Spiorad na Mara Offshore Wind Farm

Offshore Project

Environmental Impact Assessment Report

Appendix 9.2: Physical and Coastal Processes Modelling Results Report, Volume 2c

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1 INTRODUCTION

1.1 OVERVIEW

1.1.1.1 This appendix of the Environmental Impact Assessment Report (EIAR) presents the physical and coastal processes modelling results of the proposed Spiorad na Mara Offshore Wind Farm (hereafter referred to as 'the Offshore Project'). It details the modelled hydrodynamic conditions in and around the Offshore Project Boundary (water depth, current speed, and bed shear stress), the baseline seabed sediment suspension and transport, the baseline wave conditions (storm event and extreme values), and how these may change due to activities associated with the construction, operational and maintenance (O&M), and decommissioning phases of the Offshore Project with respect to Physical and Coastal Processes.

1.1.1.2 This appendix should be read in conjunction with the project description provided in Chapter 3: Project Description, Volume 1a and the relevant parts of the following chapters and appendices:

- Chapter 4: Consideration of Alternatives, Volume 1a;
- Chapter 9: Physical and Coastal Processes, Volume 2a;
- Appendix 9.1: Physical and Coastal Processes Modelling Calibration & Validation Report, Volume 2c.

1.1.1 PROJECT BACKGROUND

1.1.1.1 Spiorad na Mara Limited (hereafter referred to as 'the Applicant') is proposing to develop the Project. The Project is an offshore wind farm (OWF) that will consist of up to 60 fixed-bottom wind turbine generators (WTGs).

1.1.1.2 The Project will include both offshore and onshore infrastructure. This EIAR supports the application for the offshore components of the Project as outlined in Chapter 1: Introduction, Volume 1a. The offshore components of the Project (the Offshore Project) include all infrastructure and activities located seaward of Mean High Water Springs (MHWS) within the Array Area and Offshore Cable Area of Search (OCAS) (Figure 1.2: Offshore Project Location, Volume 1b). Further detailed information is provided in Chapter 3, Volume 1a.

1.1.1.3 The Offshore Project is situated off the northwest coast of Isle of Lewis/*Eilean Leòdhais* and the Array Area is located approximately 5-13 km offshore and is approximately 161 km^2 in size. It will comprise WTGs, foundations, Offshore Cables, Offshore Substation Platform (OSP) (if required), and Landfall. The Array Area combined with the OCAS is defined as the Offshore Project Boundary. The water depths across the Array Area range from 37-67 m with the southwest corner of the Array Area reaching 72 m. The proposed WTGs, OSP (if required), and fixed foundations will be located within a Turbine Area of approximately 140 km^2, within the Array Area.

1.2 PURPOSE OF THIS APPENDIX

1.2.1.1 The appendix defines the hydrodynamic conditions within the physical processes Study Area (see Figure 9.1: Study Area and Zone of Influence, Volume 2b) and presents the modelling results associated with project activities to inform the assessments carried out in the EIAR. The appendix describes the following:

- Method and approach to modelling (Section 2);
- Baseline characterisation modelling of hydrodynamics, waves, and seabed sediments (Section 3);
- Construction activity impact modelling of suspended sediment concentration and sediment deposition (Section 4);
- Operational impact (due to presence of infrastructure) modelling of for hydrodynamics, waves, and seabed sediments (Section 5);
- Conclusions (Section 6);
- References (Section 7).

1.2.1.2 The appendix is supported by the following figures:

- Figure 1.2, Volume 1b;
- Figure 3.2a: Indicative Turbine Layout Option 1, Volume 1b;
- Figure 9.1, Volume 2b;
- Figure 9.5: Overview of seabed substrate by Folk classification, Volume 2b;
- Figure 9.6: Extraction sites for baseline sediment transport, Volume 2b.

1.2.1.3 The conclusions of this report have been used to inform any potential impacts on receptors assessed within:

- Chapter 9, Volume 2a;
- Chapter 10: Marine Sediment and Water Quality, Volume 2a;
- Chapter 11: Benthic and Intertidal Ecology, Volume 2a;
- Chapter 12: Fish Ecology, Volume 2a;
- Chapter 13: Marine Mammals, Volume 2a;
- Chapter 15: Offshore Archaeology and Cultural Heritage, Volume 2a.
- Chapter 20: Other sea users, including recreational users, Volume 2a;
- Chapter 21: Commercial Fisheries, Volume 2a.

2 METHOD AND APPROACH TO MODELLING

2.1 OVERVIEW

2.1.1.1 This section outlines the method and approach to modelling for baseline characterisation, sediment plume modelling, and the presence of infrastructure during the O&M phase. It details the models used, as well as the input parameters and assumptions that were made.

2.1.1.2 2D hydrodynamic and spectral wave models were developed in the Danish Hydraulic Institute (DHI) MIKE 2023 software suite (specifically MIKE21 flexible mesh) as described in Appendix 9.1, Volume 2c. The hydrodynamic model was coupled with a Particle Tracking (PT) module for the assessment of construction activity impact sediment plumes. The use of each model is outlined in Table 2-1.

Table 2-1 Parameters used to model cable burial

Model	Used for
Hydrodynamic	- Baseline characterisation; - Construction activity impacts (coupled with PT module); - Operational impacts due to the presence of infrastructure.
Spectral wave	- Baseline characterisation; - Operational impacts due to the presence of infrastructure.

2.1.1.3 Construction activity impacts are assumed to be representative of a worst-case scenario for O&M and decommissioning activity impacts as presented in Table 9-20 of Chapter 9, Volume 2a. This is because activities carried out during O&M and decommissioning are expected to use methodologies with the same or lesser sediment disturbance than during construction and take place over the same or lesser temporal and spatial scales. Therefore, the modelling results generated for construction activities have been used to inform the O&M, and decommissioning assessments for the EIAR, ensuring that potential activity impacts are appropriately captured within the Environmental Impact Assessment (EIA).

2.2 BASELINE CHARACTERISATION

2.2.1.1 Baseline characterisation has been carried out using a combination of desk-study information, site-specific surveys, and 2D modelling. Hydrodynamic and wave baseline have been defined using outputs from 2D hydrodynamic and spectral wave modelling (see Appendix 9.1, Volume 2c for details on setup, calibration, and validation of the models including the use of site-specific survey data in calibration).

2.2.2 HYDRODYNAMICS

2.2.2.1 The source and temporal/spatial extents of the metocean data used for the analysis of hydrodynamics in the Offshore Project Boundary can be found in Appendix 9.1, Volume 2c, alongside the calibration and validation exercise undertaken to confirm the 2D hydrodynamic model to be used in this analysis is suitable and representative of physical processes in the area covered by the model.

2.2.2.2 Baseline hydrodynamic (water depth, depth-averaged current speed and bed shear stress) conditions have been modelled to provide a basis for baseline hydrodynamic conditions of the Offshore Project. The model duration covers a month-long period to include spring and neap tides which represent a range of typical tidal conditions.

2.2.2.3 Baseline characterisation model outputs are presented in Section 3.2 for the following:

- Spatial plot of total water depth at spring and neap high and low water (note the timing of high and low water varies over the model domain; timings have been selected based on the tides in the centre of the Turbine Area as a representative value);
- Spatial plot of maximum and minimum total water depths over the 1-month model duration;
- Spatial plot of peak tidal flood and ebb current speeds during spring and neap tides (note tidal currents within the model domain flow generally parallel to the shoreline alternating between northeast (flood) and southwest (ebb) directions);
- Spatial plot of peak current speed over the 1-month model duration (note minimum speed is not shown as this is zero across the model domain);
- Timeseries plot of baseline total water depth, current speed, and bed shear stress in the middle of the Turbine Area throughout the model duration;
- Spatial plot of bed shear stress at peak flood and ebb spring and neap tides;
- Spatial plot of maximum bed shear stress over the 1-month model duration (note minimum bed shear stress is not shown as this is zero across the model domain).

2.2.3 WAVES

2.2.3.1 The source and temporal/spatial extents of the metocean data used for the analysis of wave conditions in the Offshore Project Boundary can be found in Appendix 9.1, Volume 2c. Appendix 9.1, Volume 2c also outlines the calibration and validation exercise undertaken to confirm the spectral waves models to be used in this analysis are suitable and representative of physical processes within their domain.

2.2.3.2 Baseline wave conditions have been investigated separately for measured storm conditions and for extreme events. The model was run for a 35-day period (21 November 2023 – 26 December 2023) representative of common conditions in the Offshore Project Boundary, including a storm event with a maximum Significant Wave Height (Hs) of 7.7 m, and a storm event with a maximum

Hs of 9.54 m. For extreme events, the baseline model was run separately for 4 different incoming wave directions, based on the results of an Extreme Value Analysis (EVA).

2.2.3.3 Baseline characterisation model outputs are presented in Section 3.3 for the following:

- Spatial plot of maximum significant wave height under measured storm conditions;
- Table of significant wave heights for each return period and wave direction.

Measured Storm Conditions

2.2.3.4 The selected storm Hs and Wave Period (Tp) are plotted in Plate 2-1 for reference.

Plate 2-1 WaveWatch III (left) and measured (right) significant wave height and wave period
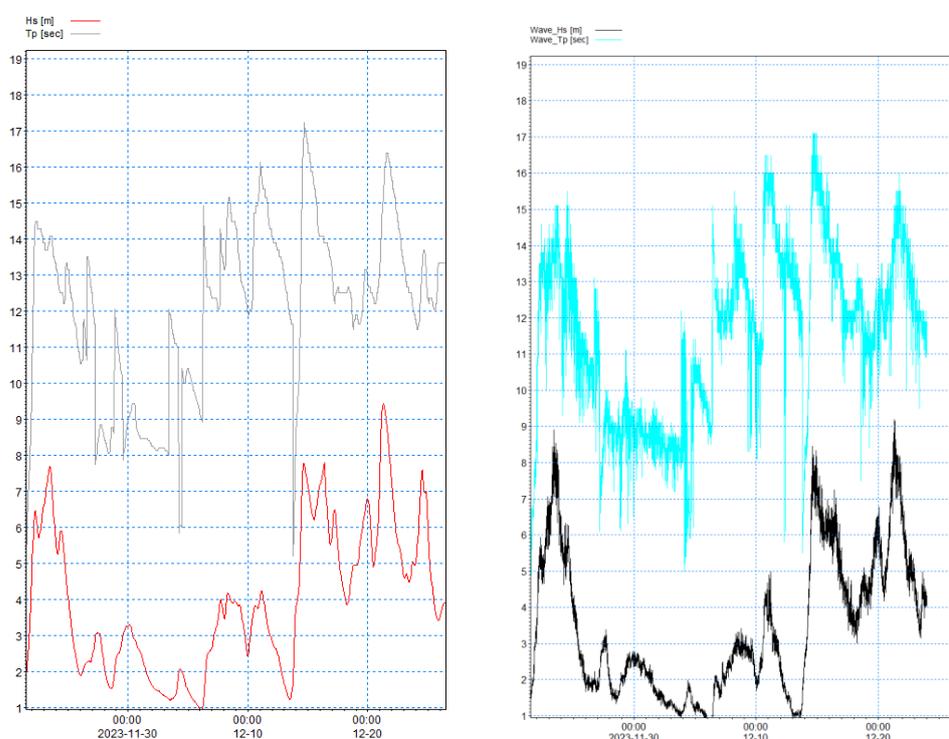
2.2.3.1 As shown in the timeseries plots, the chosen timeseries includes a range of different Hs and Tp combinations, as well as including suitable storm events for modelling standard conditions in the Offshore Project Boundary.

Extreme Value Analysis

2.2.3.2 An EVA was carried out on 41-years' of hindcast wave data obtained from the WaveWatch III global model, ranging from 1979-2013, and from 2017-2024. Wave data was downloaded for the closest point to the Turbine Area (Lat: 58.5, Long: -7.5).

2.2.3.3 The EVA Editor function within MIKE by DHI was used to estimate significant wave heights associated with specific incoming wave directions. This exercise was run separately for southerly, south-westerly, westerly, and northerly waves to ensure an accurate representation of extreme

events in the Offshore Project Boundary. A Weibull distribution was fitted to the extreme values of directionally split wave height timeseries, with sensitivity testing used to determine which threshold setting results would provide a better fit for the extreme values in each dataset (assessed using the probability plot correlation coefficient). An Inter-event time of 24 hours and Inter-event height of 0.5 m independence criteria were applied to all EVAs. A summary of thresholds used for each directional sector is included below:

- Southwest: 4.5 m;
- West: 6 m;
- Northwest: 6.5 m;
- North: 5.5 m.

2.2.3.4   The overall results for different probability distributions were all above a 0.994 goodness of fit when adopting the Probability plot correlation coefficient (PPCC I). Probability plots were created using a Weibull plotting position method and used to determine which probability distribution methods could better represent the datasets. These are shown in Plate 2-2 to Plate 2-5.

Plate 2-2 Extreme value analysis results northerly waves
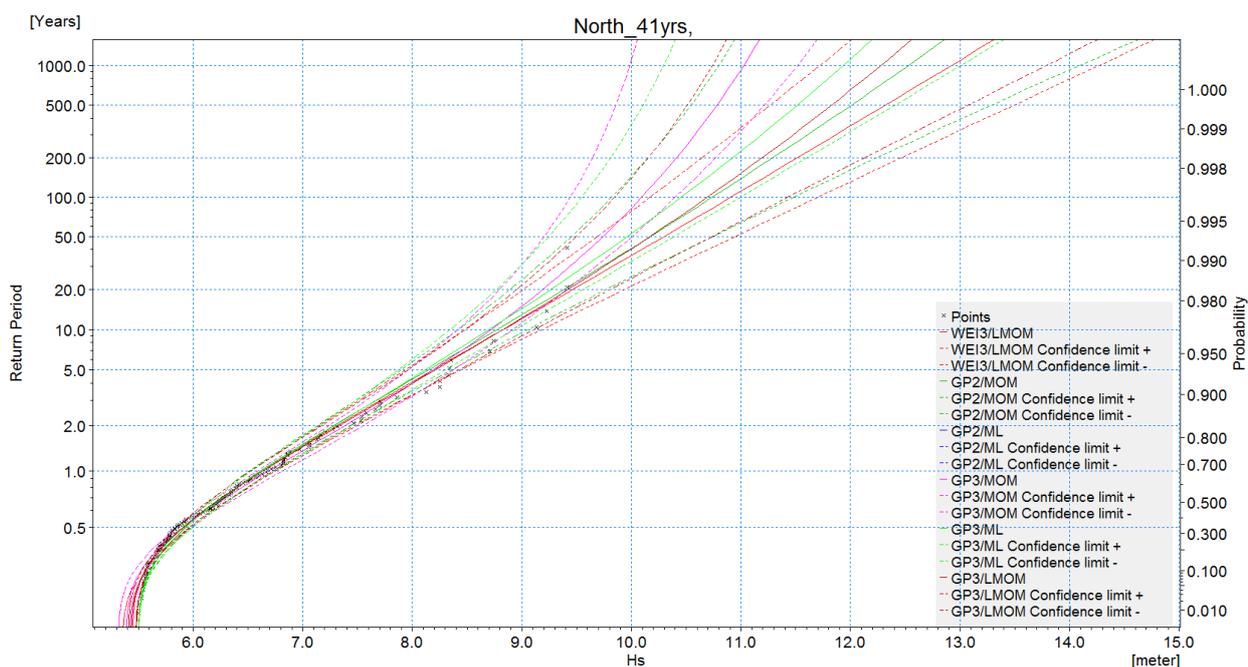
Plate 2-3 Extreme value analysis results north-westerly waves
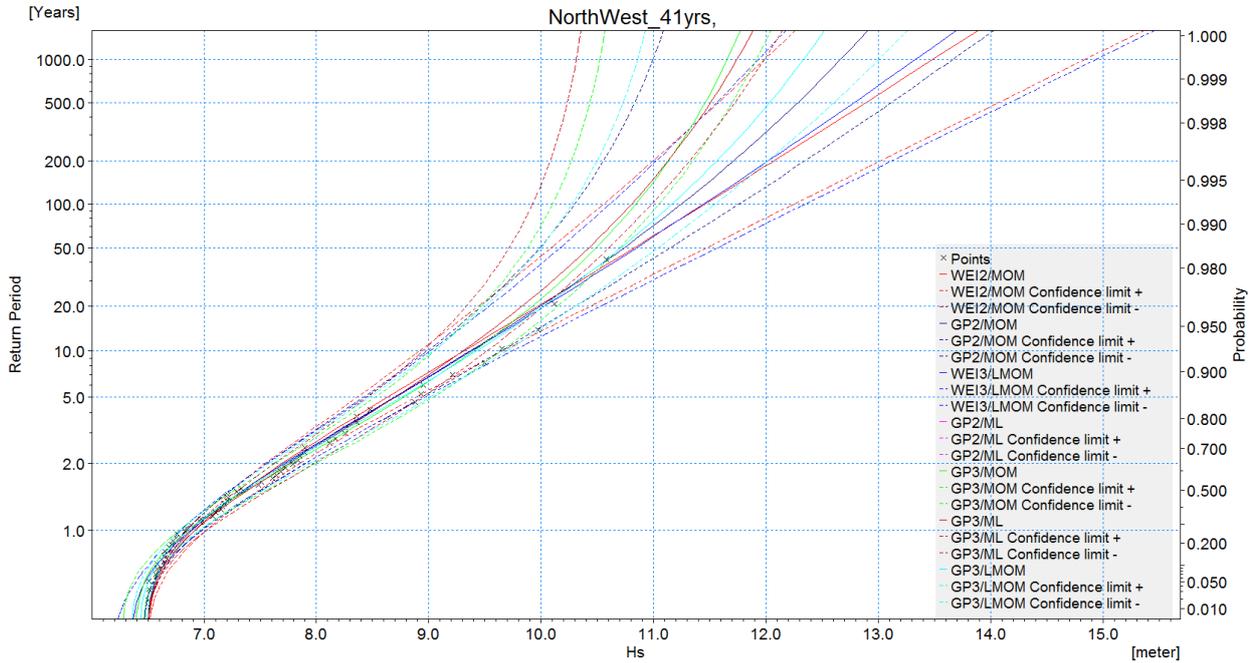
Plate 2-4 Extreme value analysis results westerly waves
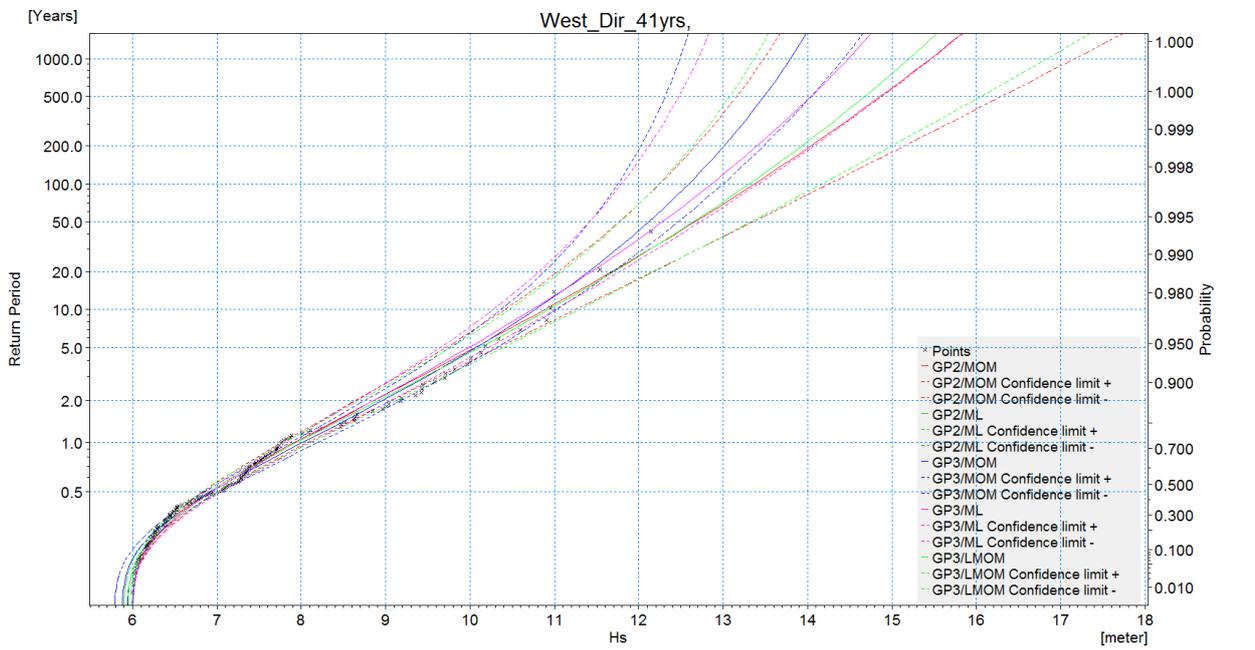
Plate 2-5 Extreme value analysis results south westerly waves
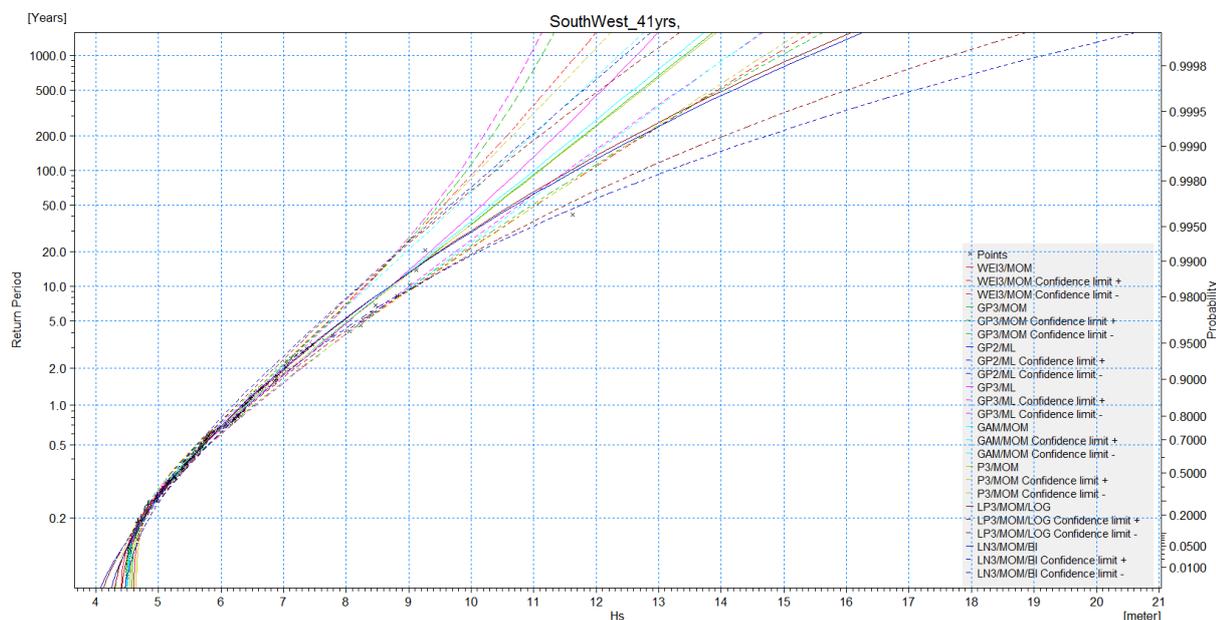
2.2.3.5   Hs for different return periods were determined from the above probability plots. Given the nature of this analysis, goodness of fit of distributions against extreme values was prioritised over lower return period events. This selection process for determining Hs values for different return periods provides a robust and conservative approach focussed on extreme events. Where the average values of the best suited distributions were higher than the best fit distribution, the average values were selected instead, to ensure a conservative approach.

2.2.3.6   Tp values to be assigned to Hs results of the EVA were selected from a scatter plot of Hs and Tp and then used alongside their corresponding Hs values in the Spectral Waves simulation for extreme events. Hs and Tp were plotted separately for each incoming direction to allow for a more accurate selection of Tp values for directionally split Hs values. A scatter plot of Hs vs Tp for the entire hindcast dataset used is shown in Plate 2-6.

Plate 2-6 Hs vs Tp scatter plot
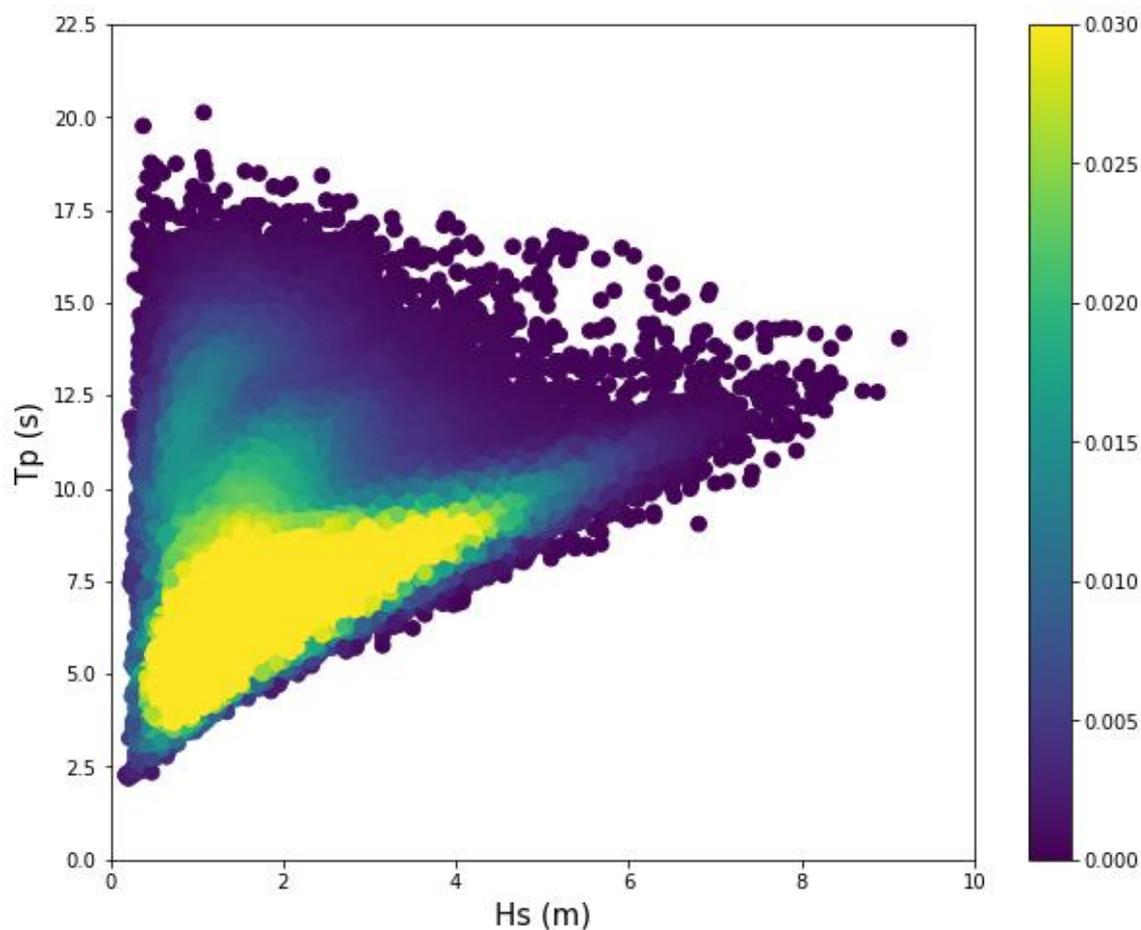
2.2.4 SEABED SEDIMENTS

2.2.4.1 Desk study information and data from site-specific geotechnical (borehole) surveys has been used to define baseline seabed sediments for the purposes of the modelling. Boulders and cobbles have not been included in the PT modelling as particles of this size (>64 mm as defined in the Wentworth scale) are too large for natural hydrodynamic and wave conditions to suspend and if disturbed by construction activities will settle without being advected.

2.2.4.2 An empirical analysis of baseline sediment transport potential has been carried out using bed shear stress data from the hydrodynamic model and site-specific measured wave data.

2.2.4.3 The extraction sites analysed for sediment transport potential which were selected to represent the different sediment properties across the Offshore Project Boundary are illustrated in Figure 9.6, Volume 2b.

2.2.4.4 The extraction locations selected cover a range of water depths and sediment types. Sediment transport potential was assessed separately for all sediment fractions present at each location because the different grain sizes are mobilised by different bed shear stresses.

2.2.4.5   Bed shear stresses due to current action were extracted from the baseline hydrodynamic model. Bed shear stresses due to wave action were calculated using the empirical formulae presented in Soulsby and Clarke (2005) with mean measured wave data. The mean Hs observed in the Turbine Area is 2.9 m and the mean Tp is 11.4 s. These values have been used to assess the wave induced sediment transport, noting that larger waves experienced during extreme storm events would have the potential to further mobilise the seabed sediment. The results of this analysis are tabulated in Section 3.4.2.

2.2.4.6   Section 3.4 contains spatial plots of seabed substrates, borehole data from site-specific surveys, and tabulated results of the baseline sediment transport of the different sediment fractions in each location.

2.3   SEDIMENT PLUME MODELLING

2.3.1   INTRODUCTION

2.3.1.1   The 2D hydrodynamic model was used to assess construction impacts by coupling it with a PT model. This model demonstrates the depth-averaged suspended sediment concentration and deposited sediment impacts of construction activities based on the proposed Offshore Project design envelope (see Chapter 3, Volume 1a). The construction activities considered are: drilling of pin piles (referred to throughout this appendix as piles) to install WTG foundations, burial of Array Cables to Final WTG and Array Cables to Landfall, drill cutting release from horizontal directional drilling (HDD), and construction of HDD exit pits.

2.3.1.2   Construction activities were modelled in different locations and combinations (referred to in this appendix as scenarios). Details of the construction scenarios considered are given in Section 2.3.2, with assumptions and parameters specific to each activity described in Section 2.3.3.

2.3.1.3   Analysis has been carried out on the model results to determine the durations for which suspended sediment concentrations are above given thresholds. This analysis is used in the assessments carried out in subsequent chapters of the EIAR. The thresholds considered are:

- 0.5 mg/l (baseline background suspended sediment concentration – see Chapter 9, Volume 2a);
- 25 mg/l (used in the water quality and fish ecology assessments - see Chapter 10, Volume 2a and Chapter 12, Volume 2a respectively).

2.3.1.4   In the presentation of sediment plume modelling results, instantaneous and maximum values are used:

- Instantaneous results are model outputs at a specific point in time during the model run. For example, to show a sediment plume extent at a certain duration after a construction activity is completed;

- Maximum results show the highest value of a parameter (for example sediment deposition thickness) reached in each element of the model throughout the model run regardless of when that value occurs. For example, to show all locations within the Study Area where a certain threshold is exceeded during the model run.

2.3.1.5 The model outputs presented in Section 4 for construction activities have been selected to provide the most relevant context for each activity and as such outputs differ in some instances between construction activities. The variance in outputs (instantaneous or maximum) for construction activities reflects the varying:

- Durations (hourly or daily), such as HDD drilling (1 hour duration) and pile activities (1 day duration). For example, activities with shorter durations are supported by maximum outputs as the short timeframe does not allow instantaneous plots to build a representative picture (due to the timestep resolution);
- Sediment types across the Offshore Project Boundary, specifically the Array Area (gravel and fine sediment) and OCAS (gravel). For example, gravel settles faster than smaller sand/silt sediments and faster than the timestep resolution associated with instantaneous outputs, meaning maximum plots are most appropriate for activities within the OCAS;
- Mobility of activity (stationary or mobile), such as pile drilling (stationary) and cable burial (mobile). For example, pile drilling within the Turbine Area is confined to discrete, stationary locations. As such, instantaneous plots appropriately characterise the spatial worst-case scenario associated with this static activity. By contrast, cable burial is undertaken continuously across the length of the OCAS and throughout the Array Area. In this case, maximum plots capture the movement of the impact source along the route, removing the need for multiple instantaneous plots at different points and reflecting the inherently mobile nature of the activity.

2.3.1.6 These model outputs are supported by tabulated outputs and timeseries plots at representative locations to demonstrate the variation of suspended sediment concentration or sediment deposition over time. Where these outputs are presented in the Appendix is dependent on whether the outputs have informed the quantitative assessment of impacts from multiple activities. Timeseries plots and tabulated outputs for:

- HDD drill cutting release are presented in Section 4.4, as they do not inform the quantitative assessment of impacts of multiple HDD activities;
- Pile drilling and cable burial activities are presented in Section 4.6, as they have been used to inform the assessment of impacts of pile drilling and cable burial activities occurring sequentially.

2.3.2 SEDIMENT PLUME MODELLING SCENARIOS

2.3.2.1 This section describes the modelling scenarios used to assess each construction activity. These have been grouped as follows: drilling of piles to install WTG foundations and cable burial, and HDD drill cutting release and HDD exit pit construction.

Drilling of Piles to Install Wind Turbine Generator Foundations and Cable Burial

2.3.2.2 3 sediment plume modelling construction scenarios (with varying combinations of locations for cable burial and drilling of piles to install WTG foundations) were considered (see Plate 2-7). These scenarios account for different sediment properties in the southwest of the Turbine Area (Scenario 1), within the buried channel in the Turbine Area (Scenario 2), and the northeast of the Turbine Area (Scenario 3), where turbines and cables will be installed. The boundaries between the areas included in each scenario is shown in Plate 2-7; Scenario 1 includes all turbines and cables to the southwest of the 'Southwest Northeast Array Boundary' line, Scenario 2 includes all turbines and cables inside the 'Buried Channel' outline, and Scenario 3 includes the turbines and cables to the northeast of the 'Southwest Northeast Array Boundary' line but outside the 'Buried Channel' outline.

2.3.2.3 An indicative layout was assumed based on the information available at the time of modelling (12 Array Cables to Landfall connected to 60 turbines). See Table 9-20 of Chapter 9, Volume 2a for further details on the physical processes maximum design scenario.

Plate 2-7 Construction modelling scenarios
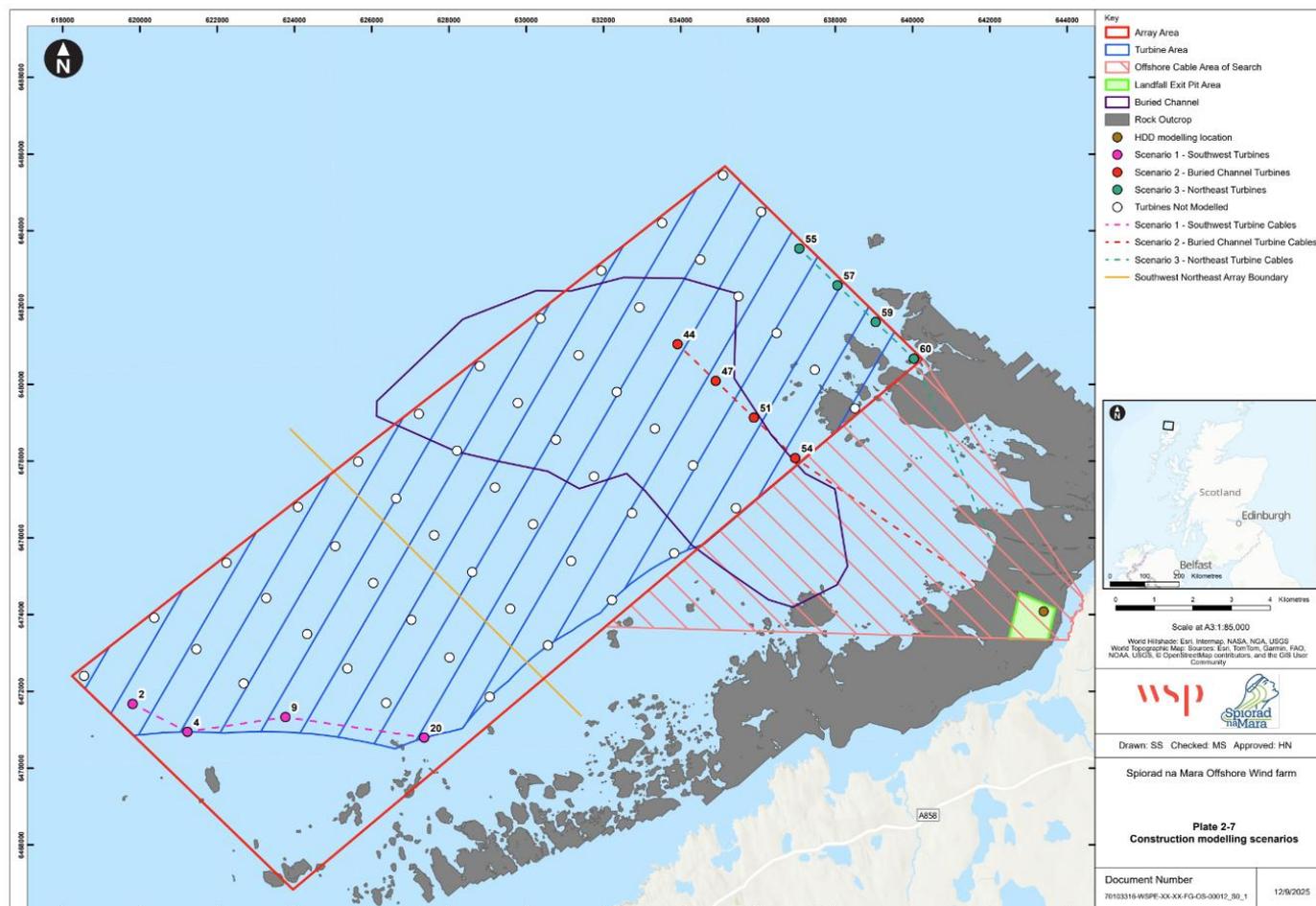
2.3.2.4   These scenarios capture the range of sediment characteristics across the Array Area, based on geotechnical investigation borehole data (Bluefield Geoservices, 2024), further detailed in Section 3.4.

2.3.2.5   The percentages of sediment fractions differ between drilling of piles to install WTG foundations and cable burial activities; drilling of piles to install WTG foundations considers the full depth of sediment data available whereas the cable burial only considers the top 2 m below the seabed surface.

2.3.2.6   Turbine and cable construction activities have been modelled independently to assess their individual impacts (see Section 4.2 and Section 4.3) and together to assess the impacts of multiple activities occurring sequentially (see Section 4.6).

2.3.2.7   Scenarios with and without sediment resuspended by hydrodynamic and wave-induced forces have been included, where appropriate. This approach provides worst case results for suspended sediment concentration (when sediment resuspension is included) and sediment deposition thickness (when sediment resuspension is not included).

2.3.2.8   Timeseries plots of suspended sediment concentration and sediment deposition thickness have been provided for combinations of drilling of piles to install WTG foundations and cable burial activities, described further in their respective sub-sections of Section 2.3.3. The data extraction locations for these timeseries plots are shown in Plate 2-8.

Plate 2-8 Locations of timeseries data extraction points
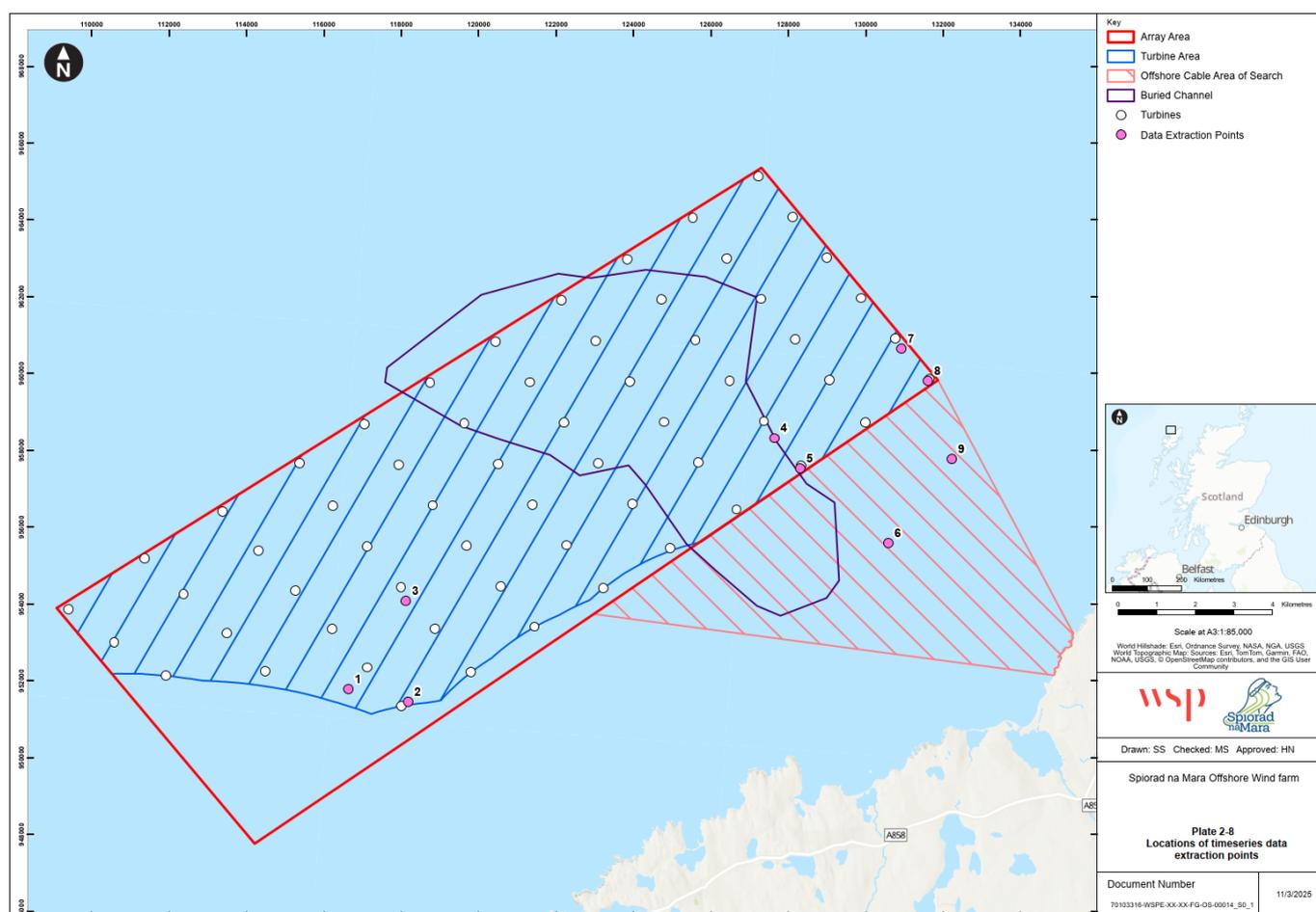
HDD Drill Cutting Release and HDD Exit Pit Construction

2.3.2.9   The 2 activities associated with HDD are HDD drill cutting release and HDD exit pit construction. HDD drill cutting release occurs at the break out location of the HDD bore and involves the release of drill cuttings into the water column. HDD exit pit construction is the excavation of a pit at the location of the HDD bore break out which will cause sediment disturbance.

2.3.2.10 1 HDD construction scenario has been assessed as the associated activities occur within a small area in which sediment properties are assumed to be consistent (Landfall Exit Pit Area in Plate 2-7).

2.3.2.11 The construction of the HDD exit pits has been assessed using sediment plume modelling outputs from burial of Array Cables to Landfall and HDD drill cutting release. In the absence of detailed

seabed sediment information in the Landfall area, these activities were used as a proxy because they cover the full range of sediment size likely to be present (coarse sediment from burial of Array Cables to Landfall and fine sediment from HDD drill cutting release). HDD exit pit construction was not modelled separately due to the overlap location and duration with the other activities. A comparison of maximum design scenario assumptions for HDD exit pit construction, HDD drill cutting release, and burial of Array Cables to Landfall is given in Table 2-8 (Section 2.3.3) to justify these assumptions.

2.3.2.12 HDD activities have the potential to cause in-combination impacts depending on the temporal and spatial proximity of different activities. The HDD exit pits will not be constructed simultaneously, however, there may be overlap between HDD exit pit construction in 1 location and drill release of cuttings from HDD in another. The activities have been assessed independently (see Section 4.4 and Section 4.5) and the results analysed considering potential overlap of activities (see Section 4.6.2).

2.3.3 SEDIMENT PLUME MODELLING PARAMETERS

2.3.3.1 This section details the sediment plume modelling parameters and assumptions used for each construction activity. This includes modelled locations, maximum design scenario parameters, and sediment assumptions. A description of model outputs presented in Section 4 is also provided.

2.3.3.2 Within the model it has been assumed that all sediment disturbed by construction activities is released within 2 m of the seabed. This is supported by the 'SeDiChem' tool (EA & APEM, 2019) and BERR (2008) which reference previously considered assumptions for offshore project related activities. Modelling the release of disturbed sediment from close proximity to the seabed results in a conservative assessment of the concentration of total suspended sediments and subsequent sediment deposition thickness. The release of sediment from a higher position in the water column (up to the water surface) increases the potential duration that sediment is in suspension and area that sediment can travel, although the spatial extent is limited by the distance of the tidal excursion. However, this would result in lower average concentrations of total suspended sediment and sediment deposition thickness compared to the 2 m seabed-release scenario and for this reason consideration of the effect of these physical processes on receptors from other chapters have used the values for sediment concentration and deposition representative of the conservative assessment across the Offshore Project Boundary.

Drilling of Piles to Install Wind Turbine Generator Foundations

Modelled Locations

2.3.3.3 The drilling of piles to install WTG foundations activities have been modelled at the locations outlined in Section 2.3.3 (see Plate 2-7). Turbines at the edge (or closest to in the case of the locations within the buried channel) of the Turbine Area were modelled as the maximum design scenario, to assess maximum sediment advection distances both within and outside of the

Turbine Area. Each construction scenario includes the drilling of piles to install WTG foundations for 4 turbines, with each turbine comprising 4 piles, as part of an indicative number of activities occurring within the month-long duration which the model was run.

Maximum Design Scenario Parameters

2.3.3.4   The maximum design scenario parameters used to model drilling of piles to install WTG foundations are shown in Table 2-2.

