EASTLAND PORT MAINTENANCE DREDGING AND DISPOSAL PROJECT

Morphological response to maintenance dredging

Report prepared for Eastland Port

June 2018

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1. INTRODUCTION

Eastland Port Ltd are seeking to renew their maintenance dredging and disposal consents at the Port of Gisborne.

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 rate of approximately 73,000 m^3 based on estimates obtained between 2002 and 2019 by Eastland Port.

Maintenance dredging is expected to occur using the Trailing Suction Hopper Dredge (TSHD) “Pukunui” although, if there are significant inflows of sediment due to large storm events, a higher productivity Trailing Suction Hopper Dredge (TSHD) may be required to ensure the required port and channel depths can be maintained. It is likely that some maintenance dredging may also be undertaken using a Backhoe Dredger (BHD) or Cutter Suction Dredger (CSD).

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 dredging material at the current disposal site.

For this purpose, the process-based model Delft3D has been used to hindcast the sediment dynamics over northern Poverty Bay and Eastland Port. This included the use of combined reduction techniques and morphological acceleration factors (MORFACs) as well as storm-induced morphological reconstructions. Qualitative and quantitative calibration is undertaken by comparing morphological model outputs against hydrographic measurements.

In the present study, the calibrated numerical model has been used to assess the likely morphological response to the continuation of the maintenance dredging program at Eastland Port. The present report is a technical reference document that investigates the likely morphological effects of the project. Details of the modelling framework and assessment approach are provided in MetOcean Solutions (2018).

The report is structured as follows; the methodology applied in this study is presented in Section 2, including a description of the different scenarios simulated here. Results of the impact of dredging are discussed in Section 3. A brief summary is presented in Section 4 while the references cited in this document are listed in Section 5.

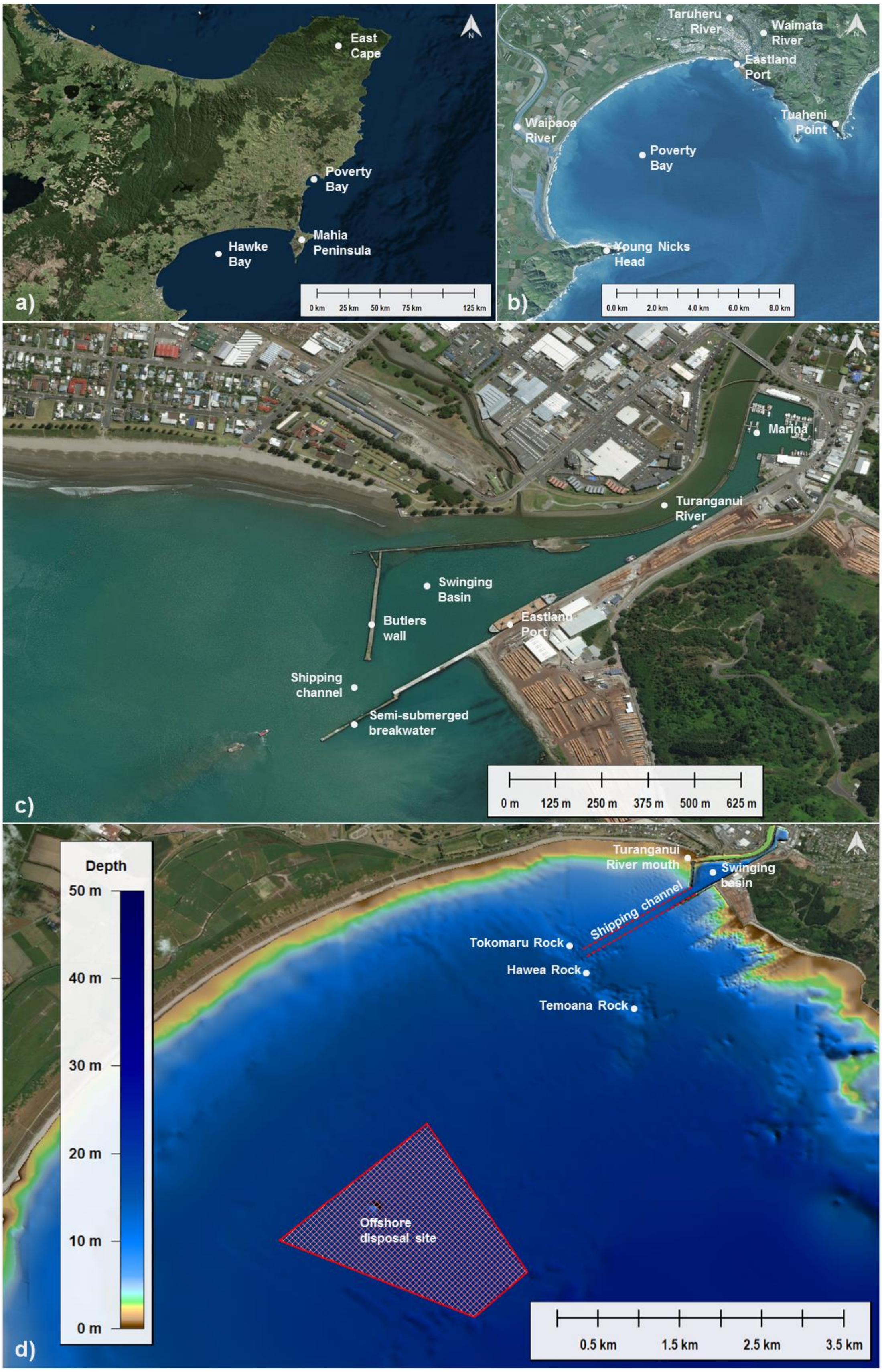

Figure 1.1 Maps showing the location of Poverty Bay (a, b), and Eastland Port (c) with the locations used in the present study. Both offshore disposal and shipping channel are indicated on top of the bathymetry in (d).

2. METHODS

The primary objective of the study is to assess the likely morphological response of the existing environment to the continuation of the maintenance dredging program. To meet this objective, the numerical modelling was carried out by using input reduction techniques combined with the use of morphological acceleration factors within the Delft3D framework. The successful validation of the numerical model in MetOcean Solutions (2018) showed this approach was suitable for predicting the medium-term sediment dynamics at Eastland Port.

In addition, a 15-day real-time event was also simulated to assess the daily variability of the infilling process within the channel. The present section details the methodology used to undertake both the impact and the dredging assessments as part of the “Eastland Port Dredged Project”.

2.1. Numerical modelling strategy

2.1.1. Initial bathymetry

In MetOcean Solutions (2018), the process-based model Delft3D was used to hindcast the sediment dynamics over northern Poverty Bay and Eastland Port. We used sediment infilling rates within the channel and in the port provided by singe- and multi-beam surveys to calibrate and validate the morphological model. The 5 x 5 m gridded existing bathymetry (Figure 2.1) was used.

