REPORT

Holyhead Waterfront Development

Hydrodynamic and Dispersion Modelling

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Royal HaskoningDHV
Enhancing Society Together

HASKONINGDHV UK LTD.

Honeycomb
Edmund Street
Liverpool
L3 9NG
Industry & Buildings
VAT registration number: 792428892

+44 151 2362944 **T**
+44 151 2272561 **F**
info.liv@gb.rhdhv.com **E**
royalhaskoningdhv.com **W**

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Author(s):	Tanja Cooper, Keming Hu

Drafted by:	Tanja Cooper
Checked by:	Keming Hu
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Appendices

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1 Introduction

Royal HaskoningDHV was commissioned to undertake a numerical modelling exercise to inform the environmental impact assessment of the proposed Holyhead Waterfront Development project.

The following numerical modelling has been carried out:

a) a two-dimensional (2D) hydrodynamic model to study impacts on the hydrodynamics close to the study site;
b) a three-dimensional (3D) hydrodynamic and sediment transport model to simulate dispersion and deposition of suspended sediment plumes arising from the proposed land reclamation, dredging during construction of the breakwater at the development site, and disposal at the offshore disposal site.

This report describes the numerical modelling exercise that was undertaken to provide simulated hydrodynamic information for the area around the study site to enable a comparison of tidal currents and bed shear stress before and after the scheme being implemented. The report also describes the dispersion modelling exercise that was undertaken to provide simulated information on suspended sediment concentrations at the study site as well as at the offshore disposal site. **Figure 1.1** shows a wider view of the study area.

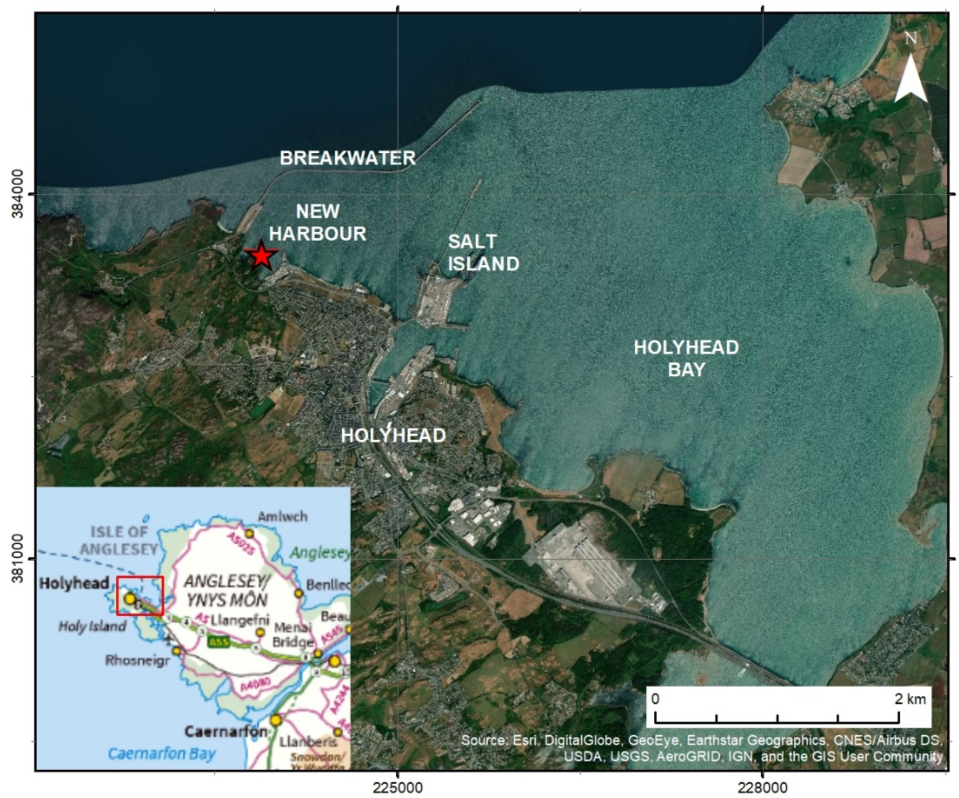

Figure 1.1: Wider view of the study area (red star indicates the study site)

The modelling work involved construction of a 2D hydrodynamic model to simulate tidal currents which was run for the following scenarios:

- 'Baseline' – with present-day bathymetry and coastline; and,
- 'With Scheme' – with the proposed breakwater and proposed land reclamation areas shown in **Figure 1.2**.

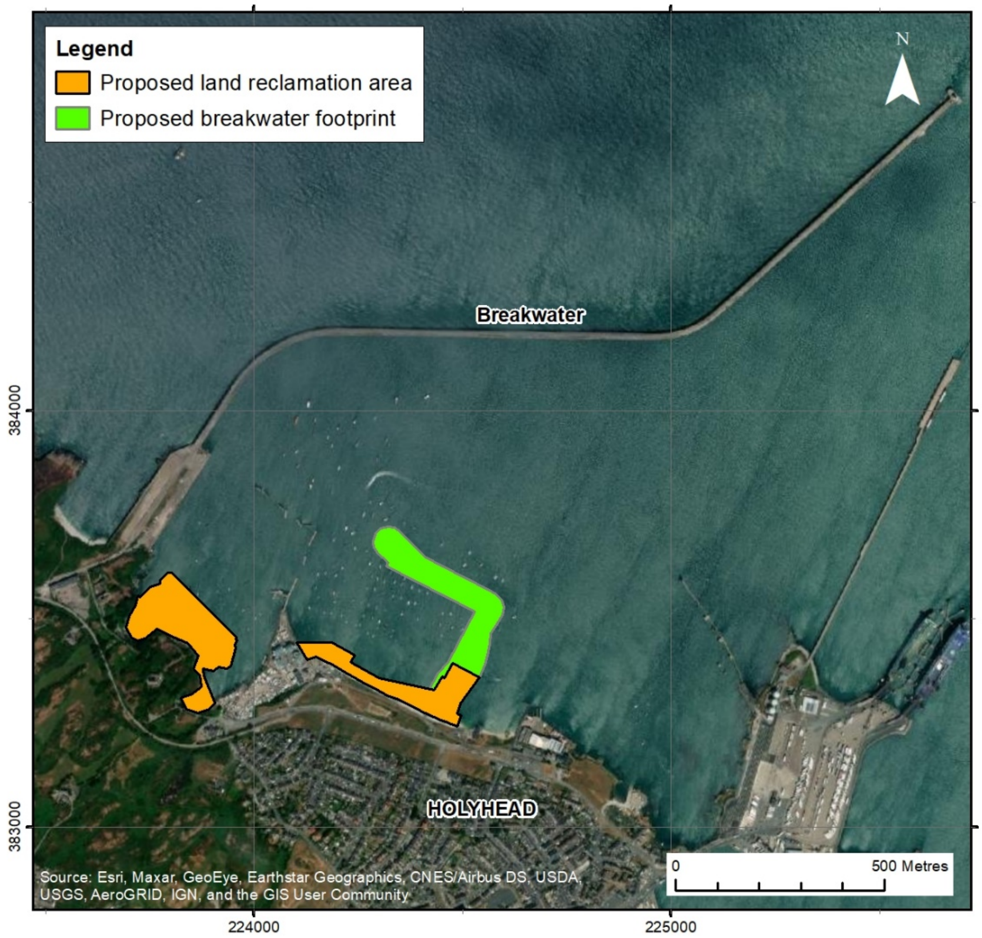

Figure 1.2: Detailed view of the study site and the proposed scheme

2 Data Collation

For this modelling exercise the following datasets were collated and used:

- The bathymetry used in the model was improved around the study site and inside the New Harbour area. The most recent bathymetry data available were surveyed between 2013 and 2015. This data was downloaded from the Admiralty Maritime Data Solution Portal https://data.admiralty.co.uk

- Recorded water level data has been sourced from BODC's Tide Gauge, located at the southern end of Salt Island, for the model duration between 1st and 31st March 2018; available for download from https://www.bodc.ac.uk

3 Hydrodynamic Model Setup

3.1 Model Description

Royal HaskoningDHV's 2D Irish Sea Regional Model, built in MIKE21-FMHD software, has been used for this study. This regional model has been calibrated against both predicted astronomic tidal elevation data and measured tidal elevation, and current data around the Irish Sea.

The 2D Irish Sea Regional Model was refined and updated around Holyhead for a previous project very close to the study site. This 2D Holyhead Bay model was re-calibrated to establish a detailed description of the water levels and currents, focusing on Holyhead Bay.

For the purpose of this study, the 2D Holyhead Bay model was further refined and updated around the study site and inside the New Harbour to focus on the proposed Holyhead Waterfront marina development to create the 2D Conygar model.

The MIKE-21/3-FMHD software was developed by the Danish Hydraulic Institute (DHI). The software has a proven track record and is widely used in many similar studies worldwide. The MIKE21/3-FMHD hydrodynamic module can be used to solve both two-dimensional (2D) and three-dimensional (3D) problems. The 2D model is based on the nonlinear shallow water equations using depth-averaged conditions. The 3D the model is based on the three-dimensional numerical solution and can provide hydrodynamic information for different water depths. The main advantages of this model are:

- The flexible triangular mesh of MIKE21/3-FMHD provides accurate boundary fitting for an area with complicated geometry, for example around Holyhead and the Inland Sea.

- The flexible mesh enables the model to use a coarser grid in the offshore area and the areas further away from Holyhead but a finer mesh in the area of greatest interest. This approach enables higher computational efficiency whilst still maintaining sufficient accuracy of mesh coverage in areas of the most interest in the present study.

3.2 2D Model Set-up

The set-up of the 2D Conygar model is described in more detail below.

a) Model Extent

The model extent covers the whole of the Irish Sea, as shown in **Figure 3.1**. The eastern boundary of the model encompasses the coastline from the Scottish island of Iona in the north to the English town of St. Ives in the south. The western boundary of the model stretches from the city of Cork on the south-west coast of Ireland up to Bulbinbeg near Malin Head in Northern Ireland.

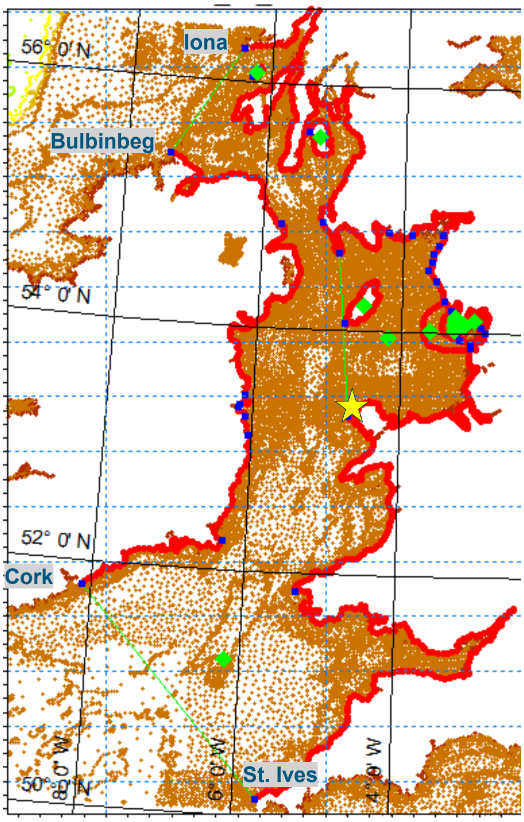

Figure 3.1: Model extent covering the Irish Sea (yellow star indicates the study site); brown dots showing bathymetry data points

b) Bathymetry

The bathymetry consists of several data sources that are listed below. **Figure 3.1** and **Figure 3.2** show the bathymetric survey data points that have been loaded into the model.

- Bathymetric surveys of Holyhead Bay and the New Harbour
- Lidar data covering mudflats inside Holyhead Bay
- C-map (digital Admiralty Charts) data covering offshore areas

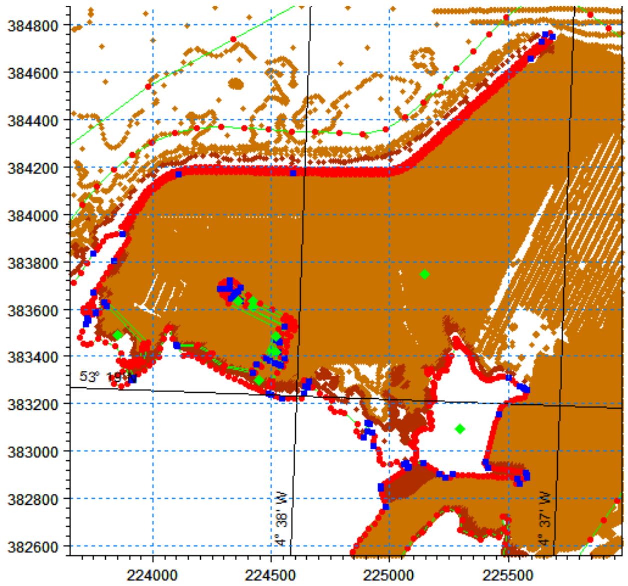

Figure 3.2: Bathymetry data points near the study site

c) Triangular Mesh Resolution

The model domain was divided into areas of different grid resolution as shown in **Figure 3.3**. A triangular mesh was generated throughout the study area with the resolution shown in **Table 3-1**.

Table 3-1: Mesh resolution

Mesh Area	Mesh resolution (m^2)	Approx. max mesh size
Offshore areas	25M to 1.5M	5km to 1.2km
Intermediate areas	300,000 to 5,000	550 to 70m
Study Area	2,500 to 500	50 to 22m

The grid is finest near the study area to give better definition as this area is of most interest in terms of assessing the changes in hydrodynamic outputs between the baseline and "with scheme" model runs. The mesh becomes gradually coarser moving away from the study area to the most offshore areas being the coarsest resolution.

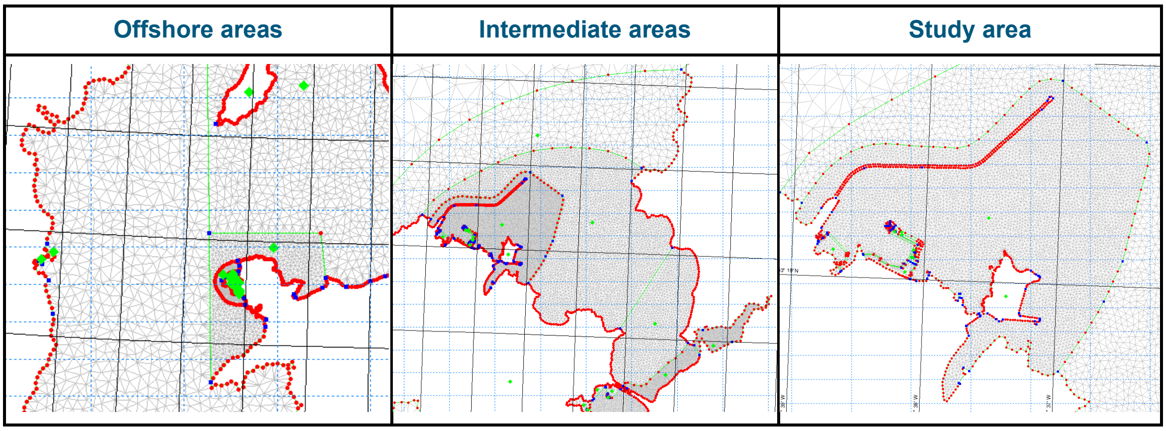

Figure 3.3: Triangular mesh resolution

e) Model Boundaries

Open model boundaries are set to drive the flow conditions in the model. This model is driven by two sets of open boundary data as illustrated in **Figure 3.4**.

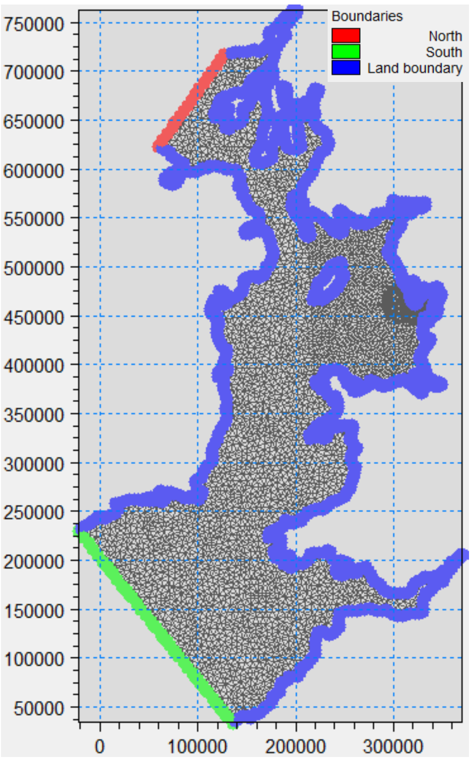

Figure 3.4: Model boundaries

The northern and southern model boundaries are varying tidal elevation boundaries using predicted tidal data. The tides are predicted using a formula developed from the information contained in Tide Tables (tidal harmonics and phase lag information) for the required time periods. The northern boundary uses tide information from two stations, namely Iona in Scotland in the east and Bulbinbeg in Northern Ireland in the west. The water levels are interpolated along the model boundary between the two tidal stations.

The southern model boundary is setup in the same way. It uses two stations, namely St. Ives in England in the east and Cork in Ireland in the west.

3.3 2D Model Calibration and Verification

The 2D Holyhead Bay model, which was utilised to construct the 2D Conygar model for this study, was already calibrated against tidal elevation and velocity data. Therefore the 2D Conygar model was verified against predicted and measured tidal elevation data for the model duration of March 2018.

For more details on the model calibration please refer to the Holyhead Port Expansion Environmental Statement, Appendices Volume 1, Appendix C – Hydrodynamic and Numerical Modelling, July 2019.

Figure 3.5 shows a comparison between predicted and modelled tidal elevation at BODC's Holyhead tide gauge for the model duration of March 2018. There is a good agreement between the modelled and the predicted water levels with differences being 0.1m or smaller. Only at low water during neap tides the modelled water level is 0.1-0.2m higher than the predicted tides but the overall tidal range during neap tides is matching well.

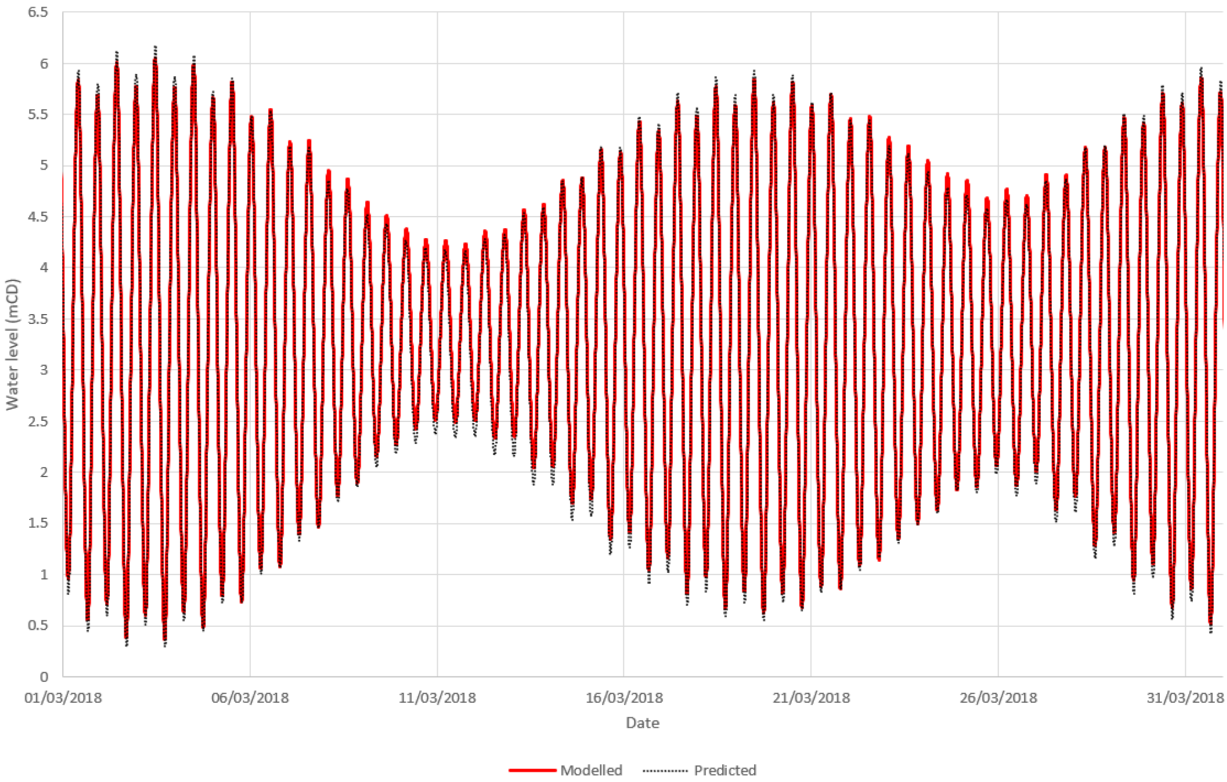

Figure 3.5: Comparison of predicted and modelled tidal elevation at BODC's Holyhead tide gauge for March 2018

Figure 3.6 shows a comparison between measured and modelled tidal elevation at BODC's Holyhead tide gauge for the model duration of March 2018. Overall there is a good agreement between the modelled and the measured water levels with differences being between 0.1 to 0.2m. During the first half of March 2018, i.e. during the first spring-neap tidal cycle, the measured data is about 0.2m to 0.3m higher than the modelled data, but the overall tidal range matches well. This is most likely to the tidal surges in the Irish Sea during this time period.

