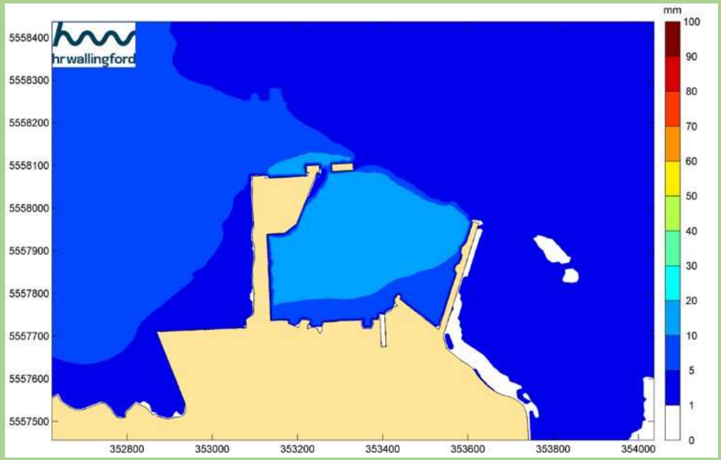
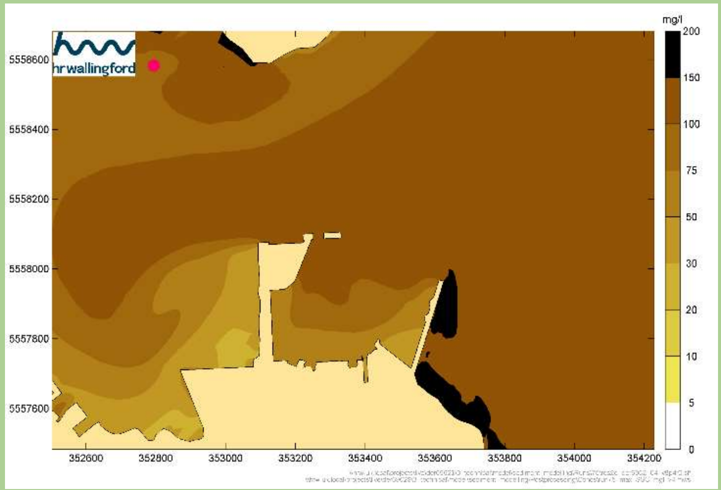
6. Coastal Processes and Sediment Regime



Modelled annual deposition of fine sediments at the existing site



Modelled maximum suspended sediment concentration during storm events (expected to occur on average once per year) at the existing site

The coastal processes and sediment regime ES chapter reports on the predicted changes as a result of the proposed development on water levels, currents, waves, suspended sediment concentration, sediment deposition and sedimentation. The chapter presents the *predicted changes* to coastal processes and sediment regime but does not assess the *effect* of these changes (such as on ecology and water quality). These effects are reported in their respective technical chapters.

Existing Conditions

Relevant data sets and information sources were reviewed to understand the existing coastal processes and sediment regime of the area, including water quality sampling data, near-surface turbidity data, and measurements of waves, water levels, currents, etc. Models were set up and calibrated against available data.

Tidal Level and Currents: Tides at Falmouth are semi diurnal with two high and low waters per day. Currents in the area are primarily driven by the rise and fall of the tides with higher currents seen towards the mouth of the harbour across from St Anthony's Head. Current speeds reduce notably into the Inner Falmouth Harbour. There are relatively low tidal currents (less than 0.2 m/s) present in the area of the proposed development.

Waves: Waves at the proposed development site are a result of both the propagation of waves from offshore and those generated by the wind flowing over Falmouth Harbour and its approaches. There are relatively low wave heights (generally less than 0.3 m) present in the area of the proposed development.

Sediment Regime: The site has generally low suspended sediment concentration and sedimentation rates. Deposition is generally very low at the site with rates generally less than 20 mm/year. There is natural variability in turbidity in the Carrick Roads channel, especially during storm events when the sediment loading of the channel increases naturally to around 75-100 mg/l.

Dredging and Disposal

A sediment model was used to predict the dispersion of fine sediment in the water and its deposition in new areas during dredging. The sediment model was also used to predict the dispersion of fine sediment in the water and its deposition in new areas following its release at the licensed disposal site in the English Channel.

In order to reduce sediment dispersion, dredging will be undertaken using a backhoe dredger(s) with a 10 m^3 (or smaller) lidded bucket, which minimises sediment mobilisation and release into the water. Dredging will be undertaken between 1.75 hours before low water to 1.75 hours before high water which also reduces total deposition of sediment to the east of the site in sensitive areas.

The modelling provided the following results:

- During dredging, mean sediment concentrations are modelled to disperse no more than 200 m outside of the red line boundary to the east and west of the site;
- In the immediate vicinity of the dredging, peak suspended sediment concentrations are around 100 mg/l above background; and
- Predicted total deposition of fine sediment at the end of dredging/disposal is minimal in more sensitive areas outside of the site boundary, with a patch of about 20 mm predicted to deposit at the end of the eastern breakwater.

Operational Stage

Tidal flow, wave and sediment transport models were run for the baseline environment (without the proposed development) and run with the proposed development in place, to predict changes to coastal processes and sediment regime as a result of the proposed development.

The modelling provided the following results:

- No effect on tidal water levels with the proposed development in place;
- Some current speed increases for the flow passing the Western Wharf on both the ebb and flood tide, however these changes are small and transient;
- Some current speed decreases associated with the increased cross sectional area with the dredging to the north of the proposed development;
- Minimum change in wave heights at the proposed development (up to 0.35 m increase for a storm event);
- Overall effect of the proposed development on suspended sediment concentrations is small; and
- The predicted change in infill volume for the overall port operational area is very small.

6 Coastal Processes and Sediment Regime

6.1 Introduction

6.1.1 This chapter reports on the coastal processes and sediment regime study undertaken for the construction and operational stages of the proposed development. It reports on the predicted change as a result of the proposed development on:

- water levels;
- current speed and magnitude;
- wave height and period;
- suspended sediment concentration;
- sediment deposition and erosion; and
- sedimentation within operational areas requiring maintenance dredging.

6.1.2 This chapter reports on the predicted magnitude of change associated with the proposed development and does not report on the effect of this change in the above processes on receptors – this is reported on in subsequent chapters such as Chapter 8: Marine Water and Sediment Quality and Chapter 9: Marine Ecology, using outputs from the coastal process modelling.

6.1.3 This chapter is supported by the following technical appendices within ES Volume 2:

- Technical Appendix 6.1 – Wave modelling;
- Technical Appendix 6.2 – Sediment transport modelling;
- Technical Appendix 6.3 – Sediment plume modelling; and
- Technical Appendix 6.4 – Tidal flow modelling.

6.1.4 The receptors covered by this chapter, comprising estuarine tides, current flows, waves, sediment transport, and morphology, do not themselves have directly applicable legislation. However, they are intrinsic to other receptors that do benefit from legal and policy protection, such as flood risk and water quality.

6.1.5 The applicable legislation that is relevant to the impact assessment for marine and coastal processes were originally framed by the Marine Strategy Framework Directive (MSFD) (2008/56/EC). The principal aim of the MSFD is for marine waters to achieve 'good environmental status' by meeting a set of defined environmental descriptors. Following the UK leaving the European Union, the requirements of the Directive are assumed to continue to apply through the application of The Marine Strategy Regulations 2010.

6.1.6 Coastal processes and sediment regime assessments also should consider the Cornwall & Isles of Scilly Shoreline Management Plan (SMP)[1] and the associated policies and management intent for the coastal frontage of the Falmouth Estuary. This region currently operates a 'Hold the Line' policy, with an anticipation for some 'Managed Realignment' in the coming epochs.

6.2 Consultation

6.2.1 Table 6-1 summarises the key EIA Scoping Opinion responses and any separate consultations that have been undertaken with respect to the coastal processes and sediment regime assessment.

Table 6-1: Summary of Consultation

Consultee /Date of Consultation	Summary of Comments	Summary of Action Taken and Where in this Chapter Comments are Addressed
Environment Agency, EIA scoping response. 14/09/2023	Flood Risk - Whilst the existing Falmouth Docks are mapped by the indicative Environment Agency flood maps as Flood Zone 1, the site area triggers the requirement for the submission of a Flood Risk Assessment (FRA) with any future application. We note that Flood Risk has been scoped out of the Environmental Statement for the reason that a technical assessment will accompany the application. We would support this approach and provide the following advice on the contents of the FRA. The FRA will need to consider climate change impacts in terms of sea level rise and increased wave and wind action and be in line with the current guidance on assessing these. The FRA needs to be supported by suitably contemporary modelling data. We note that the EIA Scoping report refers to an old Strategic Flood Risk Model but this would not be appropriate for this development, as the climate change data will now be outdated.	Whilst the FRA has been provided as a separate report, the wave modelling undertaken considers change in terms of sea level rise and increased wave and wind action and is in line with the current guidance. The modelling does not revisit extreme water level predictions as those are already established. The effects of the proposed development on the parameters that input to flood risk (water levels, wave heights) are described in this chapter and used to inform the FRA where applicable.
Environment Agency, EIA scoping response. 14/09/2023	Coastal Impacts - The EIA would need to have due consideration of the Cornwall & Isles of Scilly SMP2 and the associated policies and management intent for the coastal frontage of the Falmouth Estuary. This region currently operates a 'Hold the Line' policy, with an anticipation for some 'Managed Realignment' in the coming epochs. In relation to this, the ES would need to detail the likely impacts on the coastal processes caused by the redevelopment and extension of the current Falmouth Docks. Accordingly, it would be important to understand the impacts that the development would have on both wave climate and longshore and cross shore sediment transport. You may wish to pay particular attention to the zone of reclaimed land, situated behind the new western wharf, following the demolition of the existing causeway, as this may constitute an 'Advancing the Line' approach, which may not conform with the SMP 2011	The potential impacts to coastal processes in the vicinity of the proposed development are considered in this chapter and the associated Technical Appendices. The FRA includes consideration of the 'hold the line' policy.
Falmouth Harbour Authority, EIA scoping response. 11/09/2023	Coastal Processes and Sediment Regime - Page 25 – tables 5-3 and 5-4 notes maerl as being a sensitive environmental receptor to increased suspended sediment concentration and increased fine sediment deposition due to dredging and demolition. This is agreed but FH would like consideration also for seagrass beds within the inner harbour at Flushing and also within the Carrick roads as this habitat is also sensitive to increased turbidity and is in similar proximity to the site as the live maerl beds already mentioned.	The potential for suspended sediment to reach sensitive receptors, such as maerl beds and seagrass beds are considered in this chapter and in Technical Appendix 6.3: Sediment Plume Modelling. Assessment of the impacts of the predictions on the maerl and seagrass are covered in Chapter 9: Marine Ecology.
Falmouth Harbour Authority, EIA scoping	Coastal Processes and Sediment Regime - table 5-4 Changes to tidal currents, wave conditions, sediment transport and patterns of erosion and accretion during operational life of the scheme. Can	The footprint of changes to tidal currents, wave conditions, sediment transport and patterns of erosion and

[1] Cornwall Council, Shoreline Management Plan SMP2 2011. Available at: https://www.cornwall.gov.uk/environment/countryside/flood-risk/shoreline-management-plan-2011-smp2/. Accessed January 2025.

Table 6-1: Summary of Consultation

Consultee /Date of Consultation	Summary of Comments	Summary of Action Taken and Where in this Chapter Comments are Addressed
response. 11/09/2023	this also assess the potential impacts of nearby infrastructure such as marinas and leisure moorings as well as key habitats such as maerl & Seagrass. We have infrastructure including listed heritage quays, operational marinas and over 600 swing moorings. Changes to tidal currents could impact these through increased flow and accretion resulting in increased operational and capital expenditure.	accretion are described in this chapter and associated Technical Appendices. The assessment of the impact of these changes on nearby infrastructure is presented in subsequent relative chapters, for example, Chapter 9: Marine Ecology.
Falmouth Harbour Authority, EIA scoping response. 11/09/2023	Marine water and sediment quality - Page 33 Table 6-2 we would ask that seagrass is included as a sensitive habitat as well as maerl in relation to increased suspended sediment concentration in water column during maintenance dredging due to the proximity and sensitivity of these habitats.	The potential for suspended sediment to reach sensitive receptors, such as maerl and seagrass are considered in this chapter and in Technical Appendix 6.3: Sediment Plume Modelling. The requirement for changes to the volumes and regularity of maintenance dredging is also considered. Assessment of the impacts of the predictions on the maerl and seagrass are covered in Chapter 9: Marine Ecology.
Marine Management Organization. EIA scoping response. 25/10/2023	The release, dispersion and fate of material placed at disposal site (at sea) will be scoped-out of the assessment for the potential demolition and construction effects. The rationale for this is that the volumes and types of material to be disposed of at sea will be dependent on the levels of contamination present and will be disposed of in accordance with the licence of the disposal site, both in terms of volume and contaminant levels. Whilst the MMO understands your position, it does not account for the potential dispersal of contaminants as the material is being dredged from the wharf area. The MMO suggests this should be accounted for.	Sediment dispersion modelling for both the dredging activity at the wharfs and the disposal operations has been added to the modelling scope and is presented in this chapter and in Technical Appendix 6.3: Sediment Plume Modelling. Assessment of the impacts of the predictions are covered in Chapter 8: Marine Water and Sediment Quality.

6.3 Assessment Scope

Technical Scope

6.3.1 The technical scope of the assessment has considered the following for the construction stage:

- The dispersion and fate of sediment resuspended during dredging.
- The dispersion and fate of contaminants bound to the sediment resuspended during dredging.
- The dispersion and fate of sediment released during disposal operations at the existing licenced disposal site.
- Comparison of the changes in suspended sediment concentration and sediment deposition rate with the natural variability in these parameters during storm events.

6.3.2 The technical scope of the assessment has considered the following for the operational stage:

- The effect of the changes to the bed depths and form of the quays associated with the development on tidal propagation, water levels, current speed and direction and wave height.
- The effect of the changes to the hydrodynamic regime on suspended sediment concentration and bed deposition and erosion rates.
- The consequences of the changes to sediment deposition rates on morphological change including sedimentation within operational areas potentially requiring maintenance dredging.
- The potential for changes in the maintenance dredging requirement within the existing and proposed operational areas.

Spatial Scope

6.3.3 The study area for the assessment of coastal processes and sediment regime comprises the whole of the Fal estuary, extending westwards to Penryn and northwards along Carrick Roads to beyond Truro (see Figure 6-1). Eastward the model reaches to St Mawes. The seaward area extends 20 -30 km offshore with the south-west limit at the Lizard and north-east limit at close to Portholland, some 40 km north-east of the Lizard. The offshore study area was determined to include a full tidal excursion either side of the licensed disposal site to ensure the potential footprint of the plume from sediment disposed at the site would be included.

Temporal Scope and Assessment Scenarios

6.3.4 The assessment has considered impacts arising during the development's construction stage, in particular the capital dredging programme, which are temporary and short-term in nature, and during the development's operational stage, which are permanent and long-term in nature.

6.3.5 The rate of dredging is an important factor in the rate of sediment resuspension and resultant elevation in suspended sediment concentration. For the purposes of the assessment the dredging was assumed to be completed in approximately 58 weeks which provides a precautionary view of the rate of sediment resuspension and hence impacts.

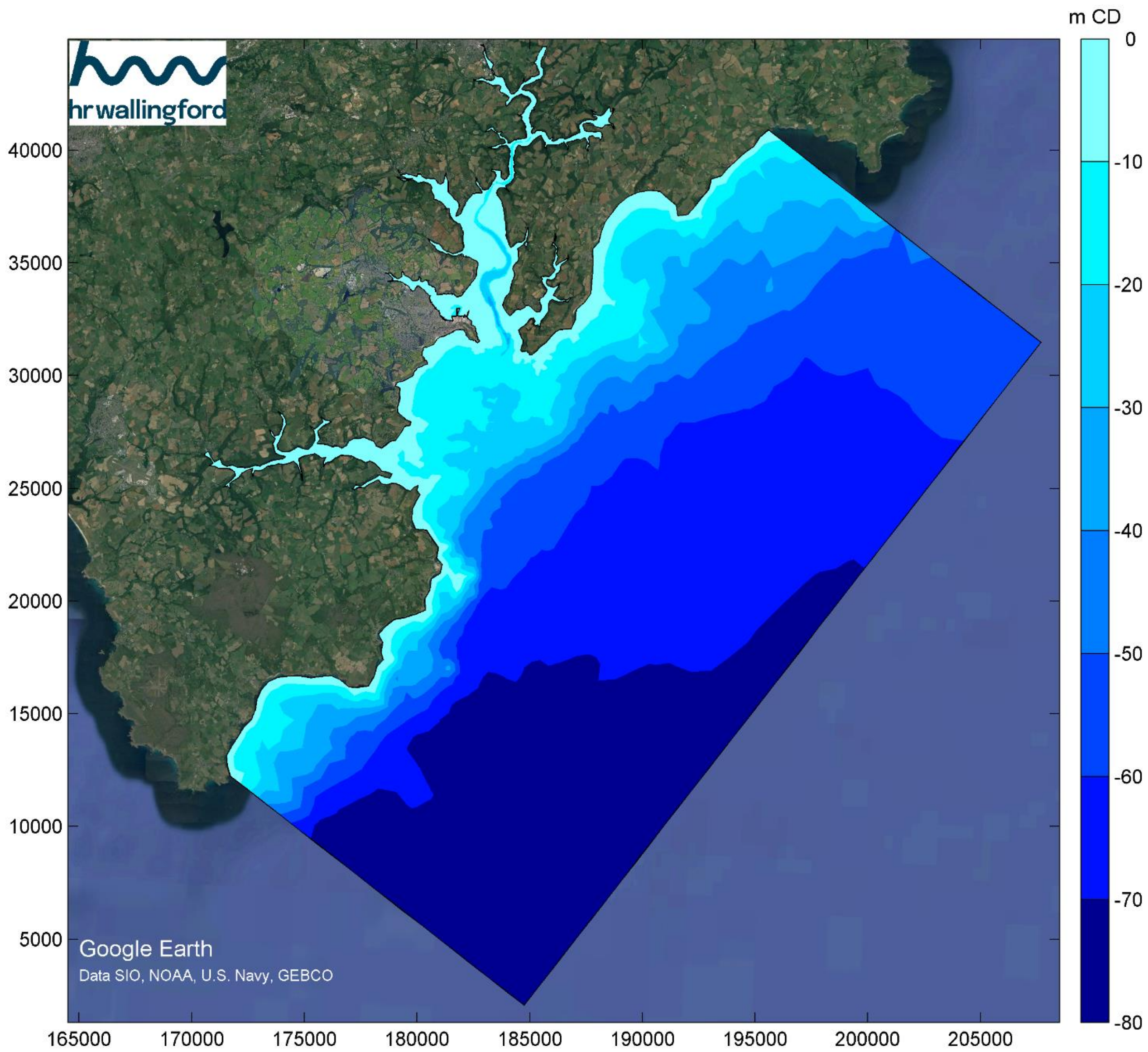


Figure 6-1 Model extent and bathymetry used for coastal processes and sediment regime modelling

6.4 Baseline Characterisation Method

Desk Study

6.4.1 In order to establish the existing baseline for coastal processes and sediment regime in the study area, relevant data were reviewed and assessed. The data sets and associated sources can be summarised as follows:

- Wave measurements from two Waverider wave buoys near Falmouth, located in 45 m and 7 m depth, provided by Cefas and funded by Environment Agency, licensed under the Cefas WaveNet Licence v1.0. The data was collected between June 1984 and June 1985. This data provided calibration and validation data for the wave modelling. Additional wave data covering 2 months of data in June to August 2024 was provided by A&P Falmouth. This data only included one event with a significant wave height of greater than 1 m so was not added to the validation dataset.
- Water quality sampling data at an Environment Agency spot sample location close to Queens Quay, available for the period January 2000 to September 2024 and accessed through the Environment Agency's Water Quality Archive (Open WIMS) web portal (https://environment.data.gov.uk/water-quality/view/landing).
- Near-surface turbidity data provided by Falmouth Harbour Commissioners (FHC) from a monitoring device at a moored buoy on the north side of the Penryn River for the period 14/08/2023 to 29/04/2024.
- HR Wallingford fixed station measurements of current speed and direction, salinity and suspended sediment concentration made at 9 locations spread throughout the Fal Estuary in May of 1985.
- Tidal diamonds from Admiralty charts.
- HR Wallingford measurements of water level made at 9 locations spread throughout the Fal Estuary in May of 1985.

6.4.2 A suite of numerical models of the coastal processes were setup, calibrated by comparison with available data and amended to represent the changes in quay lines and dredged areas associated with the proposed development.

6.4.3 To show the effects of the development in the construction stage, the sediment plume model (SEDPLUME-RW) was run using the baseline (undredged) bathymetry as a means of showing the maximum extent of any sediment released by the construction works without the likely current speed reductions at the site of the dredging reducing the distance the sediment might travel in a tidal phase.

6.4.4 To show the effects of the development in the operational stage, the tidal flow, wave, and sediment transport models were run with equivalent conditions with and without the proposed development in place. The two sets of results were then compared to demonstrate the magnitude and footprint of any change in driving coastal processes and resultant sediment regime.

Field Study

6.4.5 No data were collected specifically for the coastal processes and sediment regime assessment, however best use was made of the field data listed above.

6.4.6 For the assessment of the dredged material asset, vibrocores and surficial bed samples were taken at locations shown in Figure 6-2. These samples were used to understand the levels of contaminants present, the volumes of sediment types, and hence the most appropriate disposal method.