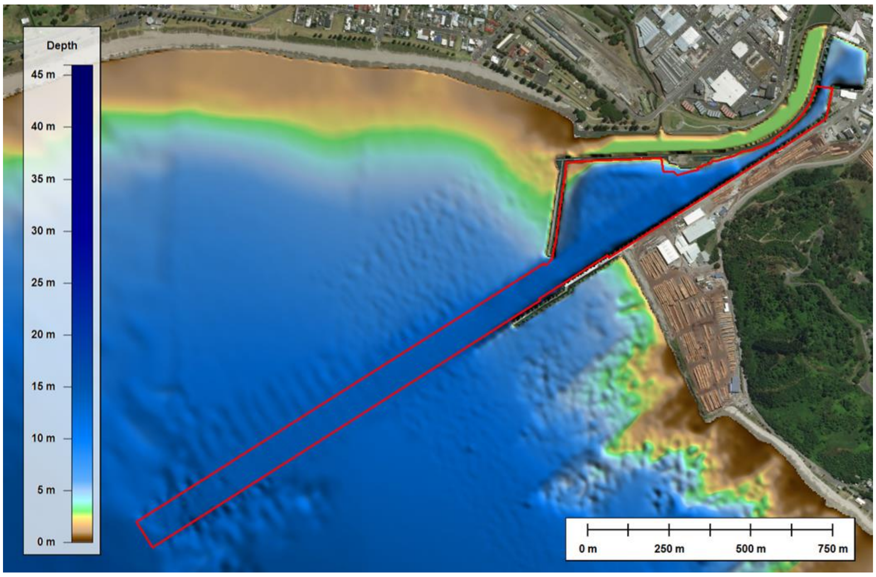

Figure 2.1 Map showing the existing model bathymetry (m).

2.1.2. Initial bed composition

An accurate definition of the surficial sediment grain size distribution in the area of interest plays an important role in correctly determining sediment dynamics and morphological response. As such, we used the multi-grain-size model defined in MetOcean Solutions (2018), which is based on sediment samplings and bed surveys. This sedimentological model was initiated with a well-mixed surficial bed layer composed of silt, fine grain-sized sand and medium grain-sized sand particles.

2.1.3. Scenarios

Both medium-term and short-term scenarios as detailed in MetOcean Solutions (2018) were simulated considering the existing bathymetry. The medium-term modelling included two simulations from June 1998 to May 1999 and from June 2002 to May 2003. These periods were characterised, respectively, by "La Niña" and "El Niño" phases of "El Nino – Southern Oscillation" (ENSO) and represent two contrasting climatic periods.

The medium-term morphological modelling was supplemented by a 15-day historical simulation (07/07/2002 – 22/07/2002) characterised by high energy wave conditions and large river discharges.

2.1.4. Forcing

Waves, currents and river discharges were defined as in MetOcean Solutions (2018) to allow assessing the effect of the continuation of the maintenance dredging on the existing sediment dynamics and morphological response. We considered the open-ocean boundary of the Delft3D – FLOW domain far enough from the dredging area to define the hydrodynamic boundary conditions from the data source corresponding to the existing environment (MetOcean Solutions, 2018).

2.2. Model settings

The same model configuration derived from the calibration and validation process was used to initiate the modelling. An overview of the parameters and settings used within Delft3D is provided in MetOcean Solutions (2018).

3. RESULTS

3.1. Morphological responses of the existing environment

To understand the morphological response of the system we determined, first, the effects of both, the incident wave climate and the hydrodynamics, and then we linked these physical changes to the predicted sediment dynamics provided by the numerical model.

3.1.1. Wave climate

The spatial wave model (SWAN) was used to quantify the effect of the channel on the incident wave climate. The effects were assessed by modelling the existing port bathymetry. In order to isolate the effect of the dredging on the wave climate, a range of wave classes as described in MetOcean Solutions (2018) was simulated.

The predicted significant wave height fields are provided in Figure 3.2 to Figure 3.7 for six representative wave classes. Wave heights, periods, directions and percentages of occurrence for the six cases are provided in Table 3.1, with incident offshore wave heights ranging from ~2.2 m to ~5.7 m. Wave classes were defined based on the wave climate at the offshore eastern boundary of the largest domain (see Figure 3.1).

The incident waves propagate approximately transversely to the shipping channel, so the actual effect of the channel on the inshore incident wave climate is relatively insignificant. Differences are expected in areas depending on the wave class simulated (e.g. Classes 4-6 are events from a more southerly orientated directions).

Table 3.1 Significant wave height, period and direction events used to quantify the effect of the existing channel on the incident inshore wave heights.

Wave Class	H_s (m)	D_p (deg)	T_p (s)	Occurrence (%)
1	2.16	100.42	10.02	38.04
2	3.18	89.86	10.56	13.78
3	4.75	73.67	10.44	5.23
4	2.49	215.40	11.98	26.87
5	3.53	219.84	12.01	12.22
6	5.72	232.19	12.05	3.8