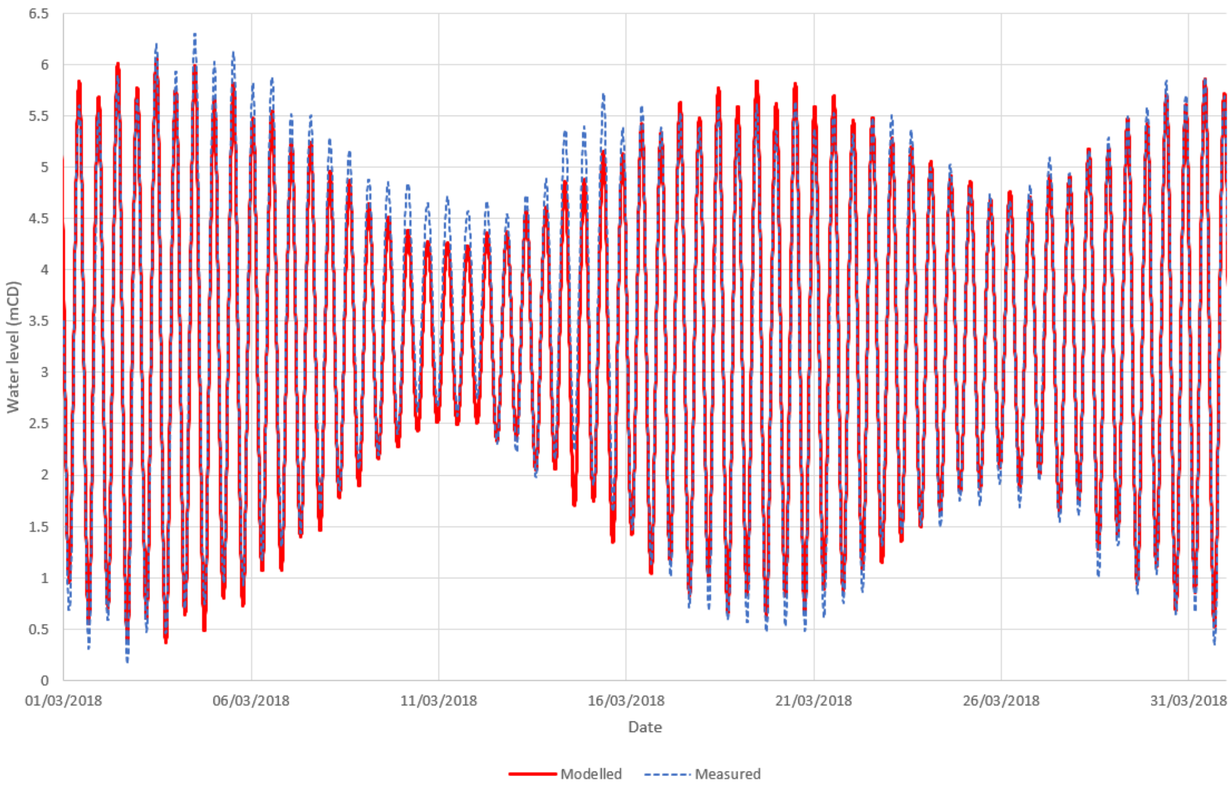

Figure 3.6: Comparison of measured and modelled tidal elevation at BODC's Holyhead tide gauge for March 2018

4 HD Model Scenarios

4.1 Description

The 2D Conygar hydrodynamic model was run for the following two scenarios shown in **Figure 4.1**:

- 'Baseline' – with present-day bathymetry and coastline;
- 'With Scheme' – with the proposed breakwater and proposed land reclamation areas.

The 2D Conygar model was run for one month for the time period between 1st and 31st March 2018.

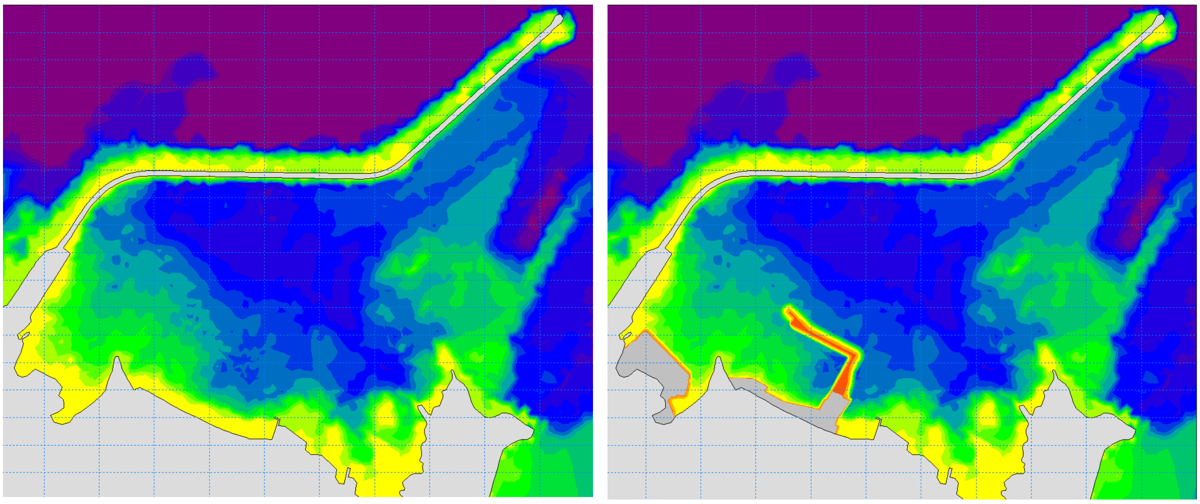

Figure 4.1: Bathymetry and coastline for 'Baseline' and 'With Scheme'

4.2 Results

The hydrodynamic model was first run for the 'Baseline' scenario using water level and tidal current velocities over one month, i.e. two spring-neap cycles. Currents conditions for peak flood and peak ebb near the study site are shown in **Figure 4.2** to **Figure 4.5** for Spring Tides and Neap Tides respectively.

The model was then re-run over the same time period under the 'With Scheme' scenario. Currents conditions for peak flood and peak ebb near the study site with the proposed scheme layout in place are shown in **Figure 4.6** to **Figure 4.9** for Spring Tides and Neap Tides respectively.

The differences between the 'Baseline' run and the 'With Scheme' run show the location and magnitude of any potential changes in tidal current velocities directly from the scheme. They are shown in **Figure 4.10** to **Figure 4.13**. The differences in current speed between the 'Baseline' scenario and the 'With Scheme' scenario are small and localised. The current speed is reduced by up to 0.02m/s during neap tides adjacent to the proposed breakwater extending in a west to east direction towards Salt Island. The current speed is marginally increased by up to 0.01m/s during neap tides in an area attached to the tip of the proposed breakwater extending by about 400m eastwards into the harbour. During spring tides, the current speed is reduced by up to 0.05m/s in adjacent areas to the proposed breakwater, and areas extending to the Holyhead Breakwater are reduced by up to 0.02m/s. The current speed is very slightly increased by up to 0.01m/s during spring tides in the area that would become the approach channel of the new marina and at the corner of the proposed breakwater reaching into the harbour.

Figure 4.14 and **Figure 4.15** show the maximum current speed throughout the whole model period of March 2018 for both scenarios respectively. **Figure 4.16** shows the location and magnitude of any potential changes in maximum tidal current velocities directly from the scheme. The maximum differences in current speed lie between a reduction of 0.06m/s and an increase of up 0.02m/s.

Figure 4.17 to **Figure 4.24** presents peak bed shear stress at flood and ebb phases of tides for the Baseline and "with scheme". The difference plots of peak bed shear stress presented in **Figure 4.25** and **Figure 4.28** demonstrate morphological insignificance of the small change of tidal currents by the proposed development.

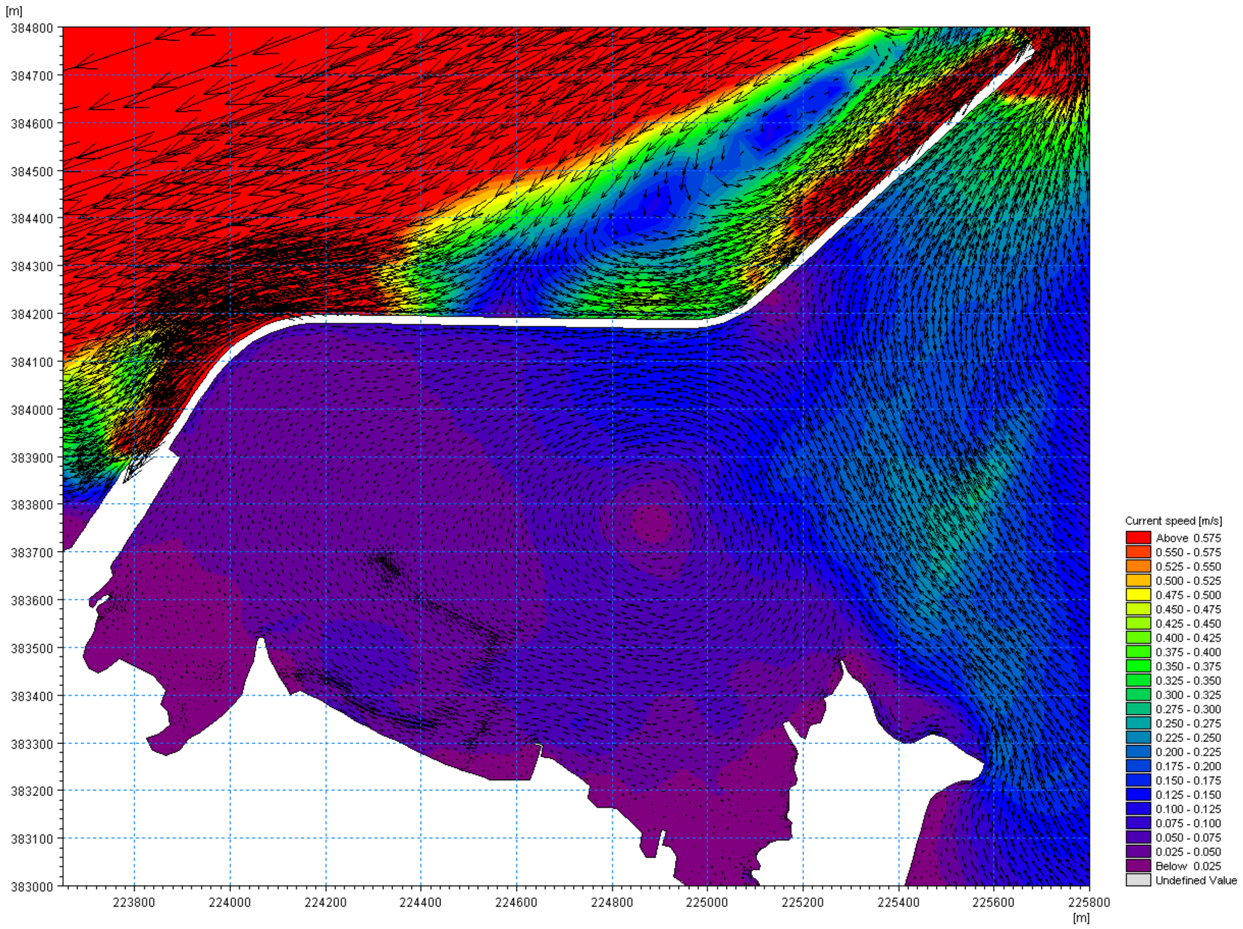

Figure 4.2: Baseline - Peak current velocities during the flood phase of a spring tide

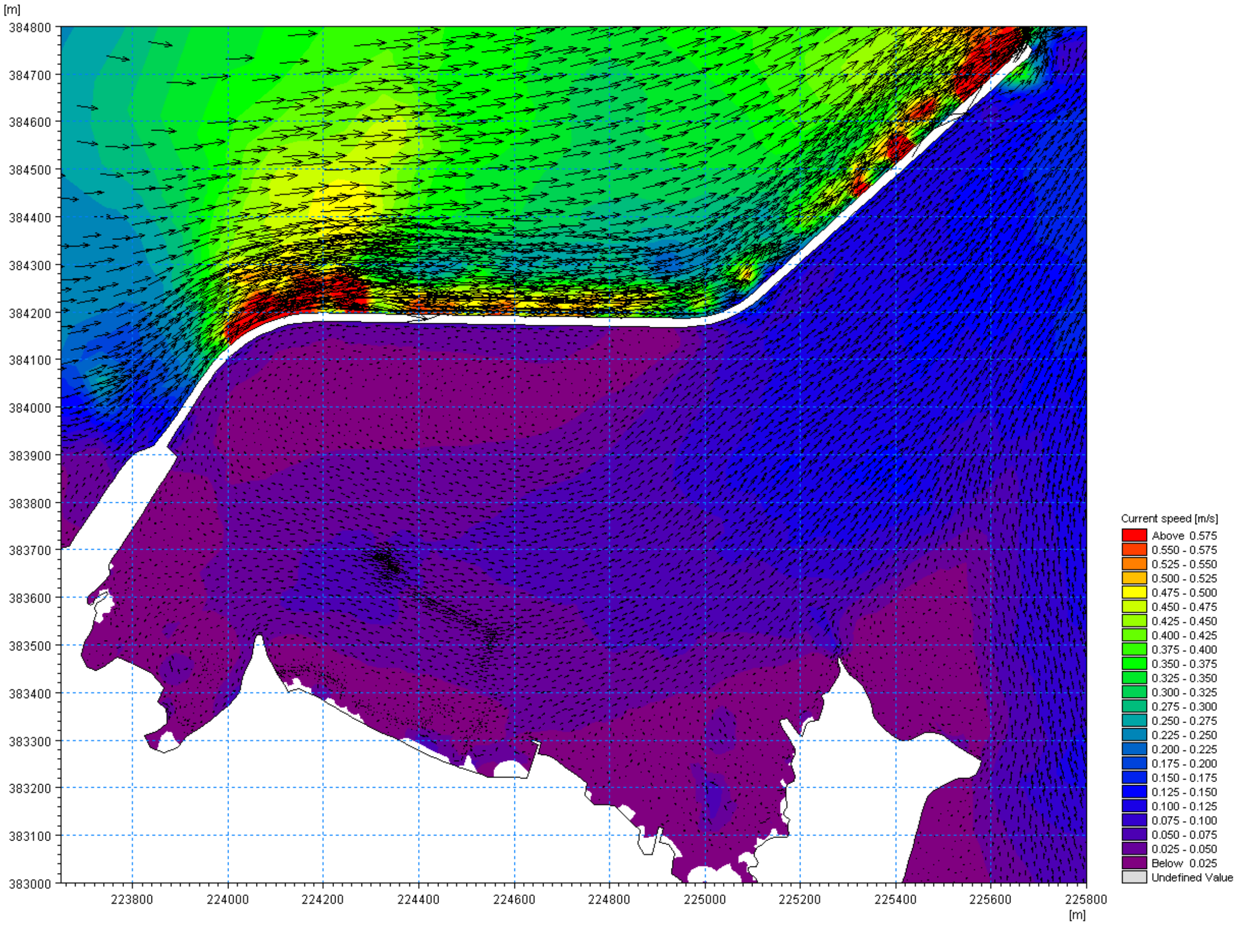

Figure 4.3: Baseline - Peak current velocities during the ebb phase of a spring tide

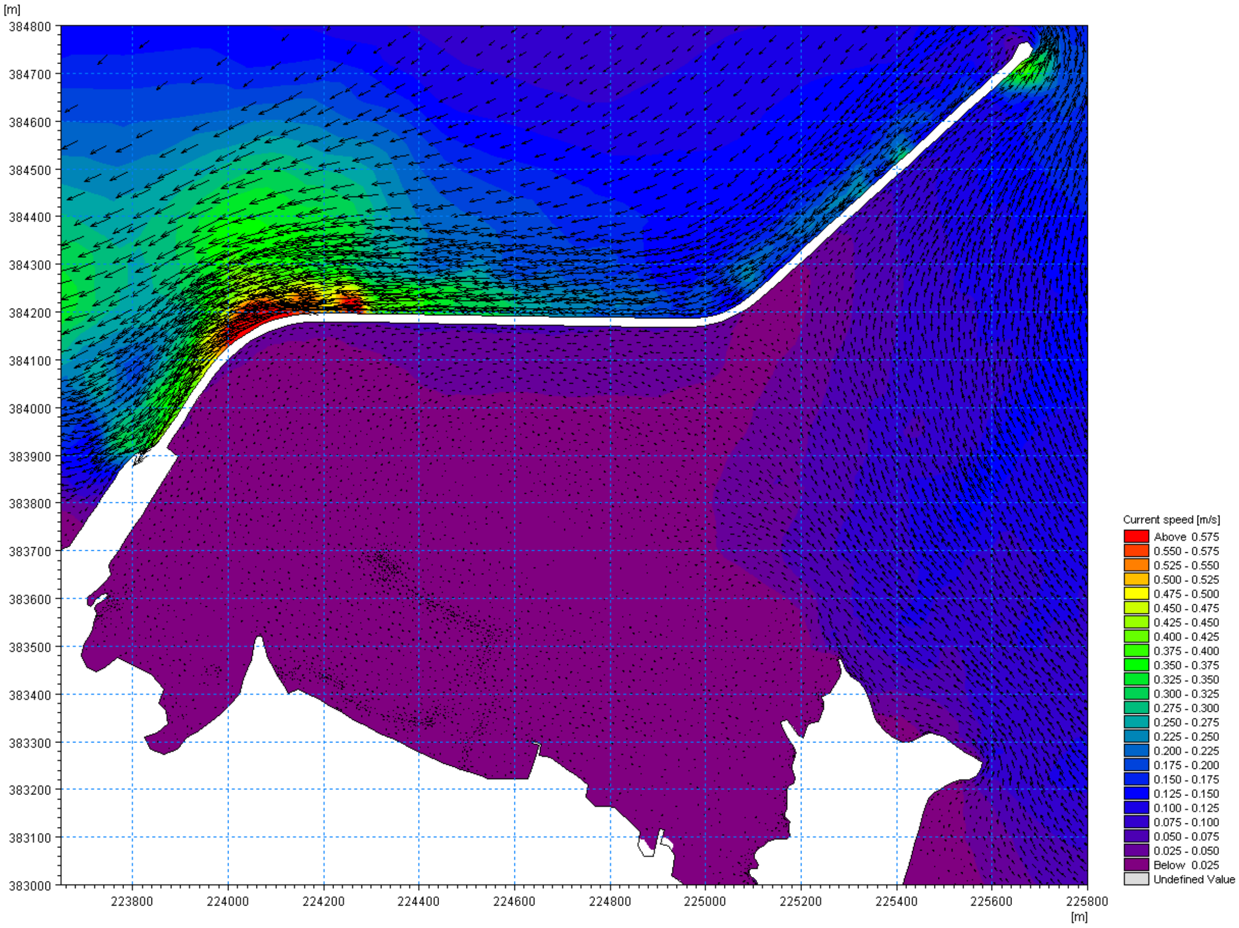

Figure 4.4: Baseline - Peak current velocities during the flood phase of a neap tide

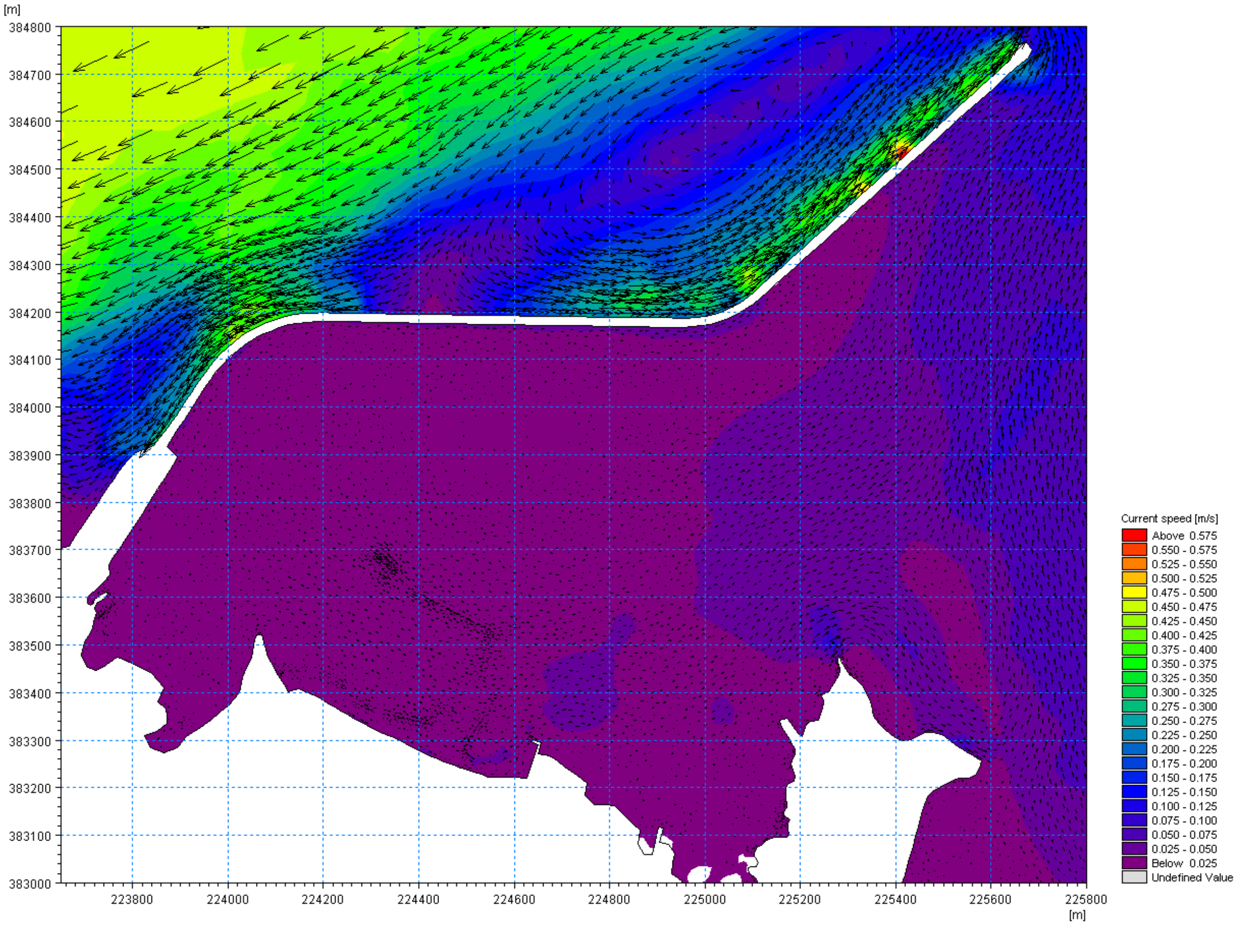

Figure 4.5: Baseline - Peak current velocities during the ebb phase of a neap tide

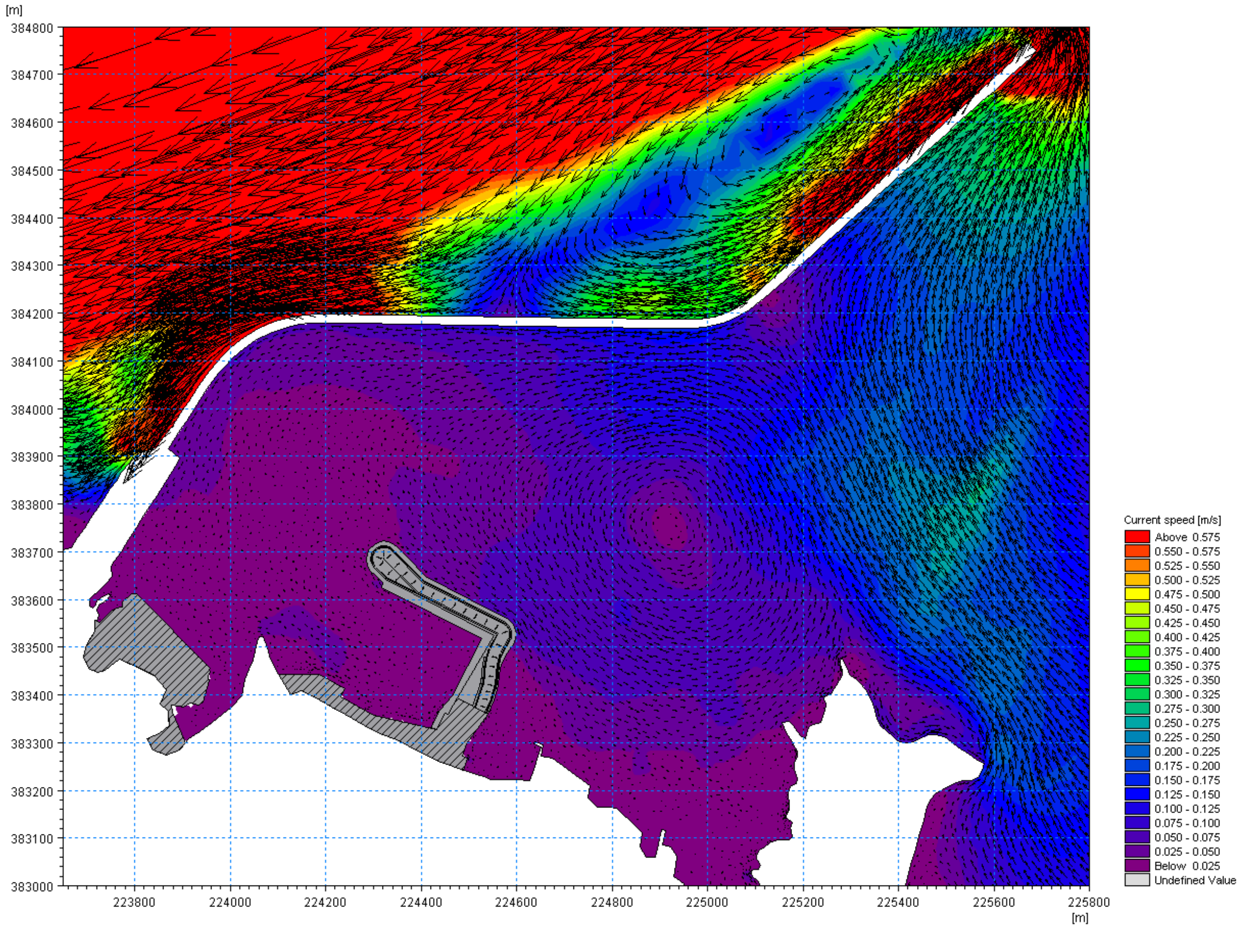

Figure 4.6: With Scheme - Peak current velocities during the flood phase of a spring tide

