetment.

MetOcean Solutions (MOS) has been contracted to investigate the effects on the waves and sediment transport associated with the dredging and disposal of capital and maintenance dredging material at the existing offshore disposal site (see Figure 1.3 and Figure 1.4). Several numerical modelling investigations have been undertaken in 2017-2018 when a greater volume of capital dredging was proposed. The capital dredging volume has now been revised as presented in Worley (2021). MetOcean Solutions has updated the modelling with regards to the effects of the proposed channel dredging and the disposal of capital and maintenance dredging material at the offshore disposal ground . MetOcean Solutions has also undertaken a wave modelling and sediment plume study of the reclamation area to understand the impact of the planned redevelopment

This summary report presents the outcome of the following investigations and associated reports (see in Appendices):

- Hydrodynamic hindcast validation – Report P0331-04
- Wave hindcast validation – Report P0331-05
- Morphological model validation – Report P0331-03
- Dredging plume modelling – Report P0331-08
- Morphological response to capital dredging – Report P0331-09
- Disposal plume modelling – Report P0331-07

- Morphological response of the offshore disposal ground to the discharge of capital dredging sediments – Report P0331-20
- Morphological response of the offshore disposal ground to the discharge of maintenance dredging sediments - Report P0331-21
- Morphological response of the shoreline to the disposal of capital dredging sediments - Report P0331-22
- Morphological response of the shoreline to the disposal of maintenance dredging sediment - Report P0331-23
- High resolution wave modelling of existing and proposed port configurations– Report P0331-26
- Effects of breakwater upgrade on local wave climate – Report P0331-27
- Assessment of potential sediment plume during Port reclamation works – Report P0331-28
- Eastland surfbreak assessment – Report P0331-30
- Proposed Monitoring for Capital and Maintenance Dredging - P0331-31

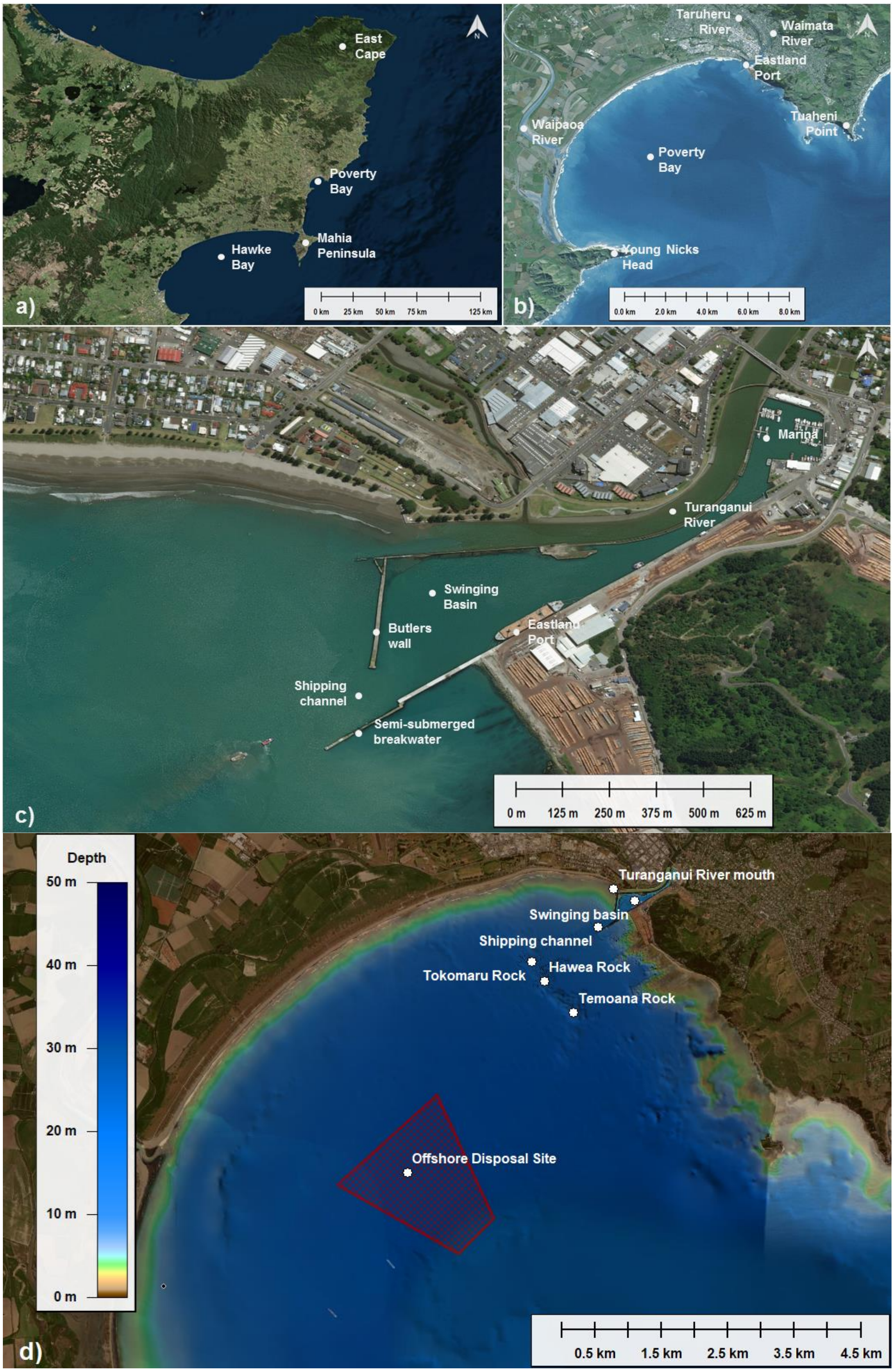

Figure 1.1 Maps showing the location of Poverty Bay (a, b), and Eastland Port (c) with focus on the location of the offshore disposal ground (red hatched area in panel d). Colormap in (d) represents the bathymetry.

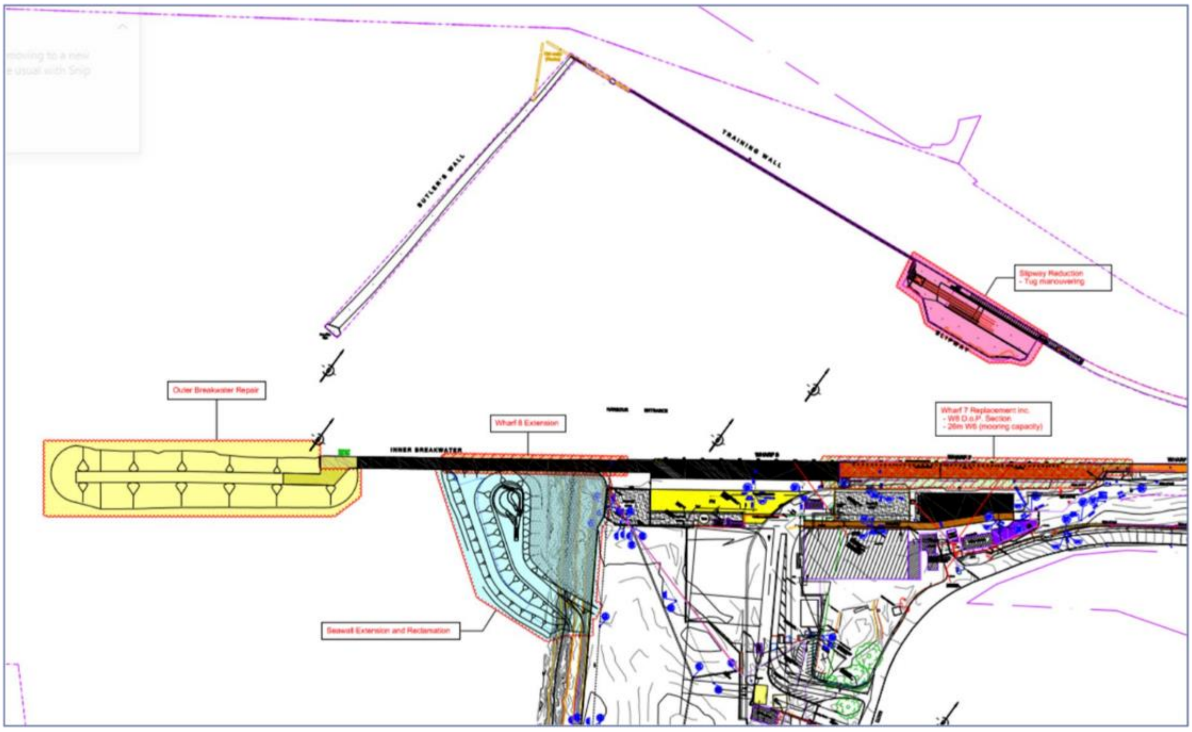

Figure 1.2: Eastland Port layout. The proposed developments considered in this study, reclamation and breakwater refurbishment, are highlighted in blue and yellow respectively.

Figure 1.3 Vessel releasing its overflow mixture in the oceanic environment.

Figure 1.4 Backhoe dredging – the backhoe is placed onto a barge and dispose removed sediment into the vessel.

2. Methodology

MetOcean Solutions (MOS) has been contracted to provide coastal oceanographic expertise to investigate both physical and morphological effects and associated sediment transport patterns resulting from the dredging and disposal of Maintenance and Capital dredged material.

For this purpose, different numerical models were applied. Below is a brief description of each model.

2.1 Wave modelling

The numerical wave transformation model Spectral WAve Nearshore (SWAN) was used to characterise the wave climate, both within and offshore Poverty Bay. A multiple-nesting approach (Figure 2.1) was applied to produce a 10-year wave hindcast for Poverty Bay spanning 1996 to 2005. Measured wave data over years 2007 and 2008 was used to calibrate and validate the numerical model.

SWAN is a third-generation ocean wave propagation model which solves the spectral action density balance equation. The model simulates the growth, refraction and decay of each frequency-direction component of the complete sea state, providing a realistic description of the wave field as it changes in time and space. Physical processes that are modelled include the generation of waves by surface wind, dissipation by white-capping, resonant nonlinear interaction between the wave components, bottom friction and depth limited wave breaking energy dissipation.

A detailed description of the model equations, parameterisations and numerical schemes can be found in Holthuijsen et al., (2007) or the SWAN documentation[1].

The wave hindcast model validation is presented in MetOcean Solutions, 2017a - P0331-05.

[1] http://swanmodel.sourceforge.net/online_doc/online_doc.html

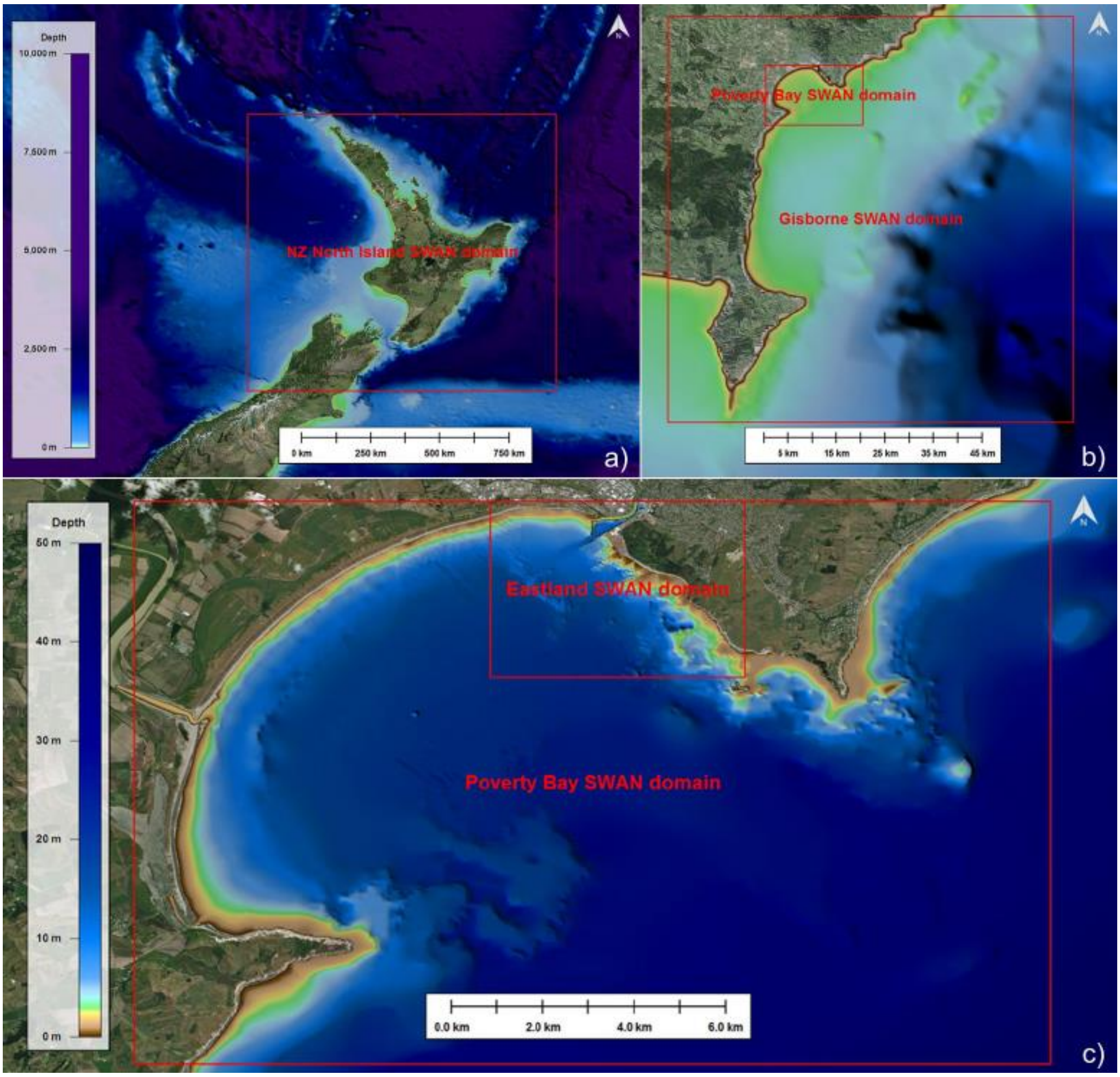

Figure 2.1 Map showing the SWAN nested domains used to simulate the spectral transformation of the offshore wave climates to the nearshore zone.

2.2 Hydrodynamic modelling

A modelling approach was developed which nest the Finite-element (FE) unstructured-grid SCHISM model within a coarser Regional Ocean Modelling System (ROMS) model to perform a dynamical downscaling of the circulation from deep ocean areas to the eastern shelf of the North Island (New Zealand) and Poverty Bay.

ROMS model

The hydrodynamic model Regional Ocean Modelling System (ROMS, Haidvogel et al., 2008) was used to recreate a 10-year regional hindcast. ROMS is widely used in the scientific and commercial consultancy communities at ocean basin, regional and coastal scales. ROMS has a curvilinear horizontal coordinate system and solves the hydrostatic, primitive equations subject to a free-surface condition. The terrain-following vertical coordinate system results in accurate modelling of shelf seas with variable bathymetry.

SCHISM model

The unstructured-grid SCHISM model (Figure 2.2) was nested within ROMS to increase the available resolution and more accurately account for complex topographical features (rocky reef etc.) in the relatively shallow Poverty Bay environment.