Table 2-2 Parameters used to model drilling of piles to install WTG foundations

Parameter	Value	Justification
Turbine arrangement	60 turbine layout	Largest number of turbines and the closest proximity between turbines.
Number of piles per WTG	4	Maximum volume of total sediment disturbance.
Number of concurrent pile drilling events	3	Maximum volume of sediment disturbed simultaneously.
Drilling duration per pile	18.5 hr duration	Maximum concentration of suspended sediment. While other technical topics have used maximum 12-hour drilling duration, 18.5 hours has been used for this assessment as a pre-cautionary worst case to ensure that both flood and ebb tides are covered at each location as a worst-case extent of impacts.
Pile diameter	5 m	As specified in the design envelope
Pile depth	• 70 m in Turbine Area outside buried channel; • 120 m within buried channel.	Maximum volume of sediment disturbance.
Timing within tidal cycle	Commencing during a neap-spring tide.	Highest current speeds leading to furthest sediment advection distances.

Sediment Assumptions

2.3.3.5   The sediment properties and release rate (mass flux) of the different sediment fractions considering the parameters in Table 2-2 are shown in Table 2-3. Average dry density for the sediment in each area is based on data from the geotechnical investigation (Bluefield Geoservices, 2024). The release rate - sediment mass flux - is calculated by multiplying the sediment volume per fraction by the density, and dividing by the drilling duration.

Table 2-3 Mass flux arising from drilling of piles to install WTG foundations

Construction scenario	Volume of sediment per pile (m³)	Sediment d_{50} (mm)	Average dry density (kg/m³)	Sediment fractions (%)	Sediment mass flux (kg/s)
1	1,374	Silt – 0.03 Sand – 0.12 Gravel – 12.92	1,640	Silt - 57 Sand - 32 Gravel - 11	Silt – 19 Sand – 11 Gravel – 4 Total – 34
2	2,356	Silt – 0.15 Sand – 0.21 Gravel – 10.00	1,655	Silt - 5 Sand - 64 Gravel - 31	Silt – 3 Sand – 38 Gravel – 18 Total – 59
3	1,374	Silt – 0.15 Sand – 0.21 Gravel – 10.00	1,655	Silt - 5 Sand - 64 Gravel - 31	Silt – 2 Sand – 22 Gravel – 11 Total - 34

2.3.3.6 The sediment size information used in the modelling are based on the borehole data introduced in Section 2.2.4 and detailed in Table 3-2. The borehole depths below the seabed are ~10 m which is deeper than cable burial and HDD activities. In contrast, the foundation depth of piles is up to a maximum of 70 m to 120 m depending on location within the Turbine Area (see Table 2-2). This means that sediments released may be finer or coarser than the sediments at the depths covered by the boreholes. As a result, plume extents may vary from those indicated by the modelling outputs presented in Section 4.2. However, as the maximum sediment advection distance during a tidal cycle is limited by the peak spring tidal excursion ellipse, the plume extents presented are considered a reasonable worst-case.

Description of Model Outputs Presented

2.3.3.7 The following model outputs associated with drilling of piles to install WTG foundations as a singular activity are presented in Section 4.2:

- Spatial plots of instantaneous suspended sediment concentration during and after drilling of piles to install WTG foundations for each scenario. Times vary per location/scenario depending on the maximum extents of the sediment plume on a flood or ebb tide. Outputs are presented for selected modelled turbine drilling locations based on which location per scenario had the worst-case results and are applicable to all turbine locations within that scenario. The relevant modelled turbine drilling location is indicated in the plate caption for each modelled output that is presented in Section 4.2;
- Spatial plots of instantaneous sediment deposition thickness after drilling of piles to install WTG foundations for each scenario (worst case assuming no sediment resuspension).

2.3.3.8 The following model outputs associated with, multiples activities, drilling of piles to install WTG foundations and cable burial are presented in Section 4.6.1 (assuming drilling activity and cable burial activities will occur sequentially):

- Spatial plots of maximum suspended sediment concentration associated with the drilling of piles to install WTG foundations and sequential cable burial for each scenario;
- Timeseries plots of suspended sediment concentration associated with drilling of piles to install WTG foundations and sequential cable burial with and without sediment resuspension at the locations shown in Plate 2-8;
- Tabulated values of duration over concentration thresholds associated with drilling of piles to install WTG foundations and sequential cable burial with and without sediment resuspension at the locations shown in Plate 2-8;
- Spatial plots of maximum sediment deposition thickness associated with drilling of piles to install WTG foundations and sequential cable burial for each construction scenario;
- Timeseries plots of sediment deposition thickness associated with drilling of piles to install WTG foundations and sequential cable burial with and without sediment resuspension at the locations shown in Plate 2-8.

2.3.3.9 Consideration of sediment resuspension (including timeseries plots) associated with individual activities has been included with the analysis of multiple activities occurring sequentially (drilling and cable burial activities) for efficiency of results presentation.

Cable Burial

Modelled Locations

2.3.3.10 The cable burial activities covering both Array Cables to Final WTG and Array Cables to Landfall have been modelled at the locations outlined in Section 4.3. For scenario 1 (Southwest Turbine Area), no Array Cable to Landfall is shown due to refinement of the OCAS during the modelling process (refer to Chapter 4, Volume 1a for further detail). The potential impacts from cable burial activities from the Array Cable to Landfall in scenario 1 are not expected to exceed those assessed for scenario 2 (within the Buried Channel) and scenario 3 (Northeast Turbine Area) due to the consistent sediment properties and similar hydrodynamic conditions across the OCAS. As such, the modelling results presented are considered representative of the overall cable burial activities within the OCAS.

2.3.3.11 It is assumed that cable burial starts at the rock outcrop (shown in Plate 2-7) with surface lay over the rock outcrop to HDD exit pit location. However, it is noted that Array Cables to Landfall in scenario 3 cross the rock outcrop close to the Turbine Area. This is a conservative assumption since this cable route is modelled as jet trenched (see Table 9-22 of Chapter 9, Volume 2a for further context on this assumption). However, these would likely be surface laid over rocks. Therefore, the modelled scenarios included within this assessment result in greater sediment disturbance than is likely to occur during construction.

2.3.3.12 The maximum design scenario parameters used to model cable burial activities for both Array Cables to Final WTG and Array Cables to Landfall are detailed in Table 2-4.

Table 2-4 Parameters used to model cable burial

Parameter	Value	Justification
Construction method	Jet trenching	Maximum volume of sediment disturbance of construction methods being considered.
Cable layout	12 Array Cables to Final WTG and 12 Array Cables to Landfall (assumes Landfall Substation).	Maximum length of cable burial.
Trench width	7 m	Maximum value to represent a worst case.
Trench depth	2 m	Maximum value to represent a worst case.
Installation rate	300 m/hr	Assumption based on similar assessments.
Percentage of sediment released into water column	20%	Assumption based on similar assessments.

Sediment Assumptions

2.3.3.13 The sediment properties and release rate (mass flux) of the different sediment fractions considering the cable burial parameters in Table 2-4 are detailed in Table 2-5. Average dry density for the sediment in each area is based on data from the geotechnical investigation (Bluefield Geoservices, 2024). Sediment mass flux is calculated by multiplying the sediment volume per fraction by the density and dividing by the drilling duration.

Table 2-5 Mass flux arising from cable burial activities

Construction scenario	Cables included	Volume of sediment disturbance per hour (m³)	Sediment d50 (mm)	Average dry density (kg/m³)	Sediment fractions (%)	Sediment mass flux (kg/s)
1	Array Cables to Final WTG	420	Silt – 0.03 Sand – 0.12 Gravel – 12.92	1,640	Silt - 36 Sand - 26 Gravel - 39	Silt – 69 Sand – 49 Gravel – 74 Total – 192
2 & 3	Array Cables to Final WTG	420	Silt – 0.15 Sand – 0.21 Gravel – 10.00	1,655	Silt - 4 Sand - 79 Gravel - 18	Silt – 7 Sand – 152 Gravel – 34

Construction scenario	Cables included	Volume of sediment disturbance per hour (m³)	Sediment d50 (mm)	Average dry density (kg/m³)	Sediment fractions (%)	Sediment mass flux (kg/s)
						Total – 193
1, 2, & 3	Array Cables to Landfall	420	Gravel – 30.40	1,800	Silt- 0 Sand - 0 Gravel - 100	Gravel (total) - 210

Description of Model Outputs Presented

2.3.3.14 The following model outputs associated with cable burial as a singular activity are presented in Section 4.3:

- Spatial plots of instantaneous suspended sediment concentration during and after burial of Array Cables to Final WTG in each scenario. Times at which the outputs are provided vary per location depending on the maximum extents of the sediment plume on a flood or ebb tide. Worst-case sediment plume extents are presented for a select number of times which are applicable to the whole cable length in a given scenario;
- Spatial plots of maximum suspended sediment concentration arising from burial of Array Cables to Landfall for the scenarios where they are modelled. Instantaneous plots have not been shown for the burial of Array Cables to Landfall (i.e. within the OCAS) because the gravel sediment fraction settles faster than the timestep resolution of model outputs;
- Spatial plots of maximum sediment deposition thickness associated with burial of Array Cables to Final WTG for all scenarios and Array Cables to Landfall for the scenarios where they are modelled (worst case assuming no sediment resuspension).

2.3.3.15 Model outputs associated with multiple activities occurring sequentially (cable burial and drilling of piles to install WTG foundation) are described in Section 2.3.3.8 and presented in Section 4.6.1.

2.3.3.16 Consideration of sediment resuspension (including timeseries plots) associated with individual activities has been included with the analysis of multiple activities occurring sequentially (drilling and cable burial activities) for efficiency of results presentation (see Section 4.6.1 for further details).

Horizontal Directional Drilling - Drill Cutting Release

Modelled Locations

2.3.3.17 Drill cutting release from HDD has been modelled in a single representative location within the perimeter of the Landfall Exit Pit Area (shown in Plate 2-7). This approach has been taken because the final exit point locations will be determined during detailed design.

2.3.3.18 The maximum design scenario parameters used to model HDD drill cutting release are detailed in Table 2-6.

Table 2-6 Parameters used to model HDD drill cutting release

Parameter	Value	Justification
Bore volume (m^3)	1,285	Largest volume of sediment assumes drilling fluid volume released is equal to full volume of bore.
Release duration (hr)	1	Conservative assumption to release highest concentration of sediment.
Percentage fines in drilling fluid (%)	27	Highest value to release largest volume of sediment.
Timing of activity	Both peak spring tide and neap slack tide.	Peak spring tide will result in largest sediment advection distance while neap slack tide results in highest suspended sediment concentrations.

Sediment Assumptions

2.3.3.19 The sediment properties and release rate (mass flux) considering the parameters presented in Table 2-6, are detailed in Table 2-7. Average dry density for the sediment in each area is based on data from the geotechnical investigation (Bluefield Geoservices, 2024).

Table 2-7 Mass flux arising from HDD drill cutting release

Parameter	Value
Fines d_{50} (mm)	0.03
Volume of sediment released (m^3)	347
Fines average dry density (kg/m^3)	2,400
Calculated release rate (mass flux) (kg/s)	230

2.3.3.20 Sediment resuspension has not been considered for the slack tide scenario as current velocities are small.

Description of Model Outputs Presented

2.3.3.21 The following model outputs associated with HDD drill cutting release as a singular activity are presented in Section 4.4:

- Spatial plots of maximum suspended sediment concentration for each release scenario;
- Timeseries plots of suspended sediment concentration for each release scenario;
- Tabulated values of durations over concentration thresholds;

- Spatial plots of maximum sediment deposition thickness for each release scenario.

2.3.3.22 Section 4.6.2 contains analysis of multiple HDD activities (HDD drill cutting release and HDD exit pit construction) outputs. As mentioned in Section 2.3.2, HDD exit pit construction was quantitatively assessed using model outputs from burial of Array Cables to Landfall (described in Section 2.3.3.14) and HDD drill cutting release (described in Section 2.3.3.21) and therefore no additional outputs are presented.

Horizontal Directional Drilling - Exit Pit Construction

Modelled Locations

2.3.3.23 The modelled locations of the activities used to assess HDD exit pit construction are shown in Plate 2-7. As described in Section 2.3.2, the burial of Array Cables to Landfall and HDD drill cutting release are representative of HDD exit pit construction.

Maximum Design Scenario Parameters

2.3.3.24 The assumptions made for the purposes of this assessment, including comparisons to the maximum design scenarios modelled for release of HDD drill cutting and cable installation are outlined in Table 2-8. Justification for the assessment of HDD pit construction based on the modelled outputs relating to both HDD drill cutting and the Array Cable to Landfall is provided in Table 2-8.

Table 2-8 Assumptions used in assessment of HDD exit pit construction

Parameter	HDD exit pit construction maximum design scenario assumptions	Comparison of release of HDD drill cutting and Array Cable to Landfall maximum design scenarios modelled
Volume of sediment excavated per HDD exit pit	75 m length x 5 m width x 3.5 m depth = 1,312.5 m^3	Release of HDD drill cuttings 1,285 m^3 per bore which is assumed to be released in 1 hour. HDD Exit pit is equivalent to 62.5% of volume of cable trench volume released per hour.
Sequencing of HDD exit pit construction	Not simultaneous but HDD exit pit construction in one location could occur at the same time as drill release of HDD in another.	Cable installation and drill release of HDD have been modelled individually.
Method of construction	Rock grinding (releasing fine sediment) or rock cutting (releasing coarse sediment).	Cable installation sediment plume modelling near Landfall uses 100% gravel sediment (coarse).
Seabed conditions	Mixture of surface sediment and rock outcrop.	Drill release of HDD sediment plume modelling uses 100% silt sediment (fine).

Parameter	HDD exit pit construction maximum design scenario assumptions	Comparison of release of HDD drill cutting and Array Cable to Landfall maximum design scenarios modelled
Number of HDD exit pits	Up to 13 (1 per maximum design scenario number of HDD bores plus one spare).	Up to 12 Array Cables to Landfall and 13 HDD drill cutting release locations comprise the maximum design scenario.

Sediment Assumptions

2.3.3.25 HDD exit pits will be constructed using rock cutting or grinding. To account for the potential range of sizes of sediment that could be released from these activities, the construction of HDD exit pits has been assessed using sediment plume modelling outputs from Array Cable to Landfall burial (coarse sediment) and release of HDD drill cutting (fine sediment). This is appropriate because these construction activities generate sediment disturbance of a similar particle size and magnitude of sediment flux (based on construction information available) in the same location as the HDD exit pit construction.

Description of Model Outputs Presented

2.3.3.26 HDD exit pit construction has been quantitatively assessed using the model outputs described for cable burial and HDD drill cutting release and therefore no additional outputs are presented. The outputs used in the assessment are described in Section 2.3.3.14 (for cable burial) and Section 2.3.3.21 (for drill cutting release) and are analysed in Section 4.5 (for HDD exit pit construction in isolation) and Section 4.6.2 (for multiple HDD activities in a single location and multiple locations).

2.4 PRESENCE OF INFRASTRUCTURE DURING THE OPERATIONAL AND MAINTENANCE PHASE

2.4.1 OVERVIEW OF BLOCKAGE EFFECT ASSUMPTIONS

2.4.1.1 For the O&M phase of the Offshore Project, hydrodynamic, wave, and sediment transport effects due to the presence of infrastructure have been assessed. The presence of infrastructure in the water has the potential to cause blockage effects to the hydrodynamics and waves. The maximum design scenario for hydrodynamics and waves is the same (described in this Section), however the assumptions required for the hydrodynamic and spectral wave models vary (described in Sections 2.4.2 and 2.4.3).

2.4.1.2 The physical and coastal processes O&M phase modelling considers effects after turbines are installed in an indicative 60-turbine layout with an OSP as shown in Figure 3.2a, Volume 1b. This

arrangement is considered to be the maximum design scenario as it produces the greatest blockage effects. The turbines are arranged in an approximately 2.4 km x 1.4 km grid.

2.4.1.3   The turbines will be constructed with 3 or 4 leg jacket pile foundations with a maximum overall width at the seabed of 50 m. Due to model resolution constraints and to represent the maximum design scenario blockage effects, for the purposes of the O&M assessment the turbines have been modelled as 50 m diameter monopiles, representing a worst case in comparison to jacket pile structures which water can flow through.

2.4.1.4   Hydrodynamic and spectral wave model outputs relating to the presence of infrastructure during the O&M phase have been presented in Sections 5.2 and 5.3 as spatial difference plots. These plots show the difference between the model outputs with infrastructure present and the model outputs for the baseline scenario (presented in Section 3), demonstrating the changes that occur as a result of the Offshore Project.

2.4.2   HYDRODYNAMICS

2.4.2.1   Operational impacts due to the presence of infrastructure have been modelled for a spring-neap tidal cycle to assess a range of typical tidal conditions.

2.4.2.2   The turbines have been represented in the 2D hydrodynamic model as solid circular structures with a 50 m diameter throughout the water column. This is a worst-case representation of the blockage effects caused by the turbines; in reality a jacket tripod will have space between the piles allowing the water to flow between them.

2.4.2.3   The assessment of operational hydrodynamic impacts due to the presence of infrastructure has considered; the change in maximum water depths between the baseline and post-development runs; the change in current speed during peak spring and neap flood and ebb currents for baseline and post-development runs; the change in bed shear stress during peak spring and neap flood and ebb currents for baseline and post-development runs; and the change in wave conditions for baseline and post-development runs.

2.4.2.4   Operational impacts due to presence of infrastructure model outputs are presented in Section 5 for the following:

- Spatial plot of difference in maximum water depth compared to baseline;
- Spatial plot of difference in current speed during peak spring and neap flood and ebb currents compared to baseline;
- Spatial plot of difference in maximum current speed compared to baseline;
- Spatial plot of difference in bed shear stress during peak spring and neap flood and ebb currents compared to baseline;
- Spatial plot of difference in maximum bed shear stress compared to baseline.

2.4.3 WAVES

2.4.3.1 Operational impacts due to the presence of infrastructure have been investigated for both a typical storm condition scenario, with an estimated return period of around 1 year, and for extreme storm conditions, up to and including 1,000 years return period storm conditions.

2.4.3.2 To adequately represent the post-development changes in the Offshore Project Boundary and the introduction of turbines and OSP, structures have been introduced into the baseline spectral waves model. These have been introduced at their indicative locations, and are represented by circular piers, each with a 50 m diameter. As structures are typically smaller than the grid resolution, the model represents these by using a subgrid scaling technique. The method used, introduces a decay term to reduce wave energy behind the specified structures. This method most accurately represents the structures that will be present, while allowing for potential changes in the specific type of foundation that will be introduced. The chosen approach allows for a worst-case scenario of the area taken up by each individual structure.

2.4.3.3 The impacts of the Turbine Area on measured storm conditions in the Offshore Project Boundary have been assessed through an analysis of the differences in Hs in post-development conditions when compared to the baseline scenario. The selected storm event conditions used are therefore the same ones presented in the baseline assessment.

2.4.3.4 Operational impacts due to presence of infrastructure model outputs are presented in Section 5.3 for the following:

- Spatial plot of difference in significant wave height compared to baseline at representative; peak for each incoming wave direction during measured storm conditions;
- Timeseries plot showing difference of significant wave height compared to baseline;
- Spatial plot of difference in significant wave height compared to baseline during 1in1 and 1in100 year return period events for each incoming wave direction.

2.4.4 SEABED SEDIMENTS

2.4.4.1 Sediment transport potential in the O&M phase has been assessed using the same method outlined in Section 2.2.4. Bed shear stress has been extracted from the O&M phase hydrodynamic model (presented in Section 5.2.3) and wave height parameters adjusted according to the O&M phase wave modelling (presented in Section 5.3.1). Typical hydrodynamic and wave conditions (i.e. not storm events) have been assessed in line with the baseline characterisation. The results of this analysis are tabulated in Section 5.4.

3   BASELINE CHARACTERISATION MODELLING RESULTS

3.1   OVERVIEW

3.1.1.1   This section presents outputs from the baseline characterisation modelling of hydrodynamics and waves, alongside characterisation of seabed sediments and sediment transport potential.

3.2   HYDRODYNAMICS

3.2.1   WATER DEPTH

3.2.1.1   The modelled water depths at spring and neap high and low water are shown in Plate 3-1 to Plate 3-4.

3.2.1.2   At high water during a spring tide, the water depth in the Turbine Area ranges from approximately 45-70 m. At low water during a spring tide, the water depth in the Turbine Area ranges from approximately 40-65 m.

Plate 3-1 Total water depth - spring high water

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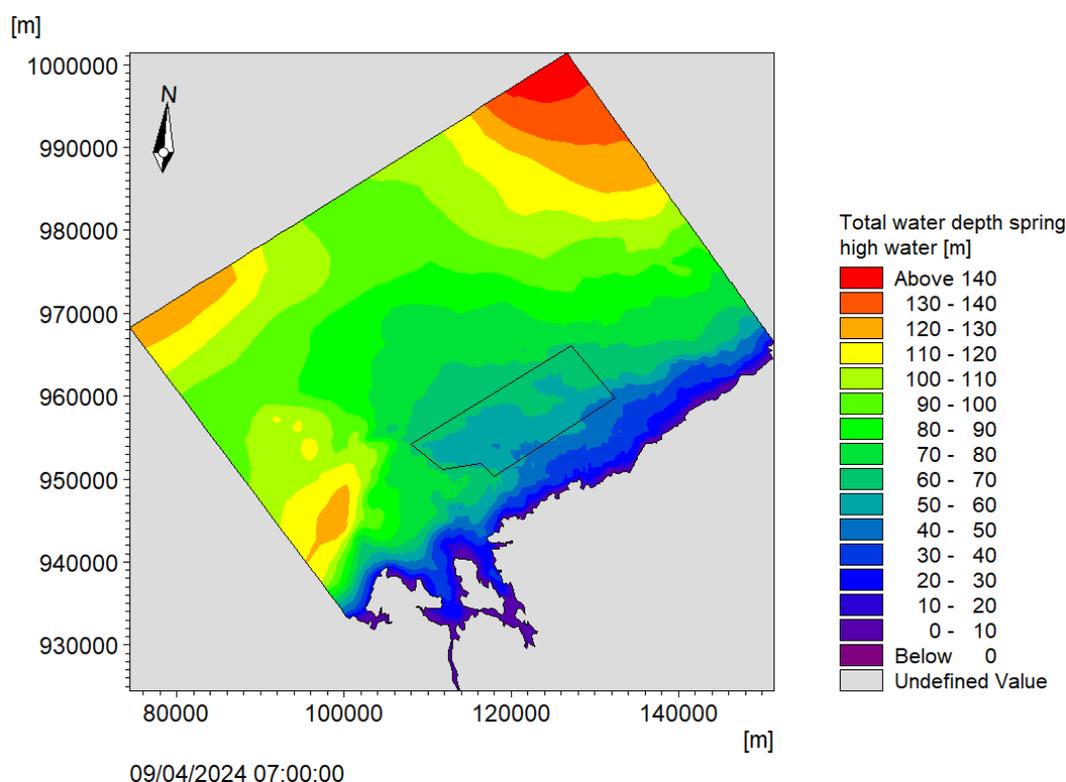
Plate 3-2 Total water depth - spring low water

09/04/2024 13:00:00
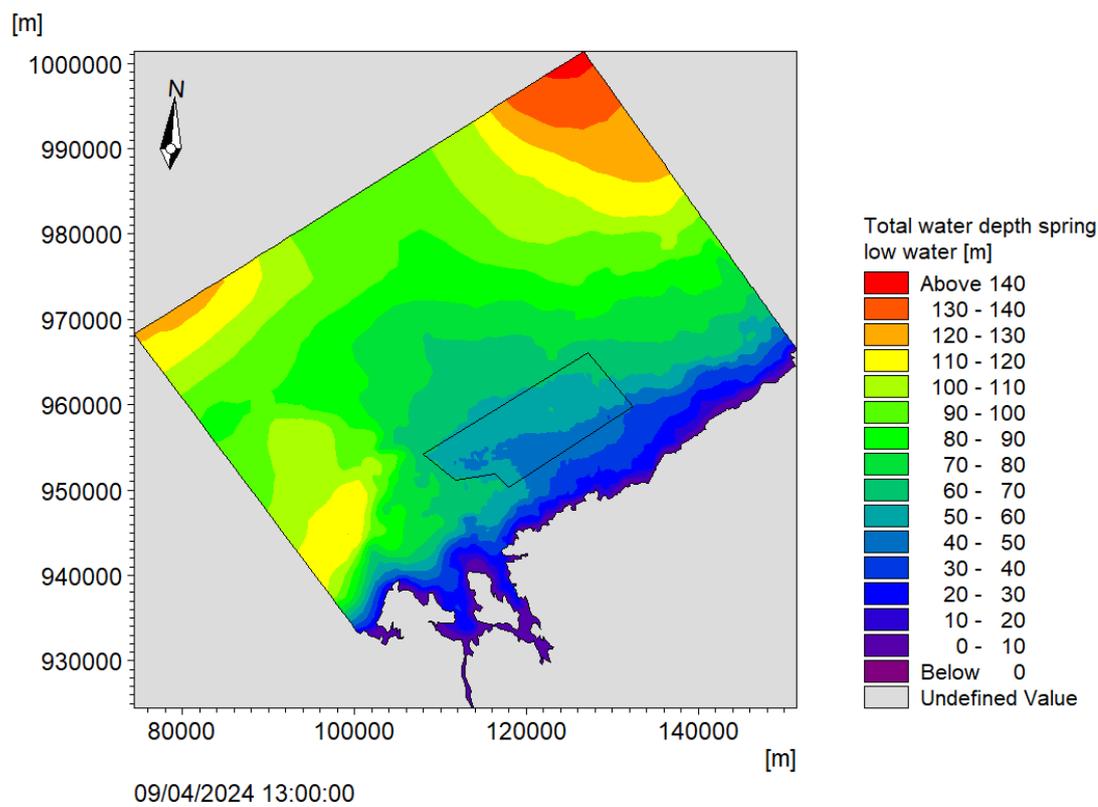
Plate 3-3 Total water depth – neap high water

16/04/2024 13:30:00
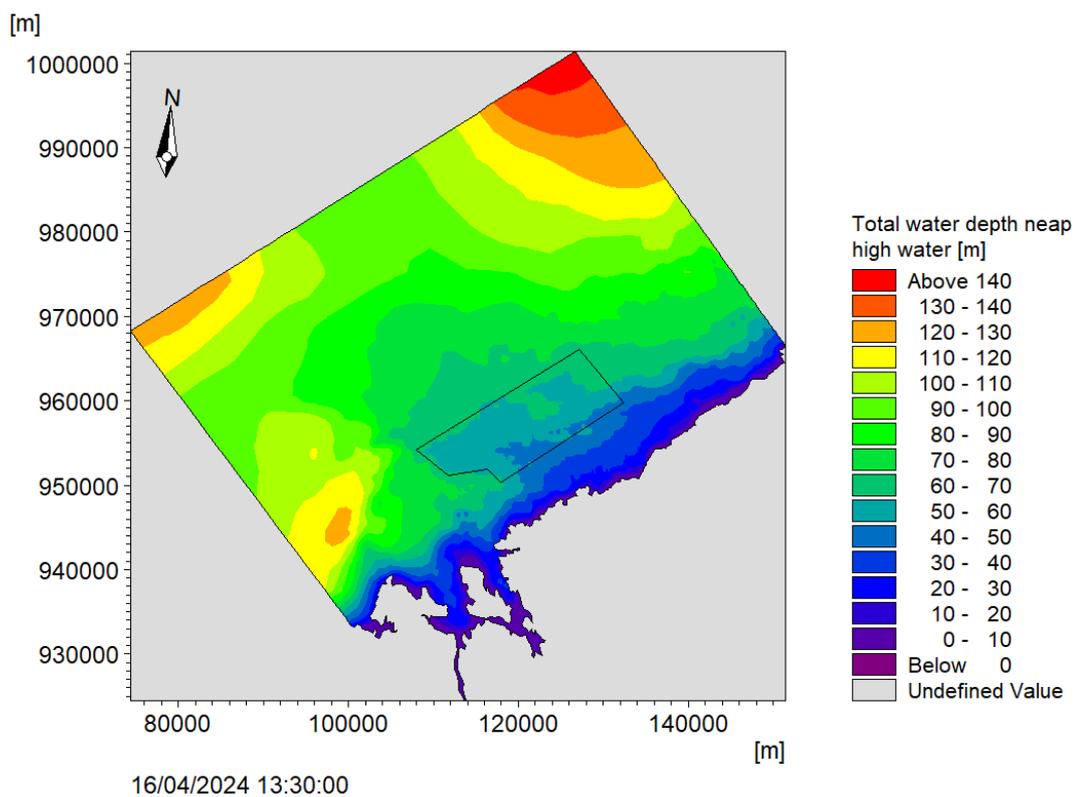
Plate 3-4 Total water depth - neap low water

16/04/2024 20:00:00
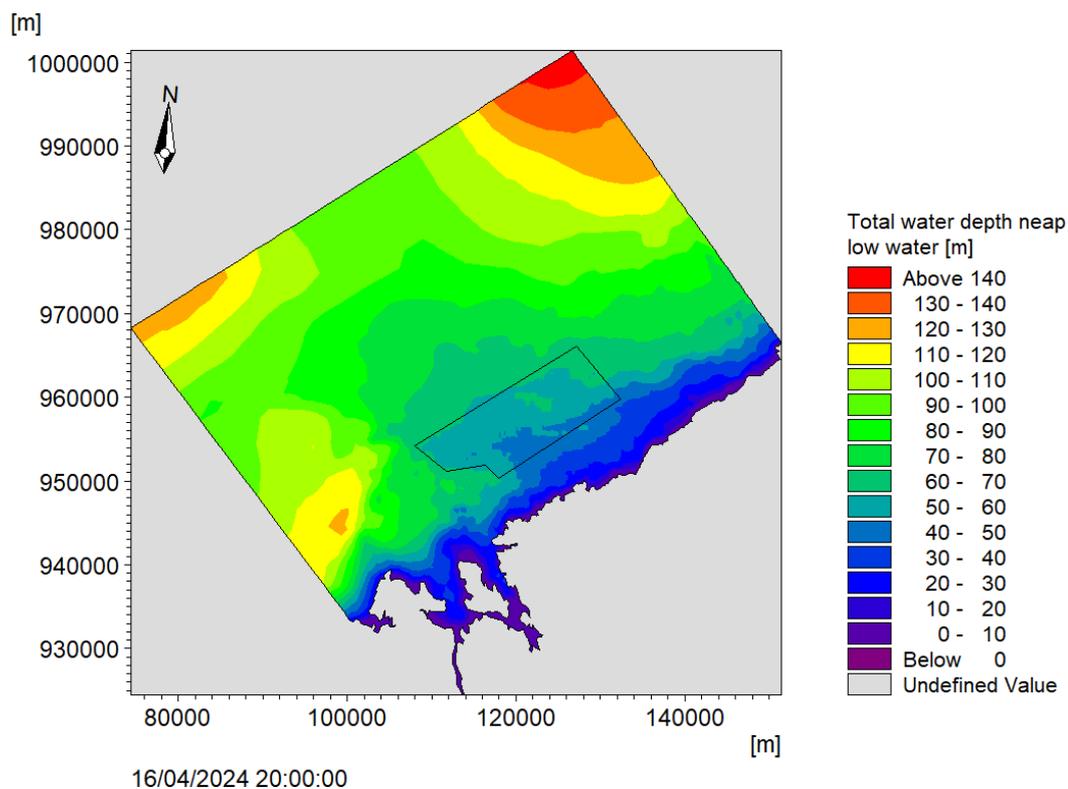
3.2.1.3   The maximum and minimum water depths over the 1-month model duration are shown in Plate 3-5 and Plate 3-6. The minimum depth is approximately 40 m in the eastern corner of the Turbine Area. The maximum depth is approximately 70 m in the northern corner of the Turbine Area.

3.2.1.4   The similarities between the spring high water depth and maximum water depth plates indicate that there is minimal tidal phase difference across the model domain. The tidal range is consistent across the model domain with a slight reduction moving offshore, and larger towards the north than the south.

Plate 3-5 Total water depth – statistical minimum
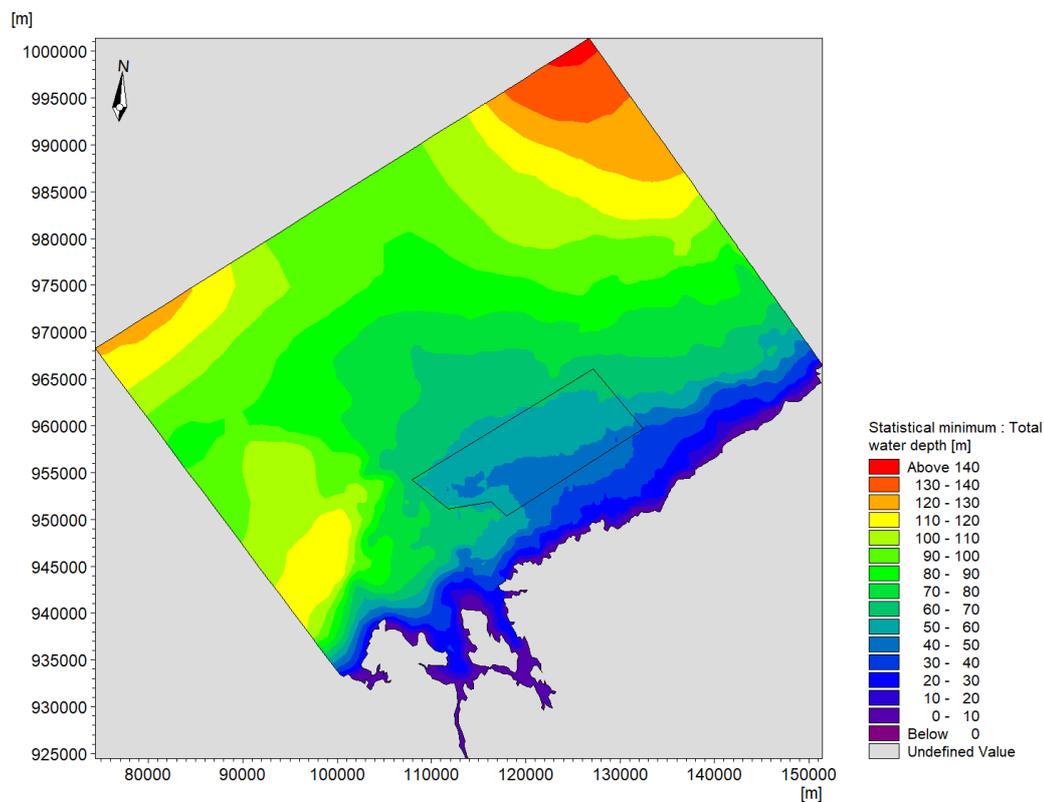
Plate 3-6 Total water depth – statistical maximum
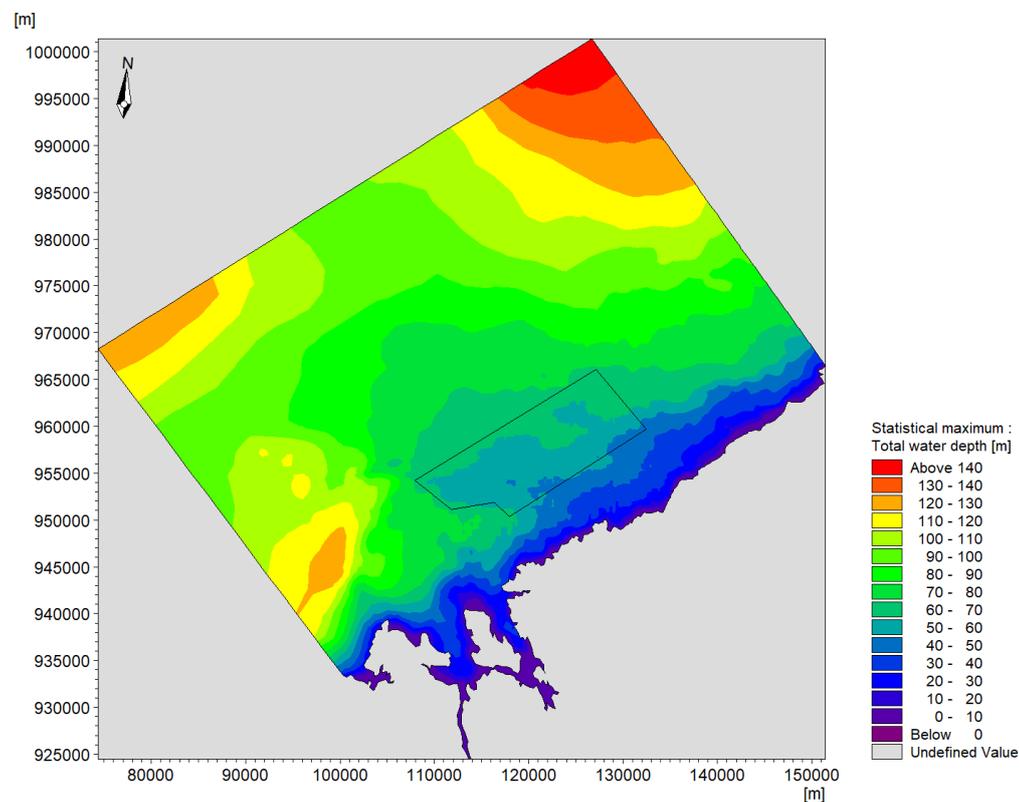
3.2.2 CURRENT SPEED

3.2.2.1 The modelled peak tidal flood and ebb current speeds during spring and neap tides are shown in Plate 3-7 to Plate 3-10.

3.2.2.2 Within the Turbine Area, current speeds are predominantly higher in the northeast than in the southwest, regardless of current direction. Peak flood current speeds during spring tides range from 0.40 m/s-0.55 m/s. Peak spring ebb current speeds range from 0.35 m/s-0.50 m/s. Peak neap flood current speeds range from 0.05 m/s-0.20 m/s. Peak neap ebb current speeds range from 0.05 m/s-0.10 m/s.

Plate 3-7 Peak current speed – spring flood tide

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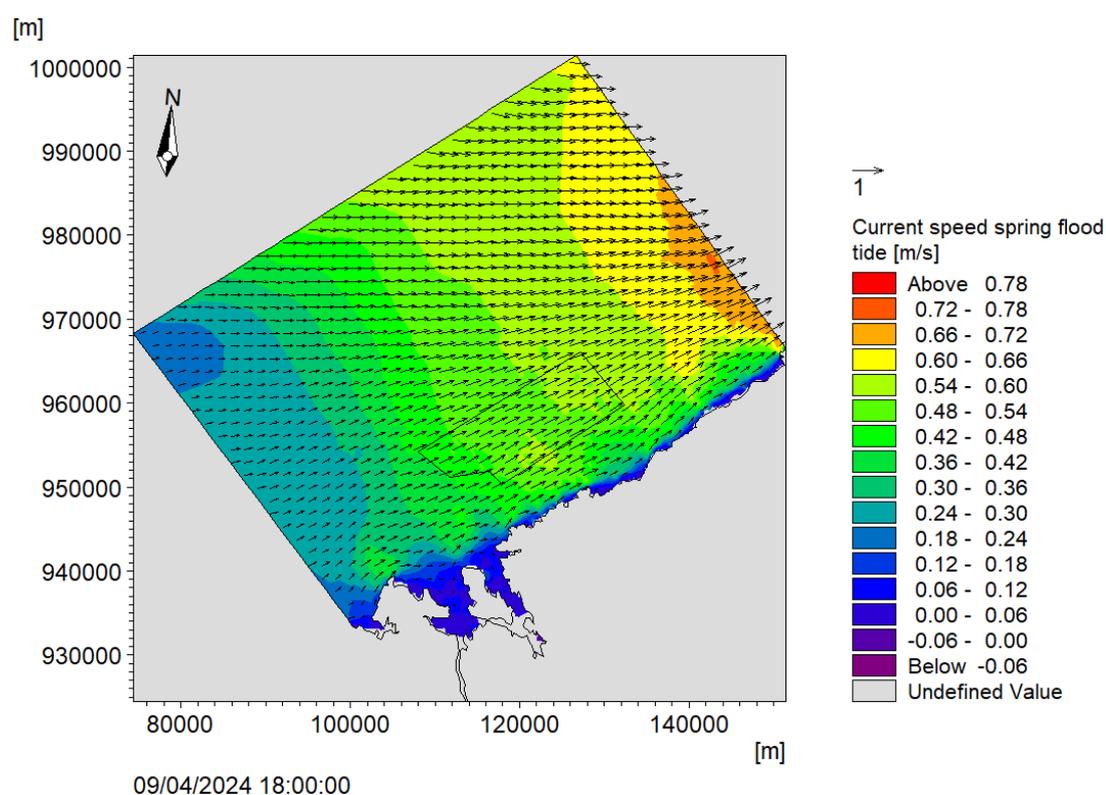
Plate 3-8 Peak current speed – spring ebb tide

09/04/2024 11:30:00
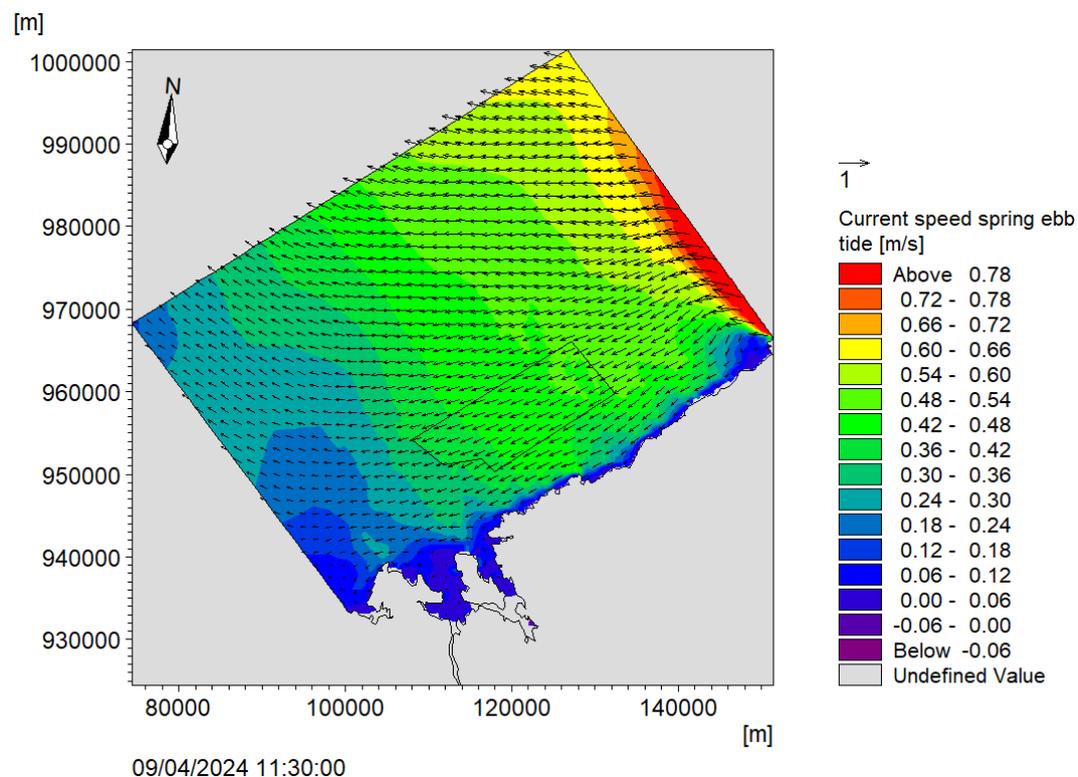
Plate 3-9 Peak current speed – neap flood tide

16/04/2024 23:30:00
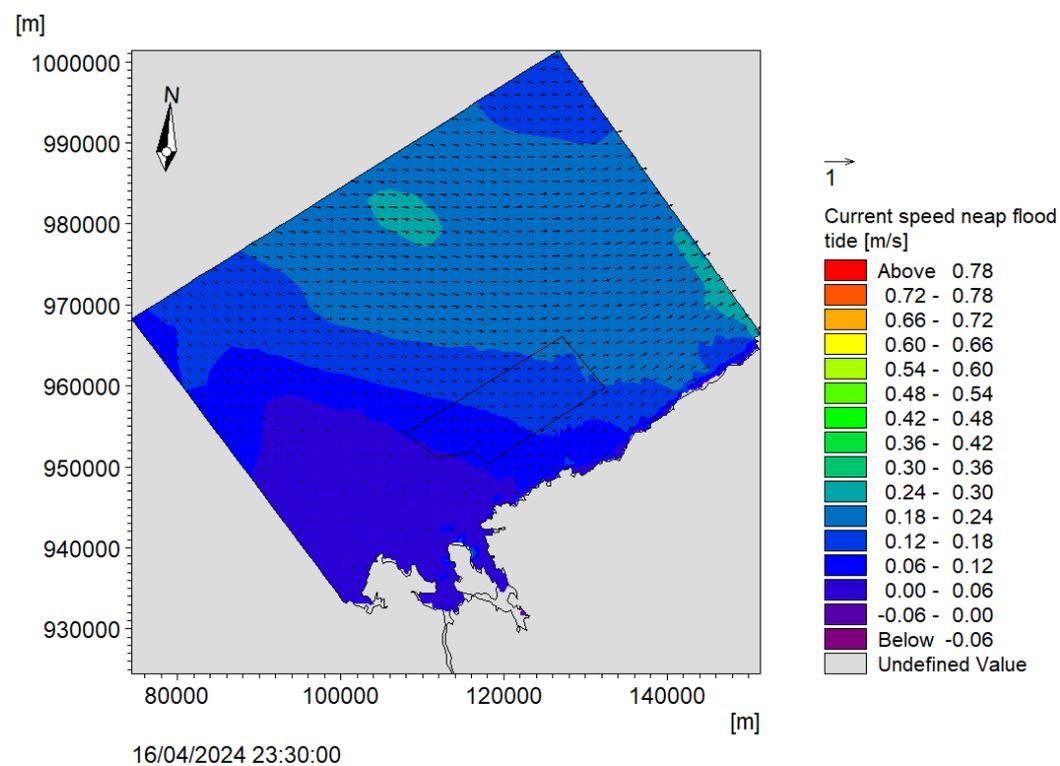
Plate 3-10 Peak current speed – neap ebb tide

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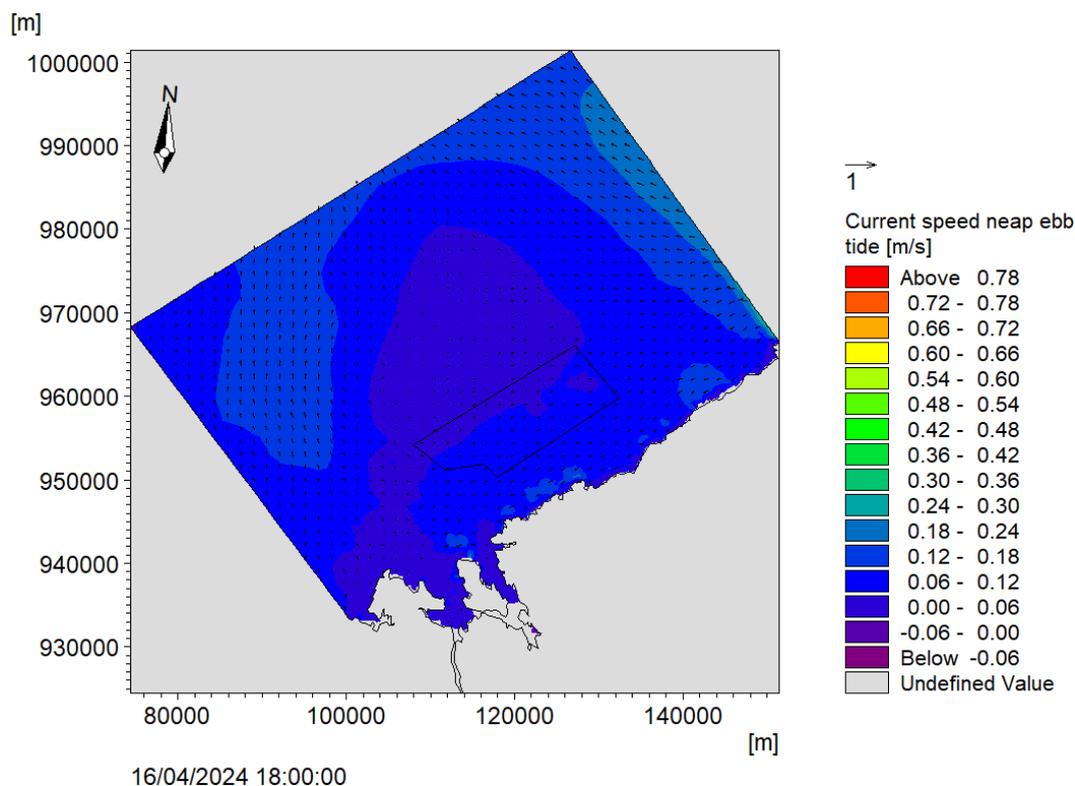
3.2.2.3 The maximum current speeds over the model duration are shown in Plate 3-11. Similarly to the Turbine Area, speeds in the broader model domain are higher in the north than the south. The highest maximum current speed is approximately 1.1 m/s near the coast at the northern edge of the model domain, and the lowest maximum current speed is approximately 0.1 m/s in an onshore inlet.