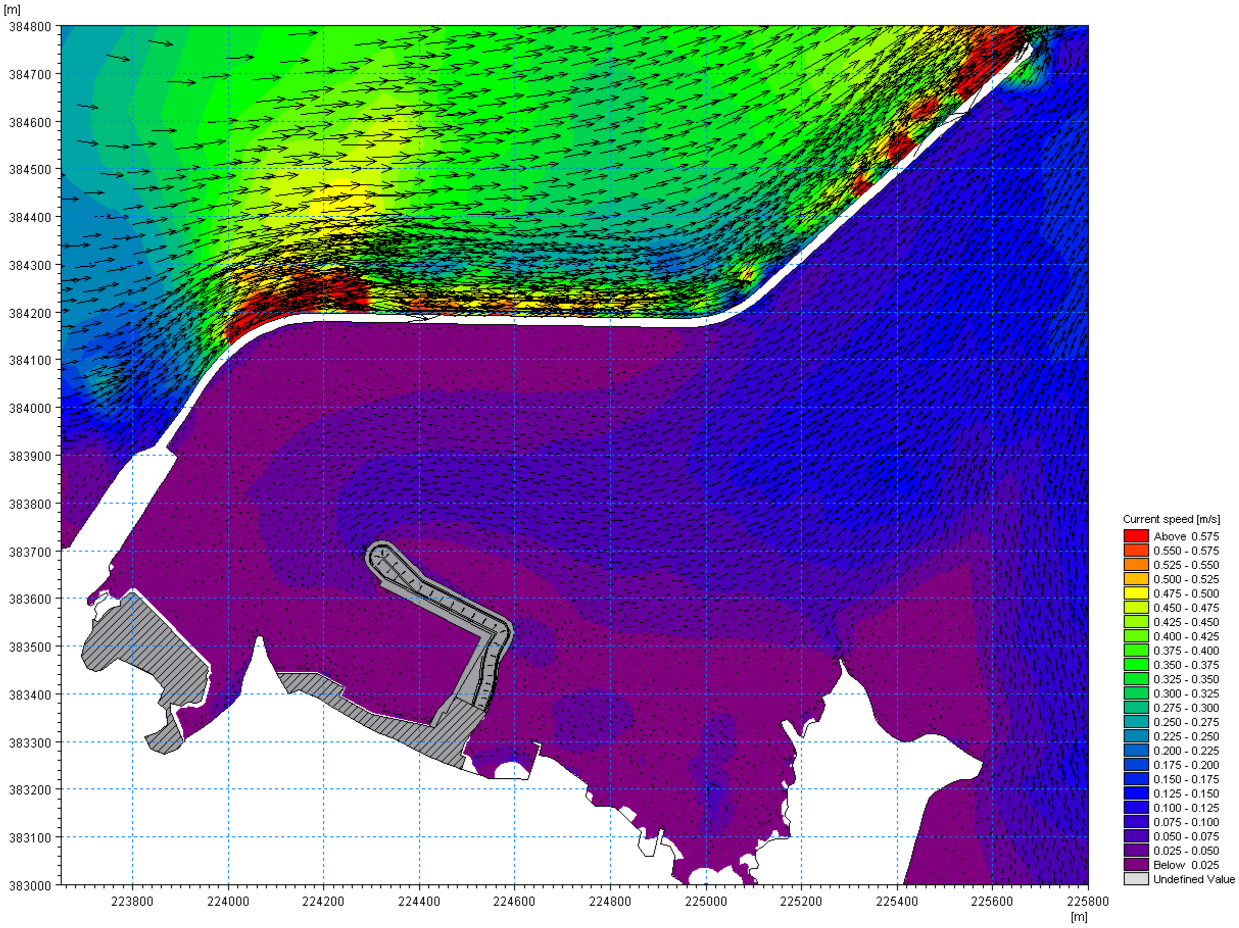

Figure 4.7: With Scheme - Peak current velocities during the ebb phase of a spring tide

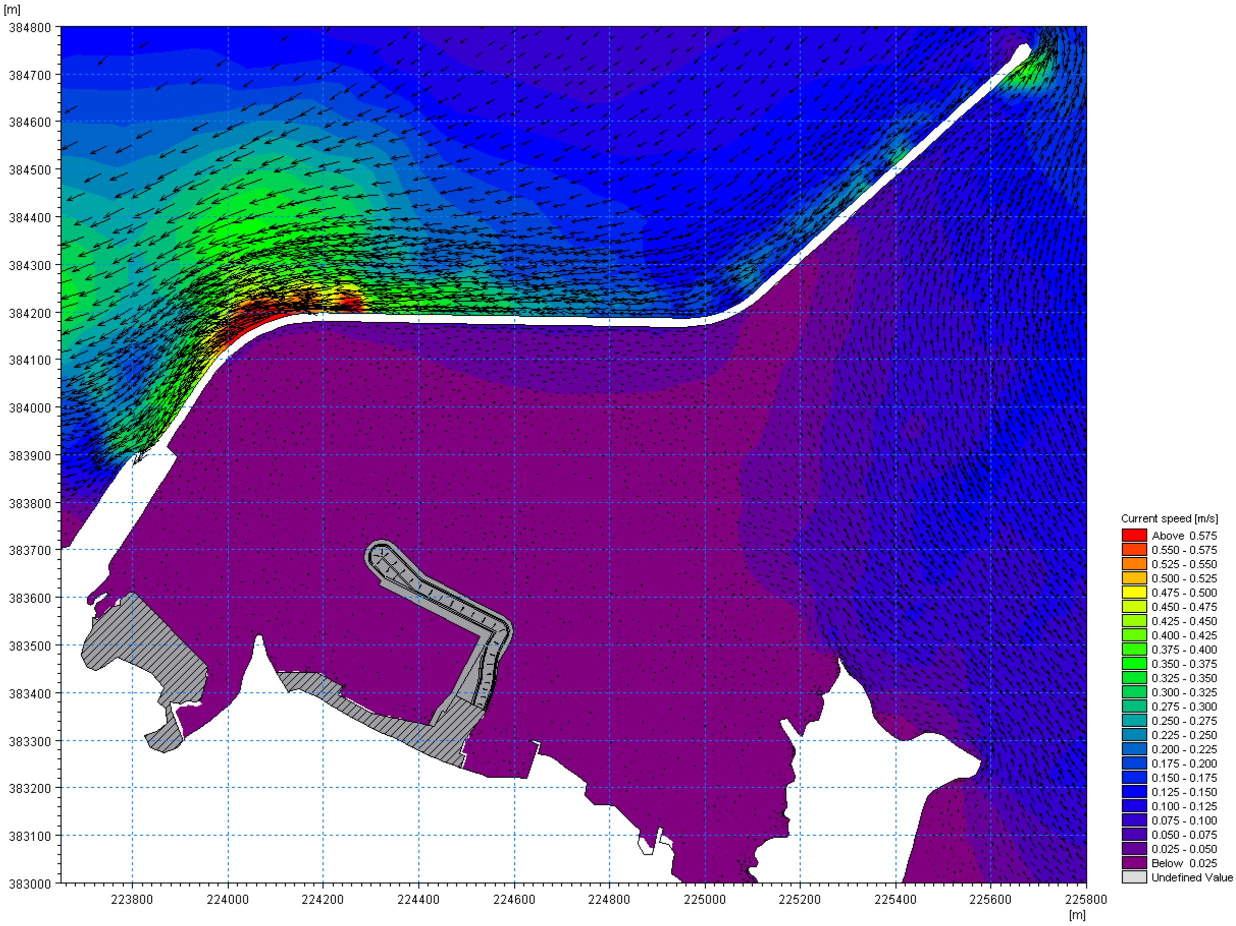

Figure 4.8: With Scheme - Peak current velocities during the flood phase of a neap tide

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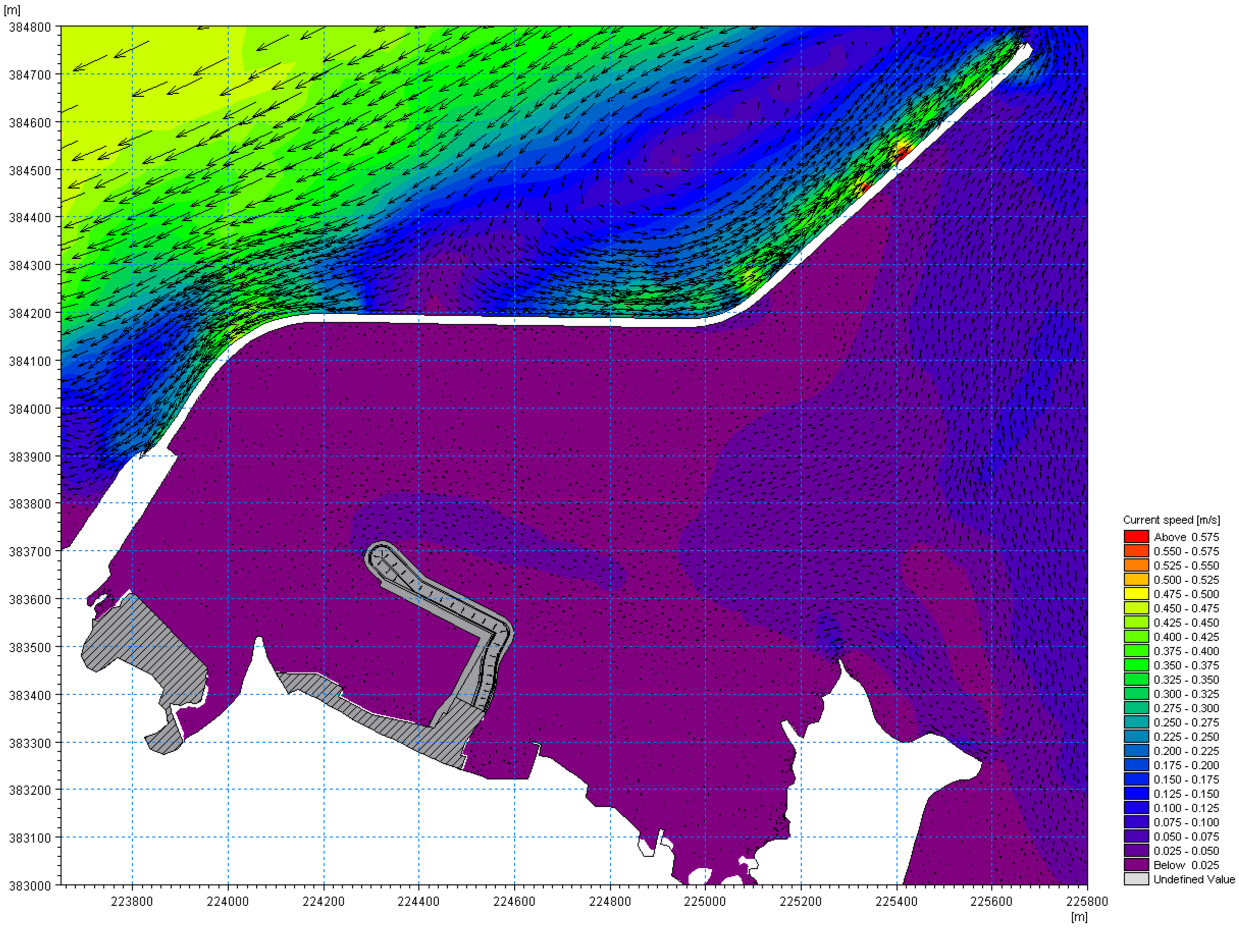

Figure 4.9: With Scheme - Peak current velocities during the ebb phase of a neap tide

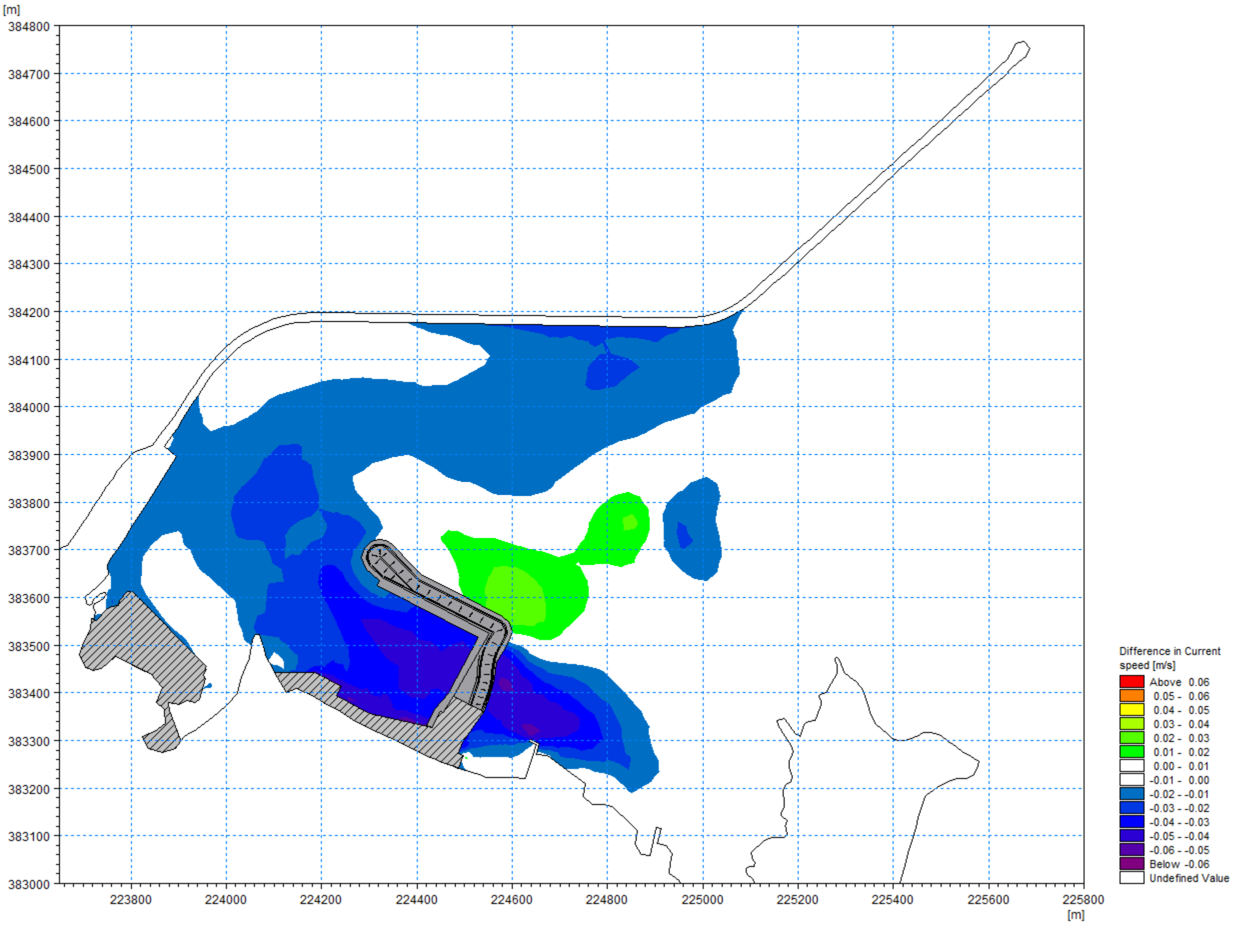

Figure 4.10: Difference in peak current velocities due to the scheme during the flood phase of a spring tide

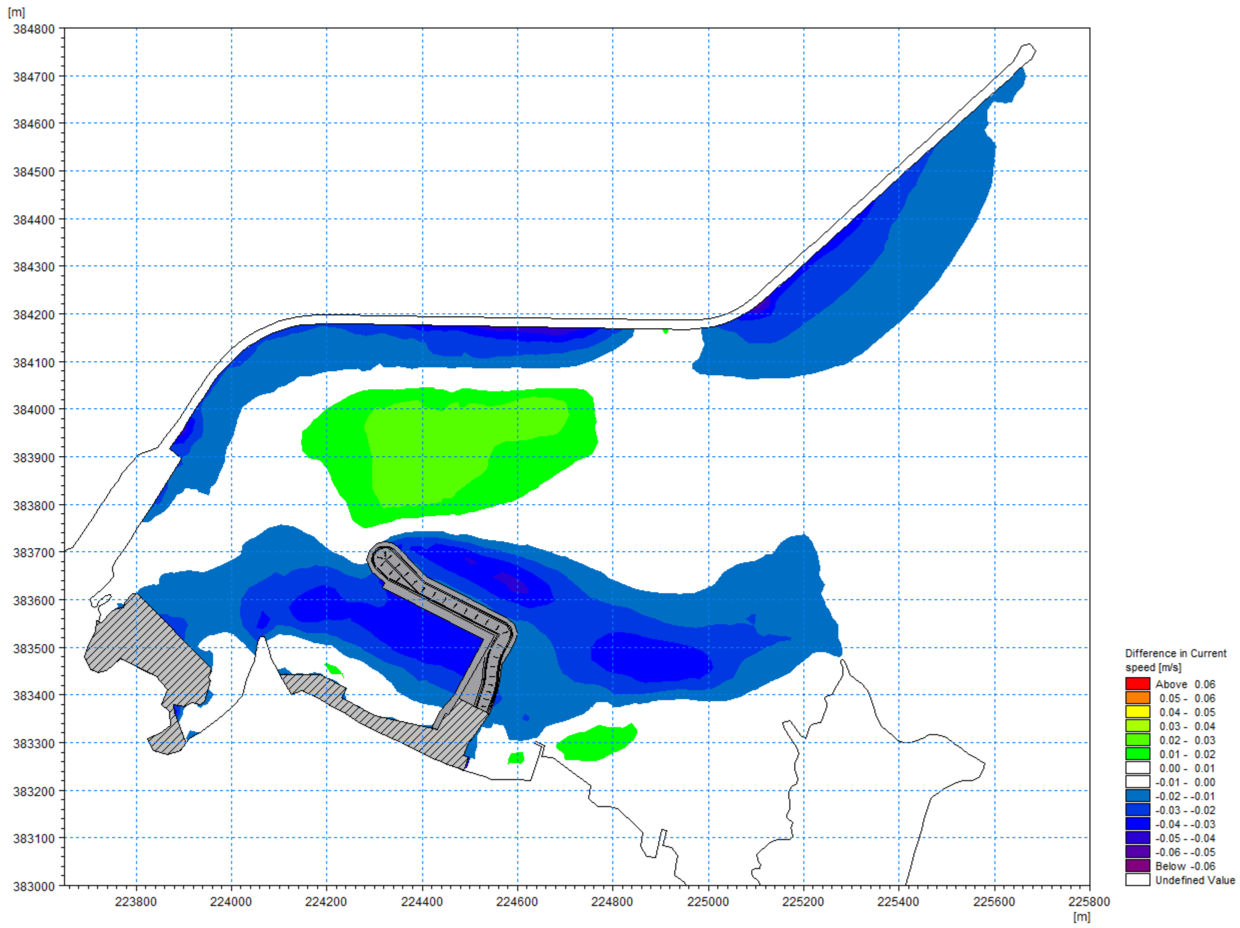

Figure 4.11: Difference in peak current velocities due to the scheme during the ebb phase of a spring tide

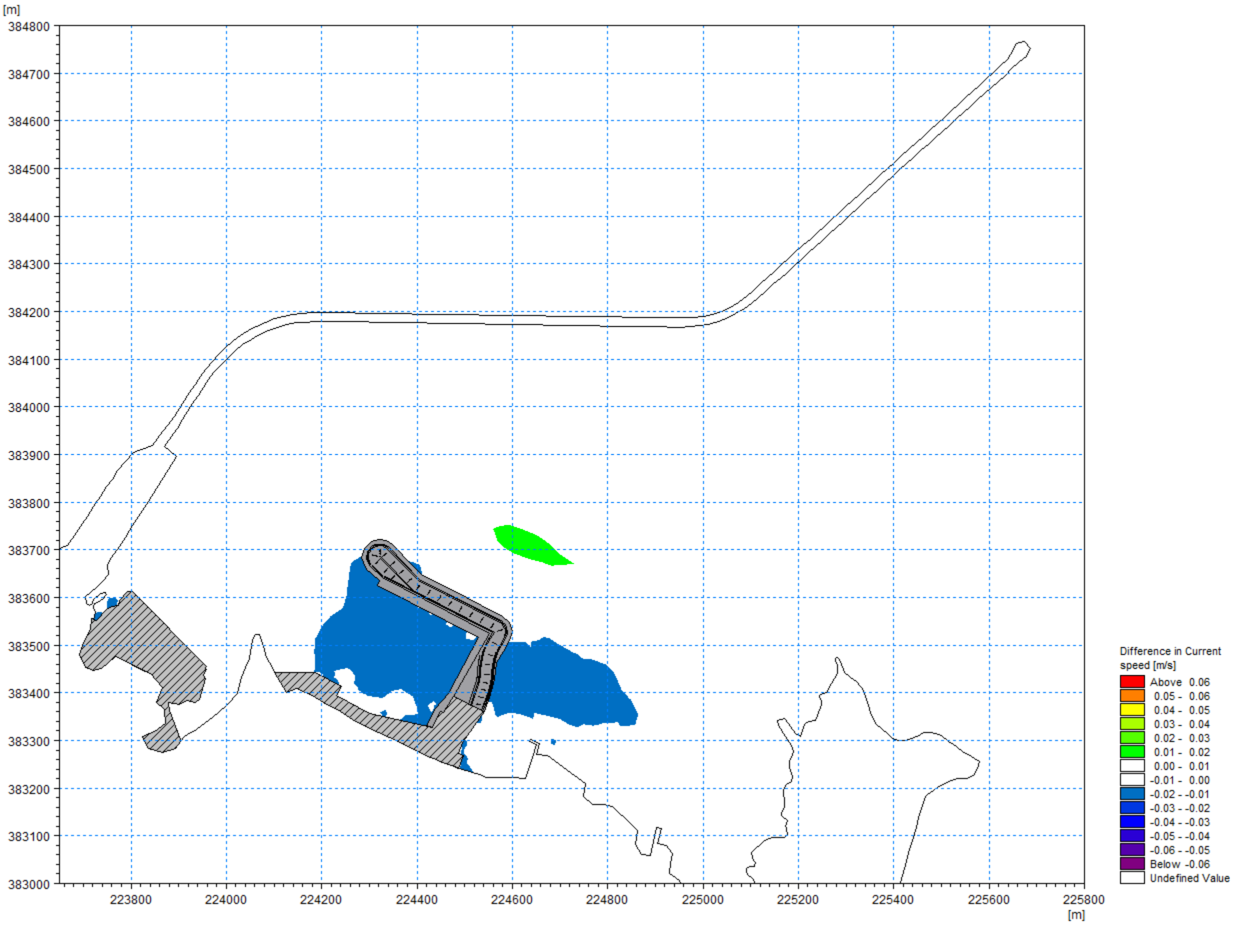

Figure 4.12: Difference in peak current velocities due to the scheme during the flood phase of a neap tide