SCHISM is a prognostic finite-element unstructured-grid model designed to simulate 3D baroclinic, 3D barotropic or 2D barotropic circulation. The barotropic mode equations employ a semi-implicit finite-element Eulerian-Lagrangian algorithm to solve the shallow-water equations, forced by relevant physical processes (atmospheric, oceanic and fluvial forcing). A detailed description of the SCHISM model formulation, governing equations and numerics, can be found in Zhang and Baptista (2008).

The hydrodynamic hindcast model validation is presented in MetOcean Solutions, 2017b - Report P0331-04.

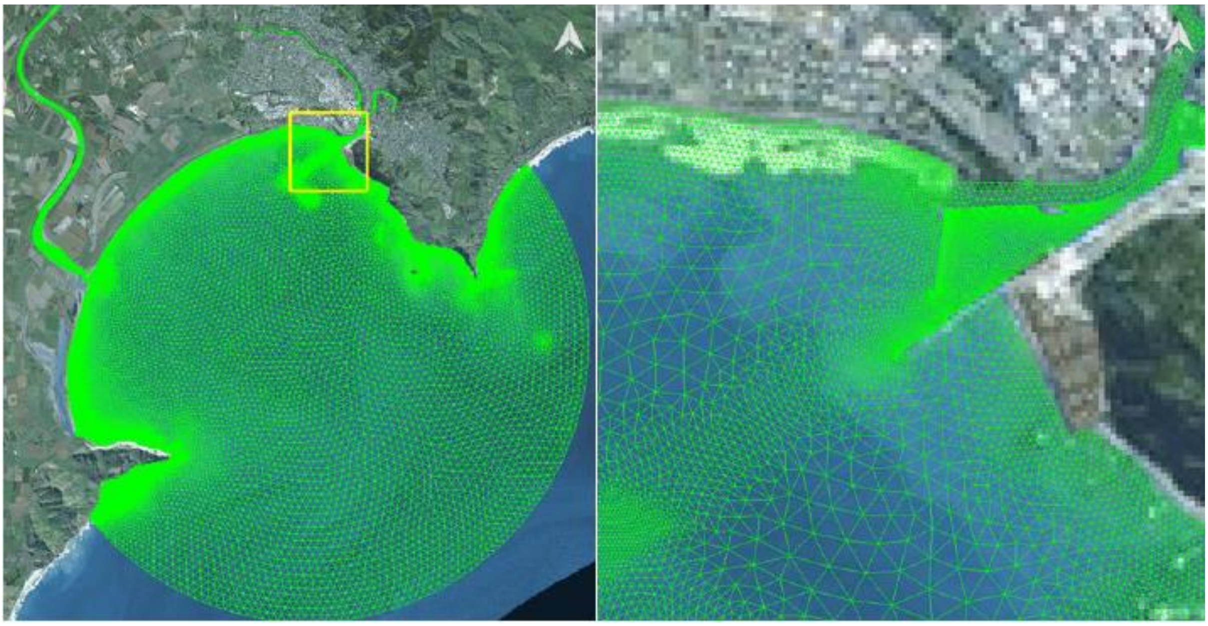

Figure 2.2 Unstructured mesh-grid used in SCHISM to simulate the hydrodynamics over Poverty Bay (left) and Eastland Port (right).

2.3 Morphological modelling

The modelling system Delft3D (Lesser et al., 2004) was used to set up and run high-resolution process-based morphodynamic models. The software is based on interlinking three separate components (Delft3D – WAVE, Delft3D – FLOW and Delft3D – MOR, Figure 2.3) that together simulate flows, waves and sediment transport. The three components are fully coupled to simulate morphodynamic feedbacks. Delft3D has been specifically developed to simulate the dynamics of complex coastal regions controlled by a wide range of physical and morphological process interactions.

The methodology to replicate the annual sediment transport included the use of combined reduction techniques and morphological acceleration factors (MORFACs) as well as storm-induced morphological simulations.

The morphological model validation is presented in MetOcean Solutions, 2018e - P0331-03.

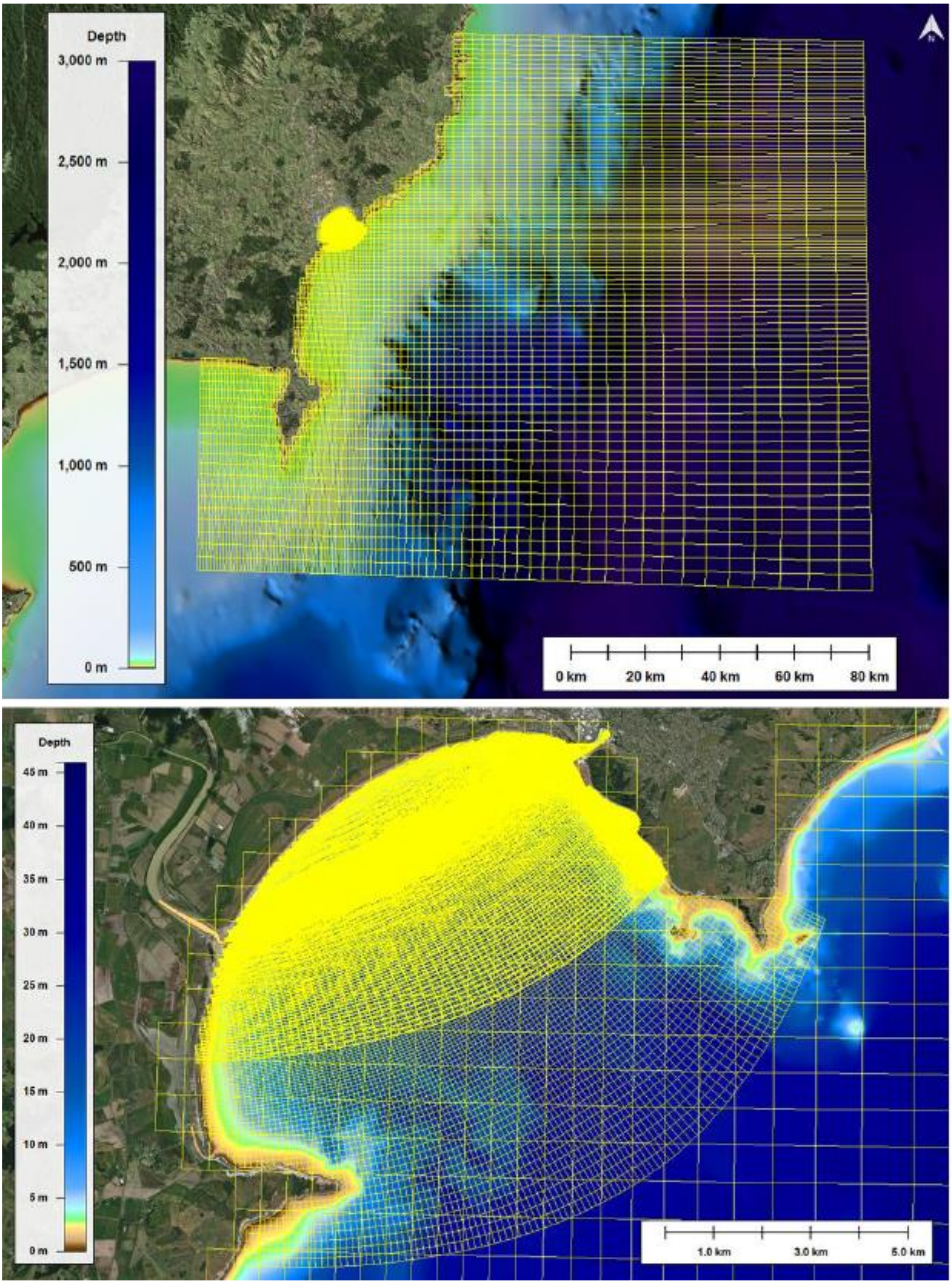

Figure 2.3 Map showing the three-level nesting strategy applied in Delft3D – WAVE, Delft3D – FLOW and Delft3D – MOR to replicate the wave, hydro, and sediment dynamics over Poverty Bay and Eastland Port. The resolution of the finest grid ranges between 7 and 120 m, with a particular focus on Eastland Port. The intermediate and coarse grid resolutions range between 60 – 200 m and 600 - 6000 m, respectively.

2.4 Particle tracking modelling

A Lagrangian model developed by MOS was used to simulate the trajectories of particles released at the dredging and disposal sites. The model consists of trajectory scheme applied to the 3D Eulerian current field, solving for the motion of discrete particles.

The processes by which sediment is released and suspended in the water column during dredging operations depend on the choice of the source term magnitudes and release depths for the particle tracking simulations (Figure 2.4 to Figure 2.6).

Concentration and depositional thickness computation were undertaken using the kernel estimation approach proposed by Botev, et al. (2010). Based on a given cloud of particles (Xpart,Ypart), the method yields a probability density function PDF(x,y), derived from the kernel density estimator describing the density of particles throughout the domain. The PDF(x,y) is provided over a rectangular grid with a resolution that can be adjusted by the user.

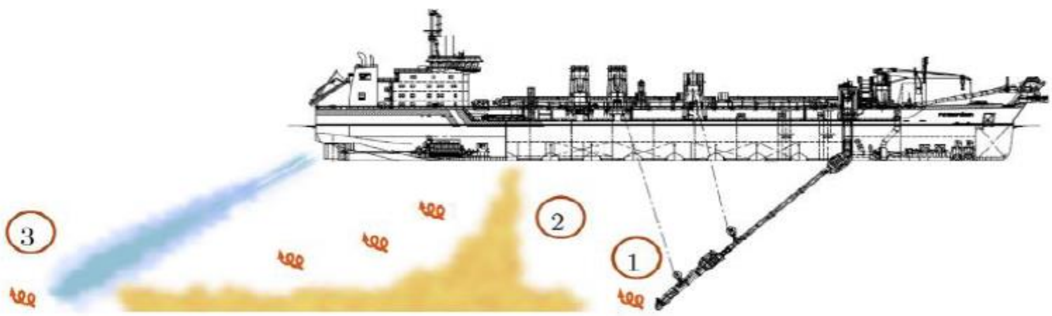

Figure 2.4 Sediment suspension sources of Trailing Suction Hopper Dredger: 1-Drag Head, 2-Overflow, including de-entrainment during plume descent through the water column and density current on the seabed, 3-Propeller wash (from Becker J. et al., 2015).

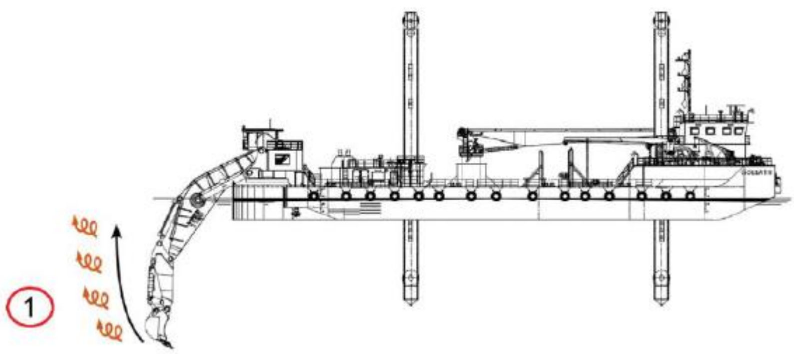

Figure 2.5 Sediment suspension sources of a Backhoe Dredger (from Becker J. et al., 2015).

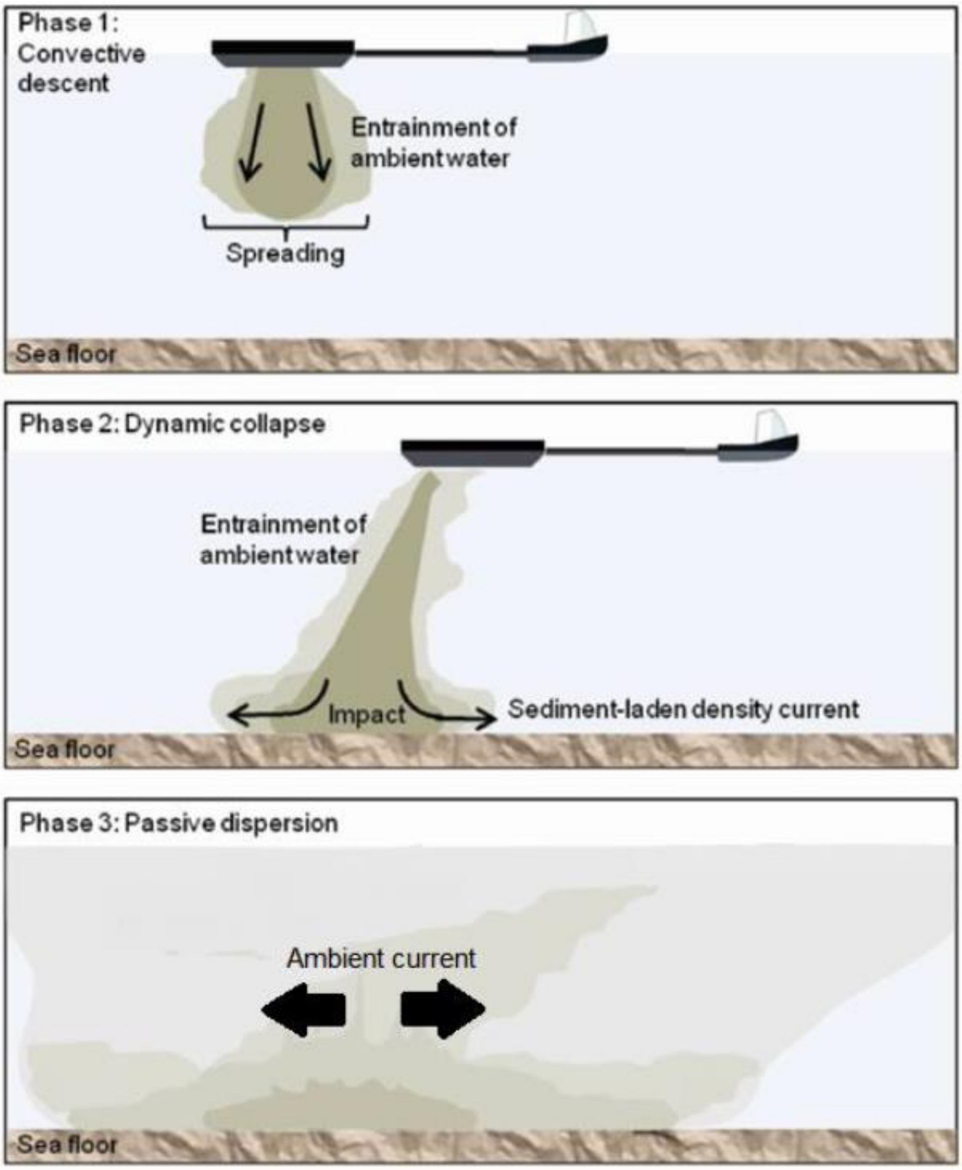

Figure 2.6 Three main phases occurring during the disposal of dredged material: 1) Convective descent, 2) Dynamic Collapse, and 3) Passive plume dispersion. Similar processes are expected when dense overflow sediment mixture is released during dredging.

3. Coastal Settings

3.1 Bathymetry

MetOcean Solutions compiled an extensive national and regional bathymetric dataset derived from Electronic Navigation Charts (ENC). These datasets were updated with hydrographic surveys within Eastland Port and the surroundings. Specialist data manipulation tools were used for merging, interpolation and QA of raw bathymetry data when establishing numerical model domains. Note that GEBCO data (Becker et al., 2009) was also used to characterise the deepest areas.