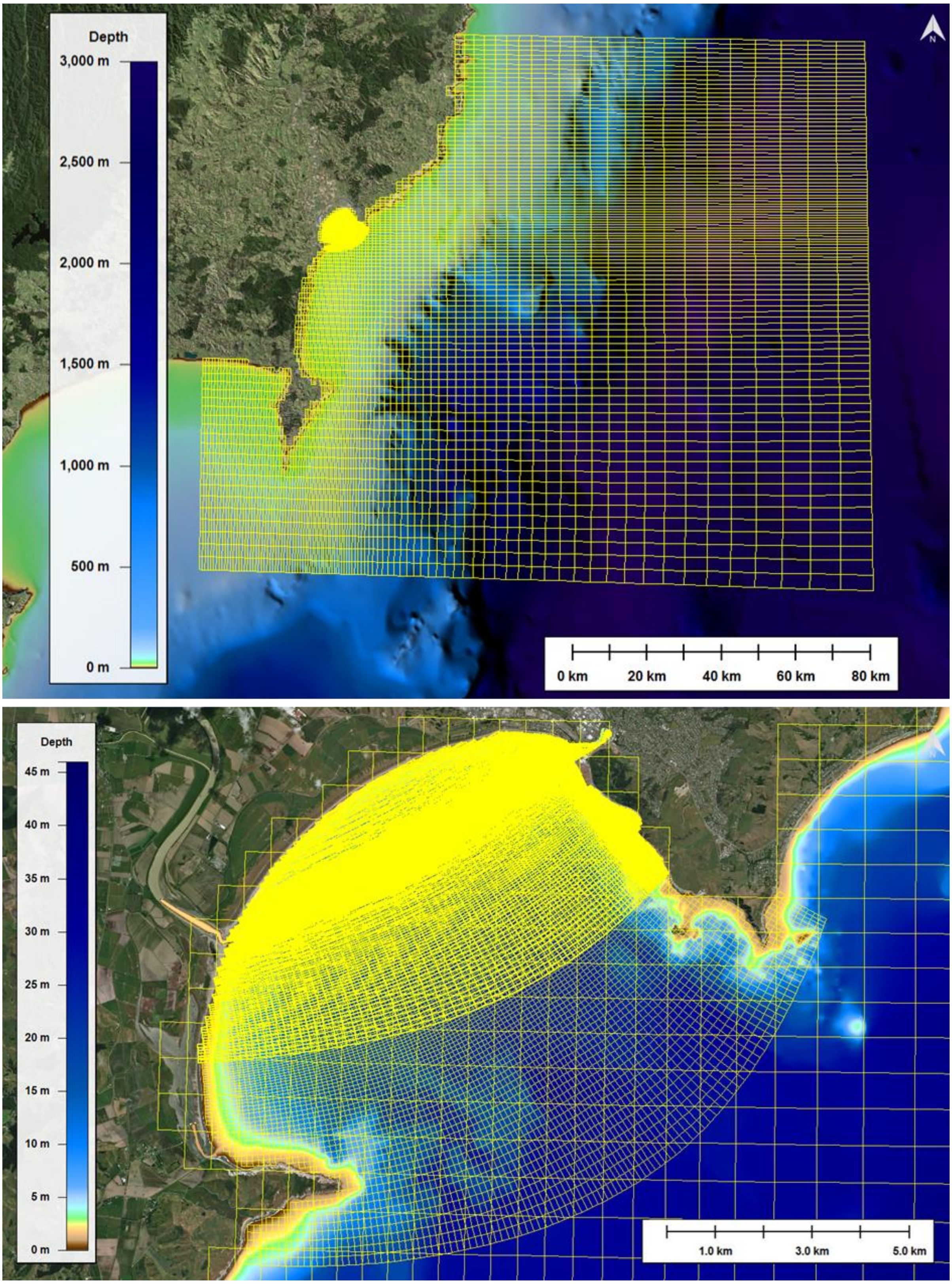

Figure 3.1 Model domains used to simulate the propagation from offshore to inshore. Wave classes were defined based on the wave climate at the eastern most boundary of the larger domain (i.e. top panel)

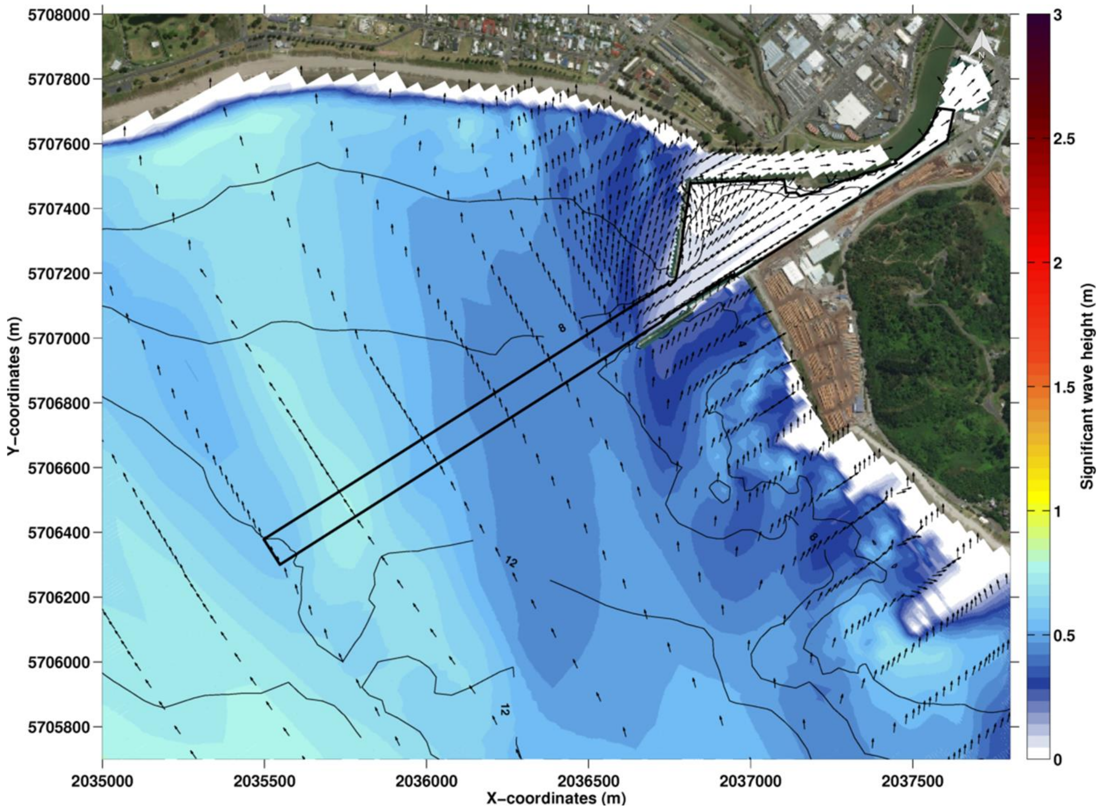

Figure 3.2 Predicted significant wave height (Class 1) for the Existing configuration of Eastland Port. The black polygon indicates the shipping channel.