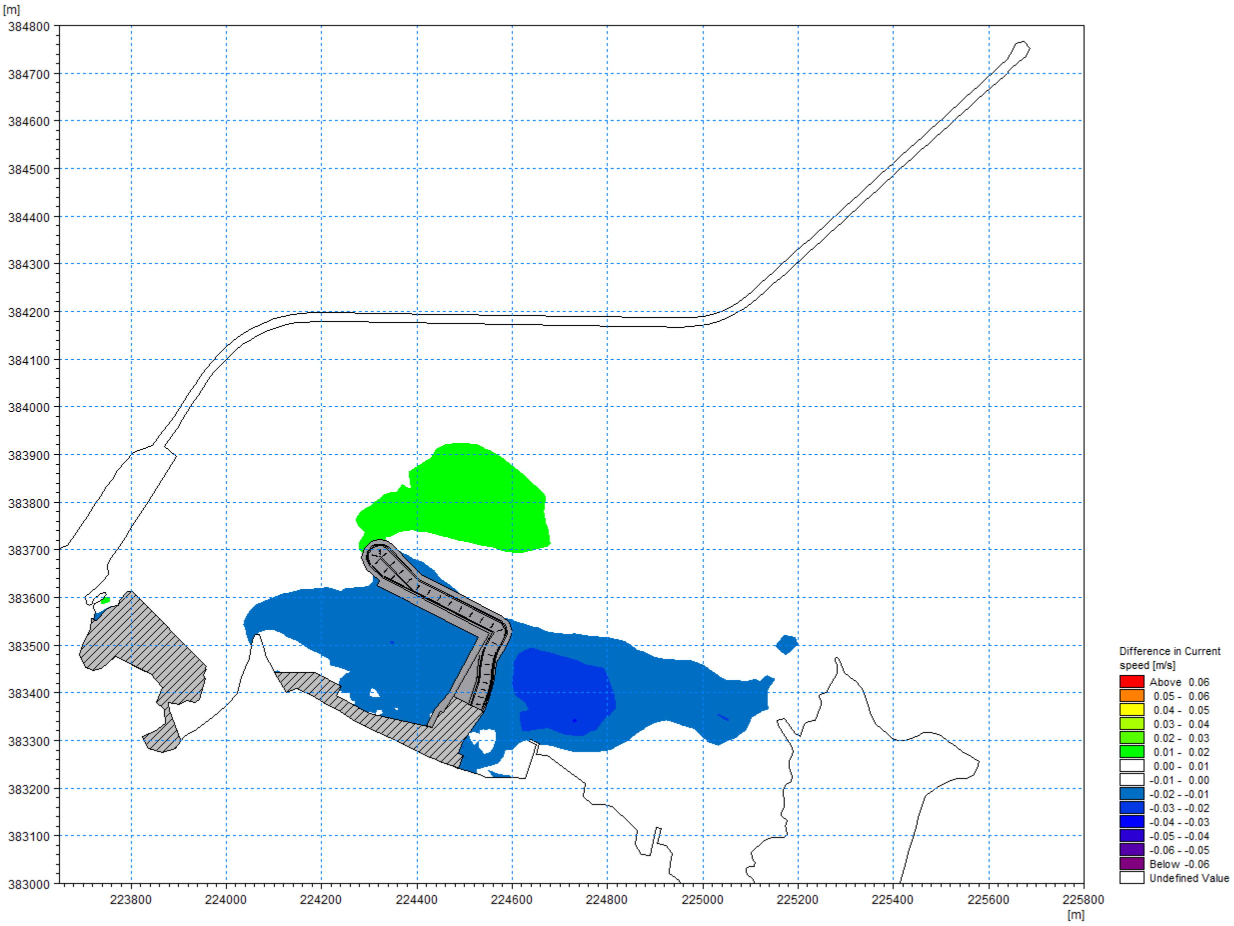

Figure 4.13: Difference in peak current velocities due to the scheme during the ebb phase of a neap tide

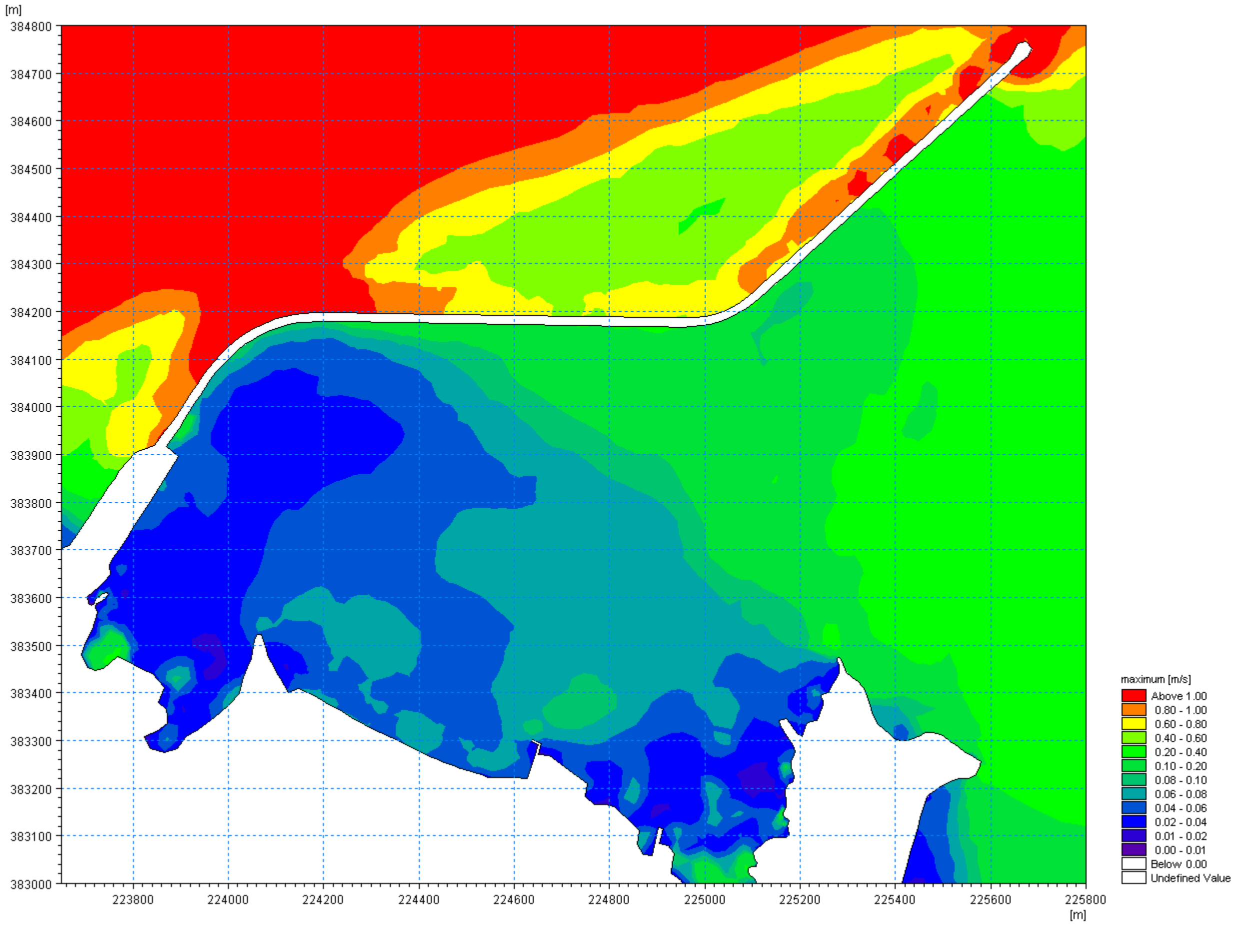

Figure 4.14: Baseline - Maximum current velocities throughout model period of March 2018

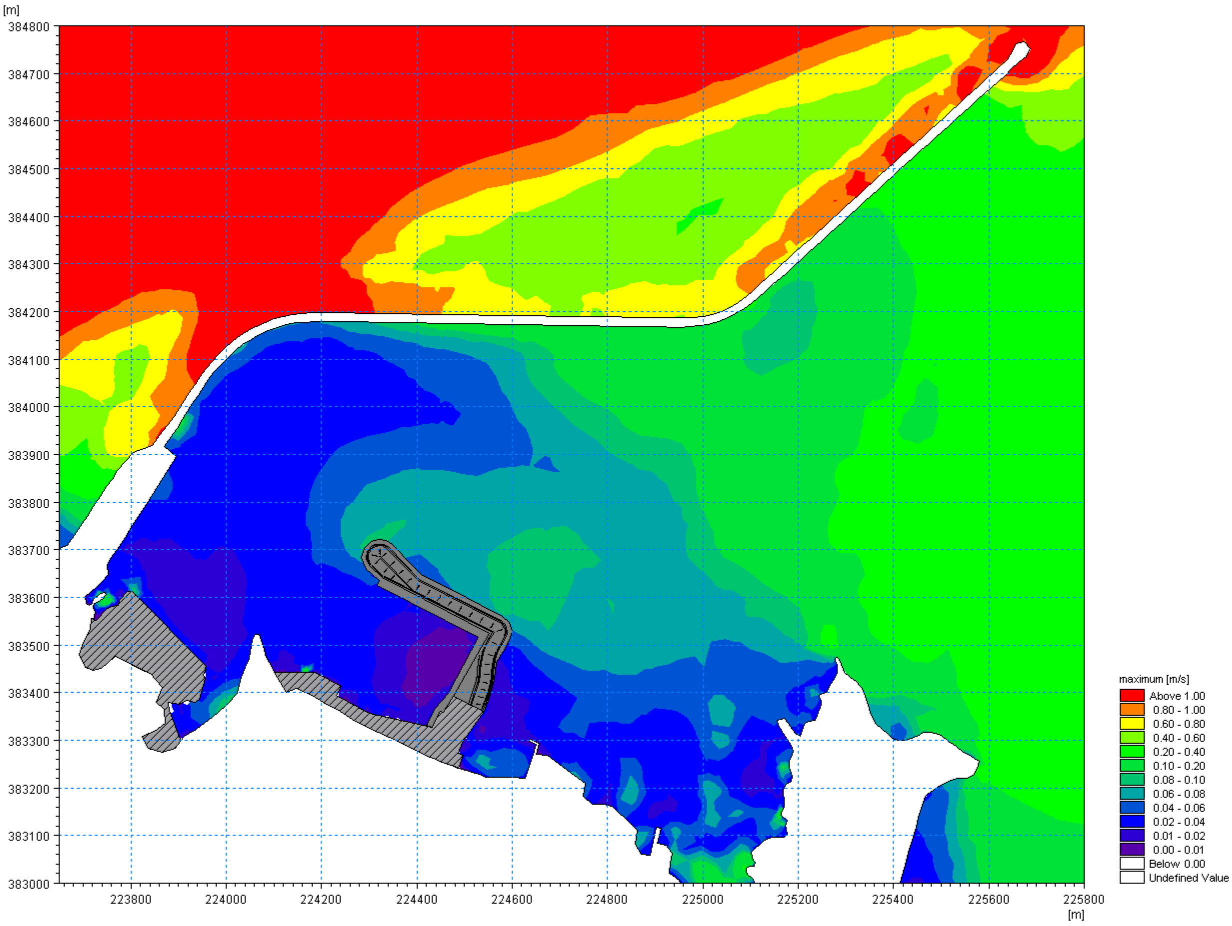

Figure 4.15: With Scheme - Maximum current velocities throughout model period of March 2018

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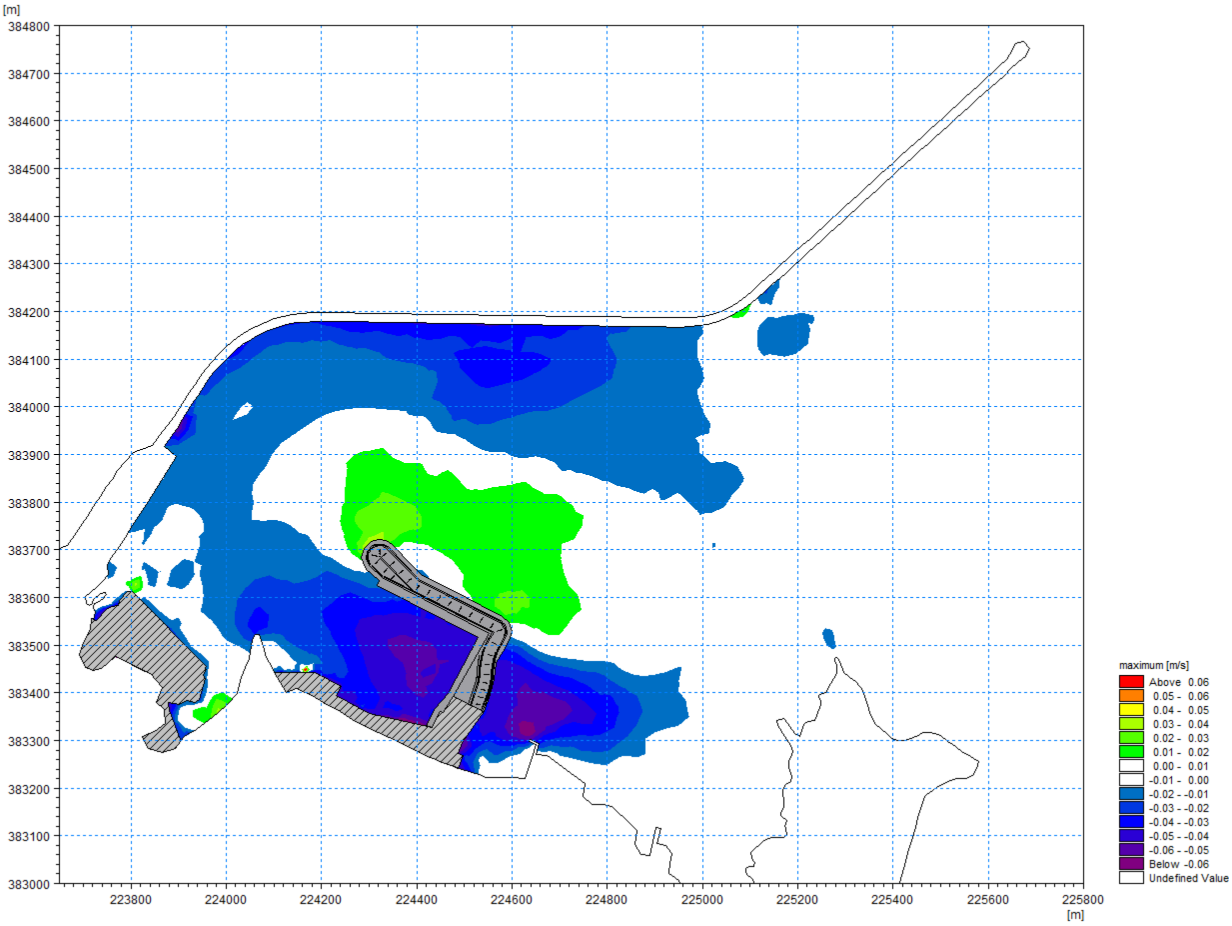

Figure 4.16: Difference in maximum current velocities due to the scheme throughout model period of March 2018

The bed shear stress for the 'Baseline' scenario is shown in **Figure 4.17** to **Figure 4.20**. The bed shear stress in the New Harbour and near the study site are generally below 0.015N/m^2. **Figure 4.21** to **Figure 4.24** show the bed shear stress for the 'With Scheme' scenario. The differences between the 'Baseline' scenario and the 'With Scheme' scenario show the location and magnitude of any potential changes in bed shear stress directly from the scheme. They are shown in **Figure 4.25** to **Figure 4.28**. The differences in bed shear stress are all below +/-0.015N/m^2.