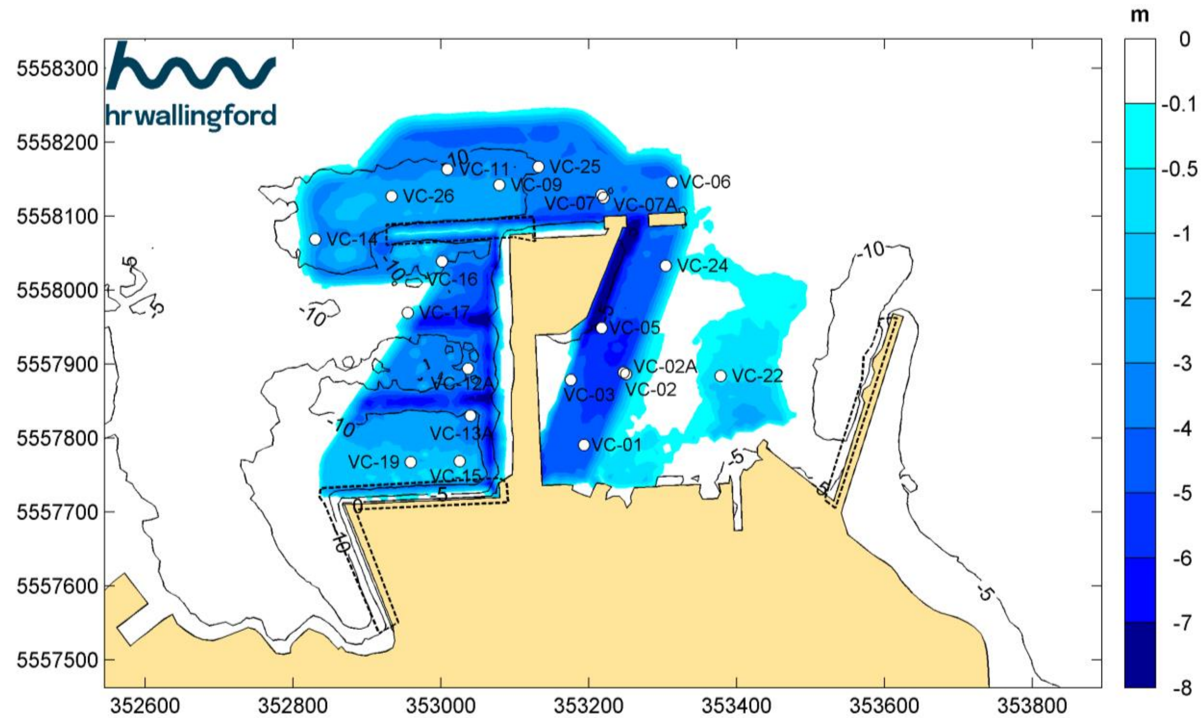


Figure 6-2 Locations of sediment sampling overlaid on the proposed depth of dredging for the proposed development

6.4.7 The data indicates that the local sediment to be dredged, both at the surface and within the bed, is predominantly gravelly sandy mud. The fine sediment (silt/clay) content is 47% at the surface and 67% in total within the bed sediment that will be removed.

6.4.8 The levels of contamination found in the sediment were assessed using a risk-based approach. For further information, refer to ES Technical Appendix 8.3 Ground Investigation Interpretative Report.

6.4.9 Mean contaminant concentrations for those contaminants considered a potential risk to the marine environment (and therefore making the sediments unsuitable for disposal to sea), i.e. Cu, Hg, Pb, Zn, Tributyltin, Dibutyltin and PCBs have been calculated for the North, East and West areas of the proposed dredging. Mean concentrations within the different areas are used here because in practice hotspots of contamination will be mixed with less contaminated material within a bucket and mixed again when released into the water column through the dispersion and movement of water. Those mean values exceeding the Chemical Action Level (CAL)2 level are presented in **bold**. The values are summarised in Table 6-2. Sediments above CAL2 are considered unsuitable for uncontrolled disposal at sea without special handling and containment.

Table 6-2 Calculated mean contaminant concentrations for North, East (Western Wharf) and West (FLOW Basin) areas (mg/Kg)

Area	Cu	Hg	Pb	Zn	Tributyltin	Dibutyltin	PCBs
North	136	2.4	169	354	0.82	0.21	0.16
East	346	**3.6**	115	374	**5.2**	0.77	**0.20**
West	**466**	**3.5**	**526**	**1982**	0.85	0.23	**0.21**
CAL2	*400*	*3*	*500*	*800*	*1*	*1*	*0.2*

6.5 Assessment Method

Construction Stage

6.5.1 The 3D sediment plume dispersion model SEDPLUME-RW has been employed in this study to consider the fate of fine material released by the proposed dredging activities. This model is able to use either 3D flow model output or 2D flow model output (the latter, with an assumption of a logarithmic velocity profile through the water column) to predict the 3D movement of sediment particles.

6.5.2 Dispersal in the direction of flow is provided by the shear action of differential current speeds while turbulent dispersion is modelled using a random walk technique. The deposition and erosion of particles are modelled by establishing critical bed shear stresses for erosion and deposition. Erosion of deposited material occurs when this erosion threshold is exceeded while deposition occurs when bed shear stress falls below the deposition threshold.

6.5.3 Note that the dispersion modelling does not represent background concentrations but simulates the increase of suspended sediment concentrations caused by the plumes generated by the dredging activities over and above these background concentrations.

6.5.4 Note also that the plume dispersion modelling represents the fate of fine sediment only. Sand (or gravel) particles disturbed by the dredger are considered to settle out rapidly either in, or in the vicinity of, the dredger and the fate of these particles is not considered in this report. For a detailed description of the model and its set up, refer to Technical Appendix 6.3.

Dredging task

6.5.5 The total capital dredging volume for the proposed development is around 643,000 m^3. The vast majority of this volume involves dredging berths around the present down to 10.5 mCD with the reminder arising from removal of the western wharf jetty and from a skim of a patch east of the site. Approximately one third of the sediment proposed for removal is contaminated (levels above which are suitable for disposal at sea).

6.5.6 The dredging method has been identified as a backhoe dredger (BHD) in order to keep the rate of release of fine sediment into the wider estuary (and in particular the maerl habitats found in the vicinity) as low as possible. The contaminated material will be removed using an "environmental bucket" which generally means a lidded bucket which is designed to minimise release of suspended sediment losses to the water column. The size of the lidded bucket used in the simulations is 10 m^3. This is a precautionary choice which seeks to minimises the dredge programme, whilst still providing a lidded bucket. The final choice of the plant will be defined by the contractor; however, it will not be larger than the plant simulated.

6.5.7 The types of marine plant proposed can be in considerable market demand. In addition, the requirement for a relatively large, lidded bucket for removal of the contaminated material may also prove challenging. These challenges may result in the use of two smaller dredgers acting in parallel to achieve a targeted schedule. However, for this study a single large backhoe dredger, with larger productivity, has been used as this will result in a larger footprint of plume impact (than two smaller dredgers) and therefore is conservative.

6.5.8 In line with recent projects at the site, dredging was limited to occur during the flood tide. Following investigation of the sensitivity of released sediment deposition in the area classified as 'live maerl overlying dead maerl' (refer to ES Chapter 9: Marine Ecology for further detail), the timing of the period of dredging was amended to be from 1.75 hours before low water to 1.75 hours before high water, which minimises fine sediment deposition in the more sensitive areas.

6.5.9 Once the contaminated sediment has been removed the remainder (around 422,000 m^3) will be removed using the same 10 m^3 lidded bucket backhoe dredger. The production rate for the dredger is presented in Table 6-3.

Table 6-3 Calculated dredger production rates

Description	Production rate (m^3/wk)
Medium BHD with lidded bucket	11,000

Disposal

6.5.10 It is currently thought that around on third of the proposed capital volume (around 221,000 m^3) is contaminated and will require appropriate on-land disposal. The remainder will be disposed offshore at Falmouth Bay Disposal Site (PL075).

Dredging scenarios modelled

Dredging

6.5.11 Three simulations were undertaken to reproduce the effects of the proposed dredging. These simulations all simulated a 15-day period and represented dredging in the eastern, northern and western parts of the site. HR Wallingford's dredger production model was used to calculate the sediment release source terms and the rate of movement of the dredger as it progresses through the area to be dredged. The dredger's sediment release and progress rate as simulated are shown in Table 6-4 and the dredging paths represented in the model over the simulation are shown in Figure 6-3. The west area is also referred to as the FLOW basin. The eastern area is referred to as the Western Wharf.

Table 6-4 Input fine sediment release rates used in sediment dispersion modelling

Dredging Plant	Mean release rate of fine sediment (kg/s)	Mean weekly progress of dredger over the ground (m)
Medium-sized BHD with lid	1.7	290

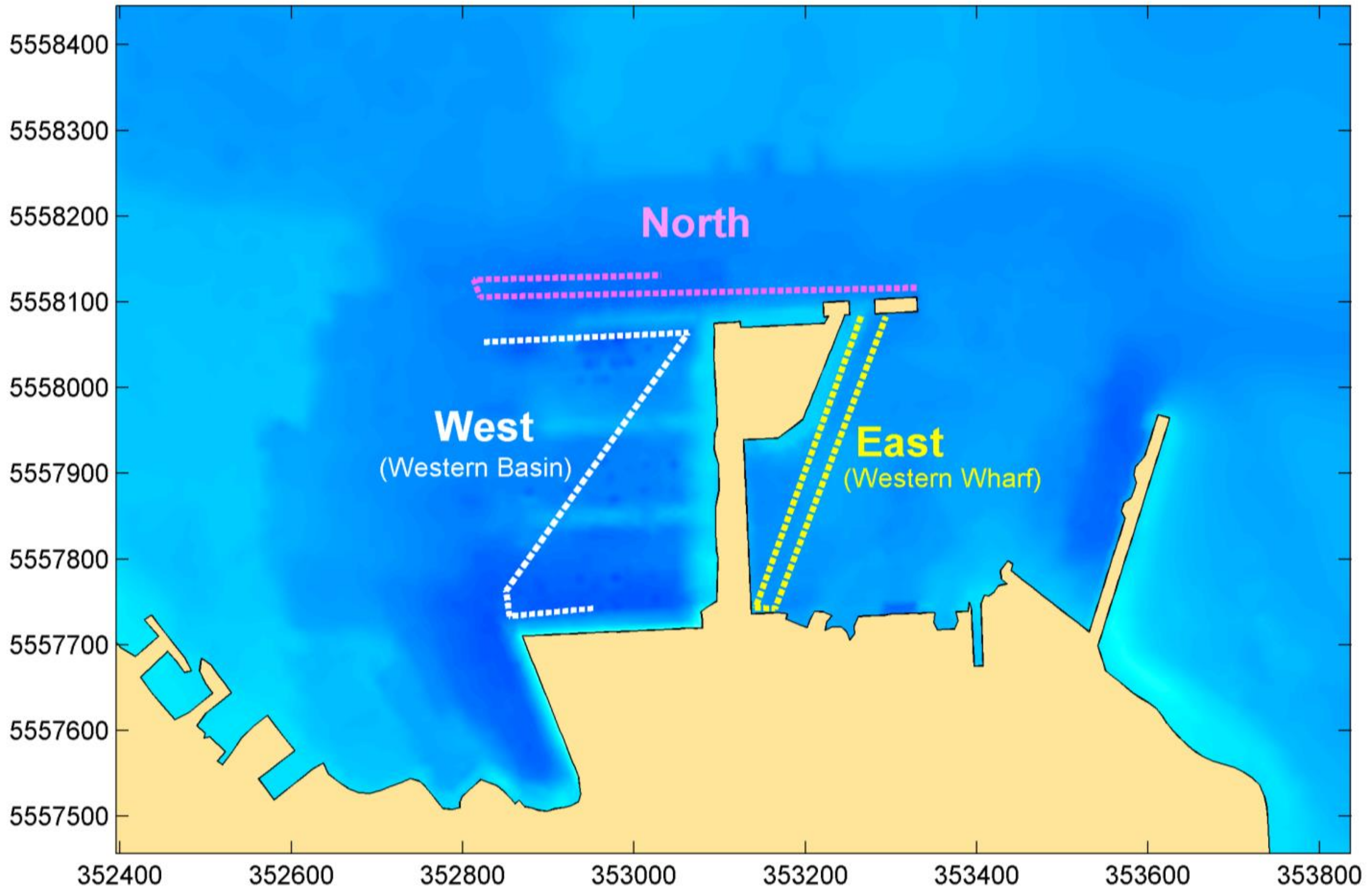


Figure 6-3 Dredging paths used in sediment dispersion modelling

Disposal

6.5.12 The simulation represented the regular placement of uncontaminated capital material by barge from the proposed dredging operations outlined above. The simulation was based on two barges of 700 m^3 capacity placing material at the disposal site every 94 minutes and it was assumed that this disposal operation would be representative for capital dredging in the east, north and west of the dredging site. The placed sediment was assumed to be on average 17% gravel, 16% sand and 67% silt/clay on the basis of the vibrocore samples.

Operational Stage

6.5.13 The following models were applied to establish baseline conditions and predict the effects of the proposed development.

Tidal regime

6.5.14 Tidal flow modelling was undertaken using the TELEMAC module of the TELEMAC-MASCARET suite of models, an industry-accepted finite element modelling system currently being used by more than 200 professional and research organisations worldwide. TELEMAC uses an unstructured, triangular grid to finely resolve waters with complex coastlines and accurately represent dredged extents. For this study, considering the well mixed nature of the flow at the study site, TELEMAC-2D, which simulated depth averaged currents was used.

6.5.15 The baseline model bathymetry was defined using bathymetric data from the United Kingdom Hydrographic Office (UKHO), supplemented with data obtained from International Hydrographic Charts from C-Map (https://www.c-map.com/), and recent local surveys covering the approaches to and within the harbour carried out in 2020 and 2022, supplied by the client for the study, (Figure 6-4).

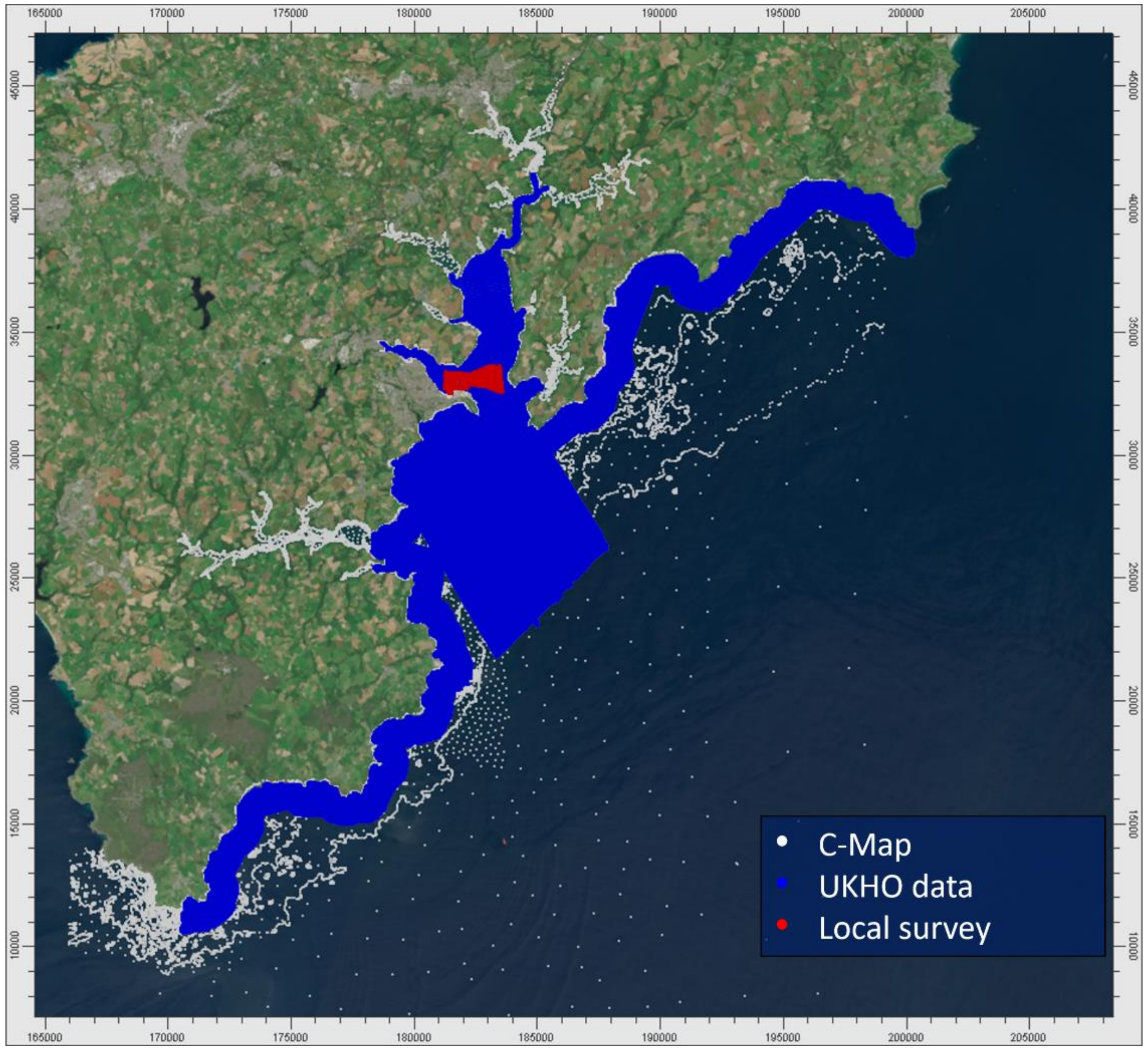


Figure 6-4 Bathymetric data sources

6.5.16 Tidal boundary conditions for the flow model were obtained from version 9.1 of the TPXO global tidal model (Egbert and Erofeeva, 2002[2]).

6.5.17 The Fal River, together with the various creeks that flow into the Fal Estuary, provides very little freshwater input to the estuary system (National River Flow Archive, https://nrfa.ceh.ac.uk). For this reason, the tidal flow model was run without freshwater input.

6.5.18 The model was calibrated against the current and water level data listed in Section 6.4 before simulating a spring neap cycle for the baseline and proposed development scenarios. As well as being used for the assessment of impacts on tidal currents the model also provided the hydrodynamics for the sediment plume modelling.

6.5.19 Full details of the tidal model set up, calibration and scenario simulations are provided in Technical Appendix 6.4.

2 Egbert, G.D. and Erofeeva, S.Y. (2002). Efficient Inverse Modeling of Barotropic Ocean Tides, Journal of Atmospheric and Oceanic Technology, 19(2): 183-204.

Waves

6.5.20 Waves at the site consist of wind waves generated over the restricted fetches of the Fal Estuary from the North to North-east together. Swell from offshore also propagates into the estuary through Falmouth Bay and enters the Docks Basin and may also reflect towards the Docks Basin from the rocky shores to the North.

6.5.21 As waves propagate towards the site, they will be modified by the processes of depth refraction and shoaling as they travel through increasingly shallow water. Wave models that simulate the nearshore wave transformation processes are well established and for the present study the spectral wave model SWAN (Simulating Waves Nearshore) has been used.

6.5.22 SWAN is a third generation spectral wave model, which simulates the transformation of random directional waves considering the following processes:

- Wave shoaling;
- Wave refraction;
- Depth-induced breaking, bottom friction and whitecapping;
- Wave growth due to wind;
- Wave reflections from structures or rocky shorelines; and
- Far-field wave diffraction.

6.5.23 The SWAN model has been extensively validated (Holthuijsen et al, 1997[3], Booij et al, 1999[4] and Ris et al 1999[5]) and is ideally suited to the transformation of wave energy in relatively large coast areas. The model also includes wave generation by the wind within the model area.

6.5.24 The wave model domain, model mesh, bathymetry and layout were identical to the tidal flow model to maintain consistency, both with the tidal flow model and with the sediment transport model.

6.5.25 The SWAN model was run in stationary mode for a fixed set of driving conditions (offshore waves, winds and water level), by applying spatially uniform winds across the whole domain and offshore waves from the Met Office NWS offshore data point along the seaward boundary, with uniform water levels across the domain.

6.5.26 The offshore wave climate was analysed in deep water at the Met office's North West Shelf (NWS) offshore point, based on the long term NWS hindcast dataset (Figure 6-5). The NWS model is forced by lateral boundary conditions from the Met Office's global wave hindcast. The atmospheric wind forcing is given by the European Centre for Medium Range Weather Forecasts (ECMWF) numerical weather prediction reanalysis. The resolution is 1.5 km and the hindcast data are available hourly from 1980 to near present-day.

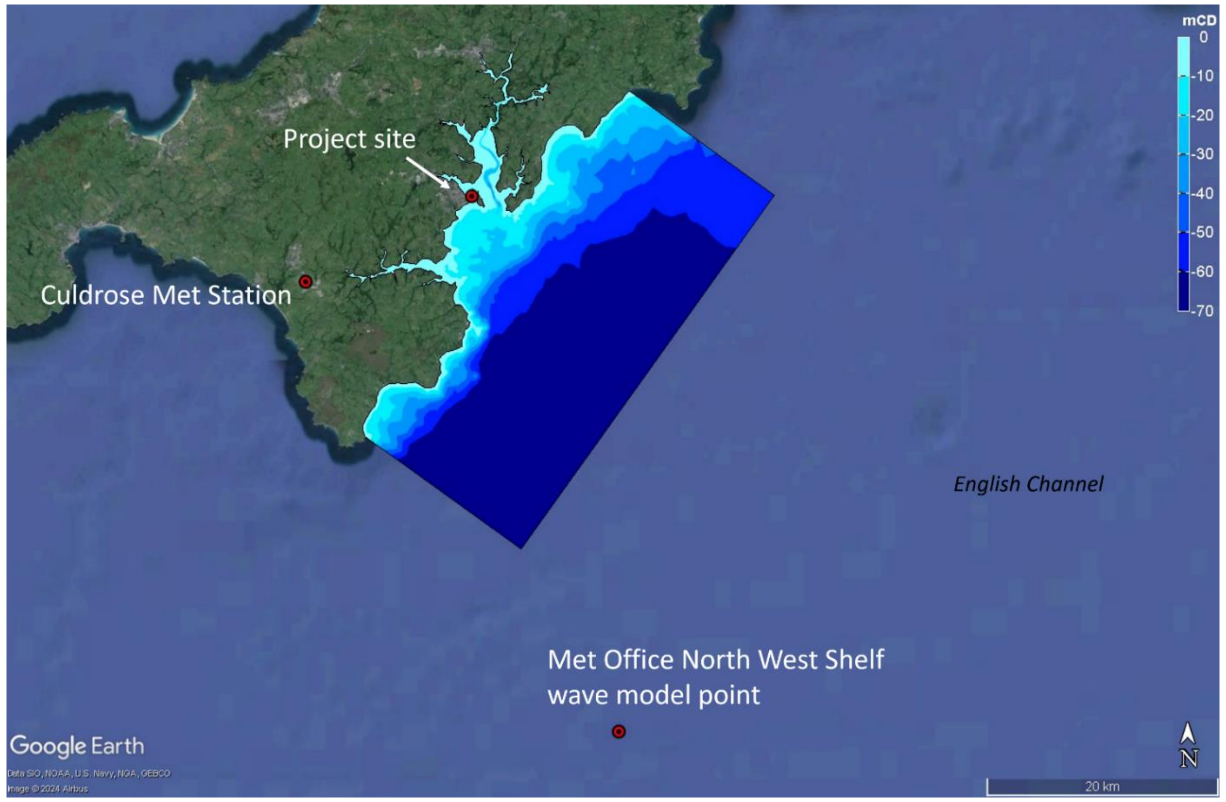


Figure 6-5 Location of wind measurements and offshore Met Office NWS hindcast wave data point

6.5.27 The SWAN model was calibrated by comparison with two Waverider wave buoys near Falmouth, located in 45m and 7m depth covering the period between June 1984 and June 1985. The calibration and validation exercise was undertaken in two stages:

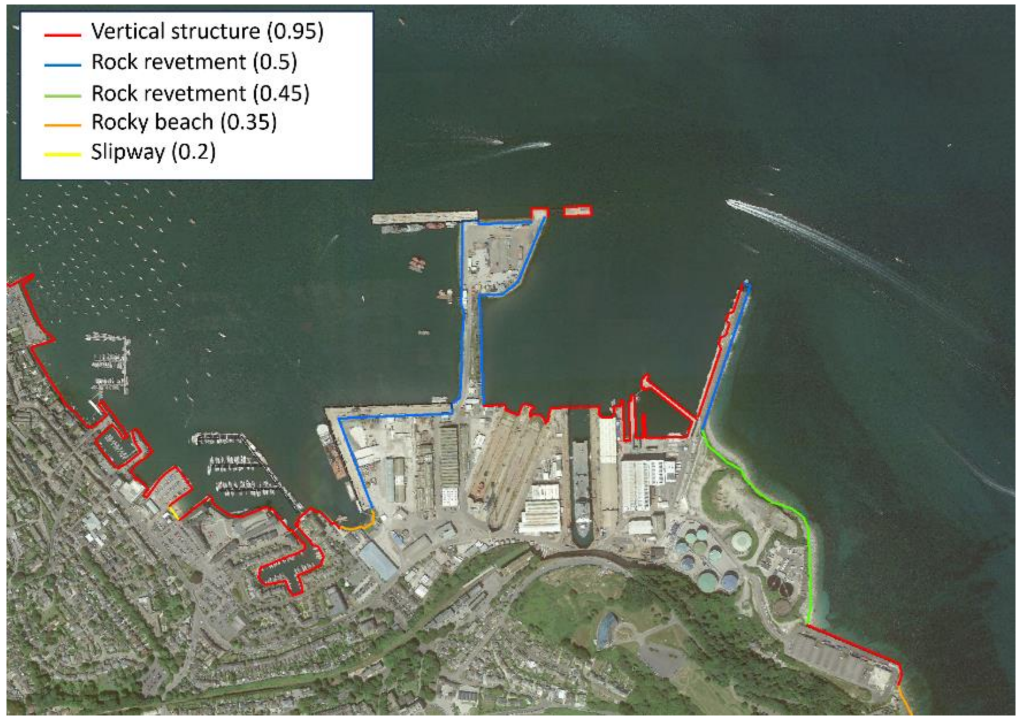
- Comparison of measured waves at the offshore 45m buoy and the Met Office NWS hindcast model at the same location and derivation of adjustment factors for the hindcast model;
- Comparison of measured waves and SWAN predictions at the two buoys for selected winter peaks;
- Comparison with measured waves at a wave buoy located in the entrance of the docks, for the time period between 16 June until 21 Aug 2024.