Plate 3-11 Peak current speed – statistical maximum
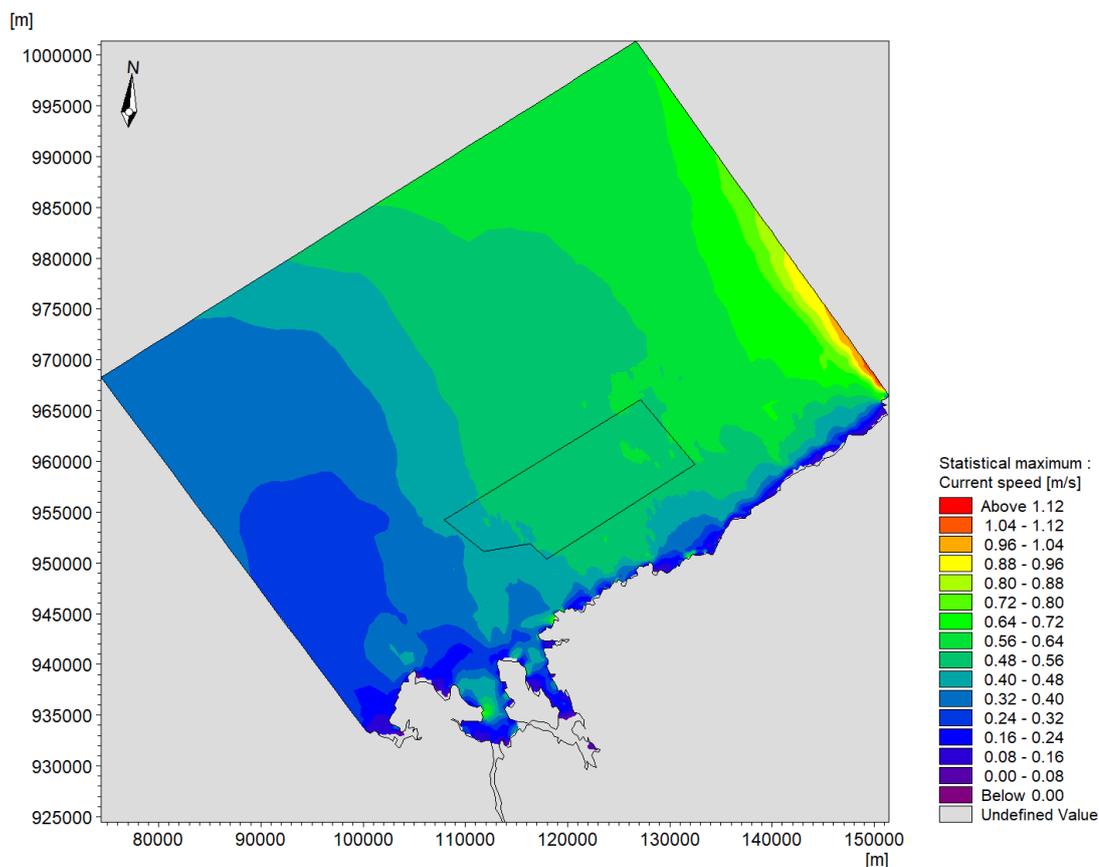
3.2.2.4 A timeseries plot of baseline current speed and water depth in the middle of the Turbine Area throughout the model duration are shown in Plate 3-12.

Plate 3-12 Baseline current speed and water depth timeseries
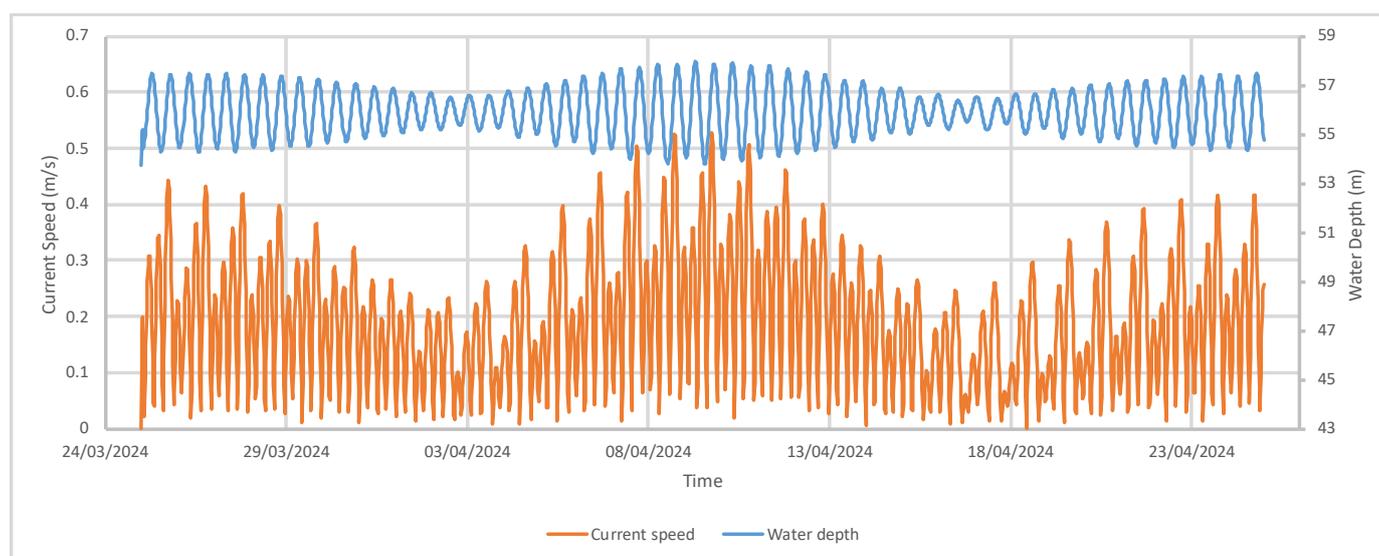
3.2.3 BED SHEAR STRESS

3.2.3.1 The modelled bed shear stress at peak flood and ebb spring and neap tides are shown in Plate 3-13 to Plate 3-16.

3.2.3.2 Similarly to current speeds, within the Turbine Area shear stresses are predominantly higher in the north than the south, regardless of current direction. Peak flood bed shear stresses during spring tides range from 2.0 N/m^2-1.1 N/m^2. Peak spring ebb bed shear stresses range from 1.6 N/m^2-0.8 N/m^2. Peak neap flood bed shear stresses range from 0.2 N/m^2-0.02 N/m^2. Peak neap ebb bed shear stresses range from 0.05 N/m^2-0.01 N/m^2.

Plate 3-13 Bed shear stress - spring flood tide
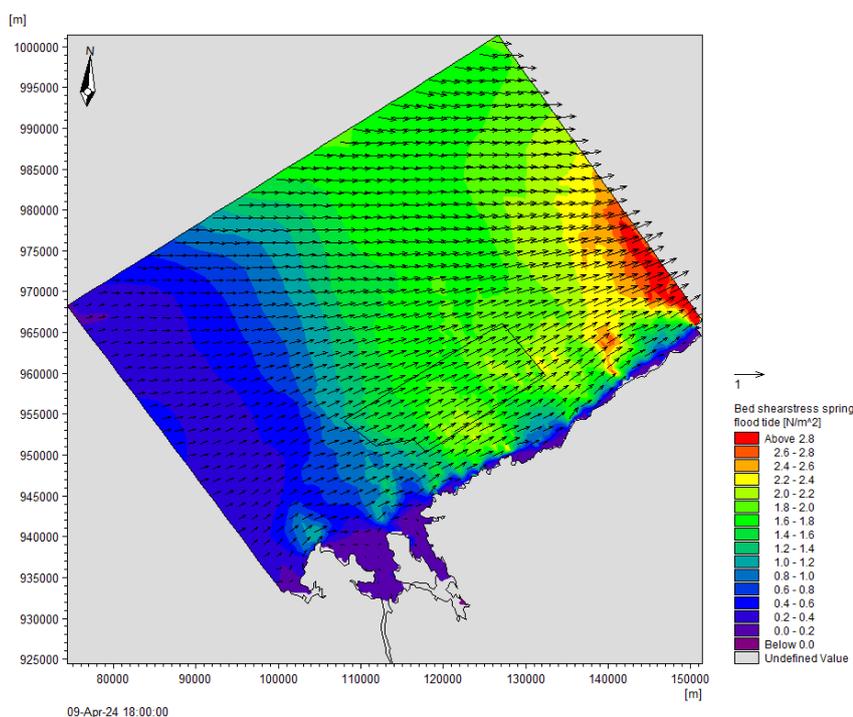
Plate 3-14 Bed shear stress - spring ebb tide

09-Apr-24 11:30:00
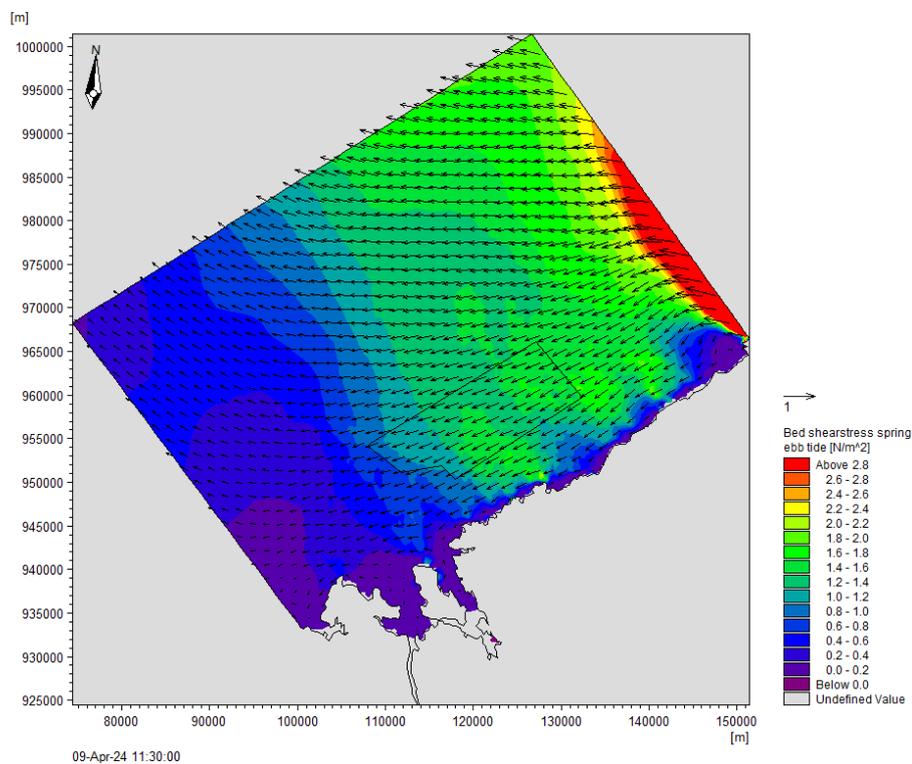
Plate 3-15 Bed shear stress - neap flood tide

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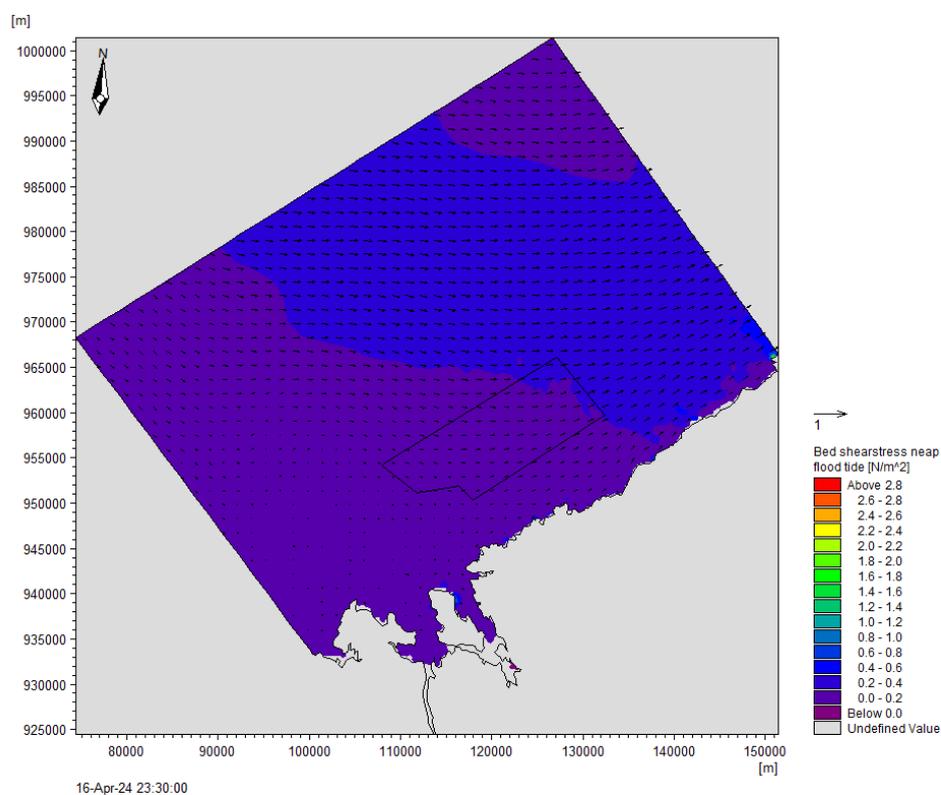
Plate 3-16 Bed shear stress – neap ebb tide

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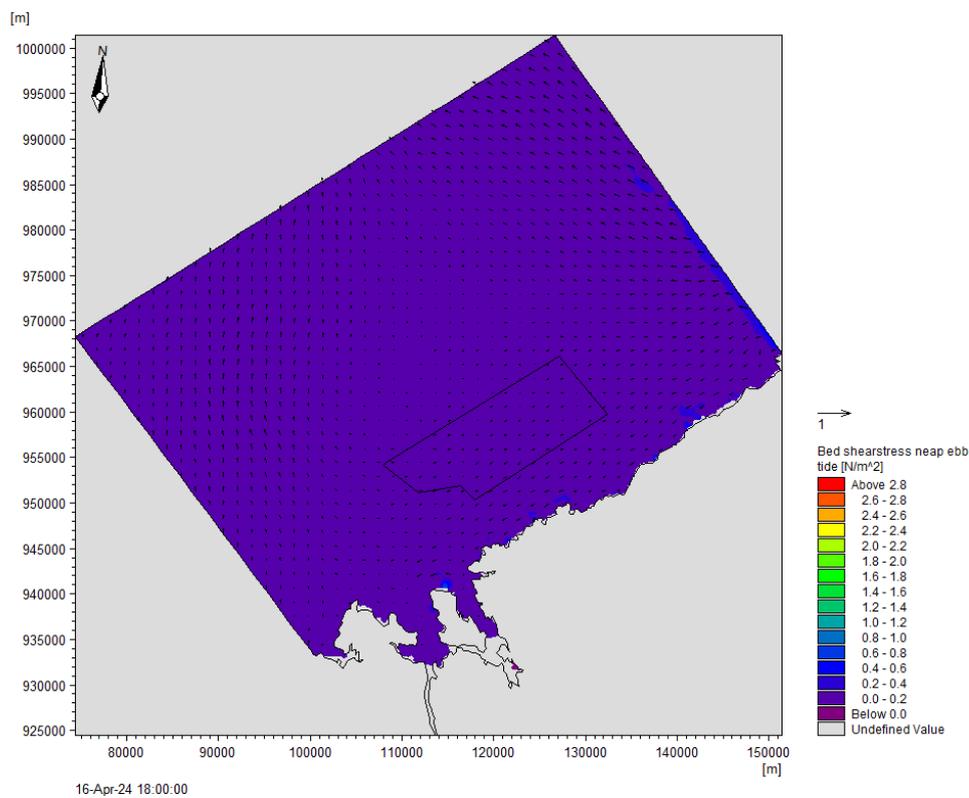
3.2.3.3 The maximum bed shear stresses over the model duration are shown in Plate 3-17. Similarly to the Turbine Area, speeds in the broader model domain are higher in the north than the south. The highest maximum bed shear stress is approximately 9 N/m^2 near the coast at the northern edge of the model domain and the lowest maximum bed shear stress is approximately 0.3 N/m^2 in an onshore inlet around Great Bernera/*Beàrnaraigh*.

Plate 3-17 Bed shear stress – statistical maximum
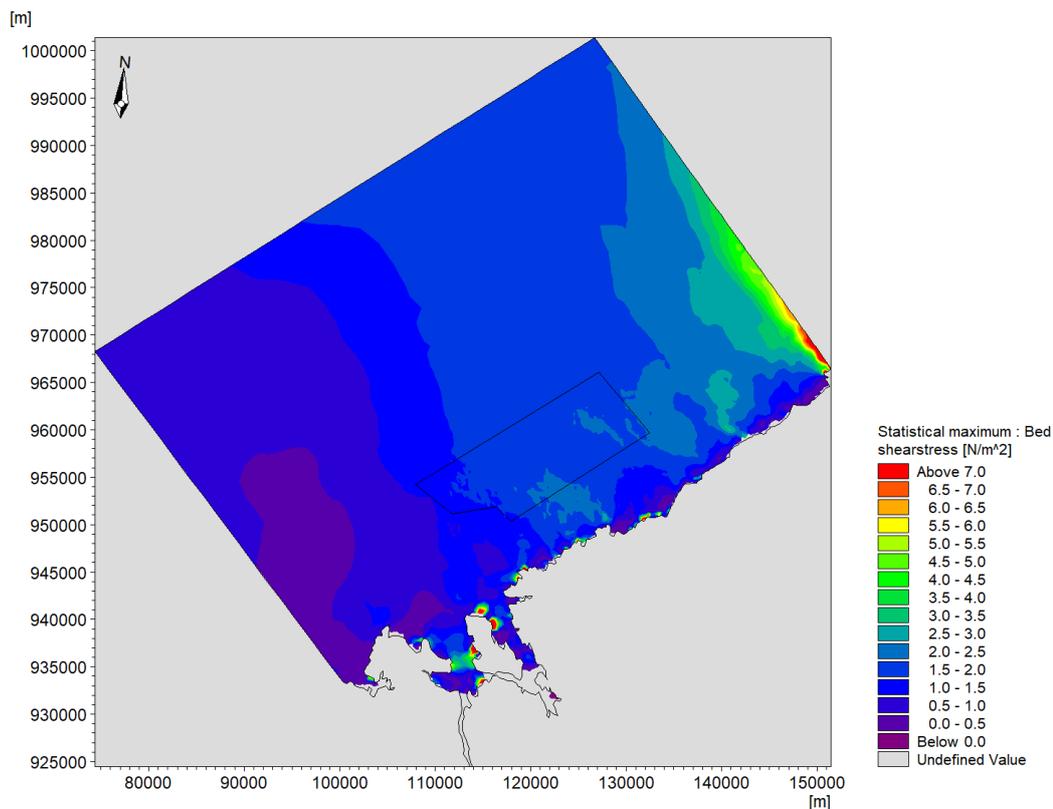
3.2.3.4   A timeseries plot of baseline bed shear stress and water depth in the middle of the Turbine Area throughout the model duration are shown in Plate 3-18.

Plate 3-18 Baseline bed shear stress and water depth timeseries
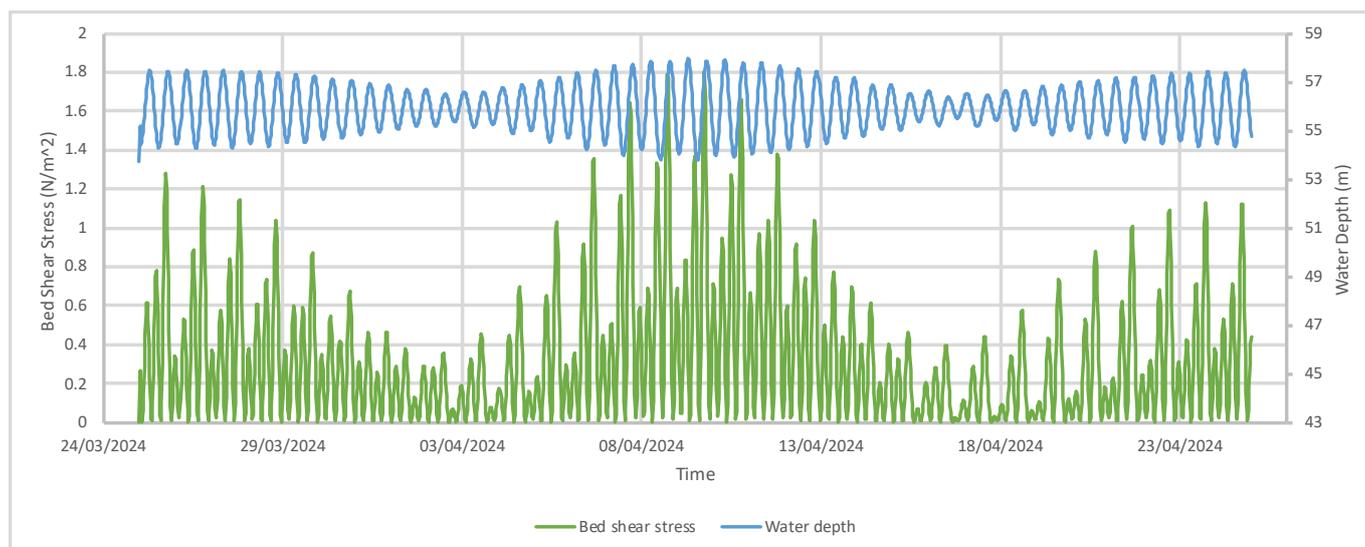
3.3 WAVES

3.3.1 MEASURED STORM CONDITIONS

3.3.1.1 The results for the baseline scenario under these conditions are shown in Plate 3-19. The Hs within the Turbine Area is between 9.0 m and greater than 9.5 m.

Plate 3-19 Baseline scenario - maximum significant wave height
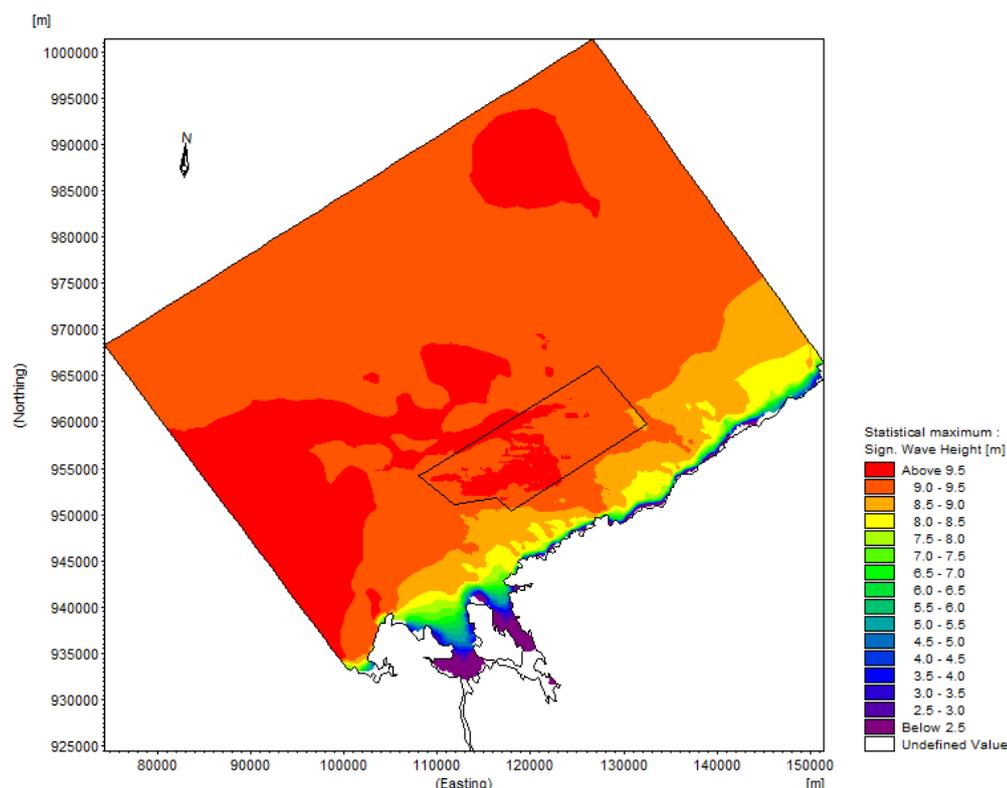
3.3.2 EXTREME EVENTS

3.3.2.1 The EVA results for each direction are shown in Table 3-1.

Table 3-1 Significant wave height extreme value analysis results by direction

Direction	Significant wave height Hs (m) for return period (years)							
	1	5	10	50	100	200	500	1000
Southwest	6.40	7.83	8.64	10.65	11.61	12.64	14.11	15.32
West	8.01	9.85	10.68	12.28	12.86	13.40	14.04	14.48
Northwest	6.92	8.64	9.38	10.70	11.16	11.56	12.03	12.37
North	6.69	8.06	8.70	9.99	10.48	10.95	11.52	11.93

3.4   SEABED SEDIMENTS

3.4.1   SEABED SUBSTRATE

3.4.1.1   Within the Array Area and OCAS, seabed sediments generally range from gravelly sand in the west to gravel in the east (see Figure 9-5, Volume 2b). For more information on seabed sediment data see Section 9.6.2 of Chapter 9, Volume 2a.

3.4.1.2   The locations of borehole sampling undertaken as part of the geotechnical investigation (Bluefield Geoservices, 2024) are shown in Plate 3-20. The Scotwind Site Boundaries depicted in Plate 3-20 have been revised post completion of the geotechnical surveys and therefore do not reflect the revised Offshore Project Boundaries, however the borehole locations remain accurate.

3.4.1.3   Table 3-2 sediment information provided by the sampling (this table only includes boreholes that had particle size distribution data and were used in the sediment plume modelling) is summarised in Table 3-2.

Plate 3-20 Borehole locations in geotechnical survey (Bluefield Geoservices, 2024)
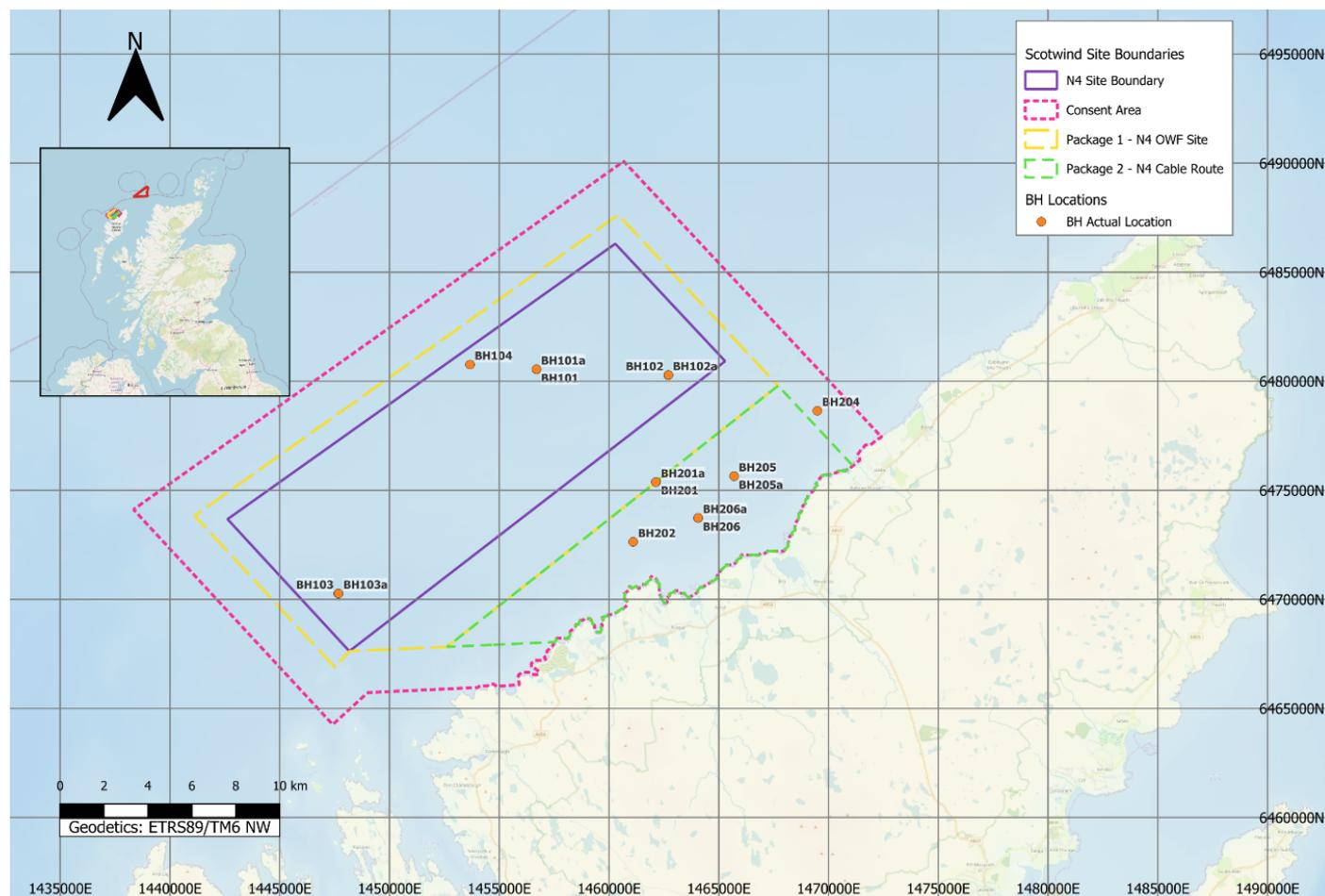
Table 3-2 Sediment information from borehole samples

Borehole	Depth below seabed (m)	Sediment description
BH101	0 – 1.4	Fine to medium sand
	1.4 – 1.57	Slightly sandy fine to medium gravel
	1.57 – 3.12	No data collected
	3.12 – 3.35	Medium to coarse gravel
	3.35 – 3.37	Fine sand
	3.37 – 6.84	No data collected
BH101A	0 – 1	Destructive drilling
	1 – 1.39	Slightly gravelly fine to medium sand
	1.39 – 2.19	Fine to medium sand
	2.19 – 2.39	Gravelly fine to coarse sand
	2.39 – 2.79	Sandy fine to medium gravel
	2.79 – 3	No data collected
	3 – 3.08	Fine sand with occasional fine to medium gravel
	3.08 – 4.14	No data collected
	4.14 – 4.26	Fine sand
	4.26 – 4.49	Coarse sand
	4.49 – 4.74	Very sandy fine gravel
	4.74 – 5.49	Slightly sandy fine gravel
	5.49 – 8.84	No data collected
	8.84 – 9.28	Slightly silty fine to medium sand
BH103	0 – 0.25	Gravelly slightly silty fine to medium sand with occasional cobble
	0.25 – 0.45	Slightly gravelly sandy silty clay with laminations of fine to medium sand
	0.45 – 3.29	No data collected
	3.29 – 3.39	Medium to coarse gravel
	3.36 – 3.86	Slightly gravelly sandy silty clay with occasional pockets of fine to medium sand
	3.86 – 6.09	No data collected
	6.09 – 9.05	Slightly sandy silty clay
	9.05 – 14.12	No data collected
BH103A	0 – 0.33	Slightly sandy slightly gravelly clay
	0.45 – 3.30	No data collected
	3.30 – 3.40	Gravelly silty clay
	3.40 – 4.15	Silty clay with rare sand pockets
	4.15 – 4.23	Sandy silty clay with gravel
	4.23 – 4.28	Silty clay
	4.28 – 4.36	Silty clayey fine to medium sand
	4.36 – 4.83	Silty clay with rare fine sand pockets
	4.83 – 6.41	No data collected
BH104	0 – 3.29	Destructive drilling zone
	3.29 – 3.55	Fine to medium sand with pockets and laminations of clay

Borehole	Depth below seabed (m)	Sediment description
	3.55 – 3.80	Fine to medium gravel
	3.80 – 6.29	No data collected
	6.29 – 6.49	Slightly silty fine sand
	6.49 – 6.74	Fine to medium sand
	6.74 – 7.41	Very sandy medium to coarse gravel
	7.41 – 9.29	No data collected
	9.29 – 9.79	Fine to coarse sand with occasional pockets of silt, clay, and fine gravel
	9.79 – 10.49	Slightly gravelly medium to coarse sand
	10.49 – 10.59	Fine to coarse gravel
	10.59 – 12.53	No data collected
BH201A	0 – 0.20	Fine to coarse gravel with few cobbles
	0.20 – 2.50	No data collected
	2.50 – 2.70	Fine to coarse gravel
	2.70 – 2.95	Silty fine sand with numerous pockets of clay
	2.95 – 4.30	Sandy silt with numerous pockets and laminations of clay
	4.30 – 5.75	Very silty fine sand

3.4.2   SEDIMENT TRANSPORT

3.4.2.1   The calculated percentage of time that bed shear stresses due to combined wave and current action are greater than the threshold for sediment suspension during the baseline spring-neap tidal cycle is detailed in Table 3-3. Analysis locations are labelled in Figure 9.6, Volume 2b.

3.4.2.2   Finer sediments (silt and sand) are more frequently mobilised than coarser sediments (gravel). Silts in the northeast Turbine Area are less frequently mobilised than in the southwest Turbine Area because the sediment in the northeast is generally coarser. Gravel sediments are not mobilised in the period assessed (25 March-25 April 2024) where the maximum wave height was <5 m. However, more energetic waves greater than 5 m have been measured in the Turbine Area which would generate bed shear stresses high enough to mobilise this sediment.

Table 3-3 Percentage of time sediment would be mobile under baseline conditions at the locations shown in Figure 9.6, Volume 2b

Location	Sediment	Time that combined wave and current bed shear stress greater than suspension threshold
Southwest of Turbine Area	Silt	100%
	Sand	66%
	Gravel	0%
Northeast of Turbine Area	Silt	69%
	Sand	66%
	Gravel	0%
Middle OCAS	Gravel	0%

Location	Sediment	Time that combined wave and current bed shear stress greater than suspension threshold
HDD Exit Pit	Silt	100%

3.4.2.3 Information regarding baseline suspended sediment concentrations is included in Section 9.6.2 of Chapter 9, Volume 2a.

4 SEDIMENT PLUME MODELLING RESULTS

4.1 OVERVIEW

4.1.1.1 This section presents outputs from the sediment plume modelling of drilling of piles to install WTG foundations, burial of Array Cables to Final WTG and Array Cables to Landfall, and drill cutting release from HDD activities. It also includes the assessment of HDD exit pit construction.

4.2 DRILLING OF PILES TO INSTALL WIND TURBINE GENERATOR FOUNDATIONS

4.2.1 SUSPENDED SEDIMENT CONCENTRATION

Scenario 1 – Southwest Turbine Area

4.2.1.1 Spatial plots of instantaneous suspended sediment concentrations during and after drilling of piles to install WTG foundations in scenario 1 are shown in Plate 4-1 to Plate 4-3. These plots show the concentration and furthest extent of the plume reached on a flood (Plate 4-1) and ebb (Plate 4-2) tide during drilling, and the concentration and extent of the plume 5.5 hours after completion of drilling (Plate 4-3). Further information on suspension duration is shown in the timeseries plots in Section 4.6.1.

4.2.1.2 The modelling indicates that suspended sediment is advected to the northeast of the modelled turbine location 9 hours after the activity commences due to the prevailing direction of the flood tide. 15 hours after the drilling of piles to install WTG foundations commences, suspended sediments are advected to the southwest, since this point in time coincides with an ebb tide.

4.2.1.3 Suspended sediments resulting from the drilling of piles to install WTG foundations in scenario 1 have the potential to be advected approximately 12-15 km (in a plume up to 500 m wide) centred around the modelled turbine location with a concentration generally less than 40 mg/l. Once the sediment is released during drilling, it remains in suspension within the water column for approximately 12 hours after completion of drilling (see timeseries plots in Section 4.6.1).

Plate 4-1 Instantaneous suspended sediment concentration 9 hours after scenario 1 drilling of piles to install WTG foundations commences at turbine location 20 (maximum extent on flood tide)

25/03/2024 09:00:00

Plate 4-2 Instantaneous suspended sediment concentration 15 hours after scenario 1 drilling of piles to install WTG foundations commences at turbine location 20 (maximum extent on ebb tide)

25/03/2024 15:00:00

Plate 4-3 Instantaneous suspended sediment concentration 11.75 hours after scenario 1 drilling of piles to install WTG foundations commences at turbine location 20 (5.5hr after completion of drilling)

25/03/2024 23:45:00

Scenario 2 – Buried Channel

4.2.1.4   Spatial plots of instantaneous suspended sediment concentration during and after completion of drilling of piles to install WTG foundations in scenario 2 are shown in Plate 4-4 and Plate 4-5. These plots show the furthest extent of the plume reached on a flood (Plate 4-4) and ebb (Plate 4-5) tide during drilling.

4.2.1.5   Suspended sediments resulting from the drilling of piles to install WTG foundations in scenario 2 are advected <3 km (in a plume up to 250 m wide) from the pile location with a concentration up to 5 mg/l away from the modelled turbine location. Once the sediment is released during drilling, it is only suspended for less than an hour since current speeds greater than approximately 0.35 m/s (i.e. at mid-tide) are required for the sediment to remain in suspension. Further information on suspension duration is shown in the timeseries plots in Section 4.6.1.

Plate 4-4 Instantaneous suspended sediment concentration 7.25 hours after scenario 2 Turbine Area drilling of piles to install WTG foundations commences at turbine location 54
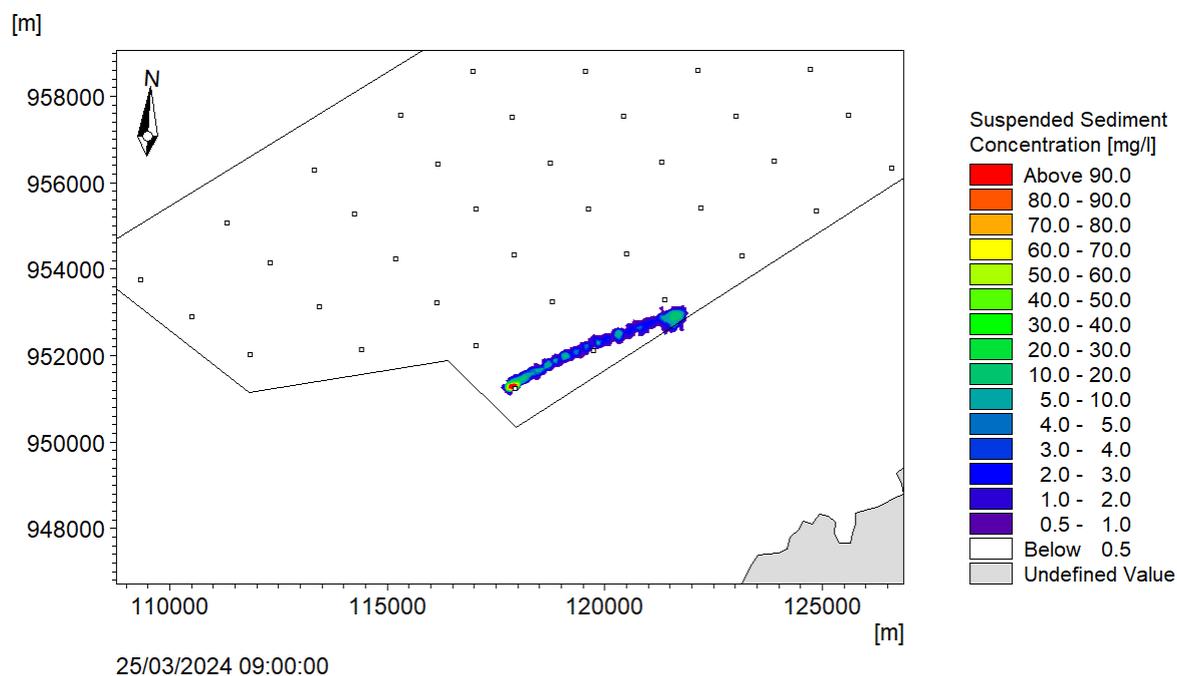

25/03/2024 07:15:00

Plate 4-5 Instantaneous suspended sediment concentration 10.75 hours after scenario 2 drilling of piles to install WTG foundations commences at turbine location 54

25/03/2024 10:45:00

Scenario 3 – Northeast Turbine Area

4.2.1.6   Spatial plots of instantaneous suspended sediment concentration during and after completion of drilling of piles to install WTG foundations in scenario 3 are shown in Plate 4-6 and Plate 4-7.

These plots show the furthest extent of the plume reached on a flood (Plate 4-6) and ebb (Plate 4-7) tide during drilling.