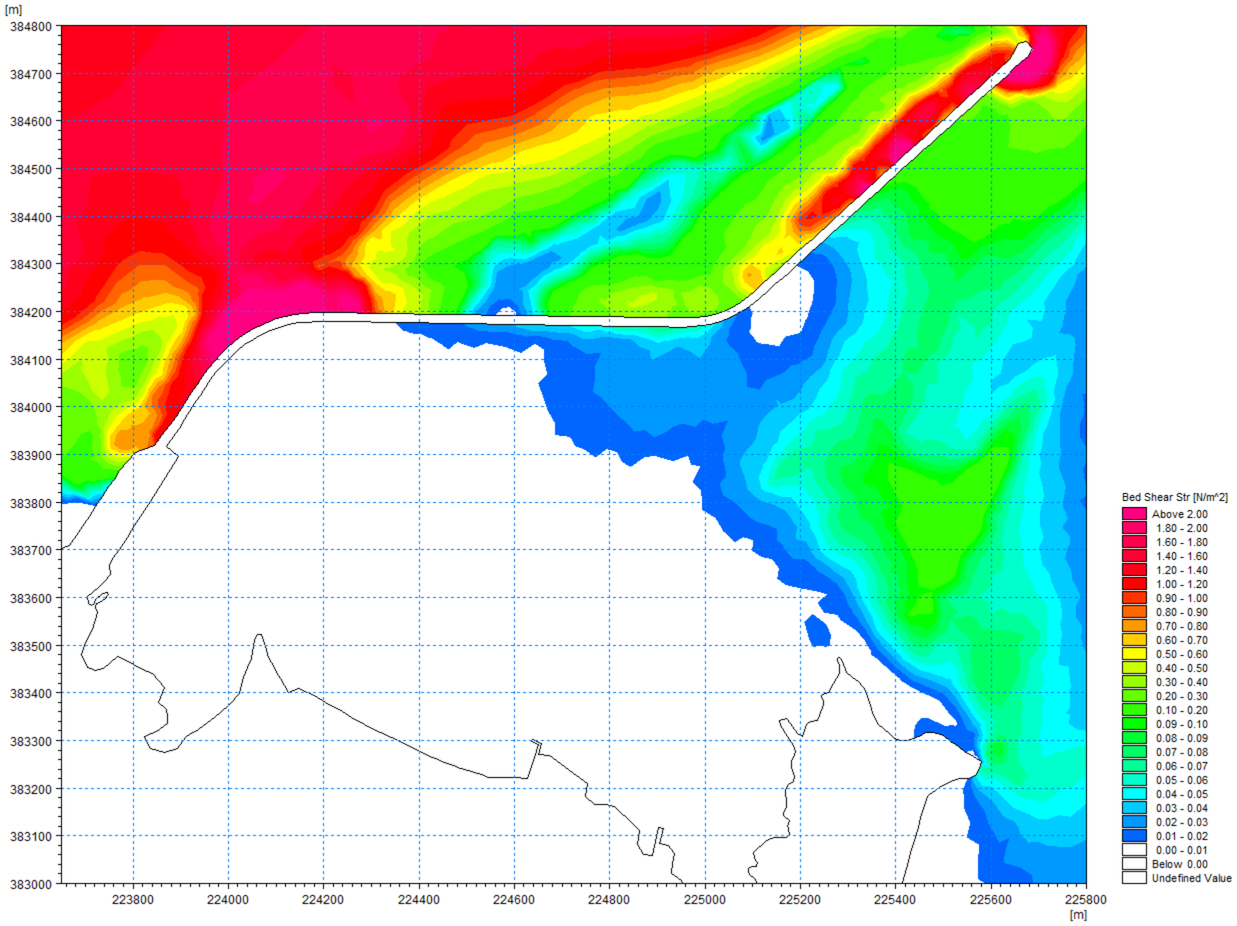

Figure 4.17: Baseline - Bed Shear Stress during the flood phase of a spring tide

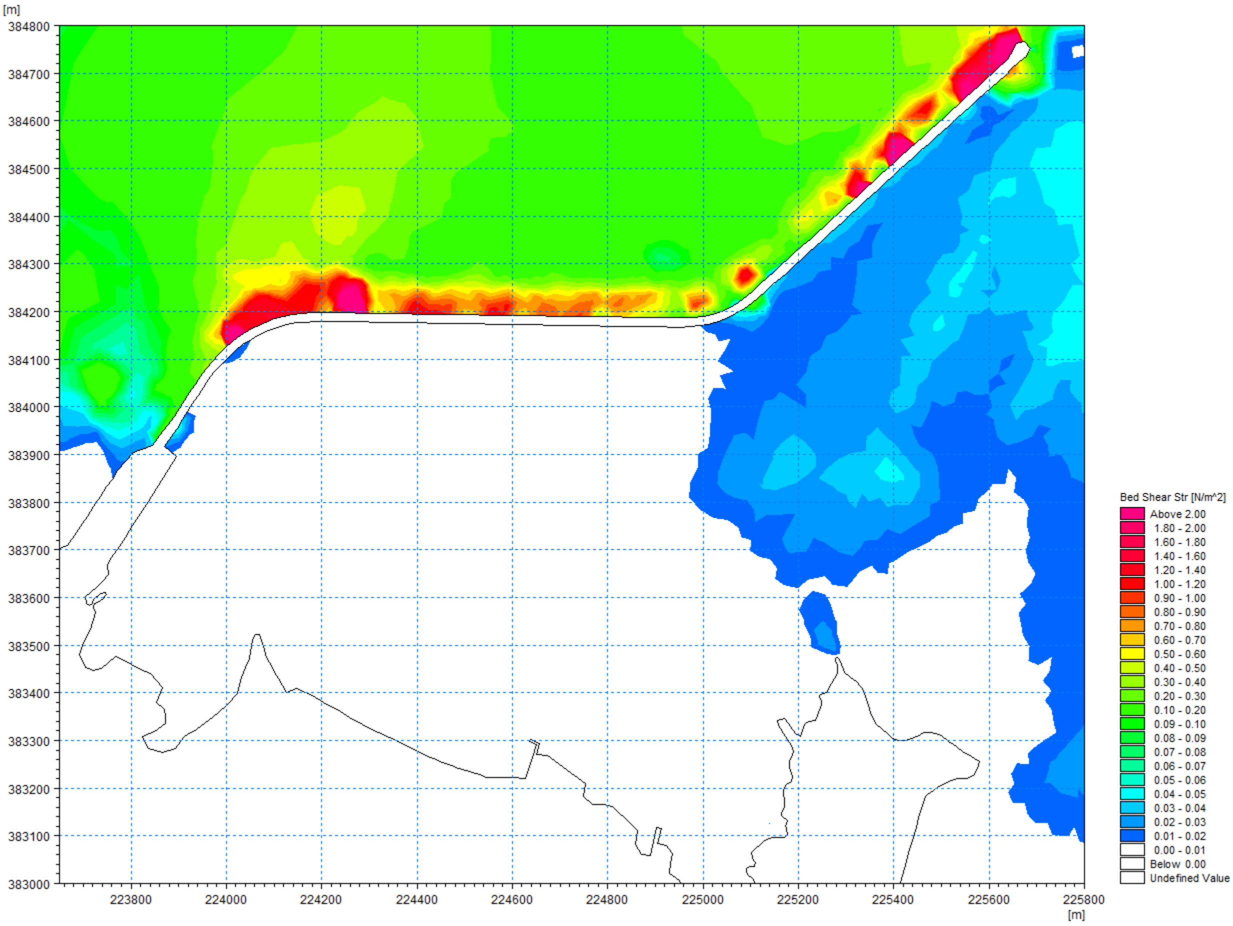

Figure 4.18: Baseline - Bed Shear Stress during the ebb phase of a spring tide

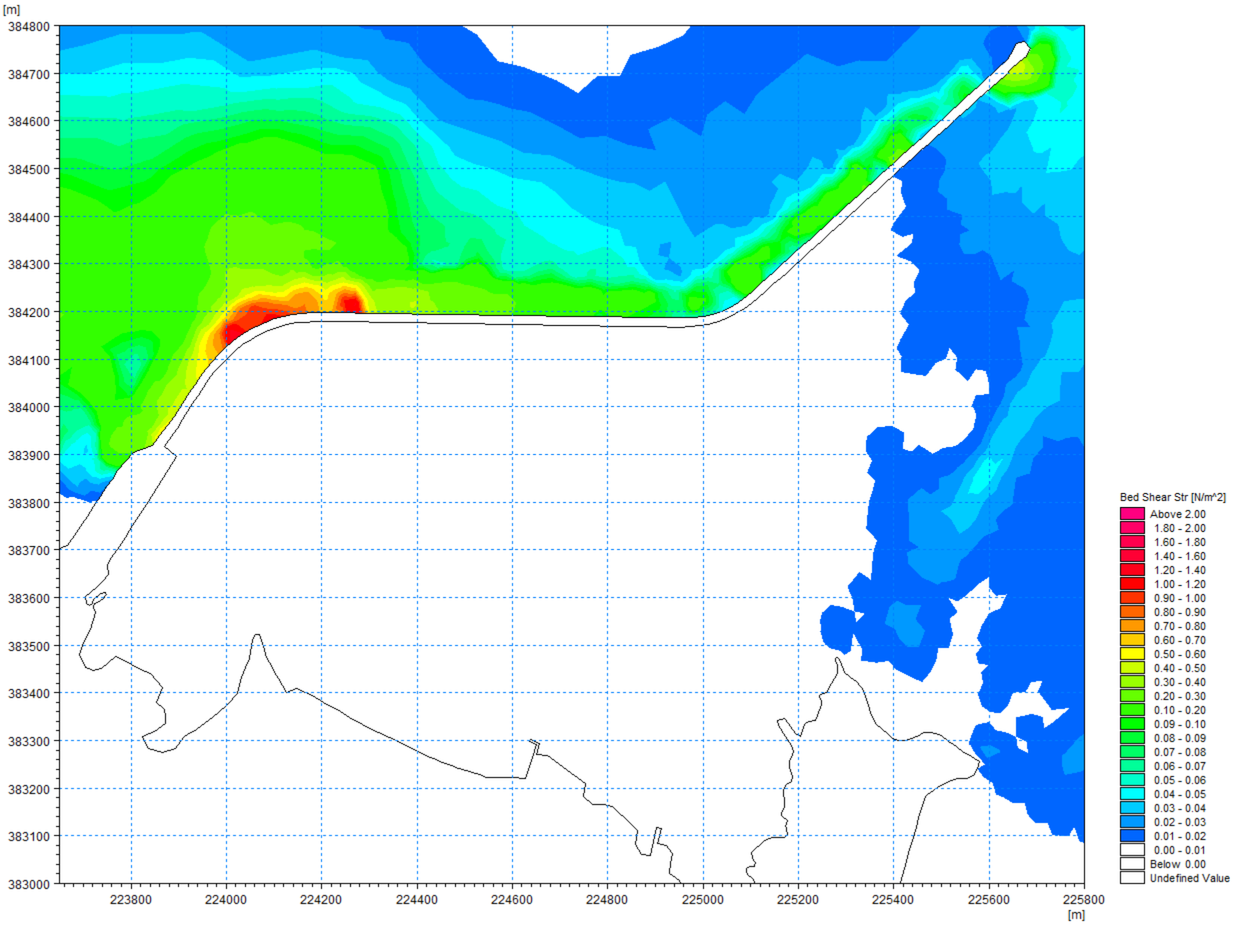

Figure 4.19: Baseline - Bed Shear Stress during the flood phase of a neap tide

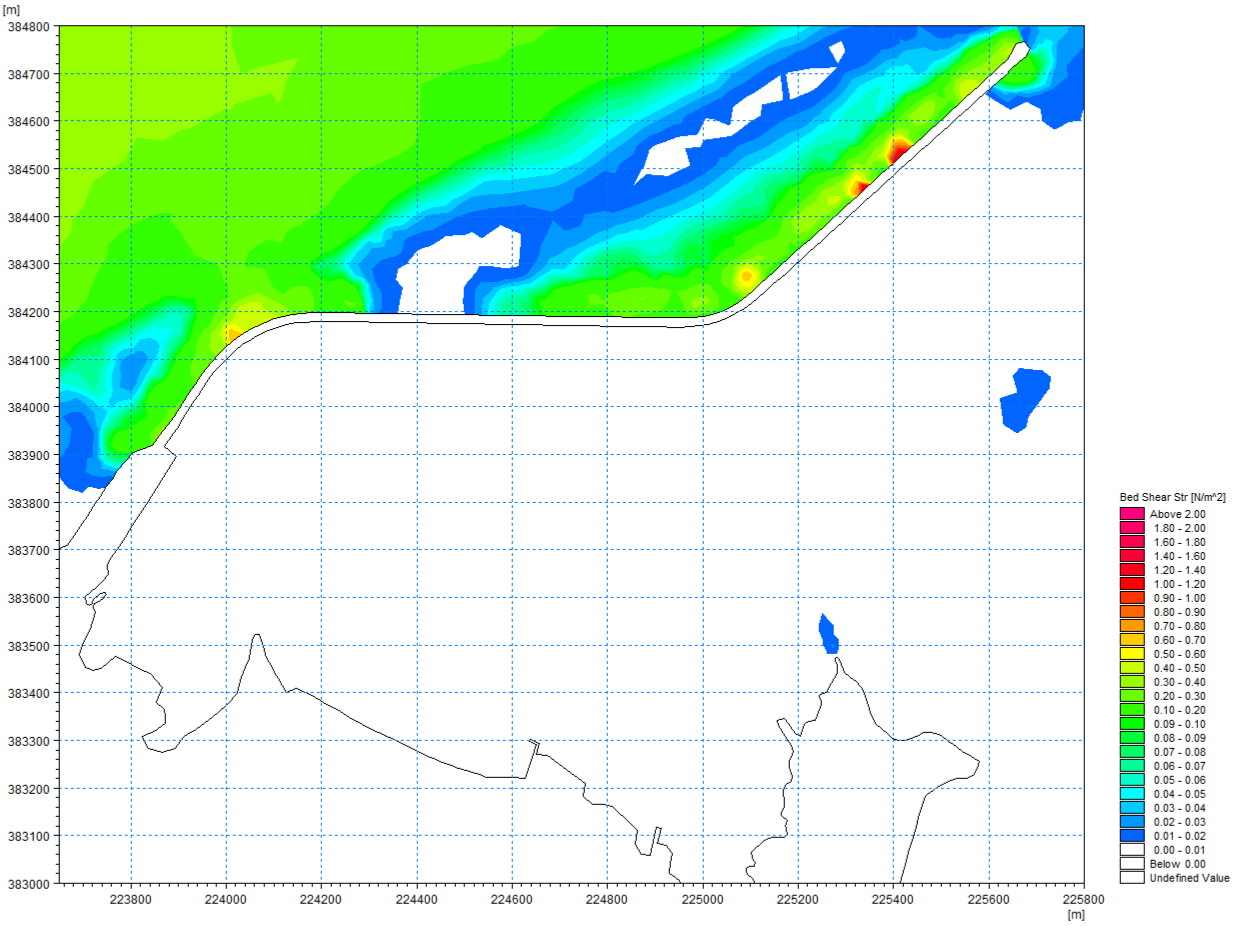

Figure 4.20: Baseline - Bed Shear Stress during the ebb phase of a neap tide

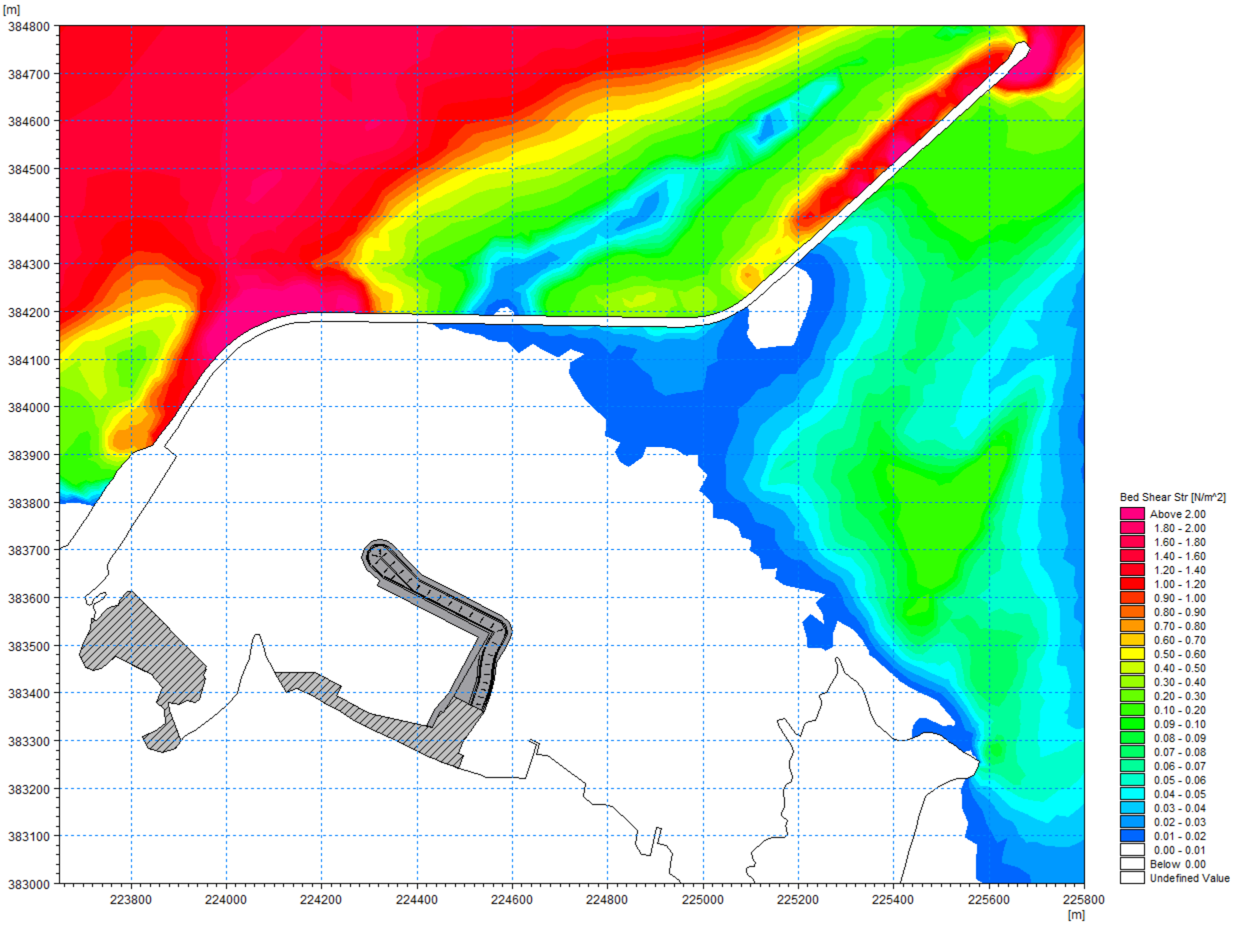

Figure 4.21: With Scheme - Bed Shear Stress during the flood phase of a spring tide

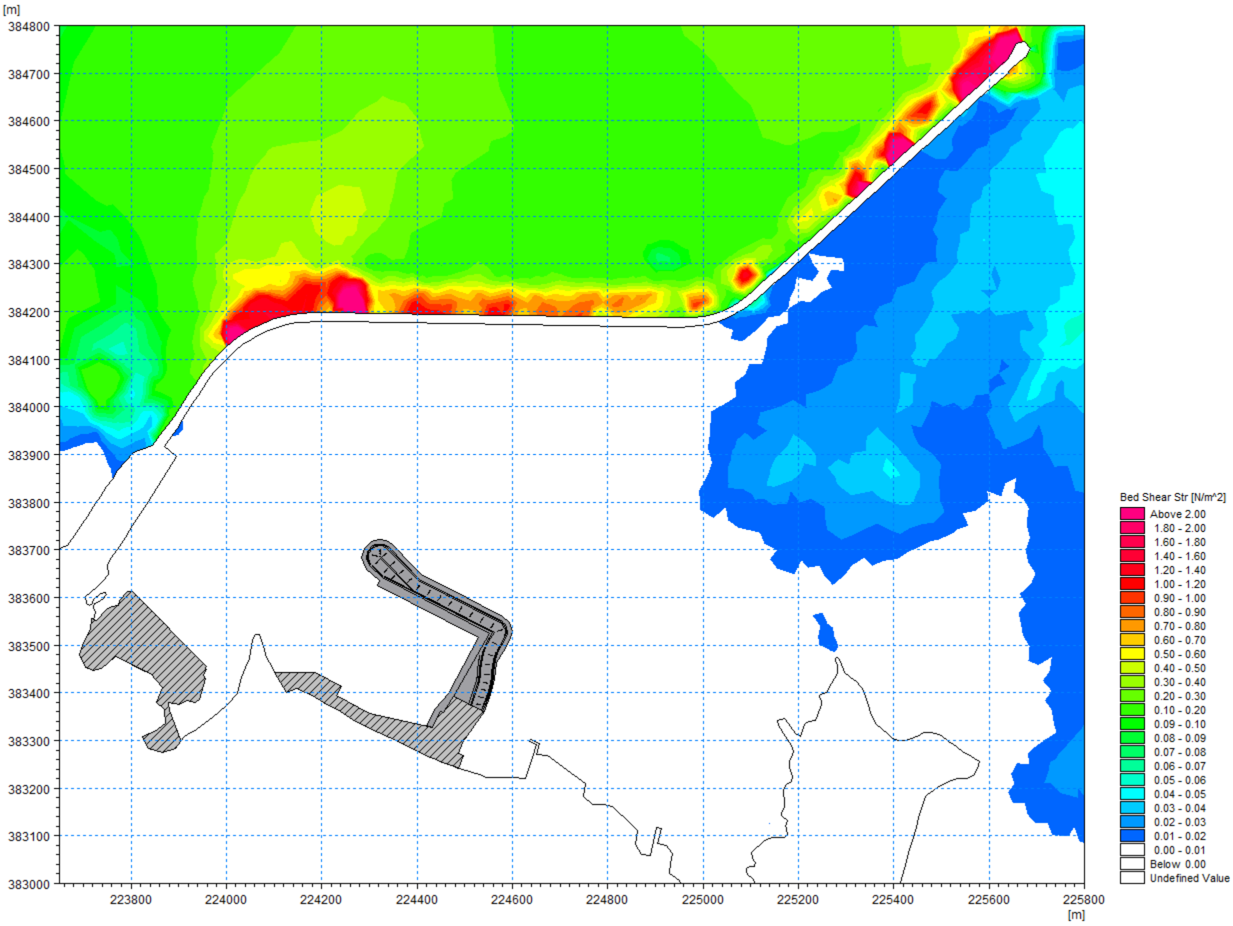

Figure 4.22: With Scheme - Bed Shear Stress during the ebb phase of a spring tide

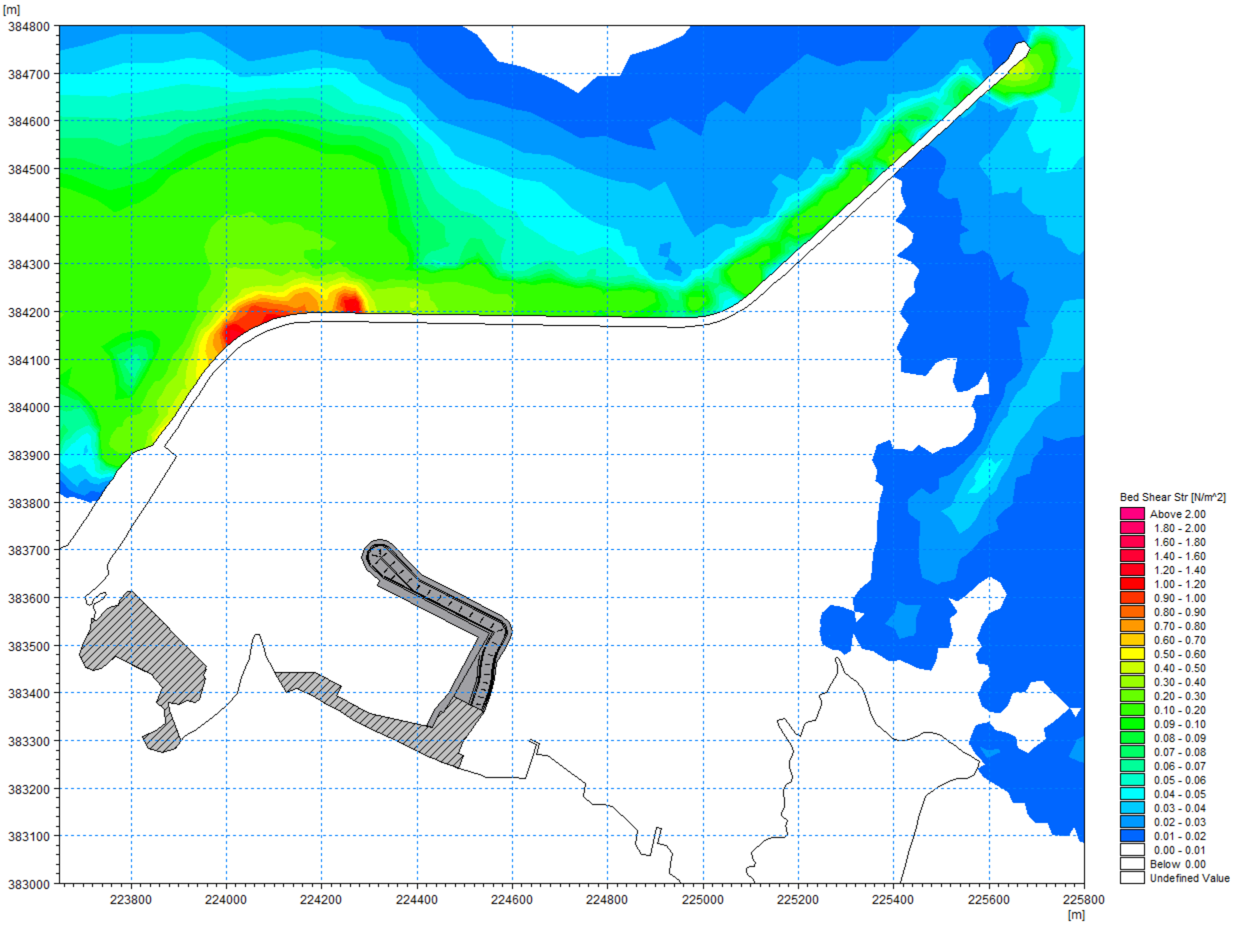

Figure 4.23: With Scheme - Bed Shear Stress during the flood phase of a neap tide