Water depth data was specifically created over Poverty Bay to interpolate to the computational grids of the wave, hydrodynamic, and morphological models (Figure 3.1).

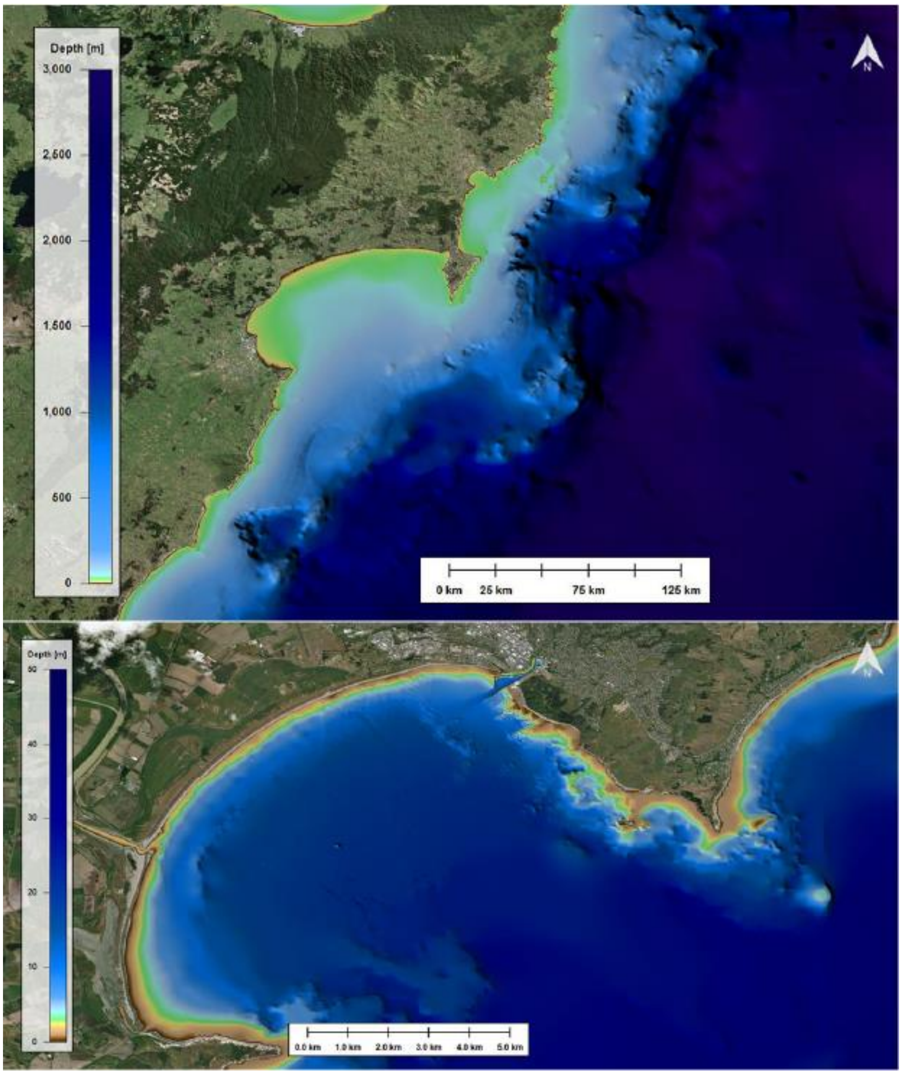

Figure 3.1 Map showing both the 500 x 500 m (top) and the 5 x 5 m (bottom) gridded bathymetries used to interpolate the water depth to the computational grid in SWAN.

3.2 Wind

Measured winds were available from Gisborne Airport weather station and Hicks Bay, located at East Cape. The time series of measured wind speed covered the period from 2000 to 2008. Measured winds tend to be primarily orientated NW/SE (Figure 3.2). Gisborne Airport presents complex topography while Hicks Bay is one of the most exposed locations along the East Coast. This data was used for model verification.

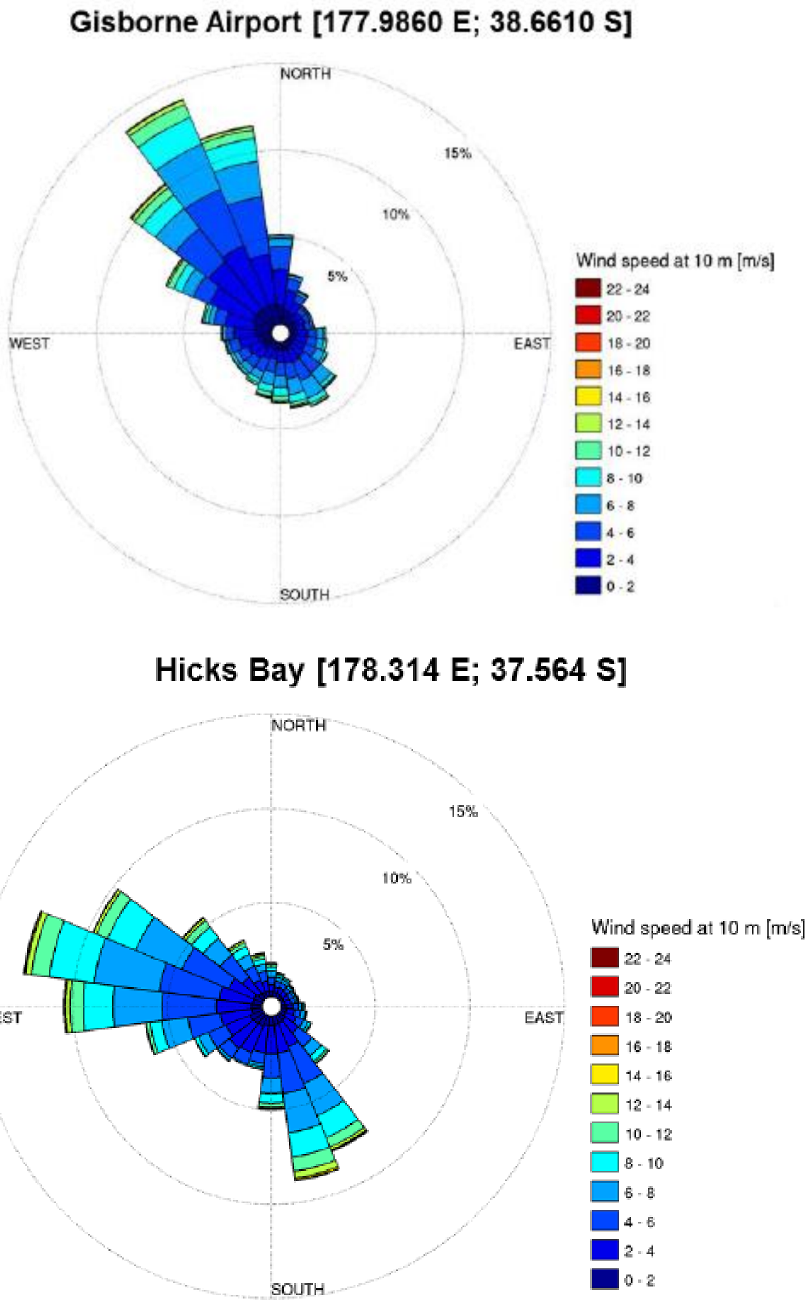

Figure 3.2 Measured wind roses at Gisborne Airport (top) and Hicks Bay (bottom) for the period 2000 – 2008. Winds are reported in the "coming from" directional reference.

3.3 Wave climate

Available measured wave data covered a period between 2007 and 2008 at sites WB1 and A1 (Figure 3.3). A1 is located north of the Eastland Port's shipping channel, and partially sheltered by the complex shallow reef offshore Kaiti Beach. Cape Kidnappers and Mahia Peninsula are shown to affect the propagation of wave energy into the coastal and nearshore regions. The dissipative effects caused by Tokomaru, Hawea and Temoana Rocks and the entrance to Eastland Port contribute to significantly attenuate the wave energy over the northern area of Poverty Bay.

The 10-year (bias-corrected) SWAN hindcast data at Sites WB1 and A1 were used to characterise the nearshore wave climate (Figure 3.4).

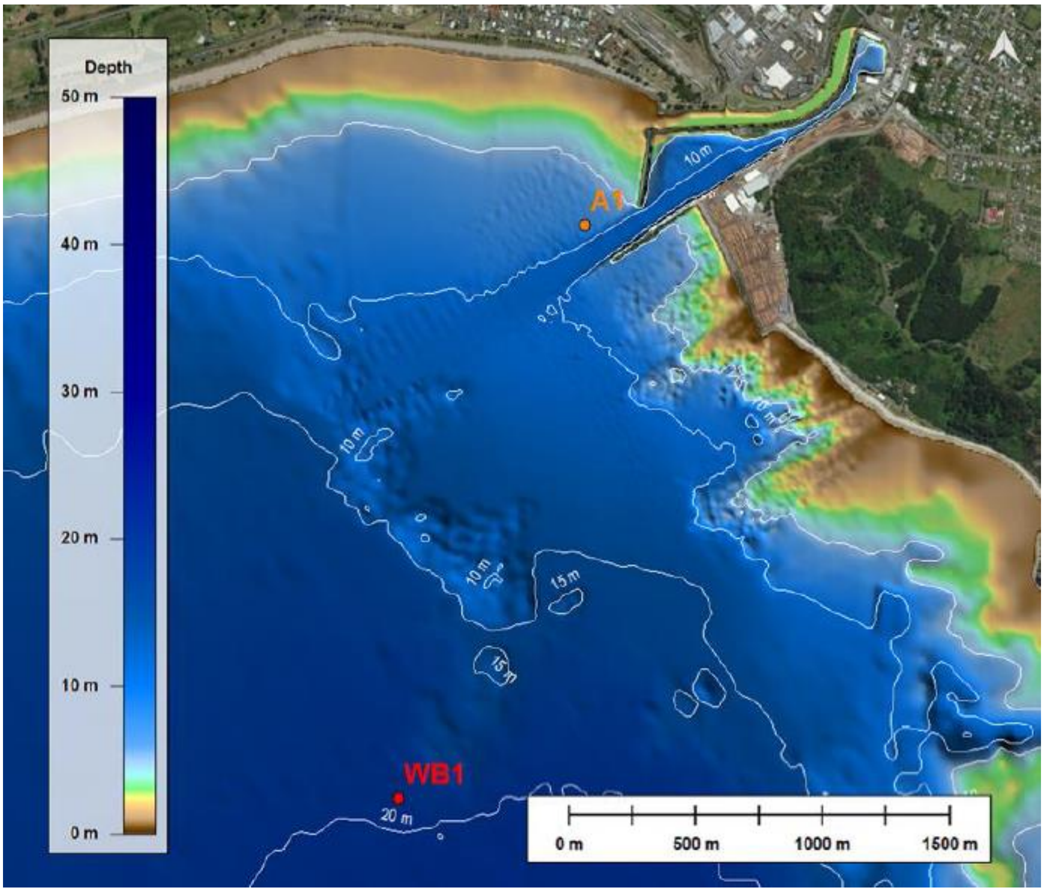

Figure 3.3 Map showing the bathymetry over Poverty Bay. The orange dots indicate the location of the S4 current meter data used to validate the SWAN wave model.

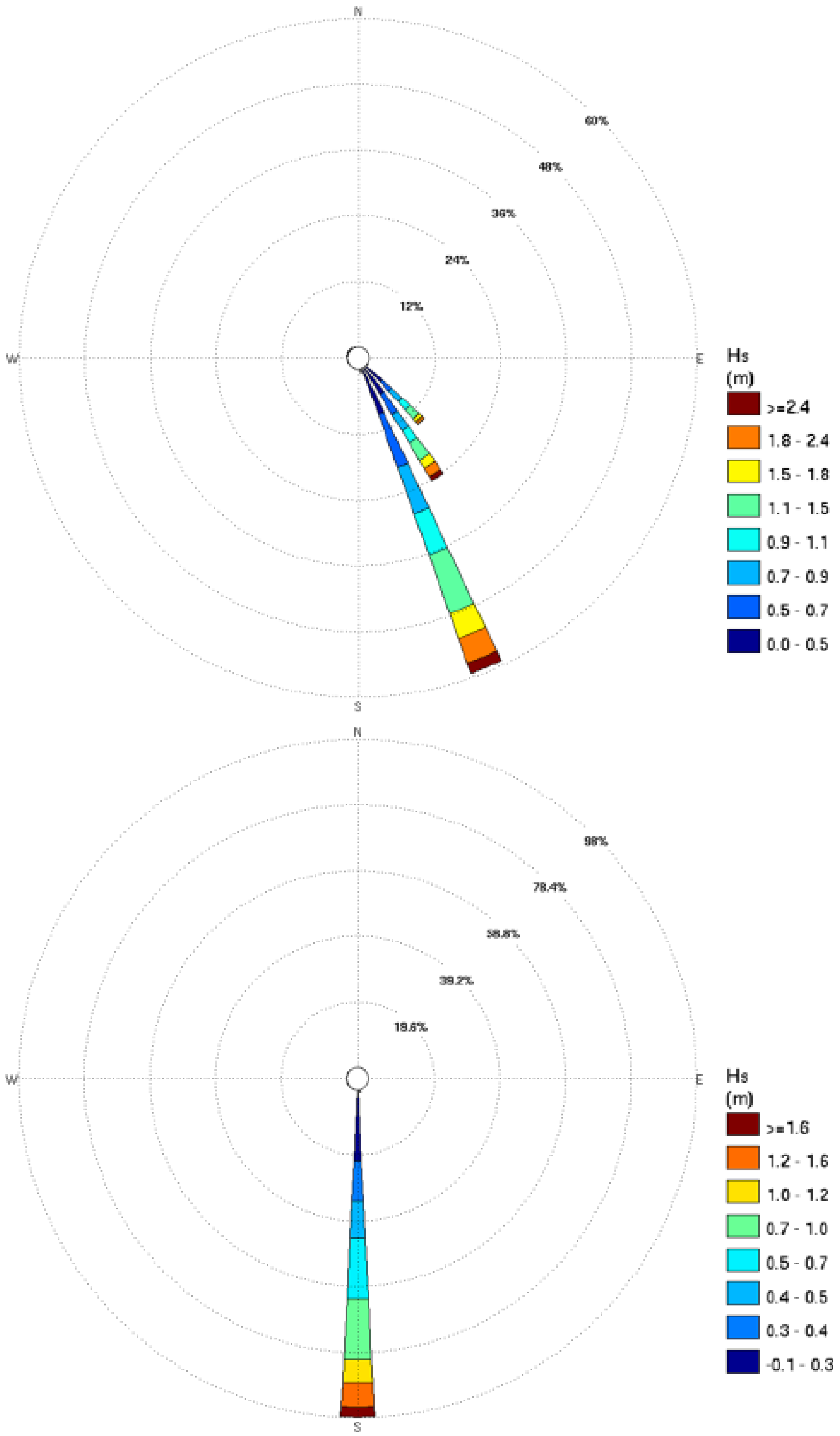

Figure 3.4 Wave rose diagrams based on 10 year hindcast data (1996 – 2005) at Sites WB1 (top) and A1 (bottom). The direction follows the nautical "coming from" convention.

