BEFORE THE WHANGAREI DISTRICT COUNCIL AND NORTHLAND REGIONAL COUNCIL

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of a resource consent application by Northport Limited under section 88 of the Resource Management 1991 for a port expansion project at Marsden Point
APPLICATION NO.	APP.005055.38.01 LU 2200107

STATEMENT OF EVIDENCE OF BRETT JAMES BEAMSLEY

(HYDRODYNAMIC, MORPHODYNAMIC AND PLUME MODELLING)

24 August 2023

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Environment Law and Strategy

INTRODUCTION

Qualifications and experience

1. My name is Dr Brett James Beamsley.

2. I am the General Manager of MetOcean Solutions ("MOS") which in 2018 became fully amalgamated within The Meteorological Service of New Zealand ("MetService"). As well as providing operational forecasting, MOS is a science-based consultancy that offers specialist numerical modelling and analytical services in meteorology and oceanography. I have held this position for five years, prior to which I held the position of senior scientist and project director within MOS.

3. I have a PhD in physical oceanography and nearshore sediment dynamics from the University of Waikato. I have more than 25 years' experience in physical oceanography, coastal processes and ocean engineering application. I have prepared and presented hydrodynamic evidence at six council resource consent hearings, and Environment Court hearings.

4. I am familiar with the application site and the surrounding locality.

5. I first became involved in the Northport expansion project in 2017. Since that time, I have been part of the expert team undertaking assessment of the proposal for expansion. I helped prepare the following three reports (together the "MetOcean Reports") that are attached to the application as Appendix 9 and dated August 2022:

   (a) Hydrodynamic Modelling Update (the "Hydrodynamic Report");

   (b) Morphodynamic Modelling for the Northport Environment (the "Morphodynamic Report"); and

   (c) Dredge Plume Modelling (the "Dredge Plume Report").

6. Below are the qualifications and experience of other co-authors of the reports listed above:

   Dr Alexis Berthot – Marine Project Consultancy Manager

   Alexis has more than 20 years' experience in coastal, ocean and estuarine research and consulting and has provided professional services for a wide range of coastal and ports projects. He has a PhD in Physical Oceanography from the University of Western Australia. His expertise is in numerical modelling and data analysis with particular emphasis in hydrodynamic, wave, sediment transport and morphological modelling. Alexis has extensive experience in undertaking hydrodynamic modelling in support of environmental impact assessment, harbour engineering and channel optimisation projects.

Simon Weppe - Physical Oceanographer

Simon is a specialist numerical modeller with expertise in many numerical solutions. His experience extends from wave and hydrodynamics models to sediment transport and coastal system morphodynamics. His MSc in oceanography was from the University of Waikato and his thesis focused on the field monitoring and modelling of oceanographic and morphodynamic processes in the vicinity of a submerged reef. Since joining MOS in 2010, Simon has been involved in a wide range of consultancy projects including large scale dredging and disposal projects at many locations in NZ, as well as wave penetration and agitation in harbours and ports. He is an experienced user of the open source Deflt3D suite as well as nearshore wave models. Simon's modelling expertise extends to Lagrangian modelling applied to dredging and disposal plumes, oil spill tracking and pollution dispersal, and is responsible for open sourcing the Lagrangian particle tracking model.

Dr Mariana Cussioli - Physical Oceanographer

Mariana is an oceanographer, specialising in coastal oceanography and coastal environments. She has previous experience in consulting and numerical modelling for several projects involving dredging and coastal developments, such as marinas and piers. She has a PhD in Coastal Oceanography from the University of Waikato and her expertise extends from hydrodynamic, wave and sediment transport modelling to modelling and monitoring of dredging plumes and sediment disposal. Mariana is also an experienced user of the Delft3D numerical modelling system for hydrodynamic, wave and sediment transport applications.

Holly Watson – Physical Oceanographer

Holly has five years of industry experience working as a physical oceanographer at coastal engineering consultancies in Australia. Holly has completed a master's thesis under scholarships where she developed a hydrodynamic model of Tauranga Harbour for port development and environmental assessment purposes. She is a coastal scientist and oceanographer with specialist experience in the fields of coastal and ocean modelling of hydrodynamics, sediment transport and wave conditions. Holly also has experience in statistical modelling and data analysis. Her expertise lies in coastal hydrodynamics with experience in numerical modelling and geographical mapping. Holly has experience working with Delft3D, Delft-FM, SWAN, coupled DFM and SWAN, SWASH, Mike21-FM, Mike21, Global Mapper, QGIS and MATLAB software packages.

Dr Sarah Gardiner - Physical Oceanographer – GIS Specialist

Sarah has 12 years' experience as a physical oceanographer. She holds an MRes degree in Coastal Engineering and a PhD in estuarine hydrodynamics and habitat stability (University of Southampton, UK). She has research interests involving marine geomorphology and coastal habitats and she specialises in the application of GIS, including bathymetry and habitat mapping, data capture, processing & spatial analysis. Sarah has experience in coastal management, policy and spatial planning with reference to shoreline management plans. She is custodian of the company's bathymetry datasets and plays a core role in development of the numerical model domains for structured and unstructured grids used in the forecasting and hindcasting systems.

Code of Conduct

7. I confirm that I have read the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note (2023) and I agree to comply with it. In that regard, I confirm that this evidence is written within my expertise, except where I state that I am relying on the evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

SCOPE OF EVIDENCE

8. In my evidence, I;

   (a) provide an executive summary of my key conclusions;

   (b) summarise and discuss the results of modelling undertaken and the key conclusions in each of the MetOcean Reports;

   (c) summarise the response to further information requested pursuant to section 92 of the RMA,

   (d) address issues raised in the section 42A report;

   (e) respond to submissions received; and

   (f) comment on the draft proposed conditions advanced by Northport.

EXECUTIVE SUMMARY

9. Northport is a commercial port situated at Marsden Point near Whangarei in Northland, New Zealand.

10. Northport is proposing to expand the port's capacity by reclaiming land, building additional berths and dredging a larger turning basin. The proposed dredging footprint and depth are displayed in Figure 2. A detailed description of the proposal is set out in the Application.[1]

11. Over the last 11 years, MOS has undertaken several modelling studies of Whangarei Harbour. This includes the characterisation of the physical environment of Whangarei Harbour and the establishment of wave, current and sediment dynamics numerical models initiated in 2015-2016 with the Channel Infrastructure NZ Limited (previously the New Zealand Refining Company Limited) ("Channel Infrastructure") proposed deepening of the shipping channel to its Marsden Point site. The MetOcean Reports are informed by each of these previous studies and draw from this existing knowledge and previous model setups and development.

12. The MetOcean Reports consider the new proposed layout and include the following modelling studies:

    - Hydrodynamic modelling: we updated the bathymetry with the proposed dredge footprint and ran a full month of hydrodynamics (two spring/neap tide cycles).
    - Morphodynamic modelling: we modelled morphological change in the vicinity of the proposed dredge footprint and reclamation over a five-year period.
    - Sediment plumes modelling: we modelled sediment plumes which may be generated during the proposed dredging operations.

13. With regards to hydrodynamics, the results of the modelling showed only a minor effect of proposed layouts on the current field in the nearshore area surrounding the port. Small decreases in current speed near the reclamation area indicates a potential for an increase in sedimentation. Calibration and validation of the hydrodynamic model suggest the model satisfactorily reproduce the range of hydrodynamic conditions in the environs

14. The effect of the proposed design on the morphodynamics is expected to be limited to the immediate port environs. Significant differences observed between the existing and

[1] See sections 1.4 and 3.

design scenarios are mainly attributed to the combination of dredging (deepening), slope changes, and the transport of sand wave features previously characterized in this region. Despite some predicted changes to the sediment transport and bathymetry within Marsden Bay, model results suggest these will not alter the bay morphology.

15. With regards to dredging, sediment plume and deposition footprints are, in general, elliptical, centred on the release sites, and follow a northwest-southeast pattern consistent with the hydrodynamics. The proposed reclamation has a limited impact on general plume dispersion patterns with a slight flow deflection in its vicinity. Predicted deposition fields for the proposed bathymetry (i.e., post-dredging) indicate possible sediment accumulation near the northwest and southeast edges of the new turning basin.

16. The outcomes of these reports have provided information to assist other experts engaged by Northport assess the actual and potential environmental effects associated with the proposal for a range of disciplines (marine ecology, coastal processes, avifauna, and marine mammal effect assessments).

17. A summary of each report and key conclusions is set out below.

HYDRODYNAMIC MODELLING

Methodology

18. The Hydrodynamic Report describes the methodology and outcomes of hydrodynamic modelling which included the effects of the proposed reclamation and dredging layout on hydrodynamics.

19. The main purpose of this study was to provide further details on the effects of the proposed port development on hydrodynamics within Northport. This technical report included the review of previous modelling MetOcean has carried out around the reclamation area and dredge footprint, and simulations of the hydrodynamics covered two spring/neap tidal cycles (a full month).

20. The two spring/neep cycles encompass a range of hydrodynamic conditions with which to assess the change in currents related to the proposed design.