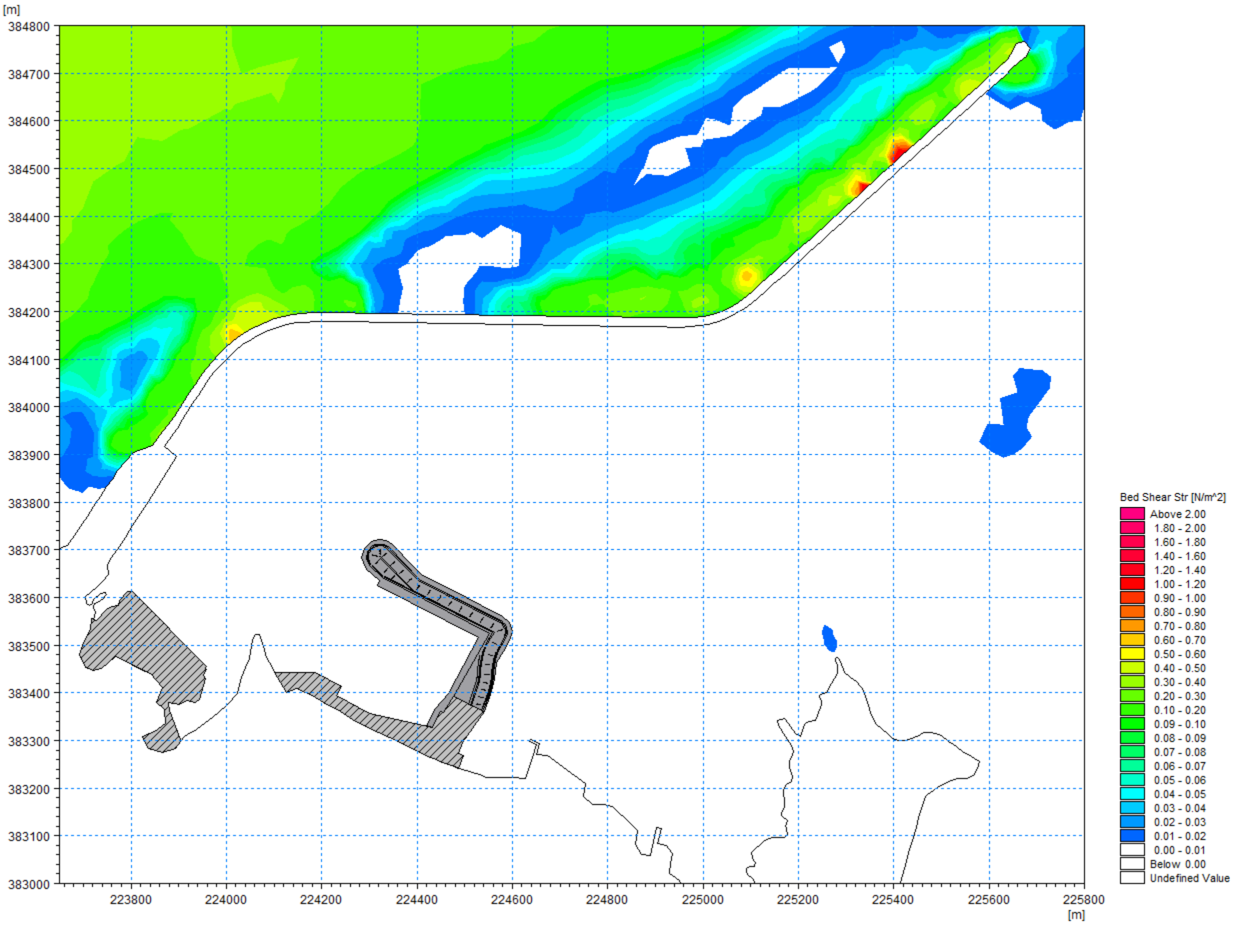

Figure 4.24: With Scheme - Bed Shear Stress during the ebb phase of a neap tide

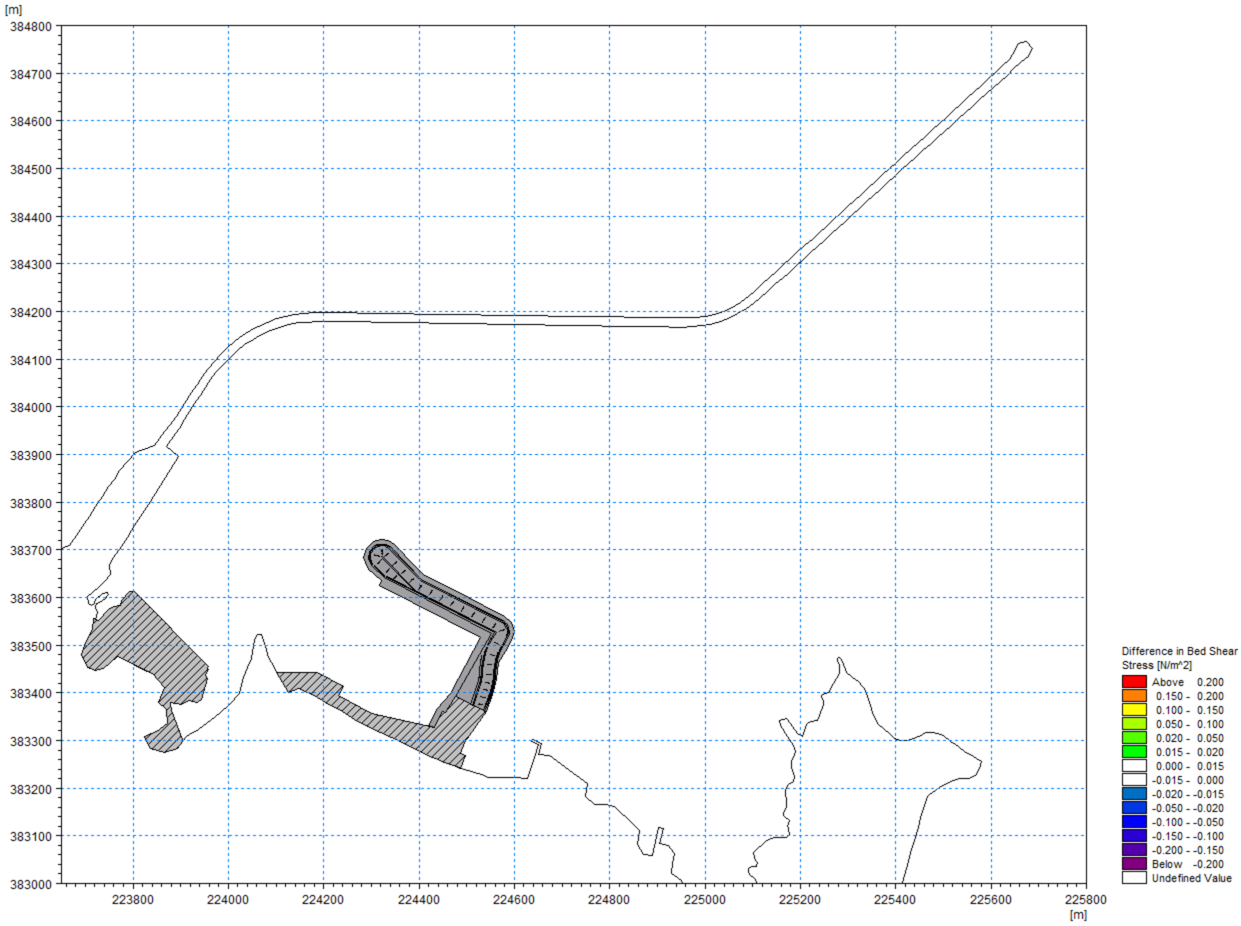

Figure 4.25: Difference in Bed Shear Stress during the flood phase of a spring tide

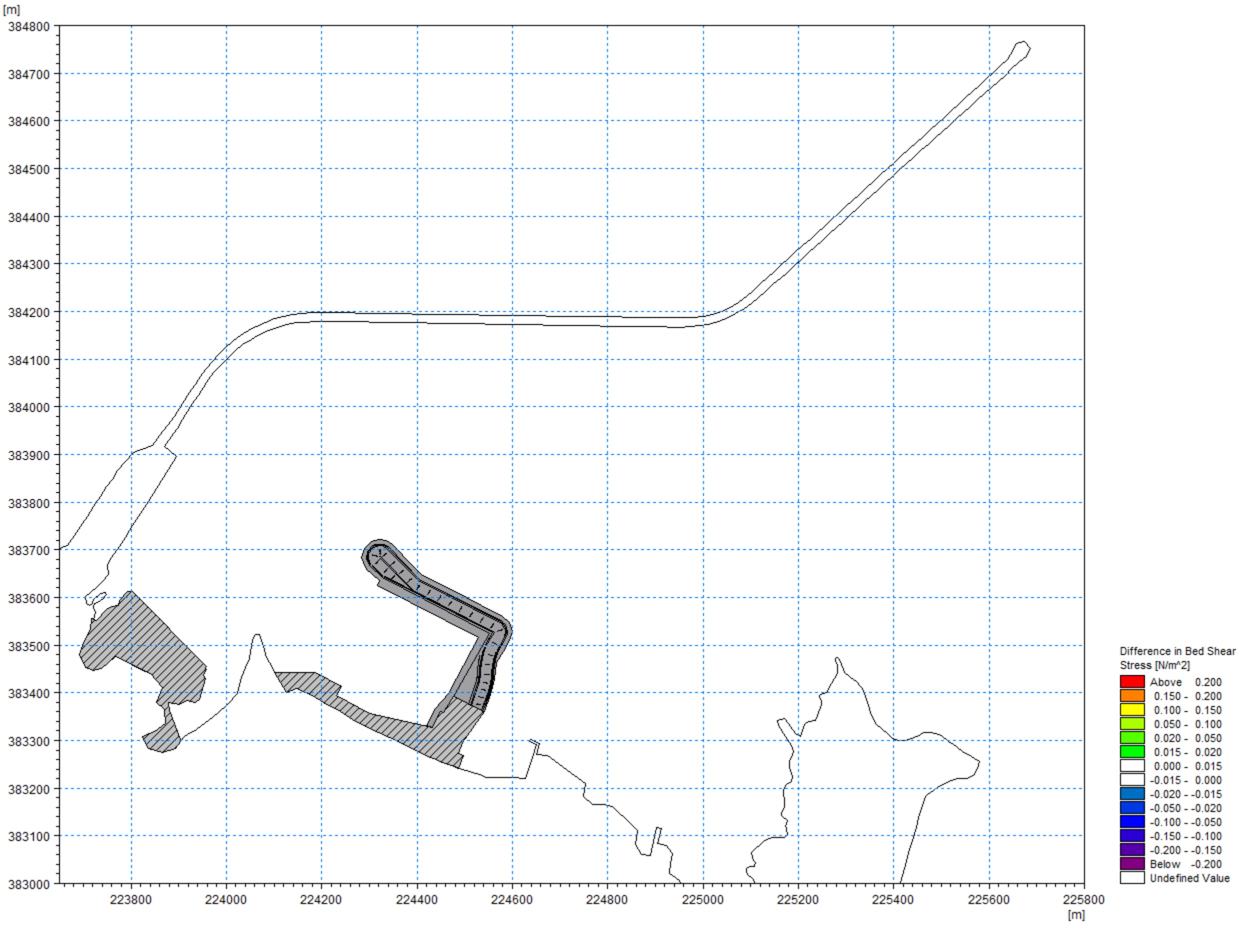

Figure 4.26: Difference in Bed Shear Stress during the ebb phase of a spring tide

Royal HaskoningDHV

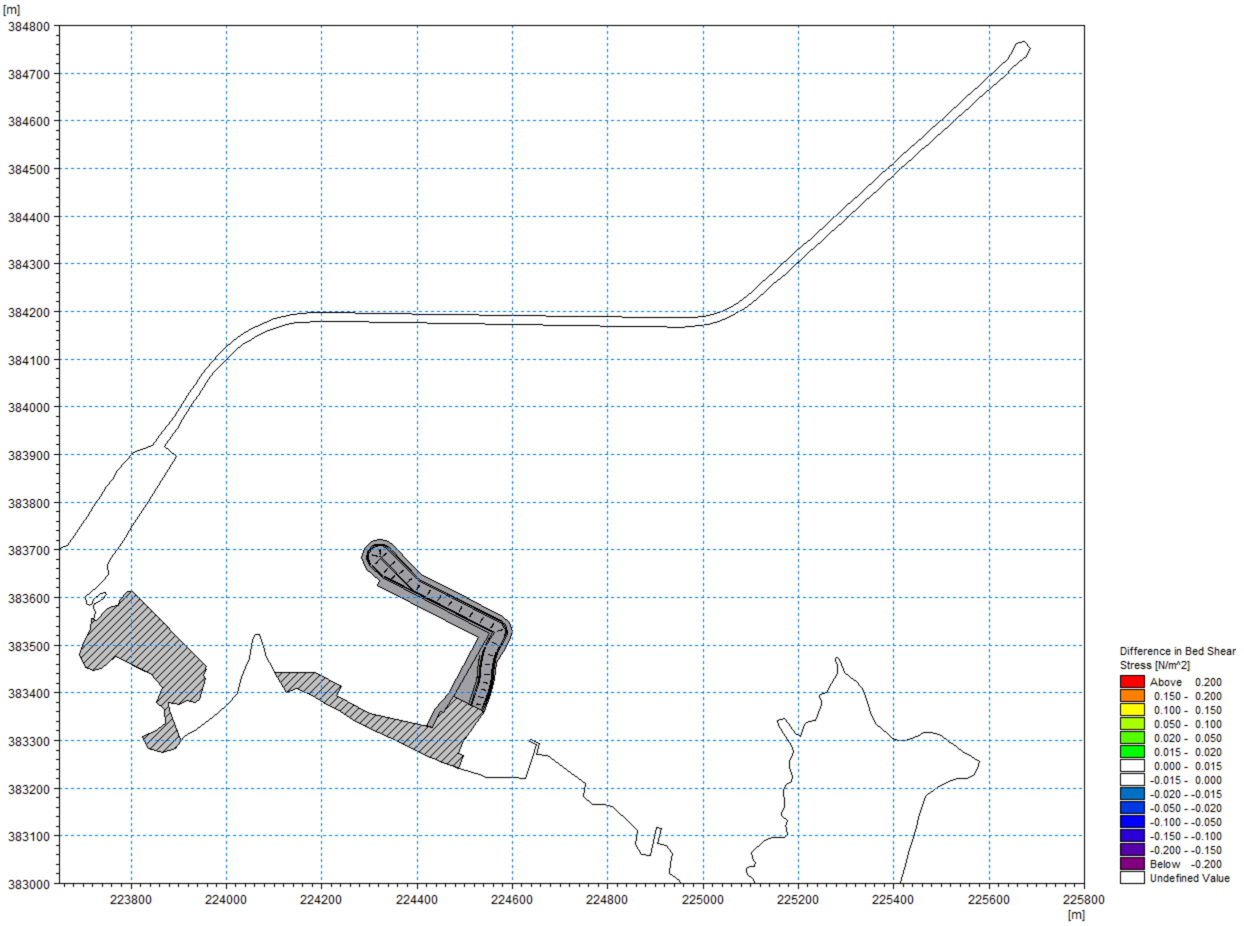

Figure 4.27: Difference in Bed Shear Stress during the flood phase of a neap tide

Royal HaskoningDHV

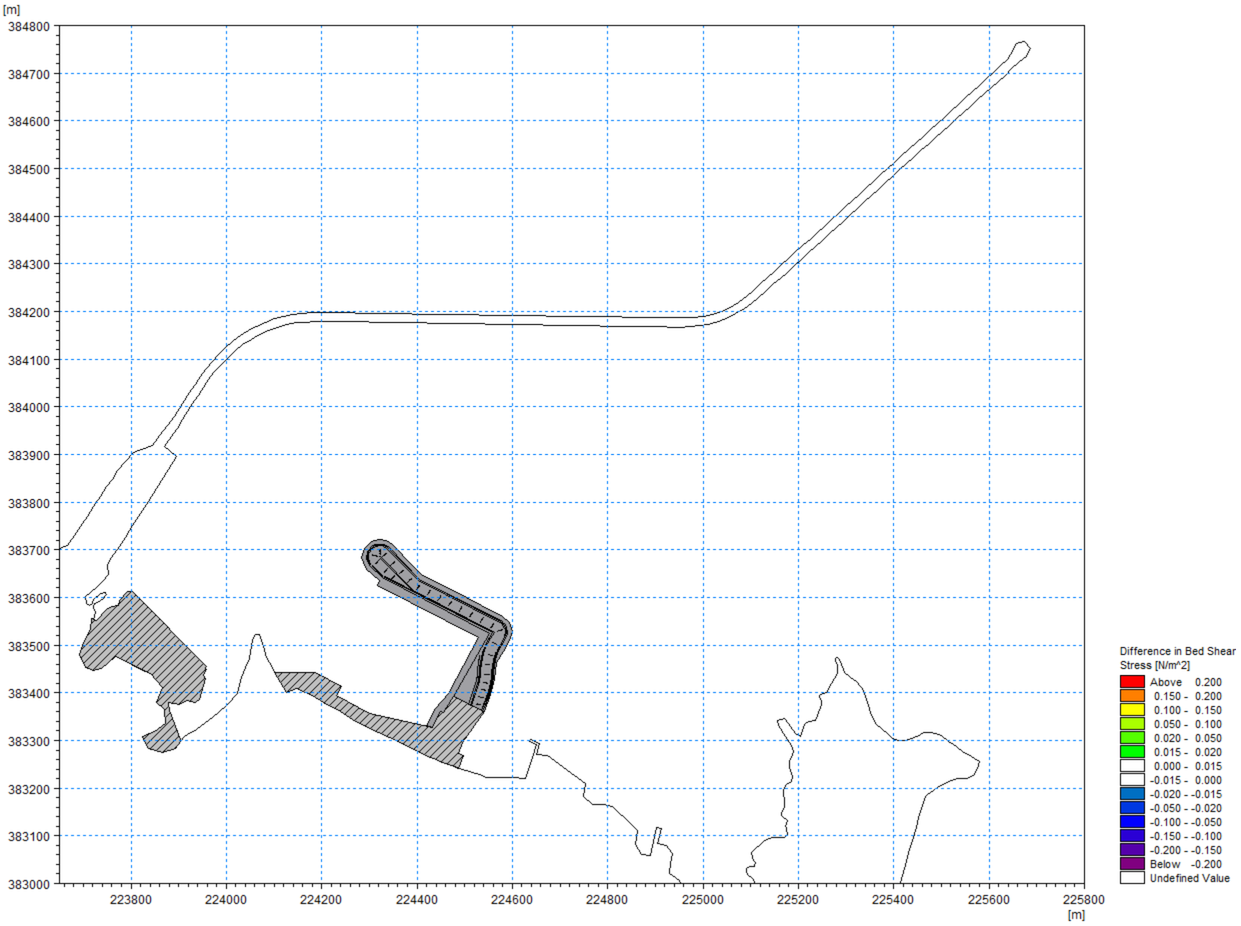

Figure 4.28: Difference in Bed Shear Stress during the ebb phase of a neap tide

4.3 Conclusion

The changes in current speed due to the scheme are predominantly between +/-0.01 and +/-0.01m/s and are localised. Therefore the changes do not appear to have any significant impact on the velocities in this area.

The changes in bed shear stress due to the scheme are below +/-0.015N/m^2 and therefore have little morphological significance.

5 Sediment Dispersion Model Setup

5.1 3D Model Set-up

The sediment dispersion models were set up by coupling a sediment transport model built in MIKE3-MT model with a 3D hydrodynamic model built in MIKE3-HD.

For the sediment dispersion modelling two nesting 3D models were set up. The first 3D model covers Holyhead Bay and the Holyhead Waterfront Development Site, extending from the Inland Sea and the River Afon Alaw to approximately 2km offshore beyond Holyhead Breakwater.

The second 3D model covers the Offshore Holyhead North Disposal Site, the north-west corner of Holyhead Island and the extent of the first 3D model.

In both 3D models, 10 vertical layers were introduced to differentiate between suspended sediment concentrations throughout the water column, e.g. between near the sea bed and near the water surface.

The model boundary conditions for the two 3D models are provided by the 2D Conygar Model.

Figure 5.1 and **Figure 5.2** show the extents of the 3D models that were used for the Holyhead Waterfront Development Site and the Offshore Holyhead North Disposal Site respectively.

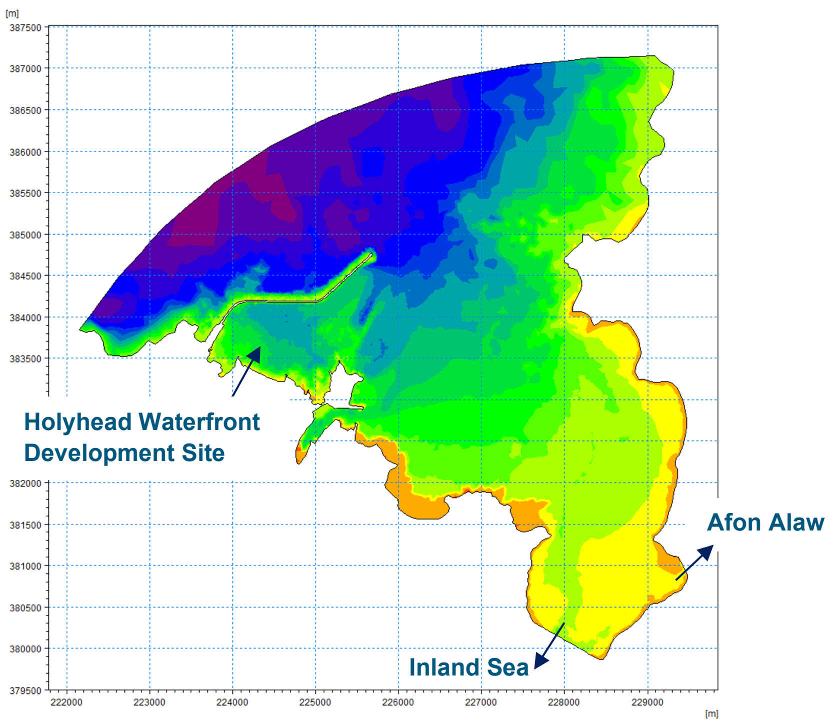

Figure 5.1: 3D Model Extent for Holyhead Waterfront Development

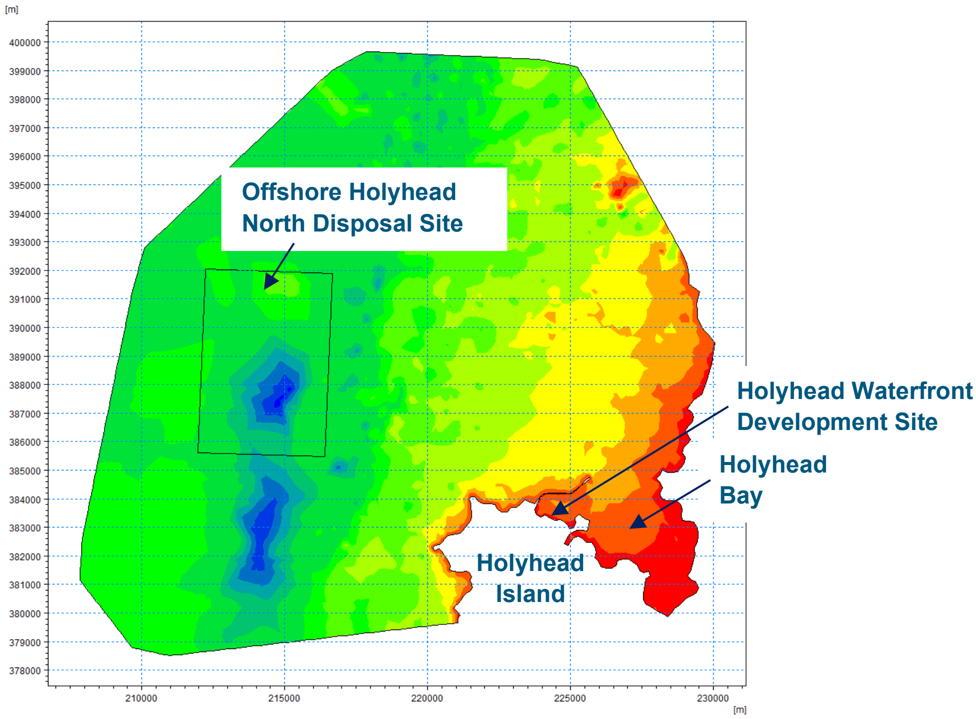

Figure 5.2: 3D Model Extent for Offshore Holyhead North Disposal Site

The dredging method, dredging schedule and details of the sediment release settings for the plume dispersion model are described in this section. The dispersion model has been setup in order to simulate sediment plumes arising from dredging, land reclamation and offshore disposal during the construction phase.

The sediment dispersion model has been run for a 5.2-week period to cover the full duration of the dredging schedule. Due to the uncertainty of the time when the dredging will take place, the worst scenario in terms of the tides has been chosen, and the model has been run for the period of March/April in which spring tides are slightly higher.

In order to simulate the sediment dispersion close to natural conditions, wave disturbance effect has been included in the MIKE3-MT model using a 1 in 1 year wave condition with waves approaching Holyhead Bay from a north-westerly direction. 1 in 1 year wave condition is considered to be the upper limit of dredging operation, therefore, the worst scenario with respect to wave climate. **Figure 5.3** shows the propagation of 1 in 1 year wave condition into the Holyhead Waterfront Development Site. The wave conditions were produced by a MIKE21-SW spectral wave model. Details of the wave transformation modelling are provided in the technical note titled “Holyhead Waterfront Development – Wave Transformation Model” (reference: PB8908-RHD-ZZ-ZZ-FN-C-002).