4.2.1.7   Suspended sediments resulting from the drilling of piles to install WTG foundations in scenario 3 are advected <500 m (in a plume up to 300 m wide) from the modelled turbine location with concentrations less than 5 mg/l away from the modelled turbine location. Once the sediment is released, it is only suspended for less than an hour since current speeds greater than approximately 0.35 m/s (i.e. at mid-tide) are required for the sediment to remain in suspension. Further information on suspension duration is shown in the timeseries plots in Section 4.6.1.
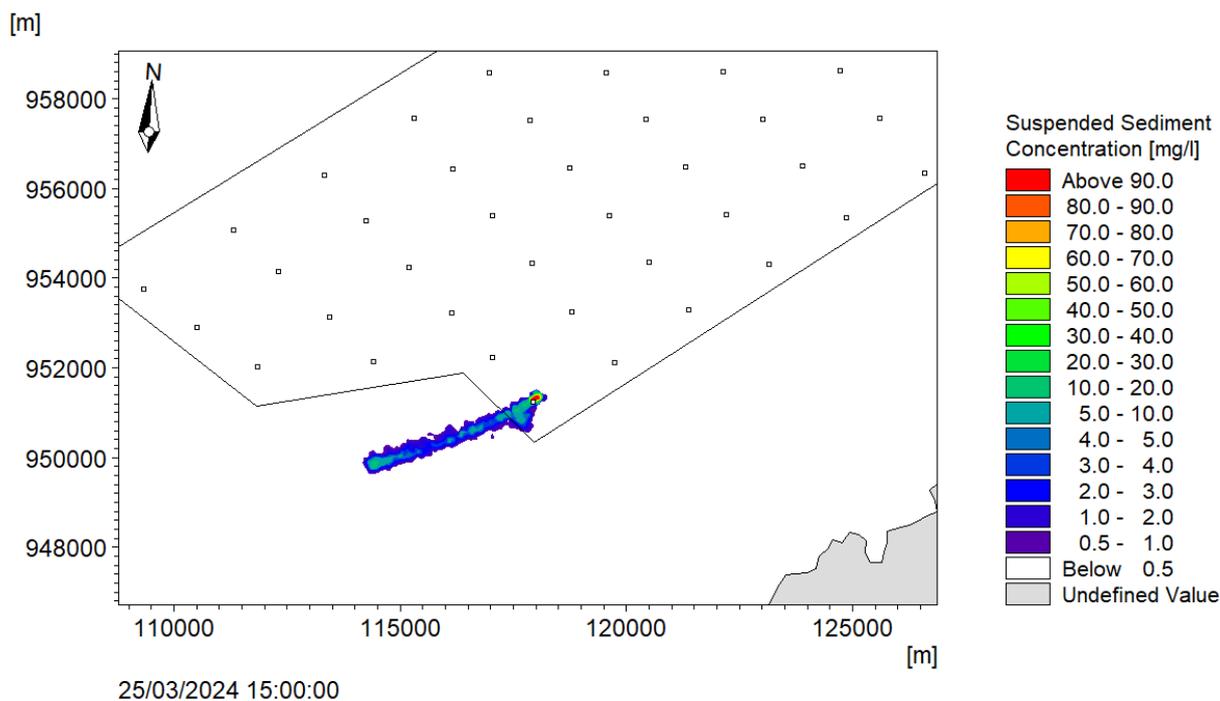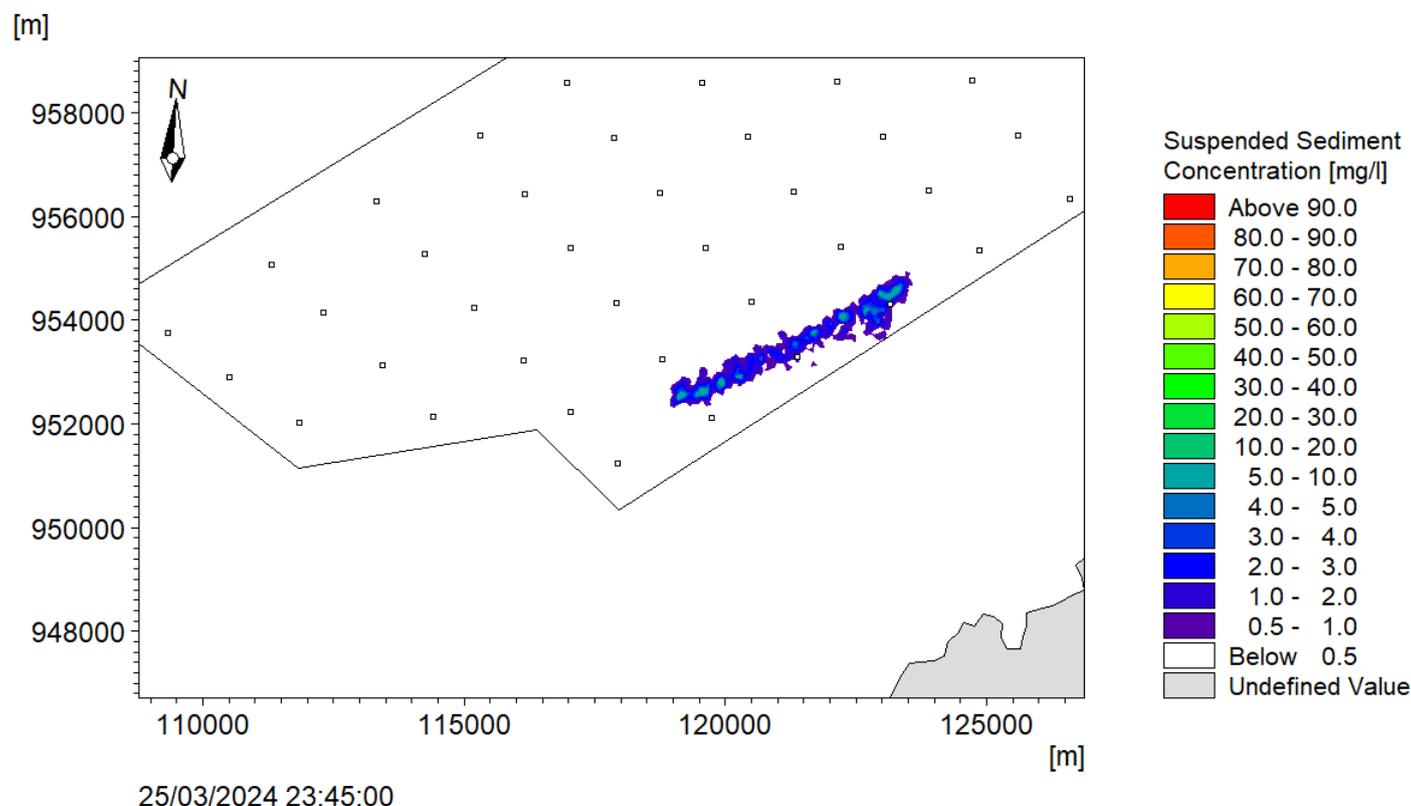
Plate 4-6 Instantaneous suspended sediment concentration 11.5 hours after scenario 3 drilling of piles to install WTG foundations commences at turbine location 60
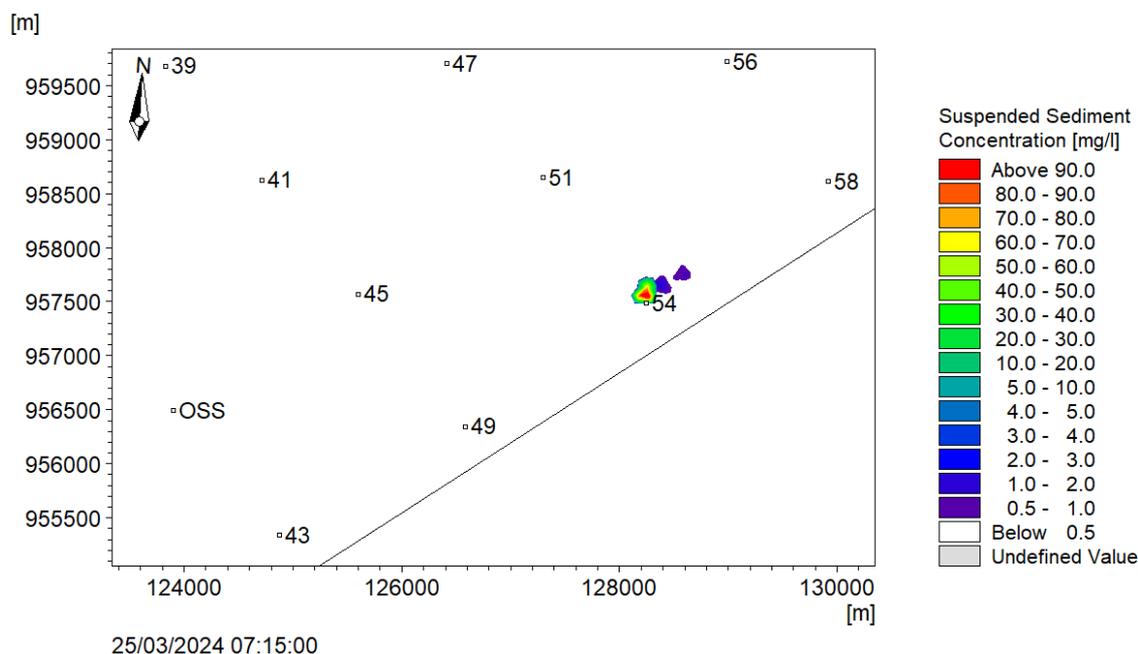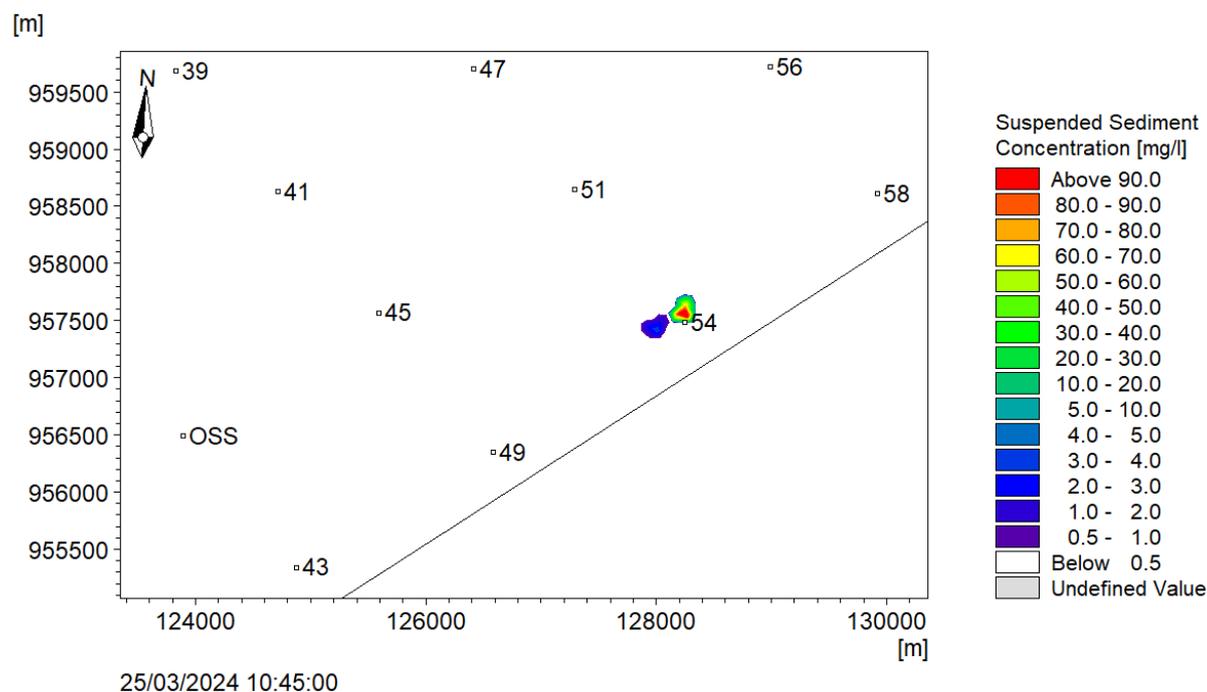

25/03/2024 11:30:00
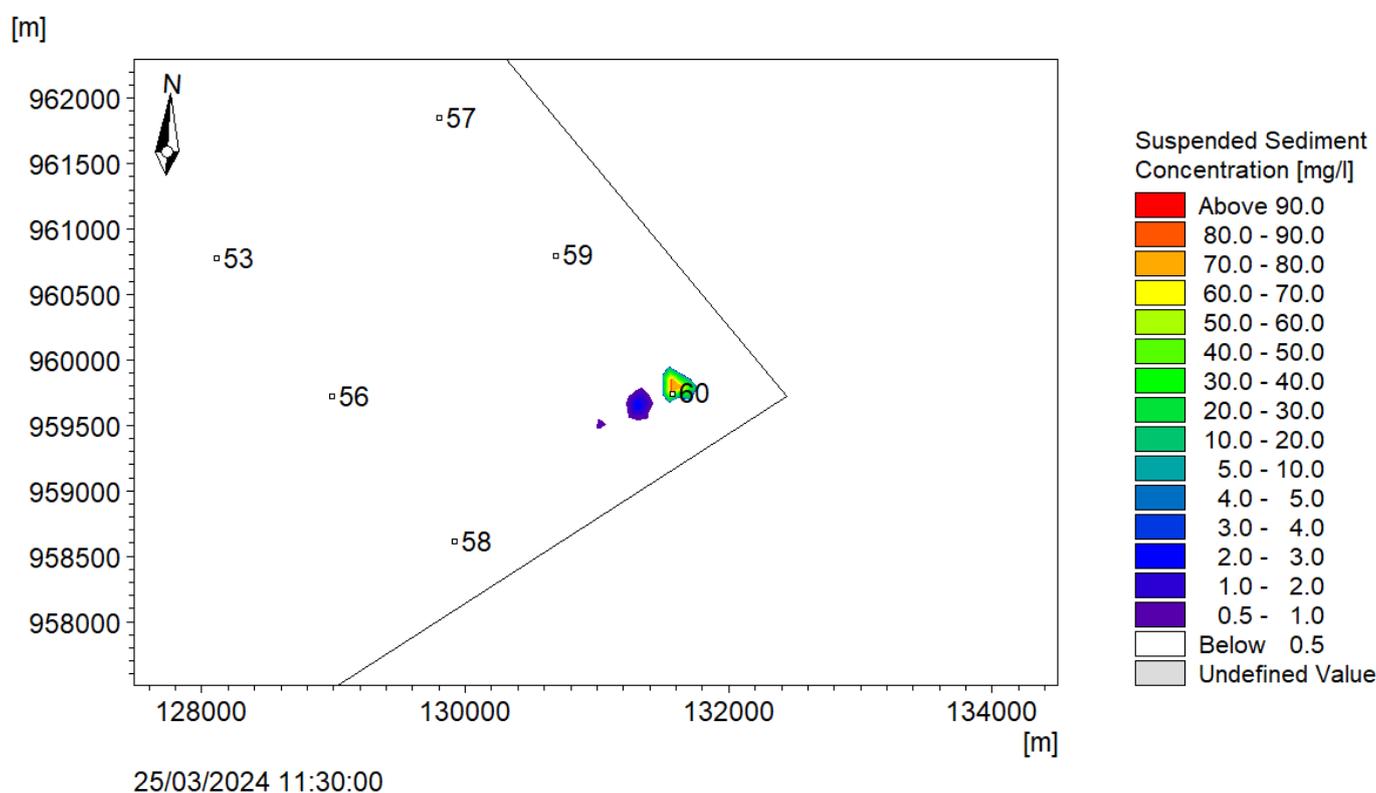
Plate 4-7 Instantaneous suspended sediment concentration 16 hours after scenario 3 drilling of piles to install WTG foundations commences at turbine location 60

25/03/2024 16:00:00
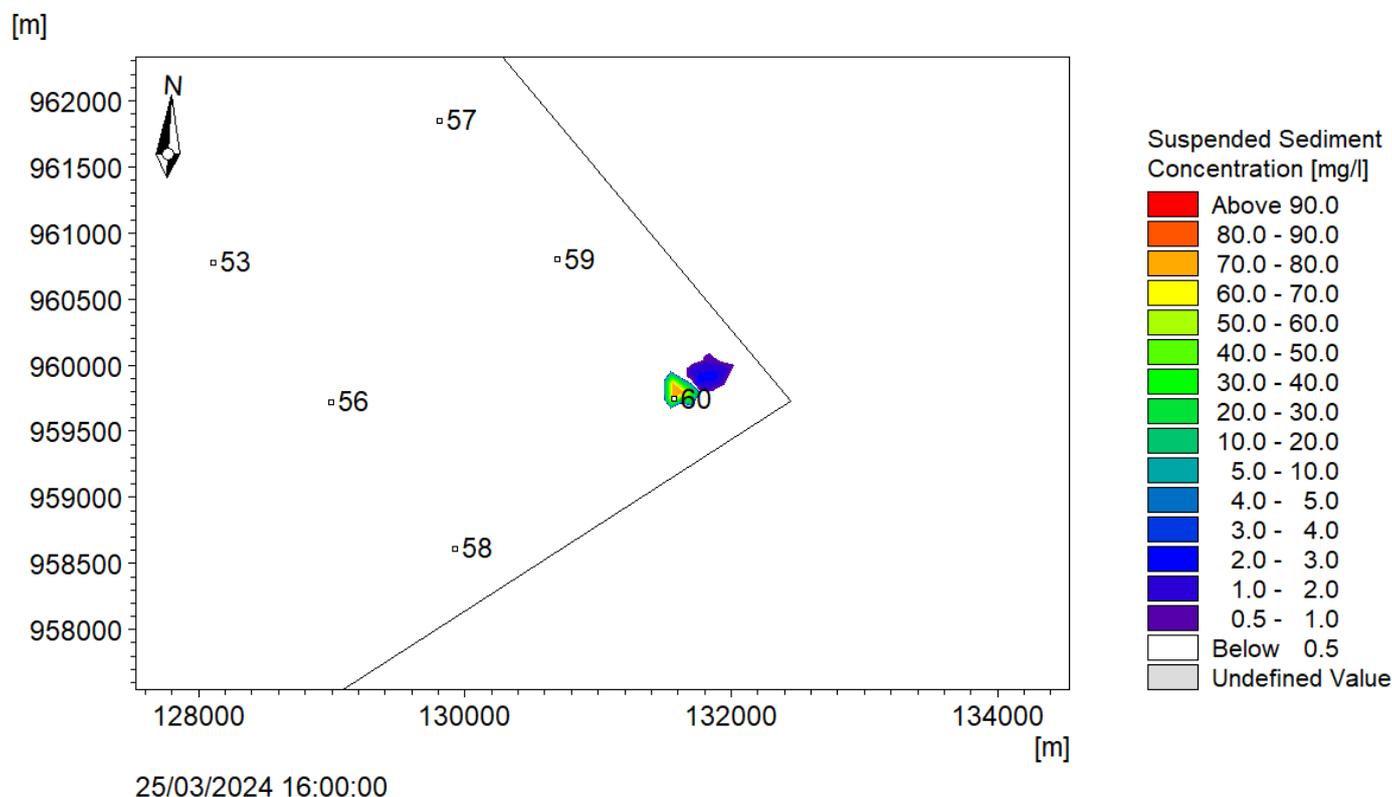
4.2.2   SEDIMENT DEPOSITION

Scenario 1 – Southwest Turbine Area

4.2.2.1   A spatial plot of sediment deposition thickness 5.5 hours after completion of drilling of piles to install WTG foundations in scenario 1 (conservatively assuming no sediment resuspension) is shown in Plate 4-8. Further information on deposition thickness over time is shown in the timeseries plots in Section 4.6.1.

4.2.2.2   Overall, the modelling indicates that the largest deposition thicknesses of 20 cm occur in the immediate vicinity (<1 km in the direction of the tidal current, up to 150 m wide) of the modelled turbine locations. Generally, deposition thicknesses resulting from drilling of piles to install WTG foundations are less than 1 cm at a maximum distance of 7.5 km in the direction of the tidal current (over an area up to 1 km wide) from the modelled turbine location.

Plate 4-8 Sediment deposition thickness 5.5 hours after completion of drilling of piles to install WTG foundations at turbine location 20 in scenario 1 (no resuspension)

26/03/2024 00:00:00

Scenario 2 – Buried Channel

4.2.2.3   A spatial plot of sediment deposition thickness 5.5 hours after completion of drilling of piles to install WTG foundations in scenario 2 (conservatively assuming no sediment resuspension) is shown in Plate 4-9. Further information on deposition thickness over time is shown in the timeseries plots in Section 4.6.1.

4.2.2.4   Overall, the modelling indicates that the largest deposition thicknesses of 30 cm occur in the immediate vicinity (<1 km in the direction of the tidal current, up to 150 m wide) of the modelled turbine locations. Generally, deposition thicknesses resulting from drilling of piles to install WTG foundations are less than 1 cm at a maximum distance of 2 km in the direction of the tidal current (over an area up to 350 m wide) from the modelled turbine location.

Plate 4-9 Sediment deposition thickness 5.5 hours after completion of drilling of piles to install WTG foundations at turbine location 54 in scenario 2 (no resuspension)

26/03/2024 00:00:00

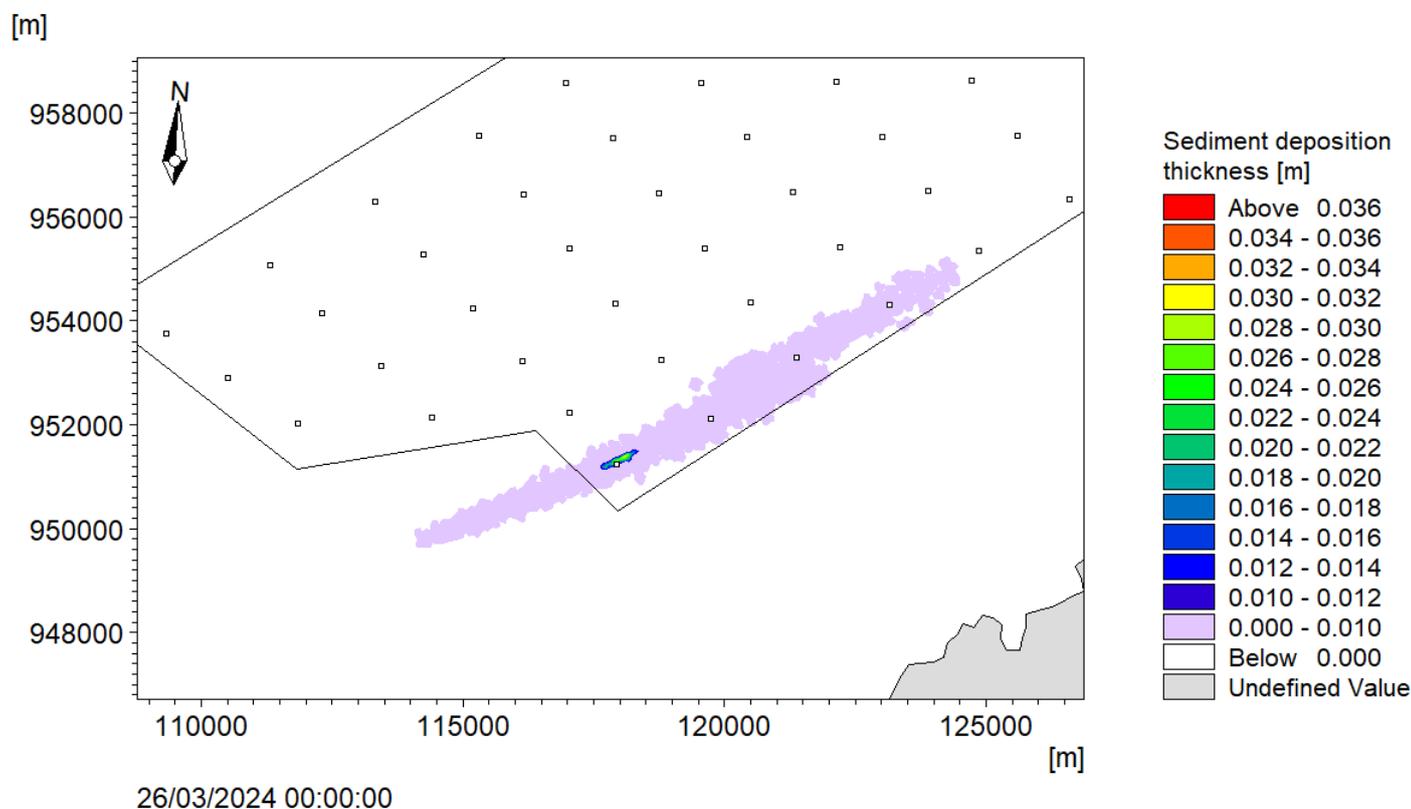## Scenario 3 – Northeast Turbine Area

4.2.2.5 A spatial plot of sediment deposition thickness 5.5 hours after completion of drilling of piles to install WTG foundations in scenario 3 (conservatively assuming no sediment resuspension) is shown in Plate 4-10. Further information on deposition thickness over time is shown in the timeseries plots in Section 4.6.1.

4.2.2.6 Overall, the modelling indicates that the largest deposition thicknesses of 30 cm occur in the immediate vicinity (<1 km in the direction of the tidal current, up to 200 m wide) of the modelled turbine locations. Generally, deposition thicknesses resulting from drilling of piles to install WTG foundations are less than 1 cm at a maximum distance of 2 km in the direction of the tidal current (over an area up to 900 m wide) from the modelled turbine location.
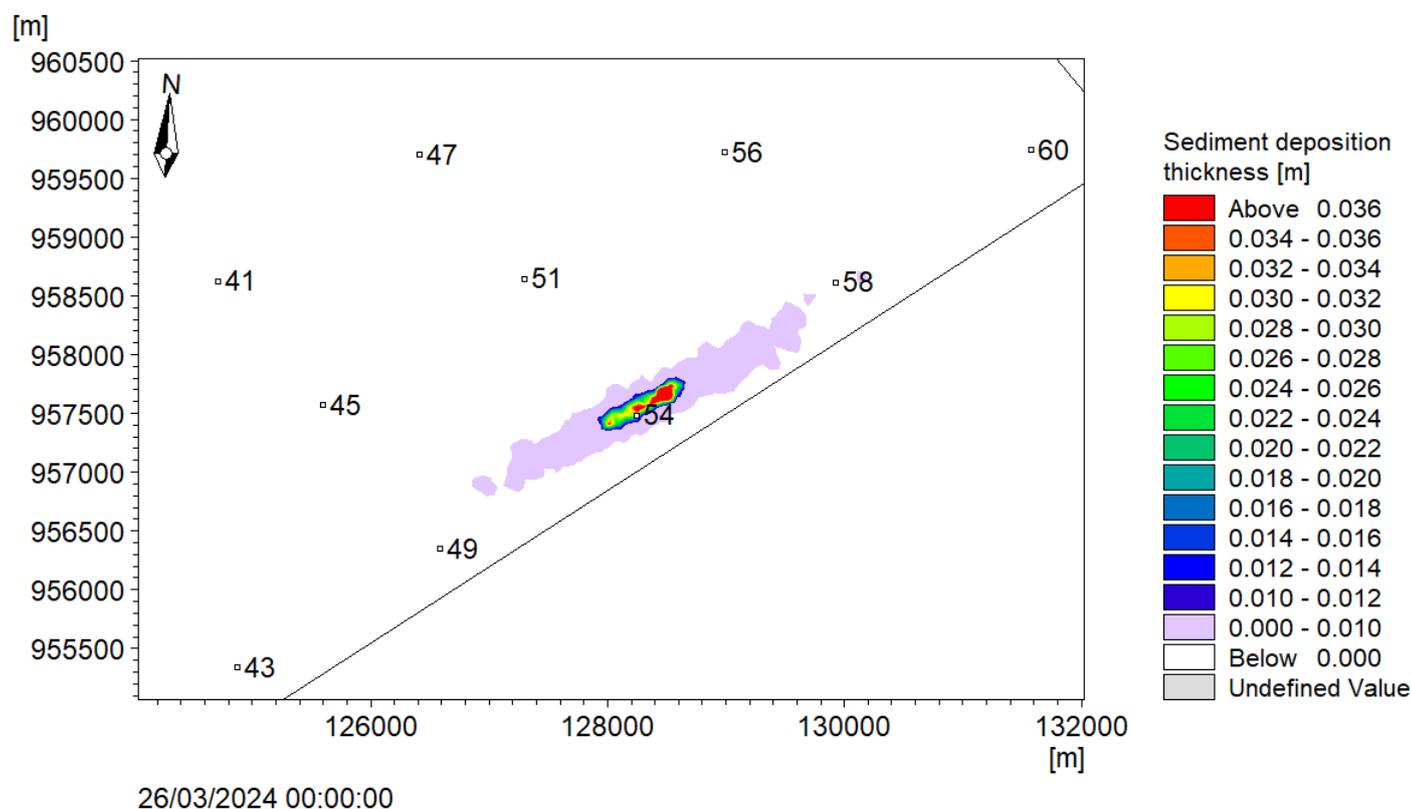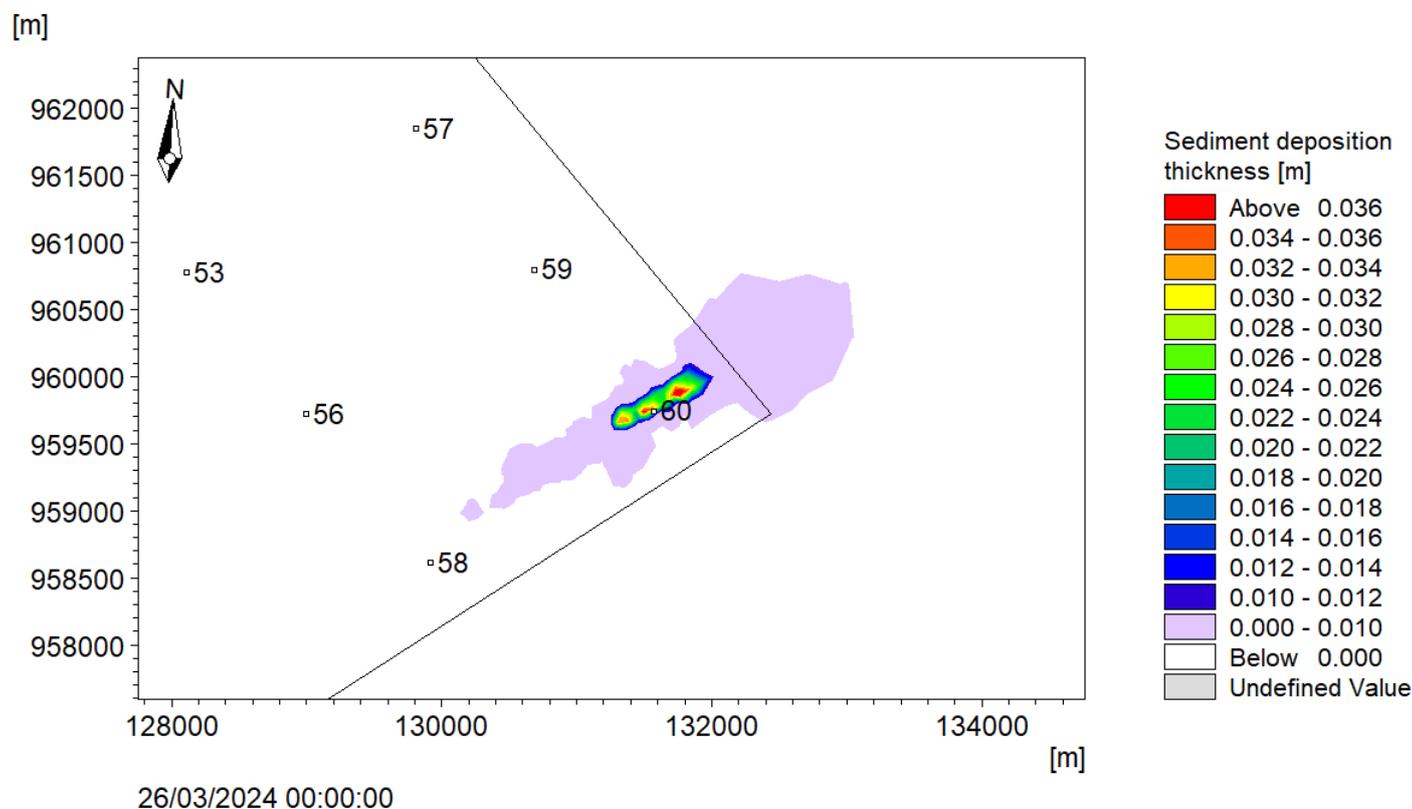
Plate 4-10 Sediment deposition thickness 5.5 hours after completion of drilling of piles to install WTG foundations at turbine location 60 in scenario 3 (no resuspension)

26/03/2024 00:00:00

4.3   CABLE BURIAL

4.3.1   SUSPENDED SEDIMENT CONCENTRATION

Scenario 1 – Southwest Turbine Area

Array Cables to Final WTG

4.3.1.1   The instantaneous suspended sediment concentration during and after completion of Array Cables to Final WTG burial between 2 turbines in scenario 1 are shown in Plate 4-11 to Plate 4-13.

4.3.1.2   Suspended sediments resulting from the Array Cables to Final WTG burial in scenario 1 have the potential to be advected approximately 10 km in a plume up to 450 m wide centred around the cable route with a concentration ranging from approximately 5 mg/l and 100 mg/l within 10 km and 1 km of the cable route respectively. Once the sediment is released during cable burial, it remains in suspension within the water column for most of the tidal cycle (up to approximately 12 hours after cable burial is completed). Further information on suspension duration is shown in the timeseries plots in Section 4.6.1.

Plate 4-11 Scenario 1 Array Cables to Final WTG burial instantaneous suspended sediment concentration 3 hours after burial commences between turbine locations 20 and 9

02/04/2024 09:15:00
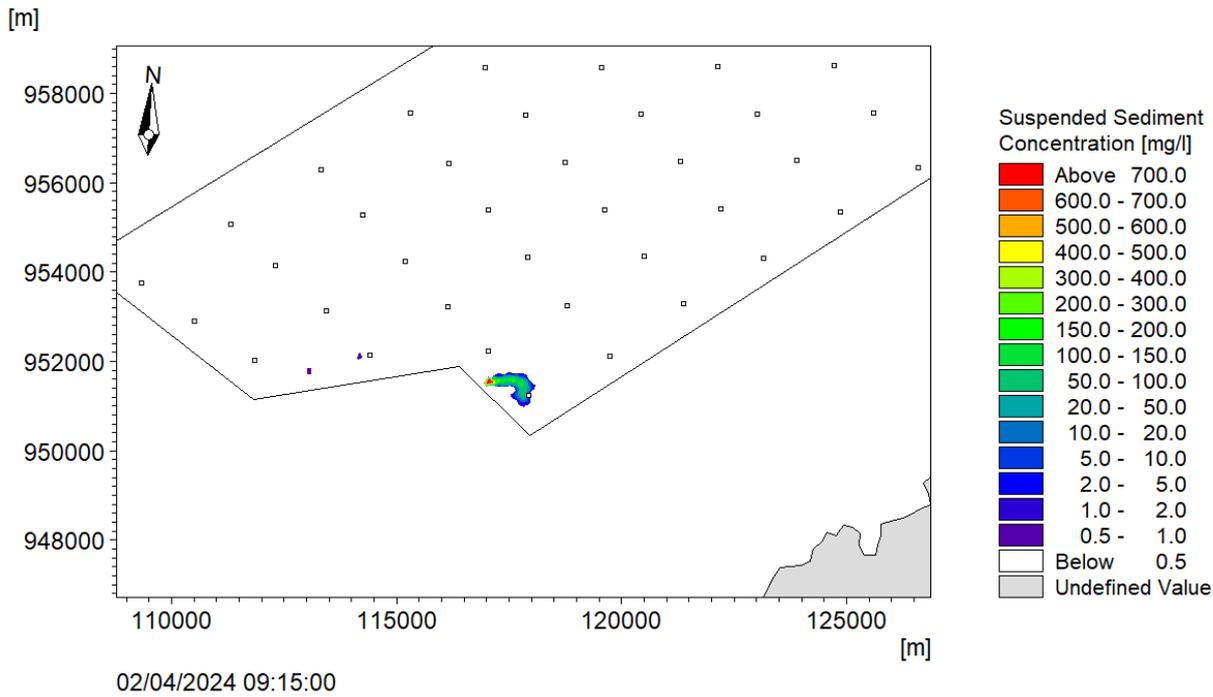
Plate 4-12 Scenario 1 Array Cables to Final WTG burial instantaneous suspended sediment concentration 9 hours after burial commences between turbine locations 20 and 9
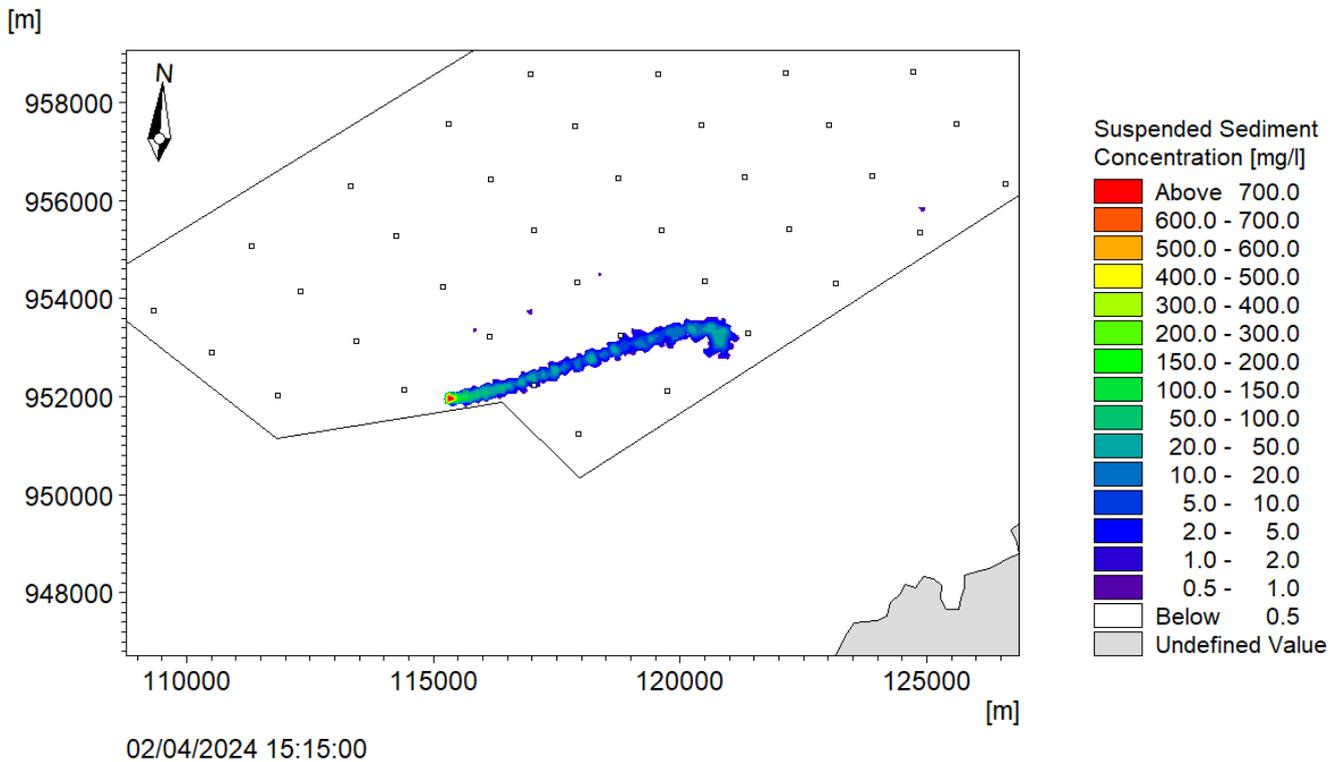
02/04/2024 15:15:00

02/04/2024 21:15:00
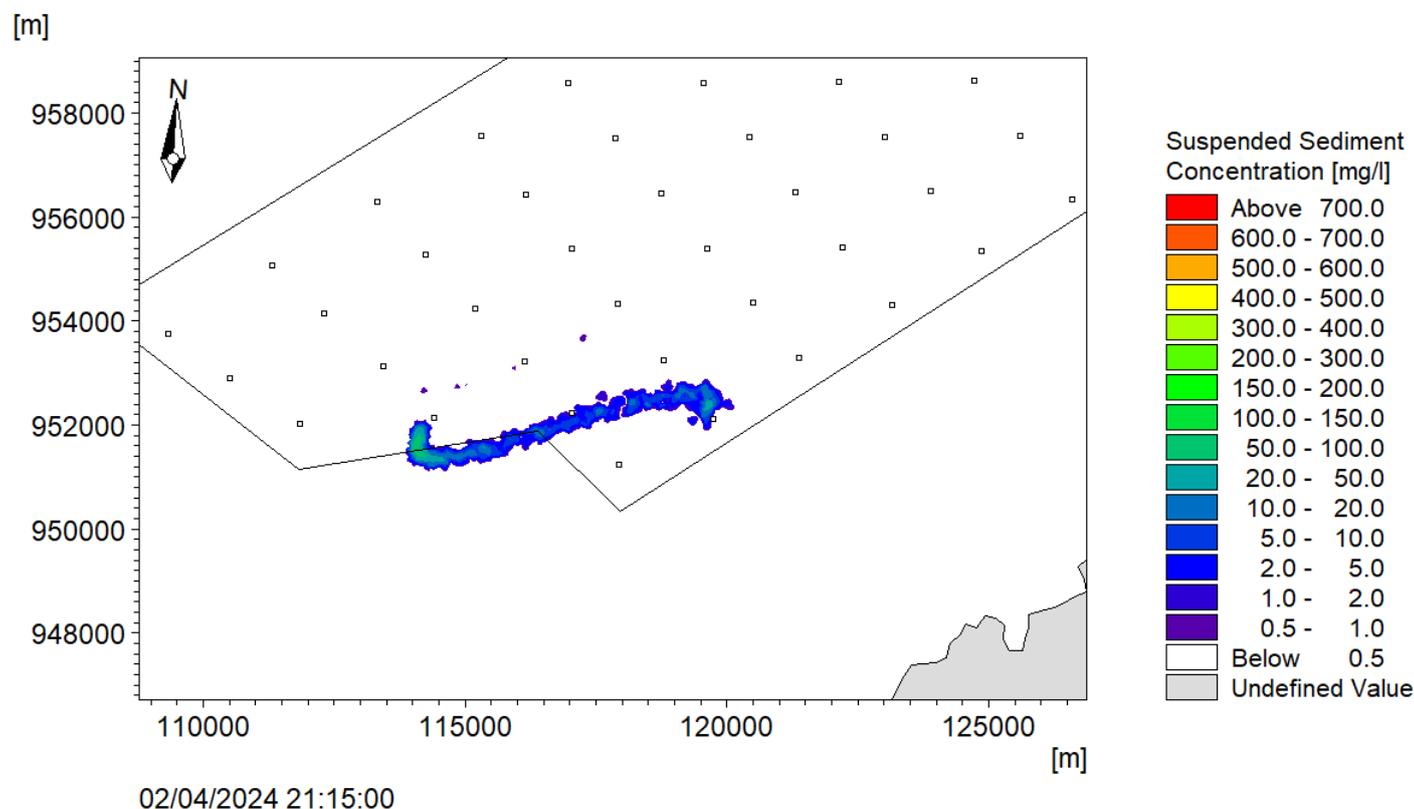
Scenario 2 – Buried Channel

Array Cables to Final WTG

4.3.1.3   The instantaneous suspended sediment concentration during and after completion of Array Cables to Final WTG burial between 2 turbines in scenario 2 are shown in Plate 4-14 to Plate 4-16.

4.3.1.4   Suspended sediments with a concentration of approximately 200-300 mg/l resulting from the burial of Array Cables to Final WTG in scenario 2 are advected <500 m from the cable route in a plume up to 500 m wide. Once the sediment is released during cable burial, it is only suspended for a brief period (less than 1 hour) since current speeds greater than approximately 0.35 m/s are required for the sediment to remain in suspension. Further information on suspension duration is shown in the timeseries plots in Section 4.6.1.

4.3.1.5   In scenario 2, the plume is much smaller – less than 0.5 km compared to approximately 10 km in Scenario 1 - due to the coarser sediment and lower percentage of fines present.

Plate 4-14 Scenario 2 instantaneous suspended sediment concentration 3.25 hours after Array Cables to Final WTG burial commences between turbine locations 54 and 51

01/04/2024 03:15:00

Plate 4-15 Scenario 2 instantaneous suspended sediment concentration 6.75 hours after Array Cables to Final WTG burial commences between turbine locations 51 and 47

01/04/2024 06:45:00

Plate 4-16 Scenario 2 instantaneous suspended sediment concentration 10.75 hours after Array Cables to Final WTG burial commences between turbine locations 47 and 44

01/04/2024 10:45:00

Array Cable to Landfall

4.3.1.6   A plot of the maximum suspended sediment concentration over the model duration arising from the Array Cable to Landfall burial in scenario 2 is shown in Plate 4-17.

4.3.1.7   Suspended sediments resulting from the Array Cable to Landfall burial in scenario 2 are advected <200 m (width of plume) from the cable route with concentrations above 350 mg/l (maximum 830 mg/l at an isolated location <5 m^2).

Plate 4-17 Maximum suspended sediment concentration arising from scenario 2 Array Cable to Landfall burial (to turbine location 54)
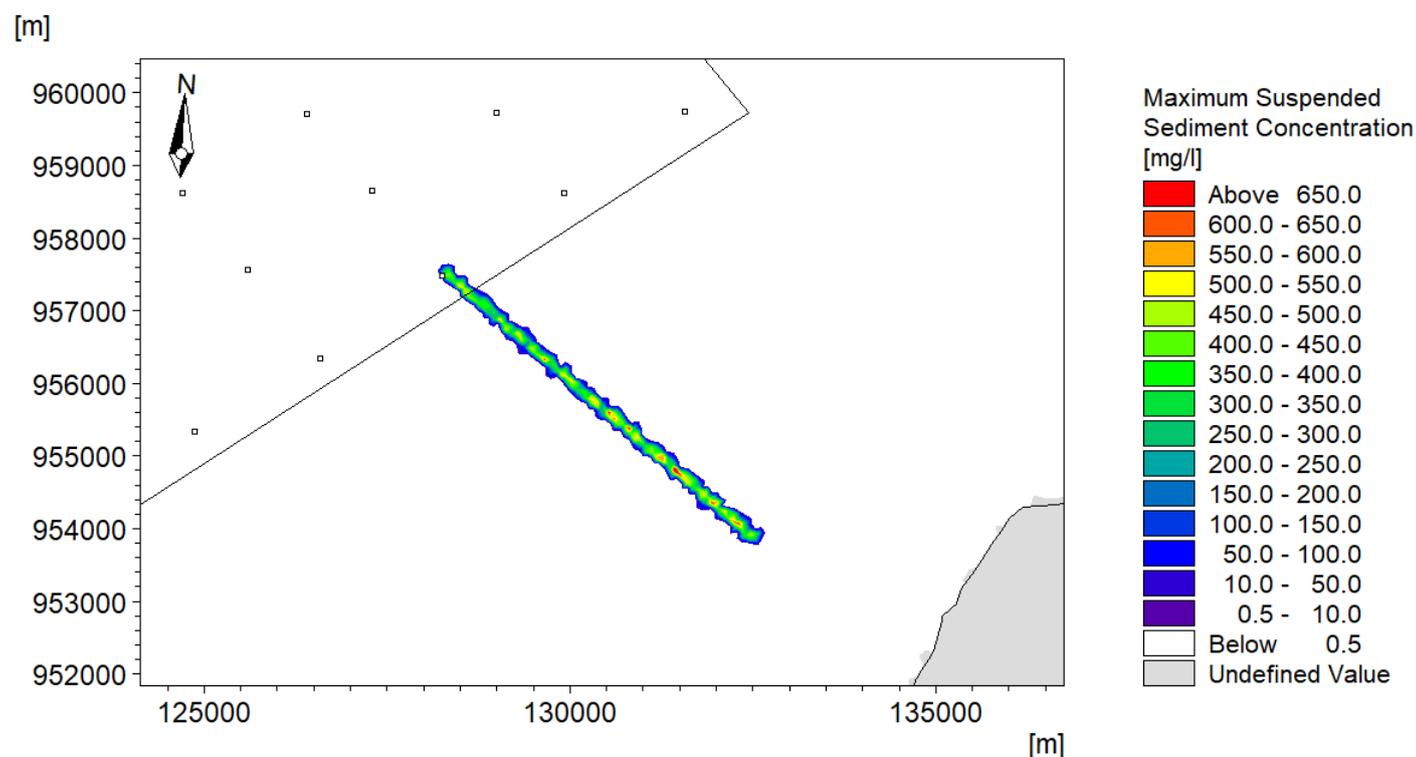
Scenario 3 – Northeast Turbine Area

Array Cables to Final WTG

4.3.1.8   The instantaneous suspended sediment concentration during and after completion of Array Cables to Final WTG burial between 2 turbines in scenario 3 are shown in Plate 4-18 to Plate 4-20.