21. In basic terms, the approach involved defining the harbour bathymetry using a finite-element unstructured mesh that varied spatially. We reviewed the mesh resolution (the dimension of each cell that make up the mesh) in the area around the reclamation and the revised dredge footprint. Areas of the mesh with a higher resolution describe the

simulated phenomenon in greater detail. The mesh resolution varied from approximately 300 m at the open boundary (further from the area of interest) to approximately 5 m nearshore and in the proposed dredged and reclamation areas (area of interest, Figure 1 and Figure 2).

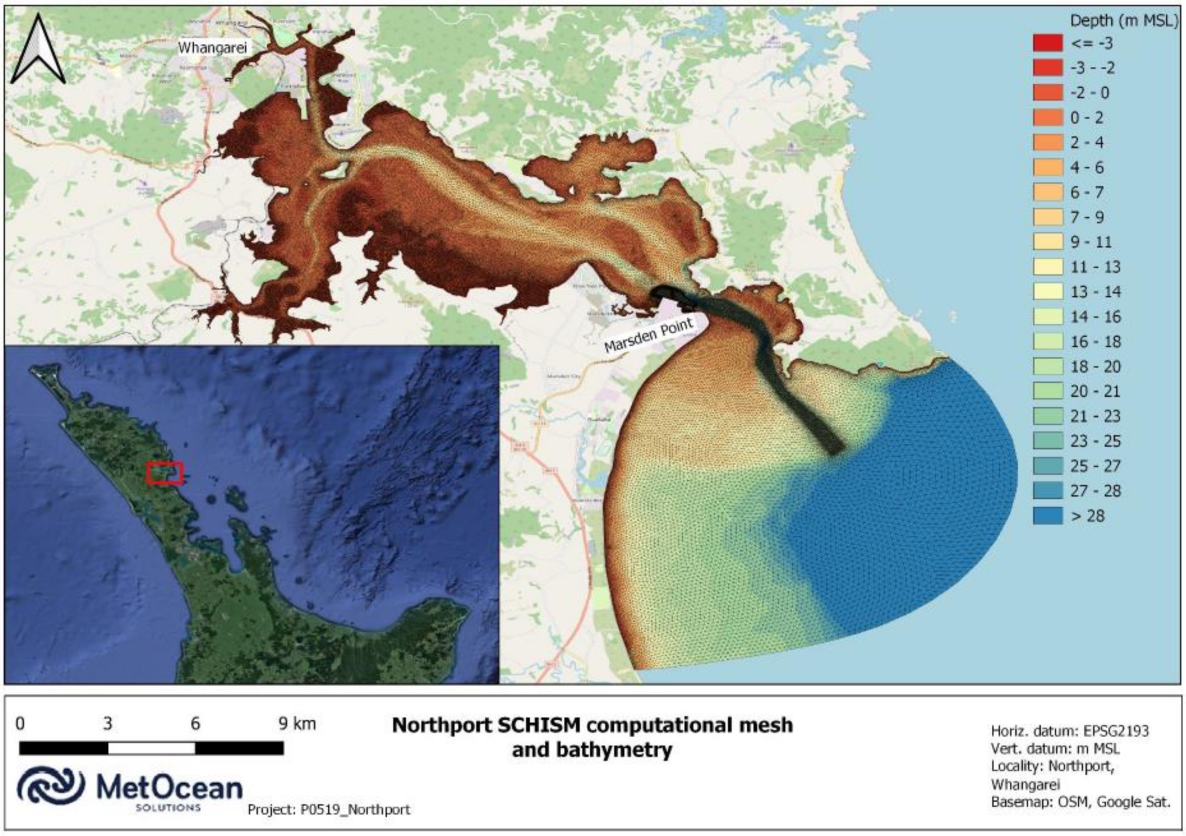

Figure 1 SCHISM computational mesh and bathymetry.

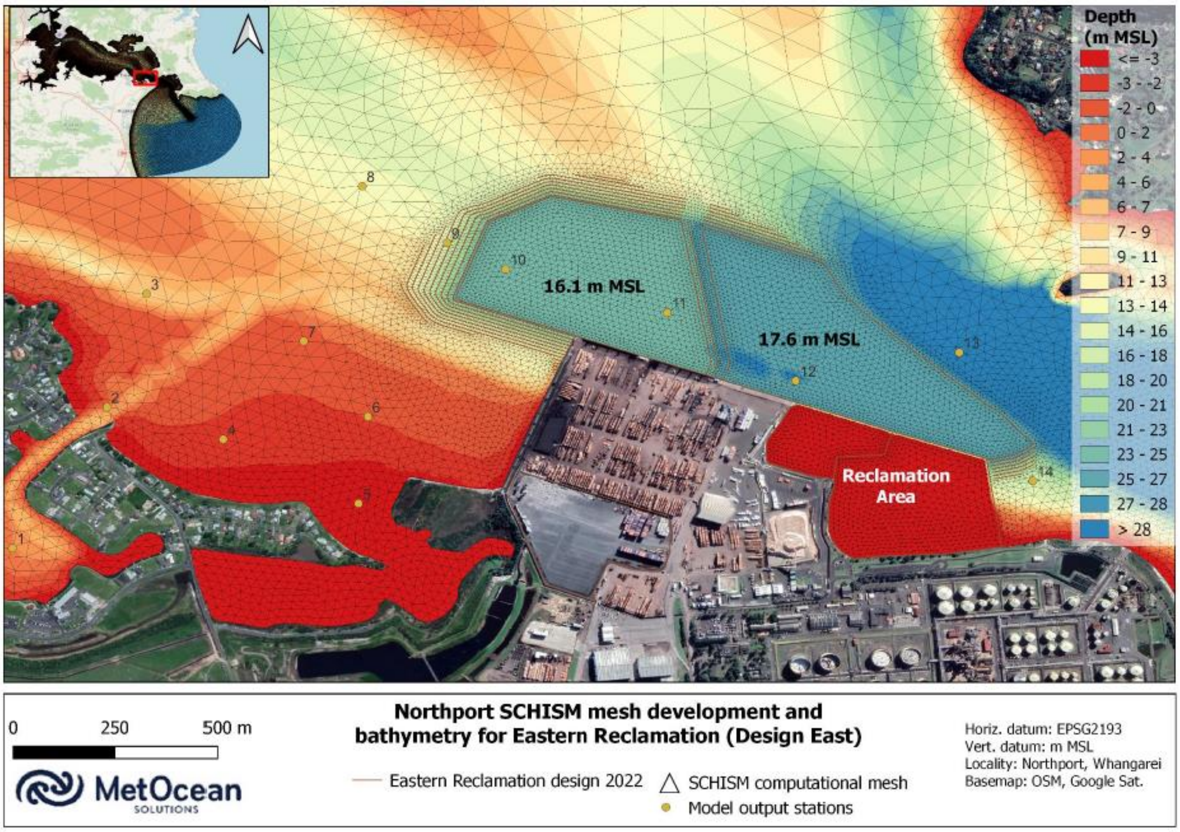

Figure 2 SCHISM computational mesh and bathymetry for the Reclamation design case (Design East). Numbers refer to stations where detailed analysis were undertaken.

22. Bathymetry used in our previous studies was updated with the most recent bathymetric survey data provided by Northport and upstream in Portland Channel and Wellington Reach, both undertaken in February-March 2022 at 2m resolution.

23. The updated existing bathymetry were used as the base for the existing model layout. The existing bathymetry layout was then modified to account for the proposed reclamation and dredging option detailed in Figure 2.

24. The numerical model Semi-Implicit Cross-scale Hydroscience Integrated System Model ("SCHISM") was used to model the 3D hydrodynamics of Whangarei Harbour. SCHISM is open-source, computationally efficient and is extensively used within the scientific community. Its governing equations are similar to other open-source models such as Delft3D and Regional Ocean Modelling System ("ROMS"). The ability to efficiently model the environs using unstructured meshes makes SCHISM an appropriate model for the purpose of this study.

25. MOS undertook model calibration and validation for previous studies in Whangarei Harbour and ran sensitivity tests to ensure the updated SCHISM mesh showed consistent results within the present study.

26. SCHISM was ‘forced’ (i.e., boundary condition) with tidal constituents along the open boundary derived from a ROMS model of the wider environs, with a spatial resolution of 0.3 km. Current velocity, residual components, salinity and temperature were also interpolated onto the 3D SCHISM gridded boundary from ROMS. Near surface wind field from a Weather Research and Forecasting (“WRF”) hindcast were used in the study. In my experience this hindcast approach is entirely appropriate and industry standard.

27. We simulated the proposed reclamation hydrodynamics over a full month period (two spring/neap cycles) and compared these to simulations with the existing bathymetry (updated with the latest survey).

Results

28. Comparison of the modelled water levels and currents between the existing and design (reclamation) simulations were assessed at representative locations (sites in Figure 2). These sites were chosen to cover various locations around the area of interest. Specifically, areas were included where changes could potentially be of concern (e.g., entrance to the marina, sites of cultural significance, etc.) and sites of interest based on discussions with specialists working on the downstream reports using our model outputs for their assessments.

29. Comparison of the tidal planes showed no changes at station 3 in Blacksmith Creek and only a 0.01 m decrease in the lowest astronomical tide (“LAT”) at station 10 (see Figure 2) within the dredge footprint (Table 1).