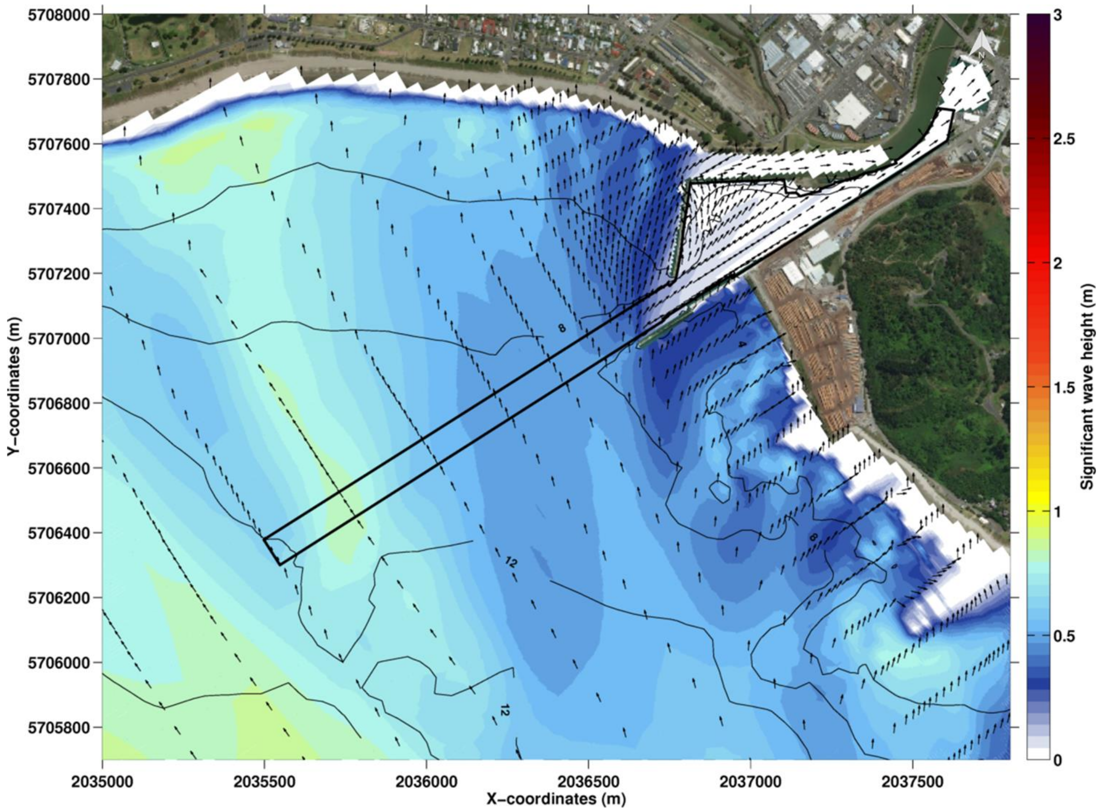

Figure 3.3 Predicted significant wave height (Class 2) for the Existing configuration of Eastland Port. The black polygon indicates the shipping channel.

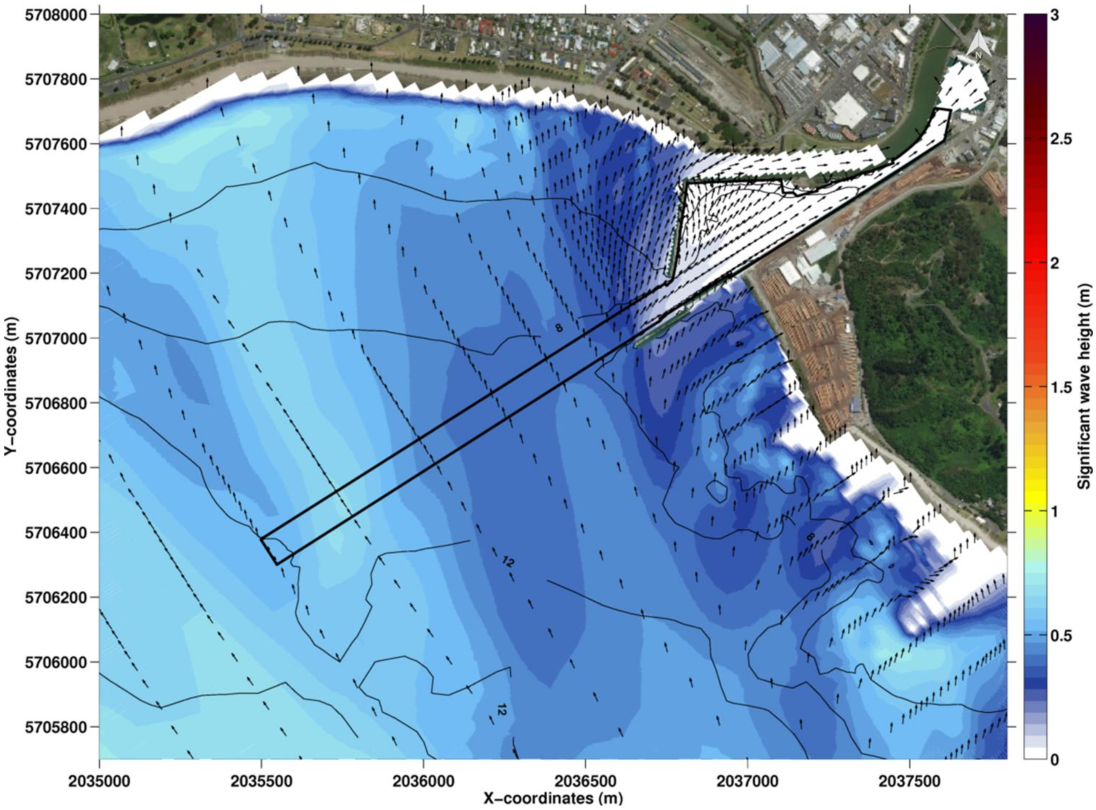

Figure 3.4 Predicted significant wave height (Class 3) for the Existing configuration of Eastland Port. The black polygon indicates the shipping channel.