3.4 Hydrodynamics

Poverty Bay is a complex coastal embayment essentially influenced by:

- inner continental shelf currents
- river discharge
- wind upwelling and down-welling
- vertical mixing due to salinity and temperature gradients
- tidal dynamics

Influence of shelf currents on the inner circulation

During events characterised by southerly flowing shelf currents and low-river discharge, Tuaheni Point at the northern end of Poverty Bay deflects currents into the bay. This induces an anticlockwise circulation initiated over the deeper area of the bay, as shown in the hydrodynamic model results (Figure 3.5). The presence of Mahia Peninsula and the orientation of the coastline cause this recirculation to develop, which in turn pushes away the northward shelf currents.

By contrast, northerly flowing shelf currents generate a clockwise gyre in the bay (Figure 3.5). Southward shelf currents are more frequent than northerly flows but comparisons between monthly depth-averaged current indicate that the anticlockwise circulation gyre pattern dominates in the bay.

Influence of river discharge on the inner circulation

Both the Waipaoa and Turanganui Rivers (though to a lesser extent) discharge relatively high volumes of fresh water into Poverty Bay, and as such can significantly influence the bay-wide hydrodynamics within this micro-tidal semi-enclosed system. South-eastward surface currents associated with moderate to strong Waipaoa river discharge generate a complex hydrodynamic system which can extend to the outer parts Poverty Bay. The influence of the Turanganui River appears mainly constrained to the northern margin of the bay, although exceptional rainfall events within the catchment area can result in significant surface currents extending to the entrance of the bay.

Mixing processes within Poverty Bay

The strong salinity gradient during large river discharge episodes generates density driven mixing processes that affect the hydrodynamics of the bay. During NW wind episodes, wind-driven surface offshore currents and onshore bottom currents lead to upwelling along the coast.

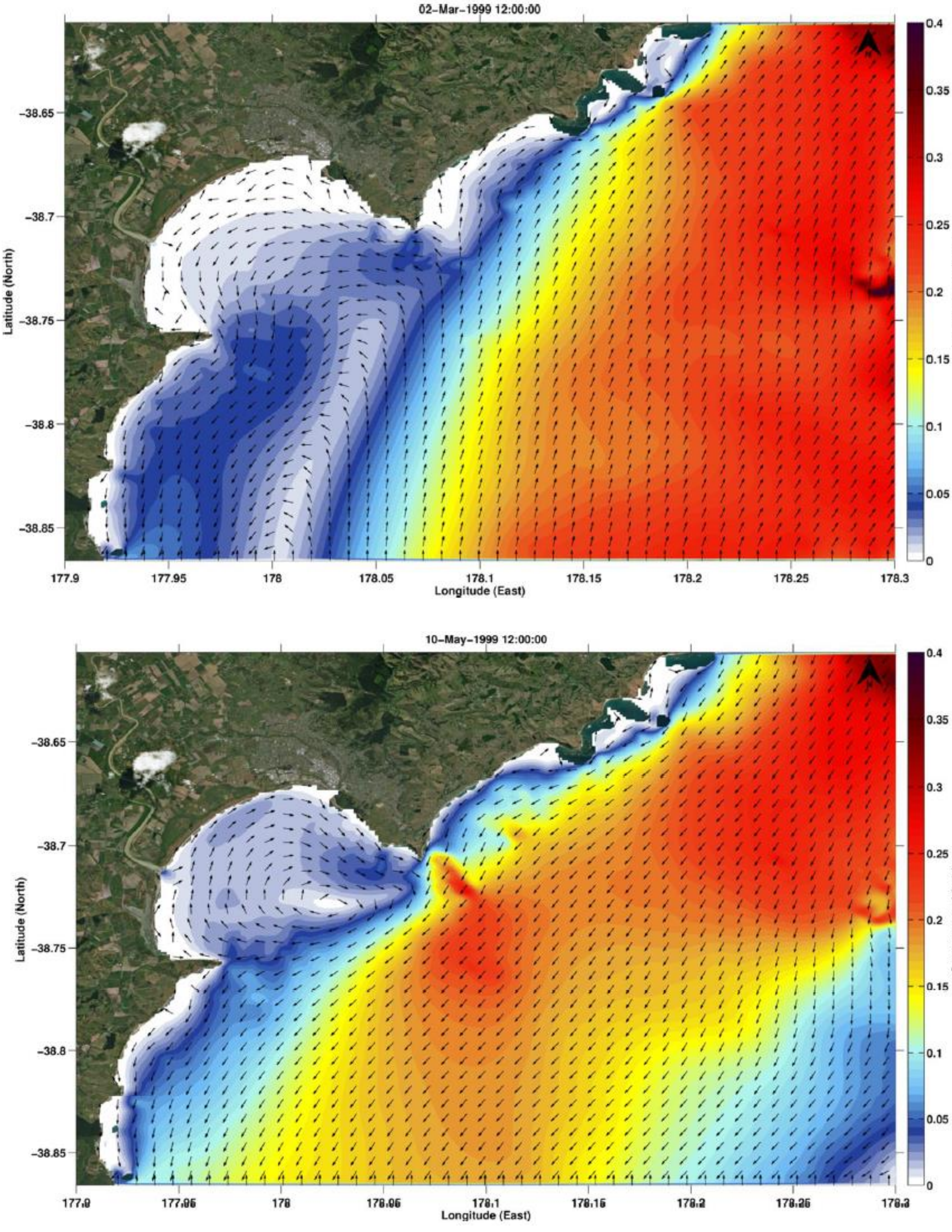

Figure 3.5 Daily depth-averaged current fields predicted by the ROMS model within Poverty Bay and over the adjacent continental shelf region.

3.5 Sediment and morphology

Poverty Bay is characterised by five surficial sediment textural types described in Beamsley (2003) as follows and represented in the model as in Figure 3.6:

- Well sorted sands near the beaches
- Moderately well sorted silty sands covering most of the bay
- Moderately well-sorted silty sands with more clay in the southern corner of Poverty Bay
- A patch of finer sediment near Young Nick's Head
- Poorly sorted material in and adjacent to the dredge spoil mound

Surficial sediments are comprised of predominantly fine sand and mud (silt and clay) in the bay and Eastland Port, while medium to coarse sands are found near the Waipaoa river mouth and beaches.

The relative distribution of cohesive versus sandy material is seen to significantly vary throughout the region of interest, from the channel basin (80%-20%) to the outside of the port (20%-80%).

As described by Black et al. (1997) and Beamsley (2003), the entrance to Eastland Port and the Swinging Basin act as a sediment trap. The energy gradient within the port entrance and Swinging Basin results in a gradient in sediment grain sizes, with fine-grained sand particles preferentially settling in the port entrance. Finer sediment (i.e., Very Fine Sand and Mud) are held in suspension and advected into the Swinging Basin where they undergo relatively increased flocculation processes under spatially varying salinity gradients near the river mouth and settle out of suspension.

While the eastern section of the channel is exposed to accretion due to near-bed sediment supplies, the sediment dynamics over the western section is mainly linked to the large deposition of silt occurring in the centre of Poverty Bay from the Waipaoa River. The formation of a mud blanket between the 12 m and 15 m isobath in the model is consistent with the sediment dynamics of the embayment described in Smith (1988).

Annual volumetric infilling rates

Infilling of the Eastland Port navigation channel and inner basin occurs over time. Eastland Port estimated that approximately 80,000 $m^3.yr^{-1}$ and 20,000 $m^3.yr^{-1}$ of sediments deposit into the navigation channel and inner basin at Eastland Port (Eastland Port, 2013). These estimates were obtained by considering both hydrographic survey and dredging records between 2009 and 2013. Black et al. (1997) provided a total infilling rate of 103,000 $m^3.yr^{-1}$ over a surface area of 137,300 m^2 covering both the outer channel and the inner basin based on sediment transport numerical modelling.

Shoreline changes

The beach areas, except Kaiti Beach, are characterised by nearshore coastal progradation in agreement with Smith (1988) and Foster and Carter (1997). Smith (1988) notes that, based on aerial photographs, approximately 2000 $m3.yr^{-1}$ of sediment is supplied annually to Kaiti Beach. The resultant volumetric changes are, however, negligible compared to the magnitude of the sediment fluxes near the Turanganui River mouth and adjacent beaches.

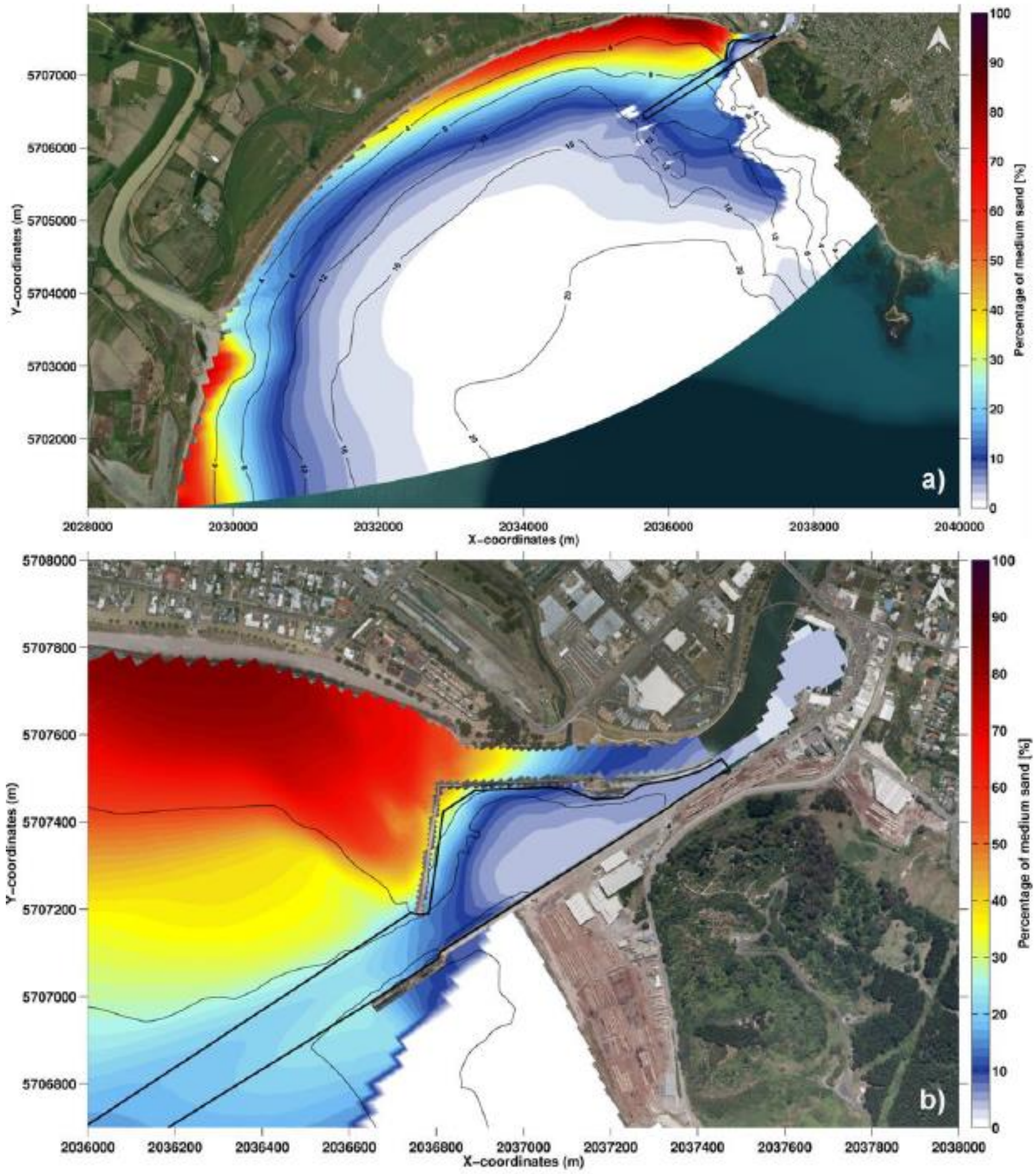

Figure 3.6 Model initial spatial distribution (%) of medium sand (250 µm) in the surficial bed layer over (a) Poverty Bay and (b) Eastland Port.

4. Assessment of effects

4.1 Dredging plume modelling

The Dredge sediment plume modelling is presented in MetOcean Solutions, 2018c - P0331-08 and focuses on the characterisation of the sediment plume patterns expected during the dredging of the shipping channel, swinging basin and berth pockets. Dredging operations were simulated using particle-tracking modelling over two different 1-year periods within contrasting historical contexts, namely El Niño/La Niña episodes.

The modelling was undertaken based on 2018 proposed capital dredging and has not been updated for revised 2021 capital dredging campaign (Worley 2021). However, as the 2021 proposed capital dredging covers the same area (i.e., outer shipping channel, swinging basin, etc.) and same type of sediments as the modelling presented in MetOcean Solutions (2018c), the modelling outcome presented in this report is valid for the proposed 2021 campaign (i.e., is anticipated to present similar plume dispersion patterns).

Three different dredging methods were considered, using a vessel (e.g., Pukunui) of 480 m^3, using a larger capacity Trailer Suction Hopper dredge (e.g., Albatros - 1860 m^3) and dredging using backhoe. Source terms considered in the simulations include drag head disturbance, propeller wash, de-entrainment from released overflow mixture, near-bed density current, surface losses, and bucket losses for backhoe dredging.

The general plume dispersion patterns vary along the shipping channel following ambient current regimes (Figure 4.1). Dispersion patterns are typically elliptical, with an elongation northwest-southeast, along the outer channel; this characteristic is conserved moving towards the Port entrance but becomes combined with an increasing northeast-southwest dispersion characteristic associated with the “flushing” flows in and out of the Port swinging basin. Dispersion patterns further into the Port swinging basin become elongated in the northeast-southwest direction, following the general channel orientation. The larger hopper volume, dredging and overflow source terms associated with the Albatros vessel generally result in *Suspended Solids Concentration (SSC)* magnitudes that are significantly larger than levels obtained for the vessel or backhoe scenarios.

Plume dispersion simulations were reproduced assuming two different settling velocities for the cohesive sediment class. It is noted that although some of the dispersion footprints associated with the smaller settling velocity (0.1 $mm.s^{-1}$) may seem significant, footprint “edges” are often associated with SSC levels of order 1-10 $mg.L^{-1}$ which can be smaller than the background SSC (e.g., due to river discharges or other sources). The effective SSC increase could be mitigated by altering the operating mode (no overflow or use a "green valve") and/or duration of the overflow phase when applicable.