4.3.1.9   Suspended sediments with a concentration of approximately 200-300 mg/l resulting from the Array Cables to Final WTG burial in scenario 3 are advected <500 m from the cable route in a plume up to 250 m wide. Once the sediment is released during cable burial, it is only suspended for a brief period (less than 1 hour) since current speeds greater than approximately 0.35 m/s are required for the sediment to remain in suspension. Further information on suspension duration is shown in the timeseries plots in Section 4.6.1.

Plate 4-18 Scenario 3 instantaneous suspended sediment concentration 4.25 hours after Array Cables to Final WTG burial commences between turbine locations 59 and 57
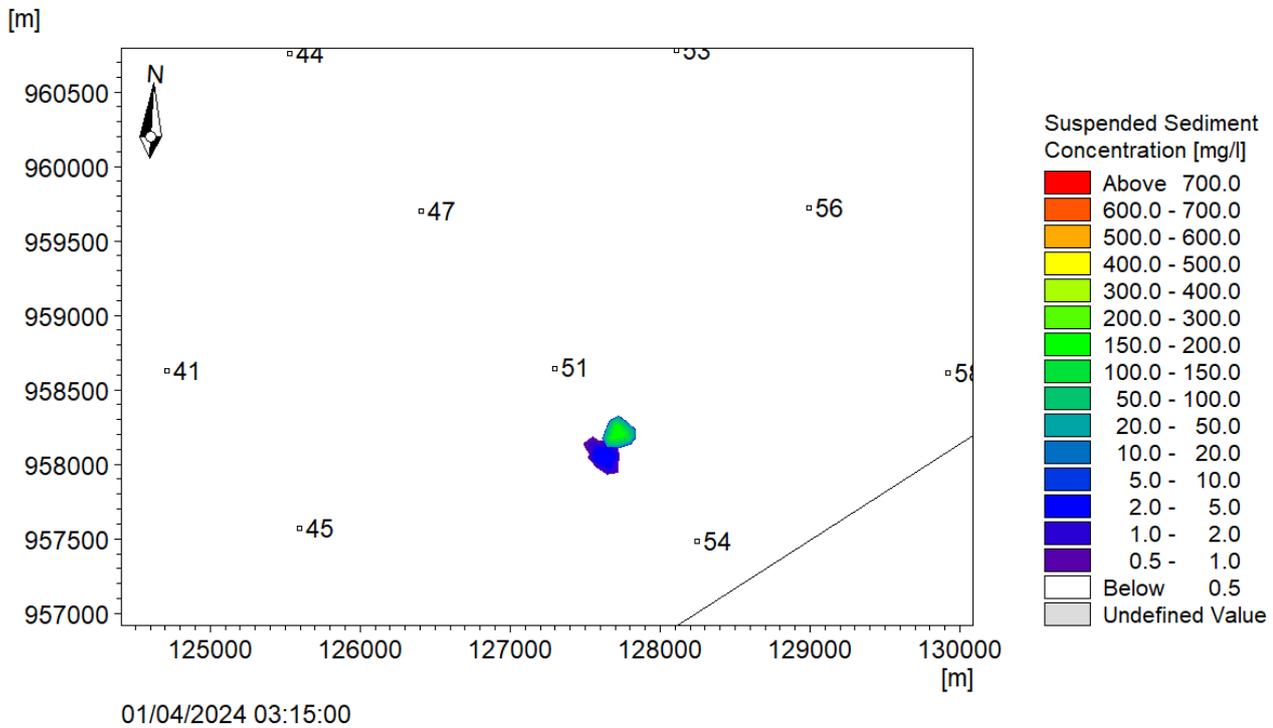

01-Apr-24 04:15:00
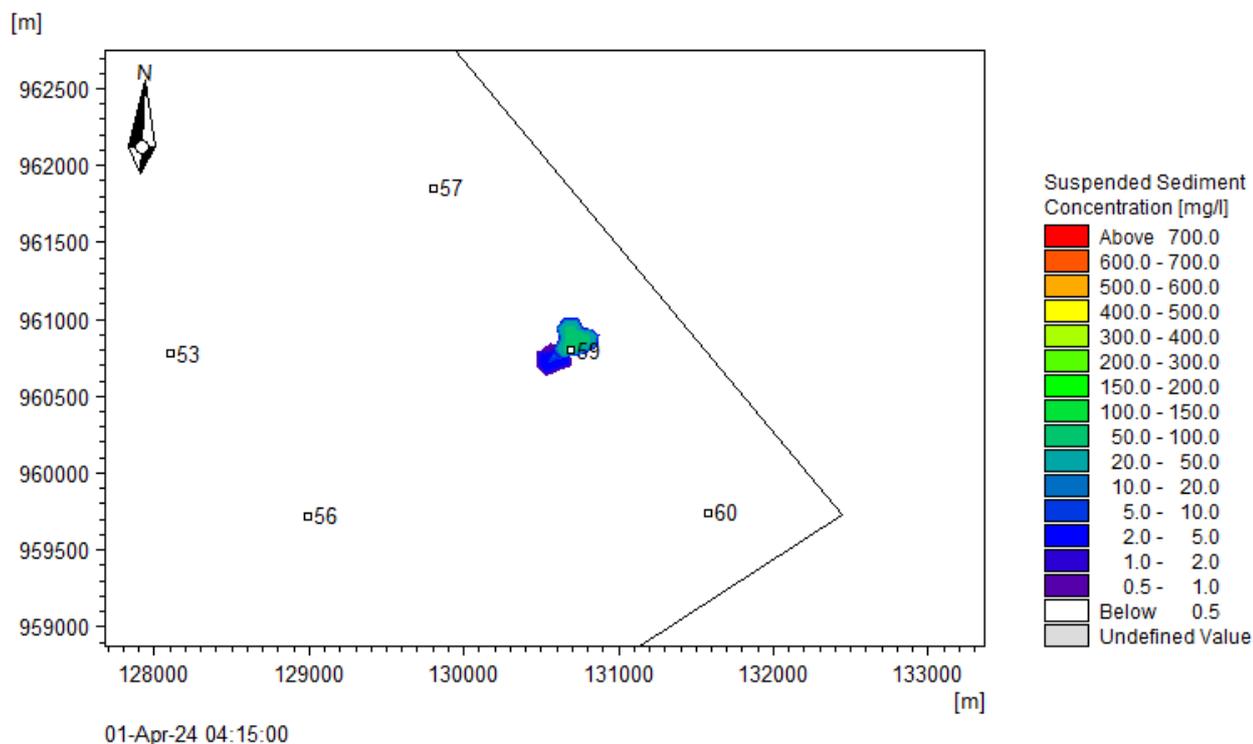
Plate 4-19 Scenario 3 instantaneous suspended sediment concentration 6.75 hours after Array Cables to Final WTG burial commences between turbine locations 59 and 57

01-Apr-24 06:45:00
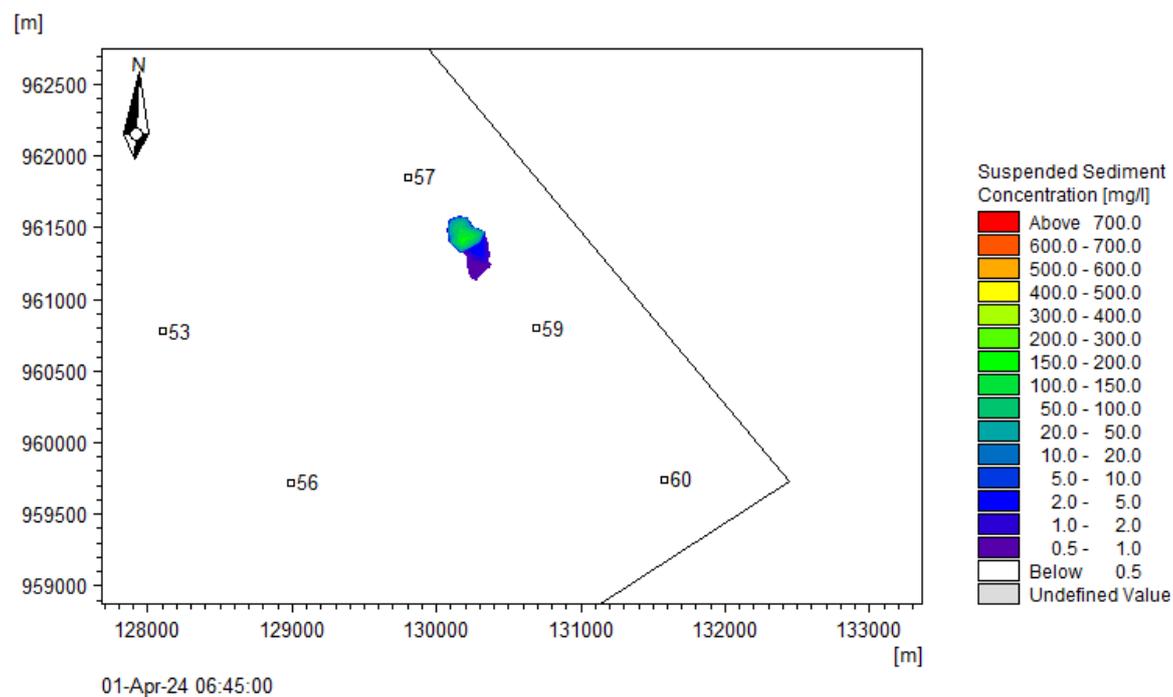
Plate 4-20 Scenario 3 instantaneous suspended sediment concentration 8.25 hours after Array Cables to Final WTG burial commences between turbine locations 59 and 57
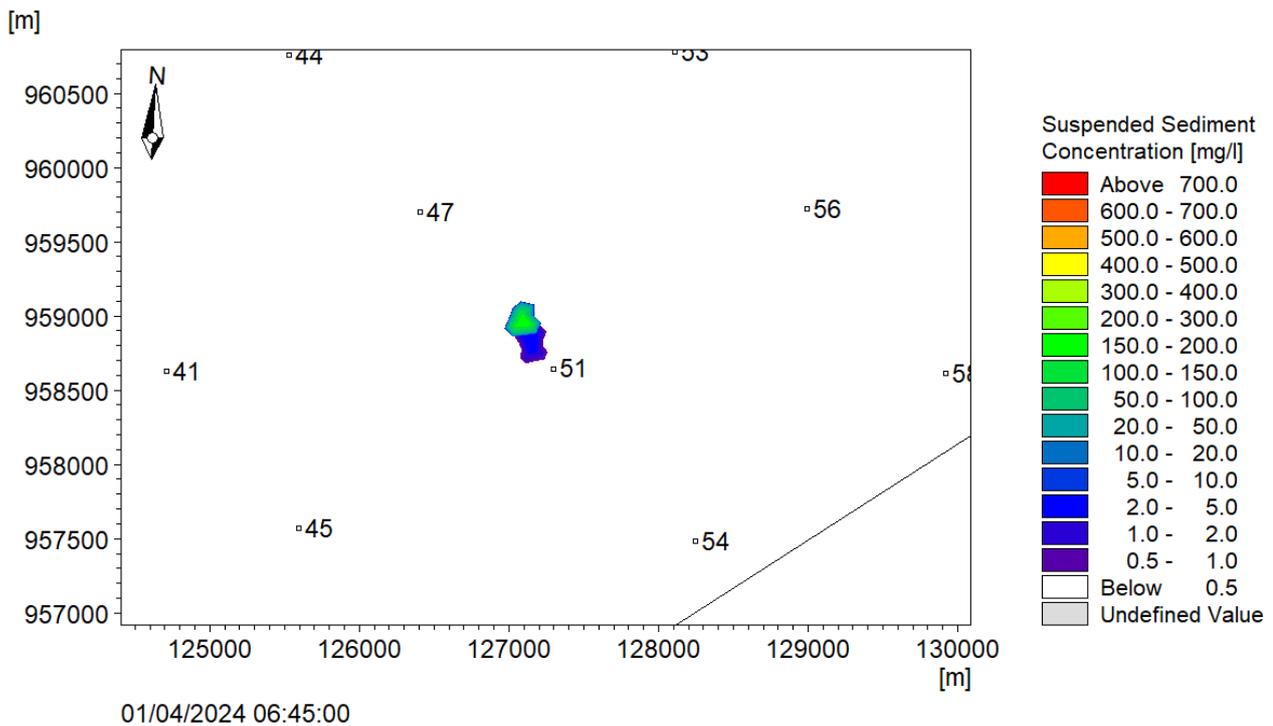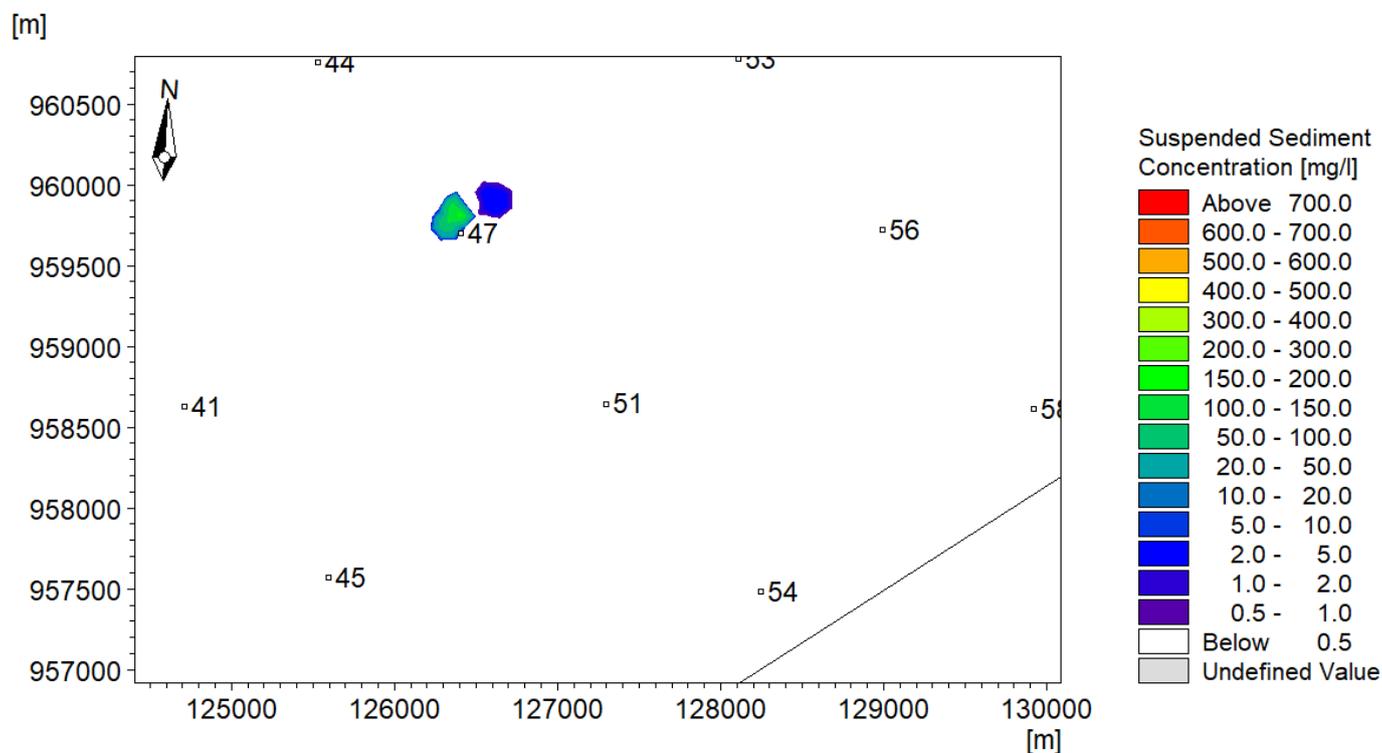

01-Apr-24 08:15:00
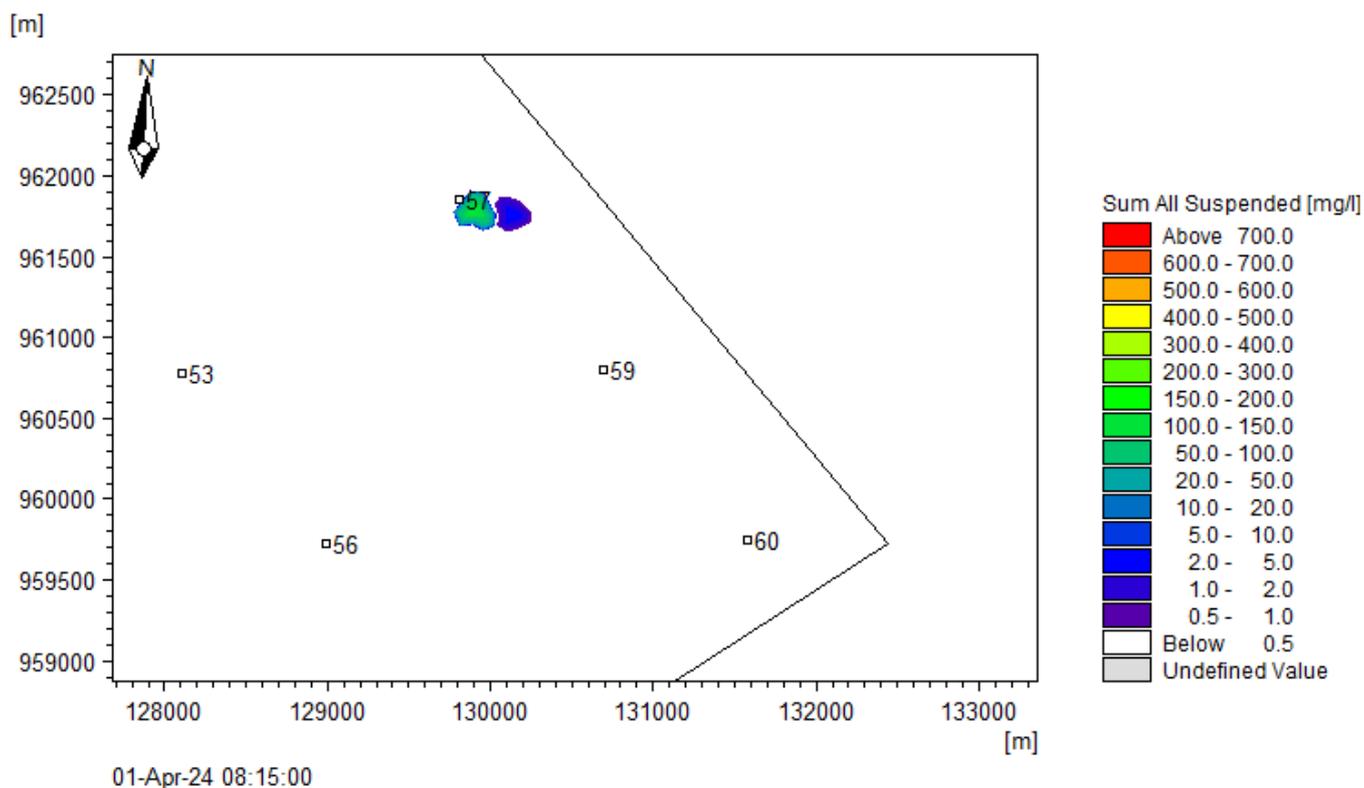
Array Cable to Landfall

4.3.1.10 A plot of the maximum suspended sediment concentration over the model duration arising from Array Cable to Landfall burial in scenario 3 is shown in Plate 4-21.

4.3.1.11 Suspended sediments resulting from Array Cable to Landfall burial in scenario 3 are advected <200 m (width of plume) from the cable route with concentrations above 350 mg/l (maximum 840 mg/l at an isolated location <10 m^2).

Plate 4-21 Maximum suspended sediment concentration arising from scenario 3 Array Cable to Landfall burial (to turbine location 60)
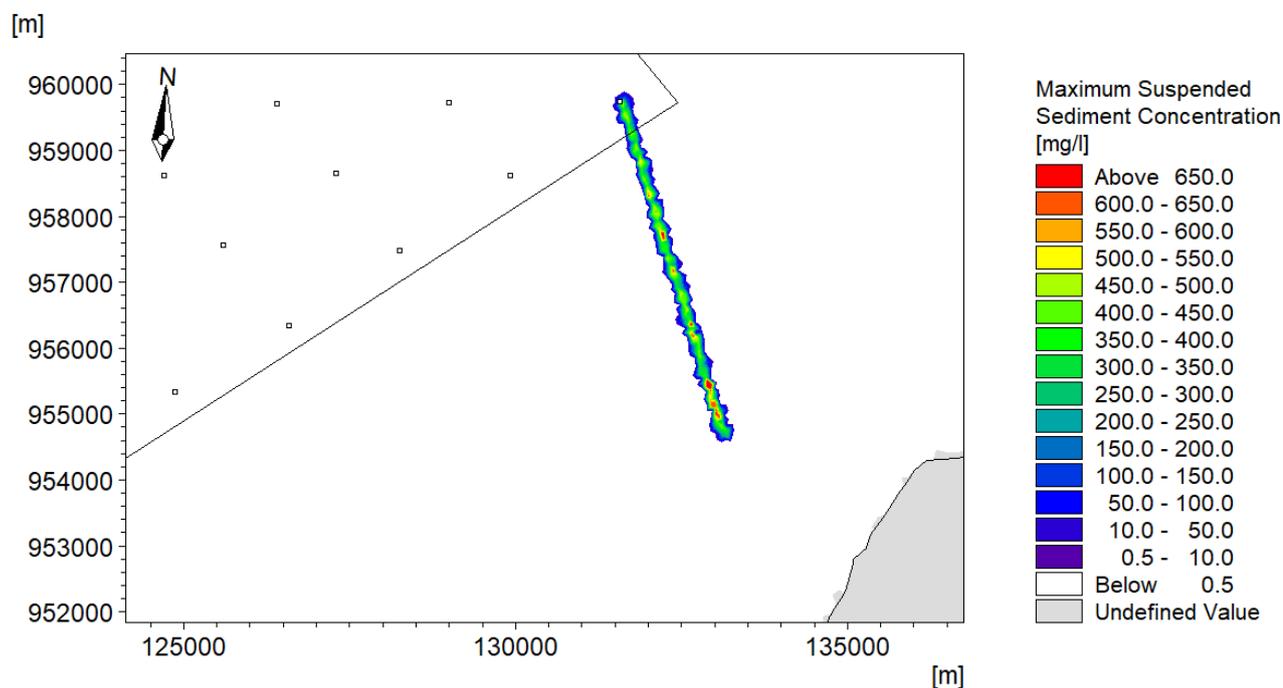
4.3.2   SEDIMENT DEPOSITION

Scenario 1 – Southwest Turbine Area

4.3.2.1   A spatial plot of maximum sediment deposition thickness following completion of cable burial in scenario 1 (conservatively assuming no sediment resuspension) is shown in Plate 4-22.

4.3.2.2   Overall, the modelling indicates that the largest deposition thicknesses of 10 cm occur in the immediate vicinity (<400 m width of plume) of the cable burial. Generally, deposition thicknesses resulting from cable burial are less than 1 cm with a maximum distance of approximately 5 km from the cable burial activity.

Plate 4-22 Maximum sediment deposition thickness arising from cable burial in scenario 1 (no resuspension)
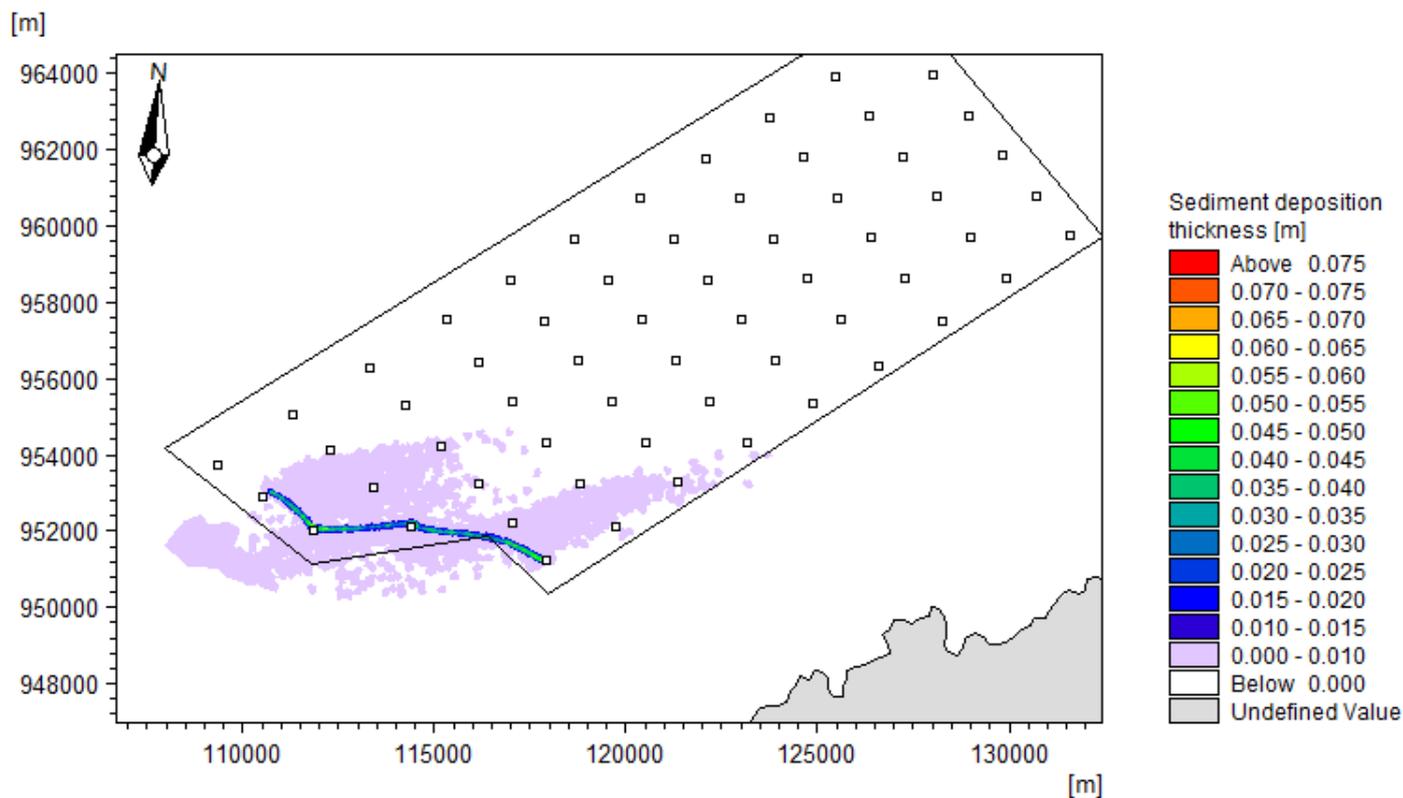
Scenario 2 – Buried Channel

4.3.2.3   A spatial plot of maximum sediment deposition thickness following completion of cable burial scenario 2 (conservatively assuming no sediment resuspension) is shown in Plate 4-23.

4.3.2.4   Overall, the modelling indicates that the largest deposition thicknesses of 3 cm occur in the immediate vicinity (<400 m width of plume) of the cable burial. Generally, deposition thicknesses resulting from cable burial are less than 1 cm with a maximum distance of approximately 3 km from the cable burial activity. This distance is smaller than seen for scenario 1 due to the coarser sediment in this location.

Plate 4-23 Maximum sediment deposition thickness arising from cable burial in scenario 2 (no resuspension)
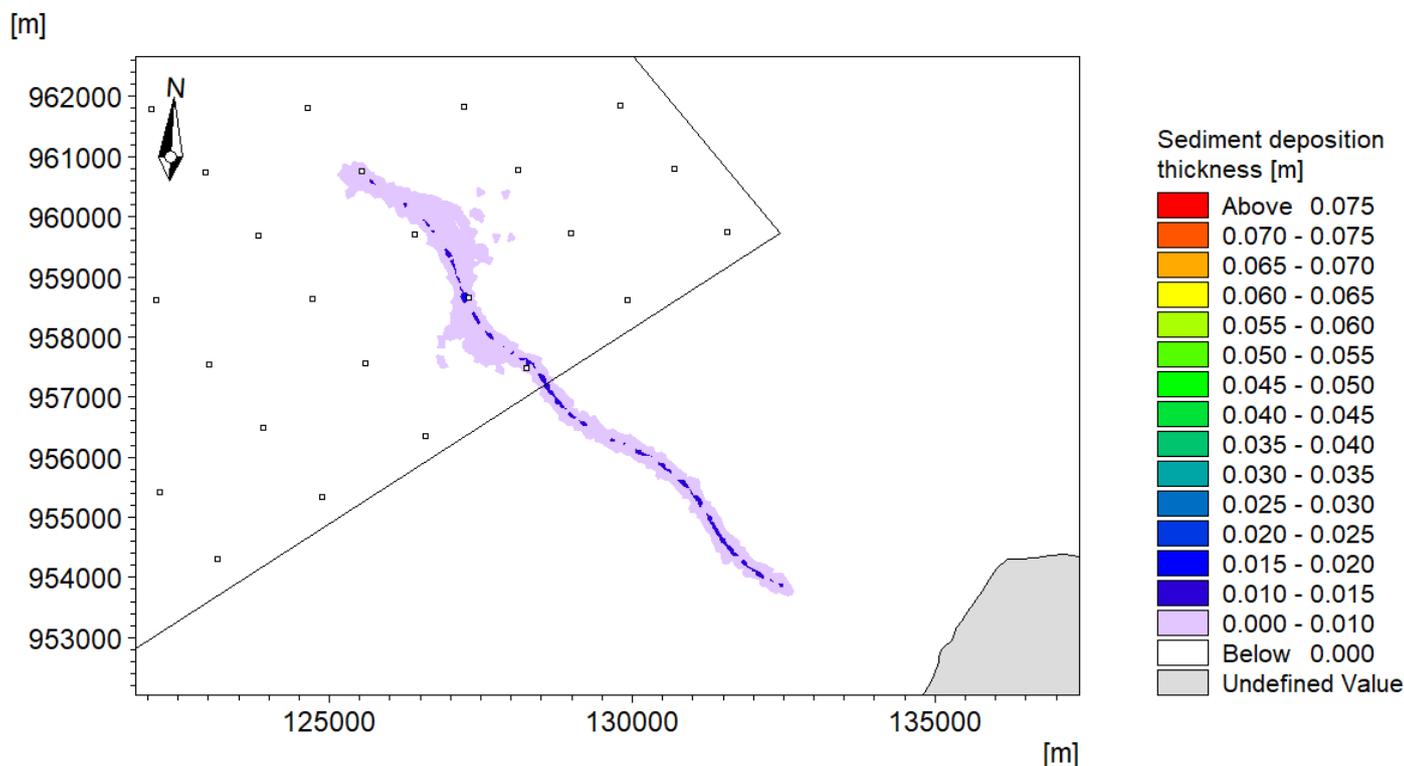
Scenario 3 – Northeast Turbine Area

4.3.2.5 A spatial plot of maximum sediment deposition thickness following completion of cable burial in scenario 3 (conservatively assuming no sediment resuspension) is shown in Plate 4-24.

4.3.2.6 Overall, the modelling indicates that the largest deposition thicknesses of 3 cm occur in the immediate vicinity (<400 m width of plume) of the cable burial. Generally, deposition thicknesses resulting from cable burial are less than 1 cm with a maximum distance of approximately 2 km from the cable burial activity. This distance is smaller than seen for Scenario 1 due to the coarser sediment in this location.

Plate 4-24 Maximum sediment deposition thickness arising from cable burial in scenario 3 (no resuspension)
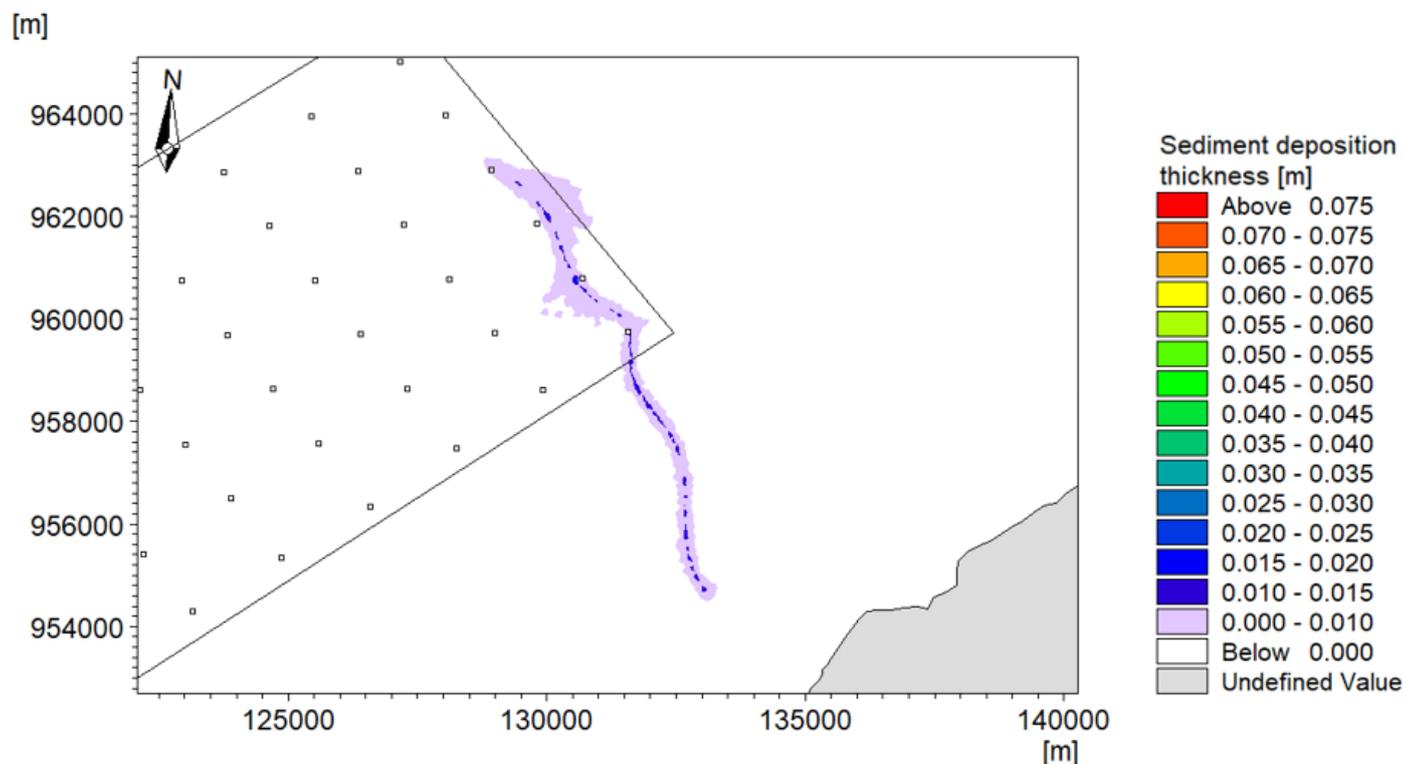
4.4   HORIZONTAL DIRECTIONAL DRILLING - DRILL CUTTING RELEASE

4.4.1   SUSPENDED SEDIMENT CONCENTRATION

#### Mid Spring Flood Tide Release

4.4.1.1   A spatial plot of the maximum suspended sediment concentration arising from HDD drill cutting release at peak spring flood tide is shown in Plate 4-25.

4.4.1.2   Suspended sediments resulting from the HDD drill cutting release during a peak spring tide have the potential to be advected approximately 6 km centred around the HDD modelling location. A maximum concentration of 1,000 mg/l occurs up to 1 km from HDD modelling location in the direction of the tide over a width of up to 250 m. A maximum concentration of up to 50 mg/l occurs over an area of approximately 12 km^2 around the HDD modelling location (6 km in the direction of the tidal current and up to 2 km wide).

4.4.1.3   Once the sediment is released following breakout of the HDD bore, it remains in suspension within the water column for most of the tidal cycle (approximately 12 hours after drill release is completed).

Plate 4-25 Maximum suspended sediment concentration arising from drill cutting release from HDD at peak spring flood tide
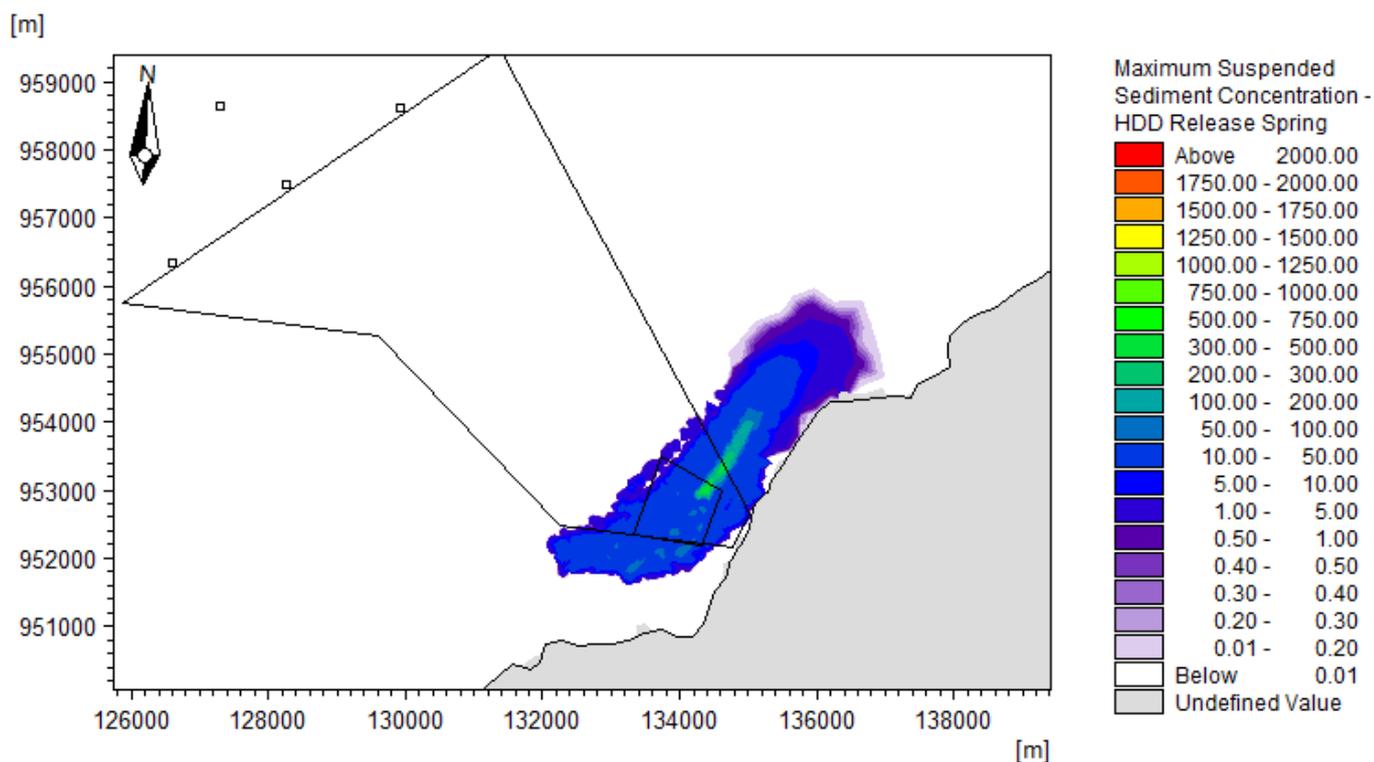
4.4.1.4 Timeseries plots of the suspended sediment concentration approximately 200 m northeast of the HDD modelling location arising from drill cutting release from HDD at peak spring flood tide without and with sediment resuspension respectively are shown in Plate 4-26 and Plate 4-27. Suspended sediment concentrations return to baseline levels within 1-2 days following completion of the construction activity.

4.4.1.5 The peak concentration reached at the data extraction location without sediment resuspension was approximately 275 mg/l and the peak with resuspension was approximately 400 mg/l. It is noted that these peaks last for 1-2 hours.

Plate 4-26 Suspended sediment concentration arising from drill cutting release from HDD at peak spring flood tide (no resuspension)

Plate 4-27 Suspended sediment concentration arising from drill cutting release from HDD at peak spring flood tide (with resuspension)


Neap Tide Slack Water Tide Release

4.4.1.6　A spatial plot of the maximum suspended sediment concentration arising from drill cutting release from HDD at neap tide slack water is shown in Plate 4-28.

4.4.1.7　Suspended sediments resulting from the drill cutting release from HDD during a neap tide have the potential to be advected approximately 3 km centred around the HDD modelling location. A maximum concentration of 1,000 mg/l occurs up to 1 km from the HDD modelling location in the direction of the tidal current over a width of up to 300 m. A maximum concentration of up to 50 mg/l occurs over an area of approximately 3 km^2 around the HDD modelling location (3 km in the direction of the tidal current and up to 1 km wide).

4.4.1.8　Once the sediment is released following breakout of the HDD bore, it remains in suspension within the water column for most of the tidal cycle (approximately 12 hours after drill release is completed). As shown in the above plates, the modelling indicates that suspended sediment

concentration returns to baseline levels within 1 day following completion of the construction activity.

Plate 4-28 Maximum suspended sediment concentration arising from drill cutting release from HDD at neap tide slack water

4.4.1.9   A timeseries plot of the suspended sediment concentration approximately 200 m northeast of the release point arising from drill cutting release from HDD at neap tide slack water without sediment resuspension is shown in Plate 4-29.

4.4.1.10   The peak concentration reached at the data extraction location without sediment resuspension was approximately 650 mg/l. It is noted that this peak lasts for 1-2 hours only.

Plate 4-29 Suspended sediment concentration arising from drill cutting release from HDD at neap tide slack water (no resuspension)
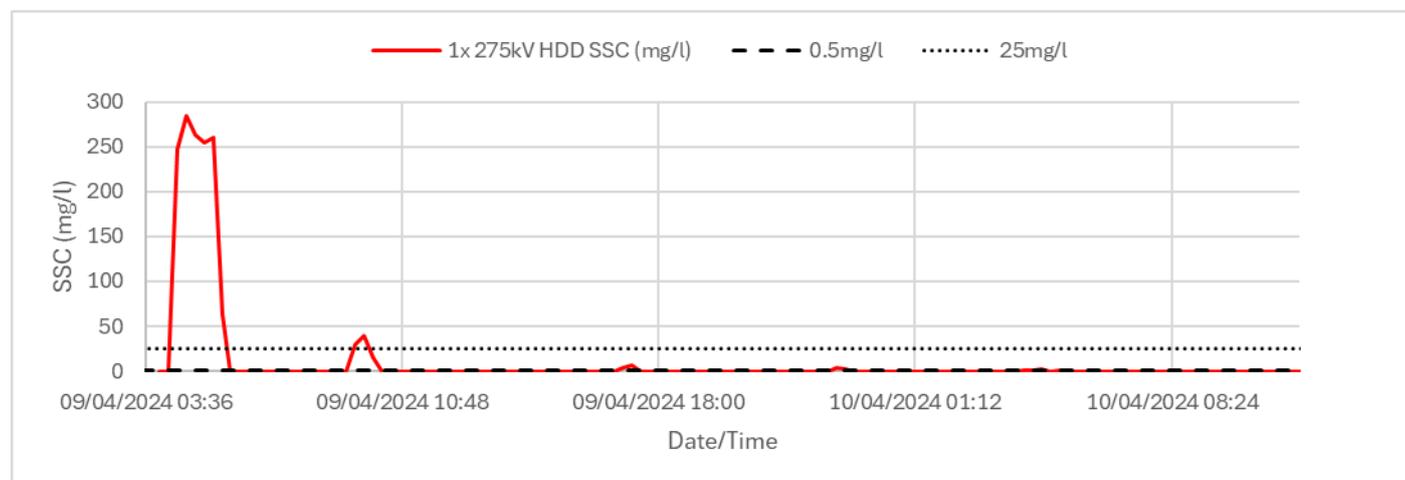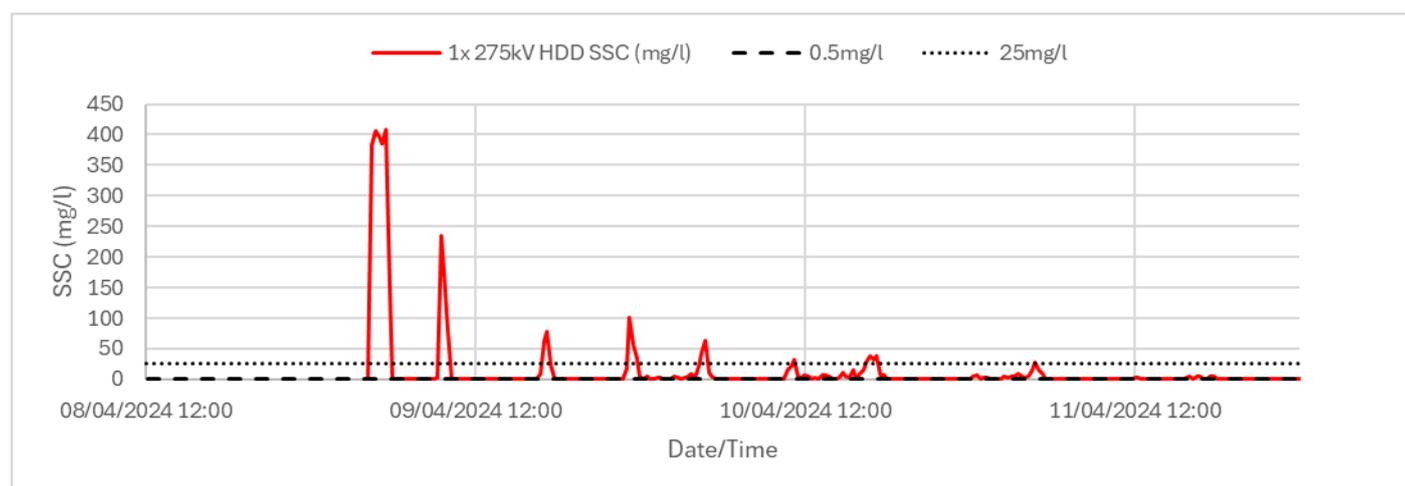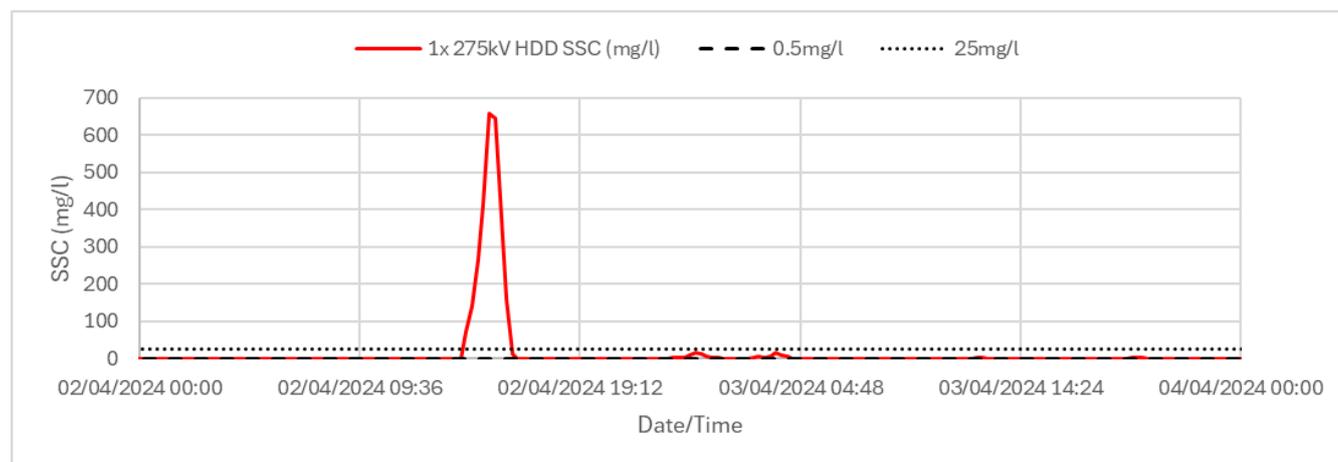

Drill Cutting Release Suspended Sediment Summary

4.4.1.11 Approximate durations where suspended sediment concentration arising from drill cutting release from HDD is greater than 25 mg/l and 0.5 mg/l are detailed in Table 4-1.