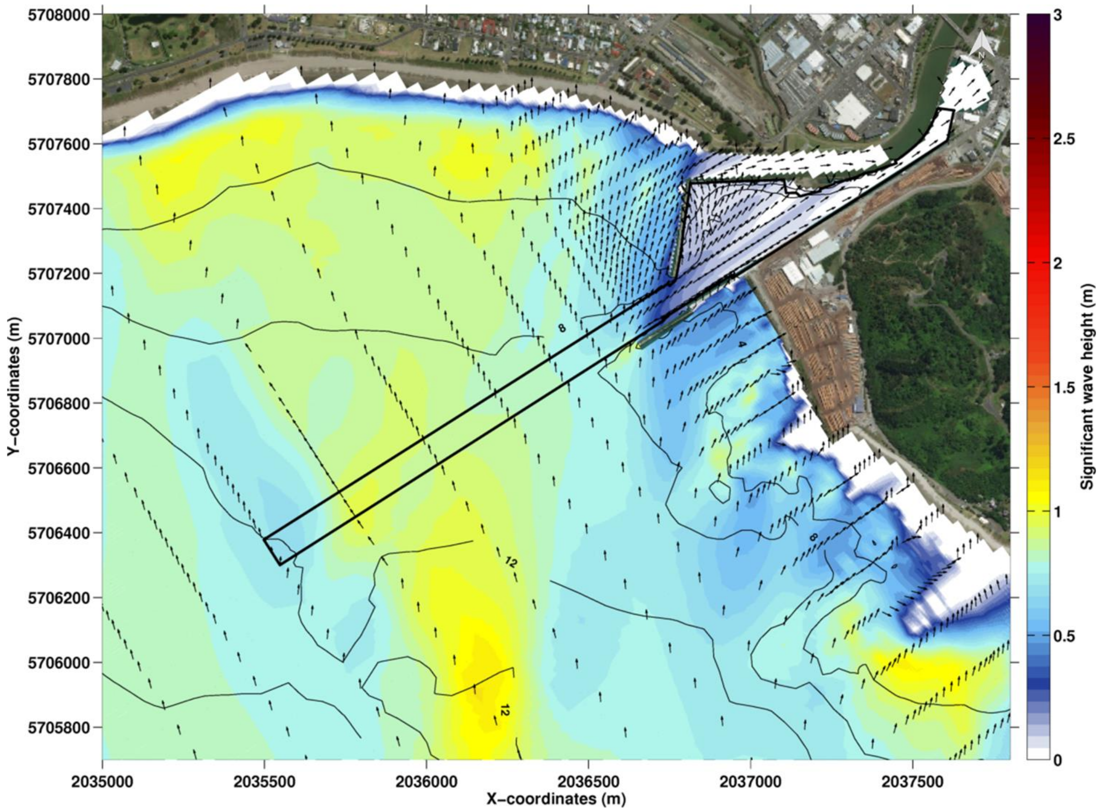

Figure 3.5 Predicted significant wave height (Class 4) for the Existing configuration of Eastland Port. The black polygon indicates the shipping channel.

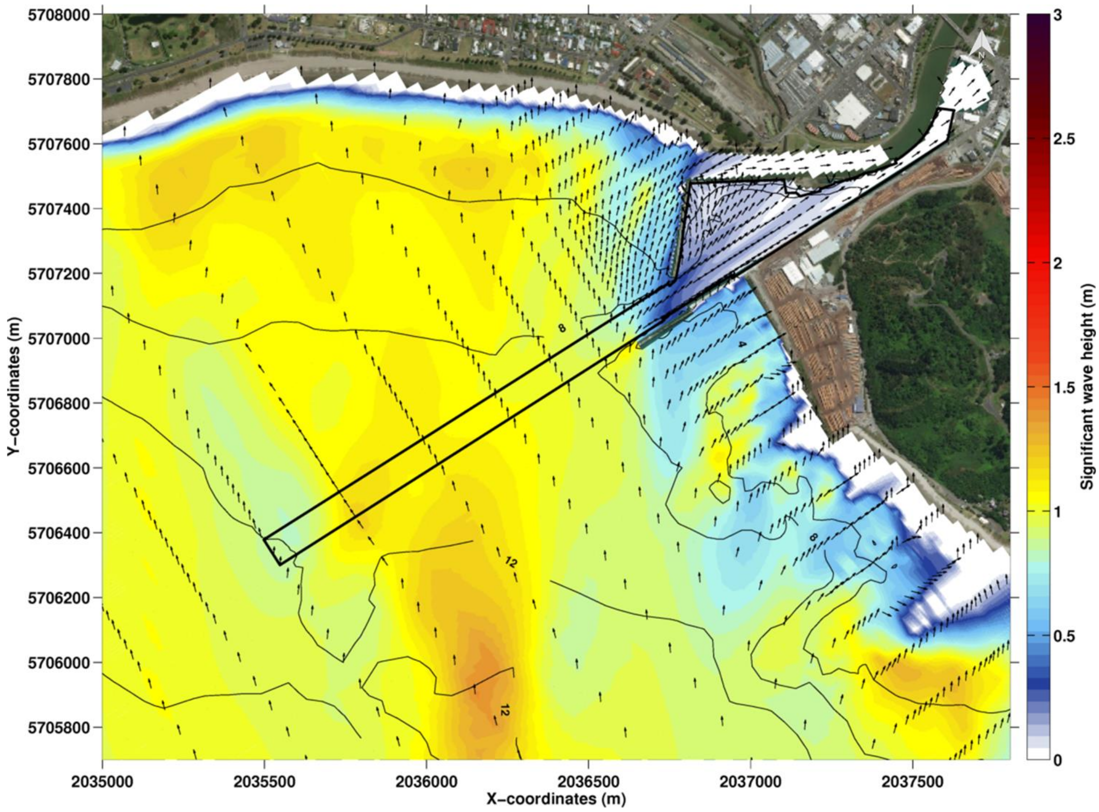

Figure 3.6 Predicted significant wave height (Class 5) for the Existing configuration of Eastland Port. The black polygon indicates the shipping channel.

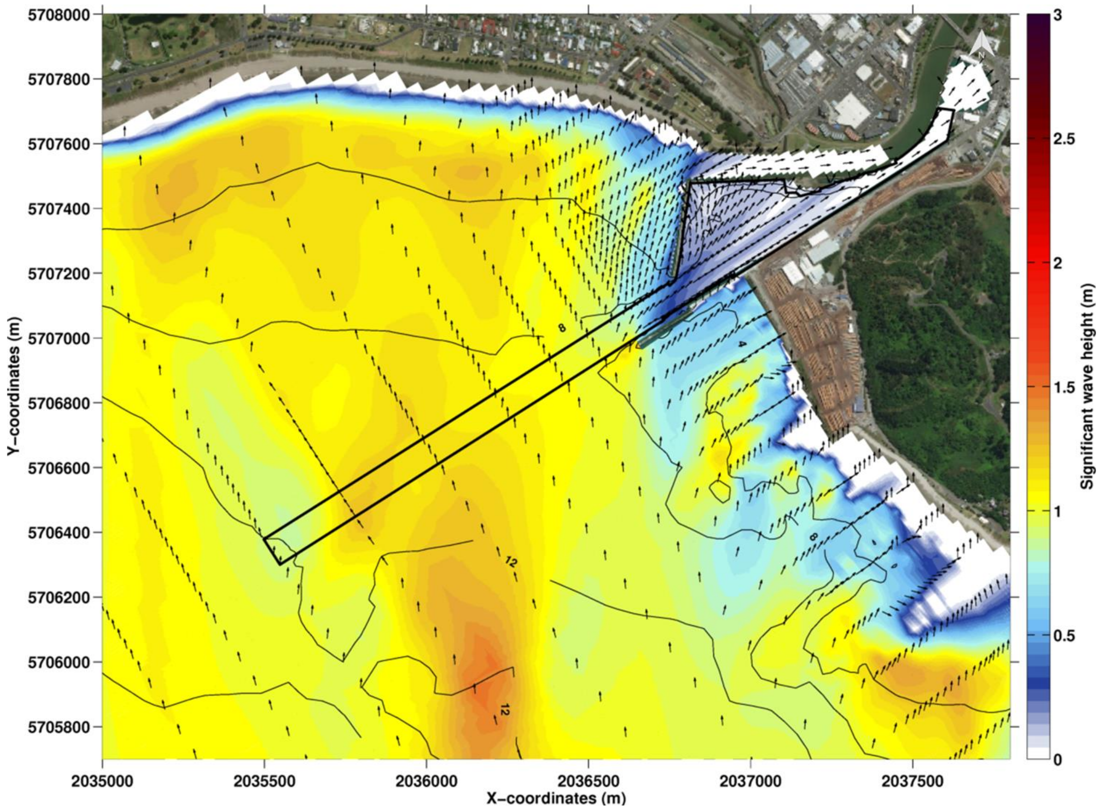

Figure 3.7 Predicted significant wave height (Class 6) for the Existing configuration of Eastland Port. The black polygon indicates the shipping channel.