6.5.28 Reflection coefficients for the existing and proposed quay lines were defined as shown by Figure 6-6. A reflection coefficient of 1.0 indicates that all the incident wave energy will be reflected, while a lower reflection coefficient indicates that some wave energy will be dissipated.

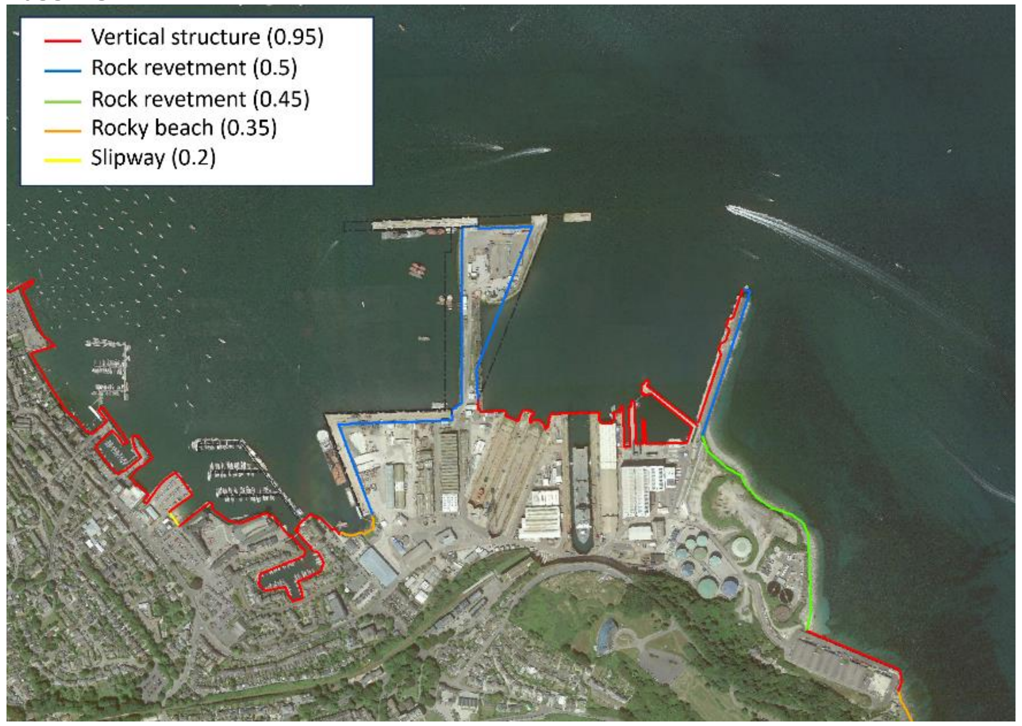
[3] Holthuijsen, L.H., Booij, N., Ris, R, C., Andorka Gal, J,H., and de Jong, J, C, M., (1997). A verification of the third-generation wave model "SWAN" along the southern North Sea coast, Proceedings 3rd International Symposium on Ocean Wave Measurement and Analysis, WAVES'97, ASCE, 49-63.

[4] Booij, N., Ris, R, C., and Holthuijsen, L, H., (1999). A third-generation wave model for coastal regions, Part I: Model description and validation, J. Geoph. Research, 104, C4, 7649-7666.

[5] Ris, R, C., Booij, N., and Holthuijsen, L, H., (1999). A third-generation wave model for coastal regions, Part II: Verification, J. Geoph. Research, 104, C4, 7667-7681.



Baseline



Proposed Development

Figure 6-6 Reflection coefficients used in wave modelling

Extremes

6.5.29 The wave assessment investigated waves with frequency of an average return period of 0.2 years and 1 year as input to the EIA. Additionally, wave return periods of 10, 50 and 200 years were simulated to provide extreme wave conditions in the inner harbour for design purposes. The extreme wave results are included in Technical Appendix 6.1.

6.5.30 Extreme winds were estimated from the long term time-series of measured winds at Culdrose (1973-2023).

6.5.31 A list of independent peaks over a threshold were extracted from the wind time-series with a minimum separation time between neighbouring peaks of 48 hours. Extreme wind speeds conditional on the wind direction sector (30° sectors) were estimated by fitting a Weibull distribution to the independent peak wind speed values.

6.5.32 Extreme waves were derived from the long term time-series at the NWS offshore data point.

6.5.33 Extreme significant wave heights conditional on the wave direction sector were estimated in 30° sectors by fitting a Weibull distribution to the independent peak significant wave height values above a threshold, with a minimum separation time between neighbouring peaks of 48 hours.

6.5.34 Full details of the tidal model set up, calibration and scenario tests are provided in Technical Appendix 6.1.

Sediment regime

6.5.35 Due to the relatively low wave heights (generally less than 0.3 m) and tidal currents (less than 0.2 m/s) present in the area of the proposed development, little movement of coarser sediments such as sand or gravel sizes was considered likely. Therefore, the focus of the sediment transport modelling was on finer cohesive sediments (silts and clays). Previous studies at the site (HR Wallingford, 2008[6]) indicate that the sea bed is very stable in nature over the longer term and this is evidenced by the lack of maintenance dredging requirements within the existing location of the proposed development, hence it is a reasonable assessment that significant quantities of mobile sand are not present in the area of the proposed development.

6.5.36 Fine sediment transport was simulated with the GAIA module of the TELEMAC-MASCARET suite. GAIA is able to model complex sediment and morphodynamic processes in coastal areas, rivers, lakes and estuaries, accounting for spatial and temporal variability of sediment size classes (uniform, graded or mixed), properties (cohesive and non-cohesive) and transport modes (suspended, bedload and both simultaneously). For the present study, GAIA was coupled to the TELEMAC-2D hydrodynamic model of Falmouth (ES Technical Appendix 6.4) and the wider Fal estuary. To provide wave stirring, spatially varying wave fields were incorporated from the SWAN spectral wave model of the site (ES Technical Appendix 6.1).

6.5.37 The sediment transport model was parameterised with a variable settling velocity proportional to the suspended concentration, included the effect of wave stirring, and used a two layer bed sediment model. Full details of the model setup, comparison to data and scenario testing are provided by Technical Appendix 6.2.

6.6 Assessment Criteria

6.6.1 There are no specific assessment criteria against which to assess impacts on coastal projects. Where the changes in the hydrodynamic or sediment regimes have impacts on sensitive receptors, they are described and assessed in the relevant chapters of the ES.

6.7 Assumptions and Limitations

6.7.1 The exact equipment and programme to be used for the dredging is not known. Therefore, it was necessary to make assumptions regarding the equipment used based on a reasonable worst case scenario and the resulting sediment release source levels. The assumed sediment release rates are described in Table 6-4.

6.8 Baseline Conditions

Tidal levels

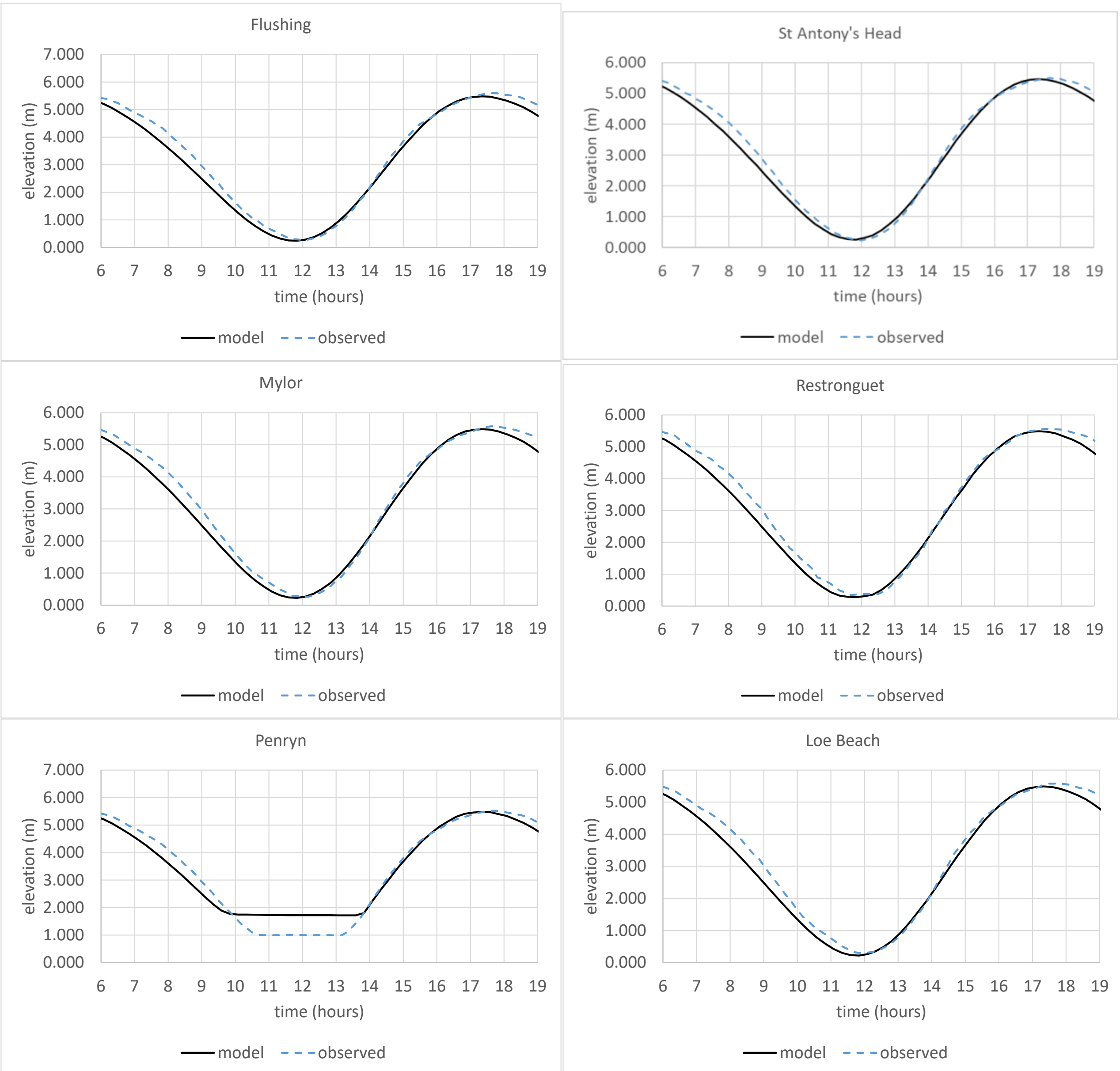
6.8.1 Tides at Falmouth are semi diurnal with two high and low waters per day.

6.8.2 The standard source for predicted tidal level information is UK Admiralty tide tables for 2023. The standard port nearest to the site is Falmouth. The difference between Ordnance Datum (OD) and Chart Datum (CD) at Falmouth is 2.91 m. The standard-tidal levels for Falmouth are given in Table 6-5.

6 HR Wallingford (2008). Falmouth Cruise Terminal, Hydrodynamic and sedimentary studies, Royal Haskoning, HR Wallingford Report EX 5809, 2008.

Table 6-5 Standard tidal levels (2023) for Falmouth	
Tidal level	**Tidal level (m CD)**
Highest Astronomical Tide (HAT)	5.7
Mean High Water Springs (MHWS)	5.1
Mean High Water Neaps (MHWN)	4.1
Mean Sea Level (MSL)	3.0
Mean Low Water Neaps (MLWN)	1.8
Mean Low Water Springs (MLWS)	0.5
Lowest Astronomical Tide (LAT)	-0.2

6.8.3 The model simulation of the water levels is shown compared to those observed on 05/05/1985 are shown by Figure 6-7.



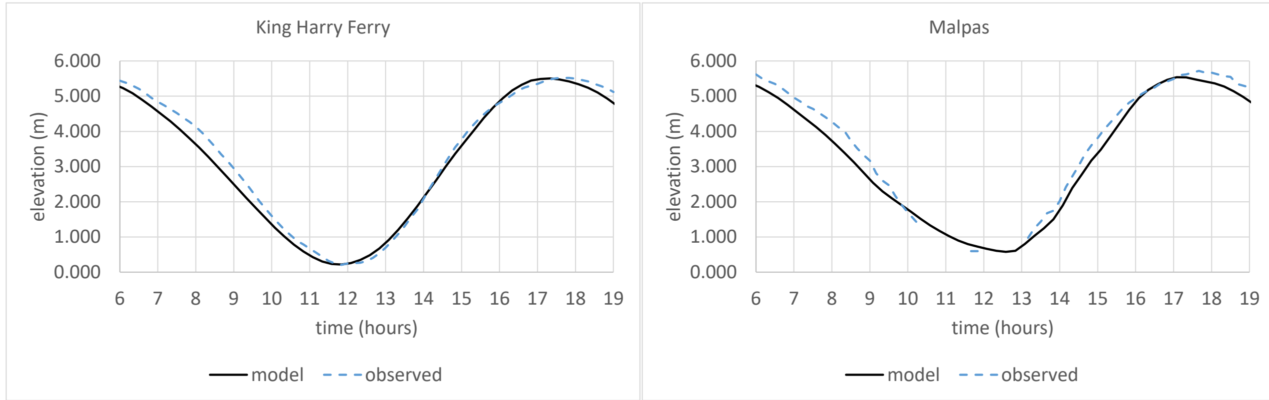


Figure 6-7 Comparison of observed and simulated spring tide water levels

Tidal currents

6.8.4 Currents in the area are primarily driven by the rise and fall of the tides with higher currents seen towards the mouth of the harbour across from St Antony's Head. Current speeds reduce notably into the Inner Falmouth Harbour with peak values in the range 0.2 – 0.3 m/s (Figure 6-8). Low strength current recirculations are seen in the area between the Western and Eastern Wharfs and, during the flood tide to the west of Queen's Quay.

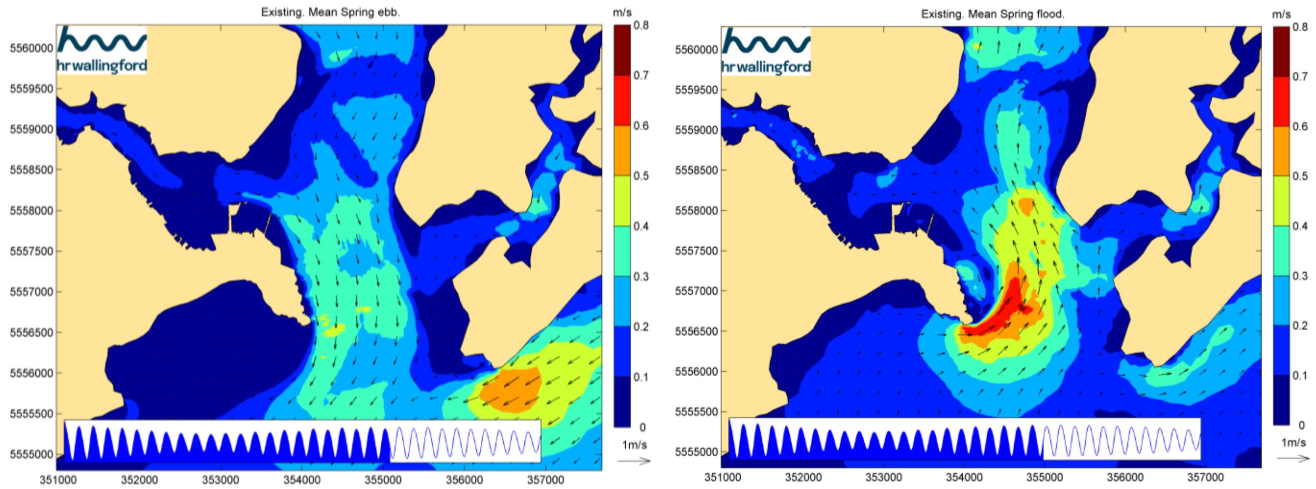


Figure 6-8 Predicted current speed and direction at peak ebb and flood tide – baseline conditions

Waves

6.8.5 Waves at the proposed development site are a result of both the propagation of waves from offshore and those generated by the wind flowing over Falmouth Harbour and its approaches.

6.8.6 Wind conditions representative of the site have been derived from observations at Culdrose between 1973 and 2023, obtained from the National Centers for Environmental Information (NCEI) database of the United States National Oceanic and Atmospheric Administration (NOAA). Figure 6-9 shows the annual wind rose based on the data. Figure 6-5 shows the location of the observations.

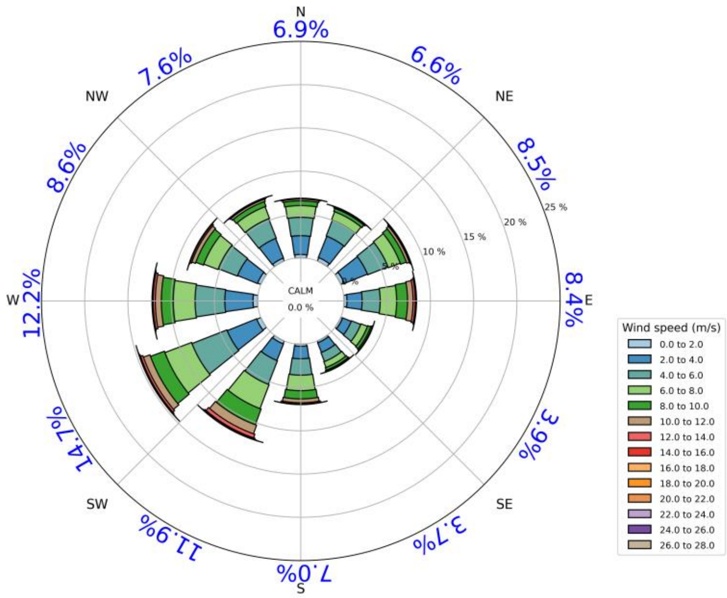


Figure 6-9 Annual wind rose at Culdrose (from data 1973 to 2023)

6.8.7 A list of independent peaks over a threshold were extracted from the wind time-series with a minimum separation time between neighbouring peaks of 48 hours. Extreme wind speeds conditional on the wind direction sector (30° sectors) were estimated by fitting a Weibull distribution to the independent peak wind speed values.

6.8.8 The 0.2 year return period winds were obtained from a count-back analysis of the data.

6.8.9 The offshore wave climate was analysed in deep water at the Met office's NWS offshore point, based on the long term NWS hindcast dataset. The NWS model is forced by lateral boundary conditions from the Met Office's global wave hindcast. The atmospheric wind forcing is given by the ECMWF numerical weather prediction reanalysis. The resolution is 1.5 km and the hindcast data are available hourly from 1980 to near present-day.

6.8.10 The annual wave rose at the NWS offshore point, located at 49.74°N -4.88°E, (shown by Figure 6-5) for 1980-2022 is presented in Figure 6-10 to summarise the offshore wave conditions.