4.4.1.12 Overall, suspended sediment concentrations resulting from drill cutting release from HDD returns to background levels within a 24-hour period.

Table 4-1 Suspended sediment concentration duration above thresholds arising from HDD activities

Drill cutting release from HDD scenario	Approximate duration over threshold (hours)	
	>25 mg/l	>0.5 mg/l
Mid spring flood tide release without sediment resuspension	<3	<5
Mid spring flood tide release including sediment resuspension	<6	<23
Neap tide slack water release without sediment resuspension	<3	<10

4.4.2   SEDIMENT DEPOSITION

Mid Spring Flood Tide Release

4.4.2.1   A spatial plot of the maximum sediment deposition thickness resulting from drill cutting release from HDD during mid spring flood tide, under the assumption that no sediment is resuspended by hydrodynamic forces is presented in Plate 4-30.

4.4.2.2   Overall, the modelling indicates that the largest deposition thicknesses of 7 mm occur in the immediate vicinity (<500 m) of the HDD construction activity. Generally, deposition thicknesses resulting from drill cutting release from HDD are less than 1 mm at a maximum distance of 4 km from the release location in the direction of the tidal current over a width of up to 1 km.

Plate 4-30 Maximum sediment deposition thickness arising from drill cutting release from HDD at mid spring flood tide (without sediment resuspension)

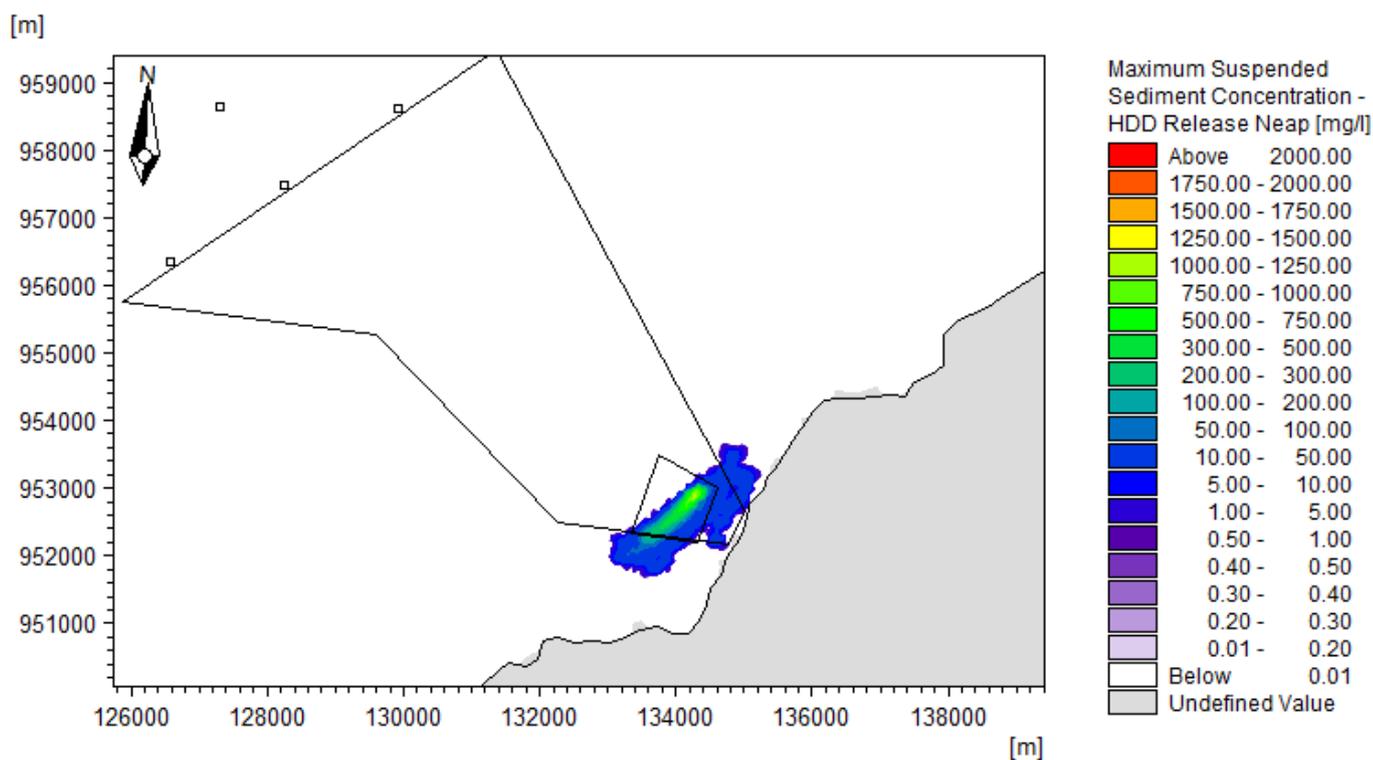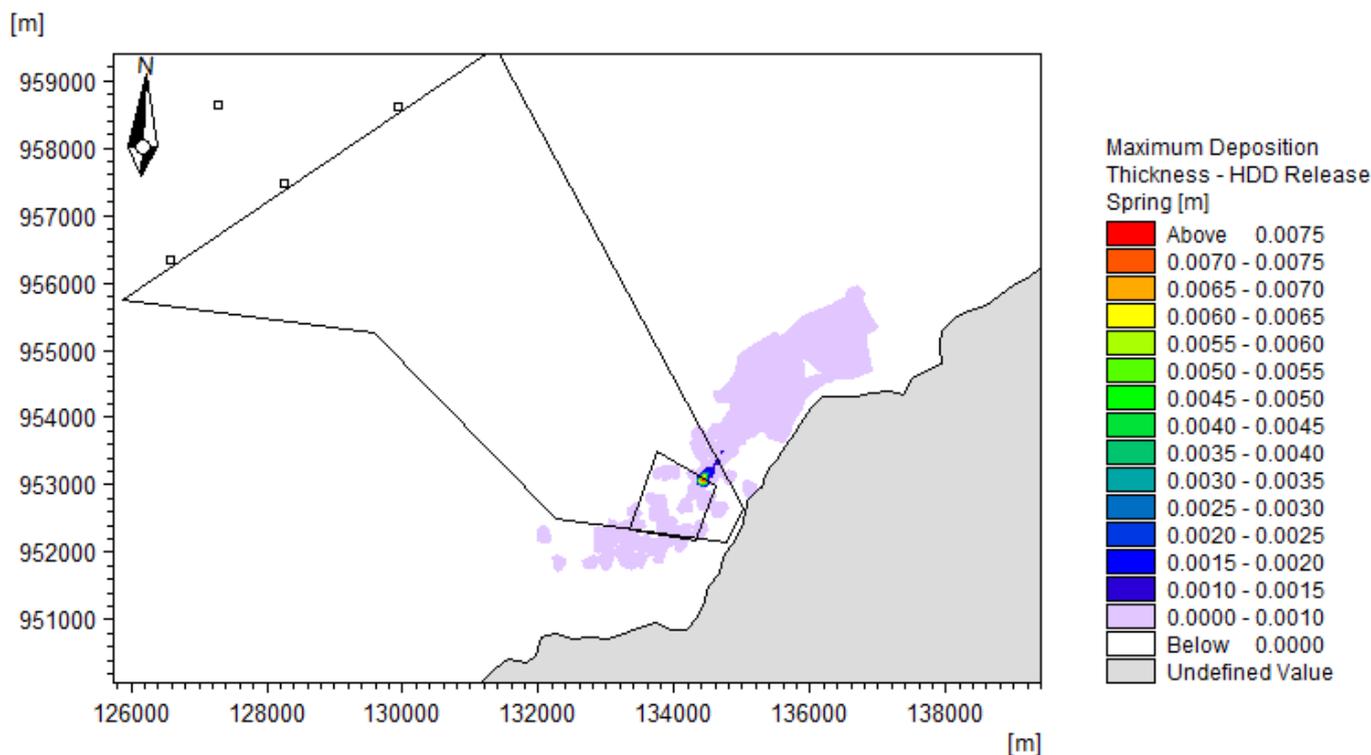### Neap Tide Slack Water Tide Release

4.4.2.3   A spatial plot of the maximum sediment deposition thickness arising from drill cutting release from HDD at neap tide slack water is shown in Plate 4-31.

4.4.2.4   As per the mid spring flood tide scenario, the results show that the largest deposition thicknesses of 7 mm occur in the immediate vicinity (<500 m) of the HDD modelling location. Generally, deposition thicknesses resulting from drill cutting release from HDD are less than 1 mm at a maximum distance of 2 km from the HDD modelling location in the direction of the tidal current over a width of up to 250 m. In comparison with the spring tide results, the extent of the sediment deposition is lower since the overall distance advected is less due to the lower current speeds.

4.5 HORIZONTAL DIRECTIONAL DRILLING - EXIT PIT CONSTRUCTION

4.5.1 SUSPENDED SEDIMENT CONCENTRATION

4.5.1.1 Based on the outputs of sediment plume modelling of Array Cable to Landfall burial and drill cutting release from HDD activities, the maximum suspended sediment concentrations caused by HDD exit pit construction are expected to range between 350 mg/l (within 200 m of HDD exit pit construction) and 1,000 mg/l (within 1 km of HDD exit pit construction) for coarse and fine sediment respectively (as described in Section 4.3.1 and Section 4.4.1).
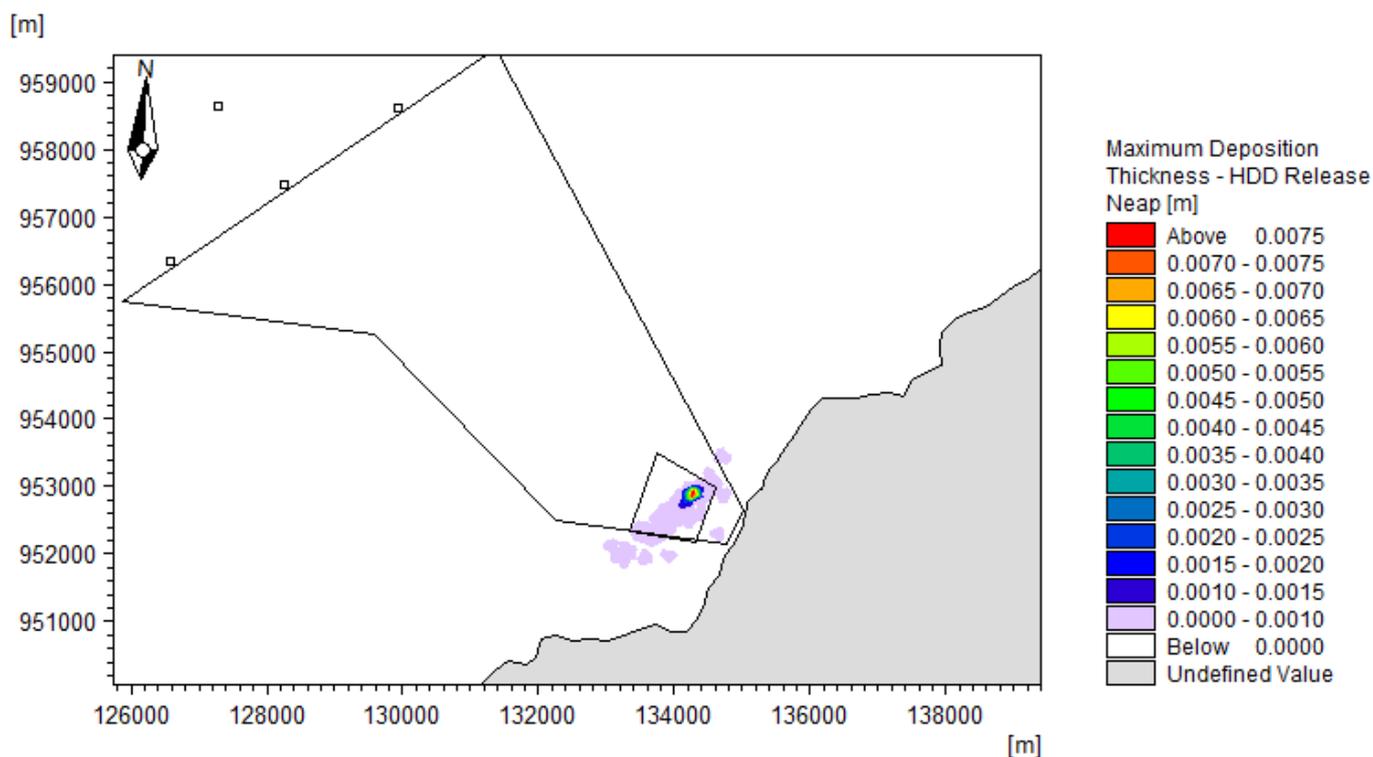
4.5.1.2 Suspended sediment concentrations are expected to be elevated above baseline condition for up to 2 days for the full range of sediment sizes (as described in Section 4.3.1 and Section 4.4.1).

4.5.2 SEDIMENT DEPOSITION

4.5.2.1 Based on the outputs of sediment plume modelling of cable burial and drill cutting release from HDD activities, the maximum sediment deposition thicknesses caused by HDD exit pit construction are expected to range between 3 cm (within 400 m of HDD exit pit construction) and 7 mm (within 500 m of HDD exit pit construction) for coarse and fine sediment respectively (as described in Section 4.3.2 and Section 4.4.2). The finer the sediment the more easily mobilised it will be by tidal currents and waves; the deposition of finer sediments will not remain for a

significant period of time (within an hour) due to resuspension from the natural hydrodynamic regime.

4.6 MULTIPLE ACTIVITIES

4.6.1 MULTIPLE ACTIVITIES: DRILLING OF PILES TO INSTALL WIND TURBINE GENERATOR FOUNDATIONS AND CABLE BURIAL

Suspended Sediment Concentration

4.6.1.1 The maximum suspended sediment concentration during the model simulation following drilling piles to install 4 WTG foundations (each with 4 piles), and associated burial of cables in scenarios 1, 2 and 3 (assuming drilling and cable burial activities happen sequentially), per month, are shown in Plate 4-32 to Plate 4-34.

4.6.1.2 In relation to the maximum design scenario assumption of 4 piles per turbine foundation, 3 piles are modelled simultaneously, with the single remaining pile for this location modelled on its own.

4.6.1.3 The impacts of cable burial activities from adjacent cables may occur within the OCAS as this is where Array Cables to Landfall will be located in close proximity to each other (in comparison to the Array Cables to Final WTGs). In the case of suspended sediment concentrations, maximum values occur at the location of the cable burial and decrease rapidly with distance in the direction of the tidal current. Assuming that cables are buried equally spaced at 150 m across the width of the OCAS (2 km), the impacts of adjacent cables are not expected to be greater than the maximum impacts along the individual cables. This is based on the model between Landfall and the Turbine Area indicating a potential zone of influence of approximately 100 m centred on the cable burial route.

4.6.1.4 Overall, the extent of suspended sediment concentration from multiple activities (scenario 1, 2, and 3 Construction Activities) is mainly constrained to the Turbine Area (with a total combined area of around 90 km^2). The suspended sediment concentration plume does extend outside the Turbine Area by approximately 3 km in the southwest corner of the Turbine Area.

4.6.1.5 These plots clearly demonstrate the influence of sediment size on plume extent; the southwest Turbine Area has finer sediments which settle slower and therefore are advected further by currents.

Plate 4-32 Maximum suspended sediment concentration arising from scenario 1 drilling of piles to install WTG foundations and sequential burial of cables
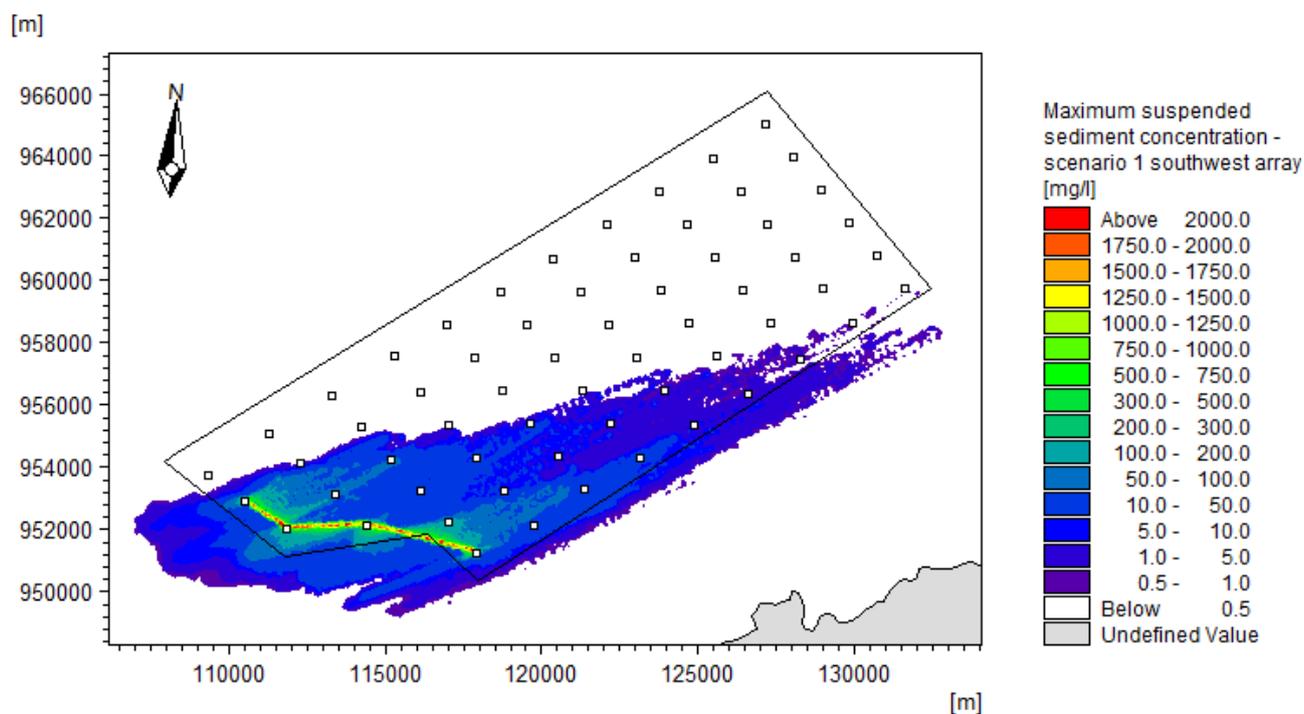
Plate 4-33 Maximum suspended sediment concentration arising from scenario 2 drilling of piles to install WTG foundations and sequential burial of cables
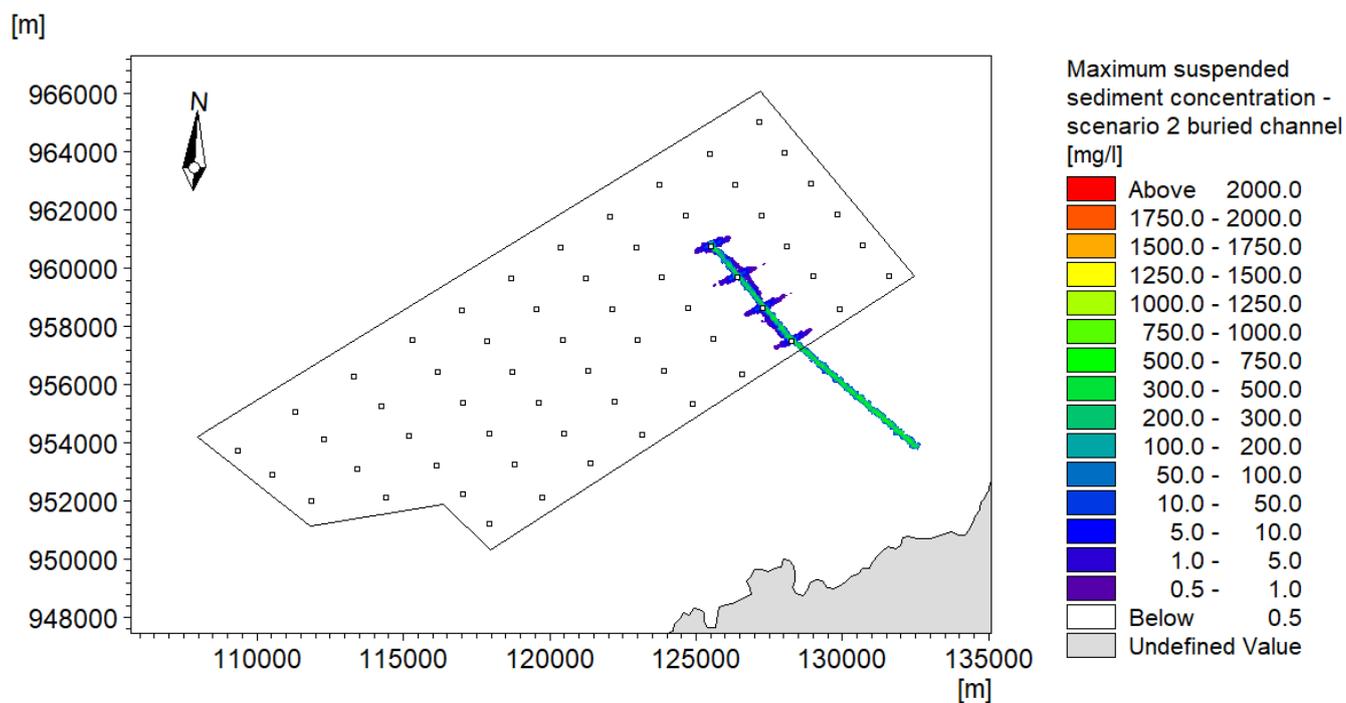
Plate 4-34 Maximum suspended sediment concentration arising from scenario 3 sequential drilling of piles to install WTG foundations and burial of cables construction activities
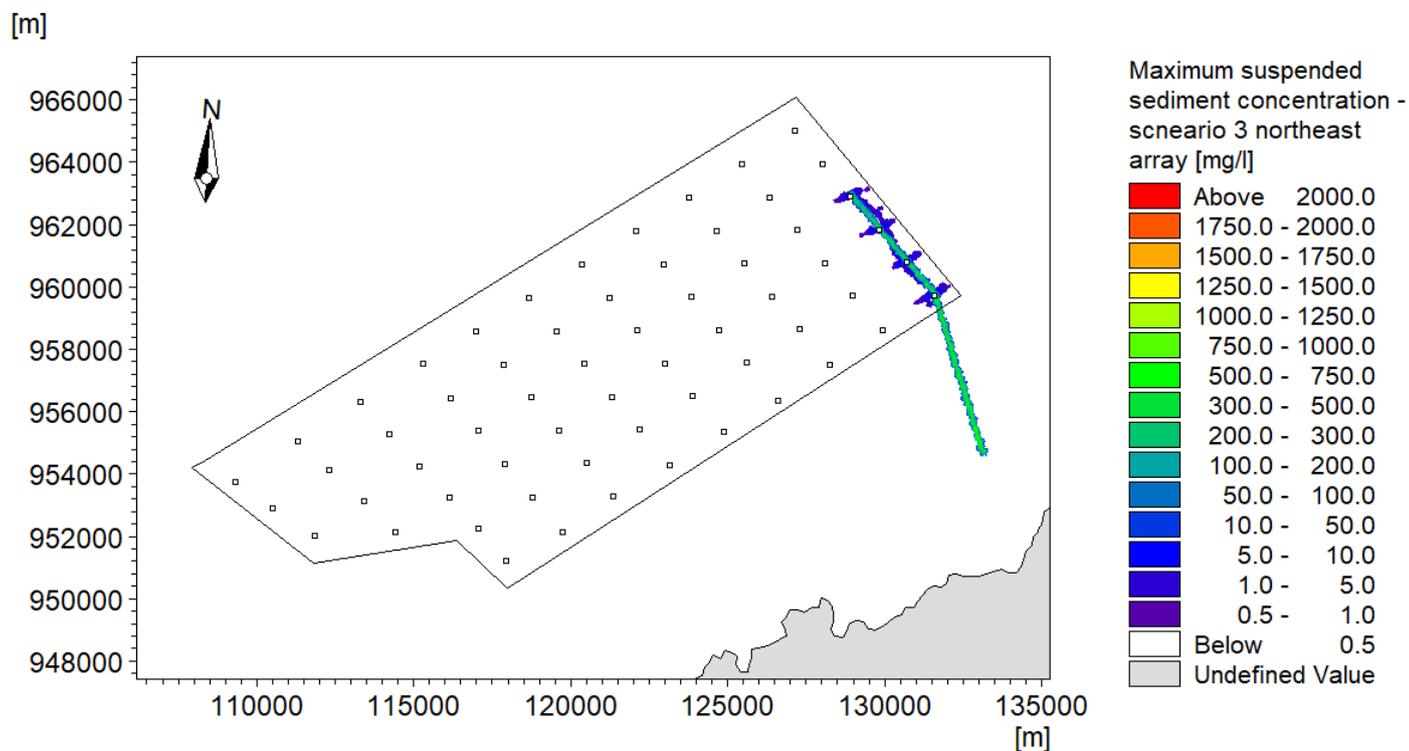
4.6.1.6   Timeseries plots of suspended sediment concentration at the data extraction points illustrated in Plate 2-8 are shown in Plate 4-35 to Plate 4-43. It should be noted that these scenarios do not include sediment resuspension. However, currents and waves will remobilise fine deposited sediment as shown in Plate 4-44 to Plate 4-52.

Plate 4-35 Suspended sediment concentration timeseries at location 1 (no resuspension)

Plate 4-36 Suspended sediment concentration timeseries at location 2 (no resuspension)

Plate 4-37 Suspended sediment concentration timeseries at location 3 (no resuspension)

Plate 4-38 Suspended sediment concentration timeseries at location 4 (no resuspension)

Plate 4-39 Suspended sediment concentration timeseries at location 5 (no resuspension)

Plate 4-40: Suspended Sediment Concentration Timeseries at Location 6 (no resuspension)

Plate 4-41 Suspended sediment concentration timeseries at location 7 (no resuspension)

Plate 4-42 Suspended sediment concentration timeseries at location 8 (no resuspension)

Plate 4-43 Suspended sediment concentration timeseries at location 9 (no resuspension)

4.6.1.7   Timeseries plots of suspended sediment concentration at the data extraction locations illustrated in Plate 2-8 are shown in Plate 4-44 to Plate 4-52. These plots include sediment resuspension, demonstrating how sediment is frequently remobilised by currents with concentrations above baseline levels generally lasting no longer than 24 hours. The peak suspended sediment concentrations in the runs with sediment resuspension are often higher than the runs without sediment resuspension due to the accumulation of suspended sediment in the water column.

Plate 4-44 Suspended sediment concentration timeseries at location 1 (with resuspension)
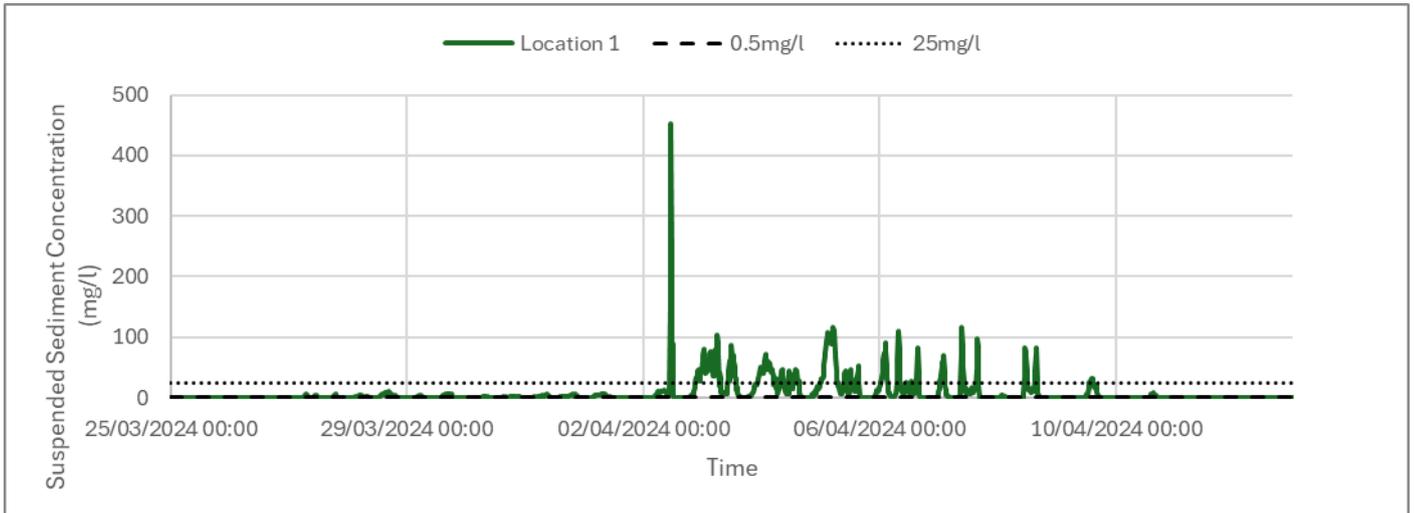
Plate 4-45 Suspended sediment concentration timeseries at location 2 (with resuspension)
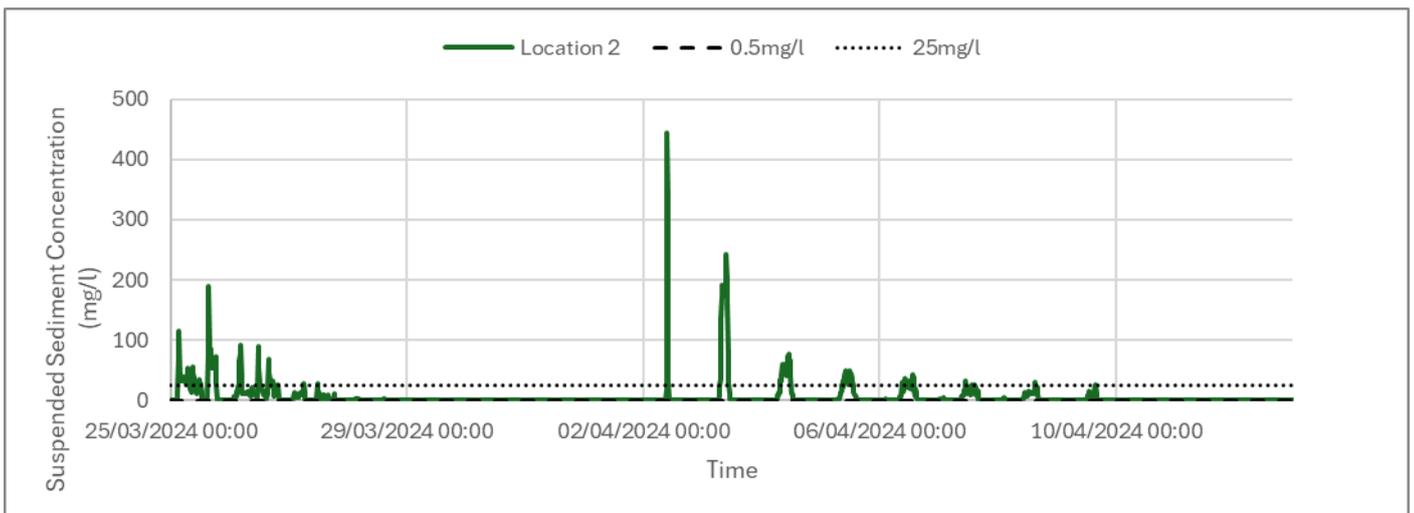
Plate 4-46 Suspended sediment concentration timeseries at location 3 (with resuspension)
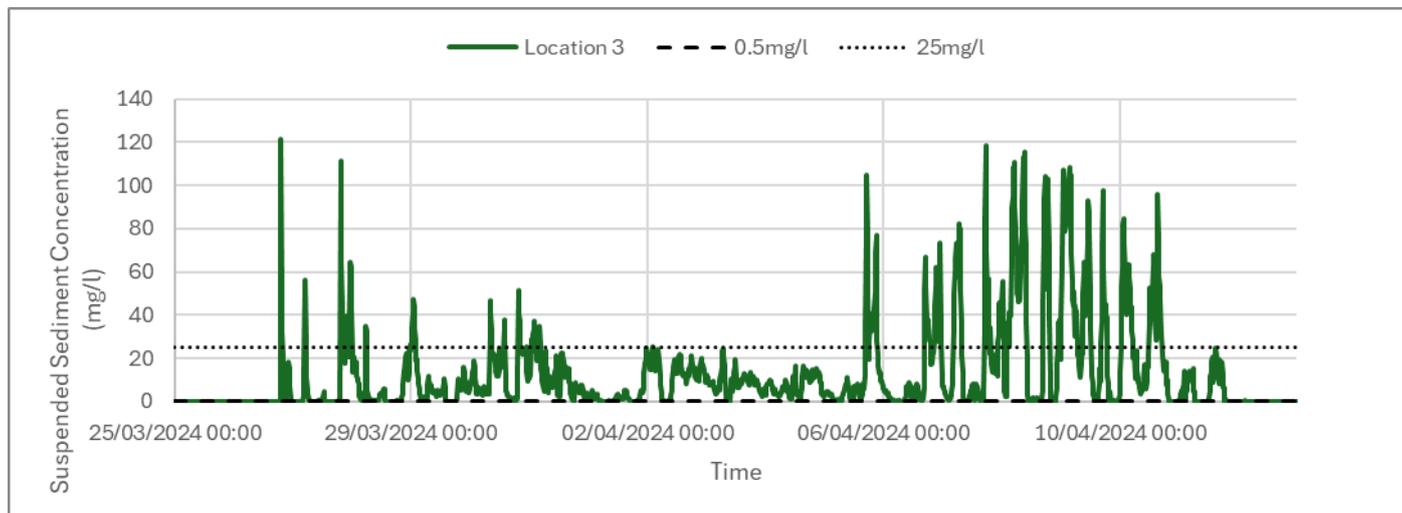
Plate 4-47 Suspended sediment concentration timeseries at location 4 (with resuspension)
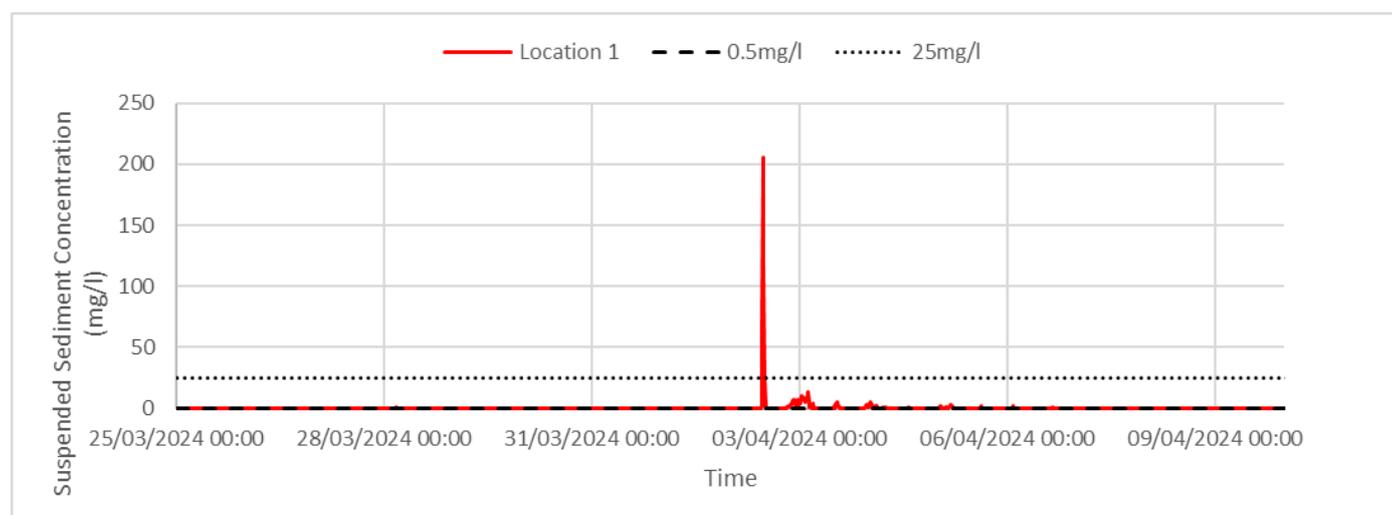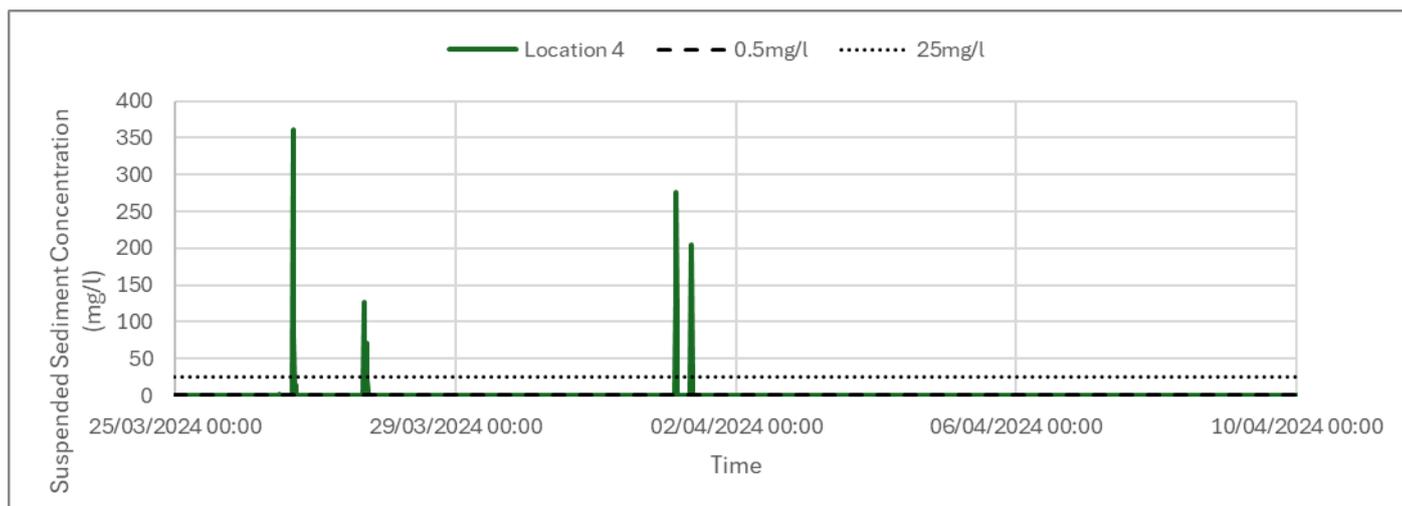
Plate 4-48 Suspended sediment concentration timeseries at location 5 (with resuspension)
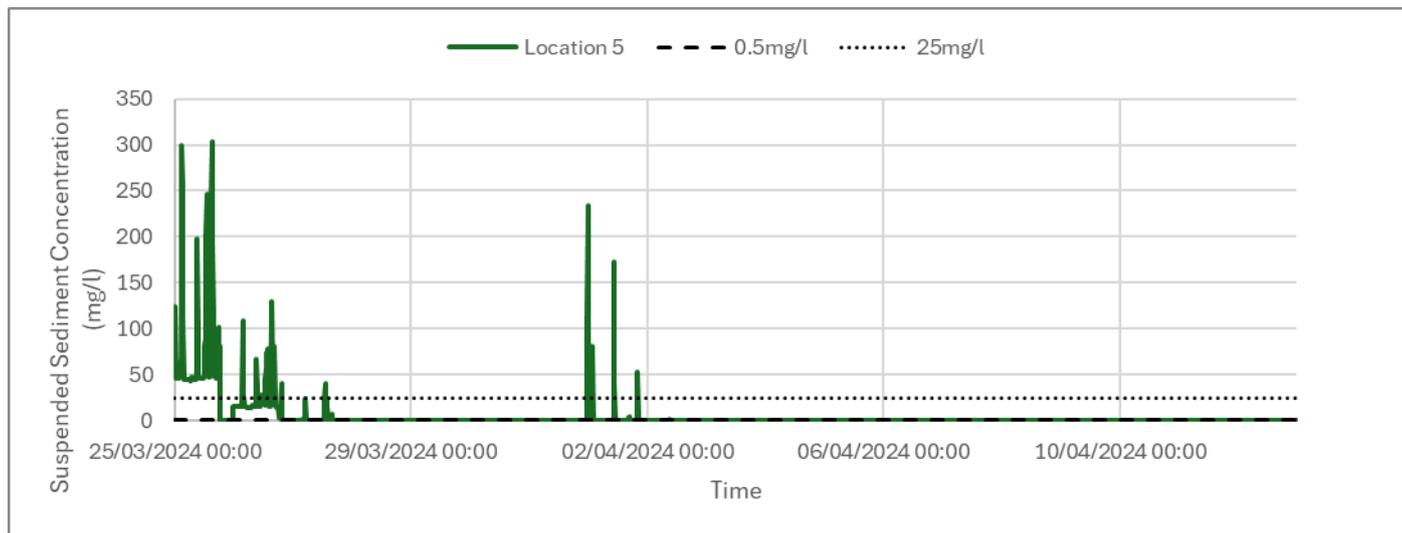
Plate 4-49 Suspended sediment concentration timeseries at location 6 (with resuspension)
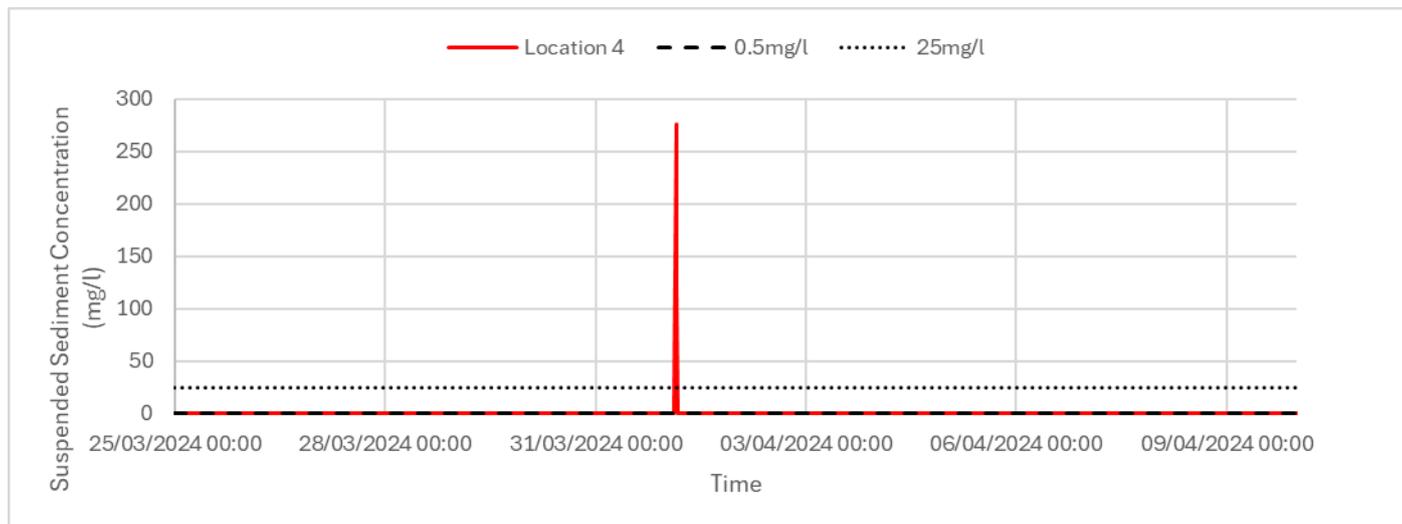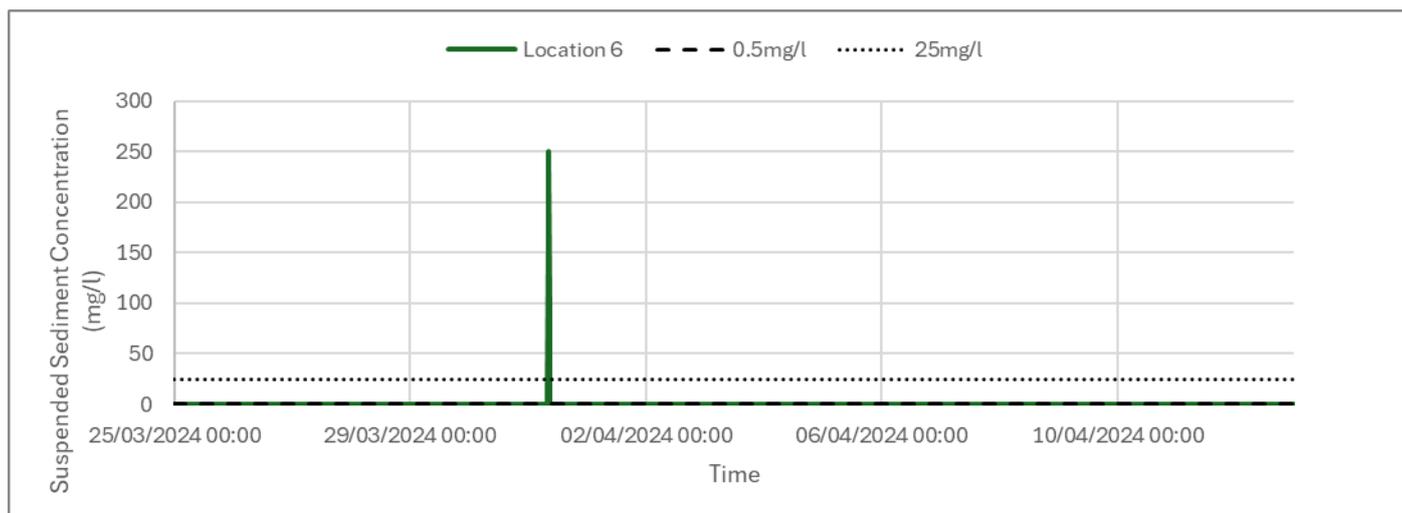
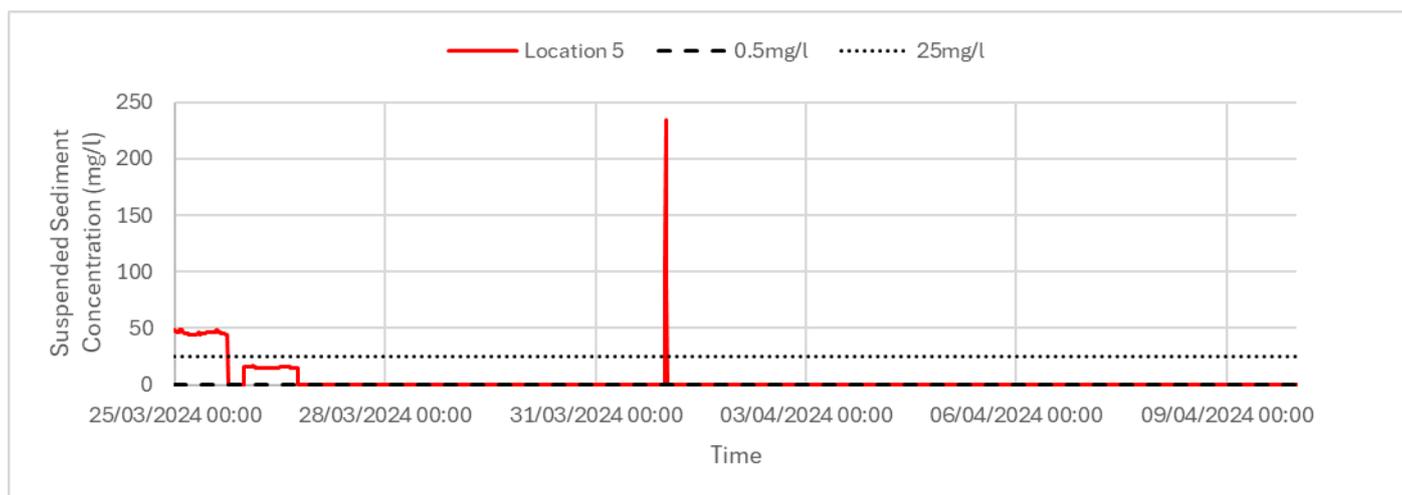**Plate 4-50 Suspended sediment concentration timeseries at location 7 (with resuspension)**
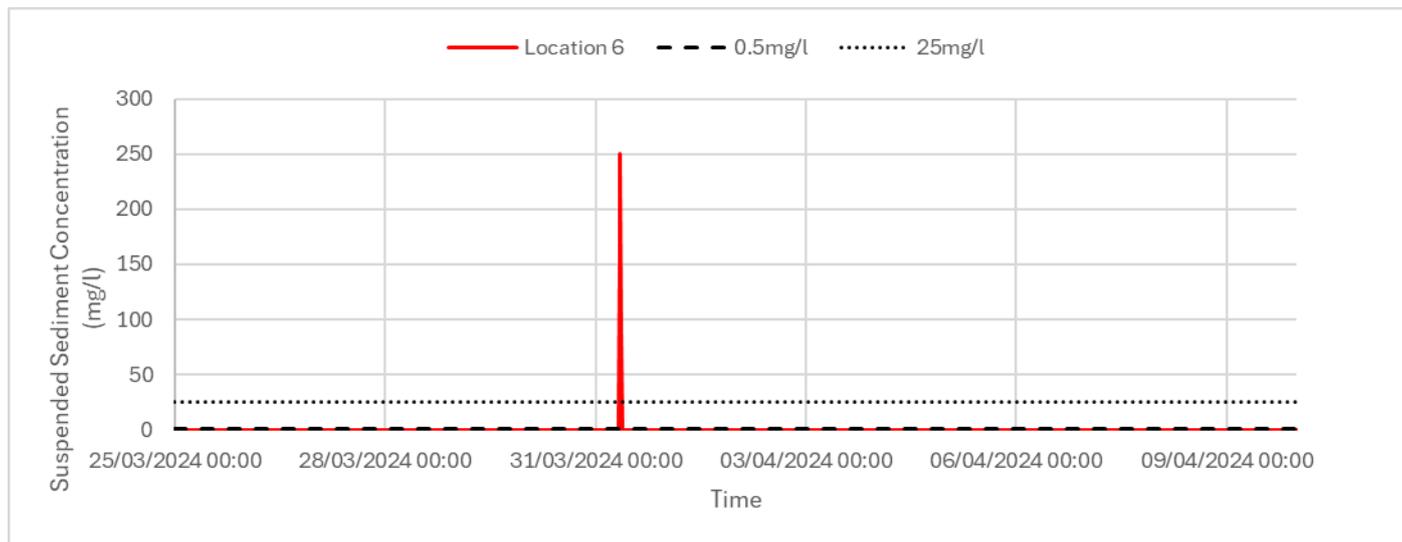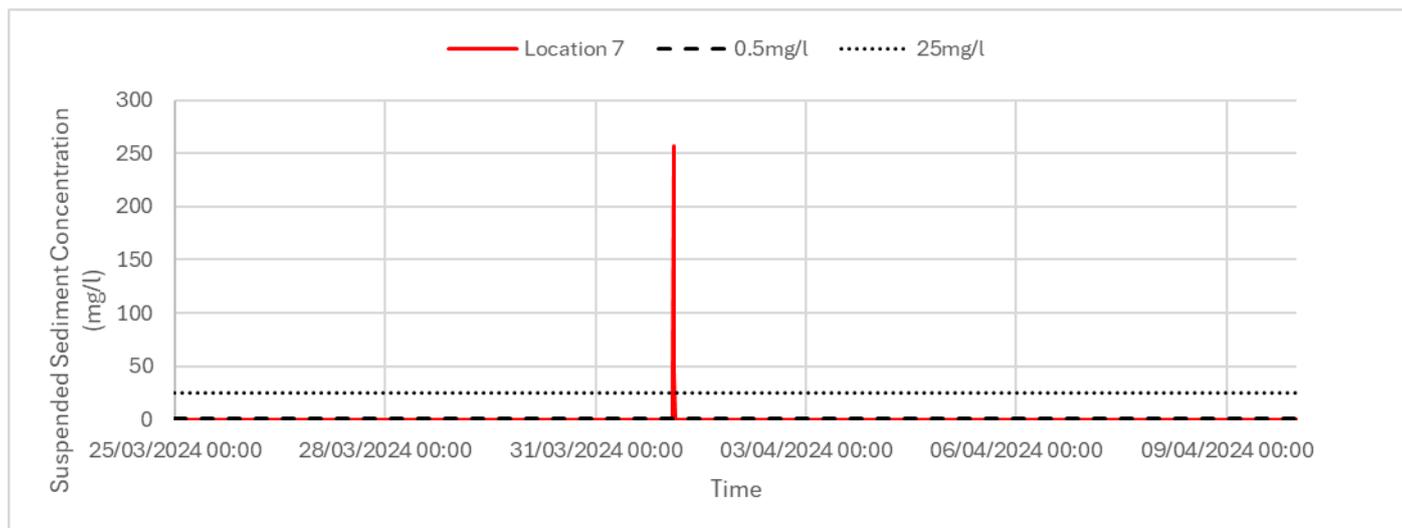