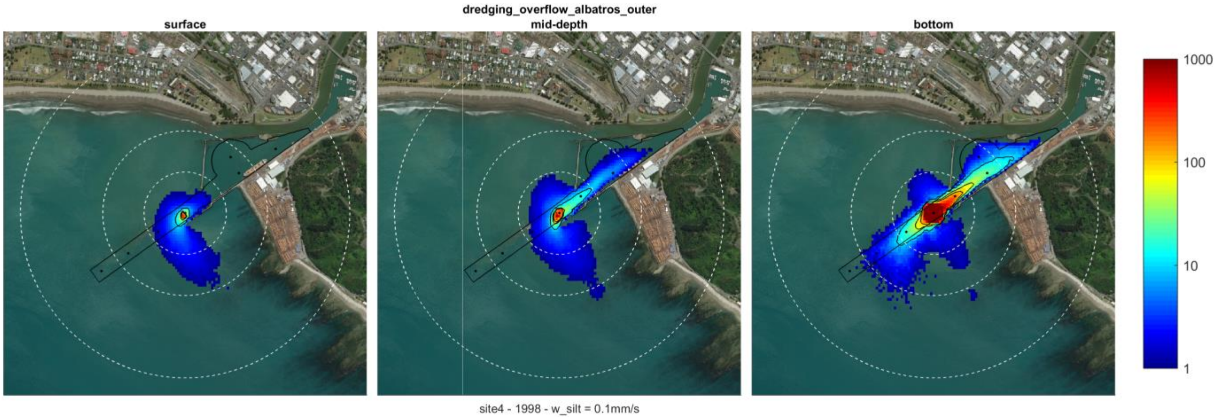

Figure 4.1 Example of probabilistic SSC fields (mg.L^{-1}) while dredging with overflow, in the outer channel (site 4), using the Albatros vessel (V=1860 m^3), derived from the annual La Niña period (June 1998 – June 1999). Dashed white circles have radiuses of 250, 500 and 1000 m. The 10, 50 and 100 mg.L^{-1} contours are shown in black.

4.2 Morphological response to port and channel deepening

Investigation of the likely morphological effects of the proposed capital dredging is presented in MetOcean Solutions (2018b - P0331-09).

Model results show that in the absence of ongoing maintenance dredging, the annual infilling rate in the channel and the inner basin will be in the range 70,000–170,000 $m^3.yr^{-1}$. (for 'La Niña' and 'El Niño' phases of ENSO respectively). The modelling was undertaken based on 2018 proposed capital dredging and has not been updated for revised 2021 capital dredging campaign (Worley 2021). Worley (2021) has proposed to adopt an annual maintenance dredging volume of 140,000 m^3 which includes sediments from the inner and outer Port navigation channel, vessel turning basin and batter, low speed ship manoeuvring area, wharf 8 and wharf 7 berth pockets and batter, and Tug manoeuvring area (Worley 2021).

The channel deepening is expected to increase the inter-annual variability of the deposition rate depending on the river discharges and incident wave climate. During large river discharges and more energetic wave events, the daily volumetric infilling rate may increase by up to 78% as a response of the proposed capital dredging.

A fraction of the infilling rate is attributed to the diffusion of sediments from the batters at the edge of the dredged channel into the channel itself; the gradual slope contributes, however, to limit the influence of waves on the bed-load component of the sediment transport.

Within the outer dredged channel, in the absence of ongoing maintenance dredging, the bathymetry is likely to quickly return to its pre-dredging state due to large muddy discharges from the rivers. More frequent maintenance dredging is expected to be required to maintain design draft over time through the entire channel.

The Eastland Port proposed dredging project is expected to have a limited impact on the environs existing morphodynamics. Subtle changes in the hydrodynamics and wave patterns to the north of the navigation channel may alter some of the sediment deposition patterns in the vicinity of the channel without fundamentally changing the overall coastal dynamics. No areas of significant erosion/accretion processes are expected to result from the proposed capital program (Figure 4.2).

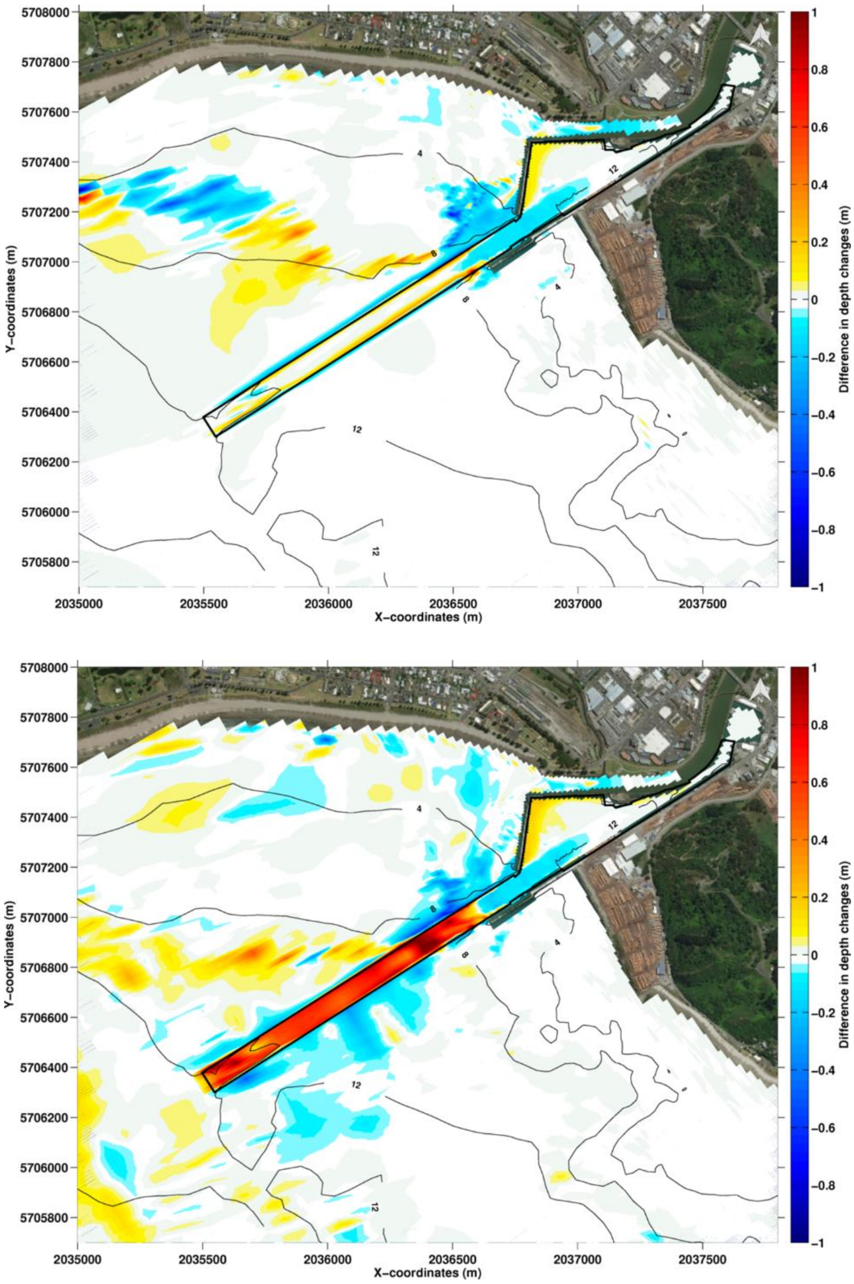

Figure 4.2 Predicted differences in morphological response over the period 1998 – 1999 ("La Niña", top) and 2002 – 2003 ("El Niño", bottom) between the post-dredging and the existing configurations of Eastland Port. The black polygon indicates the capital dredging area.

4.3 Disposal plume modelling

The characterisation of the sediment plume patterns expected during the dredge material disposal operations is presented MetOcean Solutions, 2018d - P0331-07. Disposal operations were simulated using particle-tracking modelling over two different 1-year periods within contrasting historical contexts, namely El Niño/La Niña episodes. Two different vessels with different hopper capacities are considered, i.e., the Pukunui (V= 480 m^3) and Albatros TSHD (V=1860 m^3) and two different sediment settling velocity were considered for the cohesive fraction to account for uncertainties in the flocculation effects.

The general *SSC* plume pattern consists in relatively contained plume in the surface and mid-depth layers, becoming more extended (radius of order ~200 m) in the bottom layer due to the formation of a density current. Predicted deposition patterns are predominantly circular, with thinner northwest-directed features resulting from the deposition of the passive plumes. Predictions for the vessel (hopper volume = 480 m^3) suggest *SSC* levels will generally fall below the 10 $mg.L^{-1}$ threshold within 250m of the release in the surface and mid-depth levels and within 500-700 m of the release in the bottom levels.

The above results focused on the disposal of sediment loads composed primarily of silt material (80% silt, 20% sand) since finer sediment will remain much longer in suspension in the water column and is potentially the most problematic with respect to the spatial excursion of the produced sediment plumes.

For reference, the SSC and deposition fields predicted for a disposal of predominantly "sandy" and "silty" material are compared in Figure 3.11 to Figure 3.18. The key differences between the disposal of a "sandy" versus "silty" sediment load is expectedly the total footprints of the SSC plumes and deposition fields; they are larger for the "silty" load than for the "sandy" load due to the difference in settling times. That being, the relatively more compact sediment dispersion footprint as well as the larger density used in that case (1350 $kg.m^{-3}$ for a "silty" load versus 650 $kg.m^{-3}$ for a "sandy" load) also results in locally larger SSC magnitudes and deposition thicknesses. Note that for the SSC plume, the larger levels will only be sustained for a short period of time, given the fast settling.

The mean and median footprint patterns are similar to the probabilistic results. Here, the 90^{th} footprints are useful to assess largest expected plume dispersion (extents exceeded only 10% of the time). For the results using a settling velocity of 1 $mm.s^{-1}$, the highest SSC (bottom layer) of order ~100-1000 $mg.L^{-1}$ are generally contained within 250m of the release point, dropping to less than 10 $mg.L^{-1}$ or less at 300-350 m from release. The use of a smaller settling velocity of 0.1 $mm.s^{-1}$ results in a relative widening of the general SSC footprints; bottom SSC levels immediately in the immediate vicinity of the release are relatively smaller than those predicted using 1 $mm.s^{-1}$, however the footprint of the 10 $mg.L^{-1}$ contour can extend up to 600 m from release. These concentrations are above background concentrations which can range from 130 to 230 $kg.m^{-3}$ within the port area and 20 $kg.m^{-3}$ beyond the port working area (4Sight, 2019). The results will provide guidance to the marine ecology consultant to define the potential impact of these SSC plumes on sensitive receptors.

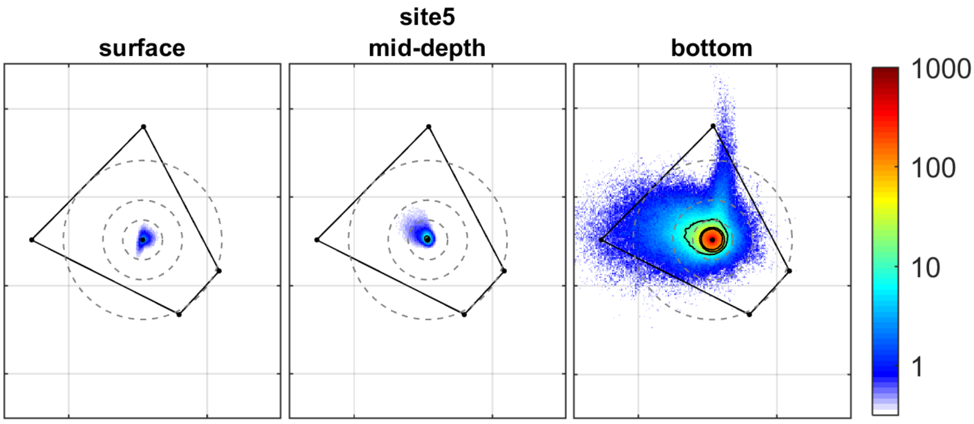

Figure 4.3 Probabilistic SSC fields resulting from the disposal of one hopper load of the vessel (V=480 m^3), derived from the annual El Niño period (June 2002-June 2003). The results assumed a settling velocity of 0.1 $mm.s^{-1}$ for the cohesive sediment class. Dashed grey circles have radiuses of 250, 500 and 1000 m. The 10, 50 and 100 $mg.L^{-1}$ contours are shown in black.

4.4 Morphological response of the offshore disposal of capital dredging

In the report MetOcean Solutions (2021d - P0331-20) we assessed the morphological effects of disposal of capital dredging sediments within Poverty Bay and examined the effect of the disposal mound on the wave climate.

The effect of the disposal mound of 0.049 m on the nearshore wave climate is negligible. The wave energy is expected to be redistributed along the beach areas adjacent to the Waipaoa River mouth. The resultant increase in significant wave height during energetic storm events is expected to be 0.01 m or less. Some very localised changes in wave direction occur which are not expected to modify the overall longshore sediment transport patterns along the beach.

Between 71% and 80% of the disposal mound associated with the simulated capital dredging volume of 135,400 m^3 is expected to be eroded, mostly related to the weakly-consolidated silt fraction. This corresponds to between 96,000 m^3 and 109,000 m^3 of sediment being advected from the disposal ground over a 1-year simulation period (for La Niña and El Niño, respectively).

The silt fraction of the disposed material is transported mostly northwest and southwest of the disposal ground. Small deposition of silt may occur to the northeast of the bay. The very fine sand particles are expected to migrate south and south-westward, with sediment expected to move to depths of 12– 24 m within the 1-year simulated period. A smaller fraction of fine sand is expected be transported over the disposal area and its margins. No sediment from the disposal mound is expected over the adjacent beach areas.

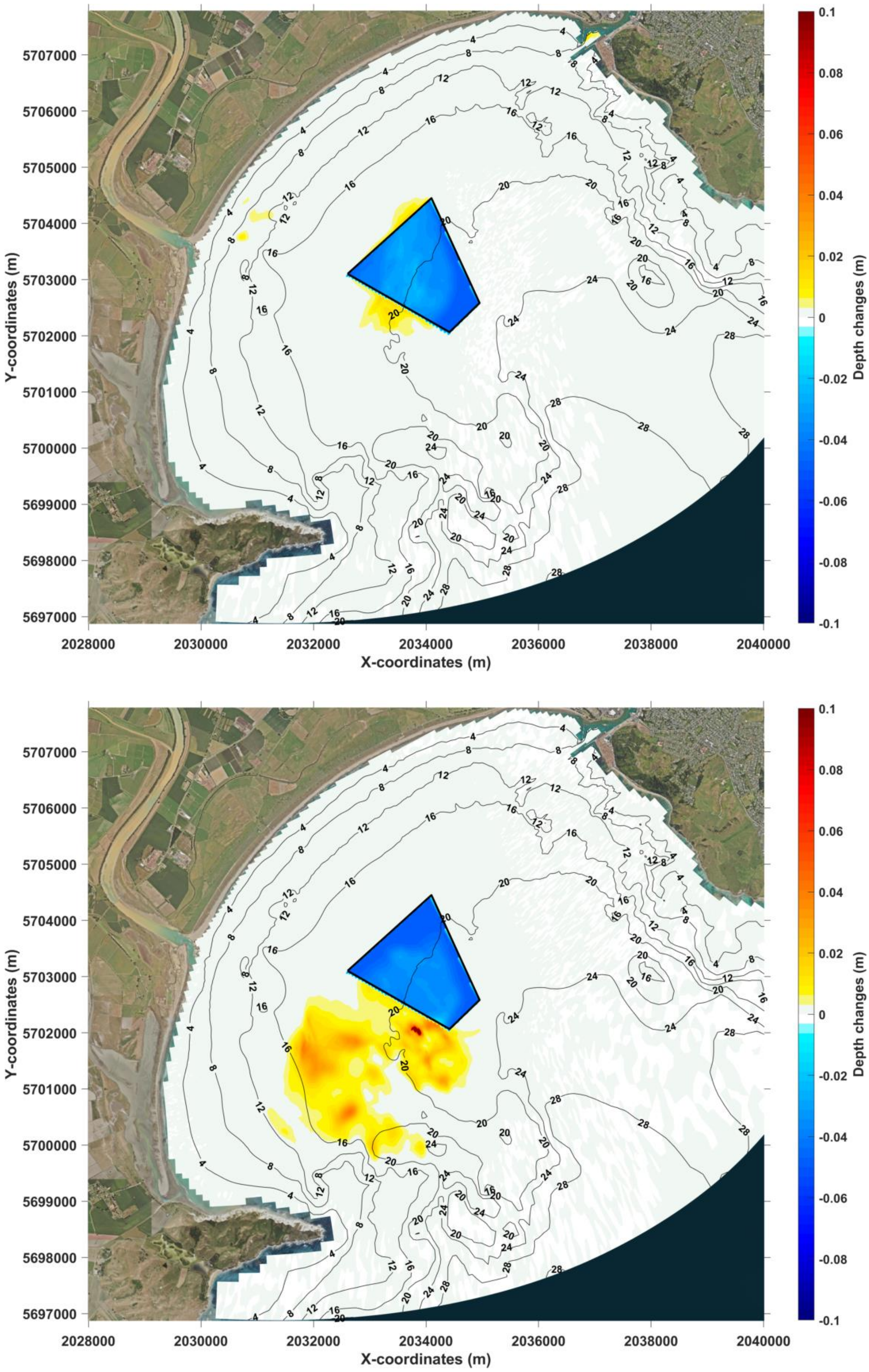

Figure 4.4 Disposal ground change predicted at the end of a 1-year La Niña (top) and El Niño (bottom) simulated periods considering disposal volumes of 135,400 m³.