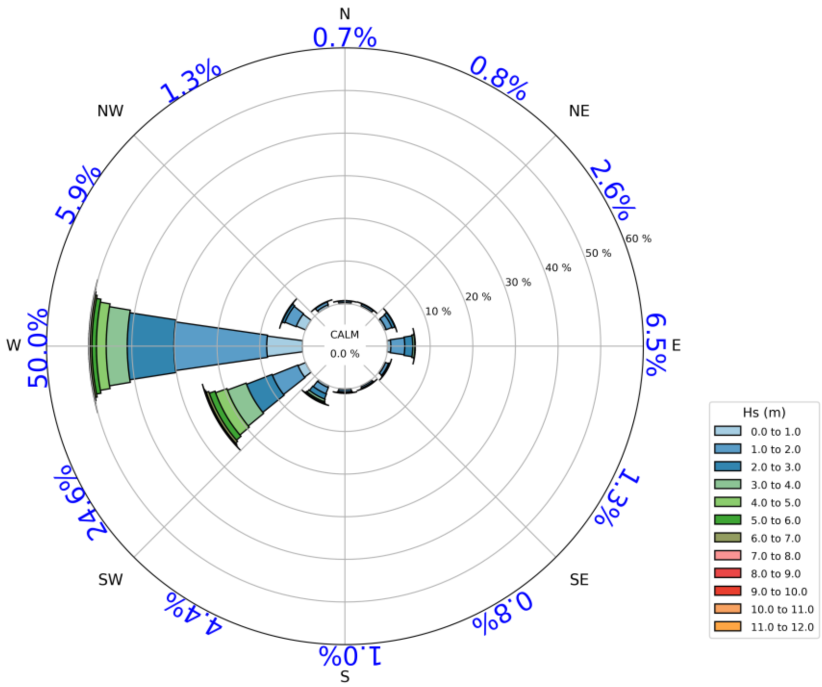


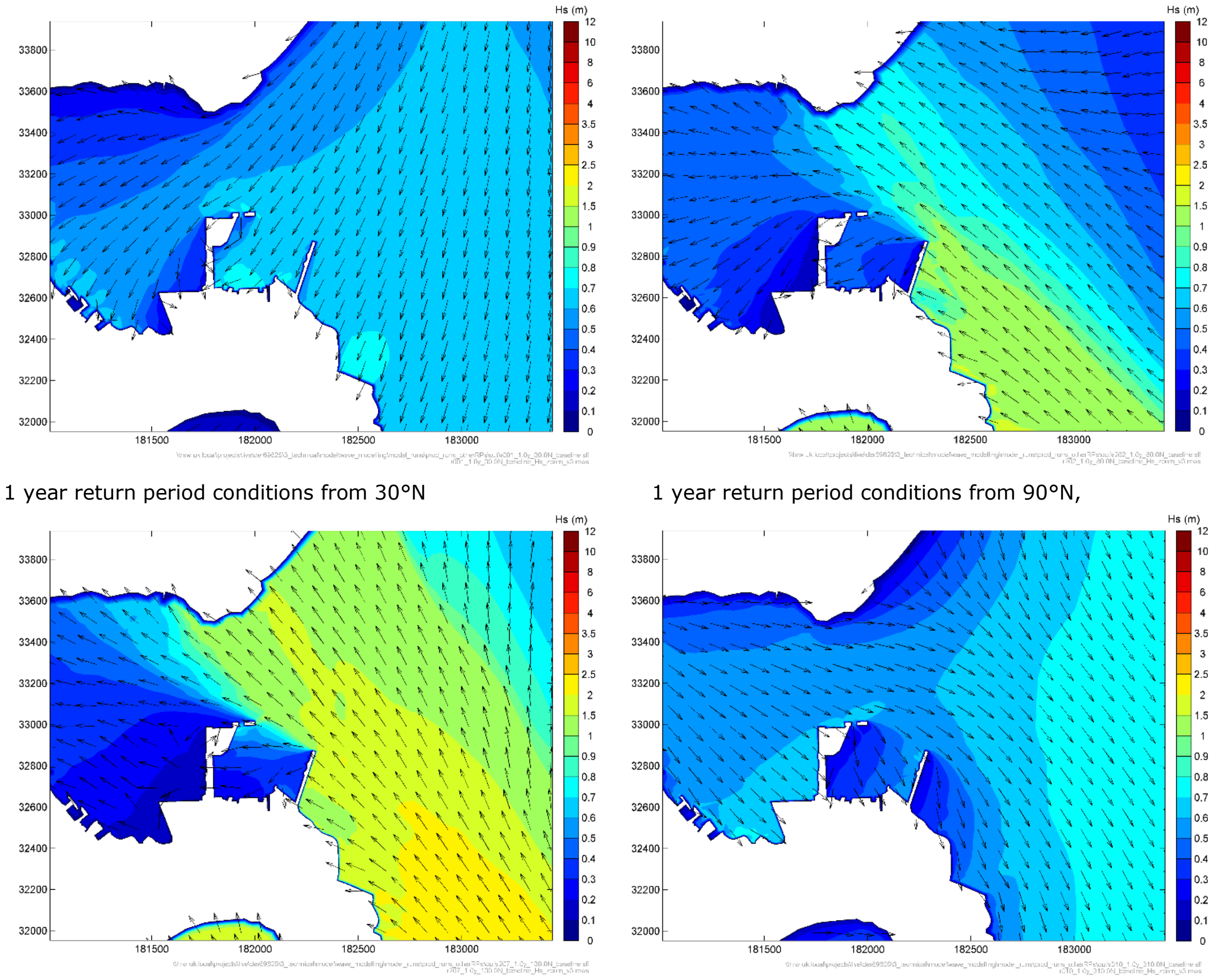
Figure 6-10 Annual average wave rose at the NWS offshore point (1980-2022))

6.8.11 As for the wind climate offshore waves in 30 degree sectors were calculated for 0.2 , 1, 10, 50 and 200 year return periods. The return period from 1 year above were estimated by fitting a Weibull distribution to the independent peak significant wave height values above a threshold, with a minimum separation time between neighbouring peaks of 48 hours.

6.8.12 The 0.2 year return period significant wave heights were obtained from a count-back analysis of the data.

6.8.13 The 200 year return period simulations (reported in Technical Appendix 6.1) were used to identify the wave conditions most likely to interact with the proposed development. Waves at the site are often a combination of wind sea and swell. Although the highest predicted wave heights are locally generated waves from sectors 30°N or 300°N, there may also be a component of underlying swell coming from offshore reaching the site at a reduced wave height with long wave periods.

6.8.14 Examples of the baseline condition wave results are shown in Figure 6-11. In this case the 1 year return period conditions are plotted.



1 year return period conditions from 30°N
1 year return period conditions from 90°N,
1 year return period conditions from 120°N
1 year return period conditions from 300°N,

Figure 6-11: Modelled 1 year return period significant wave height at Mean High Water Spring tide

Sediment regime

6.8.15 The site is located in Falmouth Inner Harbour, at the confluence of the outer Fal Estuary and the Penryn River. The estuary is a ria (drowned river valley) system with low freshwater input. The morphology of the outer estuary is relatively stable with low levels of deposition (Carrick District

Council, 2005[7]). Most sediment in the outer estuary is understood to be of a marine or erosional source, with any fluvial sediments deposited upstream within the creeks and inner estuary before reaching the outer estuary. The bed types in the estuary are generally mud or silt except at the mouth of the estuary where sand and gravels are more prevalent (HR Wallingford, 2008).

6.8.16 The available data sources for suspended sediment concentration agree that the proposed development is in an area of generally low suspended sediment concentration. As an example, Environment Agency spot sample locations are available for the period January 2000 to September 2024 and were accessed through the DEFRA WIMS web portal. The dataset contains 260 samples collected within the EIA red line boundary near the water surface (approximately 0.2 m depth), at a point close to the southern side of the existing Queens Quay, with concentrations of suspended solids recorded from January 2000 to April 2005 (62 samples). The recorded concentrations are stated to be "<3 mg/l" in 55 of the 62 samples, indicating that zero or minimal suspended sediment was found to be in the water sample. The highest recorded concentration was 21.6 mg/l on 31 October 2001. At this time the offshore wave condition was waves of significant wave height (Hs) 2.5-2.0 m from 230-270 degrees with peak period of 6-9 s. This wave condition is a reasonably common condition as can be seen by comparison with the 0.2 year return period waves from the SSW presented in Table 6-6.

6.8.17 A time-series of near-surface turbidity data was also provided by FHC from a monitoring device at a moored buoy on the north side of the Penryn River at location 181474.1 mE, 33507.6 mN for the period 14th August 2023 to 29th April 2024. The data similarly shows a low turbidity environment with measurements less than 3 Formazin Turbidity Unit (FTU) for 91% of the time. Short period spikes in the turbidity above 3 FTU are likely to be due to storms with increased wave activity. During these peaks, the turbidity can reach 6-8 FTU. Note that no information on the instrument calibration is available to accurately transform FTU to mg/l of suspended solids. A general, 'rule of thumb' factor of between 1 and 5 can be used to approximate the suspended sediment concentration associated with the observed turbidity. This factor suggests near-surface suspended concentrations of 6-40 mg/l may occur. Calibrating the turbidity meter would significantly increase the value of the collected data as the project progresses.

6.8.18 The relationship between turbidity and waves was verified by comparing the turbidity time-series with a time-series of significant wave height (Hs) from the ERA5 global coupled ocean-atmosphere model offshore of the site (also shown in Figure 6-12; the peaks in turbidity generally occur during periods of increased wave height. Further analysis of these events indicates that the offshore wave direction during these events was generally from around 180-220°N at peak turbidity.

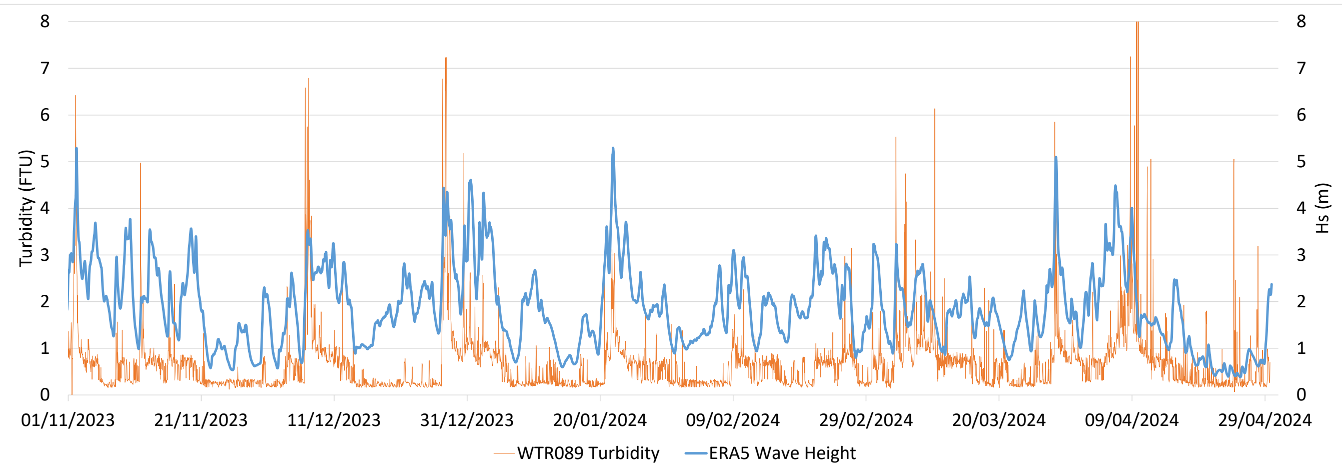


Figure 6-12: Time series of turbidity at FHC point and offshore significant wave height from ERA5.

6.8.19 The GAIA model was run for four wave conditions as detailed in Table 6-6. The offshore wave conditions simulated were selected to represent a range of conditions;

- The most commonly occurring condition (waves from the south-west).
- A morphological wave condition. This is a statistical combination of wave conditions from the south-east sector to represent the effect of the full annual wave climate from this direction on morphological change.
- The 0.2 year return period condition was selected to assess the conditions during peak concentrations of the suspended sediment measurements provided by FHC for the moored buoy on the north side of the Penryn River. This case used waves from the south-west.
- The 1 year return period condition from south-east was also selected to assess conditions during short period storm events.

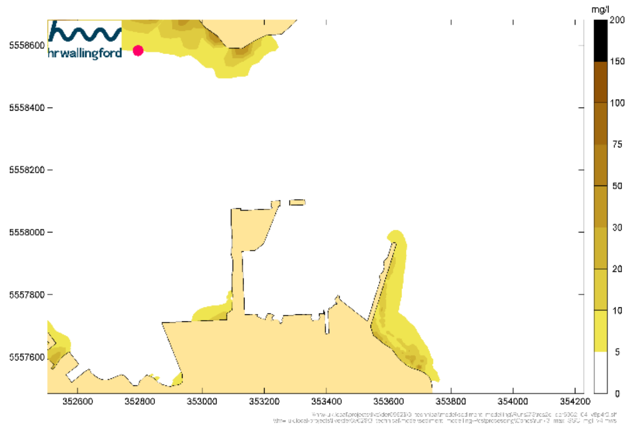
Table 6-6 Offshore wave condition used for sediment transport modelling

Overview	Hs (m)	Tp (s)	Direction (°N)
Representative waves from SW	2.0	11.0	255
Morphological condition from SE	1.9	10.2	120
0.2 year RP conditions from SSW	4.4	10.3	210
1 year RP conditions from SE	2.8	8.40	130

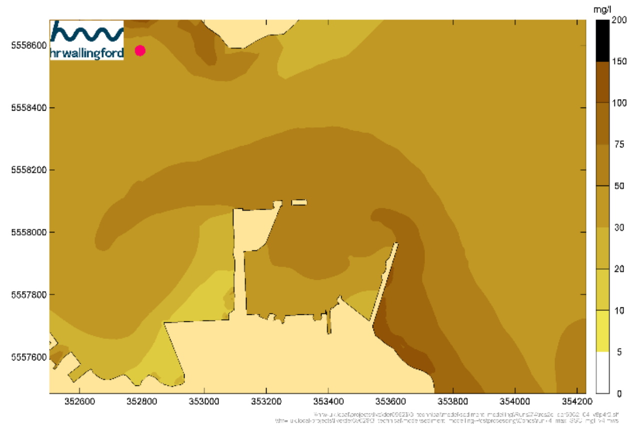
6.8.20 Figure 6-13 shows the maximum suspended sediment concentration experienced during the simulation for each of the four wave conditions modelled. In each of these figures the location of the FHC turbidity meter is shown as a red dot.

6.8.21 The highest baseline suspended sediment concentrations are predicted during more extreme storm conditions (1 year RP offshore wave condition from 130°N). Suspended sediment concentrations are increased due to the increased wave activity, and peak concentrations in the estuary to the east of the docks are around 120 to 150 mg/l. Concentrations in the vicinity of the docks are predicted to be up to 130 mg/l, but these higher concentrations will be relatively short lived – being constrained by the duration of the storm event.

6.8.22 At the site of the FHC turbidity meter, the maximum depth average suspended sediment concentrations range from about 5 mg/l for representative offshore wave conditions from SW to 75-100 mg/l for the 1 year return period offshore wave conditions from SE. These are broadly in line with the FHC buoy turbidity data noting the lack of calibration of the buoy and the difference between near surface observations and the depth-average model result.

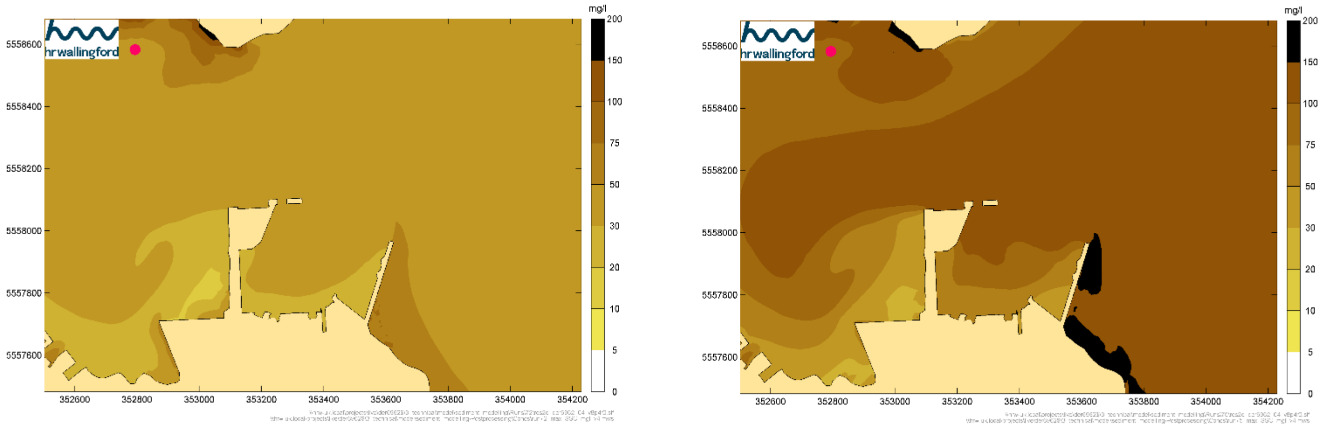


Representative offshore wave conditions from SW



Morphological offshore wave conditions from SE

[7] Carrick District Council (2005). Dredging Protocol, Baseline Document, Fal and Helford Estuaries, First Revision August 2005



0.2 year return period offshore wave conditions from SSW   1 year return period offshore wave conditions from SE

Figure 6-13 Modelled maximum suspended sediment concentration for a range of offshore wave conditions

6.8.23 Spatial maps of fine sediment deposition at the end of the 15 day spring-neap cycle from each condition were combined and scaled to estimate an indicative annual deposition within the docks. These were derived by assuming that the predicted deposition during conditions with offshore waves from 255°N and from 120°N occur around 86% and 3% of the time respectively from analysis of the offshore wave climate. For the remaining 11% of the time, it is assumed that wave conditions are calm or from a direction that does not lead to generation of fine sediment transport and deposition at the site (such as from north).

6.8.24 Figure 6-14 shows the predicted total annual depth of deposition of fine sediments for the existing (baseline) layout calculated using the proportions of time for the defined wave conditions described above. Baseline deposition is generally very low at the site with rates generally less than 20 mm/year. Of this total 3-5 mm is predicted to occur during a storm comprising a day with the annual wave condition.

6.8.25 Deposition is predicted in the areas to the east and north of the existing Queens Wharf. Little or no deposition is predicted to the west of Queens Wharf and towards Duchy Wharf. However, it is possible that further redistribution of the deposited sediment may occur by local wind or vessel generated waves.

6.8.26 It should be noted that the effect of vessel usage of the area is not included in the model. Vessels could resuspend fine sediment from the bed, for it to be transported by the passing current. Noting the low currents in the area the suspended sediment should return to deposit on the bed nearby.

6.8.27 The annual infill volume was estimated by spatially integrating the depth of deposition at the end of the simulated 15-day spring-neap cycle, with results combined and scaled using the same process as for the map of annual deposition. The infill estimates for the existing port operational area is predicted to be small; 3,560 m^3/year, and this corresponds with current experience at the port as minimal maintenance dredging is conducted in the harbour area. Most of this volume is predicted to the east of Queens Wharf with some limited areas of deposition also shown along the north side of Queens Wharf.

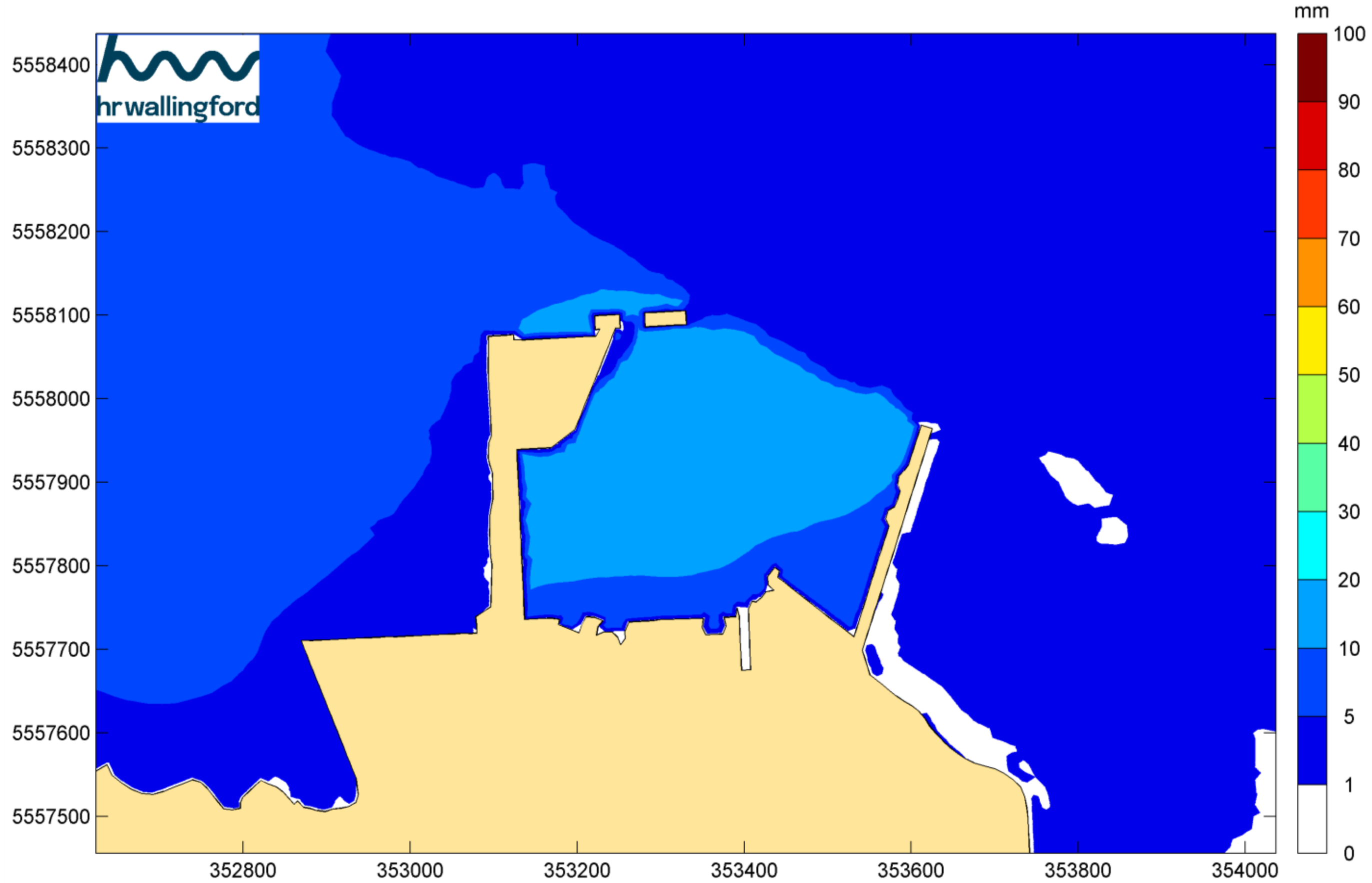


Figure 6-14 Modelled annual deposition of fine sediments

6.9 Predicted effects on coastal processes

Construction Stage

6.9.1 Three types of figures are presented to summarise the predicted changes in suspended sediment concentration and the predicted fine sediment deposition resulting from the proposed works. These are as follows:

6.9.2 **Plots of peak suspended sediment concentration increases**. These figures show the envelope of the maximum increases that occur over the simulation and so form an amalgam of results from different times over the simulation. These figures clearly indicate the scale and location of where concentration increases will occur but do not show the nature of the plume at any given time, or how representative any increases are, and so should be considered along-side the snapshot figures. For the purposes of this report only suspended sediment increases of more than 1 mg/l (approximately 20% of the typical baseline concentrations seen) are plotted.

6.9.3 **Plots of mean suspended sediment concentration increases**. These figures show the mean increases that occur over the simulation. These figures indicate the average conditions experienced at any particular location, but they do not provide information on the scale and location of the plume at any given time and so should be considered along-side the snapshot figures and the peak concentration figures. For the purposes of this report only suspended sediment increases of more than 1 mg/l are plotted.