3.1.1. Hydrodynamics

Tidal and non-tidal currents were simulated within Delft3D for a large range of hydrodynamic scenarios including high to low river discharges, clockwise and anti-clockwise circulation patterns within Poverty Bay and ebb to flood tidal stages. The effect of waves on the hydrodynamics was also captured in the modelling throughout the online coupling between Delft3D – FLOW and Delft3D – WAVE (SWAN).

A snapshot of model current velocity for the Existing configuration of Eastland Port is shown in Figure 3.8. The changes in the hydrodynamics due to the different phases of ENSO that were simulated may cause small and localised changes in the sediment deposition patterns, without fundamentally modifying the coastal system.

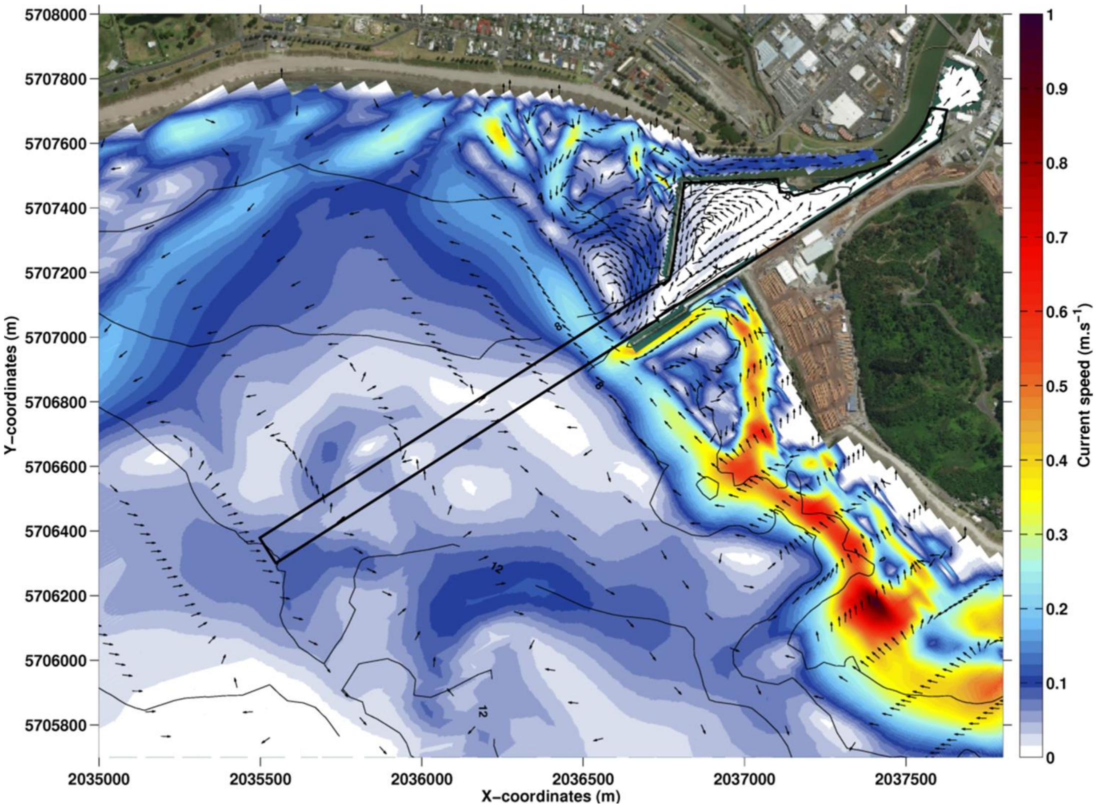

Figure 3.8 Snapshot of model current velocity (initial Class 30, “La Niña”) for the Existing configuration of Eastland Port. The black polygon indicates the shipping channel.

3.1.2. Predicted morphological response

Comparison of the predicted depth changes at the end of the 1-year simulation for both, the “La Niña” and the “El Niño” phases of ENSO, using the existing bathymetry, are provided in Figure 3.9 and Figure 3.10. These represent two contrasting climatic periods.

The ‘La Niña’ simulation period was characterised by large river discharges due to increasing rainfalls and a predominance of easterly directed (coming from) incident waves as compared to the ‘El Niño’ simulated period. As such, the wave energy available to entrain and transport surficial sediment within the port environs was relatively reduced during the ‘La Niña’ simulation (due to sheltering), leading to comparatively greater accretion of the Waikanae and Midway beaches and a reduction in the offshore diabathic sediment transport, including into the shipping channel. This process is expected to be partially compensated by increasing fluvial suspended sediment discharges from the Turanganui River; however, the model results suggest that wave processes dominate the southward migration of sediment. As described by Black et al. (1997) and Beamsley (2003), the entrance to Eastland Port and the Swinging Basin act as a sediment trap, with sediment accretion expected under both ‘La Niña’ and ‘El Niño’ conditions

During the La Niña conditions, the overall morphological response of the system is relatively minor (compared to changes during El Niño). A general pattern of accretion within the shipping channel and the immediate entrance to the Swinging Basin is expected (Figure 3.9). While still exhibiting a positive sediment budget, there is also expected to be a slight reduction to the amount of sediment being supplied to the immediate west of Butlers Wall (see Figure 3.9 and Figure 3.10). Minor fluctuations in the sediment budgets offshore Waikanea Beach are also predicted (see Figure 3.9), however these are not expected to fundamentally change the sediment budget within the environs.

During the El Niño conditions, the overall morphological response of the system is in general greater than during the La Niña period. This is attributed to more energetic wave events expected within the port environs during the El Niño phase of the ENSO. A general pattern of accretion within the shipping channel is expected (Figure 3.10), with potentially up to 1m increase deposition in areas. Minor fluctuations in the sediment budgets offshore Waikanea Beach are predicted, however these are not expected to fundamentally change the sediment budget within the environs.