Table 1 Tidal planes (m) relative to MSL for existing and design (Reclamation) simulations derived over 29-day lunar cycle for selected stations.

Parameter	**Station 3**		**Station 10**	
	Existing	Design	Existing	Design
HAT (Highest Astronomical Tide)	1.30	1.30	1.29	1.29
MHWS (Mean High Water Springs (M2+S2))	1.03	1.03	1.02	1.02
MHWN (Mean High Water Neaps (M2-S2))	0.77	0.77	0.76	0.76
MSL (Mean Sea Level)	0.00	0.00	0.00	0.00
MLWN (Mean Low Water Neaps (-M2+S2))	-0.77	-0.77	-0.76	-0.76
MLWS (Mean Low Water Springs (-M2-S2))	-1.03	-1.03	-1.02	-1.02
LAT (Lowest Astronomical Tide)	-1.31	-1.31	-1.29	-1.30

30. The largest change in mean current speed is at station 10 (see Figure 2) with a 29.6% reduction in current speed due to the change of depth between the two simulations

(existing depth 8.4 m to design depth 16.1 m mean sea level ("MSL"). Station 12 near the berth pocket and station 14 to the east of the proposed reclamation (see Figure 2) also show a reduction in current speeds. There is only a 6.7% increase in mean current speed at station 3 (Table 2).

Table 2 Current speed statistics ($m.s^{-1}$) for existing and design (Eastern Reclamation) simulations derived over 29-day lunar cycle for selected stations.

Station	Simulation	Mean	80th %tile	90th %tile	95th %tile	98th %tile	Max	% diff. in mean
Station 3	Existing	0.15	0.21	0.27	0.31	0.34	0.41	6.7%
	Design	0.16	0.22	0.27	0.31	0.35	0.42	
Station 8	Existing	0.52	0.74	0.83	0.91	0.98	1.09	0.0%
	Design	0.52	0.74	0.85	0.93	1.01	1.11	
Station 10	Existing	0.54	0.77	0.87	0.96	1.03	1.17	-29.6%
	Design	0.38	0.57	0.68	0.77	0.85	0.95	
Station 11	Existing	0.53	0.75	0.89	0.99	1.07	1.21	-7.5%
	Design	0.49	0.70	0.83	0.93	1.02	1.16	
Station 12	Existing	0.47	0.66	0.78	0.91	1.02	1.21	-19.1%
	Design	0.38	0.55	0.69	0.78	0.91	1.13	
Station 13	Existing	0.54	0.75	0.90	1.02	1.15	1.31	1.9%
	Design	0.55	0.77	0.89	0.99	1.08	1.29	
Station 14	Existing	0.42	0.61	0.73	0.82	0.95	1.24	-19.0%
	Design	0.34	0.51	0.60	0.67	0.79	1.05	

31. During a spring tide peak flood and peak ebb phase (Figure 3 and Figure 4), the potential reduction in current speed is predicted to be less than 0.5 $m.s^{-1}$ within the immediate port environs. The main areas of reduction in current speed are at the western edge of the dredge footprint and at the eastern edge of the proposed reclamation. On a flood tide, there is a decrease (<0.2 $m.s^{-1}$) in current speed on the northern channel inside the harbour entrance opposite the port due to the deepening of the dredge footprint in front of the reclamation, directing more of the tidal prism alongside the port rather than through the northern flood channel. There is also a reduction in current speed in the area around Blacksmith Creek on an ebb tide.

32. Modelled results also show a slight increase in current speeds in some areas during peak flood and ebb tides. The potential increase is predicted to be less than 0.2 $m.s^{-1}$, with localised areas with an increase of 0.4 $m.s^{-1}$ within the immediate port environs. More specifically, the results show an increase in current speed of less than 0.1 $m.s^{-1}$ in

the areas around Blacksmith Creek on a flood tide; an increase of less than 0.2 $m.s^{-1}$ in front of the reclamation area within the eastern side of the dredge footprint and to the west of the dredge footprint; and an increase of 0.4 $m.s^{-1}$ in current speeds alongside the existing berths.

33. The potential changes to current speeds during a neap tide are less than during a spring tide however exhibit similar patterns of change, with the reduction occurring at the western edge of the dredge footprint for both a flood (Figure 5) and ebb (Figure 6) tide, and a slight reduction in the lee of reclamation during an ebb tide. There is also a potential increase in current speeds to the west of the dredge footprint on a flood tide and alongside the existing berths on an ebb tide.

34. The small decrease in currents near the eastern end of the reclamation area indicates a potential for increase in sedimentation. The western edge of the dredge footprint may also see an increase for sedimentation, especially during an ebb tide when an increase in current speeds directly upstream of the dredge footprint may increase the sediment mobility to then be deposited in this area.

35. In summary, the model shows only a minor effect of proposed layouts on the current field in the nearshore area surrounding the port. The small decreases in currents near the reclamation area indicates a potential for increase in sedimentation at that location. Calibration and validation of the hydrodynamic model was originally undertaken as part of the Whangarei Harbour study for Refining New Zealand, detailed in MetOcean Solutions (2017), attached with this response. The results suggest the model appears to satisfactorily reproduce a range of hydrodynamic conditions within the harbour.

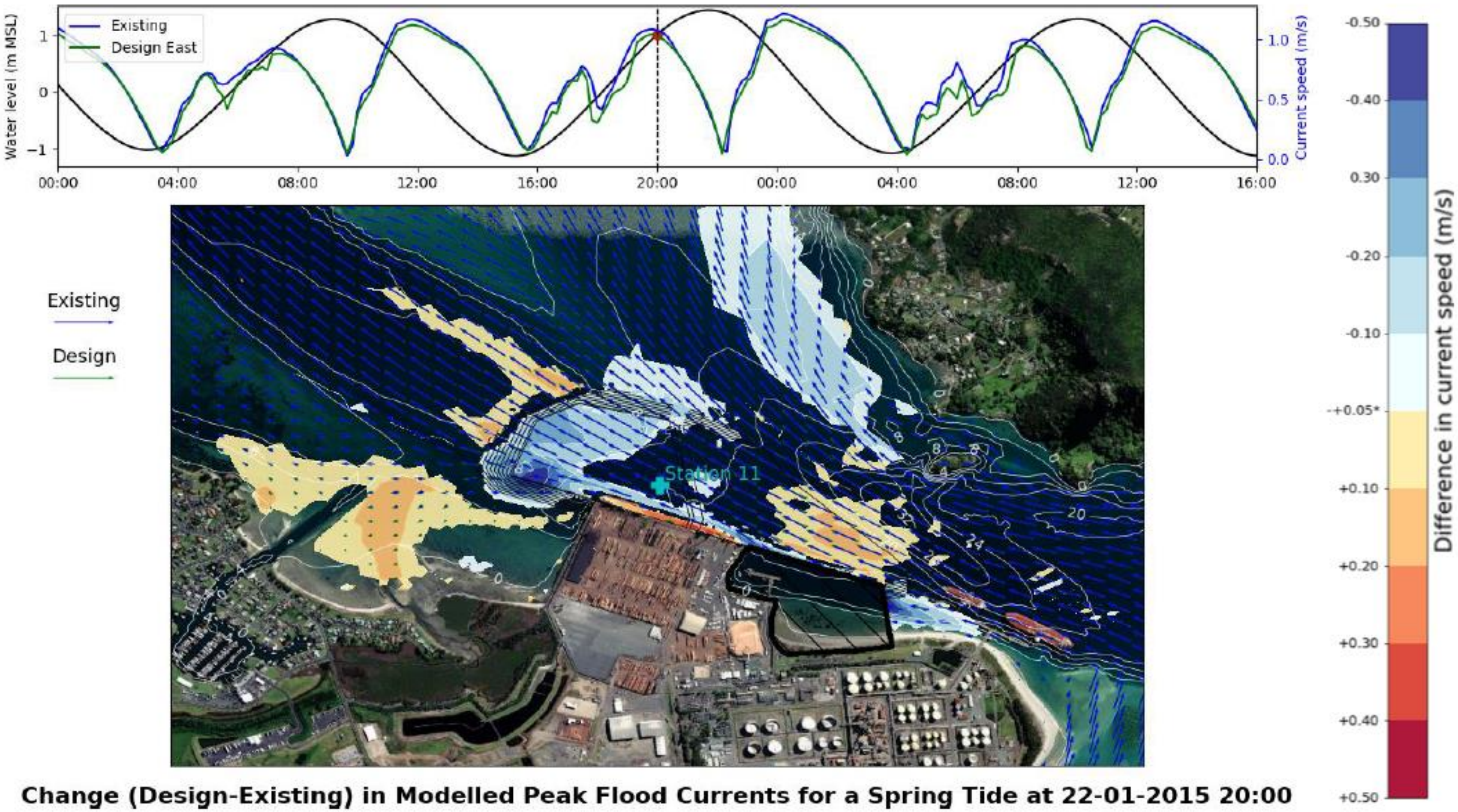

*Figure 3 Modelled current vectors for the existing and Reclamation (Design East) layout and difference in current magnitude during the peak of a flood spring tide. White depth contours are from the existing case and the black design lines display the proposed reclamation and dredging. * Note potential changes less than 0.05 m.s-1 are masked as they are within the magnitude of model error and were not considered as a meaningful change.*