6.9.4 **Plots of the predicted total deposition of fine sediment at the end of the complete dredging operation**. These figures show the extent of the predicted deposits of fine sediment at the end of the dredge. Plots are provided for the deposition at the end of dredging in each area and then the total deposition depths for the whole project are plotted. For these figures the area of dredging is masked as any deposition in these areas would be subject to re-dredging.

6.9.5 Additional time series plots of the modelled results at asset locations have been supplied for onward assessment within ES Chapter 9: Marine Ecology. For completeness, these results are included in Technical Appendix 6.3.

Dredging

6.9.6 The same dredge method is proposed for the sediment, whether the level of contamination is greater than CAL 2, or not. The only difference is the disposal method with the material contaminated beyond CAL 2 being taken onto land and the remainder being taken to sea. The dredger production rate and calculated sediment release rate is assumed to be insensitive to the disposal method. The results for dredging in the eastern part of the proposed development (Western Wharf) are provided in Figure 6-15: peak predicted increase in suspended sediment concentration, Figure 6-16: mean increase in suspended sediment concentration and, Figure 6-17: deposition depth after the completion of dredging in the eastern part of the proposed development.

6.9.7 The results show that the footprint of the plume concentration during this part of the dredge extends no more than 200 m outside of the red line boundary to the east and west of the site, at which point the increases in concentration fall below 1 mg/l. In the immediate vicinity of the dredging, concentration increases are of the order of 100 mg/l above background.

6.9.8 The mean peak increase in suspended sediment concentration resulting from dredging shows that the mean concentration increases of 1 mg/l or more are (more or less) confined to the site area defined by the red line boundary for the proposed development.

6.9.9 The predicted fine sediment deposition at the end of dredging shows close to the actual dredging area deposition depths greater than 200 mm are predicted. This deposition will be re-dredged in order to meet the required dredged level. Outside of this area, but still within the site area (red line boundary) deposition of several centimetres is predicted. Outside of the site area deposition is predicted in a specific patch located at the end of the eastern breakwater where deposition of approximately 10 mm is predicted.

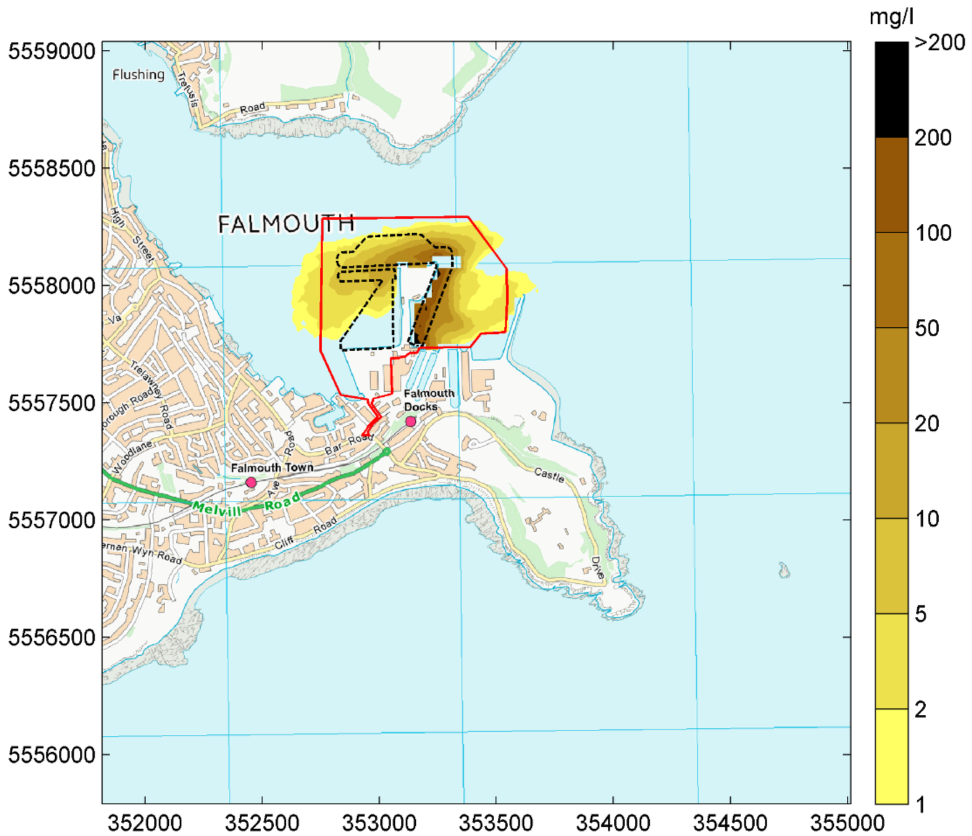


Figure 6-15 : Peak predicted increase in suspended sediment concentration, dredging in the east area (Western Wharf)

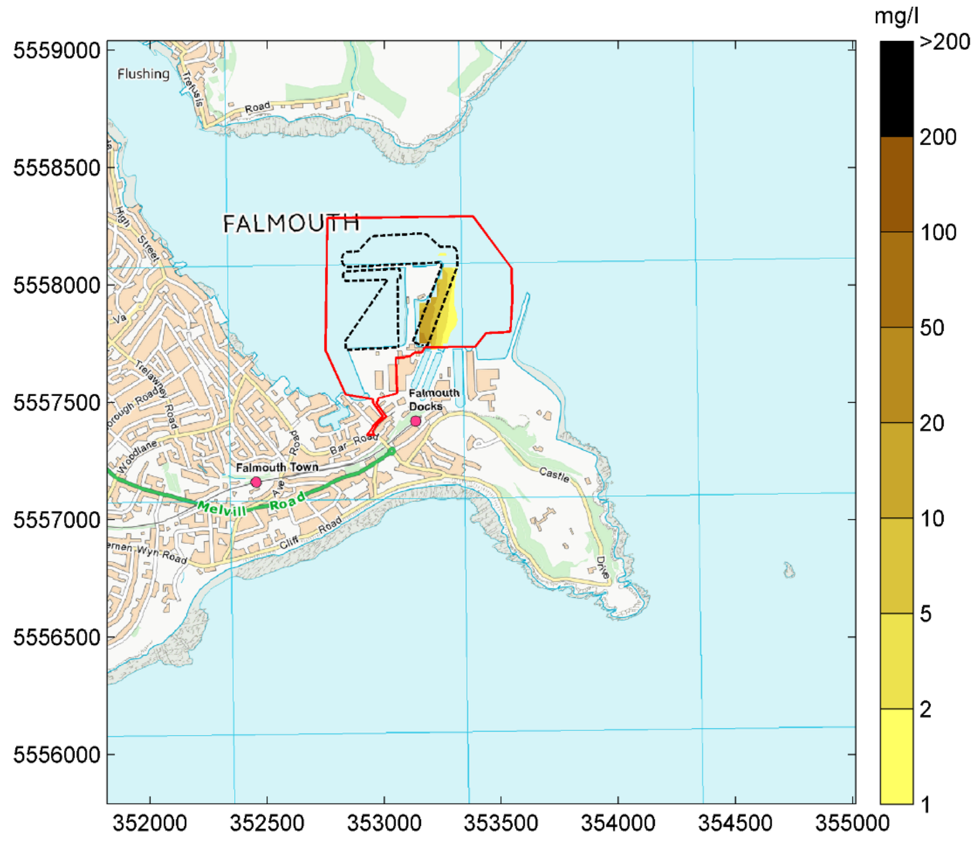


Figure 6-16 : Mean predicted increase in suspended sediment concentration, dredging in the east area (Western Wharf)

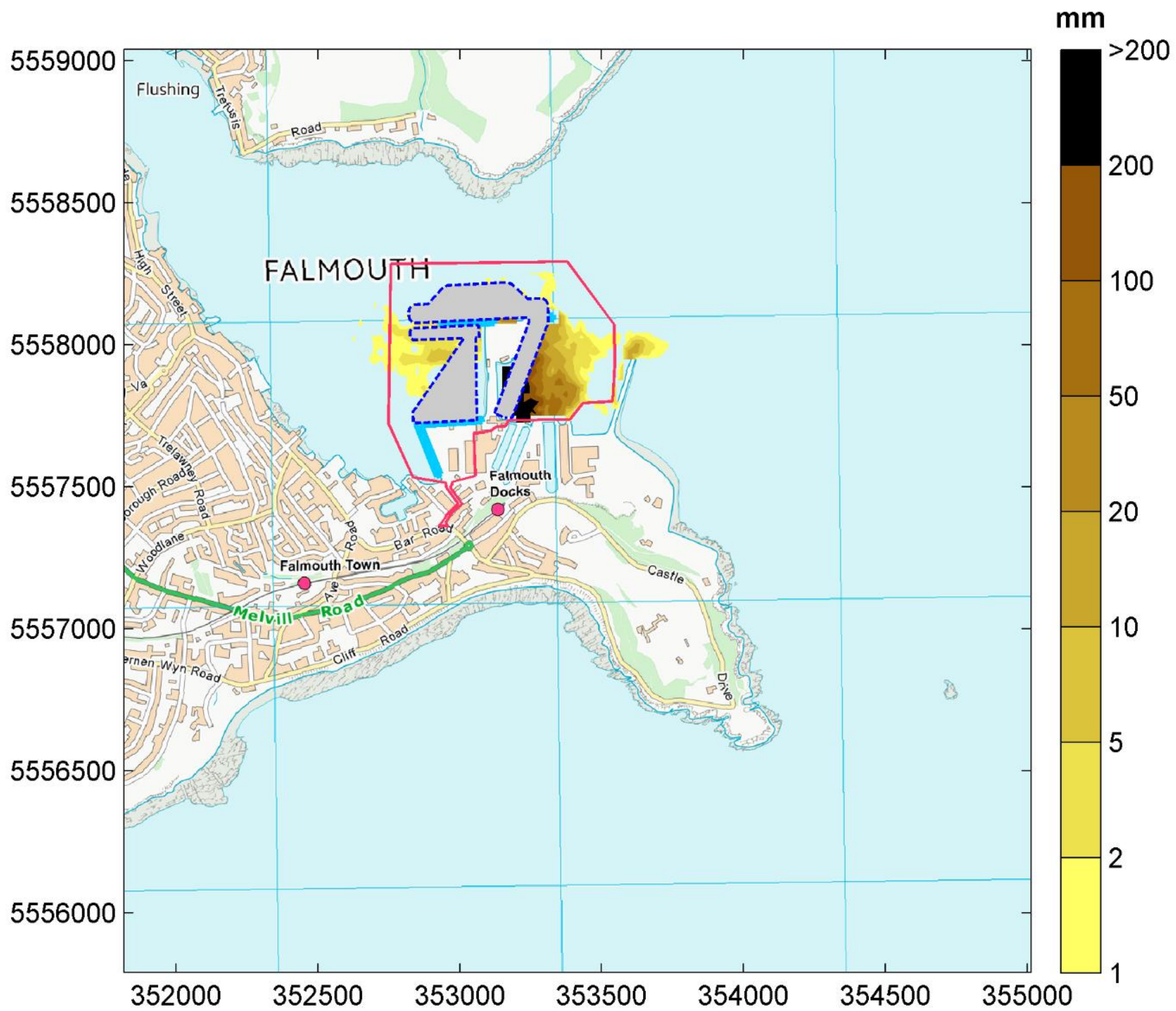


Figure 6-17 : Predicted deposition at the end of dredging in the east area (Western Wharf)

6.9.10 The results for dredging in the northern part of the proposed development (Queens Wharf) are provided in Figure 6-18 peak predicted increase in suspended sediment concentration, Figure 6-19 mean increase in suspended sediment concentration and, Figure 6-20 deposition depth after the completion of dredging in the northern part of the proposed development.

6.9.11 The predicted peak increase in suspended sediment concentration resulting from dredging sediment in the northern part of the site is shown in Figure 6-18. The figure shows that the footprint of the plume concentration extends approximately 300 m outside of the red line to the west of the site and up to 1 km east and south of the site, at which point the increases in concentration fall below 1 mg/l. In the immediate vicinity of the dredging, concentration increases are of the order of 100's of mg/l above background.

6.9.12 The mean peak increase in suspended sediment concentration resulting from dredging in the northern part of the site is shown in Figure 6-19. The figure shows that the mean concentration increases of 1 mg/l or more are confined to the site area defined by the red line other than a small patch extending 100 m west of the western limit of the red line edge of the development area.

6.9.13 The total deposition at the end of dredging in the northern section of the are to be dredged is shown in Figure 6-20. An area of approximately 100 mm of deposition is shown west of the red line boundary of the development area. Similarly to the results of the east area a patch of deposition of approximately 10 mm is shown at the end of the eastern breakwater. A second small patch of 5 mm total deposition is shown in further north of the eastern breakwater.

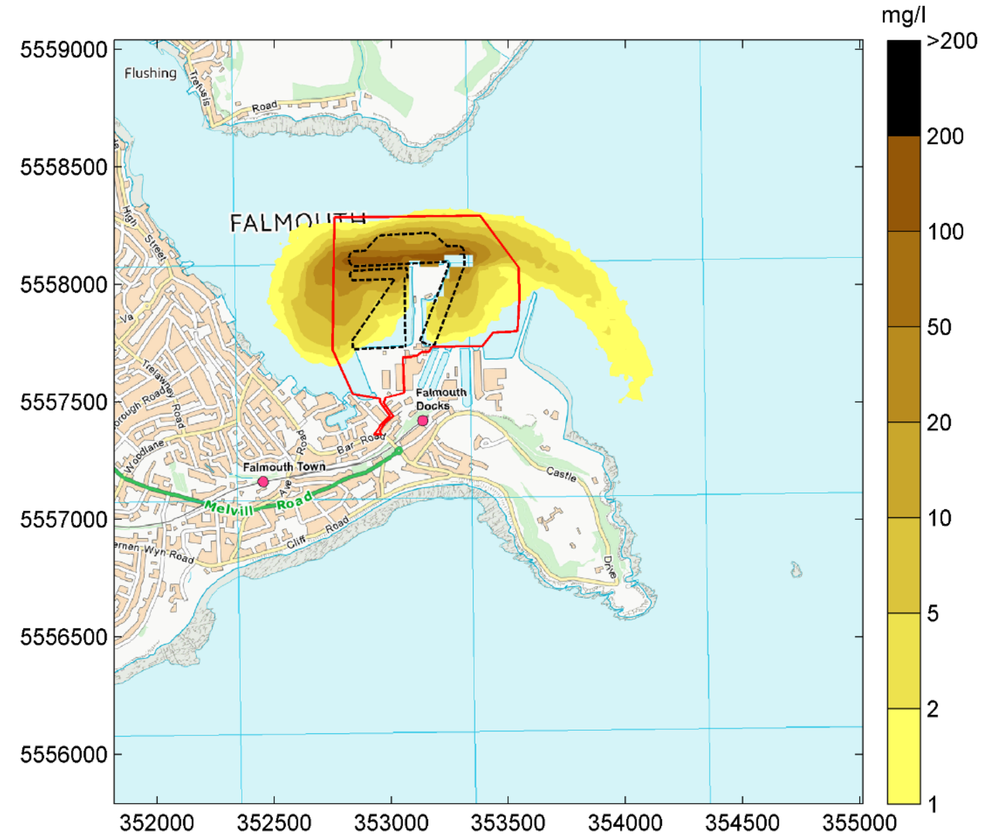


Figure 6-18 : Peak predicted increase in suspended sediment concentration, dredging in the north area (Queens Wharf)

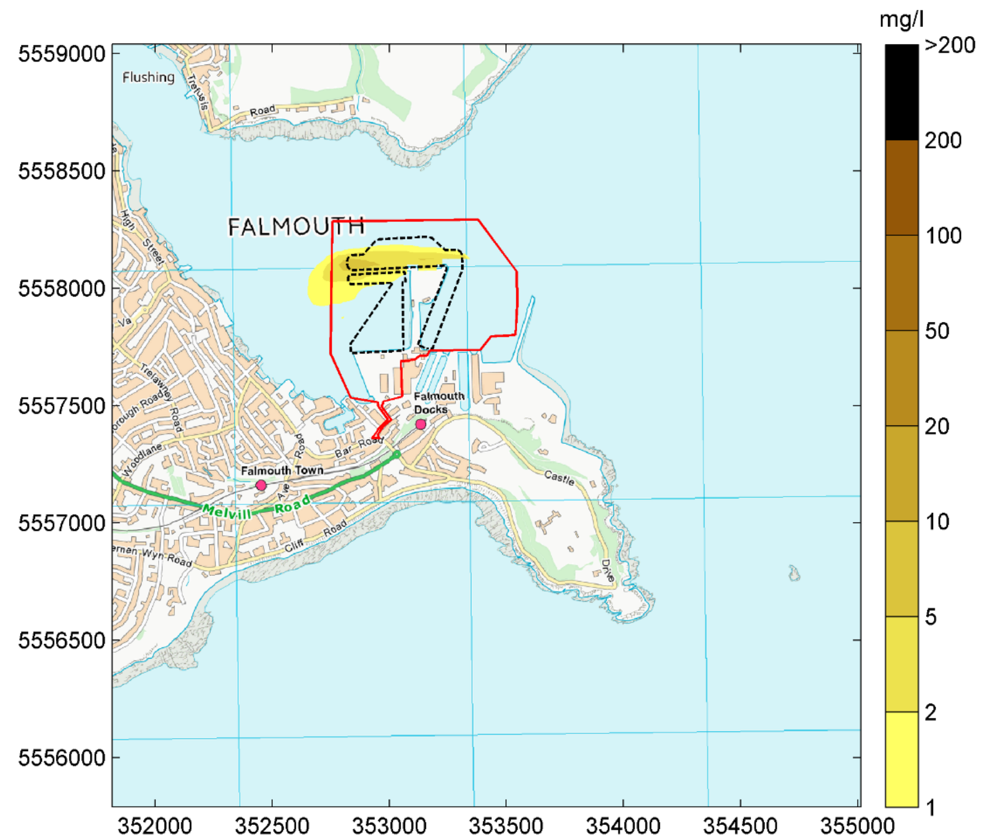


Figure 6-19 : Mean predicted increase in suspended sediment concentration, dredging in the north area (Queens Wharf)

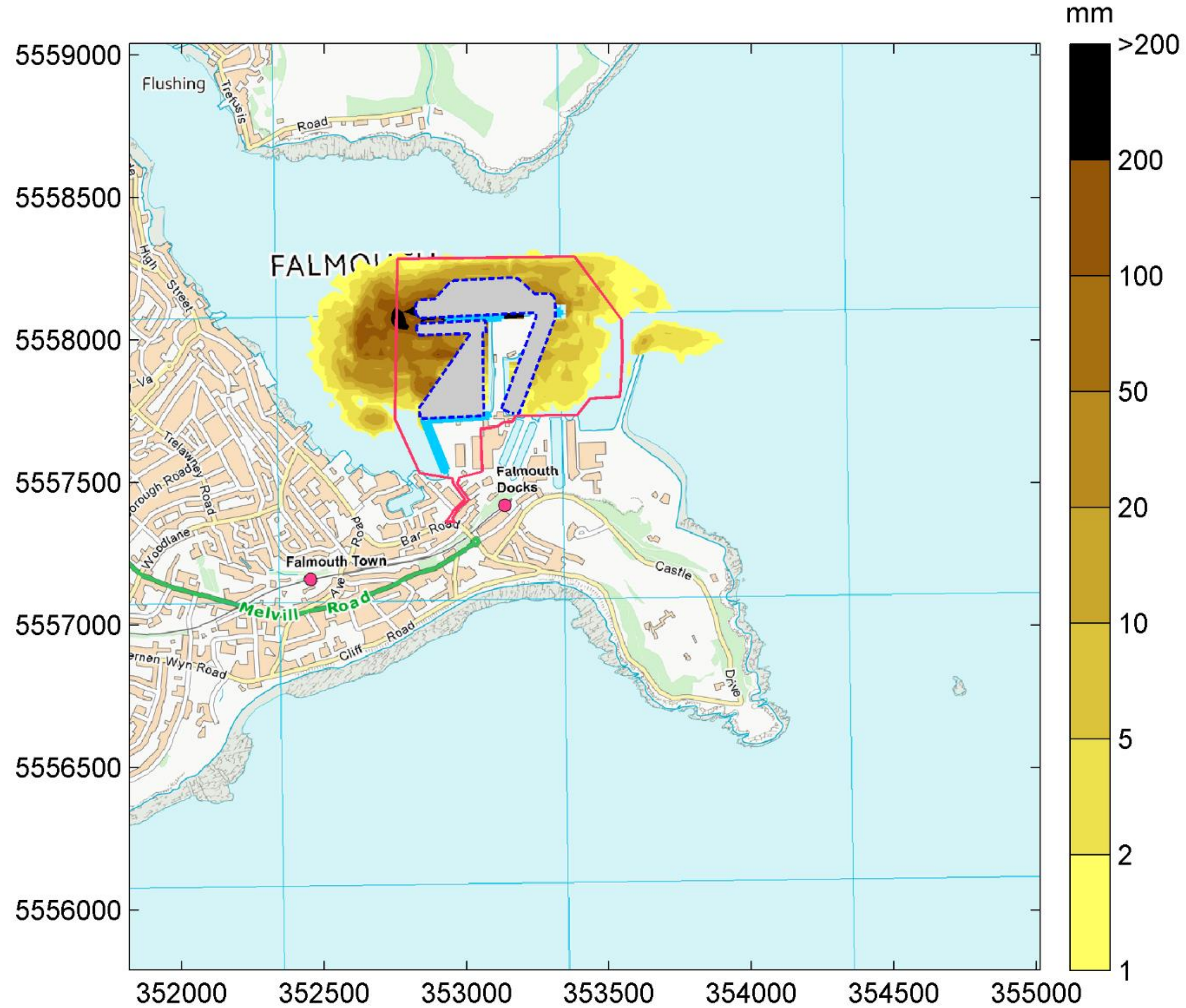


Figure 6-20 : Predicted deposition at the end of dredging in the north area (Queens Wharf)

6.9.14 The results for dredging in the western part of the proposed development (FLOW Basin)) are provided in Figure 6-21: peak predicted increase in suspended sediment concentration, Figure 6-22: mean increase in suspended sediment concentration and, Figure 6-23: deposition depth after the completion of dredging in the western part of the proposed development.

6.9.15 The predicted peak increase in suspended sediment concentration resulting from dredging sediment in the western part of the site is shown in Figure 6-21. The figure shows that the footprint of the plume concentration extends outside of the red line to the west of the site but does not go beyond the red line boundary elsewhere. In the immediate vicinity of the dredging, concentration increases are of the order of 100's of mg/l above background as might be expected.

6.9.16 The mean peak increase in suspended sediment concentration resulting from dredging in the western part of the site is shown in Figure 6-22. The figure shows that the mean concentration increases of 1 mg/l or more are (more or less) confined to the site area defined by the red line.