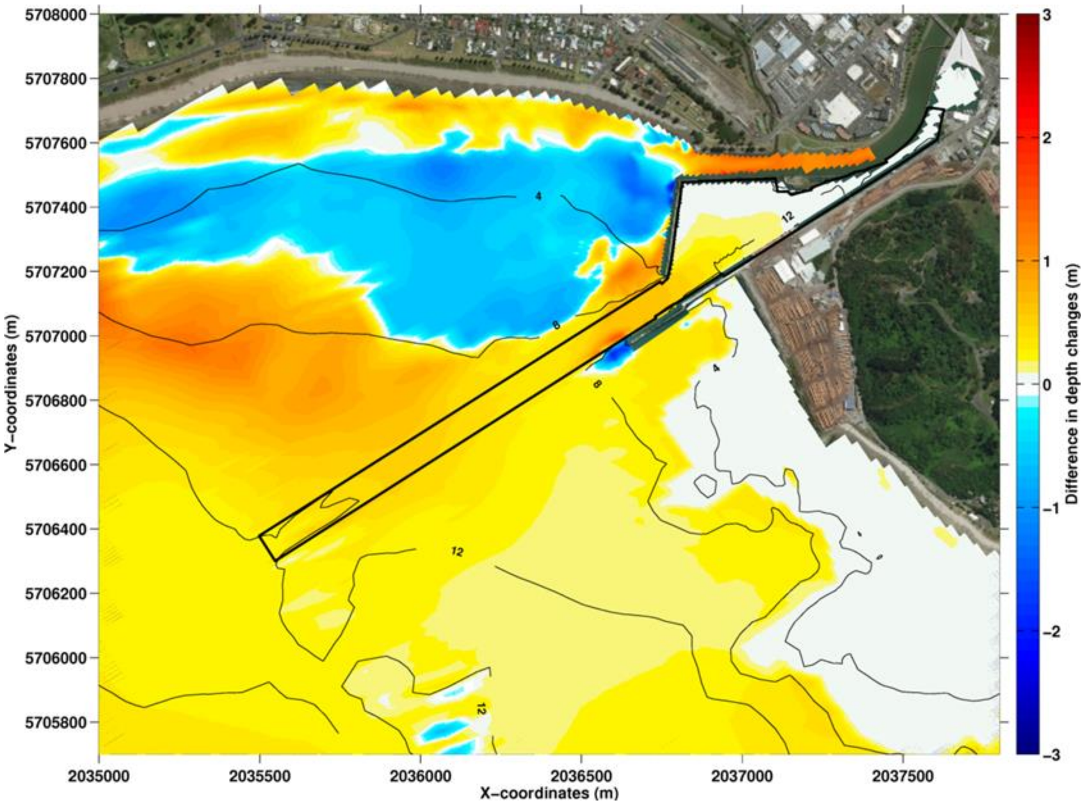

Figure 3.9 Predicted morphological change over the period 1998 – 1999 ("La Niña") for the Existing configuration of Eastland Port. The black polygon indicates the shipping channel.

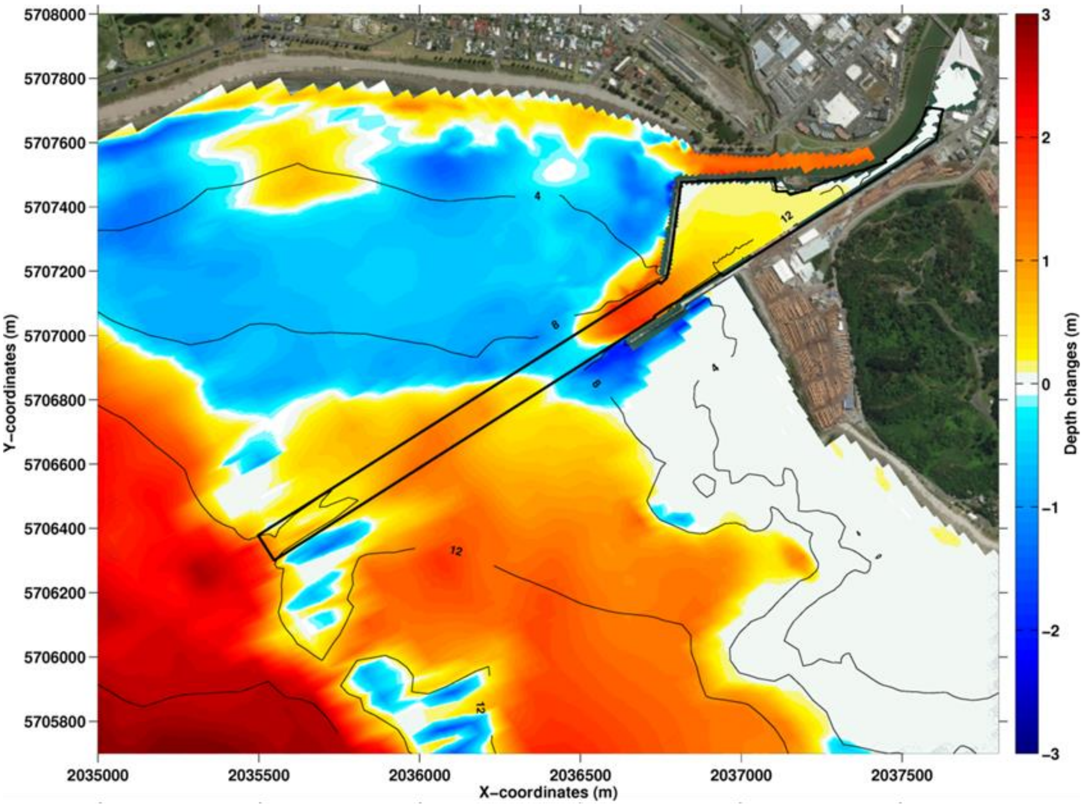

Figure 3.10 Predicted morphological change over the period 2002 – 2003 ("El Niño") for the Existing configuration of Eastland Port. The black polygon indicates the shipping channel.

3.2. Volumetric infilling rates

3.2.1. Annual volumetric infilling rates

The calibrated and validated morphological model has been used to determine potential future maintenance dredging requirements for the existing bathymetry, for both the La Niña and El Niño phases of ENSO, with results provided in Table 3.2.

During La Niña conditions is ~75,000 m^3 of sediment is expected to require dredging from both the outer Shipping Channel and inner Swinging Basin. The majority of the required dredging is expected to be within the Shipping Channel (Table 3.2).

In contrast, during the El Niño phase of ENSO, the relative increase in incident wave energy results in more infilling of the Shipping Channel and Swinging Basin. Overall requirements in dredging increase from ~75,000 m^3 for La Niña to ~120,000 m^3 for El Niño.

These results are in agreement with the inter-annual variability of the infilling rate as described by WorleyParsons (2015) which recommended a maximum annual dredge volume rate 40% higher (i.e. 140,000 $m^3.yr^{-1}$) than the average rate recorded since 2009. Further, results suggest that the inter-annual variability in infilling rates are likely to increase.