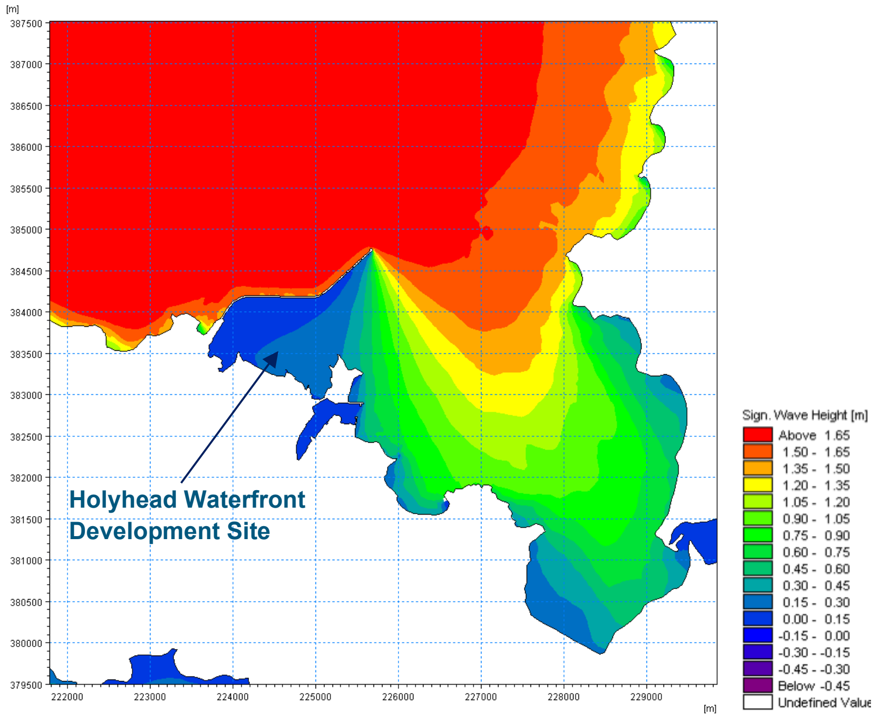

Figure 5.3: 1 in 1 year wave condition used for 3D model covering the Holyhead Waterfront Development Site

5.2 Dredging Method

The available soil data indicates that the expected dredge material can be classified as soft soil. Therefore, it is proposed for this soft sediment layer to be dredged using a Backhoe Dredger (BHD). The dredging scope consists of removing material inside the proposed breakwater footprint.

All dredged material will be taken to the Holyhead North offshore disposal site which is approximately 15km (or 8 nautical miles) away from the Holyhead Waterfront development site. The locations of the proposed land reclamation areas, proposed dredge area and dredger path are shown in **Figure 5.1**. The offshore disposal site Holyhead North is shown in **Figure 5.2**.

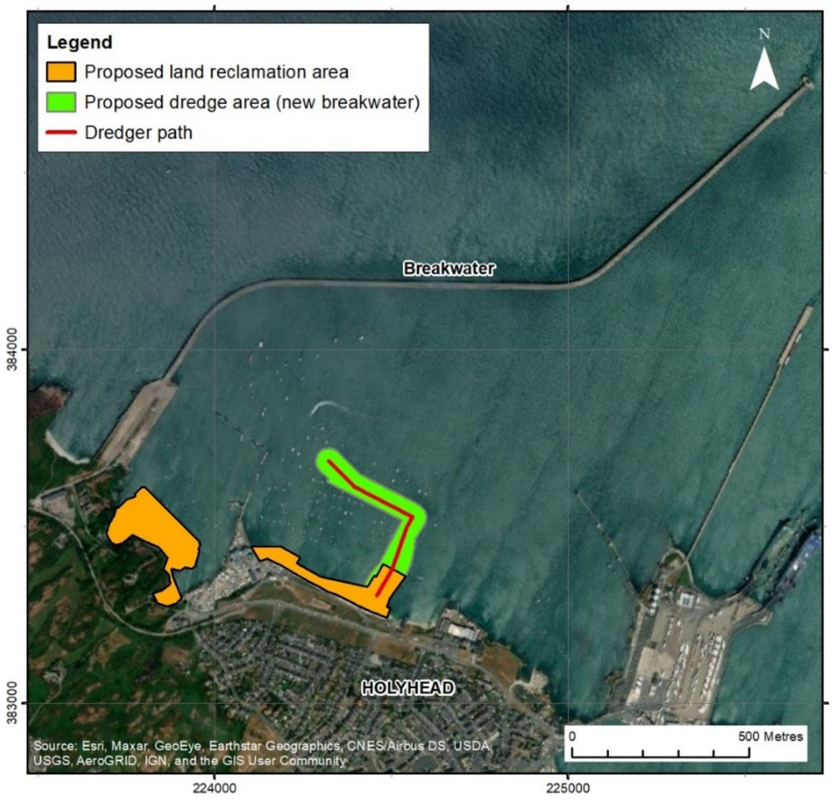

Figure 5.4: Proposed land reclamation areas, proposed dredge areas and dredger path

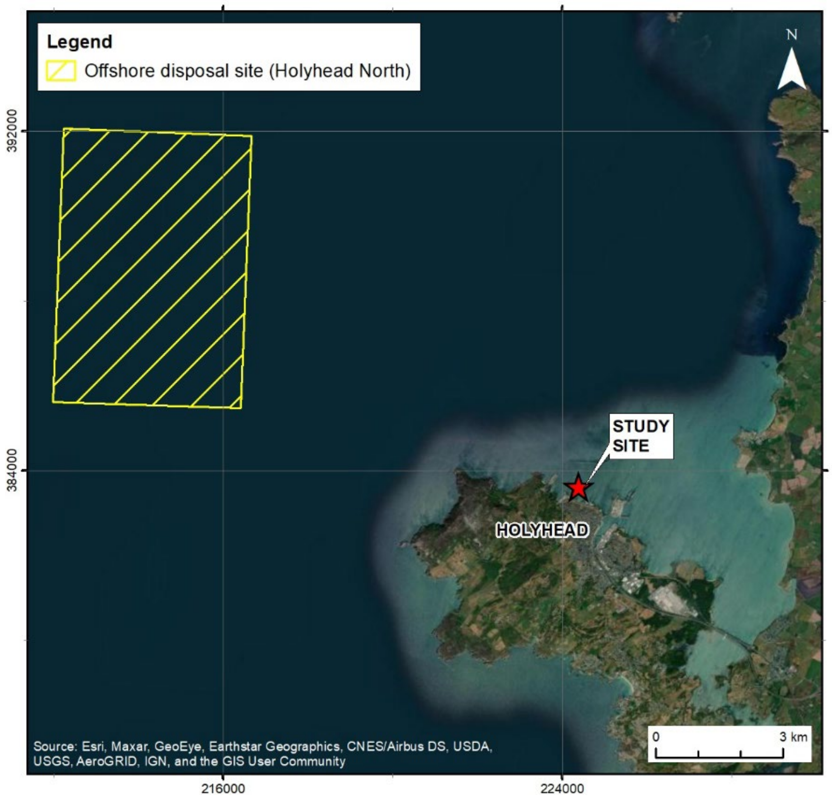

Figure 5.5: Location of offshore disposal site

5.3 Dredging Schedule

This section of the report summarises the dredging schedule used in the dispersion model. For further information on the dredging method and schedule refer to Appendix A, PB8908 Holyhead waterfront dredging note_update210316.

The dredging schedule and quantity for the BHD (Backhoe Dredger) for dredging and offshore disposal are described in **Table 5-1**. A total of 66,512 m^3 soft material will be dredged over a period of 5.2 weeks. The simulation covers the entire dredging period and the movement of dredger and transport barges were tracked for the processes of dredging, sailing, disposal and downtime for bad weather, refuelling, and equipment maintenance.

Table 5-1: Dredging schedule

	Backhoe (and barge)
Distance to disposal site (nm)	8
Barge load (m^3)	475
Barge sailing speed empty (knots)	11
Barge sailing speed loaded (knots)	10
Dredge time per barge (minutes)	125
Barge sailing time empty (minutes)	43.6
Barge sailing time loaded (minutes)	48
Discharging time (minutes)	10
Total dredging cycle time (minutes)	**124.8**
Production rate (m^3/hr)	**228**
Effective operational hours per week	**65**
Dredging volume (m^3)	**66,512**
No weeks	**5.16**

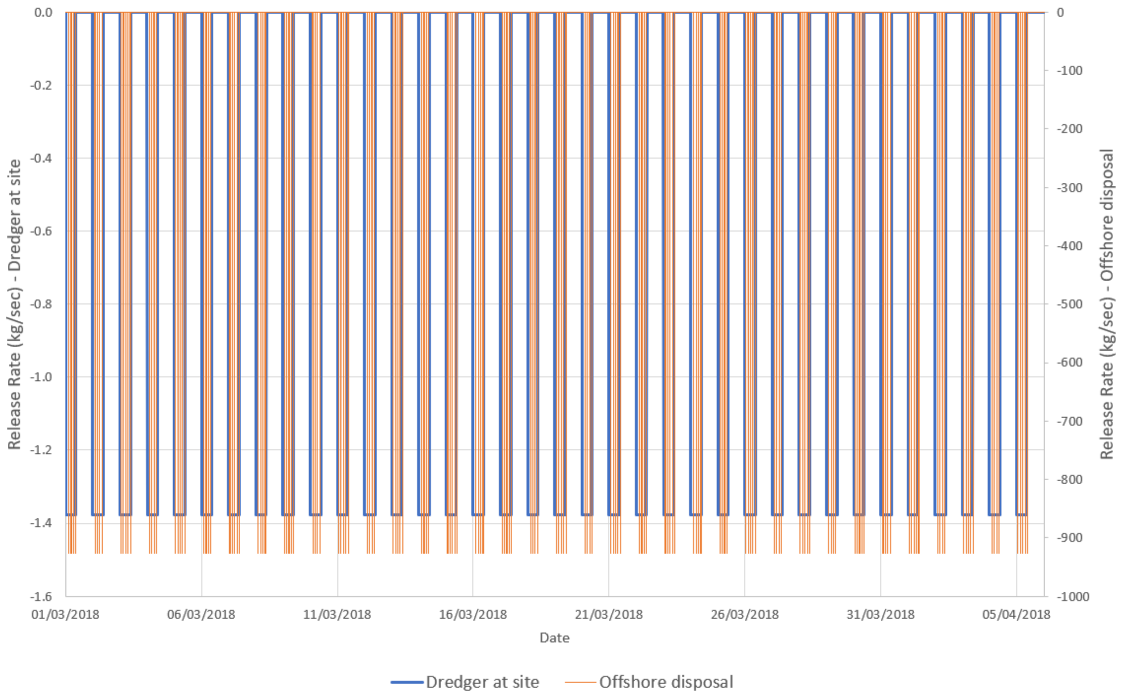

Figure 5.6: Sediment release schedule for dredger and offshore disposal

5.4 Sediment Release

The following assumptions have been made for the simulation of sediment plumes arising from dredging during the construction phase.

One backhoe dredger will be in operation, releasing material along one single line as shown on **Figure 5.4**, which is a conservative approach. The dredger will actually move around the dredging area along multiple lines which means the sediment release will be more dispersed and thus the sediment concentration will be less.

The soft soil material that will be dredged has been categorised into five sediment fractions. The sediment fractions, critical bed shear stresses and fall velocities used in the sediment dispersion model to represent bed sediment are shown in **Table 5-2**. The critical bed shear stress and fall velocities were calculated using SandCal software developed by HR Wallingford.

Table 5-2: Sediment dispersion model input settings

Sediment Grading Type	Proportions of different sediment fractions (%) BHD (soft material)	Critical bed shear stress (N/m^2)	Fall velocity (m/s)
Silt/clay	95	0.0847	0.000554
Fine sand	2	0.1548	0.00935
Medium sand	1	0.2025	0.0372
Coarse sand	1	0.657	0.135
Gravel	1	1.166	0.1734

The backhoe dredger will dredge 66,512m^3 of soft material for offshore disposal. The dredger would operate continuously filling a barge, with two barges being in operation sailing back and forth to the offshore disposal site. The dredger disperses sediment into the water column at a sediment release rate of 1.38 kg/s. The rate is calculated based on sediment loss rate (the so-called 'S-factor') of 25kg/m^3 for the Backhoe which follows the CIRIA Guidance (2000).

The backhoe will dredge for 125 minutes to load one barge, the barge will then sail for 48 minutes to the disposal site, discharge for 10 minutes with a discharge sediment rate of 927kg/s. The barge will then take 44 minutes to sail back to site. The total transport time of the barge including discharge takes 102 minutes.

The backhoe will take 5.2 weeks to complete this schedule based on that the backhoe works for 65 hours per week, which allows for downtime due to bad weather, refuelling, and equipment maintenance.

5.5 Results

The results of the sediment dispersion model simulations are shown in **Figure 5.7** to **Figure 5.14**.

Figure 5.7 to **Figure 5.9** show the maximum suspended sediment concentration at the development site for the surface layer, mid layer and bed layer, respectively. The sediment plume stays well within Holyhead Harbour and only concentrations below 10mg/l moving past the northern tip of Salt Island. The plume extent for the bed layer is slightly larger than the plume for the mid and bed layer. The suspended sediment concentrations outside most of the proposed breakwater footprint are between 5 to 100mg/l, with only approximately a 200m wide strip of plume area where the concentrations are between 450 to 100mg/l. The concentrations along the proposed breakwater footprint are between 450 to 4,500 mg/l in the bed layer, and below 800mg/l in the surface layer. The high concentration of suspended sediment along the proposed breakwater is expected as this is where the dredger will be in operation.

Figure 5.10 to **Figure 5.12** show the maximum suspended sediment concentration at the offshore disposal site for the surface layer, mid layer and bed layer, respectively. The maximum suspended sediment concentrations are low across the offshore disposal site, with the maximum being 160mg/l at the very centre of the disposal site. The plume extent is largest for the bed layer and decreases throughout the water column, being smallest at the water surface. Plume concentrations outside the offshore disposal site are predominantly between 5 to 10mg/l with only a very small area being between 10 to 15mg/l.

Figure 5.13 and **Figure 5.14** show the bed thickness change at the development site and the offshore disposal site respectively. The bed thickness change at the development site around the breakwater footprint are between 6 to 20cm. Whilst this seems quite high, it is worth to point out that this deposition is within an area where the proposed breakwater to be constructed here, i.e. this area will be covered by the proposed breakwater and therefore, the bed change is deemed of little significance. The areas away from the breakwater footprint show bed thickness changes between 1 to 6cm.

The bed thickness change at the offshore disposal site is confined to a very small and localised area of approximate 500m x 500m at the very centre of the site. The changes are between 1 to 4cm.

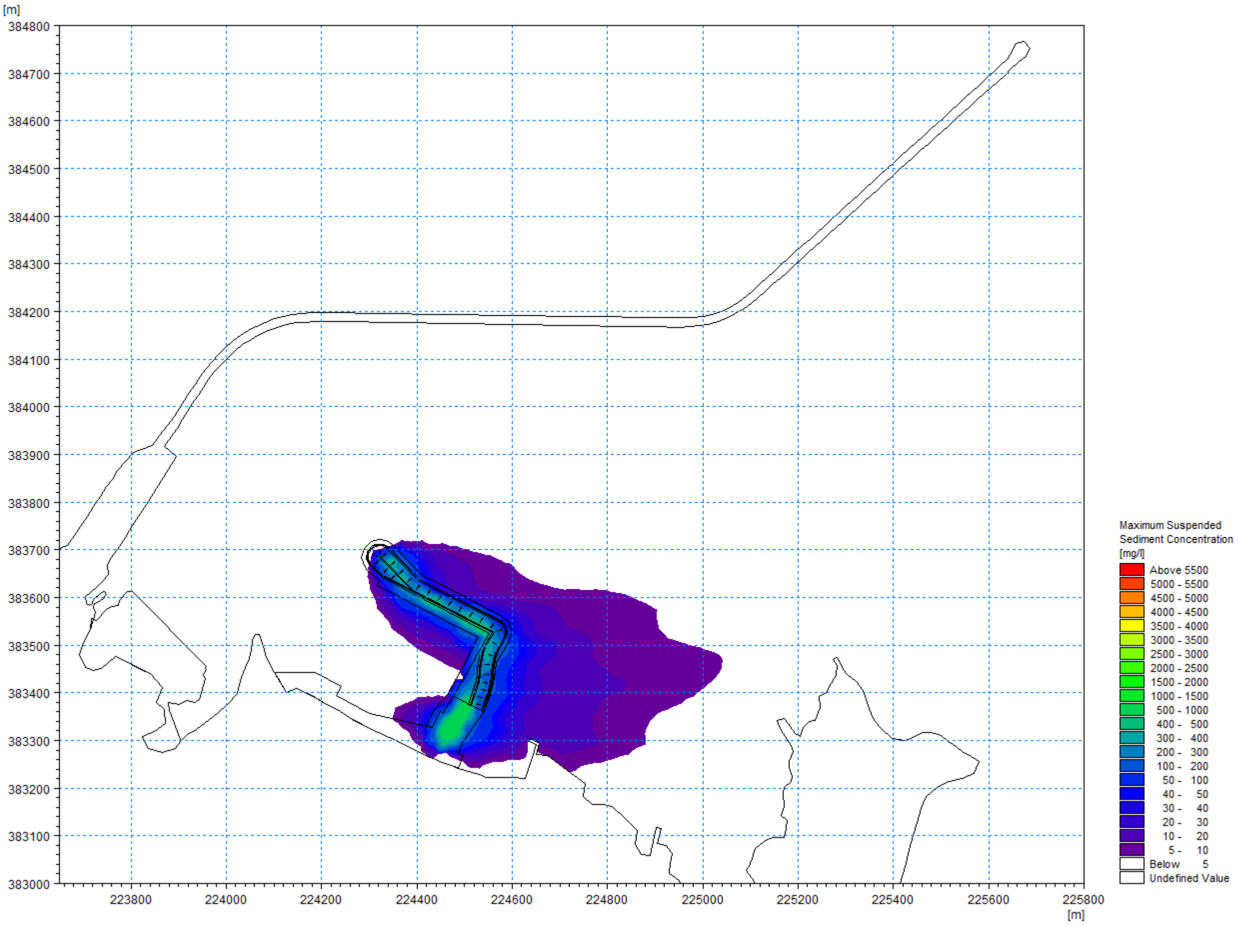

Figure 5.7: Maximum suspended sediment concentration for surface layer at development site

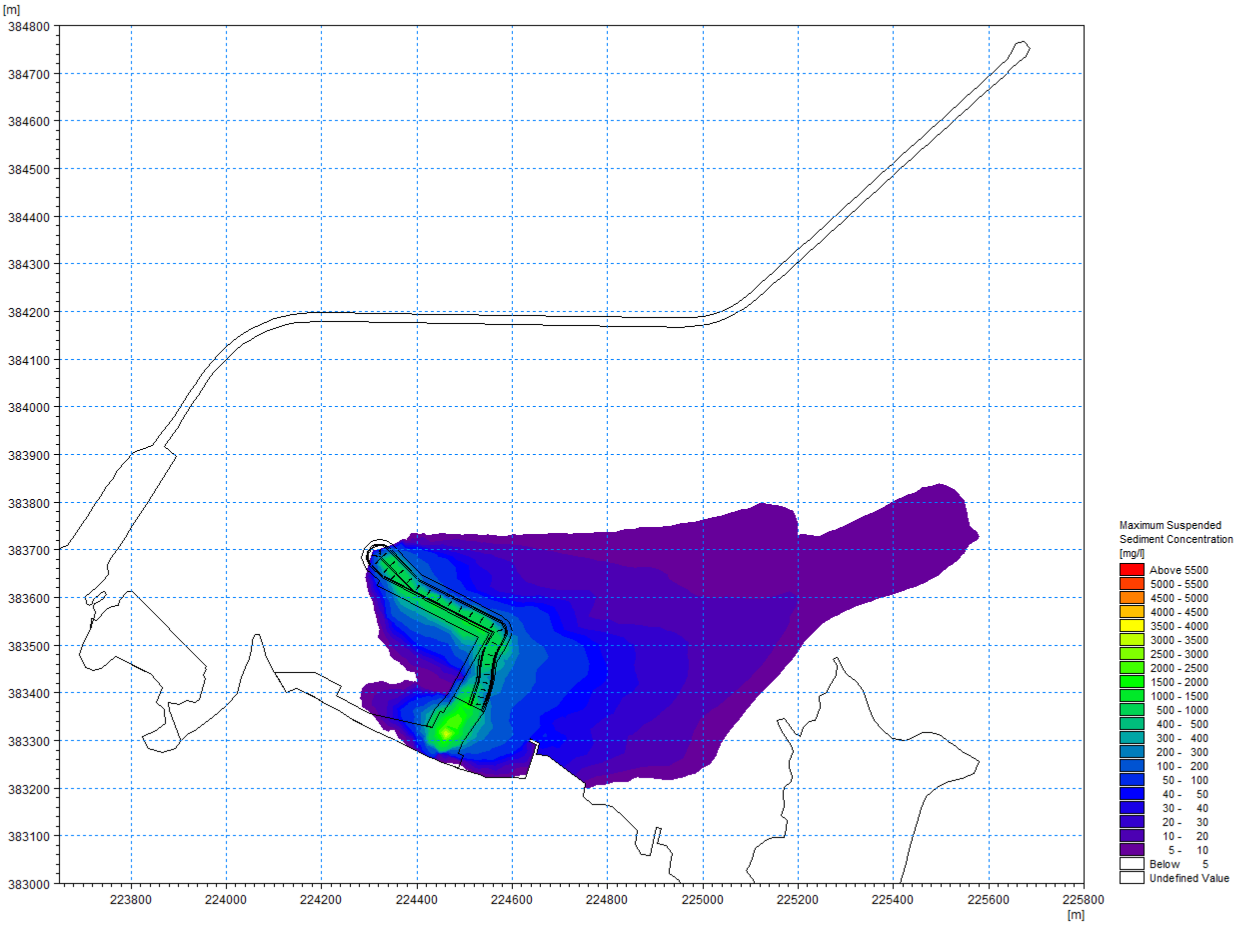

Figure 5.8: Maximum suspended sediment concentration for mid layer at development site