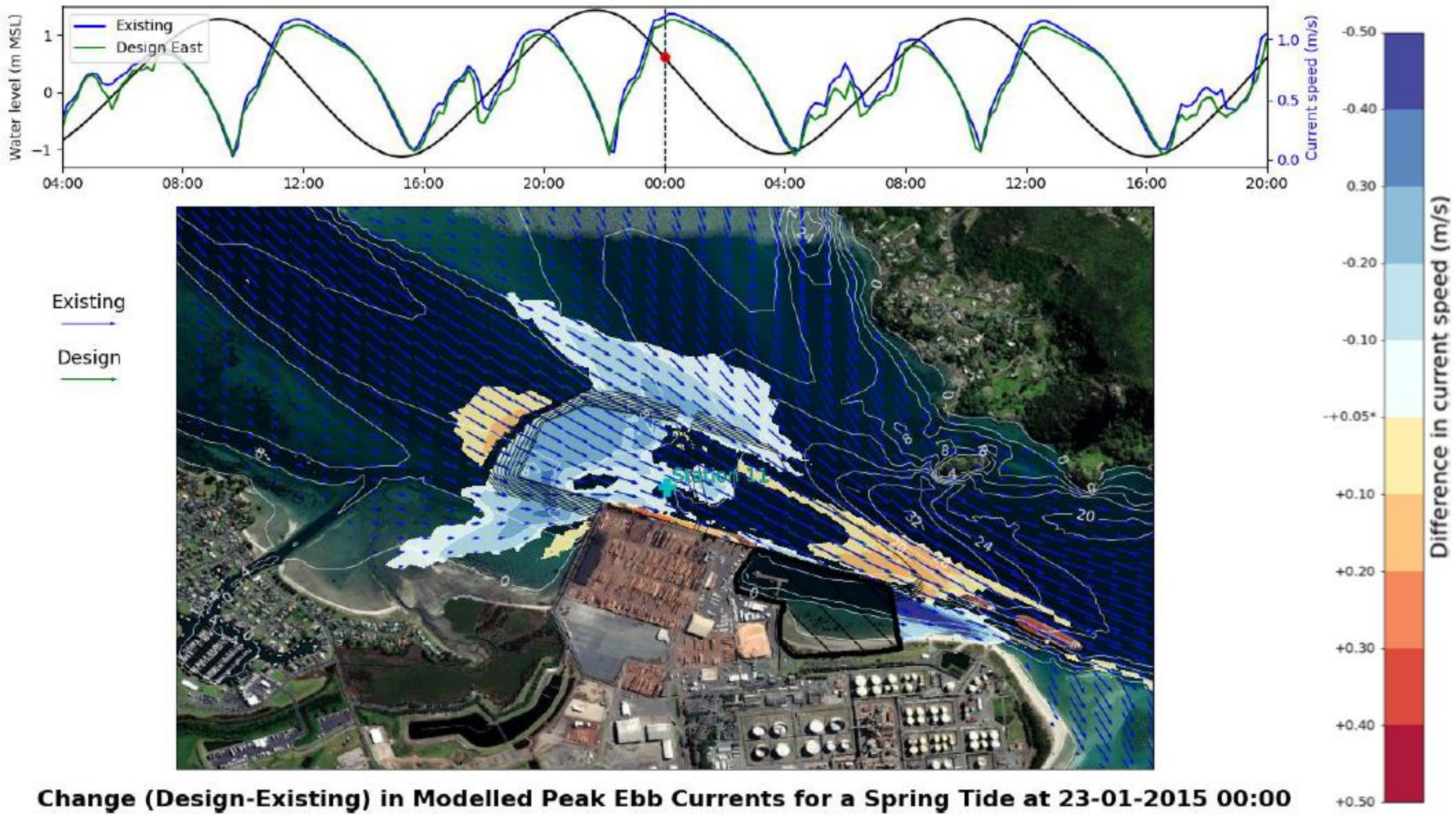

*Figure 4 Modelled current vectors for the existing and Reclamation (Design East) layout and difference in current magnitude during the peak of an ebb spring tide. White depth contours are from the existing case and the black design lines display the proposed reclamation and dredging. * Note potential changes less than 0.05 m.s-1 are masked as they are within the magnitude of model error and were not considered as a meaningful change.*

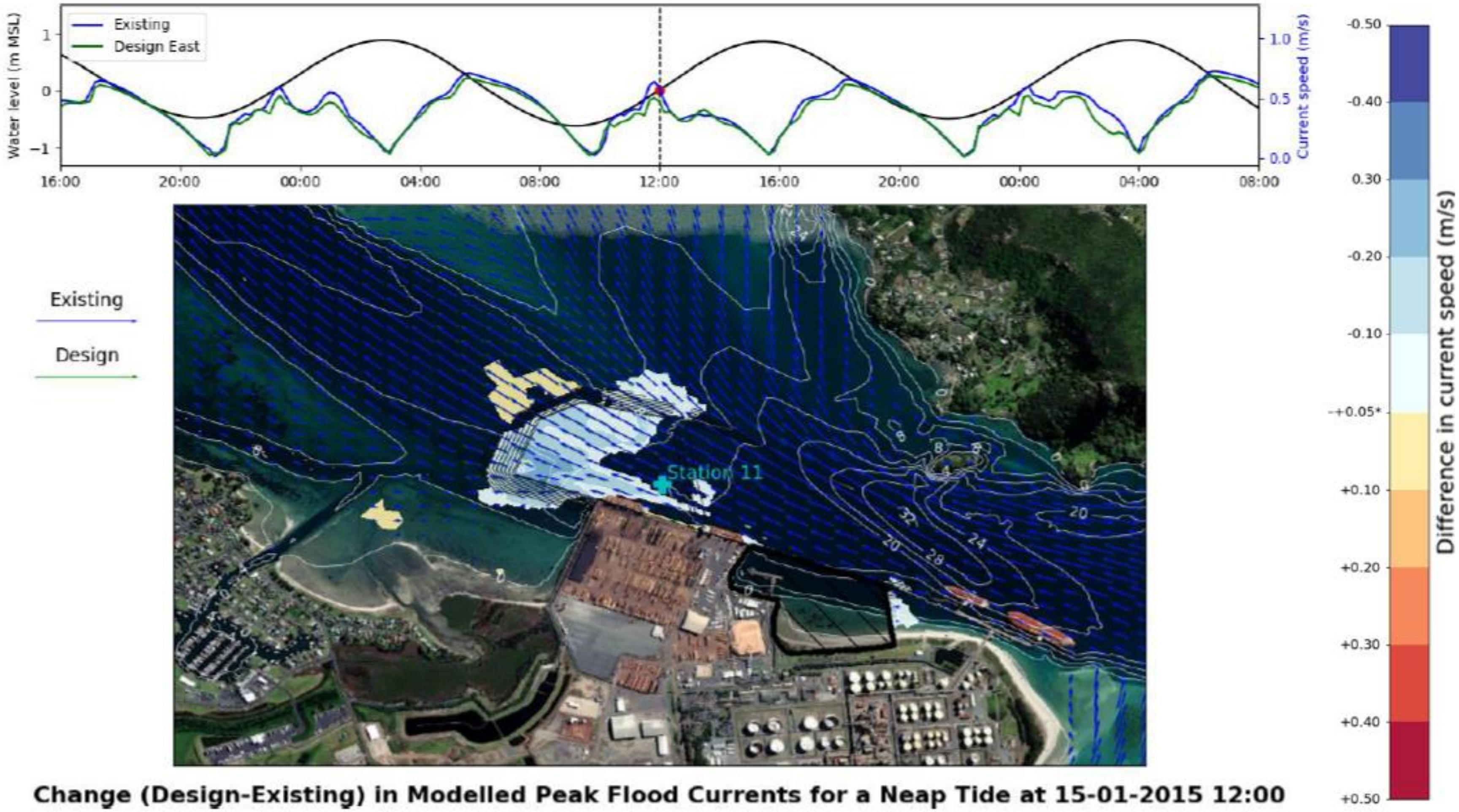

*Figure 5 Modelled current vectors for the existing and Reclamation (Design East) layout and difference in current magnitude during the peak of a flood neap tide. White depth contours are from the existing case and the black design lines display the proposed reclamation and dredging. * Note potential changes less than 0.05 m.s-1 are masked as they are within the magnitude of model error and were not considered as a meaningful change.*