Table 3.2 Average annual infilling rates predicted by the medium-term morphological modelling for the Existing configuration of Eastland Port. Estimates are provided for the outer channel, the inner basin and the sum of both areas.

Period	Configuration	Annual infilling rate [$m^3.yr^{-1}$]		
		Outer channel	Inner basin	Total
La Niña (1998/1999)	**Existing**	60,087	14,608	74,695
El Niño (2002/2003)	**Existing**	92,593	27,647	120,240

3.2.2. Daily volumetric infilling rates

Morphological modelling of a specific event with large incident wave conditions and fluvial discharges is used to examine the infilling rates for both the duration of the event and at a more granular time-step (i.e. daily).

As in MetOcean Solutions (2018), morphological modelling was simulated for the 15-day period July 7th to July 23rd, 2002, this allowed the estimation of the expected infilling rates for the existing bathymetry (as detailed in MetOcean Solutions, 2018). Results from the simulations were saved at 3-hourly time-steps and averaged on a daily basis.

Predicted average volumetric daily infilling rates for the existing configuration are provided in Table 3.3 and Figure 3.11. Over the 15-day simulated period, the average volumetric daily infilling rate is expected to be 829 $m^3.day^{-1}$. During the large river discharge on July 15th, the channel daily infilling rate increased from 280 $m^3.day^{-1}$ to ~500$m^3.day^{-1}$ (Figure 3.11).

These results are broadly consistent with those observed for the energetic El Niño annual simulations (see Sections 3.2.1), in that during energetic conditions or phases the expected infilling of the channel will become exacerbated.

Table 3.3 Average daily and annual infilling rates provided by previous studies and the present numerical modelling for the Existing configuration of Eastland Port.

Source	Conditions	Daily infilling rate	Annual infilling rate
		[$m^3.day^{-1}$]	[$m^3.year^{-1}$]
Literature: Existing configuration			
(Black et al., 1997)	Average	282	103,000
	Stormy	690	252,000
	Sever	2,000	730,000
(Beamsley, 2003)	Average to stormy	470	171,415
Numerical Modelling: Existing configuration			
Input reduction 1	La Niña	205	74,695
Input reduction 2	El Niño	329	120,240
Event 1	Average to stormy	829	302,840

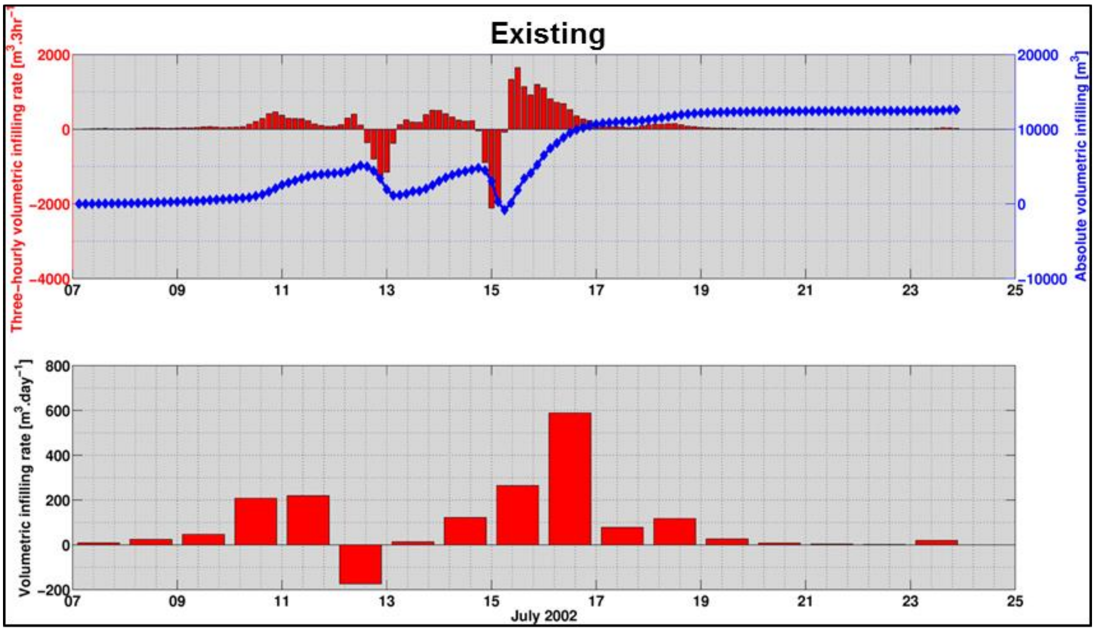

Figure 3.11 Predicted three-hourly volumetric infilling rates and absolute volumetric infilling within the channel and the inner basin for the Existing configuration. The large histograms display the volumetric infilling rates on a daily basis.

4. SUMMARY

The open-source Delft3D system was used to run high-resolution process based morphodynamic simulations within Poverty Bay and Eastland Port. The numerical modelling involved fully-coupled wave, current and seabed interactions.

Having successfully validating the morphological model against measurements in the first technical report (see MetOcean Solutions, 2018), a series of model simulations was undertaken. This aimed to investigate how the existing configuration of the port may be influenced by the “La Niña” and the “El Niño” phases of the “El Nino – Southern Oscillation” (ENSO); specifically, from June 1998 to May 1999 and from June 2002 to May 2003 respectively. An input reduction techniques and morphological acceleration factors were applied within the Delft3D modelling framework.

The main conclusions are given below:

- The continuation of the Eastland Port maintenance 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 occur during the different phases of the ENSO and alter some of the sediment deposition patterns in the vicinity of the channel without fundamentally changing the overall coastal dynamics.

- The deposition of material at the entrance of Eastland Port is expected for both periods. This is attributed to a re-orientation of the wave refraction patterns in the vicinity of the port entrance, slight modifications to the location of the current eddy in the lee of Butlers Wall and sediment trapping processes over the outer dredged channel.

- It is anticipated that, in the absence of ongoing maintenance dredging, the annual infilling rate in the channel and the inner basin will be 75,000 and 120,000 $m^3.yr^{-1}$. (for ‘La Niña’ and ‘El Niño’ phases of ENSO respectively).

- During storm conditions, the daily volumetric infilling rate may increase from ~200-300 to 800 $m^3.day^{-1}$.

- Infilling rate may temporarily increase after maintenance dredging is carried out attributed to the diffusion of sediments from the batters at the edge of the dredged areas into the channel itself; the gradual slope might contribute, however, to limit the influence of waves on the bed-load component of the sediment transport.

- Within the outer channel, in the absence of ongoing maintenance dredging, the bathymetry is likely to quickly return to its equilibrium (pre-dredging) state due to large muddy discharges from the rivers.

- Maintenance dredging is expected to be required to maintain design draft over time through the channel.

5. REFERENCES

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