4.5 Morphological response of the offshore disposal of maintenance dredging

In the report MetOcean Solutions (2021c - P0331-21), we assessed the effects of disposal of maintenance dredging sediments on the morphology and wave climate within Poverty Bay.

The effect of the disposal mound of 0.052 m on the nearshore wave climate is negligible. The resultant increase in significant wave height during energetic storm events is expected to be 0.01 m or less. Some very localised changes in wave direction occur which are not expected to modify the overall longshore sediment transport patterns along the beach.

Between 71% and 80% of the disposal mound associated with the simulated maintenance dredging volume of 140,000 m^3 is expected to be eroded, mostly related to the weakly-consolidated silt fraction. This corresponds to between 99,000 m^3 and 112,000 m^3 of sediment being advected from the disposal ground over a 1-year simulation period (for La Niña and El Niño, respectively).

The silt fraction of the disposed material is transported mostly northwest and southwest of the disposal ground. Small deposition of silt may occur to the northeast of the bay. The very fine sand particles are expected to migrate south and south-westward, with sediment expected to move to depths of 12– 24 m within the 1-year simulated period. A smaller fraction of fine sand is expected be transported over the disposal area and its margins. No sediment from the disposal mound is expected over the adjacent beach areas.

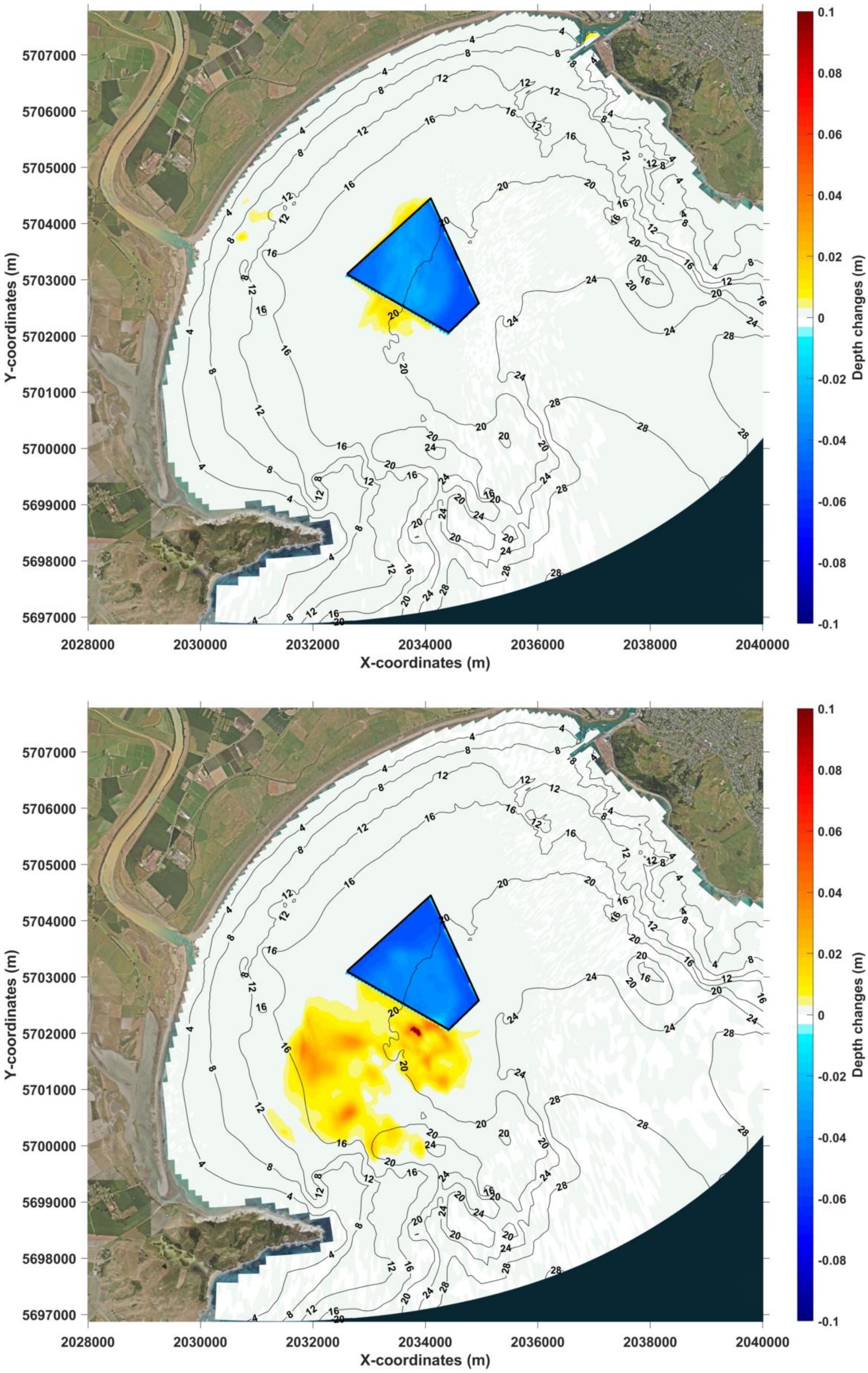

Figure 4.5 Disposal ground change predicted at the end of a 1-year La Niña (top) and El Niño (bottom) simulated periods considering disposal volumes of 140,000 m^3.

4.6 Morphological response of the shoreline to the disposal of capital dredging

In the report MetOcean Solutions, 2021b - P0331-22, we assessed effects of capital dredging disposal on the incident wave characteristics and sediment dynamics along the shoreline. The assessment was based on the morphological numerical modelling results provided in MetOcean Solutions (2021d - P0331-20) and by reviewing available literature describing the historic shoreline evolution.

The mound related to the disposal of capital dredging sediments (mound hight = 0.049 m, disposal volume = 135,400 m^3) has a negligible effect on the incident wave refraction patterns over and inshore of the disposal site, with changes in significant wave height of ±0.2% or less. Some very localised changes in wave direction occur at the 10-m isobath which are not expected to modify the overall longshore sediment transport patterns and beach shoreline. The morphological response relative to the disposal mound does not result in significant deposition of sediment on the inshore beach area.

The input of sediments from disposal of capital dredging sediments is negligible in terms of beach morphodynamics compared to the fluvial sediment inputs from the Waipaoa River discharges.

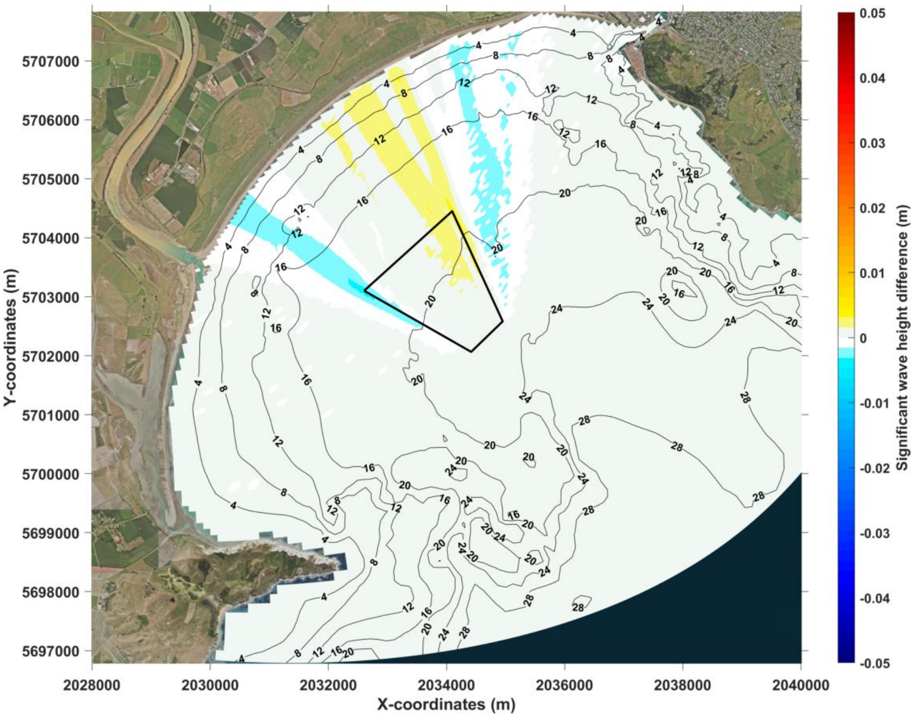

Figure 4.6 Post-disposal difference in significant wave height caused by the 5 cm disposal mound for the wave class 6 (Hs = 5.72, Tp = 12.05, Dir = 232.19).

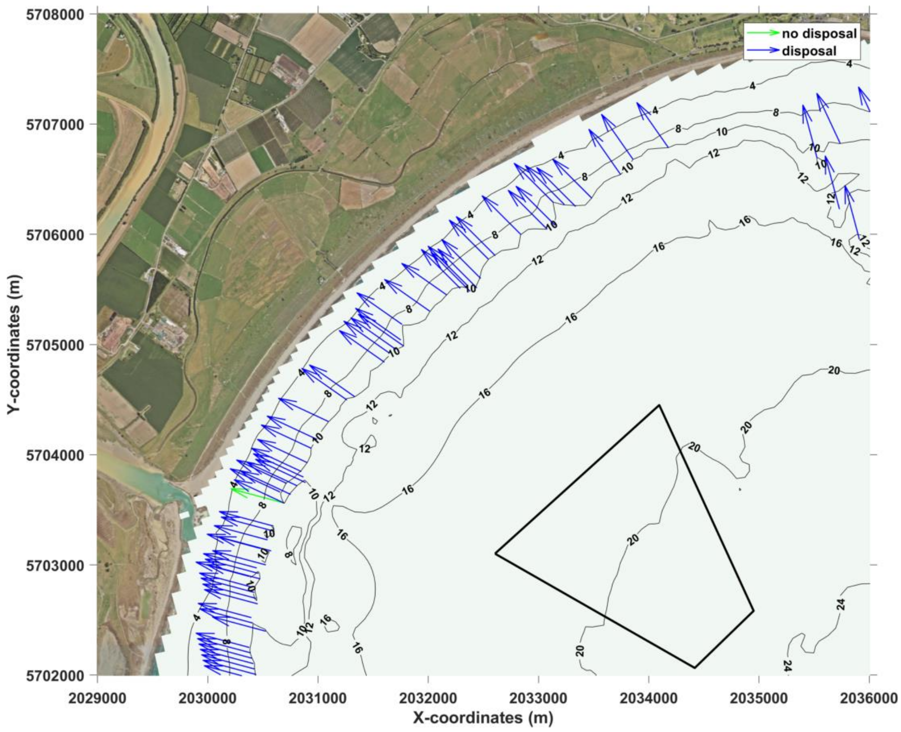

Figure 4.7 Wave direction at the 10-m isobath for the existing (green) and post-disposal (blue) scenarios for wave class 2. El Niño (Hs = 3.49, Tp = 10.80, Dir = 98.39).

4.7 Morphological response of the shoreline to the disposal of maintenance dredging

In the report MetOcean Solutions, 2021a - P0331-23, we assessed effects of maintenance dredging disposal on the incident wave characteristics and sediment dynamics along the shoreline. The assessment was based on the morphological numerical modelling results provided in MetOcean Solutions (2021c - P0331-21) and by reviewing available literature describing the historic shoreline evolution.

The mound related to the disposal of maintenance dredging sediments (mound hight = 0.052 m, disposal volume = 140,000 m^3) has a negligible effect on the incident wave refraction patterns over and inshore of the disposal site, with changes in significant wave height of ±0.2% or less. Some very localised changes in wave direction occur at the 10-m isobath which are not expected to modify the overall longshore sediment transport patterns and beach shoreline. The morphological response relative to the disposal mound does not result in significant deposition of sediment on the inshore beach area.

The input of sediments from disposal of maintenance dredging sediments is negligible in terms of beach morphodynamics compared to the fluvial sediment inputs from the Waipaoa River discharges.

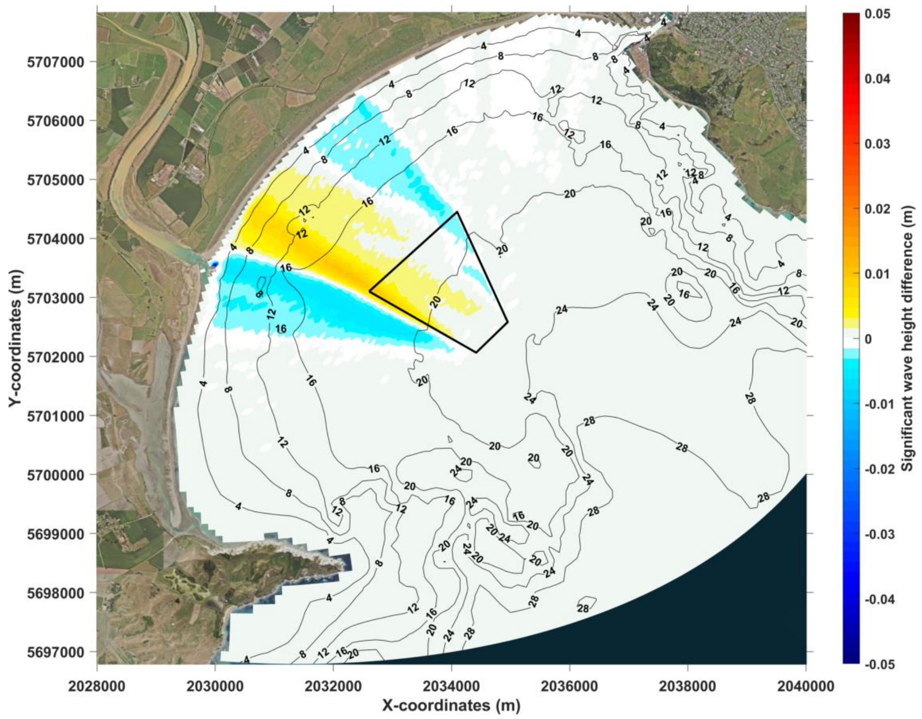

Figure 4.8 Post-disposal difference in significant wave height caused by the 5.2 cm disposal mound for the wave class 3 (Hs = 4.75, Tp = 10.44, Dir = 73.67).