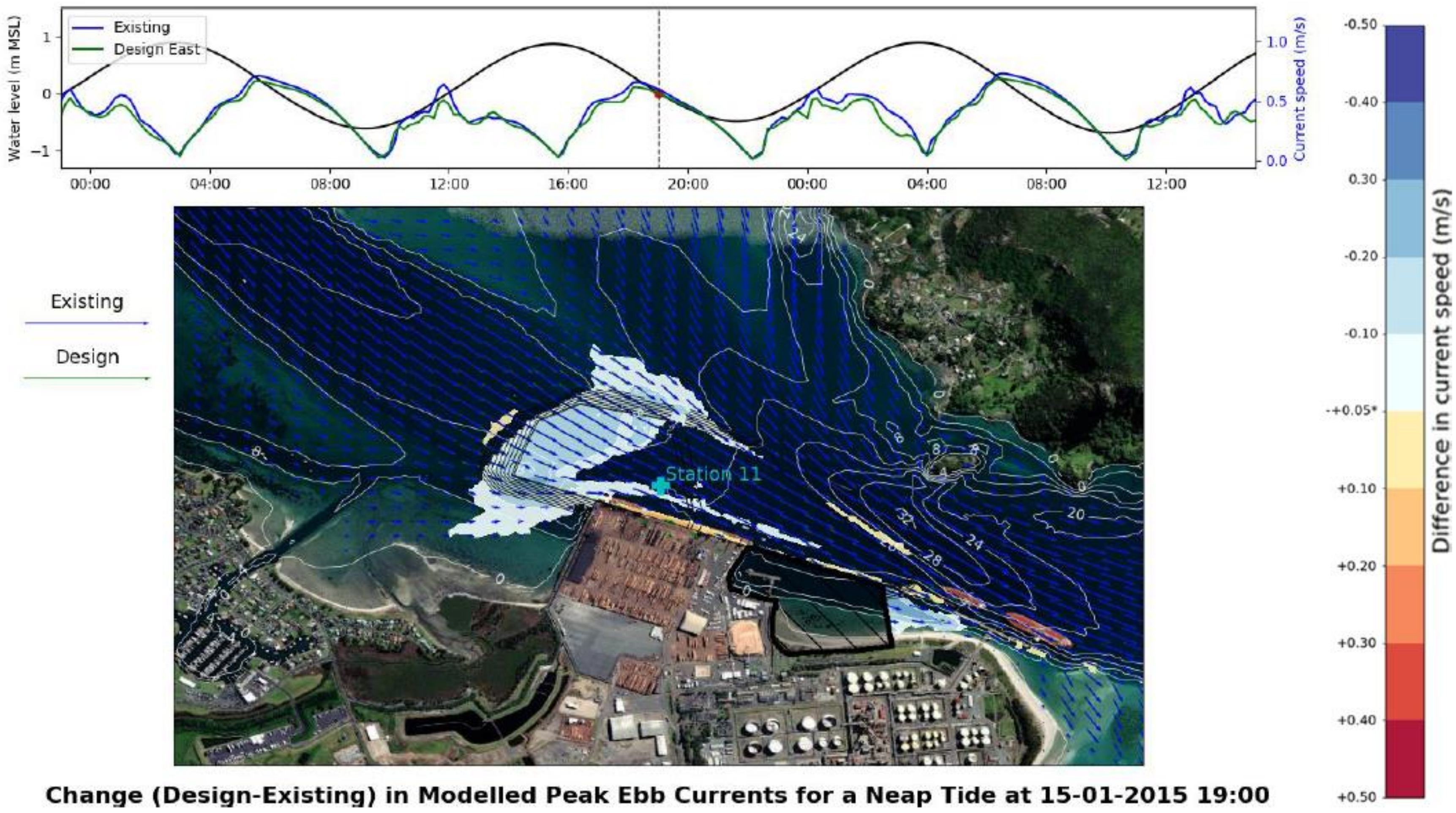

*Figure 6 Modelled current vectors for the existing and Reclamation (Design East) layout and difference in current magnitude during the peak of an ebb neap tide. White depth contours are from the existing case and the black design lines display the proposed reclamation and dredging. * Note potential changes less than 0.05 m.s-1 are masked as they are within the magnitude of model error and were not considered as a meaningful change.*

MORPHODYNAMIC MODELLING

Methodology

36. Morphological modelling is undertaken to predict the expected sediment transport and associated morphological response of the environs to the main forcing mechanisms (i.e., changes in sediment transport, erosion and sedimentation) associated with the proposed reclamation and dredging layouts. The outcomes of this investigation assisted other independent experts engaged by Northport (e.g. marine ecology, coastal processes, avifauna, and marine mammal effect assessments).

37. The morphological modelling of the existing and proposed Northport design was undertaken using the Delft3D morphological model that has been previously calibrated and validated for the Northport region (MetOcean Solutions Ltd 2018d). Model derived tidal constituents were used to define the Delft3D–FLOW boundary tidal currents.

38. The bathymetry was updated to include the hydrographic survey data of Portland Channel and Wellington Reach and the Marsden Point Harbour Survey. The reclamation layout as well as the dredging extents for the design scenario bathymetry was derived from drawings provided by Northport. The Channel Infrastructure channel deepening resource consent is not considered here.

39. The wave grid resolution (the dimension of each cell - squares or rectangles - that constitute the model grid) varied from 490 m to 4300 m for the coarser grid where wave data was applied at the boundaries. The resolution of the grids used for the hydro and morphodynamic simulations varied from 10 to 100 m with higher resolution around the port area (Figure 7).

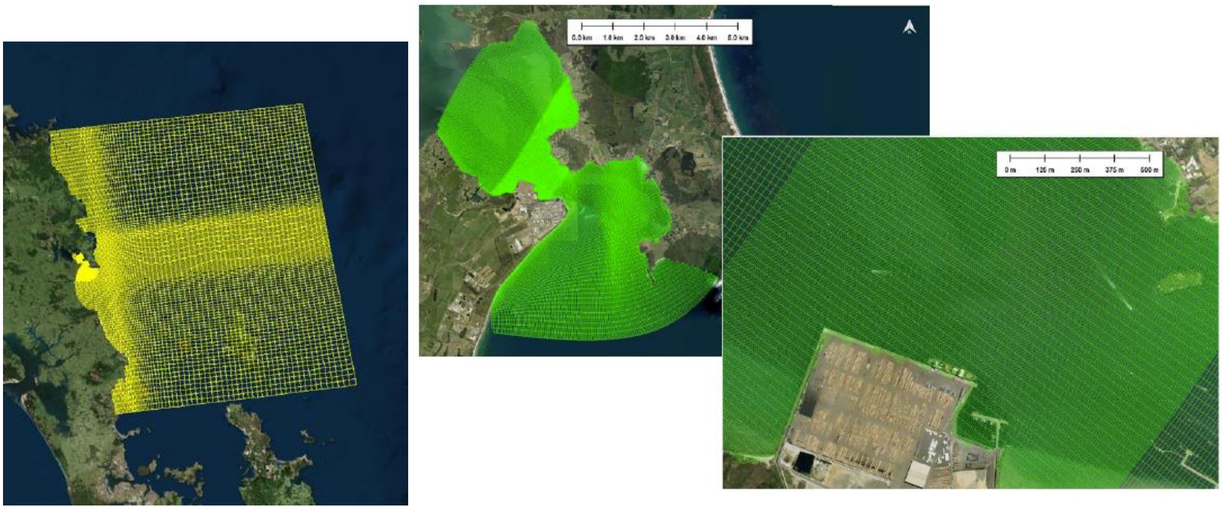

Figure 7 Map showing the Delft3D grids used to simulate the morphodynamics over Whangarei Harbour. The resolution of the wave grid (left, in yellow) varied from 490 m to 3400 m and the higher resolution hydrodynamic grids varied from 10 m to 100 m.

40. To initiate the morphodynamic modelling, it is necessary to setup a map of sediment distribution in the model. The initial map of sediment distribution was determined by running a sedimentological spin-up. This means that the model was setup with different sediment sizes uniformly distributed across the model area and run for a period of 20 days under fair-weather conditions. This allowed the different sediment fractions to be transported according to the local hydrodynamics (currents and waves). At the end of the spin-up simulation, a more realistic map of sediment distributions was produced and used as initial condition in the model simulations.

41. The model methodology applied an input reduction technique. In simple terms, input reduction means selecting a limited number of representative forcing conditions that will collectively reproduce the overall sediment transport patterns and associated morphological evolution. We selected 16 representative wave events (classes) and simulated these events by applying its parameters at the boundary of the coarser grid. Each representative wave event (wave class) is associated to a morphological acceleration factor. Because the time scale at which changes in the hydrodynamic (currents and waves) occur is much faster than the time scale for morphological changes, the morphological factor is a technique to accelerate computed morphological evolution.

42. The modelling consisted of simulating the sediment dynamics over a 5-year period, using the existing and the proposed layouts.

Results

43. Results of sediment transport are presented for the three most significant and contrasting wave classes simulated (Figure 8). For wave class 1 (H_s = 1.6 m; T_p = 9.3 s; Dir = 34.4 deg; Prob. Occ. = 15.1%), transport rate increased along the batter area west of the turning basin compared to the exiting configuration. Within the turning basin, transport rate is reduced throughout, mostly as a result of the deeper design bathymetry and removal of the sand waves located in this area. Transport rates are more significantly reduced along the batter north of the turning basin for wave class 12 (H_s = 6.6 m; T_p = 12.1 s; Dir = 119.9 deg; Prob. Occ. = 0.48%) and localised areas of reduced transport occur east of the reclamation area. Wave class 15 (H_s = 3.4 m; T_p = 8.7 s; Dir = 323.4 deg; Prob. Occ. = 2.0%) presented changes similar to wave class 1. Some localised changes also occur near the sandflat and Blacksmith Creek west of the port, as well as for nearshore areas across the main channel.