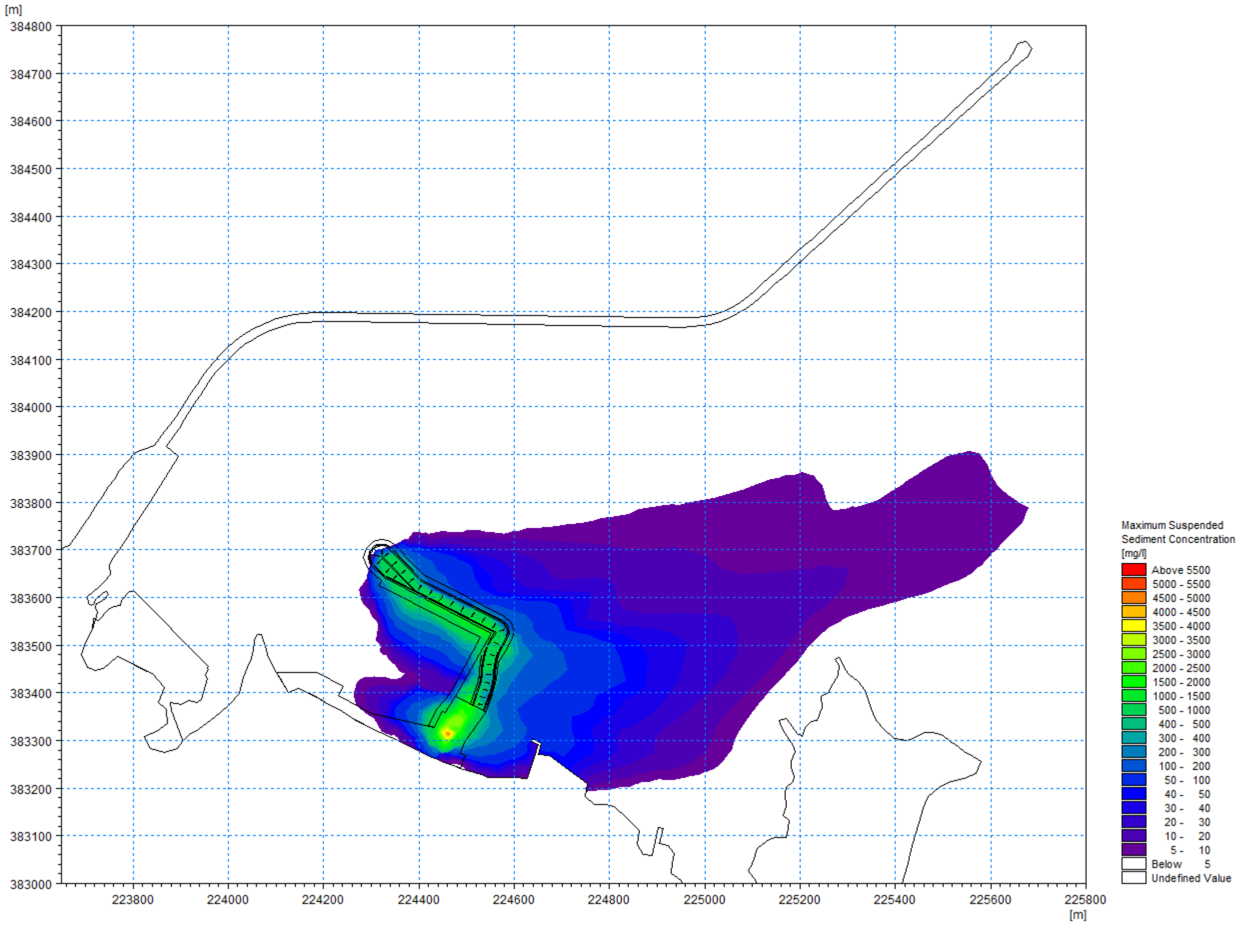

Figure 5.9: Maximum suspended sediment concentration for bed layer at development site

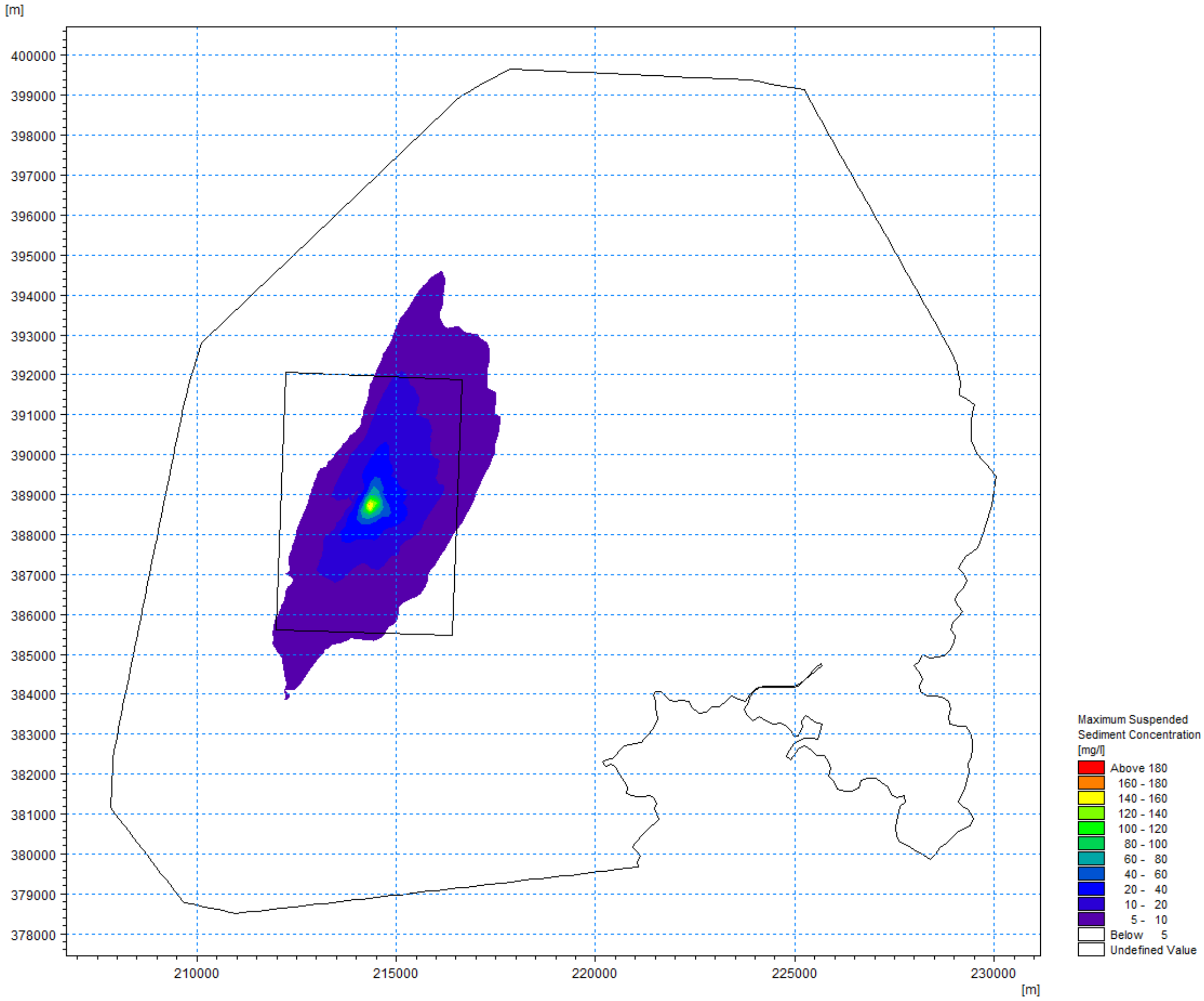

Figure 5.10: Maximum suspended sediment concentration for surface layer at offshore disposal site

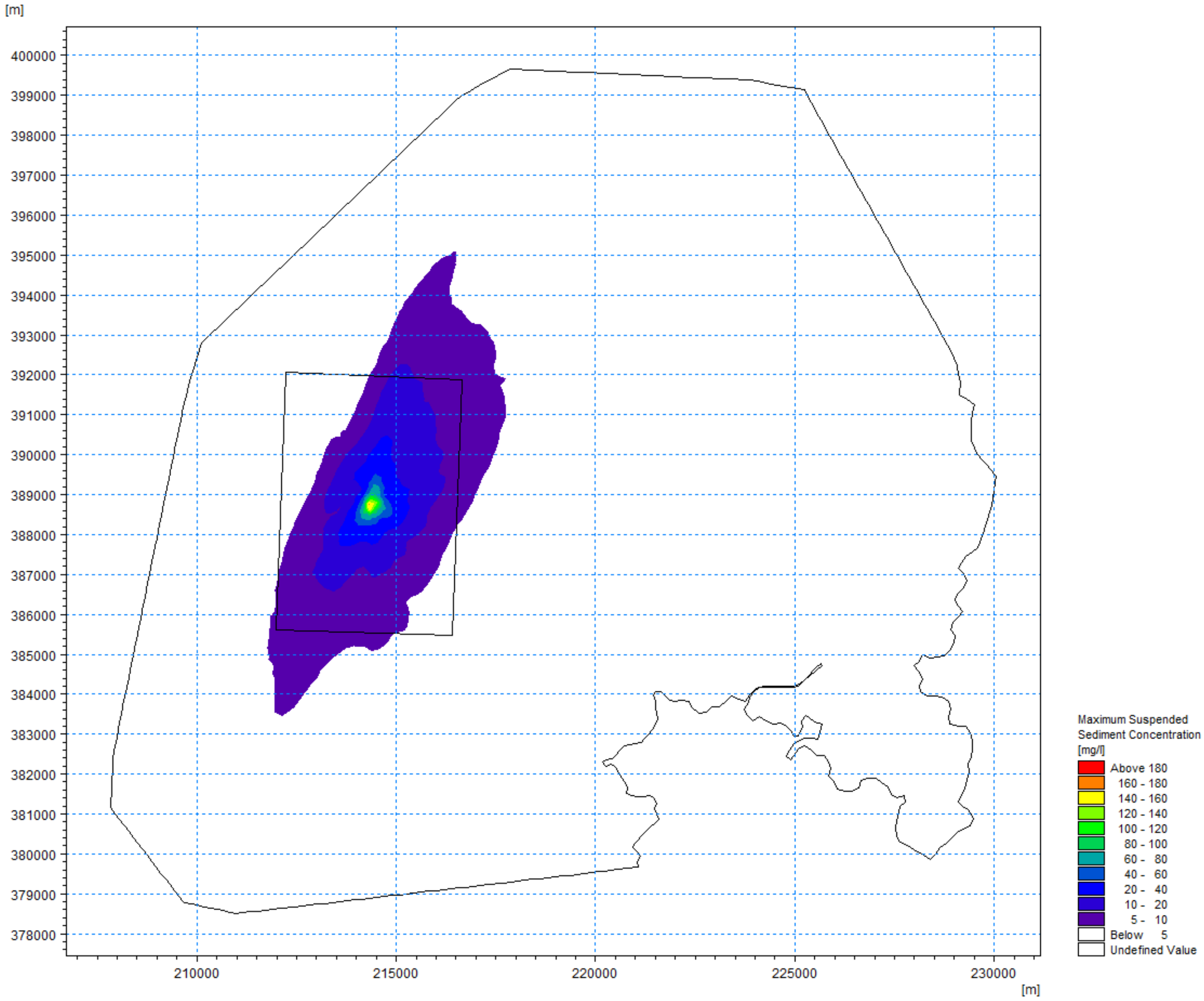

Figure 5.11: Maximum suspended sediment concentration for mid layer at offshore disposal site

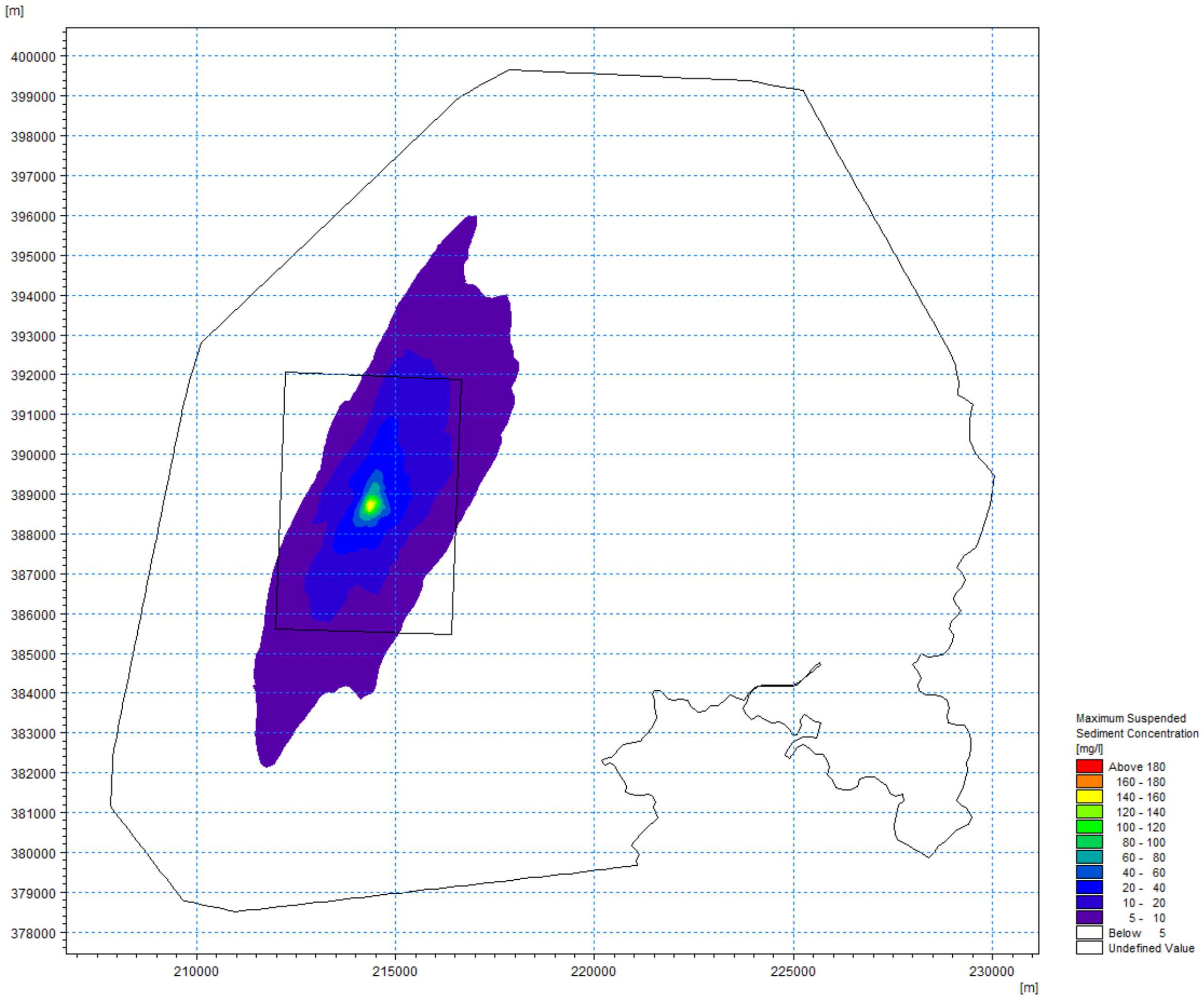

Figure 5.12: Maximum suspended sediment concentration for bed layer at offshore disposal site

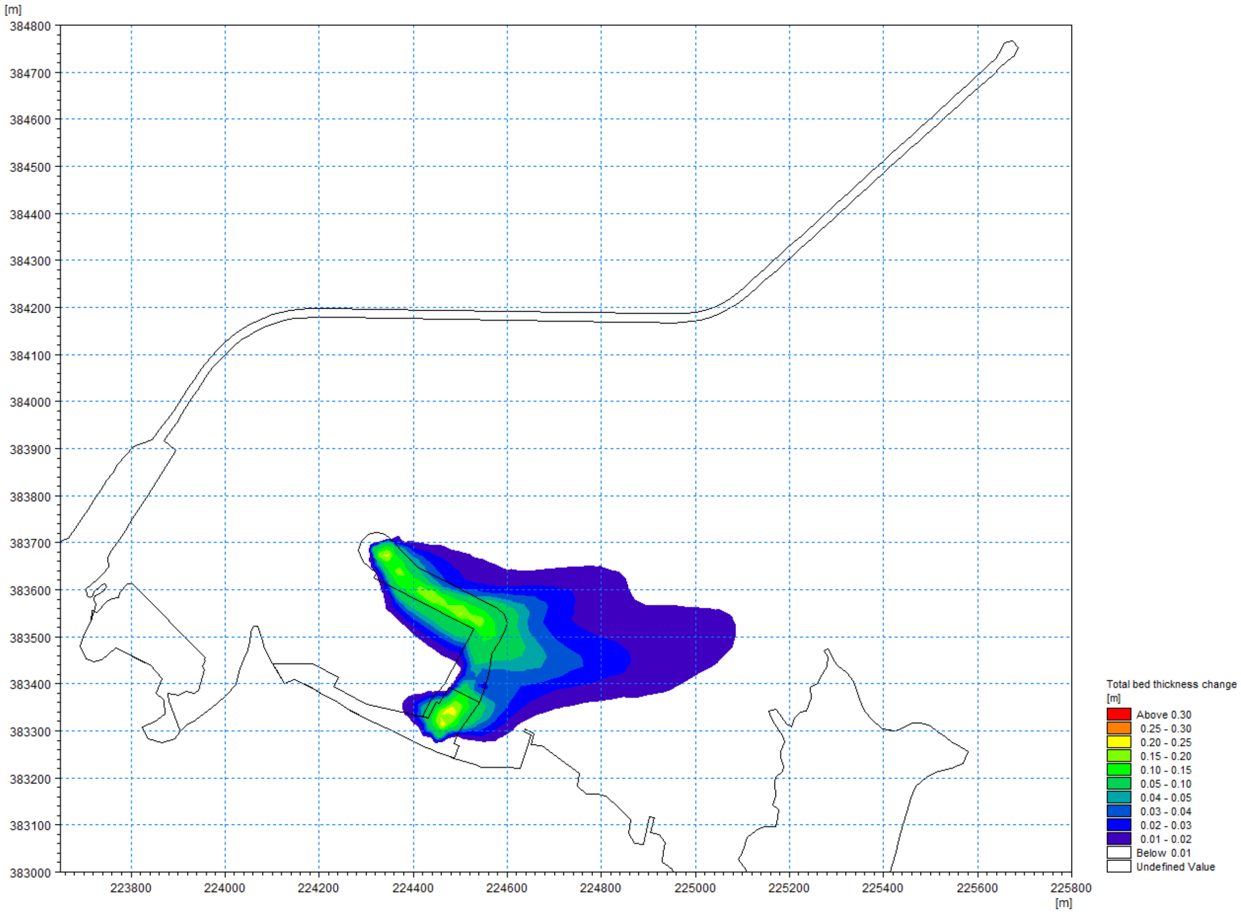

Figure 5.13: Bed thickness change at development site

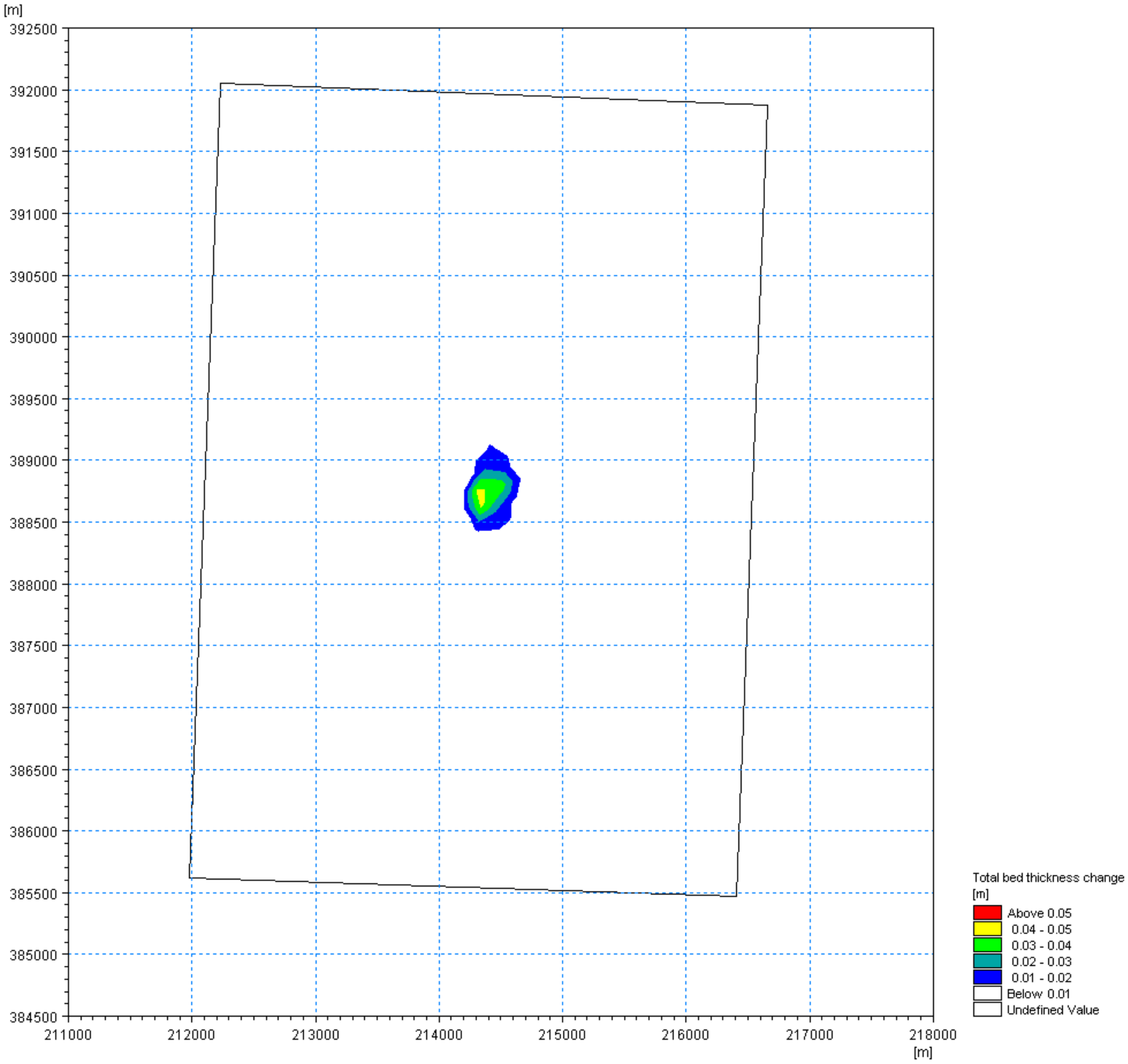

Figure 5.14: Bed thickness change at offshore disposal site

5.6 Conclusion

The maximum suspended sediment concentrations near the development site are reasonably low and the sediment plume arising during construction of the scheme stays well within Holyhead Harbour and only concentrations below 10mg/l moving past the northern tip of Salt Island. The plume extent for the bed layer is slightly larger than the plume for the mid and bed layer. The suspended sediment concentrations outside most of the proposed breakwater footprint are between 5 to 100mg/l, with only approximately a 200m wide strip of plume area where the concentrations are between 450 to 100mg/l. The concentrations along the proposed breakwater footprint are between 450 to 4500 mg/l in the bed layer, and below 800mg/l in the surface layer. The high concentration of suspended sediment along the proposed breakwater is expected as this is where the dredger will be operated.

The maximum suspended sediment concentrations at the offshore disposal site are low, with the maximum being 160mg/l at the very centre of the disposal site. The plume extent is largest for the bed layer and decreases throughout the water column, being smallest at the water surface. Plume concentrations outside the offshore disposal site are predominantly between 5 to 10mg/l with only a very small area being between 10 to 15mg/l.

The total bed thickness change due to sediment deposition during construction of the scheme around the breakwater footprint are between 6 to 20cm. Whilst this seems quite high, it is worth to point out that this deposition is within an area where the proposed breakwater is to be constructed here, i.e. this area will be covered by the proposed breakwater and therefore, the bed change along this footprint is deemed of little significance. The areas away from the breakwater footprint show bed thickness changes between 1 to 6cm.

The total bed thickness change due to sediment deposition from offshore disposal are confined to a very small and localised area of approximate 500m x 500m at the very centre of the site. The changes of bed thickness are between 1 to 4cm.