6.9.17 The total deposition at the end of dredging in the western section of the area to be dredged in the west is shown in Figure 6-23. Similarly, to the other cases a small patch of deposition is shown by the eastern breakwater, however the magnitude of deposition is much smaller being in the range 2-5 mm. West of the red line development area boundary total deposition depths of up to 50 mm are predicted.

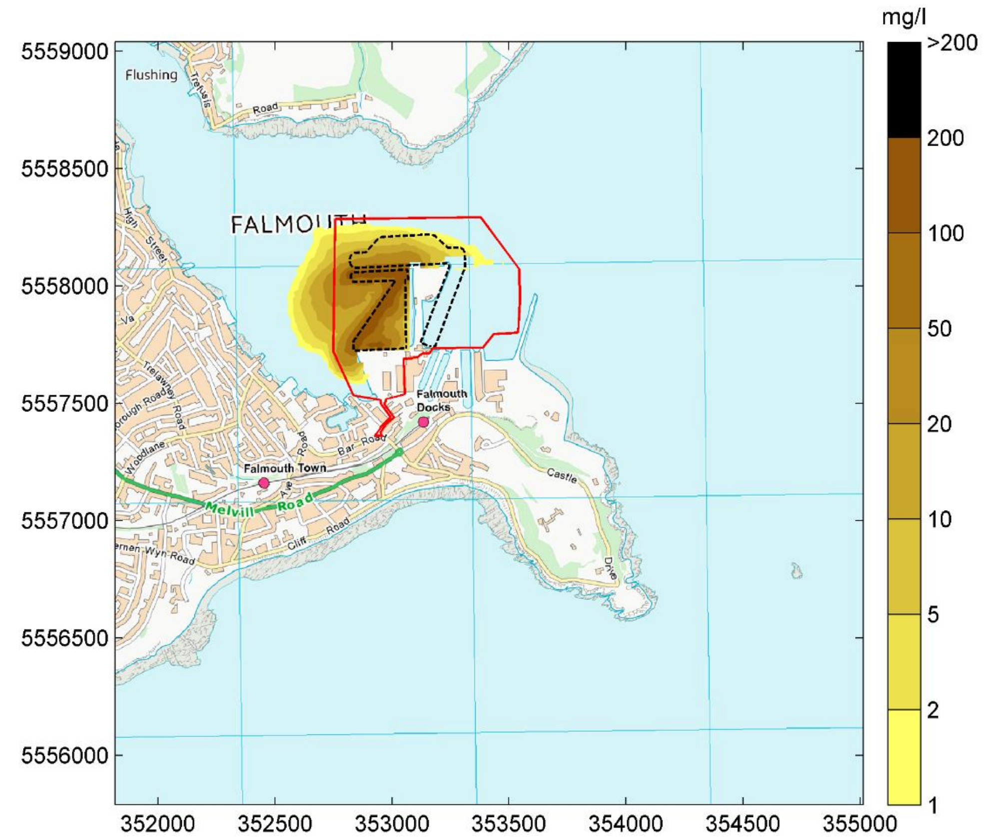


Figure 6-21 : Peak predicted increase in suspended sediment concentration, dredging in the west area (FLOW Basin)

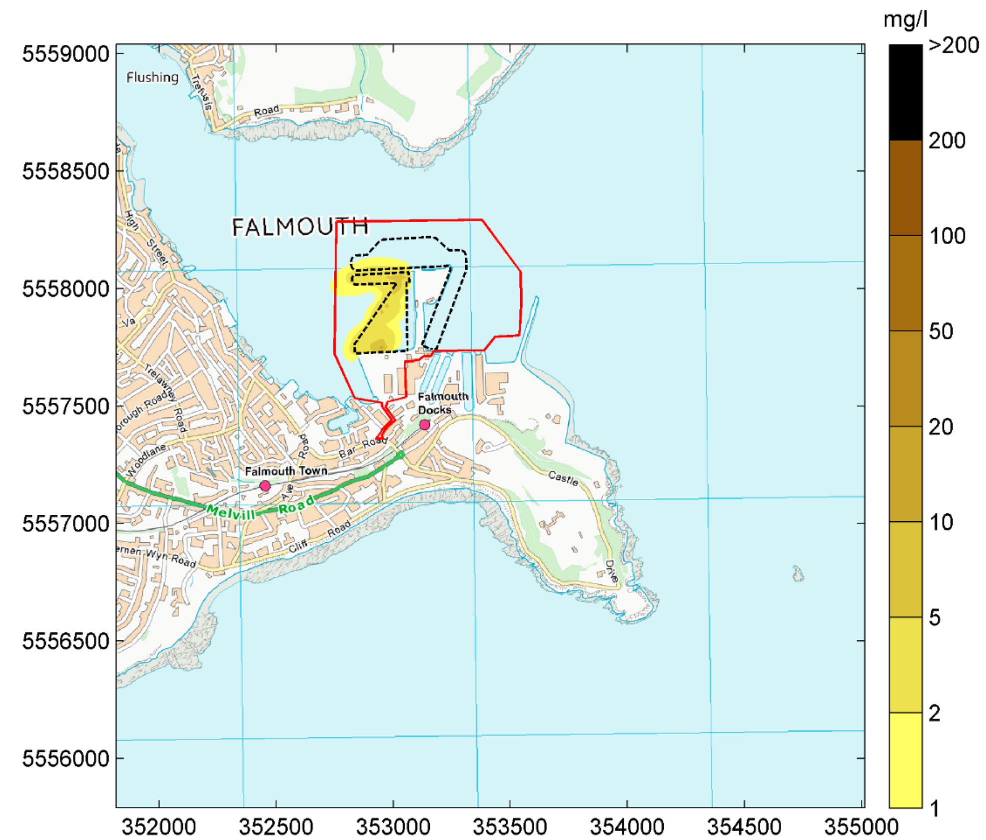


Figure 6-22 : Mean predicted increase in suspended sediment concentration, dredging in the west area (FLOW Basin)

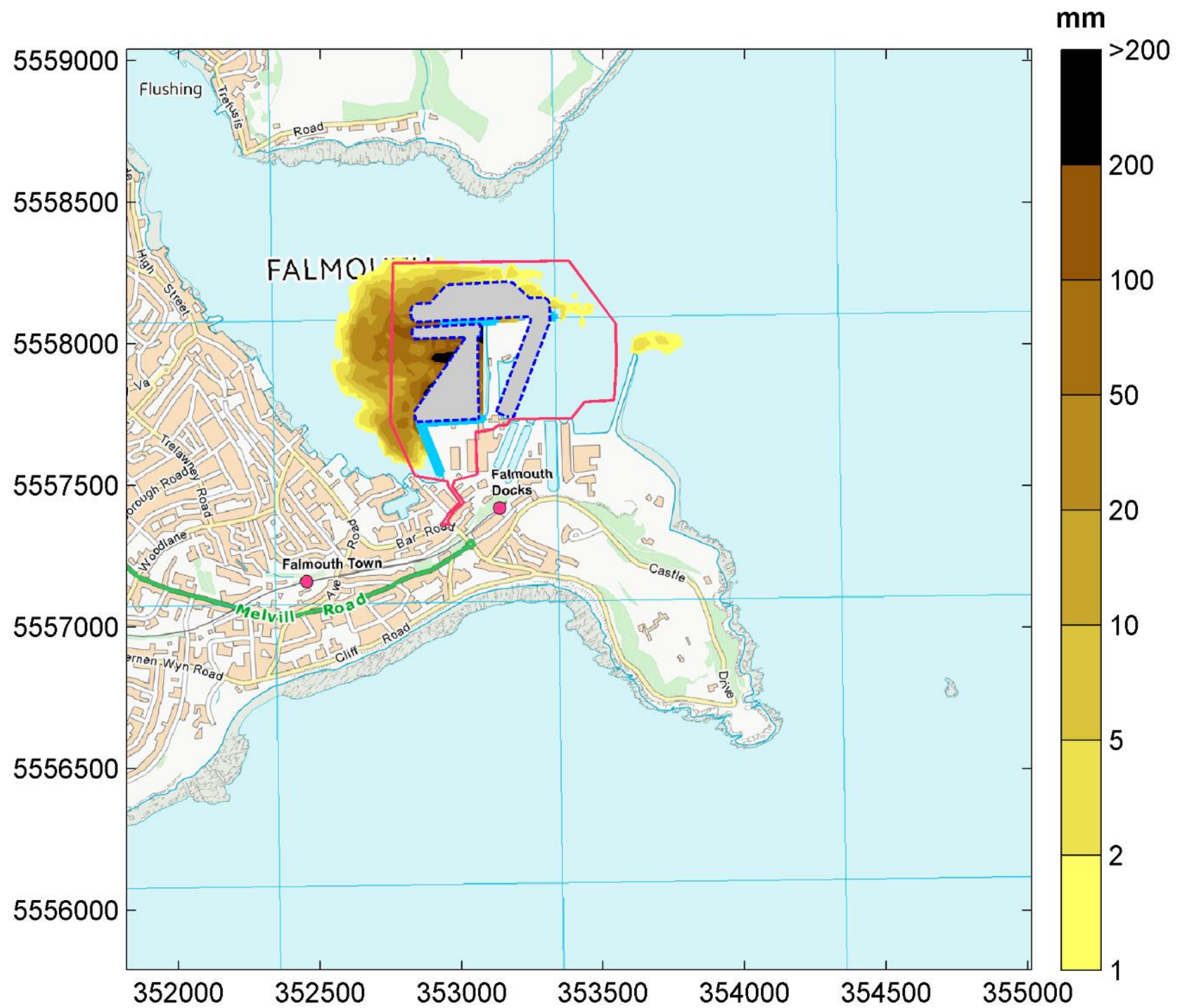


Figure 6-23 : Predicted deposition at the end of dredging in the west area (FLOW Basin)

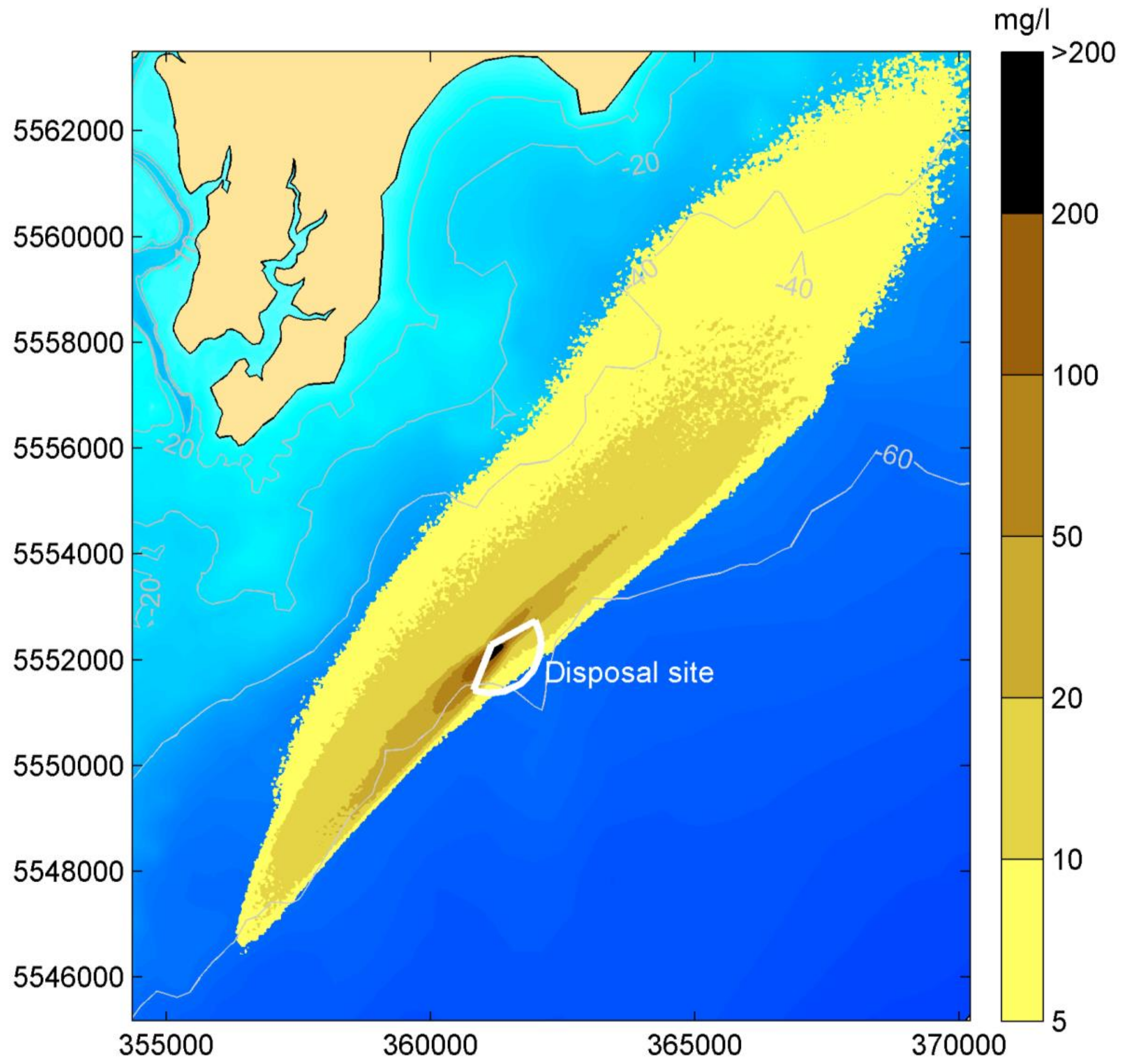


Figure 6-24 : Peak predicted increase in suspended sediment concentration, disposal of sediment at sea

Sediment disposal at sea

6.9.18 The predicted peak depth-averaged concentration increases above background resulting from disposal at sea are shown in Figure 6-24. The figure shows that the plume footprint (here defined as increases in concentration above 5 mg/l) extend up to 6.5 km SW and 13 km NE of the disposal site. Within the disposal site, at the location of the disposal, peak increases of hundreds of mg/l are predicted. This magnitude of concentration reduces to below 20 mg/l at a distance of 3.3 km from the site.

6.9.19 The predicted mean depth-averaged concentration increases above background resulting from disposal are shown in Figure 6-25. The figure shows that the plume footprint (here defined as increases in concentration above 5 mg/l) extend up to 2.4 km SW and 800 m NW of the disposal site. Within the disposal site, at the location of the disposal, mean increases of hundreds of mg/l are predicted. This magnitude of mean concentration reduces to below 20 mg/l at a distance of 900 m from the site.

6.9.20 Examples of snapshots of the disposal plume from near the end of the simulation are shown in Figure 6-26 and Figure 6-27. The figures show the plume when the plume is moving westward and eastward, just after a disposal event. It should be noted that the extent of the plume(s) at any time is much smaller than the peak concentration footprint shown in Figure 6-24

6.9.21 The predicted fine sediment deposition at the end of the (2 week) simulation is shown in Figure 6.31. It can be seen that the main body of sedimentation (as defined by deposition of less than 1 mm) extends up to 2 km NE and 3 km SW of the disposal site. Additional patches of sedimentation of 1-2 mm occur NNE of the disposal site.

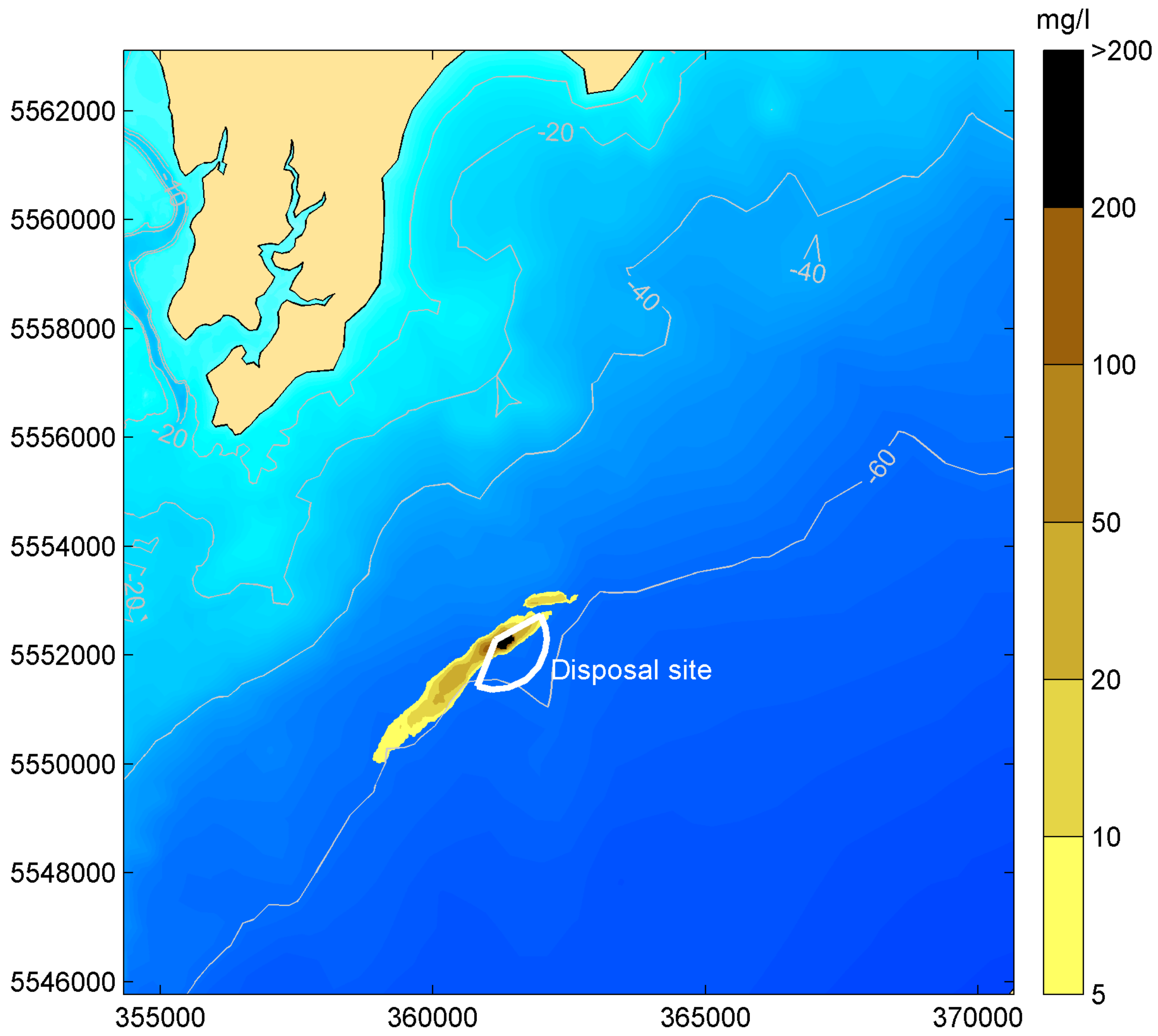


Figure 6-25 : Mean predicted increase in suspended sediment concentration, disposal of sediment at sea

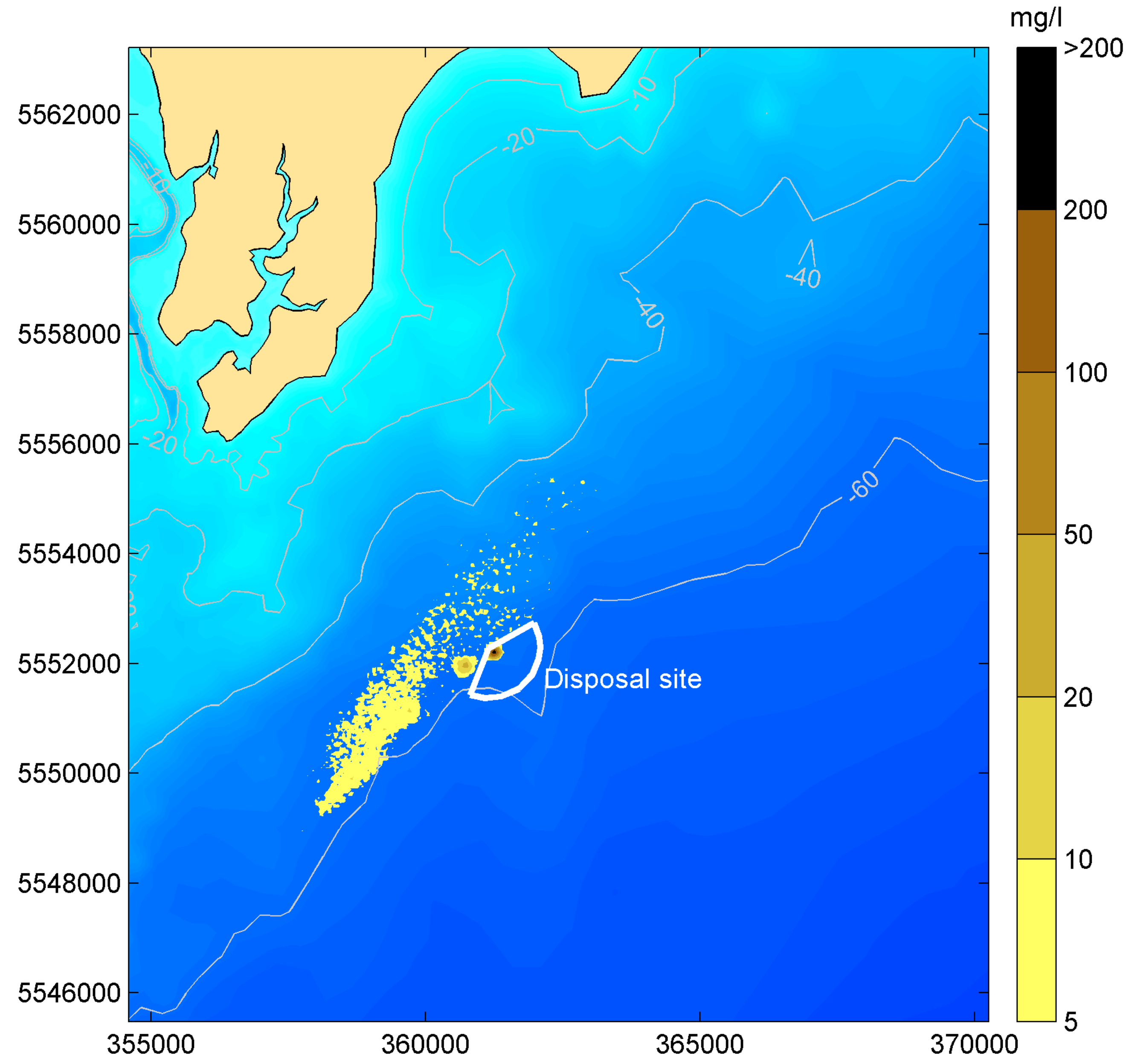


Figure 6-26 : Snapshot of the plume resulting from disposal of sediment at sea, just after disposal during NE-ward flowing currents