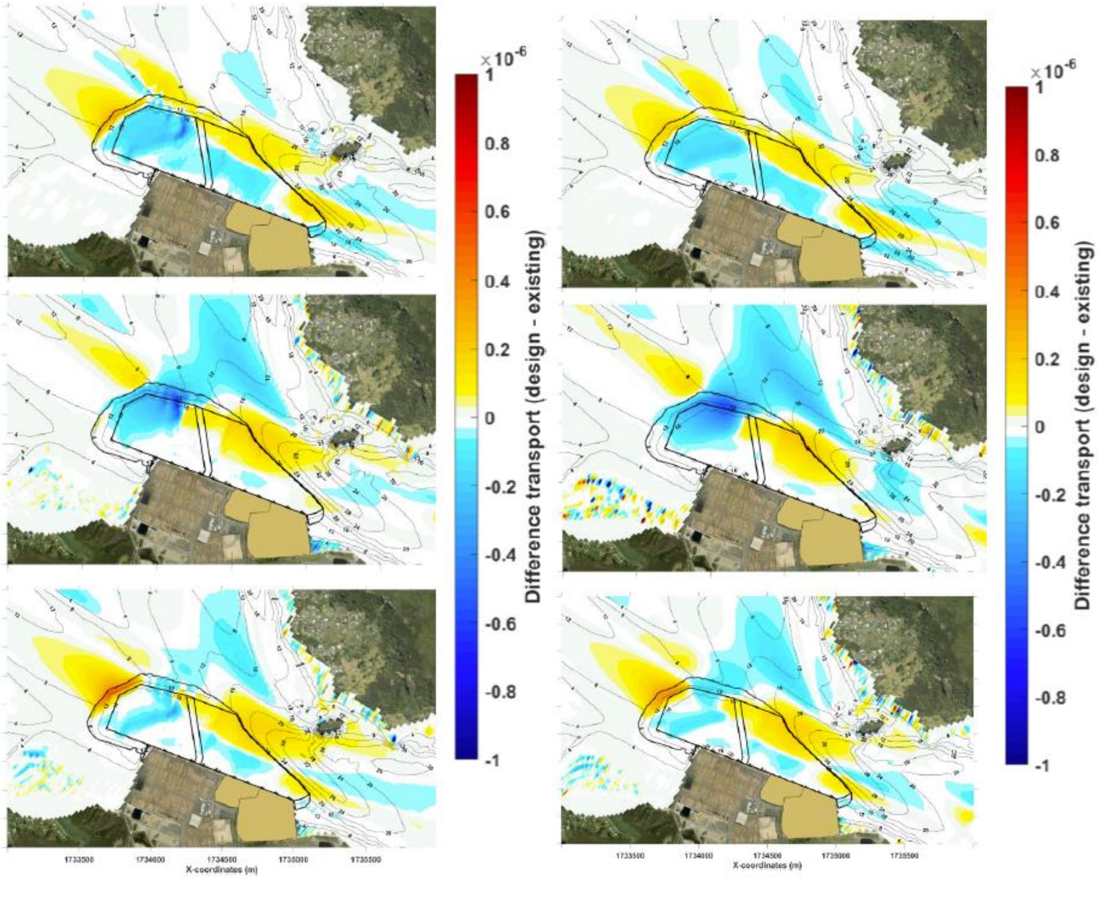

Figure 8 Difference in net transport rates between design and existing configuration averaged over one tidal cycle (~12.25 hours) for the 1st year (left) and the 5th year (right) simulation for boundaries forced with wave class 1 (top row), wave class 12 (middle row), and wave class 15 (bottom row).

44. Results of depth changes are presented as a combination of the 16 classes simulated to represent the final bathymetry (Figure 9). In general, depth changes associated with the design configuration are expected to be predominantly limited to the immediate port

environs. The largest morphological changes are predicted to occur along the batter slopes, mostly northwest of the turning basin. Turning basin and berth pockets may also experience erosion and accretions.

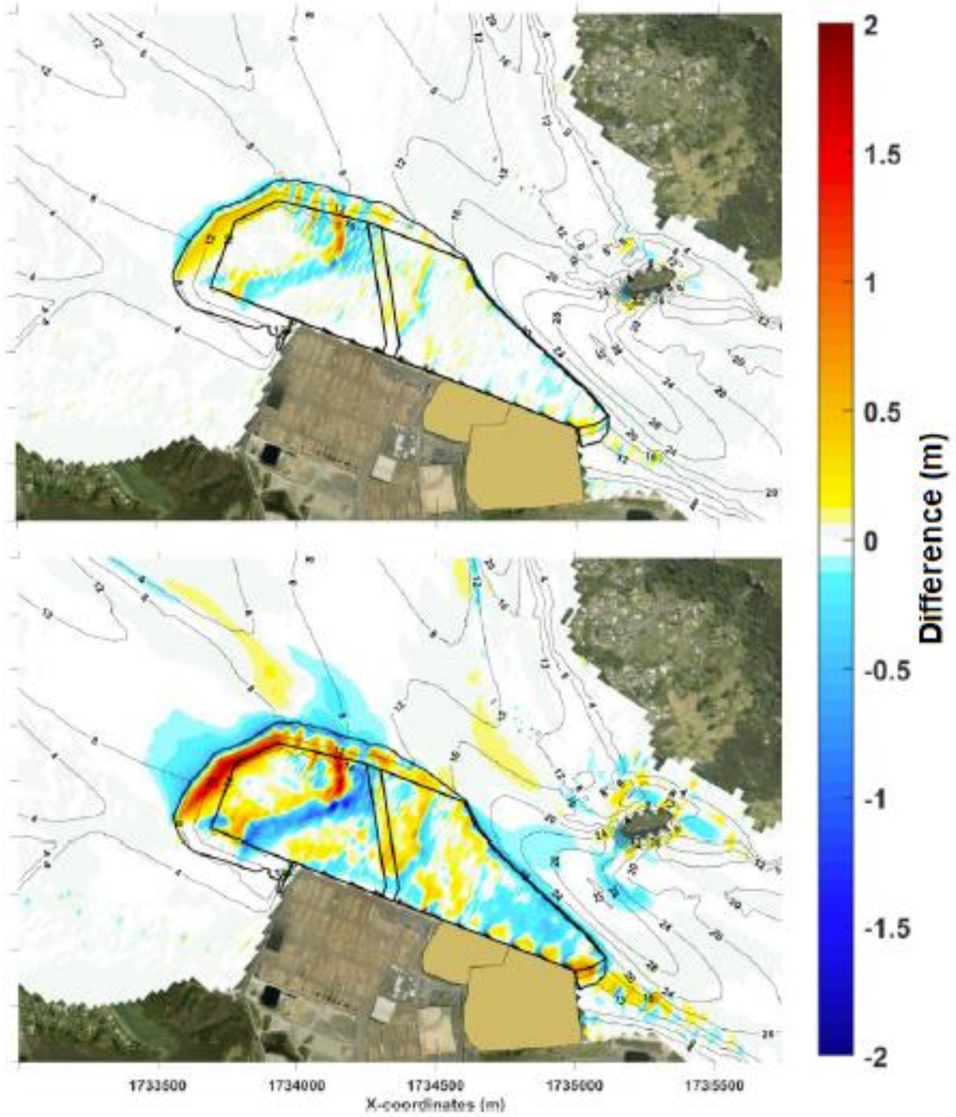

Figure 9 Relative differences between depth changes for the design and existing scenarios in 1 year (top) and in 5 years (bottom) simulation. Dashed and solid black lines represent the design footprint

45. Within the proposed dredged area, a total infilling of 5,527m^3 is expected after one year, including the batter slopes area. The expected infill after five years is of the order 24,150m^3.

46. Profiles across the batter slopes show a pattern of erosion along the crest of the batter, with deposition on the flank and at the toe of the batter, consistent with the batter moving towards an equilibrium profile shape.

47. A summary of the main conclusions are as follows:

- The effect of the proposed design on the morphodynamics is expected to be limited to the immediate port environs.
- Significant differences observed between the existing and design scenarios are mainly attributed to the combination of dredging (deepening), slope changes, and the transport of sand wave features previously characterized in this region.
- The largest depth changes are expected to occur along the batter slopes, mainly northwest of the turning basin.
- Turning basin and berth pockets also present some small rates of accretion and erosion.
- Despite some predicted changes to the sediment transport and bathymetry within Marsden Bay, model results suggest these will not alter the bays morphology.

DREDGE PLUME MODELLING

Methodology

48. The dredge plume modelling utilises the hydrodynamic model of the existing and proposed port configurations to characterise the dispersion of sediment plumes associated with the required dredging. This report provided results on plume footprint including suspended sediment concentration and sediment deposition thickness. These results were used to inform other relevant assessments for this project (e.g. marine ecology, coastal processes, avifauna, and marine mammal effects).

49. A representative range of dredging locations (Figure 10) and likely dredging methods were considered to assess the dispersion of the generated plumes. The selection of these locations aimed at covering a range of sites exposed to different hydrodynamics within the area to be dredged, i.e., closer to the port structures and further out at a site closer to the main channel and exposed to more significant tidal flows.