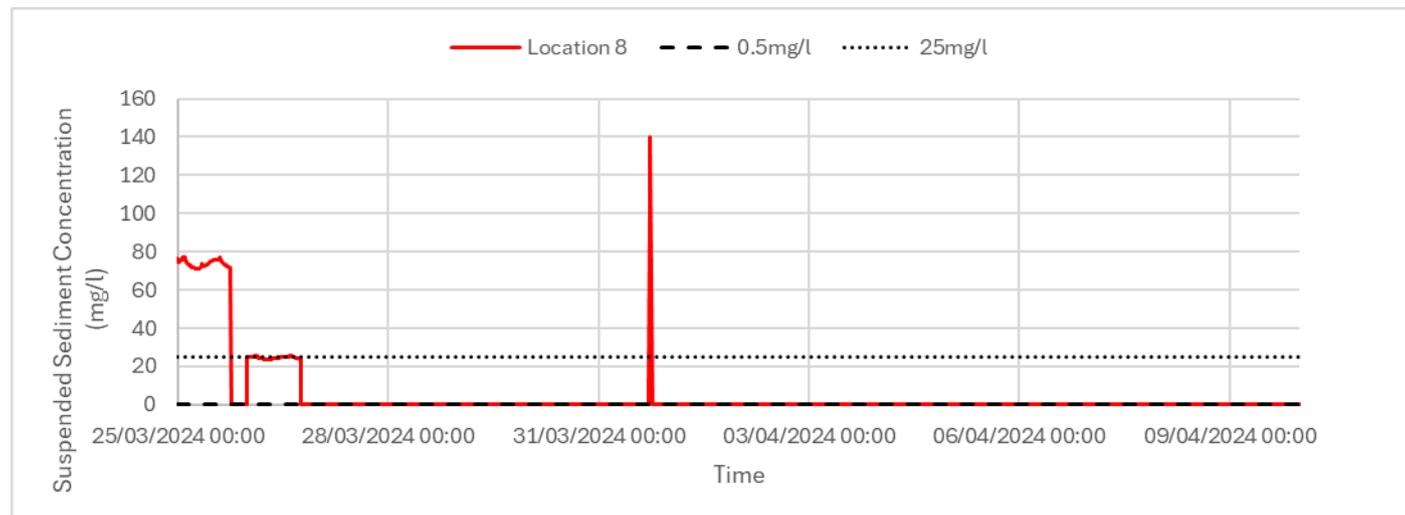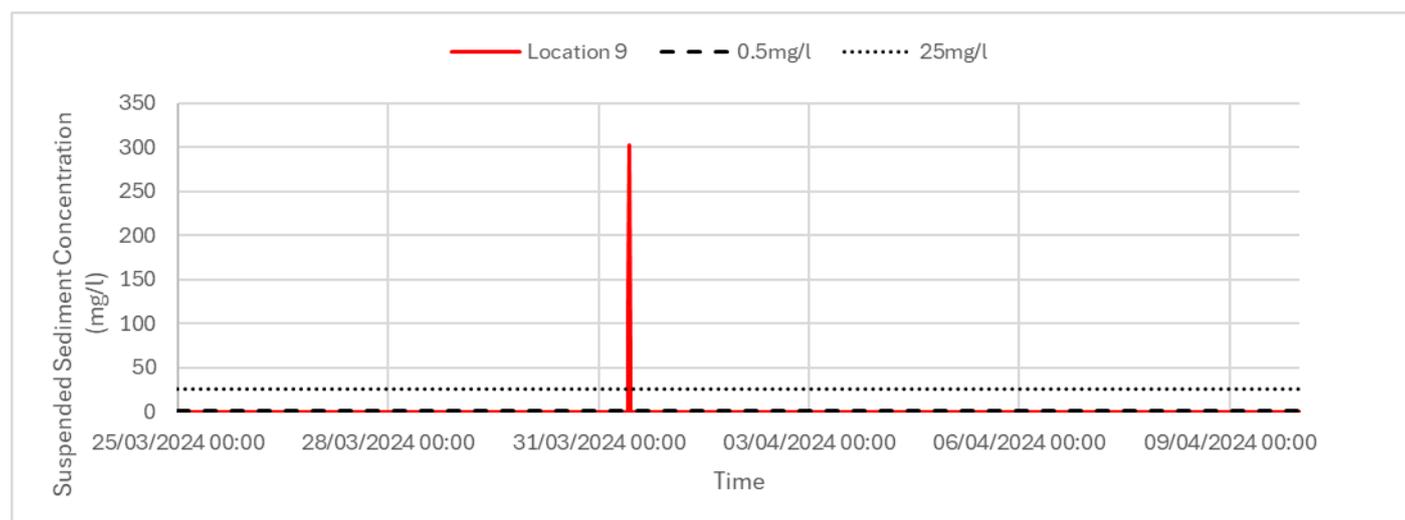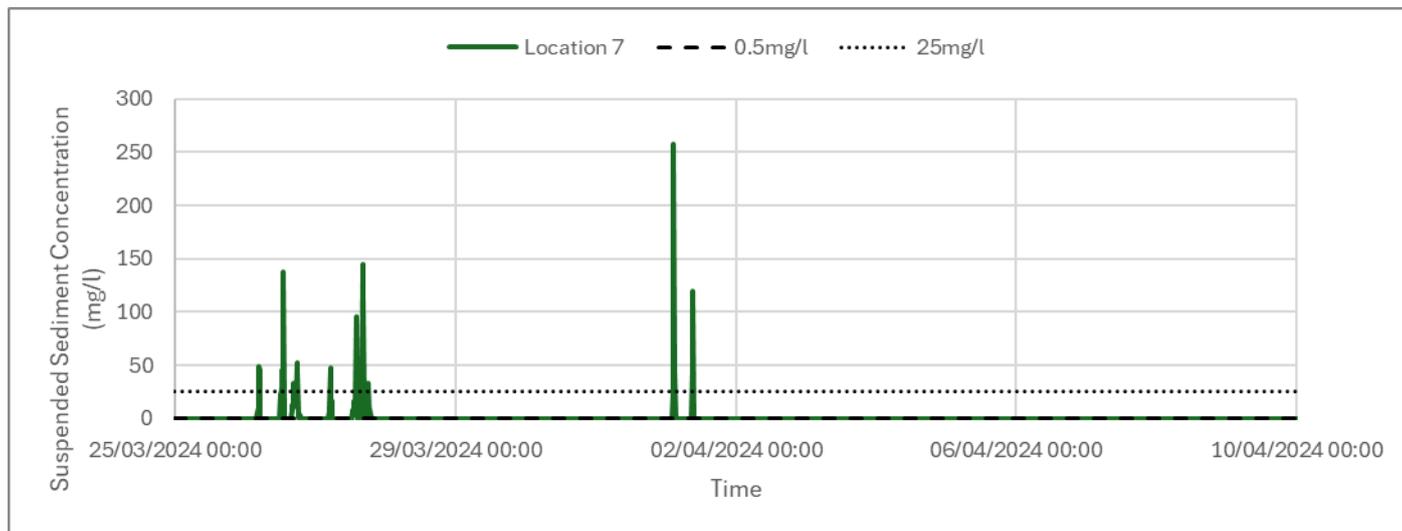**Plate 4-51 Suspended sediment concentration timeseries at location 8 (with resuspension)**
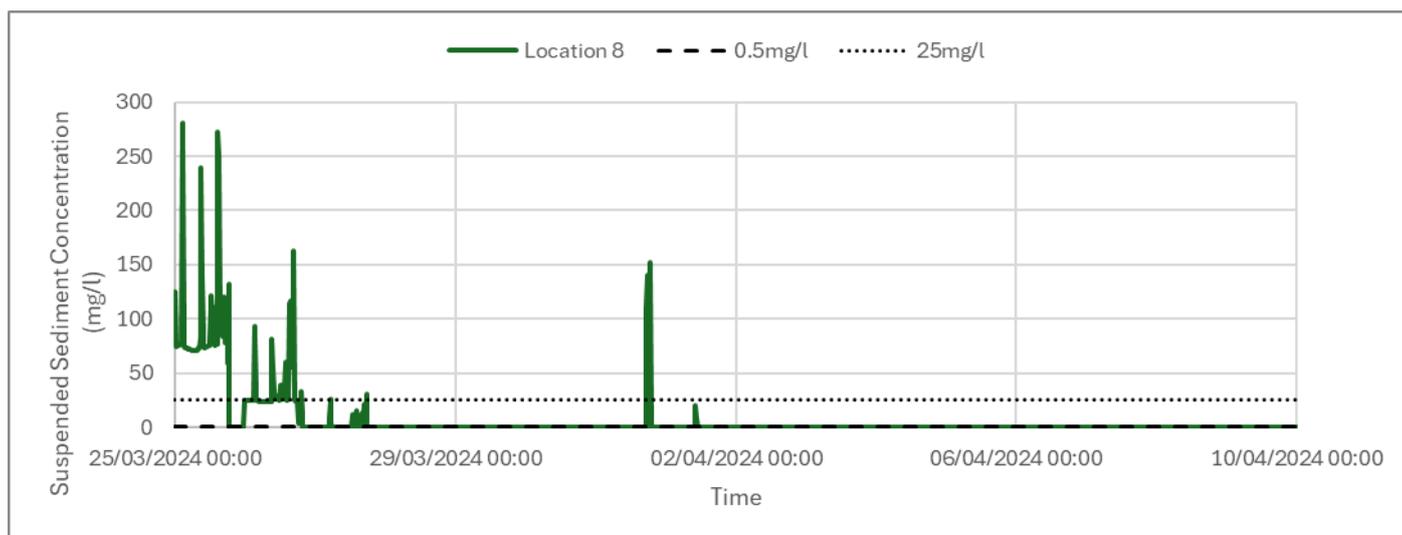
Plate 4-52 Suspended sediment concentration timeseries at location 9 (with resuspension)
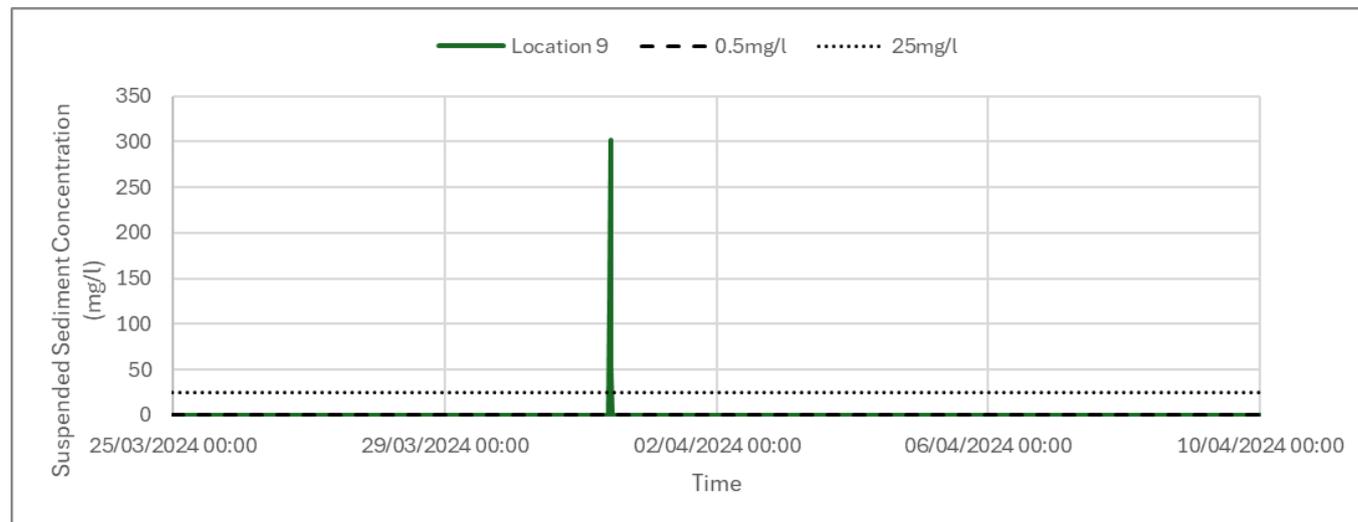
4.6.1.1 Activities and approximate durations where suspended sediment concentration is greater than 25 mg/l and 0.5 mg/l are detailed in Table 4-2. For the scenarios with sediment resuspension both the total duration and maximum consecutive duration over the threshold are reported.

4.6.1.2 Overall, the worst-case scenario in terms of increase in suspended sediment concentration results from the southwest drilling of piles to install WTG foundations and Array Cables to Final WTG burial reaching up to 450 mg/l. At location 3, this exceeds the 25 mg/l threshold for around 3 days and exceeds background concentration of 0.5 mg/l for around 13 days.

Table 4-2 Construction activities and durations causing suspended sediment concentration above concentration thresholds at point extraction locations

Location	Construction activity	Approximate duration over threshold (hours) no resuspension		Approximate duration over threshold (hours) with resuspension	
		>25 mg/l	>0.5 mg/l	>25 mg/l	>0.5 mg/l
1	Scenario 1 Array Cables to Final WTG burial	<1	<23	<52 (total) <10 (consecutive)	<183 (total) <22 (consecutive)
2	Scenario 1 drilling of piles to install WTG foundations and sequential burial of Array Cables to Final WTG	<2	<33	<34 (total) <5 (consecutive)	<108 (total) <20 (consecutive)
3	Scenario 1 drilling of piles to install WTG foundations and sequential burial of	0	<10	<67 (total) <9 (consecutive)	<313 (total) <59 (consecutive)

Location	Construction activity	Approximate duration over threshold (hours) no resuspension		Approximate duration over threshold (hours) with resuspension	
		>25 mg/l	>0.5 mg/l	>25 mg/l	>0.5 mg/l
	Array Cables to Final WTG				
4	Scenario 2 Array Cables to Final WTG burial	<1	<1	<3 (total) <2 (consecutive)	<6 (total) <2 (consecutive)
5	Scenario 2 drilling of piles to install WTG foundations and sequential burial of Array Cable to Landfall	<19*	<38	<26 (total) <19 (consecutive)	<46 (total) <20 (consecutive)
6	Scenario 2 Array Cable to Landfall burial	<1	<1	<1 (total and consecutive)	<1 (total and consecutive)
7	Scenario 3 Array Cables to Final WTG burial	<1	<1	<5 (total) <1 (consecutive)	<13 (total) <3 (consecutive)
8	Scenario 3 drilling of piles to install WTG foundations and sequential burial of Array Cable to Landfall	<19*	<39	<33 (total) <20 (consecutive)	<48 (total) <21 (consecutive)
9	Scenario 3 Array Cable to Landfall burial	<1	<1	<1 (total and consecutive)	<1 (total and consecutive)

Concentration >25 mg/l for whole working day while drilling of piles to install 3 WTG foundations are drilled simultaneously. High concentrations are not repeated the following day as the single remaining pile for this location is drilled.

Sediment Deposition

4.6.1.3 The maximum sediment deposition thickness during the model simulation following drilling piles to install 4 WTG foundations (each with 4 piles) and associated burial of cables in scenarios 1, 2, and 3 (assuming turbine and cable activities happen sequentially) are shown in Plate 4-53 to Plate 4-55.

4.6.1.4 In relation to the maximum design scenario assumption of 4 piles per turbine foundation, 3 piles are modelled simultaneously, with the single remaining pile for this location modelled on its own.

4.6.1.5 The area of sediment deposition is approximately equal to that of the area where suspended sediment is advected (around 90 km^2 total). However, sediment deposition thicknesses greater than 1 cm are confined to areas around the turbines and cables totalling approximately 1.5 km^2.

Plate 4-53 Maximum sediment deposition thickness arising from scenario 1 drilling of piles to install WTG foundations and sequential burial of cables
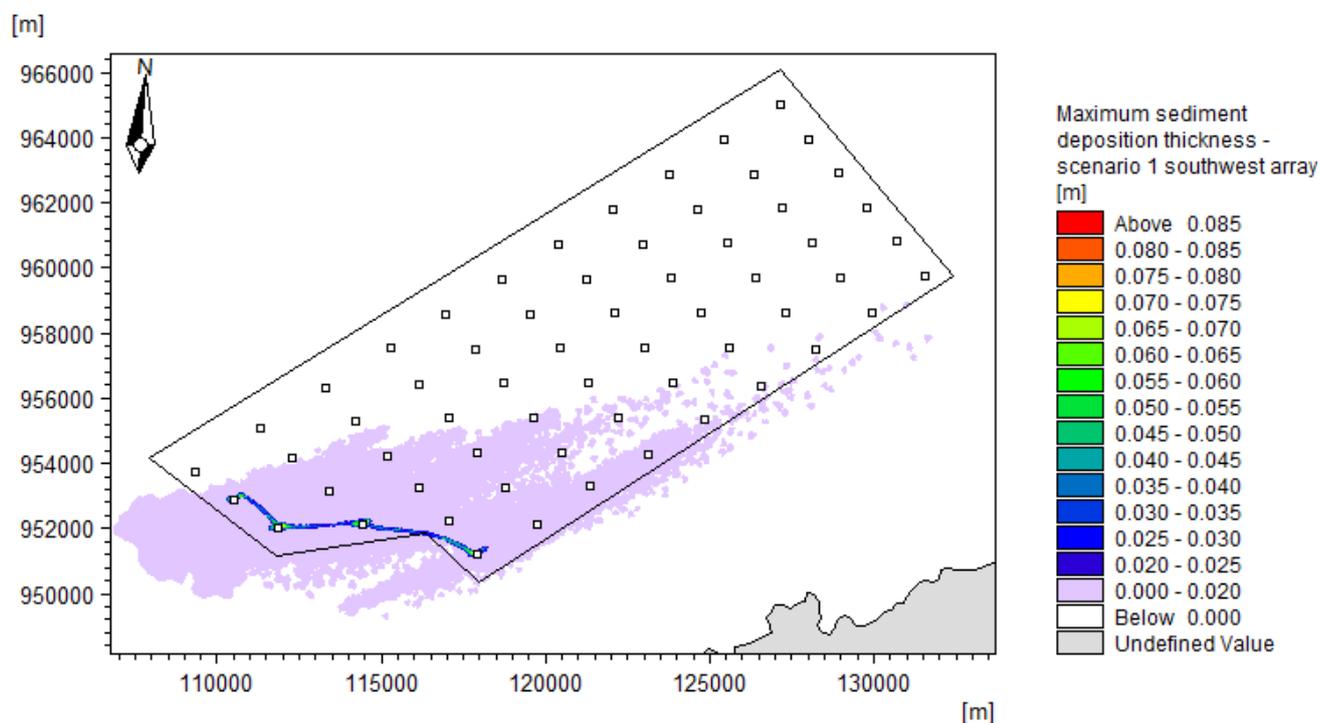
Plate 4-54 Maximum sediment deposition thickness arising from scenario 2 drilling of piles to install WTG foundations and sequential burial of cables
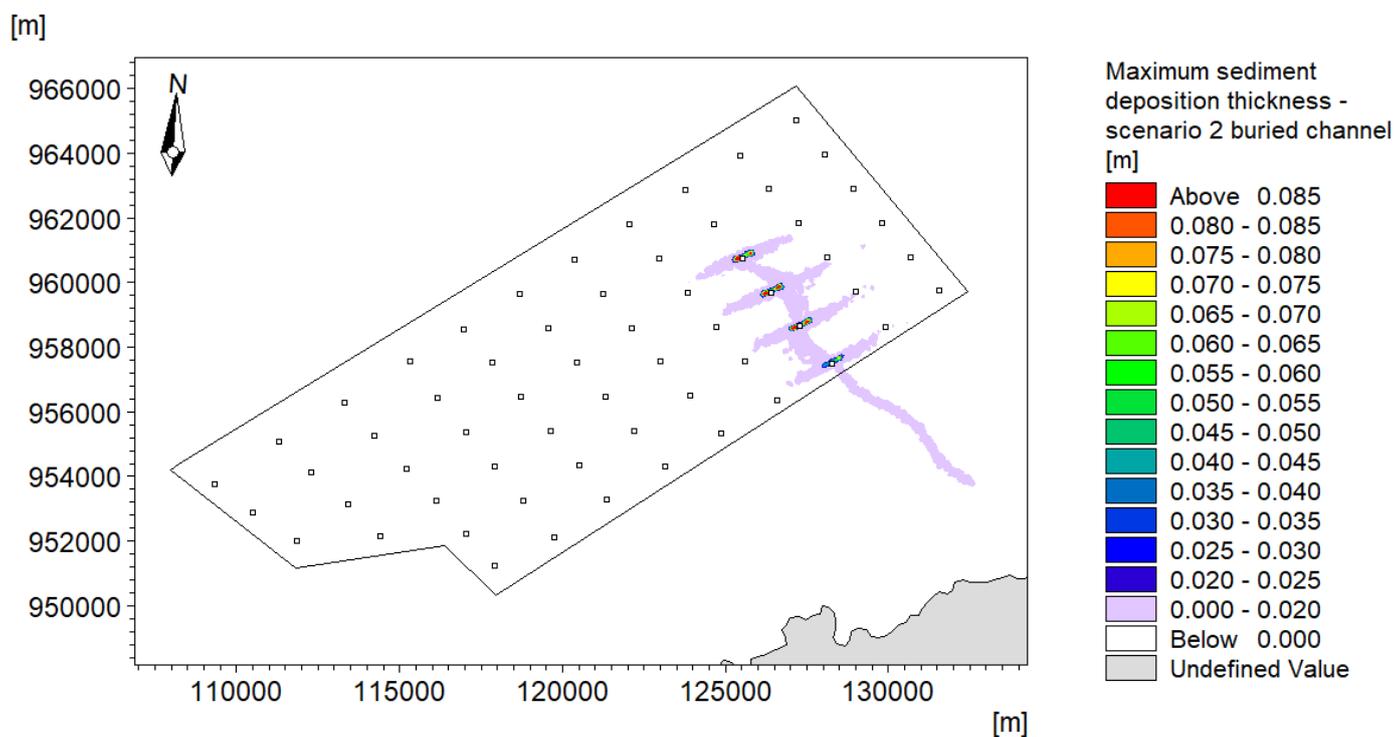
Plate 4-55 Maximum sediment deposition thickness arising from scenario 3 drilling of piles to install WTG foundations and sequential burial of cables
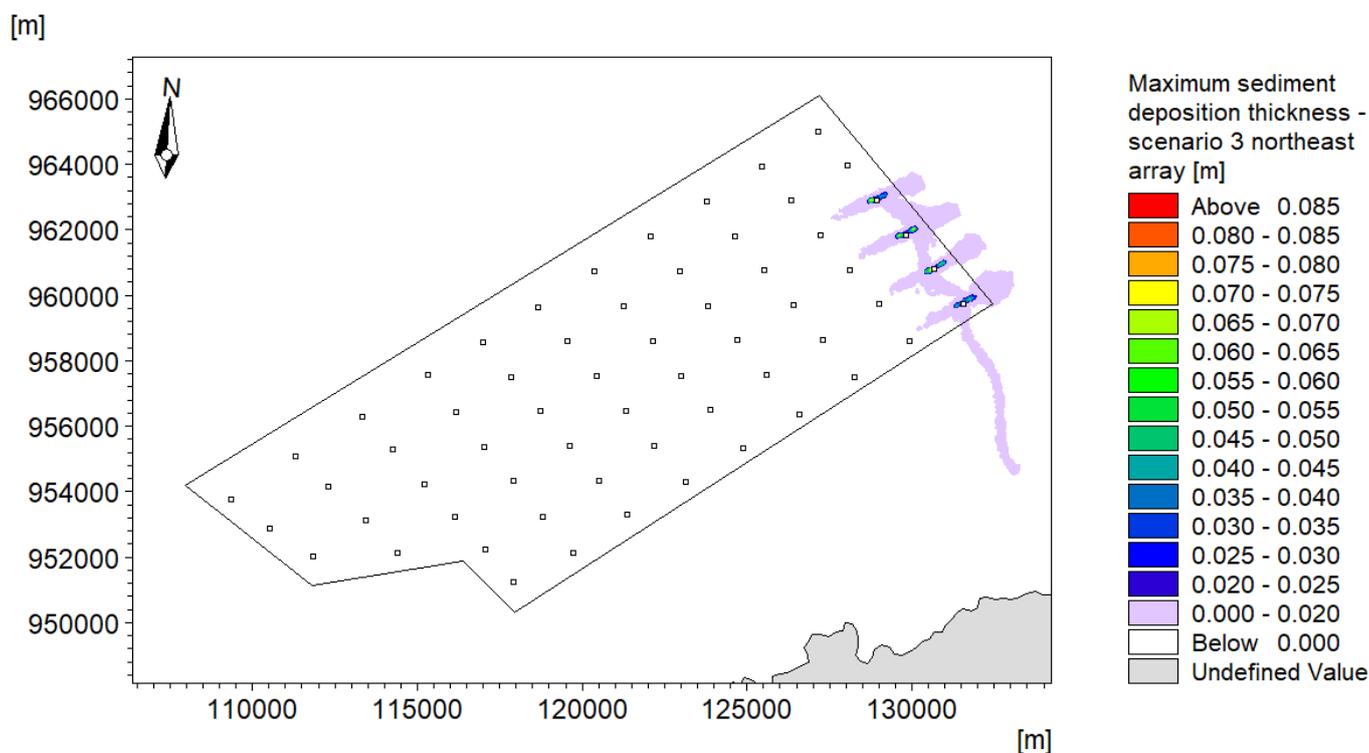
4.6.1.6   Timeseries plots of sediment deposition at the data extraction locations illustrated in Plate 2-8 are shown in Plate 4-56 to Plate 4-59. It should be noted that these scenarios do not include sediment resuspension; currents and waves will remobilise fine deposited sediment as shown in Plate 4-60 to Plate 4-64. Locations 3, 4, 6, 7, and 9 (cable burial locations in the buried channel and northeast Turbine Areas and the mid array location) do not have timeseries plots as the deposition thickness is negligible (<0.1 mm).

4.6.1.7   The modelling indicates that drilling of piles to install WTG foundations increases deposition thickness in multiple steps because the source of sediment does not move and the tide carries sediment back and forth over the data extraction location (shown at the start of the timeseries plots). Cable burial activities increase deposition thickness in a single event as the route of the cable passes the data extraction location (shown towards the middle of the timeseries plots). At the locations where both activities occur, drilling of piles to install WTG foundations contributes more to the total sediment deposition thickness than cable burial due to the static nature of drilling.

Plate 4-56 Deposition thickness timeseries at location 1 (no resuspension)
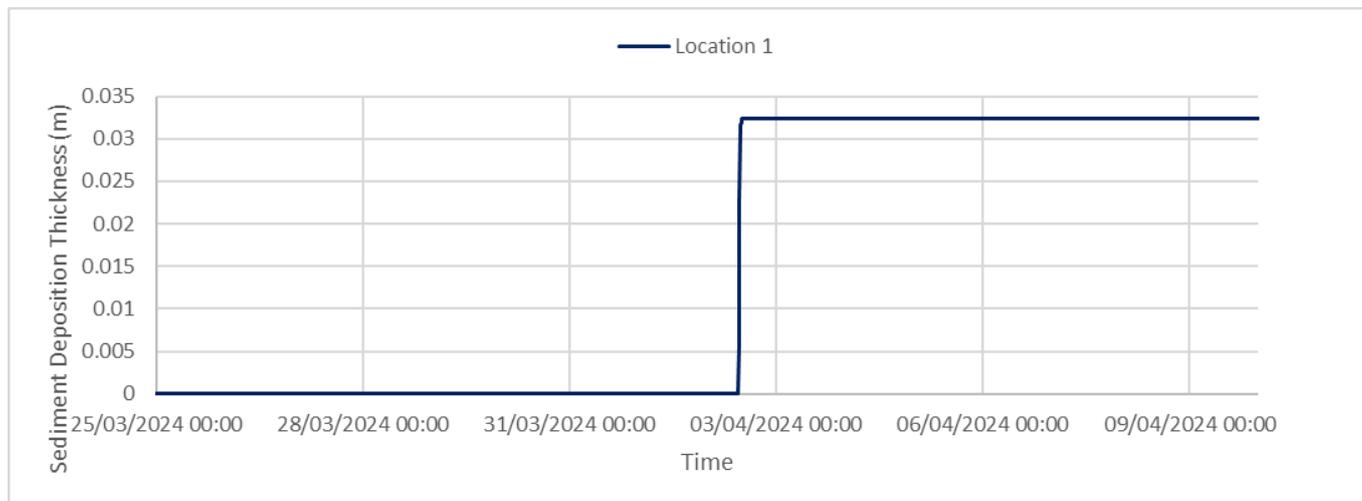
Plate 4-57 Deposition thickness timeseries at location 2 (no resuspension)
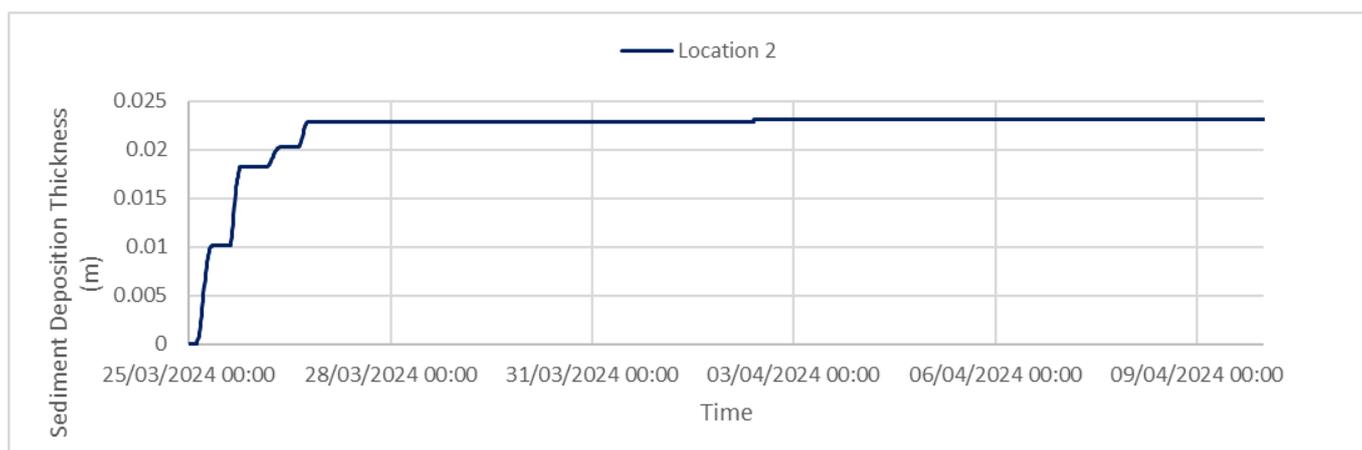
Plate 4-58 Deposition thickness timeseries at location 5 (no resuspension)
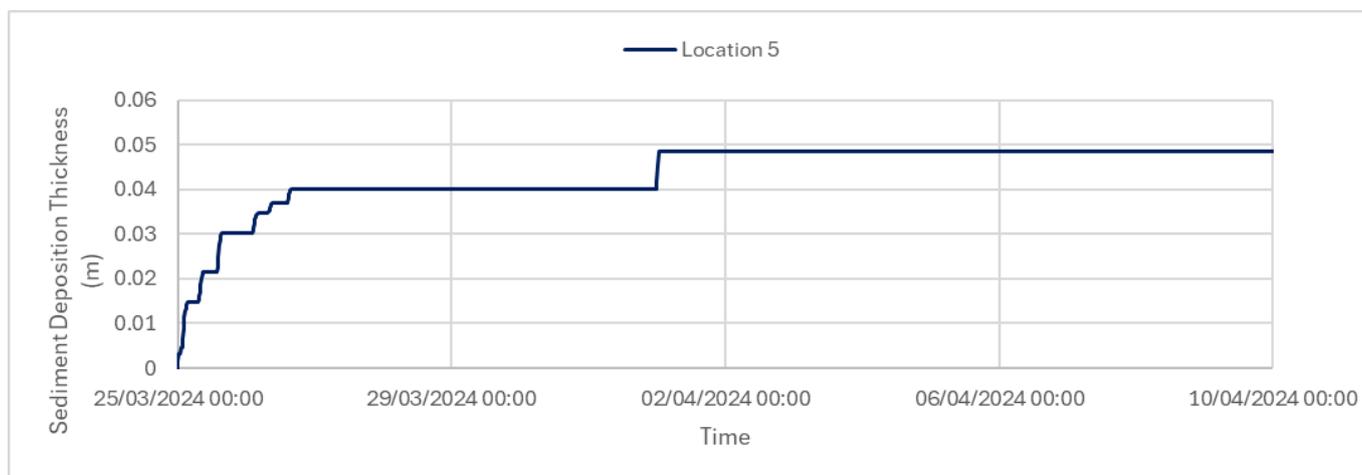
Plate 4-59 Deposition thickness timeseries at location 8 (no resuspension)
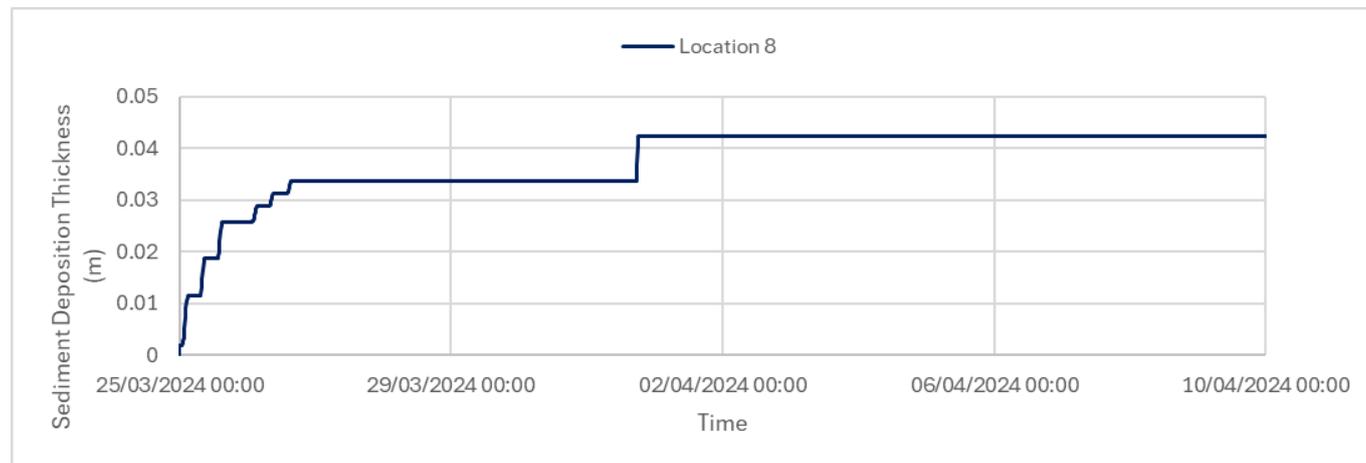
4.6.1.8   Timeseries plots of sediment deposition at the data extraction locations illustrated in Plate 2-8 are shown in Plate 4-60 to Plate 4-64. These plots include sediment resuspension, demonstrating how deposited sediment is frequently remobilised by currents.

4.6.1.9   The modelling indicates that the inclusion of sediment resuspension reduces the sediment deposition thickness resulting from individual and multiple activities. Sediment deposition thickness tends to increase to an elevated level for a brief period of time immediately following the construction activity before reducing to a stable level as sediment is resuspended.