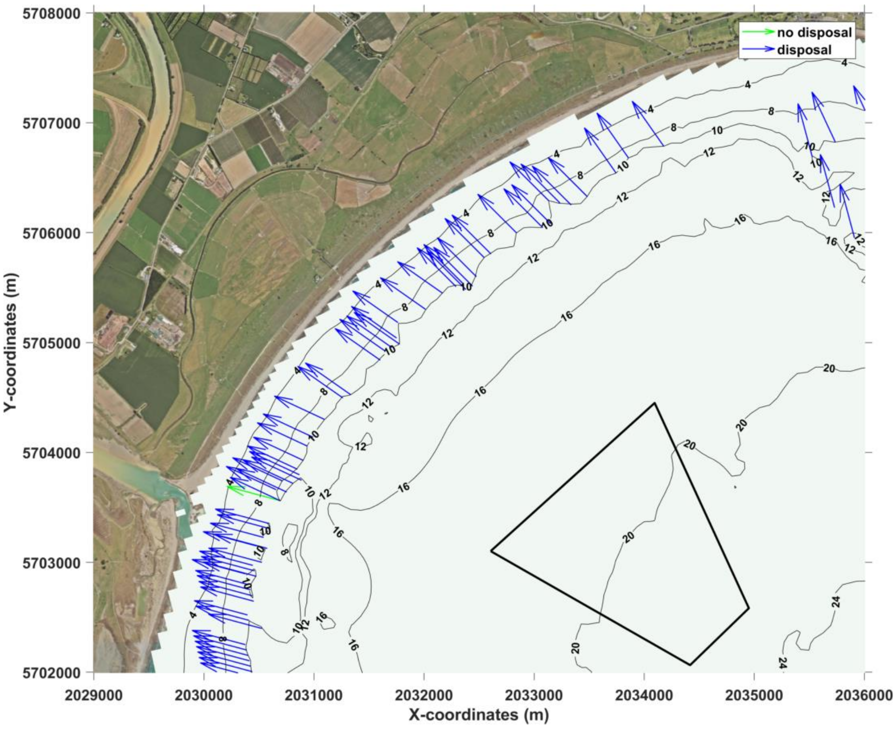

Figure 4.9 *Wave direction at the 10-m isobath for the existing (green) and post-disposal (blue) scenarios for wave class 2. El Niño (Hs = 3.49, Tp = 10.80, Dir = 98.39).*

4.8 Surfing wave dynamics

The primary objective of the study presented in MetOcean Solutions, 2021e - P0331-30 is to assess the effects of the Eastland Port reclamation, breakwater refurbishment and channel deepening on the existing nearshore wave processes within Poverty Bay. The specific focus is on how capital dredging and disposal may affect the resulting wave conditions at the Midway Beach area (which has several notable surf spots, including Pipe and Roberts Road) and at the Waipaoa River mouth (i.e., Big River). Other Nationally and regionally significant surf breaks within Poverty Bay are not expected to be impacted by the proposed capital and maintenance dredging and disposal activities.

An analysis of the wave climate was undertaken using a 10-year time-series of wave parameters extracted from a high-resolution wave hindcast implemented in a previous study to characterise the general wave climate and identify the conditions favourable for surfing events. Poverty Bay is exposed to a relatively narrow incidence wave angle window (140-170°T) due to refraction and diffraction processes around the bay headlands and as the waves propagate into the bay. A large majority (>80%) of swell-dominated events favourable for surfing conditions approach the sites with incidence directions between 150-160°T.

With respect to the surf break at the Waipaoa River (Big River), phase-averaging modelling was used to assess the potential effect of the offshore disposal mound on the inshore surfing conditions. Big River surf break does not rely on any pre-conditioning of the incident wave fields, but rather is reliant on banks controlled by the high volume river which creates consistently moving sand and shingle banks (Morse and Brunskill 2004). Modelling suggests that the inshore wave heights are expected to be modified by ±0.2% or less (i.e., 0.01 m change in height) with the location dependent on the incident wave direction. Some very localised changes in wave direction occur which are not expected to modify the overall wave pattern at the shoreline. This is expected to have a negligible effect on recreational surfing conditions at Big River.

For the wave incidences favourable for surfing conditions, the nearshore phase-resolving wave propagation modelling illustrated that significant wave focusing develops over the offshore submerged reef system which redirects wave energy specifically towards the Midway Beach region. This is combined with wave crest “snapping” which is expected to further increase the surfability of the wave field reaching the beach.

The reproduction of the wave simulations over the post developments and channel dredging bathymetry configuration suggests very limited changes to the existing wave processes in the Midway Beach region (less than 0.5-1%, or 0.013 m) and similarly for Robert Road (less than 2%, or 0.022 m), with slightly larger changes (alternating increase and decrease in wave height) along the area between these two beaches (Figure 4.10). The limited effects of the channel deepening on existing wave processes can attributed to the relatively small deepening of the outer channel and the approximate perpendicular angle of the channel relative to the incident wave direction.

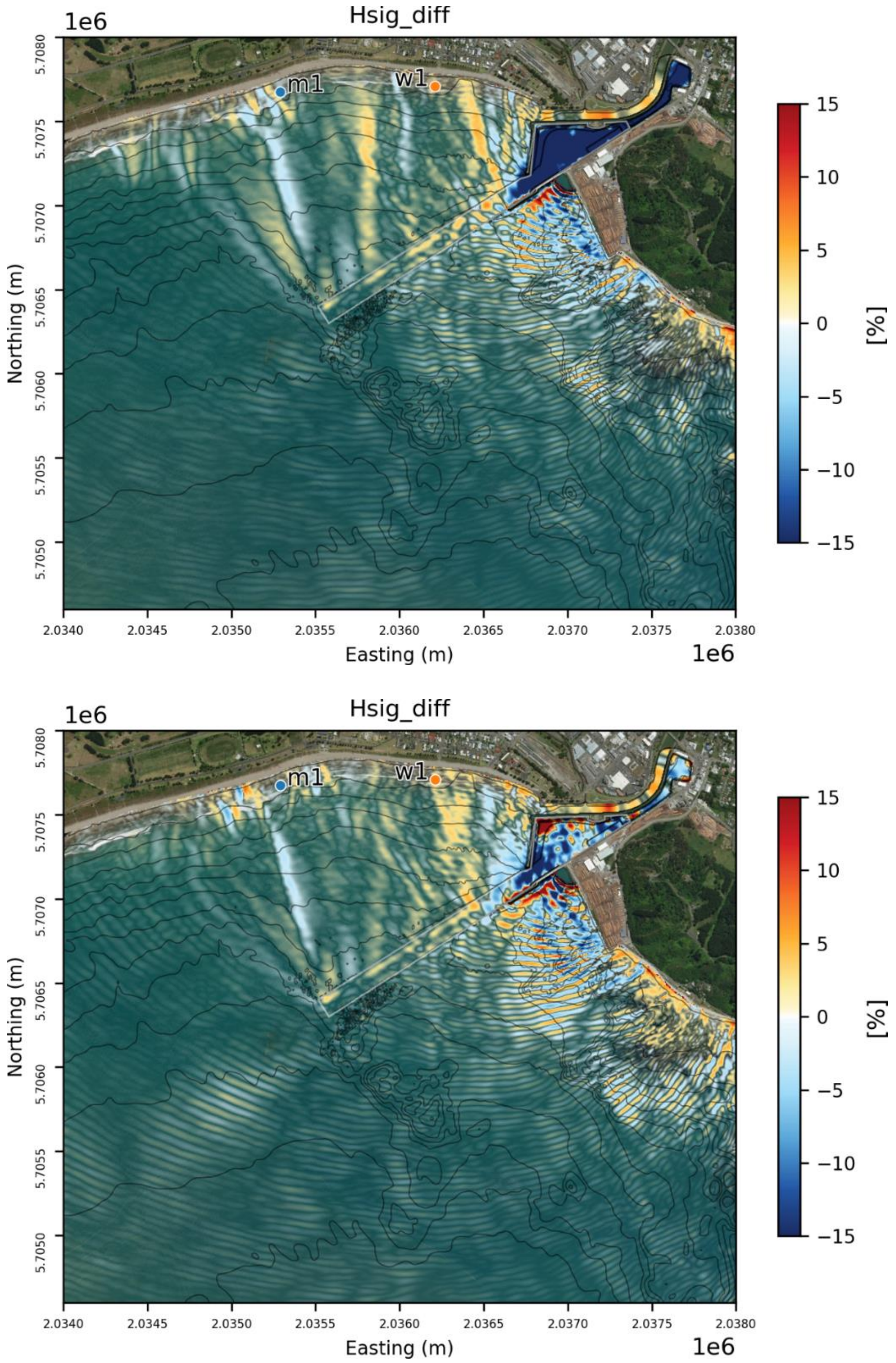

Figure 4.10 Significant wave height relative changes [%] between the existing and proposed bathymetries for idealized <u>*spectral*</u> *wave conditions* ***Hs= 2.0m, T_p =12 sec. and Dp=150°T*** *(top) and* ***Hs= 2.0m, T_p =12 sec. and Dp=160°T*** *(bottom). The channel is shown as a white polygon. Positive wave height change percentage means larger wave height on the proposed bathymetry, and vice versa.*

4.9 Effect of port reclamation on waves

A study on the effects of the reclamation near the inner breakwater (cyan area on Figure 1.2) over the wave height and wave induced currents near the port was documented in MetOcean Solutions, 2020. In this report, we used a validated wave hindcast of the area (MetOcean Solutions 2017) to select representative 10-year return wave events and simulate them in a high resolution SWASH phase resolving wave model.

The assessment was based on the simulations' results at three reference sites, for the two port configurations (before and after the new reclamation works, Figure 4.11). Note that, apart from the reclamation, there is no further change in the domain's bathymetry. The simulations were forced by four different 10-year return wave events using low, mid and high tide levels.

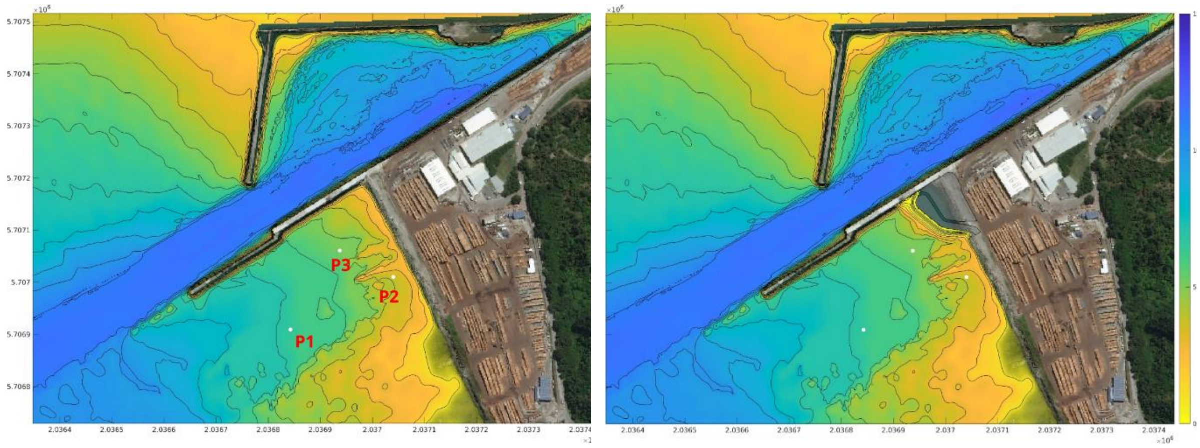

Figure 4.11 Details of the existing and post-reclamation bathymetries in the reclamation area, and reference sites P1, P2, P3.

In the existing configuration, the incoming wave/port interaction shows southeast-incident waves refracting into Poverty Bay, reaching the port's southern breakwater. A fraction of the wave energy that interact with the wall is reflected eastwards toward the existing reclamation. Some subsequent reflection back to the south is possible, though with reduced energy due to dissipation over the existing rubble mound revetment.

The reclamation in the proposed bathymetric configuration adds an element with which incoming and reflected waves interact, generally resulting in larger waves heights in the vicinity of the structure, and relatively larger wave energy radiating back towards the south. In contrast, wave heights are relatively reduced within a band along the southern training wall.

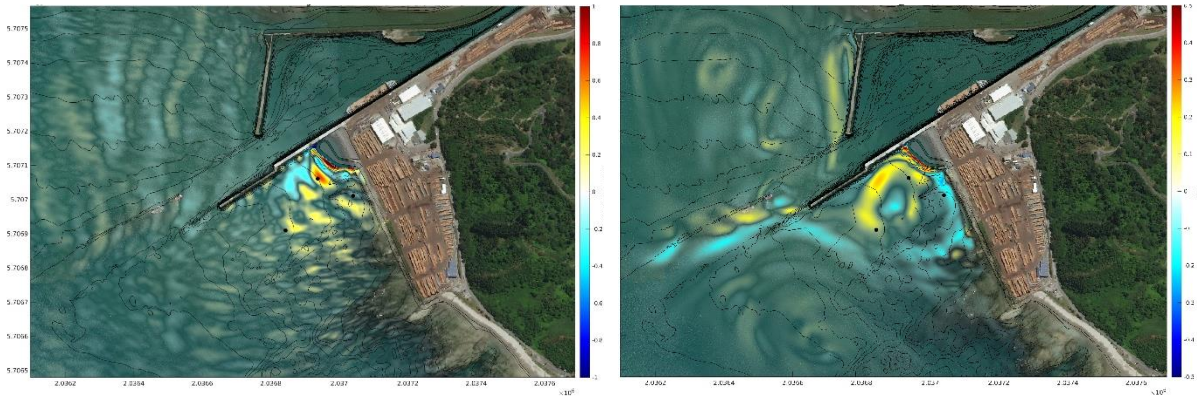

Figure 4.12 Difference of significant wave height (left) and wave induced currents (right) between the present port layout and proposed reclamation layout at high tide, for one of the 10-year return wave conditions. Red colours indicate increased wave heights after the reclamation works whereas blue represent decreased wave heights.

For the extreme wave conditions simulated, the significant wave heights are in general 8-10% larger with the new reclamation in place, reaching up to a 10-20% increase for the wave conditions simulated. For higher water levels (Figure 4.12), the same offshore conditions produced an overall increase in wave height of 15%, and up to 25% locally.

4.10 Assessment of potential sediment plumes during reclamation works

A study on the fate of sediment plumes potentially generated during reclamation works is documented in MetOcean Solutions (2022).

Fine sediments can potentially be released during the construction of the reclamation area from either release of fine sediments present on the rock and crushed rocks to be used for the reclamation revetment. For this purpose, we used a calibrated and validated Delft3D model to estimate the dispersion and fate of sediment plumes potentially generated during the reclamation works.

The modelled scenario proposed in this study represents the protection bund partially built, and a source of sediment discharge representing release of fine sediments from the surface of the rocks.