50. We assumed dredging of the turning basin (sites 1a, 1b, 2a, 2b) using both a Trailing Suction Hopper Dredge (“TSHD") (hopper volume 1860 m^3) and a Cutter Section Dredge (“CSD”). We also considered dredging near the berth pocket using a Backhoe Dredger (“BHD”). These dredging methods were provided by Northport and dredging contractors as the possible methods considered to undertake the dredging.

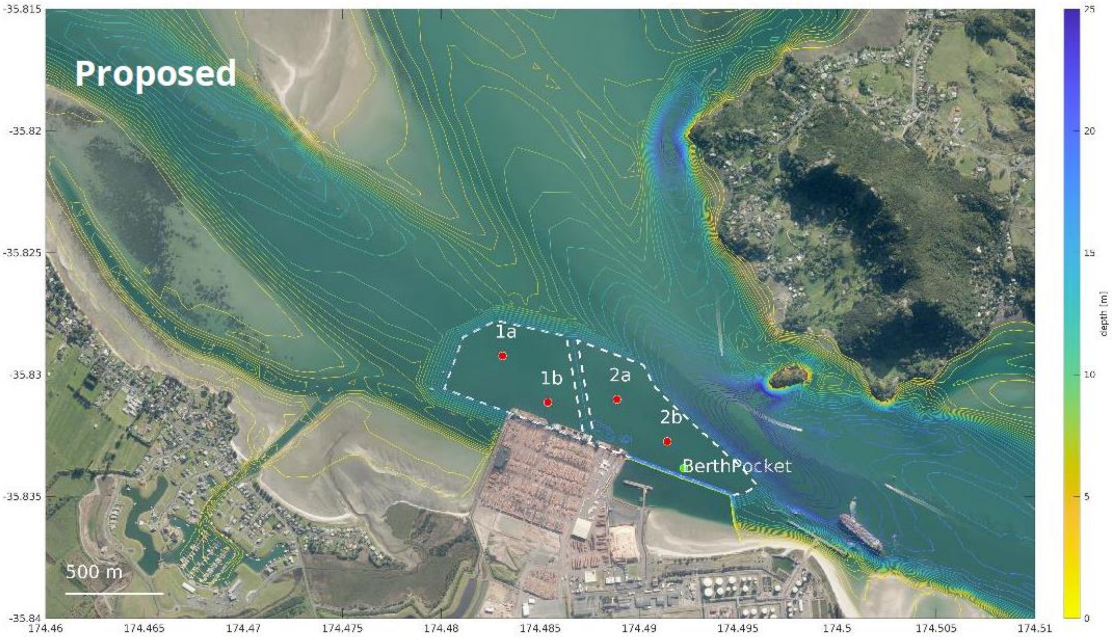

Figure 10 Dredging locations considered for the sediment plume modelling.

51. Dredging operations were simulated over a one-month period, including a complete spring/neap tidal cycle. Previous investigations have shown very little difference in sediment plumes patterns between El Niño and La Niña years, therefore simulations considered a single monthly period (September 2010, La Niña).

52. All dredgers were assumed to operate 24 hours a day, seven days a week, over the one-month period. The cycle times (times between sequential dredge hopper fills) for the TSHD varied depending on the areas to be dredged (Table 3 - information provided by Northport and dredging contractors). The CSD and BHD were assumed to operate continuously (i.e., no specific cycles). This assumption was made with the aim of covering a complete spring-neap tidal cycle at the site and thus covering the whole range of hydrodynamic conditions, providing a robust probability of the dispersion footprint. There is a significant degree of conservatism in this assumption because, in practice, the dredge operations can be intermittent (e.g., stopping overnight or during inclement weather).

Table 3 TSHD cycle times for sites of interest in turning basin.

	Site 1a	**Site 1b**	**Site 2a**	**Site 2b**
Dredging to overflow [min.]	12	12	12	12
Dredging with overflow [min.]	51	113	59	59
Pumping to shore [min.]	152	100	142	142

53. Borehole records provided information on the particle size distribution of the sediment to be dredged. Two representative sediment distributions were assumed in the modelling: a silty sand and a sandy silt. Settling velocities were derived using the equations of Van Rijn (1993) and accounted for the expected flocculation of the fine cohesive sediment. The coarse sand and gravel classes were not included in the simulation due to their fast settling and very low proportion.

54. Dredging source terms varied with the type of dredger used and were defined as in Table 4. These were defined in consultation with Northport and dredging contractors, and in my experience are appropriate.

Table 4 Summary of source terms and scaling fractions simulated.

Source terms	Release depth	Radius [m]	Fraction of production rate
TSHD			
Drag head disturbance	Bottom 3 m	20	0.03
Propeller wash	Bottom 3 m	20	0.03
Surface losses	Surface 2 m	20	0.01
Overflow (sediment de-entrained during descent)	Water column	point	0.2
Overflow (density current at the bottom)	Bottom 3 m	60	0.8
CSD			
Cutterhead disturbance	Bottom 3 m	10	0.05
BHD			
Bucket - near bed disturbance	Bottom 2 m	10	0.04
Bucket losses de-entrainment	Water column	25	0.04

55. The dispersion of sediment was simulated using OpenDrift, an open-source Python-based framework for Lagrangian particle tracking developed by the Norwegian Meteorological Institute. The sediment dispersion modelling consists of a trajectory tracking scheme applied to discrete particles in time and space-varying 3D oceanic currents.

56. Particles were released according to source terms. Individual simulations were undertaken for each sediment class and results were then combined to obtain the total suspended sediment ("TSS") plumes and deposition fields.

57. In general, mean sediment plume and deposition footprints are elliptical, centred on the release sites, and follow a clear northwest-southeast axis consistent with the ambient hydrodynamics dominated by tides and morphology of the main harbour channel. The predicted dispersion footprints indicate no significant dispersion towards the secondary northward channel (Figure 11).

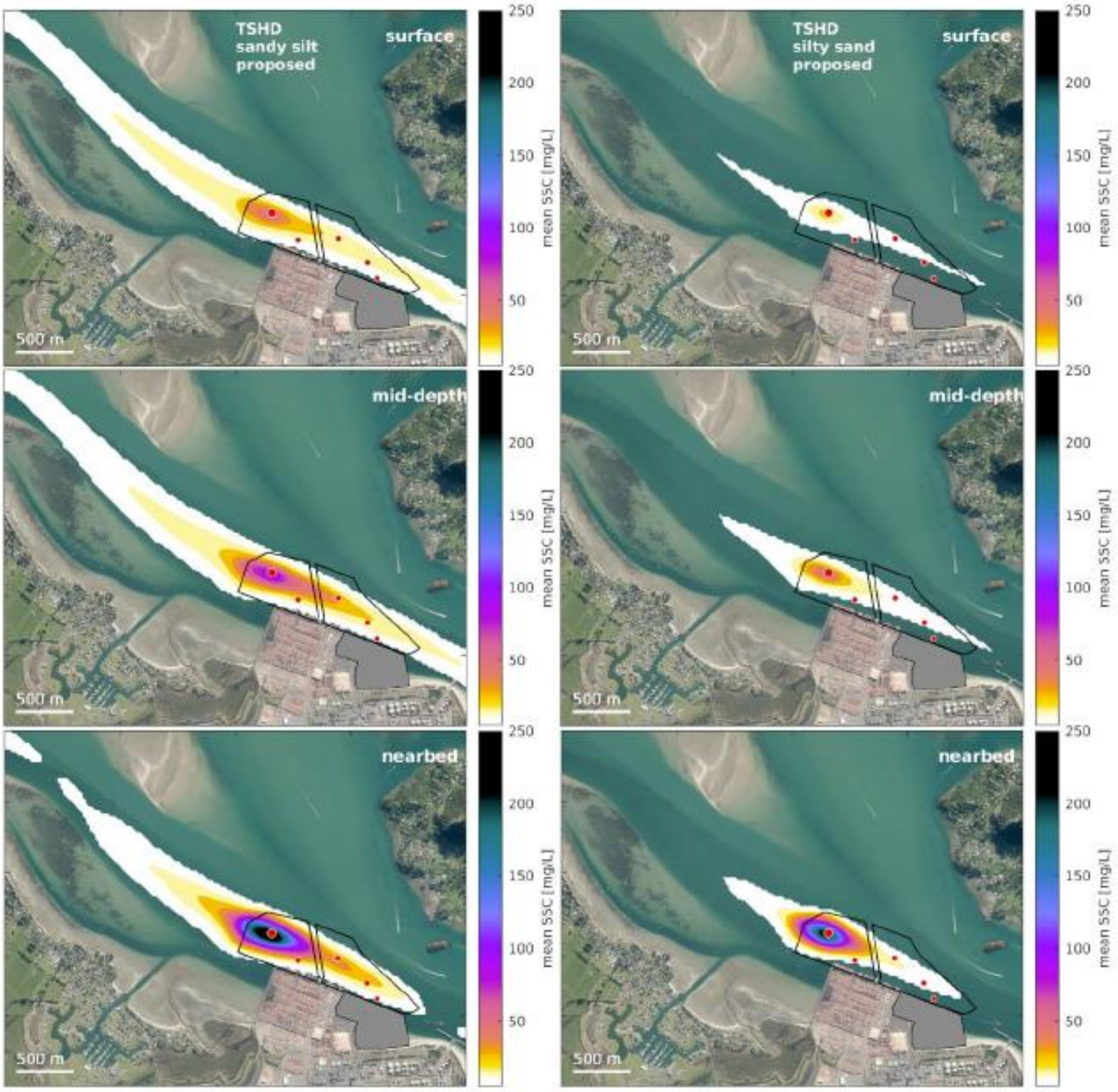

Figure 11 Mean total suspended sediment concentrations (mg.L^{-1}) at surface, mid water and nearbed levels (top to bottom) for TSHD dredging at site 1a, over the proposed bathymetry. Results are shown for the sandy silt on the left panel and silty sand on the right panel. The dredger is assumed to dredge continuously over the 1-month simulation period. TSS were masked below 5 mg.L^{-1}.