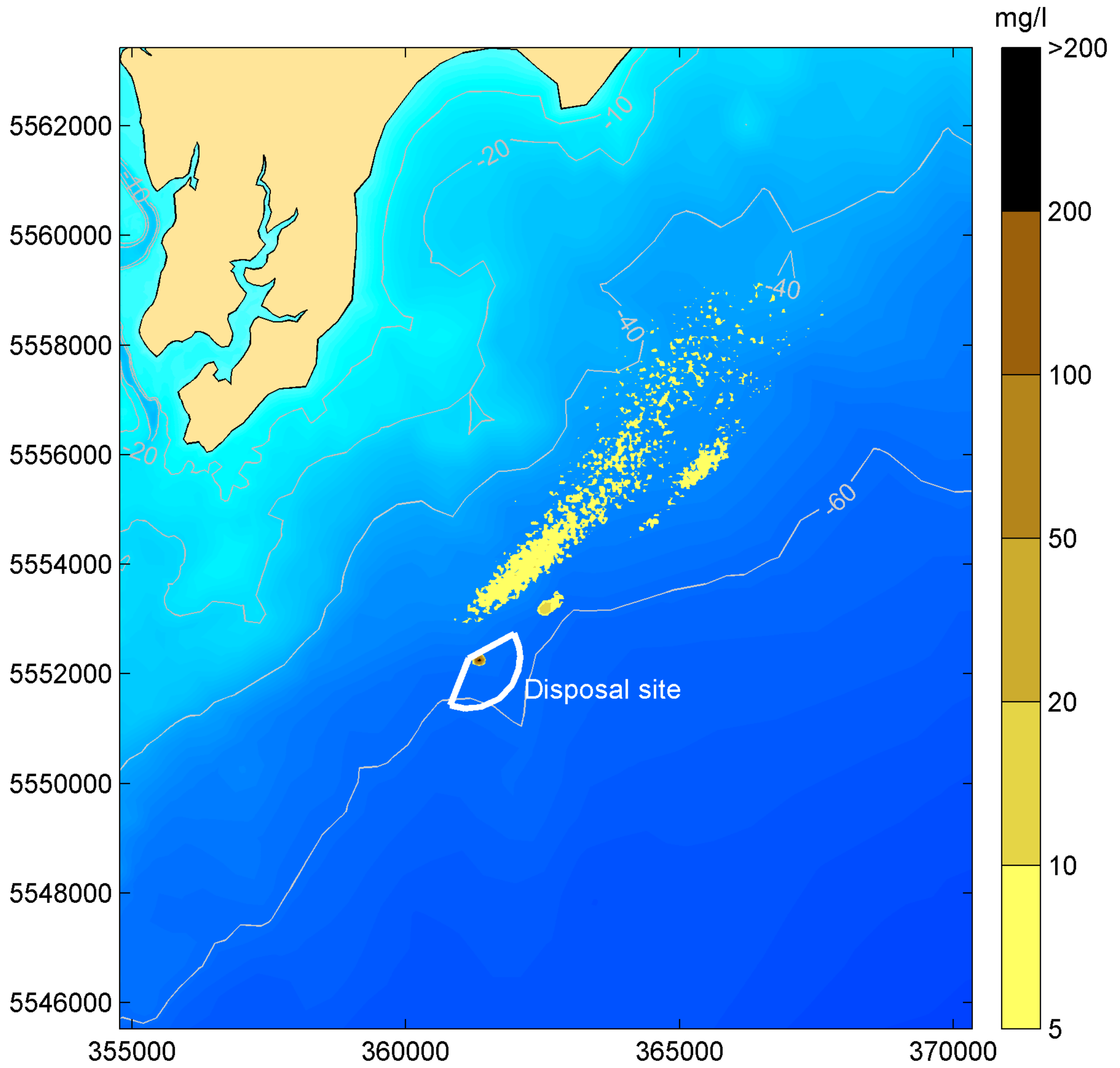


Figure 6-27 : Snapshot of the plume resulting from disposal of sediment at sea, just after disposal during SW-ward flowing currents

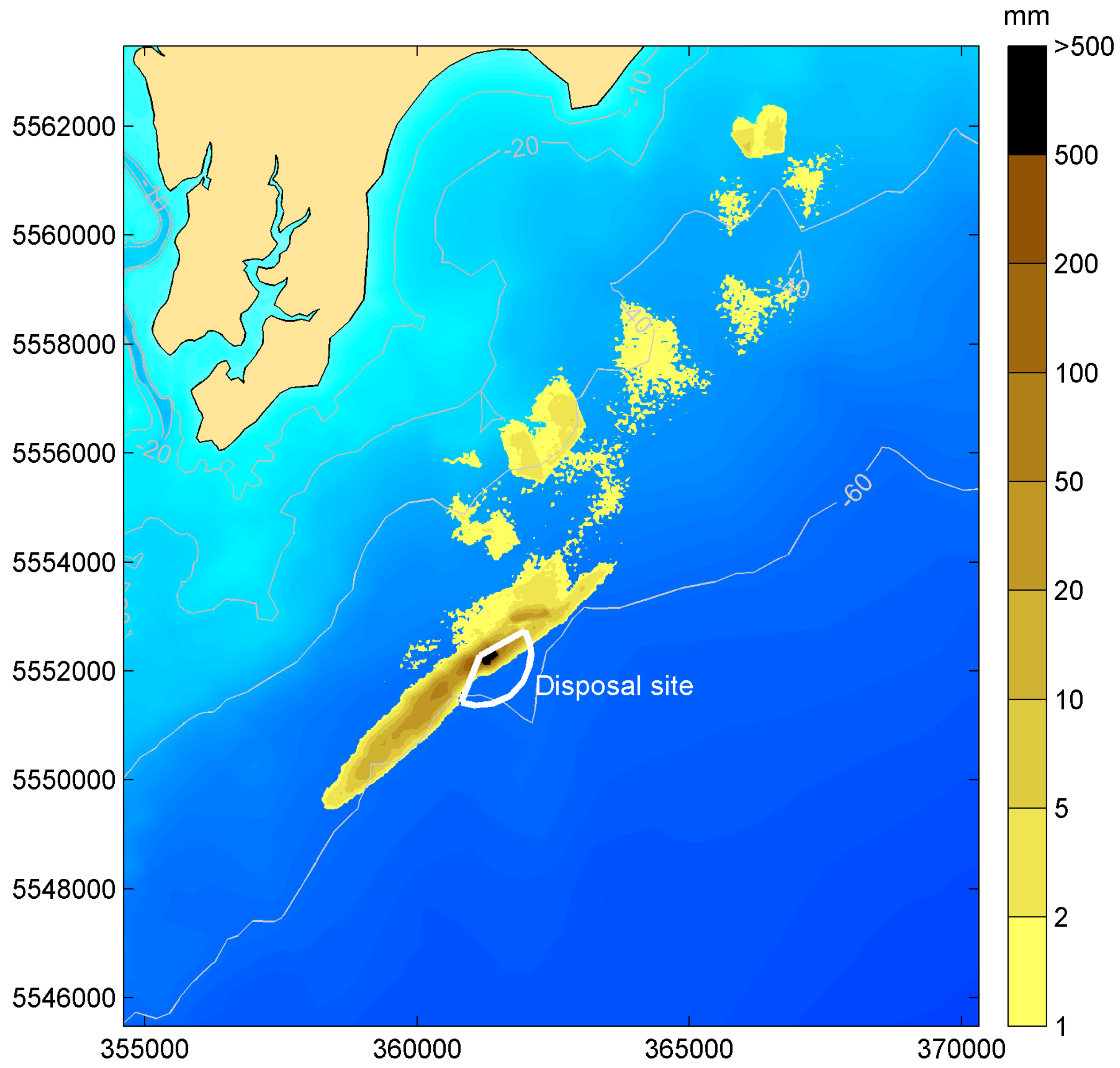


Figure 6-28 : Predicted deposition at the end of the 2 weeks of disposal of sediment at sea

Cumulative effect of whole dredge

6.9.22 Based on knowledge of the total dredging volumes in each dredge area (east north, west), a calculation of the total deposition from the whole dredging operation was undertaken. This result is plotted as Figure 6-29. It combines the total deposition plots presented for each area of dredging above.

6.9.23 In this figure the areas of dredging are masked out as any deposition in these areas will be removed during the dredging operation. Outside of this area, but still within the site area (red line boundary) deposition of a few tens of centimetres is predicted. Up to 200 mm of deposition is also predicted up to 150 m west of the site area (red line) and up to 50 mm of deposition is predicted in a localised area at the end of the eastern breakwater. Outside of these areas the predicted deposition is up to 5 mm, declining to less than 1 mm at distances of 370 m to the west of the site and 300 m to the east of the site.

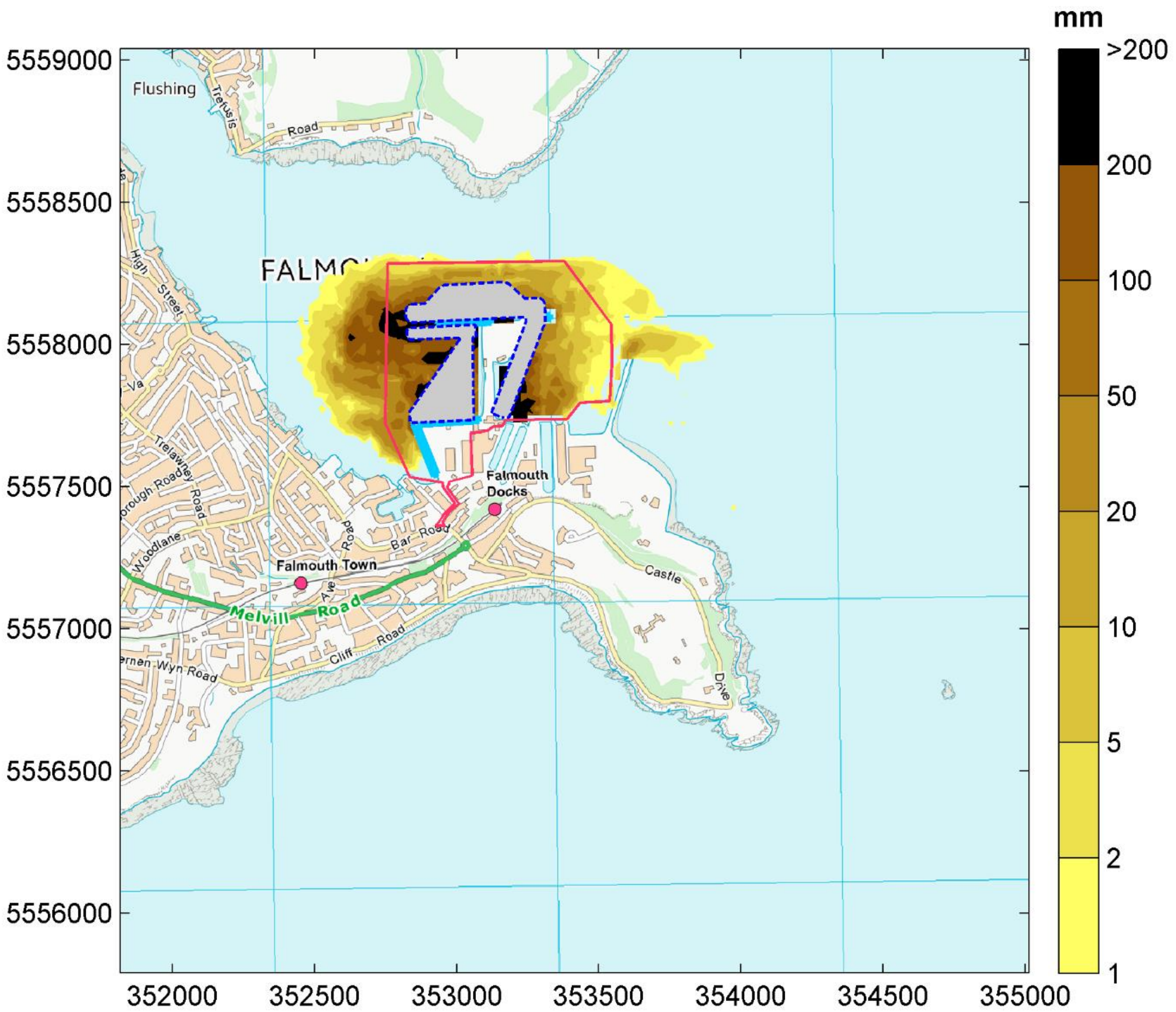


Figure 6-29 : Predicted fine sediment deposition resulting from proposed dredging works as a whole (dredging areas marked in grey).

6.9.24 The predicted total fine sediment deposition resulting from the entire disposal operation is provided in Figure 6-30. This figure indicates deposition of more than 5 mm within 3.2 km NE of, and within 2.1 km SW in the streamline of the disposal site with patches of around a centimetre of deposition up to 10 km NNE of the site. Deposition of more than 10 cm is predicted within 2.2 km (SW) and 0.5 km (NE) of the site.

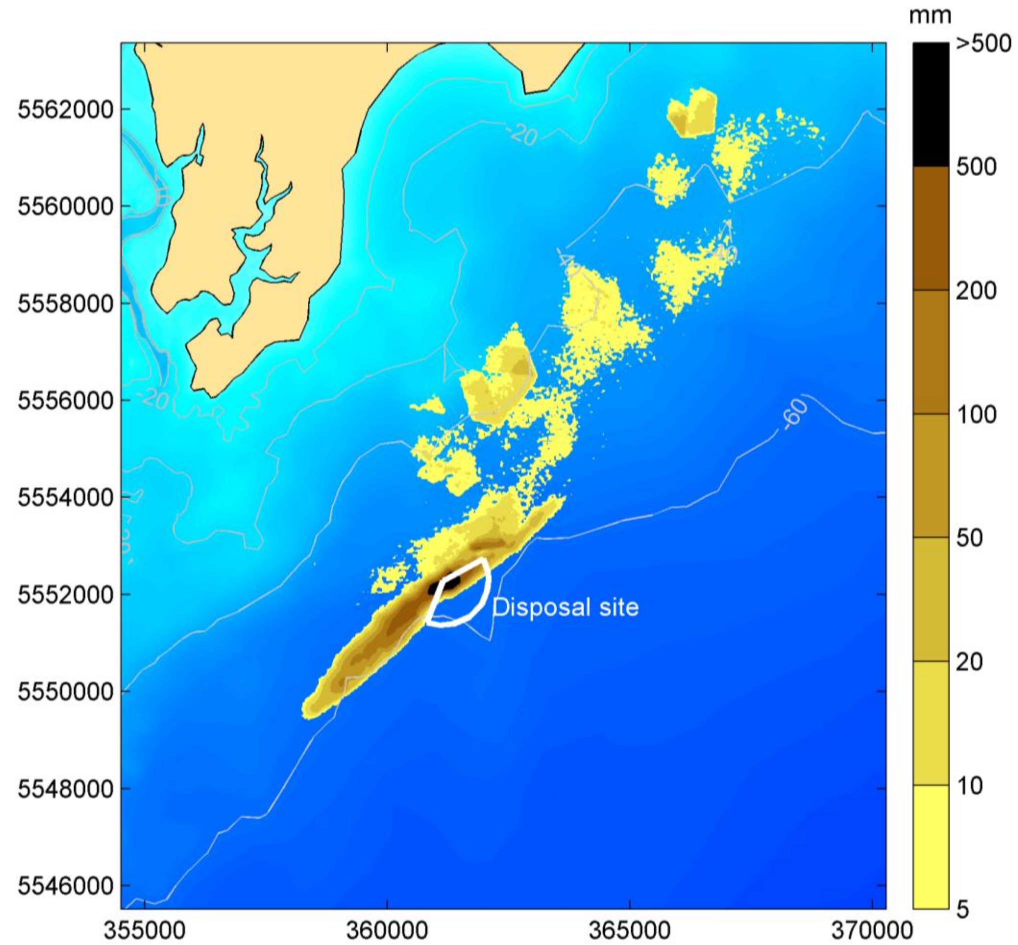


Figure 6-30 : Predicted fine sediment deposition resulting from proposed sediment disposal operations as a whole

6.10 Construction schedule

6.10.1 The schedule for completion of the dredging is presently set at 58 weeks. This programme was developed from preliminary conversations with a contractor and subsequent revision of the methodology to use a flood tide only approach. This is considered the quickest programme feasible using a single dredger and requires relatively high rates of productivity for backhoe dredgers, unlimited availability of barges for sea disposal and no restriction on production rate linked to the capacity for treating and/or transporting the contaminated sediments on land. A single backhoe dredger, with larger productivity, has been tested in the model as part of the development of the proposed methodology but this will result in a larger footprint of plume impact (than a smaller dredger or longer programme) and therefore is conservative. It is likely, due to a number of factors, such as dredger availability, dredger productivity, and rate at which the sediment can be disposed of, that the plume impact will be less than the modelled outputs, which have been based on the worst-case assumptions.

6.11 Mitigation

6.11.1 The release rates presented in Table 6-4 correspond to the lidded bucket reducing the loss of fine sediment through a smaller bucket (and smaller productivity) and through reducing losses from the absence of surcharging (heaping) of the bucket. No further mitigation benefits are ascribed to the lidded bucket through reduction in fine sediment losses. This is a conservative assumption but studies (Wang et al, 2004[8]) of the effects of lidded buckets (backhoes and grab dredgers) indicate that the evidence for additional benefits (loss reductions) is mixed. Using a lid reduces the spillage that occurs from open buckets, but the presence of the lid increases the disturbance occurring at the bed immediately prior to,

8 Wang, T., Larm K., and Hotchkiss, D. (2004). Evaluation of closed buckets for remedial dredging and case histories, Dredging '02: Key Technologies for Global Prosperity, Proceedings of the third Specialty Conference on Dredging and Dredged Material Disposal, May 5-8, 2002, Orlando, Florida.

and during, the progress of the bucket or grab through the bed. Furthermore, these studies indicates that the biggest benefits come through more controlled, slower and careful dredging (resulting in lower productivity).

6.11.2 In developing the approach to dredging and assessing the impacts, the use of flood tide only dredging has been shown to reduce the footprint and magnitude of the increases in suspended sediment concentration and deposition to the east of the dredge area. Further refinement of the timing of the dredger operations to the programme presented above has embedded further mitigation of the effect into the dredge programme.

6.11.3 One of the mitigation measures often put forward to mitigate sediment plumes arising from dredging operations is the use of silt screens (silt curtains). Silt curtains are vertical barriers positioned within the water to contain fine material (sediment) introduced into the water column by dredging or other engineering construction activities. Silt screens can either be placed immediately around the dredging operations to prevent sediment dispersion, or in front of sensitive receptor(s) to provide protection from dispersed sediment.

6.11.4 Silt screens can be very effective in the right situation – essentially benign environments with low current speeds and waves, and relatively shallow water depths, and where the silt screen is aligned parallel to the water flow. However, where current speeds are not low, where the silt screen is required to be at right angles to the current direction, or where the silt screen is exposed or in deep water, the silt screen will tend to become ineffective. Much of the area to be dredged experiences low tidal current speeds and wave heights suggesting it might be suitable for silt curtains. However, the main sediment losses associated with the BHD occur during the swing of the loaded arm to the barge. As the barge will unavoidably be outside the silt curtain most of the sediment is likely to be lost outside the silt curtain potentially negating much of its function.

6.11.5 Operational monitoring of the dredge can also be used to manage any effects. Most commonly, suspended sediment concentrations are monitored and compared to the baseline values with exceedance triggers used to decide whether the dredging operation should change or even pause. If deemed necessary, such a plan, including the approach to the baseline condition and development of the triggers, could be developed and agreed with the relevant stakeholders in advance of the dredge commencing.

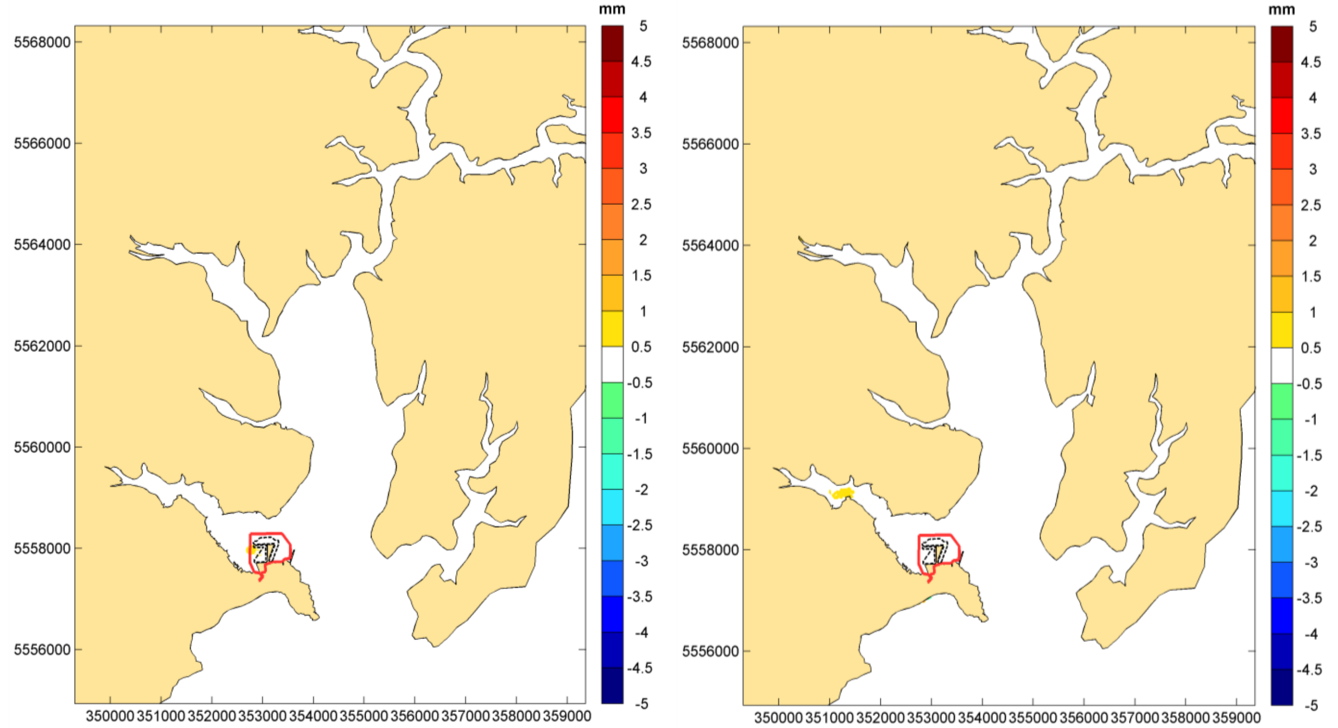
6.11.6 Real time monitoring of deposition would be much more difficult to use in a robust way due to the very low quantities of sediment involved (a few mm per week).