Based on our model results, sediment plume concentration near the port is likely to be <=0.02 kg.m^{-3} above background concentration, which is typically 0.13 to 0.23 kg.m^{-3}(4Sight 2019). The plume represents a minor increase comparatively, corresponding to 5x to 10x less the background concentration range within the port area. Further into Poverty Bay, outside the port area, background concentration is typically 0.02 kg.m^{-3} and the model results show plume of less than 0.002 kg.m^{-3}, above background, indicating that plume might have a minor contribution to the background suspended sediment concentration.

Deposition of the fine sediments on the seabed occurs mostly west of the reclamation site, along the southern side of the breakwater, and at the entrance of the port and navigation channel. These areas show most of the deposition is <0.001 m (1 mm). A narrow depositional area along the southern side of the breakwater shows higher deposition with a maximum of approximately 0.002-0.003 m.

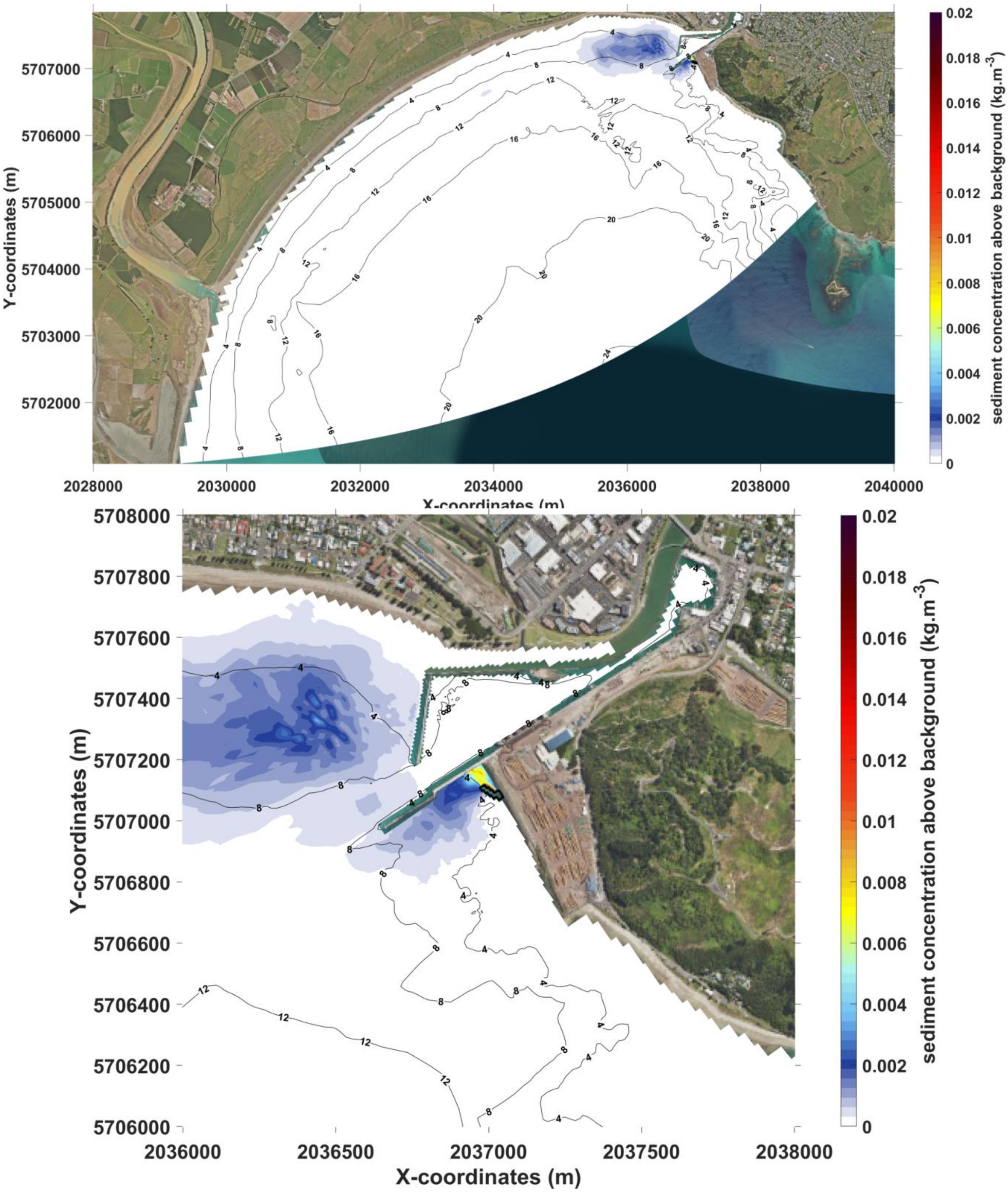

Figure 4.13 50th percentile maps of sediment concentration (kg.m-3) at bottom for scenario without flocculation ("plus 65 hydro"). Top panel overviews the entire model domain, bottom panel focuses on the reclamation area.

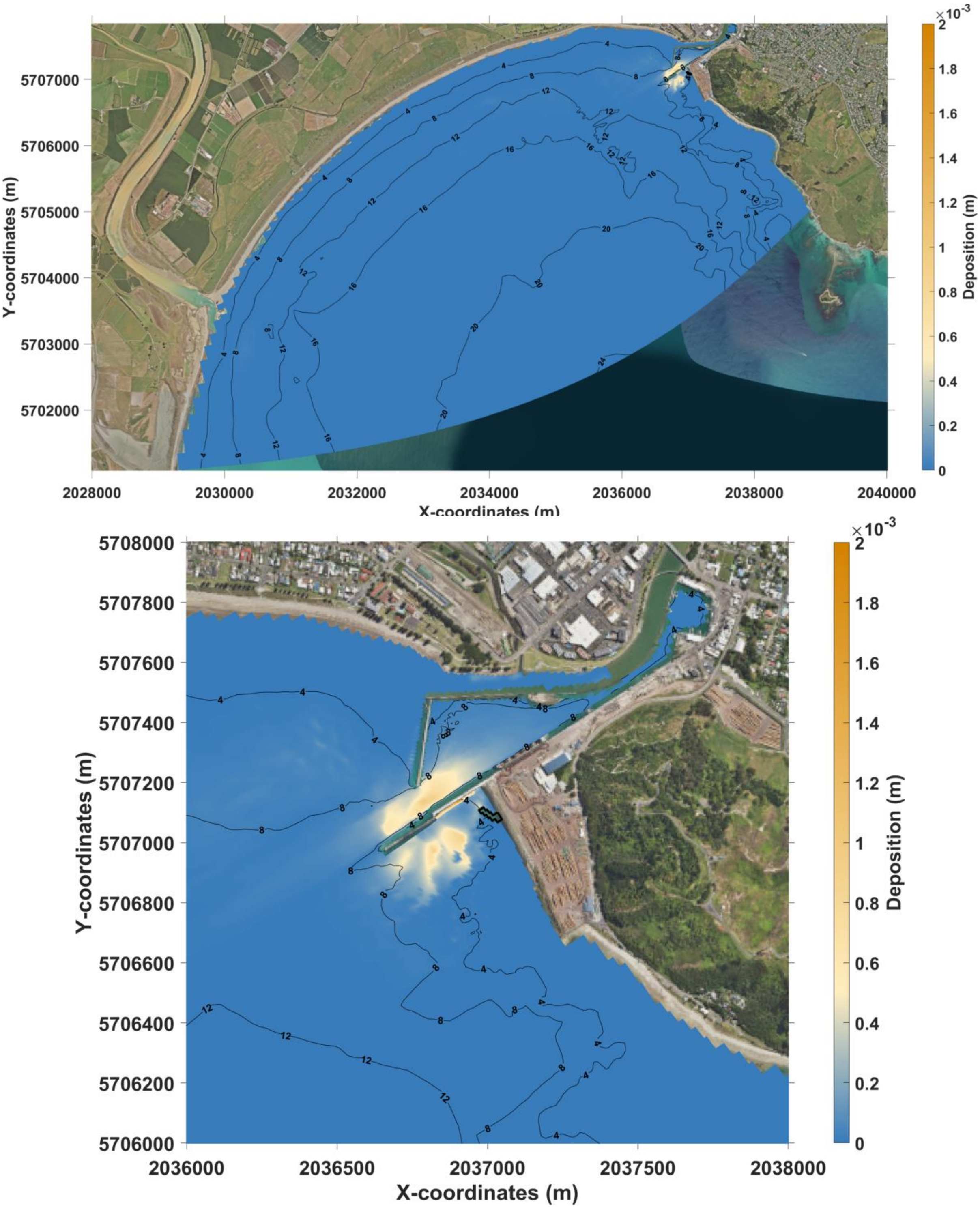

Figure 4.14 Sediment deposition (m) at the end of 15-day simulation for scenario without flocculation ("plus 65 hydro"). Top panel overviews the entire model domain, bottom panel focuses on the reclamation area.

4.11 Effects of breakwater upgrade on local wave climate

The MetOcean Solutions, 2021a report assessed the potential changes that the outer breakwater upgrade could cause in the local wave climate and hydrodynamics. The assessment consisted of using a high-resolution SWASH domain to model the present port configuration, the port layout with the reclamation works finished (cyan area of Figure 4.15), and the port layout with the refurbished breakwater (yellow area left of Figure 4.15).

The boundary forcing used to simulate each port layout is representative of the 95th percentile of the offshore significant wave height of Poverty Bay, and was sourced from the port's Triaxys buoy. The wave parameters used in the assessment were significant wave height, sea surface elevation and wave induced currents. We note that the nearshore wave model was not calibrated using field measurements, hence its results should be interpreted in a relative sense. Furthermore, even though the study accounts for the dredging in the port's basin, it does not assess the dredging isolated effects over the wave induced currents.

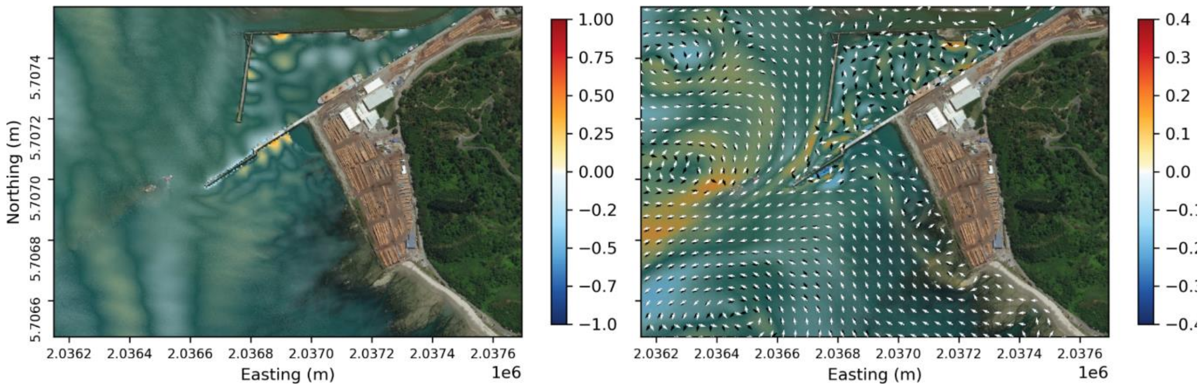

Figure 4.15 Difference plots of significant wave height (left) and wave induced currents (right) between the present and refurbished breakwater port configurations (reclamation area included). Red colours indicate increased values after the breakwater upgrade whereas blue represent decreased values. Black and white arrows show the currents direction before and after the breakwater works, respectively.

Our results show a local redistribution of the wave height gradients and the current's vortices in the port's vicinity (Figure 4.15). The changes in wave height are smaller than 0.1 m near the port and smaller than 0.03 m within the rest of the domain. The displacement of the vortices causes an increase of approximately 0.1 m/s in the current situated westward of the port, and a similar decrease in the nearshore current flowing westwards of Midway Beach. In general, the changes observed are confined to the Port's vicinity, with minimal alterations through the rest of the domain.

5. Mitigation and monitoring

A range of recommended mitigation measures and monitoring actions for the impact of the capital and maintenance dredging and disposal have been presented in MetOcean Solutions 2021f - P0331-31. These mitigation and monitoring actions could also apply to potential impact of the reclamation works.

These recommendations are based on the understanding of the physical processes and sediments transport patterns that are expected and are designed to accompany the resource consent documentation and reports, and provide options to monitor the sedimentological, hydrodynamical and morphological impact of the proposed works on the immediately impacted environs.

With respect to dredging of the shipping channel and swinging basin, recommended monitoring actions consist of annual to bi-annual hydrographic surveys of the dredged area and hydrographic survey transects tied into Gisborne District Council shoreline/beach profiles. Additionally, dredging records consisting of start/stop locations and unconsolidated volumes are recommended to be maintained.

With respect to disposal of the capital and maintenance dredge material at the offshore disposal site; recommended monitoring actions consist of annual to bi-annual hydrographic surveys of the disposal ground, hydrographic survey transects tied into relevant Gisborne District Council shoreline/beach profiles immediately inshore of the disposal ground. Further, it is recommended that hydrographic surveys of a control area be undertaken in order to differentiate between annual to interannual morphological changes within the broader Poverty Bay to those potentially occurring at the proposed disposal ground in response to capital and maintenance dredge disposal activities. If 3 or consecutive more hydrographic surveys of the disposal ground show inconsistencies with the control site in terms of morphological evolution, then it is recommended that additional analysis and reporting be undertaking. Finally, annually or every 2-years surficial sediment sampling should be undertaken within the proposed disposal ground and at a control site in order to determine if the *in-situ* surficial sediment at the disposal site changes significantly over time to a point that morphological processes could be affected.

It is understood that the physical processes modelling study will be used by others to determine the potential impact of the proposed works on the marine ecology and local sensitive receptors. This will then be used to prepare a more detailed monitoring plan in accordance with the Resource Management Act 1991, the New Zealand Coastal Policy Statement 2010 and the Tairāwhiti Resource Management Plan.

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MetOcean Solutions, 2021b. Gisborne Port – Twin Berths Project. Morphological response of the shoreline to the disposal of capital dredging sediments (No. P0331-22).

MetOcean Solutions, 2021c. Gisborne Port – Twin Berths Project. Morphological response of the offshore disposal ground to the discharge of maintenance dredging sediments (No. P0331-21).

MetOcean Solutions, 2021d. Gisborne Port – Twin Berths Project. Morphological response of the offshore disposal ground to the discharge of capital dredging sediments (No. P0331-20).

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MetOcean Solutions, 2018d. Eastland Port Maintenance Dredging and Disposal Project. Disposal plume modelling (No. P0331- 07).

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Appendix A: Reports

- Hydrodynamic hindcast validation – Report P0331-04
- Wave hindcast validation – Report P0331-05
- Morphological model validation – Report P0331-03
- Dredging plume modelling – Report P0331-08
- Morphological response to capital dredging – Report P0331-09
- Disposal plume modelling – Report P0331-07
- Morphological response of the offshore disposal ground to the discharge of capital dredging sediments – Report P0331-20
- Morphological response of the offshore disposal ground to the discharge of maintenance dredging sediments - Report P0331-21
- Morphological response of the shoreline to the disposal of capital dredging sediments - Report P0331-22
- Morphological response of the shoreline to the disposal of maintenance dredging sediment - Report P0331-23
- High resolution wave modelling of existing and proposed port configurations– Report P0331-26
- Effects of breakwater upgrade on local wave climate – Report P0331-27
- Assessment of potential sediment plume during Port reclamation works – Report P0331-28
- Eastland surfbreak assessment – Report P0331-30
- Proposed Monitoring for Capital and Maintenance Dredging - P0331-31