58. In the turning basin, general dredging plume and sediment deposition footprints of the TSHD are more extended and have larger sediment concentration levels than those of the CSD (here we are showing results for the TSHD dredger, please refer to the report MOS (2022c) for CSD results) (Figure 12). This is notably due to the THSD's overflow phase which intermittently releases significant amounts of sediment across the entire

water column, and near the seabed. The BHD dredging near the berth results in comparatively smaller plumes and depositions.

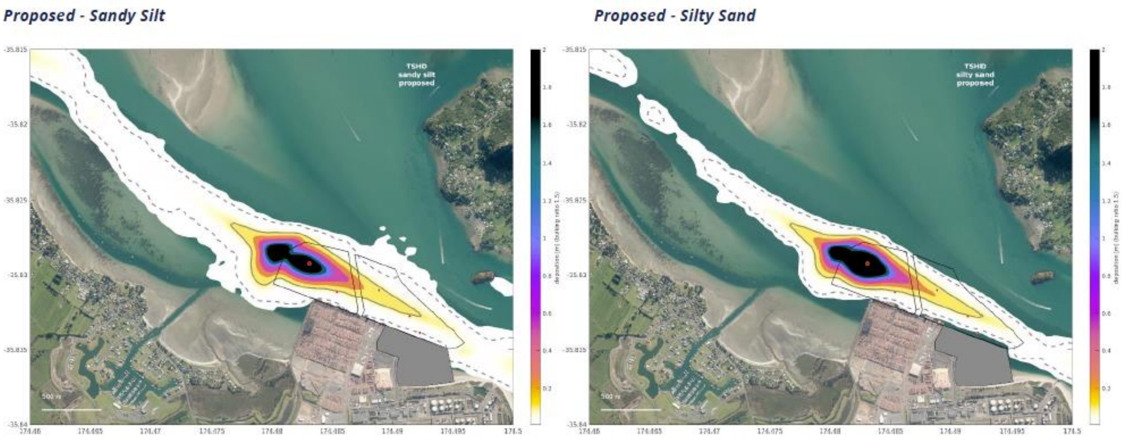

Figure 12 Cumulative sediment deposition thickness (m) for TSHD dredging at site 1a, over the proposed bathymetry. Results are shown for the sandy silt on the left panel and silty sand on the right panel . Deposition thickness was masked below 5 mm and the 1 and 10 cm contours are shown in grey (dashed and solid lines respectively).

59. Construction of the proposed reclamation has a limited impact on general plume dispersion patterns with a slight flow deflection in its vicinity.

60. Predicted deposition fields for the proposed bathymetry (i.e., post-dredging) indicate possible sediment accumulation near the northwest and southeast edges of the new turning basin, with magnitude depending on dredging locations. The depositional features could impact the amount of dredging time required to reach the required depths over these areas.

RESPONSE TO FURTHER INFORMATION REQUESTED

61. The WDC and NRC requested further information on a range of matters pursuant to s92(1) of the Act.[2] A complete response, including to those matters relevant to the MetOcean reports, was provided on or about 21 February 2023. Matters relevant to MetOcean Solutions are summarised below.

62. Item 25 requested MetOcean Solutions to provide the calibration and validation results for all reports (Hydrodynamics, Morphodynamics, and Dredge Plumes), including comparisons with original measurements. The calibration and validation for the hydrodynamic model is presented in Section 2.4 in MetOcean Solutions (2018a). MetOcean Solutions (2018b) presents the methods and results for the calibration and validation of the morphodynamic modelling. The dredge plumes model uses the

[2] Dated 19 December 2022. Items 25-28 related to the MetOcean reports.

hydrodynamic results as base for these simulations and therefore the validation of the hydrodynamics presented in MetOcean Solutions (2018a) is valid for the plume modelling..

63. Hydrodynamic model calibration and validation was originally undertaken as part of the Whangarei Harbour study for Refining New Zealand, detailed in MetOcean Solutions (2017), also attached with this response. The SELFE model (latest releases of the model are referred to as SCHISM) was calibrated and validated against both measured current velocities (sampled using a vessel mounted ADCP) and water level measurements at four locations within the harbour. The validation of the depth-averaged flows indicates the model can replicate the complex tidal hydrodynamics within the Whangarei Harbour environs. Snapshots of the measured and modelled flows for the peak tidal ebb and flood show good agreement, including zones of high flow. Quantile-Quantile plots of measured and modelled current velocities show a good correlation. Additional validation of the hydrodynamic model undertaken against LINZ published tidal elevations at two locations within Whangarei Harbour show the model captures the timing and elevation of the tidal stages well.

64. The morphodynamic modelling approach consisted in replicating the sediment dynamics over a one-year period by applying an input reduction technique and morphological acceleration factors. The morphological model was validated against bathymetric survey data. It was demonstrated that the numerical model replicated relatively well the dominant morphological processes at Northport.

65. Item 26 requested specifications of the hydrodynamics model used, including details on where the hydrodynamic currents were extracted (e.g., near surface, bottom, or depth averaged). The hydrodynamic model used is the open-source hydrodynamic modelling system: Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM) – previously known as SELFE. It is based on unstructured grid algorithms with the robustness and computational efficiency designed to address various applications across creek-lake-river-estuary-shelf-ocean scales with high accurate levels. It employs the semi-implicit time stepping with Eulerian-Lagrangian treatment of advection with an implicit transport solver using two limiter functions which have been shown to work with different Courant numbers.

66. In response to Item 27, we confirmed wind was included in the morphology input reduction methodology. Details on the wind data input reduction are presented in MetOcean Solutions, 2018b. The reduction of the wind climate was performed averaging

both zonal and meridional components of the wind velocity at 10 m associated with the wave events of each bin. Wind data were extracted from a 12 km WRF atmospheric hindcast data produced by MOS and validated at Marsden Point (Appendix C – MetOcean Solutions, 2018b).

67. In response to Item 28, we confirmed that long-term morphological validation was completed for the input reduction. Details on the morphological model validation is presented in MetOcean Solution (2018b). The calibration and validation of the morphological model was achieved by qualitatively and quantitatively comparing measured and modelled morphological changes. The Delft3D morphological model was then calibrated for changes observed between 2016 and 2017. Qualitatively, model results show a good agreement spatially with the measured morphological changes. Quantitatively, the accretion of sand from the tip of Snake Bank into the swinging basin by bedload transport is somewhat under-estimated. It is likely that a lack of resolution in the model grid resulted in decreasing bed slope gradients which influenced greatly the bedload component of the sediment transport. Irrespective, within the order of magnitude errors expected for hydrographic surveys, the model showed a good capability in predicting realistic volumetric infilling rates. The successful validation of the morphological model indicates that the modelling approach is applicable for examining both the existing morphological evolution and the response of the system to the proposed dredging and reclamations.

RESPONSE TO THE SECTION 42A REPORT

68. I have read the s42A report dated 3 August 2023 and I will focus my comments on Section 10.4.1.1 of report, 'Hydrodynamics, Morphodynamics, and Dredge Plume Modelling'.[3]

69. The s42A report notes that the MetOcean reports have been reviewed by a specialist (Dr Christo Rautenbach, of NIWA) on behalf of the Councils, and that MetOcean specialists clarified certain matters raised by Dr Rautenbach through the s92 process.

70. The s42A report records at paragraph 264 that Dr Rautenbach concludes the MetOcean reports "utilise an appropriate numerical modelling approach".

[3] It is noted that the s42A report attaches as Appendix C13 a 2 July 2021 letter from Dr Rautenbach, plus an (undated) follow up letter confirming Dr Rautenbach's key conclusion as recorded in the body of the s42A report – which we reproduce below.

RESPONSE TO SUBMISSIONS RECEIVED

71. No submissions were received that raised issues directly relevant to the MetOcean reports requiring comment.

COMMENT ON DRAFT PROPOSED CONDITIONS ADVANCED BY NORTHPORT

72. I have reviewed the draft proposed conditions being advanced by Northport, and insofar as they relate to the modelling undertaken by MetOcean, I consider them to be generally appropriate.

Dr Brett James Beamsley
MetOcean Solutions

24 August 2023

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