Operational Stage

Tidal levels

6.11.7 A change to the cross sectional area of harbour would alter the way the tide propagates into the harbour with potential effects on high and low water levels. Changes to high water levels may change the risk of flooding due to extreme tides, or alter the ecological function in high intertidal or transitional habitats. Change to low water may change the balance of intertidal and subtidal areas.

6.11.8 To assess this change the maximum and minimum water levels simulated for the full spring neap cycle were extracted and compared. Figure 6-31 shows the difference in maximum water level due to the proposed development on the left and difference in minimum water level on the right. A threshold of plotting of 0.5 mm has been used to show areas of no change, however, typically changes greater than 5-10 mm are used to investigate changes to habitat function and changes of more than 10 mm are regarded as sufficient to assess changes in flood risk however minimal. The model predicts no maximum or minimum water level greater than 1 mm, indicating no effect on habitat function or flood risk linked to the effect of the proposed development on tidal water levels.



Effect on maximum water level **Effect on minimum water level**

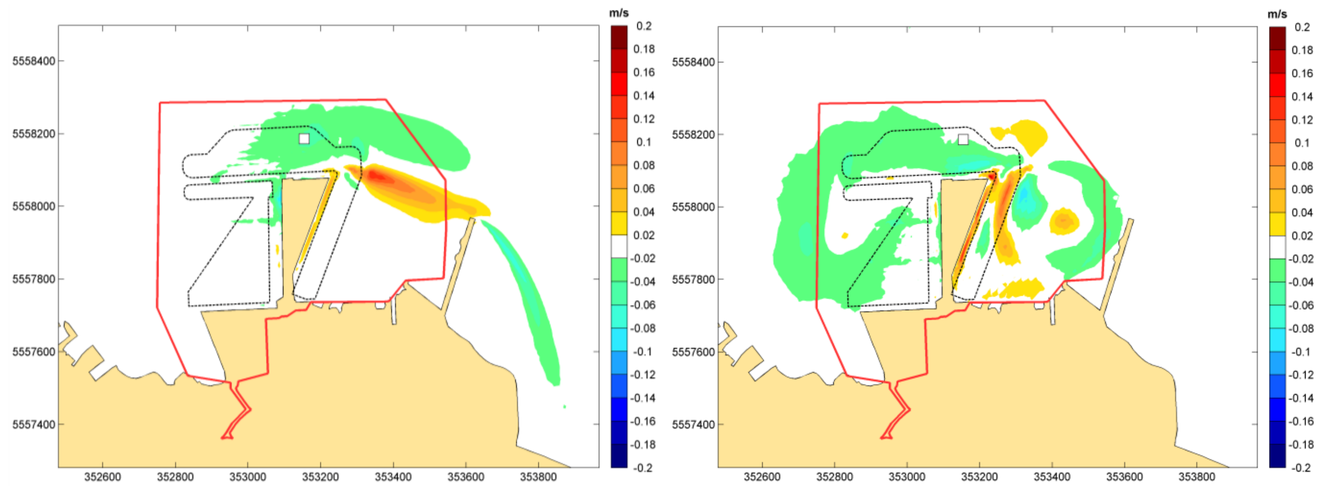
Figure 6-31 Predicted effect of the proposed development on maximum (left) and minimum (right) water levels

Tidal currents

6.11.9 The effect of the development on tidal currents is presented by comparison of the currents at time of peak ebb and flood tides, with and without the proposed development in place (Figure 6-32).

6.11.10 In these figures a minimum threshold for plotting any change of 0.02 m/s has been used. This value is much lower than that typically used for similar assessments however it does allow the full footprint of any effect to be seen.

6.11.11 The main changes seen are an area of small reduction in current speed associated with the increased cross sectional area with the dredging to the north of the proposed development included. The change to the shape and dredged depths in the western wharf area alter the slow moving circulation within the wharf area. This effect results in some speed increases for the flow passing the western wharf on both the ebb and flood tide, however these changes are small and transient.



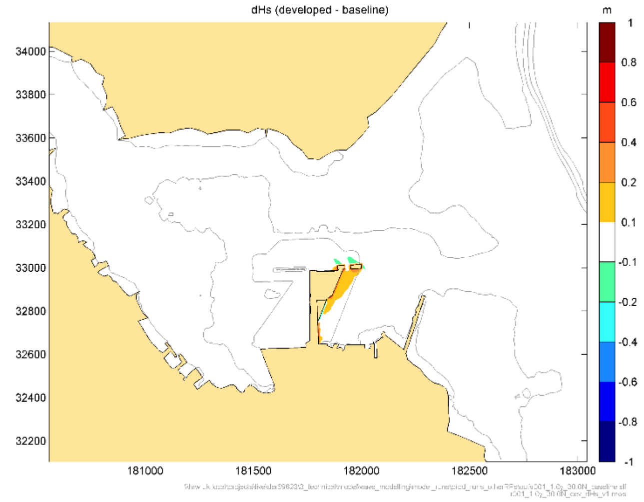
Peak ebb **Peak flood**

Figure 6-32 Predicted effect of the proposed development on current speed at time of peak ebb (left) and peak flood (right)

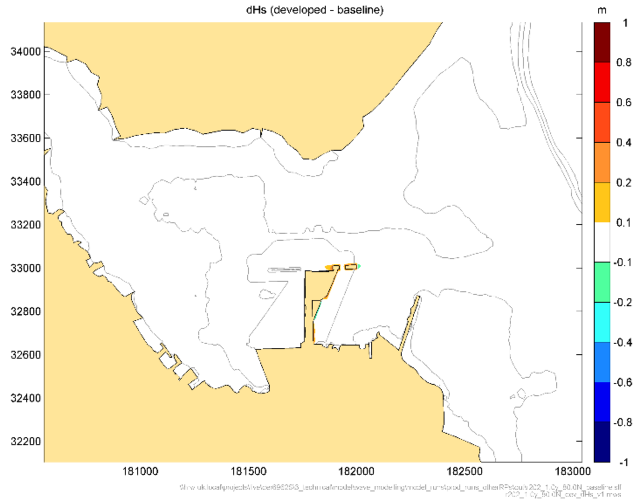
Waves

6.11.12 Figure 6-33 shows the change in significant wave height for the 1 year return period conditions at mean high water spring. These plots show the limited footprint of any effect of the proposed development.. The effects can be summarised as follows:

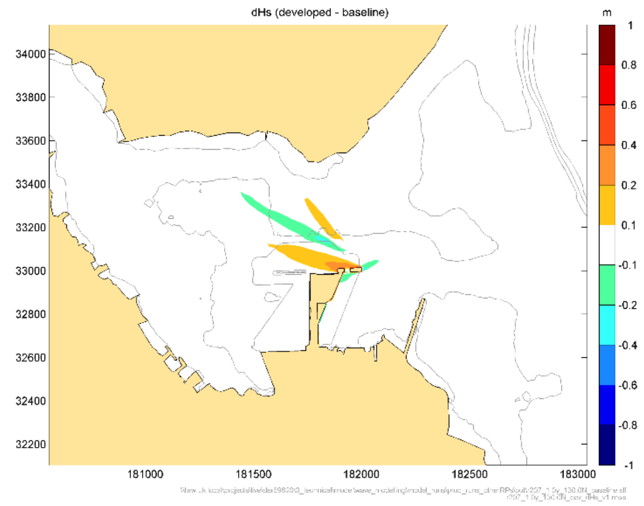
- Predicted conditions from 300°N will cause an increase in significant wave height of up to 0.3 m along the Northern Wharf for the 1 year conditions.
- Predicted conditions from 120°N will cause an increase in significant wave height of up to 0.35 m along the Northern Wharf for the 1 year conditions.
- Predicted conditions from 30°N will lead to an increase in significant wave height of up to 0.3m along the New Western Wharf and in the corner of the existing Western Wharf.
- No change in wave height greater than 0.1 m is seen along the coastline or over intertidal areas for the 1 year condition.



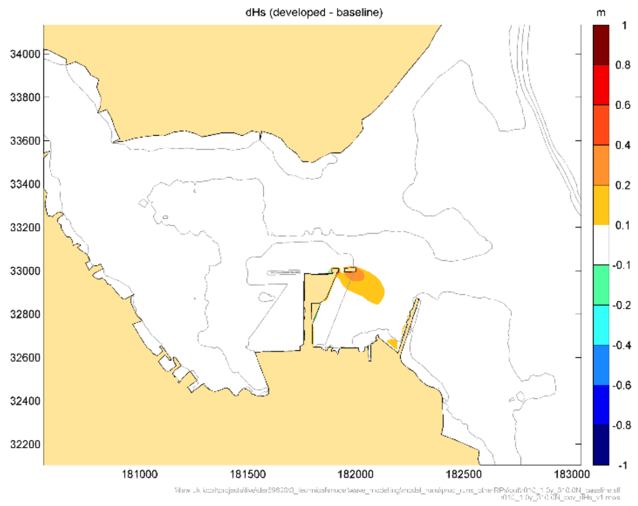
1 year return period conditions from 30°N



1 year return period conditions from 90°N,



1 year return period conditions from 120°N

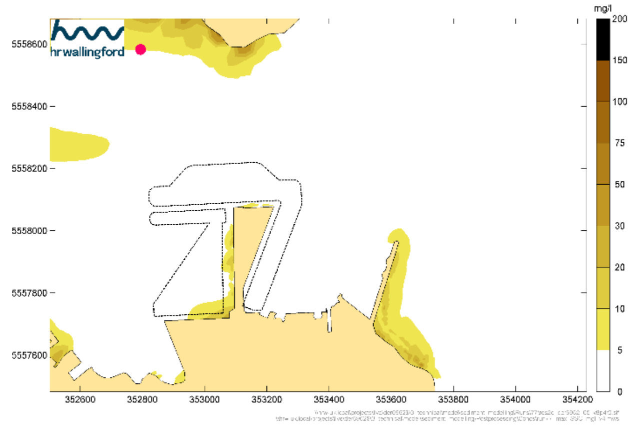


1 year return period conditions from 300°N,

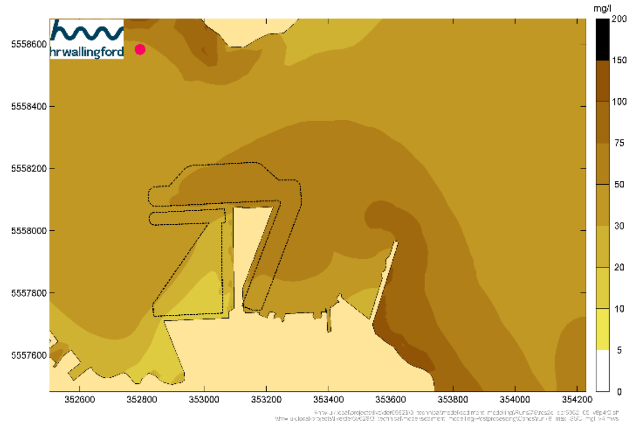
Figure 6-33 Predicted effect of proposed development on 1 year return period significant wave height at Mean High Water Spring tide

Sediment regime

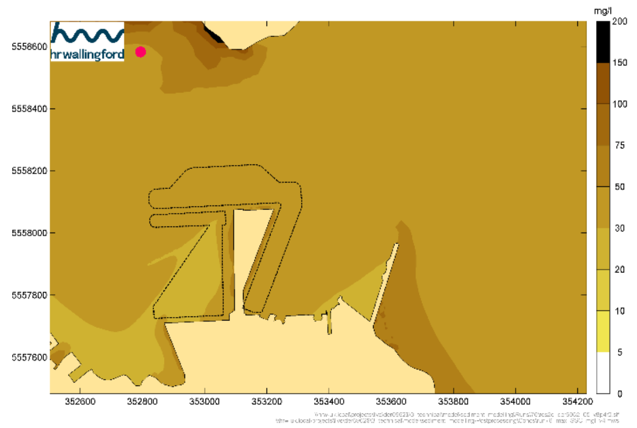
6.11.13 The effect on the fine sediment regime associated with the proposed development are shown below by repeating the plots of maximum suspended sediment concentration for the wave conditions tested. Figure 6-34 shows the model results. Some small change in the concentration contours are seen however it should be remembered that these peak values will be short lived. The overall effect of the proposed development on suspended sediment concentrations is small as might be expected considering the small effects of the development on the driving forces for sediment transport – tidal currents and waves.



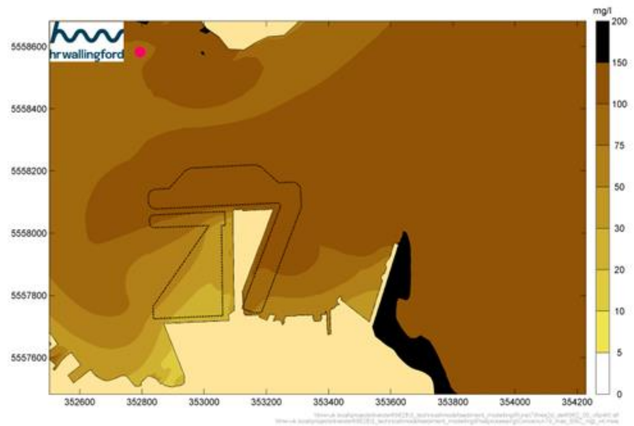
Representative offshore wave conditions from SW



Morphological offshore wave conditions from SE



0.2 year return period offshore wave conditions from SSW



1 year return period offshore wave conditions from SE

Figure 6-34 Predicted maximum suspended sediment concentration for a range of offshore wave conditions with the proposed development in place

6.11.14 Similarly to Figure 6-34, the pattern of predicted annual deposition was calculated for the case with the proposed development in place. The result is shown in Figure 6-35, with the difference compared to the baselines shown in Figure 6-36.

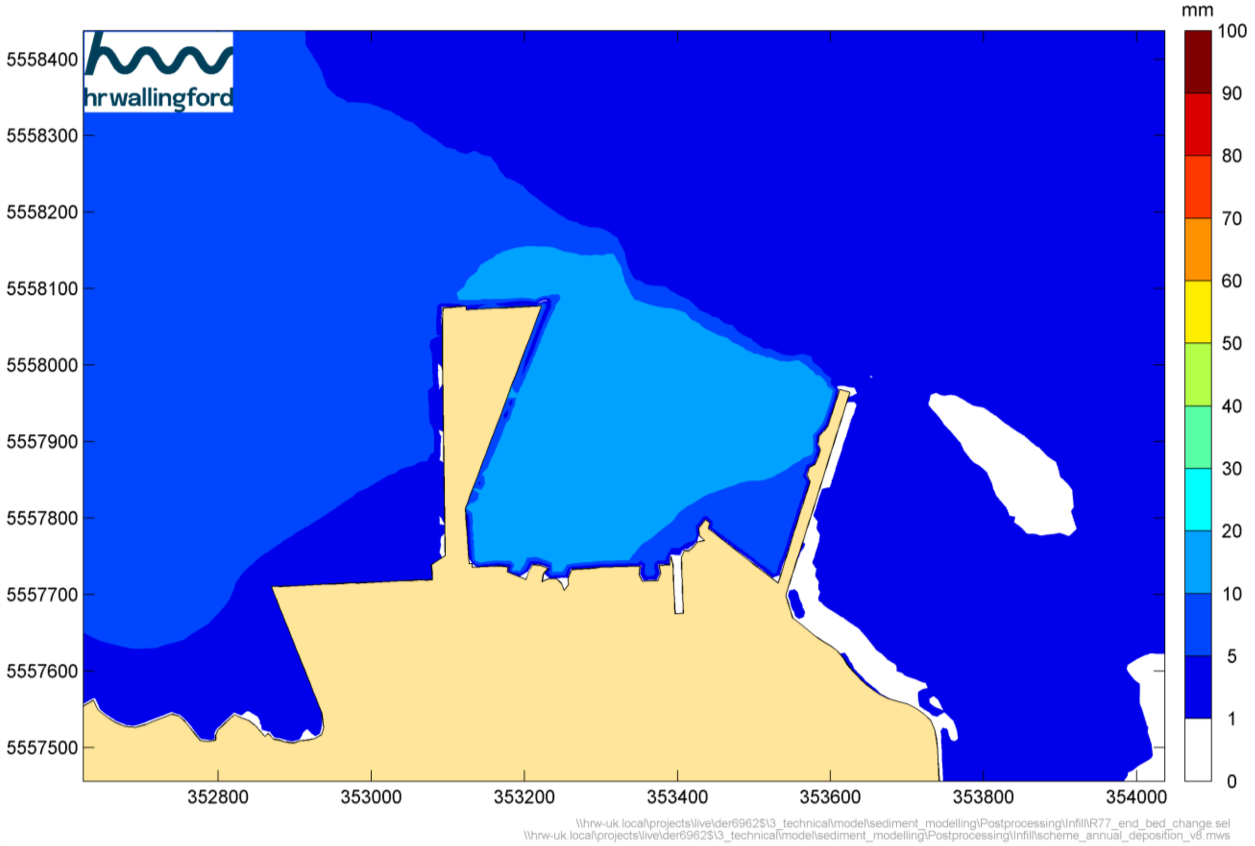


Figure 6-35 Predicted annual deposition depth of fine sediment with the proposed development in place

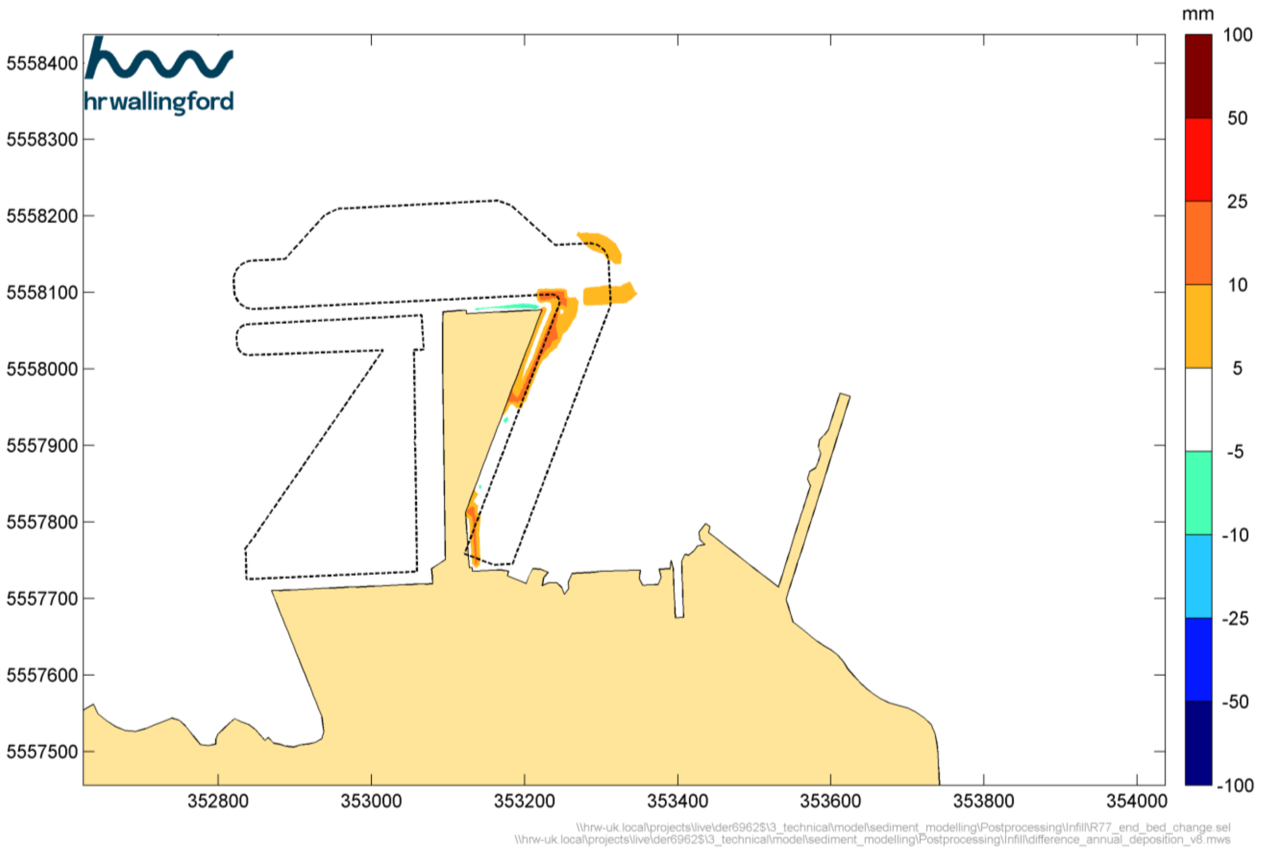


Figure 6-36 Predicted change to annual deposition depth of fine sediment with the proposed development in place

6.11.15 The infill estimates for the existing port operational area is simulated to be small; 3,560 m^3/year, and this corresponds with current experience at the port as minimal maintenance dredging is conducted in the harbour area. Most of this volume is predicted to the east of Queens Wharf with some limited areas of deposition also shown along the north side of Queens Wharf. With the proposed development in place the total infill rises to 3,800 m^3/year. This change is negligible and modifications to existing maintenance dredge requirements away from the dredged areas associated with the proposed development are unlikely to be required.

6.11.16 Within the dredged areas directly associated with the proposed development the volumes of infill are predicted to be 1,600 m^3/year. This small quantity suggests maintenance dredging every year is unlikely to be required, A suitable approach to maintenance dredging is to dredge up to approximately 8,000 m^3 every 5 years (or depending on operational requirements, up to approximately 16,000 m^3 every 10 years), as required, mostly within the eastern berth pocket (Western Wharf). It should be noted that this is an average annual sedimentation rate which will vary from year to year due to factors such as the variability of the offshore wave climate. Furthermore, in the first 1-2 years following a dredge an initial, transient increase in sedimentation would be expected due to the disturbance of the seabed sediments associated with the dredging campaign.

6.11.17 Although not included in the model, it is possible that subsequent remobilisation of the deposited material in the dry dock (e.g. by vessel propeller wash or by currents generated during emptying of the dry docks) may result in a redistribution of the predicted infill. This could potentially lead to the resuspended sediment preferentially falling into the deepened berth areas rather than being spread across the docks. For the existing layout, this might mean some fine material leaves the dock area which is evidenced by the fact that only 600 m^3 is currently dredged from the East Dock area annually (Carrick District Council, 2005). For the proposed development, however, it is possible that the remobilized sediment will preferentially end up in the deepened berths and form part of the 1,600 m^3/year average infill rate in the dredged areas associated with the proposed development.

6.11.18 In addition to the fine sediment transport as modelled, small quantities of coarser material (sand, gravel, dead maerl) will continue to be transported into the dredged areas in much the same way that they are presently.