Plate 4-60 Deposition thickness timeseries at location 1 (with resuspension)
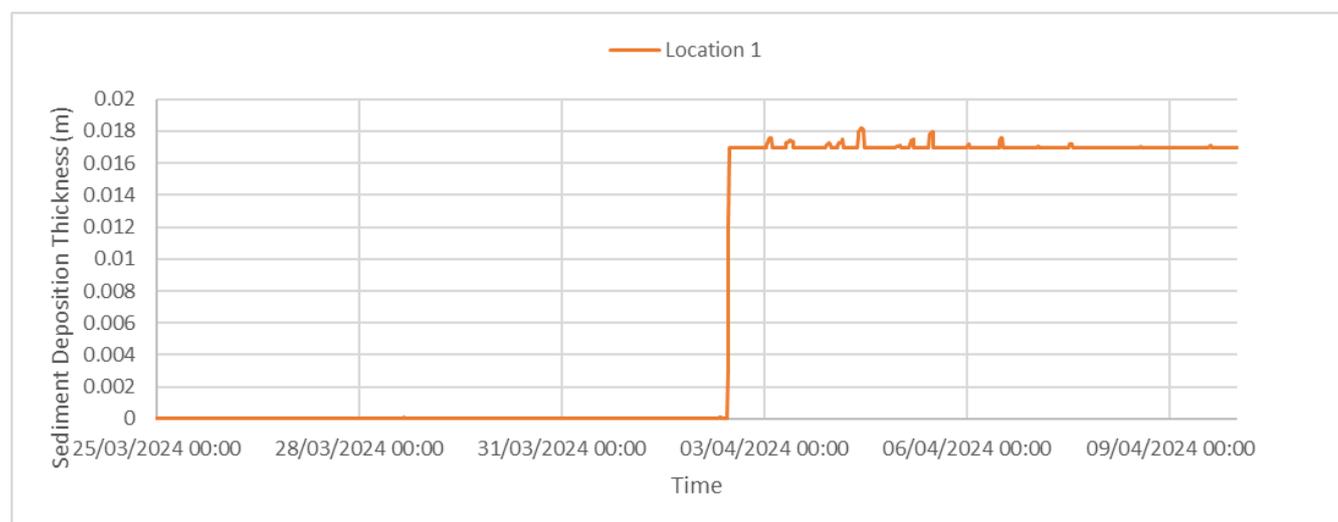
Plate 4-61 Deposition thickness timeseries at location 2 (with resuspension)
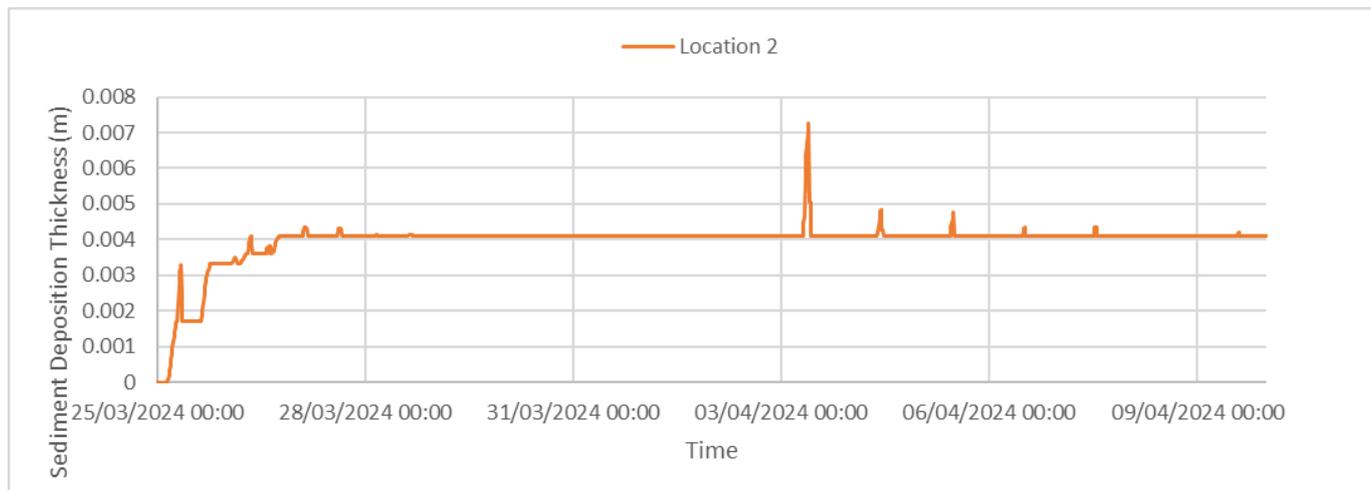
Plate 4-62 Deposition thickness timeseries at location 3 (with resuspension)
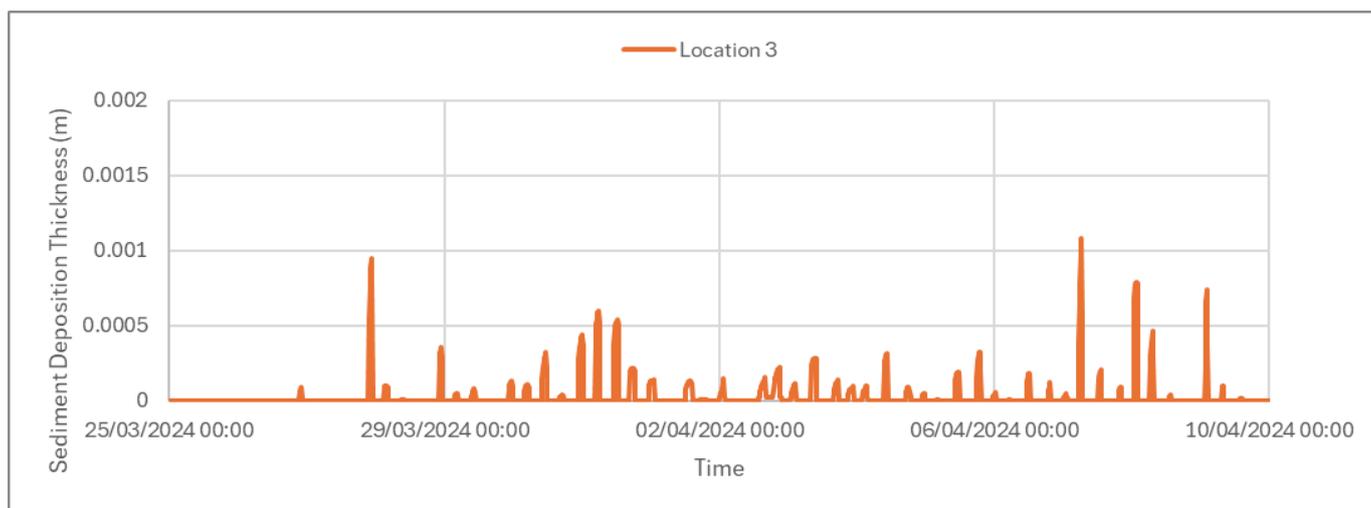
Plate 4-63 Deposition thickness timeseries at location 5 (with resuspension)
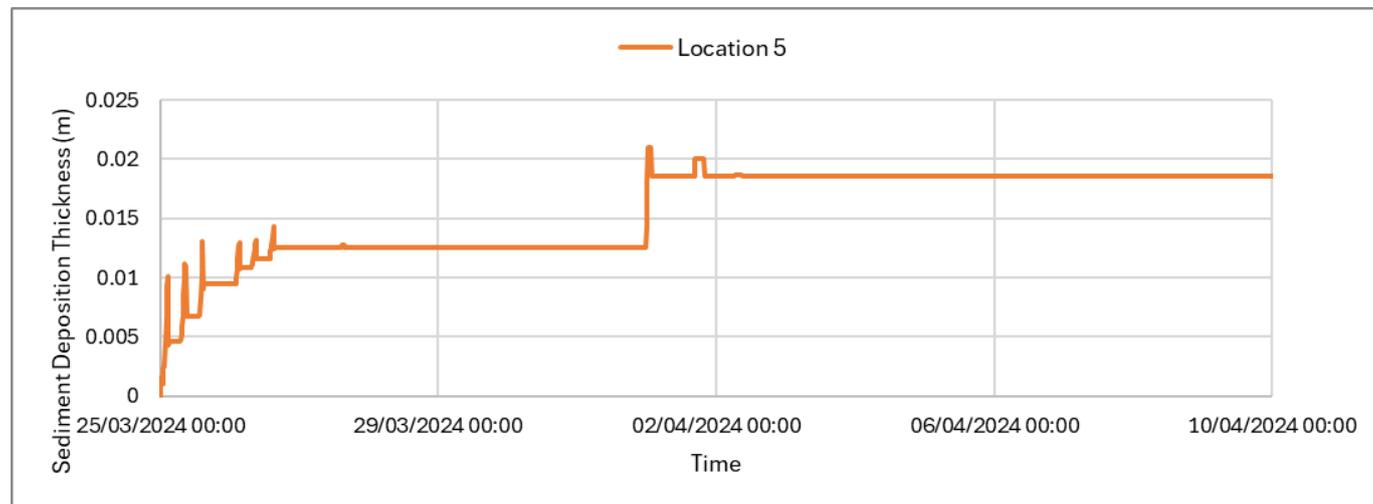
Plate 4-64 Deposition thickness timeseries at location 8 (with resuspension)
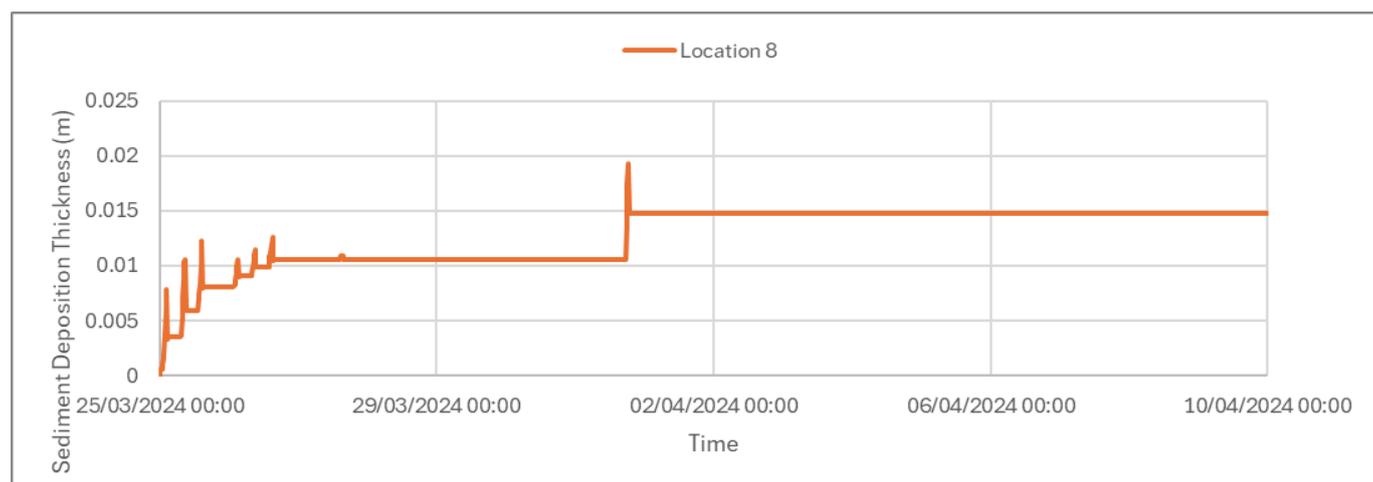
4.6.2   MULTIPLE ACTIVITIES: HORIZONTAL DIRECTIONAL DRILLING ACTIVITIES

4.6.2.1   In addition to the HDD activities considered individually in Section 4.4 and Section 4.5, sequential HDD activities (HDD drill cutting release and HDD exit pit construction) have also been quantitatively assessed to determine maximum suspended sediment concentration and sediment deposition thickness concentration arising during HDD Exit Pit construction and HDD drill cutting release.

Suspended Sediment Concentration

4.6.2.2   If multiple HDD construction activities (HDD exit pit construction and HDD drill cutting release) occur within 2 days, then there could be accumulation of suspended sediment within 1 km of the activities. Suspended sediment concentrations are expected to return to baseline conditions within 2 days of a construction activity taking place. This is based on a worst-case assumption

that the activities are aligned in the direction of the tidal current (i.e. the direction where sediment advection distances are the largest).

Sediment Deposition

4.6.2.3   There is potential impacts of sediment deposition from multiple HDD activities (drill cutting release and HDD exit pit construction) occurring in a single location or multiple locations.

4.6.2.4   In a single location, the worst-case combined sediment deposition thickness is limited by the natural re-mobilisation of sediments by tidal currents and waves. The maximum deposition thickness resulting from HDD exit pit construction or drill cutting release is 7 mm for fine sediments. These will be re-mobilised by tidal currents and waves under normal conditions so will not accumulate when the other activity occurs at the same location. The maximum sediment deposition thickness resulting from HDD exit pit construction assuming coarse sediments and HDD release of drill cuttings will be a total of 4 cm. This will be limited to the location where the HDD exit pit and release of drill cuttings overlaps.

4.6.2.5   Sediment may accumulate due to multiple HDD activities occurring in multiple locations. Sediment deposition thickness decreases with distance from the construction activity in the direction of the tidal current. Sediment deposited due to release of drill cuttings is assumed to be re-mobilised by tidal currents and waves in normal conditions so is expected to not accumulate significantly across different locations. This also applies to fine sediments released by HDD exit pit construction. For coarser sediments released by HDD exit pit construction, sediment could accumulate by up to a maximum of 3 cm per HDD exit pit within 400 m of each other if 100% of the sediment is assumed to be coarse, and the HDD exit pit locations are directly aligned in the direction of the tidal current.

5 PRESENCE OF INFRASTRUCTURE DURING THE OPERATIONAL AND MAINTENANCE PHASE MODELLING RESULTS

5.1 OVERVIEW

5.1.1.1 This section presents outputs from the modelling of hydrodynamics and waves, alongside an assessment of changes to seabed sediment transport that result from the operational impact due to presence of infrastructure.

5.2 HYDRODYNAMICS

5.2.1 WATER DEPTH

5.2.1.1 The change in maximum water depths between the baseline and post-development runs was calculated as less than ±5 mm throughout the model domain (Plate 5-1), with the largest changes being in the immediate vicinity of the turbine structures. In the majority of model elements, the difference was less than ±2 mm.

Plate 5-1 Difference in maximum water depth between post-development and baseline
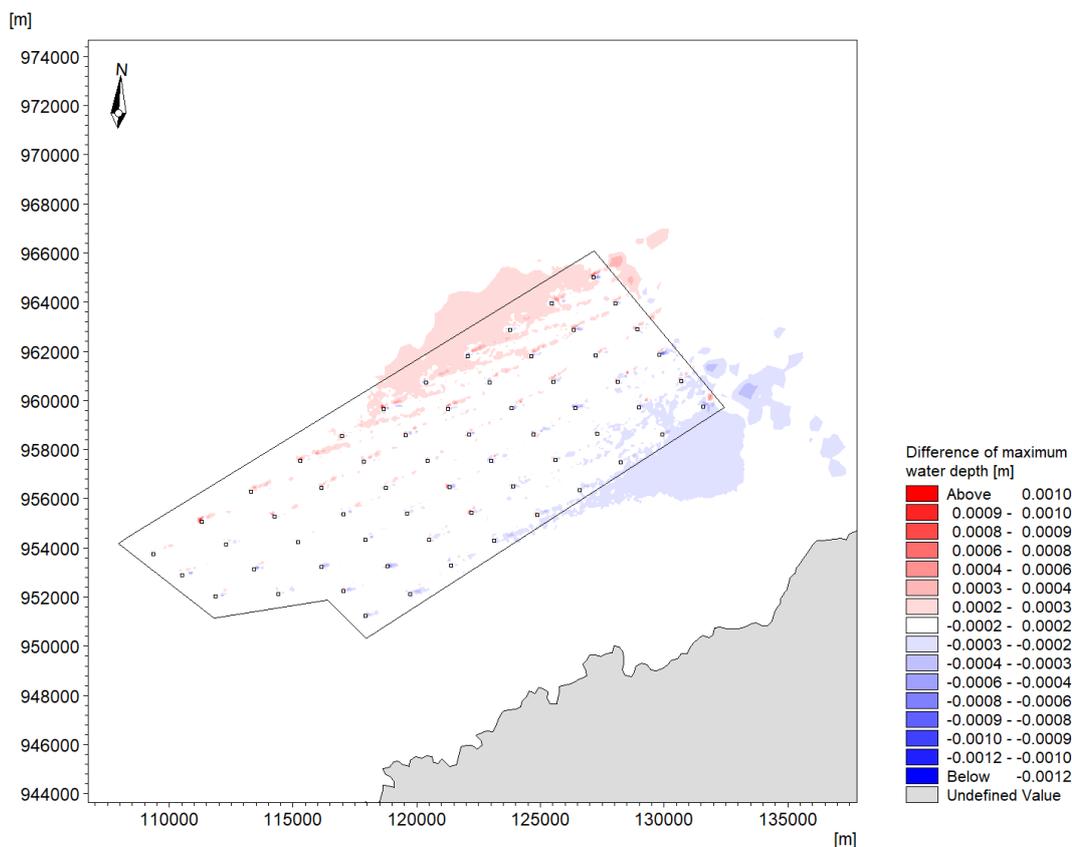
5.2.2 CURRENT SPEED

5.2.2.1 The change in current speed during peak spring and neap flood and ebb currents are shown in Plate 5-2 to Plate 5-5. Within the Turbine Area both increases (between the turbines) and decreases (in the lee of the turbines) in speed occur with differences up to ±0.05 m/s.

5.2.2.2 During neap tides the differences are smaller and constrained to the Turbine Area. Larger differences occur during spring tides and differences of up to ±0.005 m/s reach approximately 5 km away from the Turbine Area.

Plate 5-2 Difference in peak spring flood current speed between post-development and baseline

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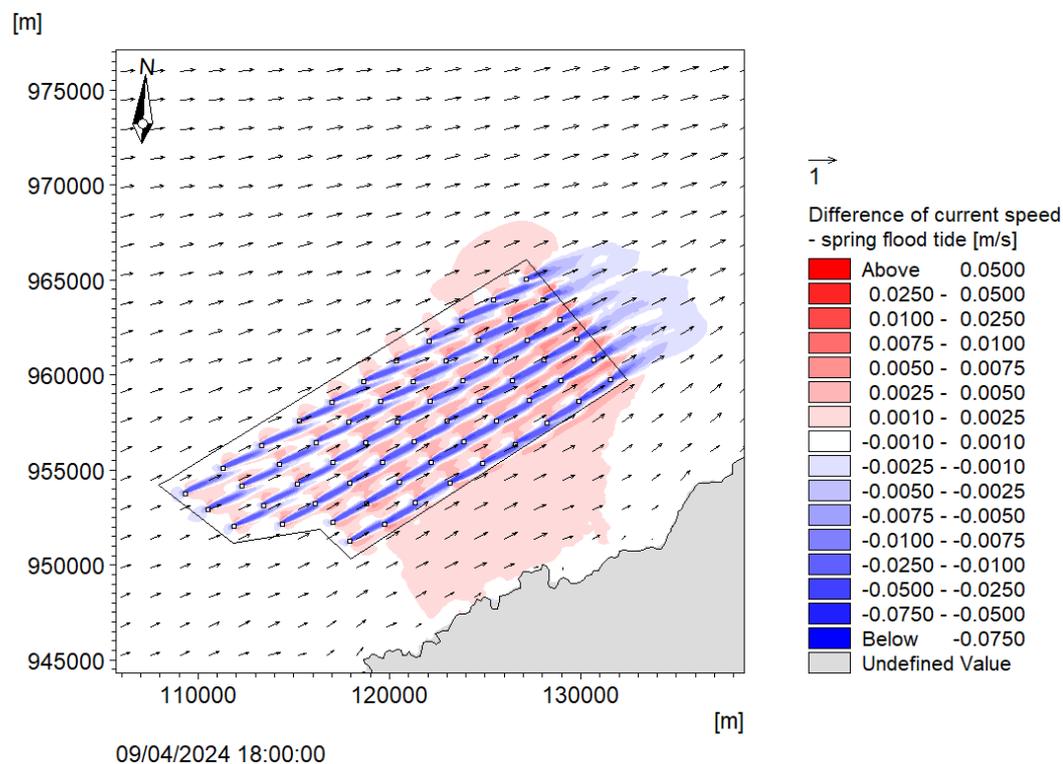
Plate 5-3 Difference in peak spring ebb current speed between post-development and baseline

09/04/2024 11:30:00
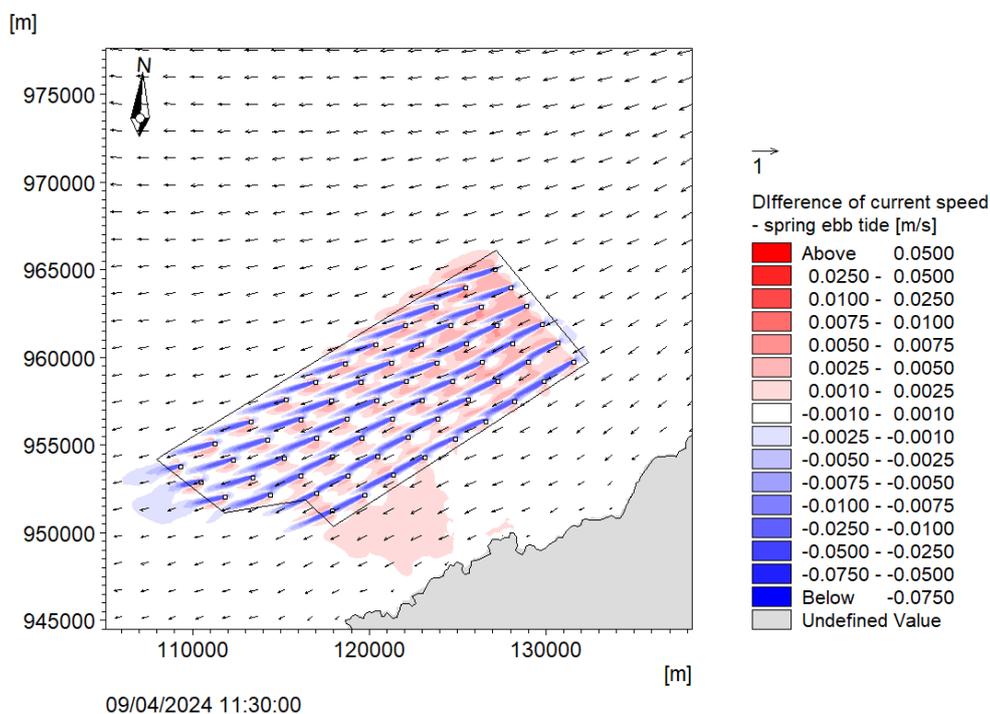
Plate 5-4 Difference in peak neap flood current speed between post-development and baseline

16/04/2024 23:30:00
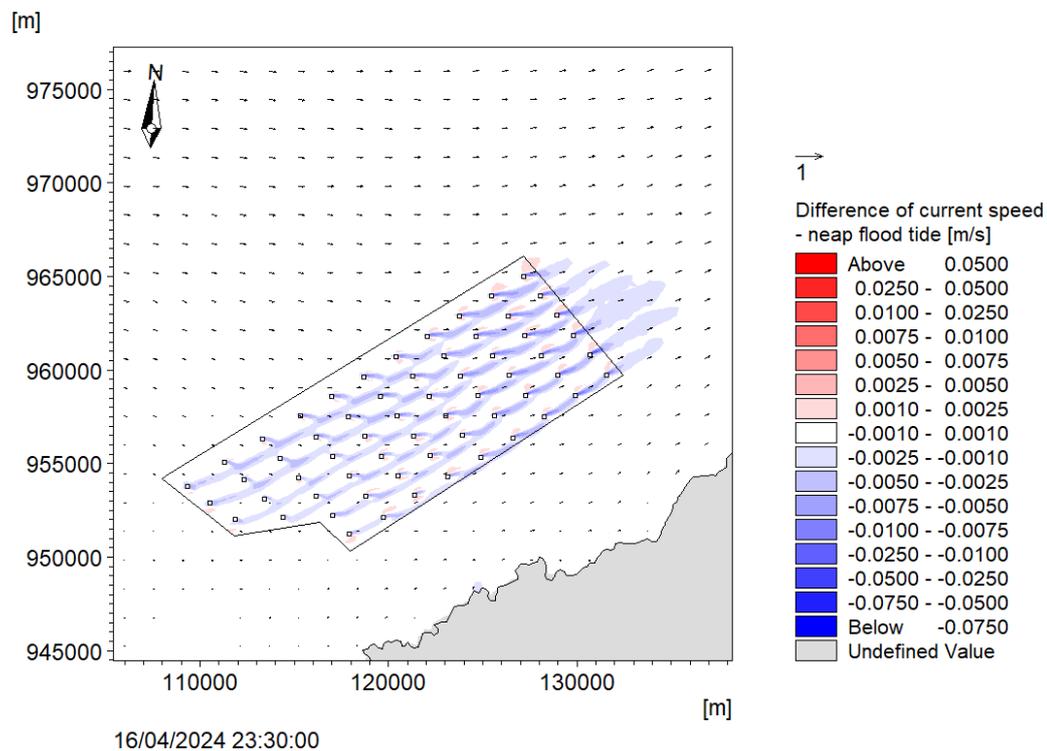
Plate 5-5 Difference in peak neap ebb current speed between post-development and baseline

16/04/2024 18:00:00
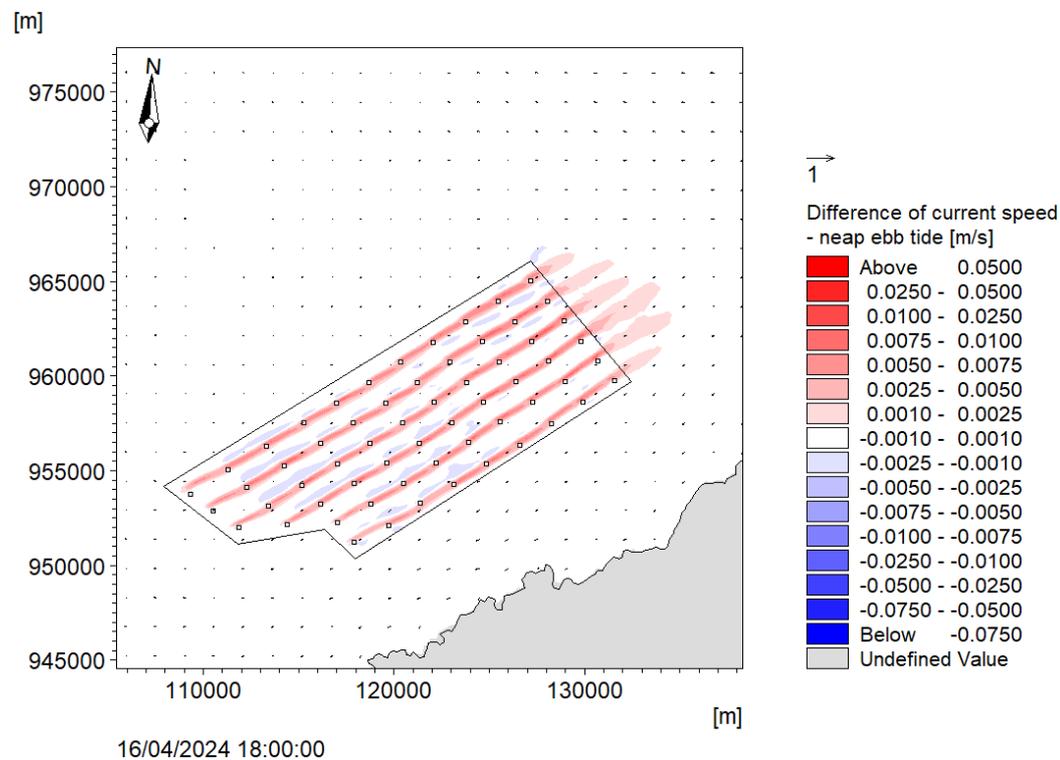
5.2.2.3   The change in maximum current speed is shown in Plate 5-6. In general, reductions in maximum current speed of up to −0.04 m/s are indicated in the lee of the turbine structures (up to 2 km away) and do not extend significantly outside of the Turbine Area. There are limited areas (up to 0.5 km^2 each) of increase (up to 0.01 m/s) between the turbines.

Plate 5-6 Difference in maximum current speed between post-development and baseline
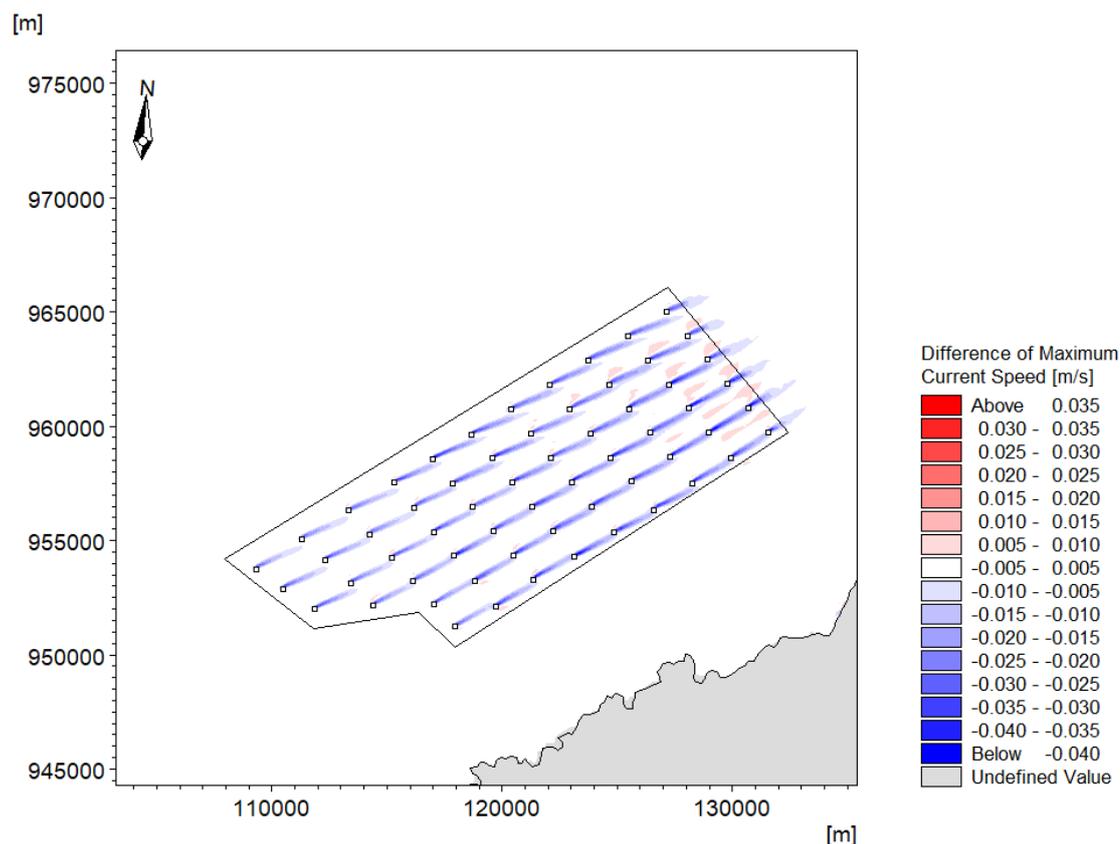
5.2.3   BED SHEAR STRESS

5.2.3.1   The change in bed shear stress during peak spring and neap flood and ebb currents are shown in Plate 5-7 to Plate 5-11. During spring tides, within the Turbine Area, increases (between the turbines) are up to 0.2 N/m^2 and decreases (in the lee of the turbines) are up to -0.05 N/m^2. These changes occur up to a distance of approximately 2.5 km from the turbines. During neap tides there are no increases indicated and minor decreases up to -0.03 N/m^2 up to a distance of approximately 1.5 km from the turbines.

Plate 5-7 Difference in peak spring flood bed shear stress between post-development and baseline

09/04/2024 18:00:00
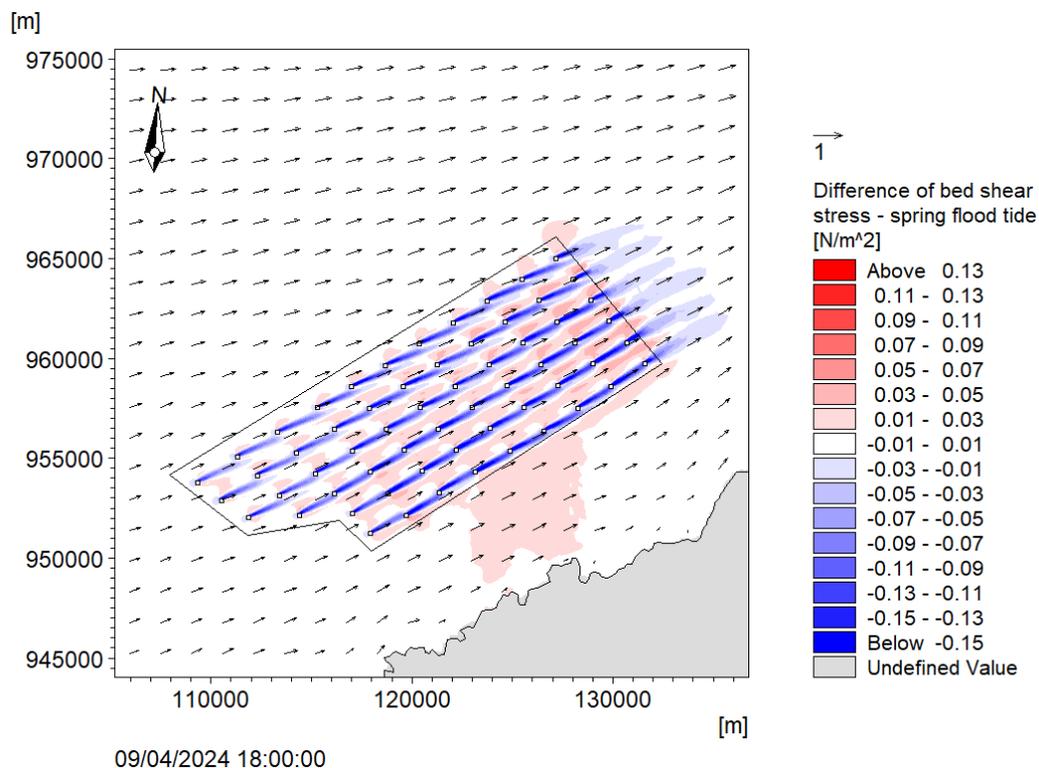
Plate 5-8 Difference in peak spring ebb bed shear stress between post-development and baseline

09/04/2024 11:30:00
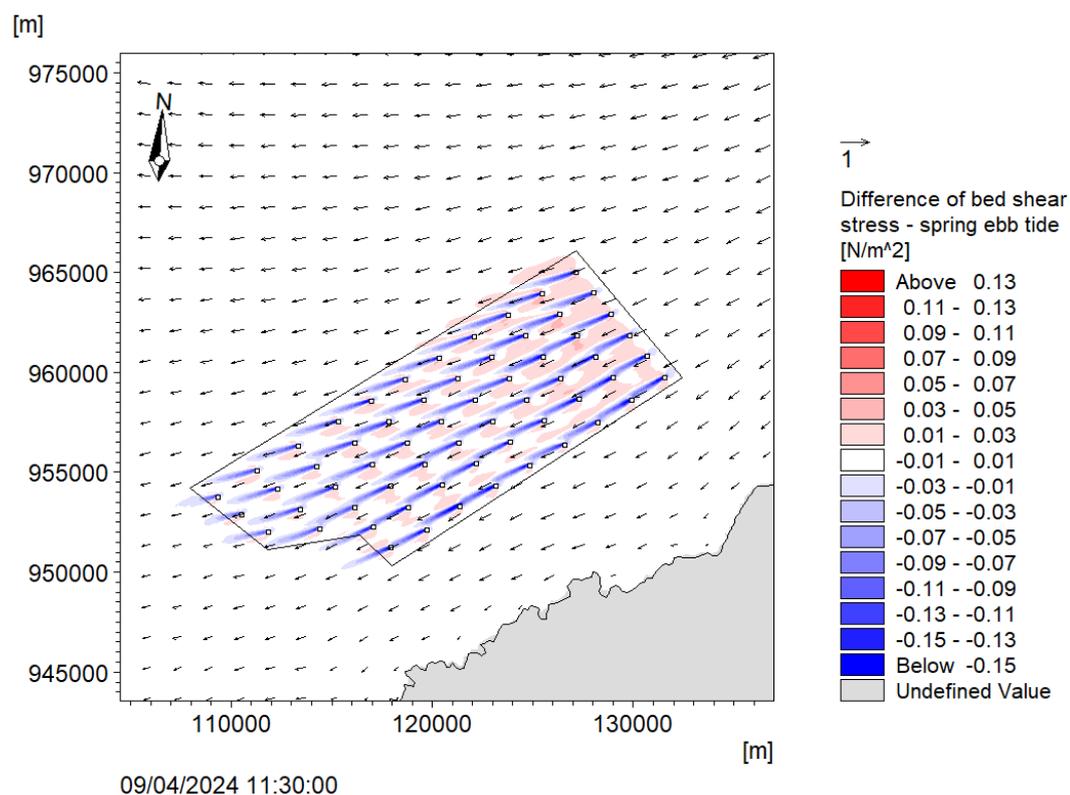
Plate 5-9 Difference in peak neap flood bed shear stress between post-development and baseline

16/04/2024 23:30:00
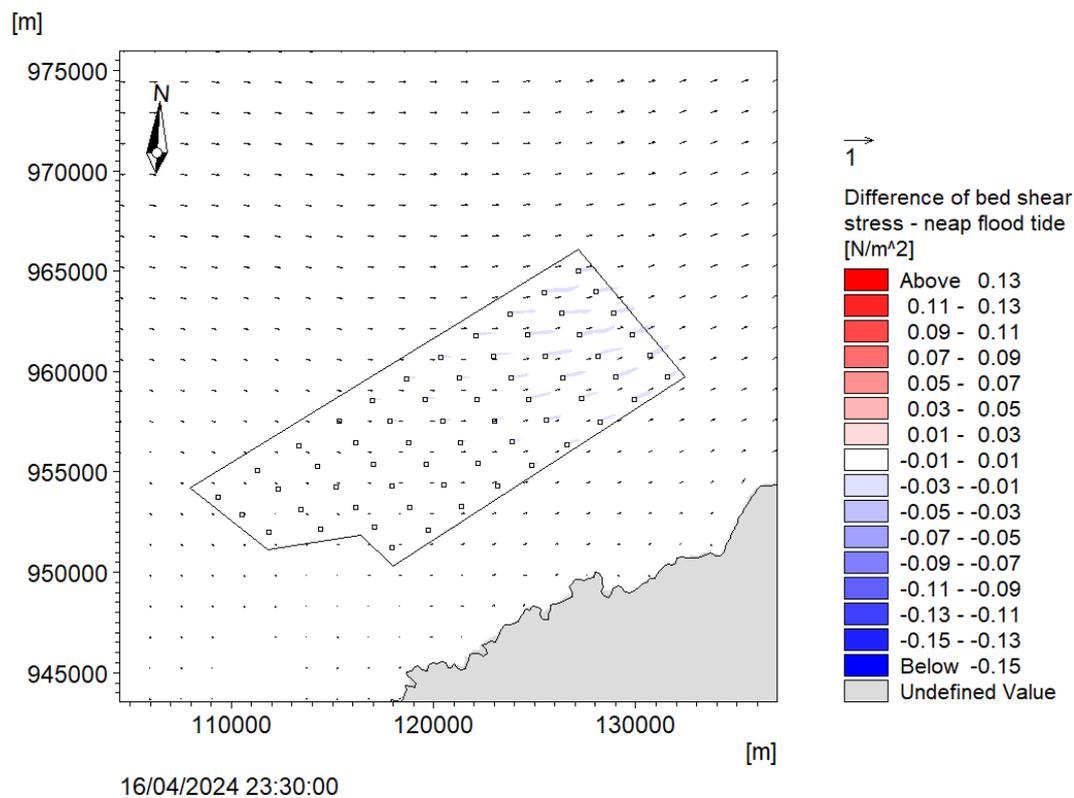
Plate 5-10 Difference in peak neap ebb bed shear stress between post-development and baseline

16/04/2024 18:00:00
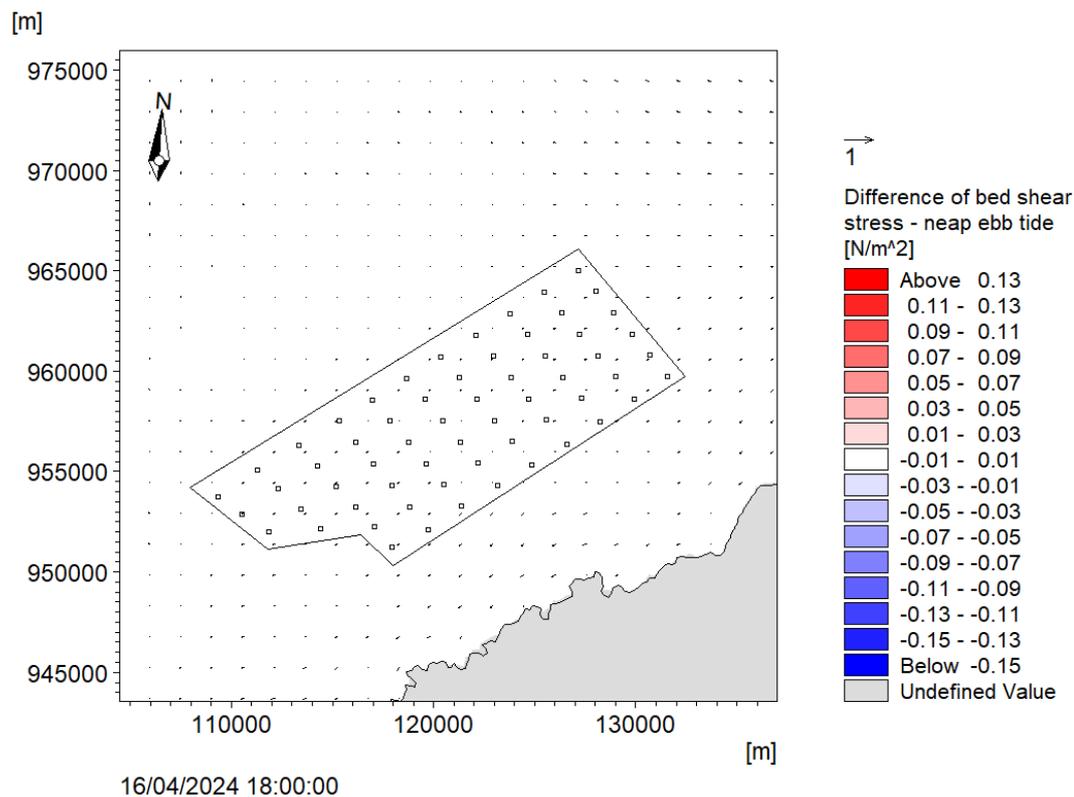
Plate 5-11 Difference in maximum bed shear stress between post-development and baseline
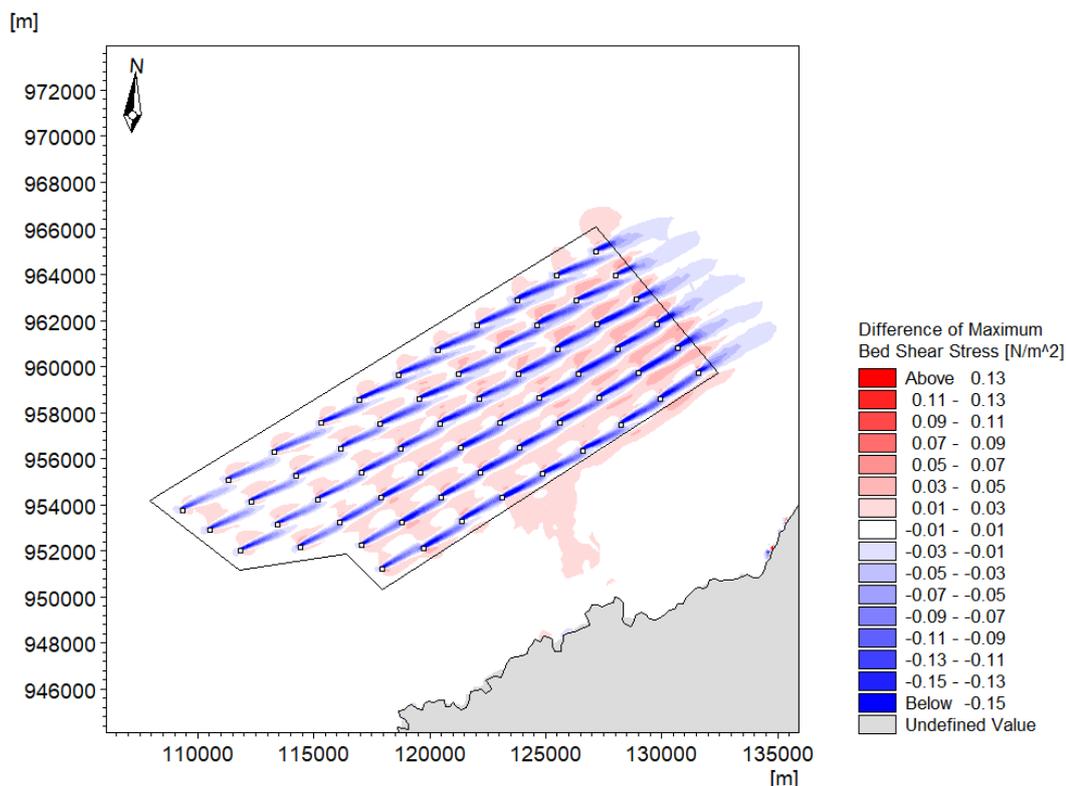
5.3   WAVES

5.3.1   MEASURED STORM CONDITIONS

5.3.1.1   The differences between post-development conditions and baseline conditions for 3 representative Hs values throughout the 35-day storm period are shown in Plate 5-12 to Plate 5-14.

5.3.1.2   Due to the presence of the Offshore Project, reductions in Significant Wave Height during measured storm conditions are indicated over large portions of the Turbine Area. This is to be expected for real storm conditions in the Offshore Project Boundary given the variability in incoming wave directions over time. Such changes would cause the wave field to impact the Turbine Area differently throughout the storm event, causing reductions throughout the model domain. These reductions are typically around 0.5 m in value, with a maximum of reduction of 0.7 m. Reductions in Hs are indicated throughout most of the modelled storm event duration, changing in spatial extent and magnitude depending on incoming wave parameters.

Plate 5-12 Hs difference between post-development and baseline conditions at representative Hs value

11/23/2023 11:00:00   Scale 1:664800
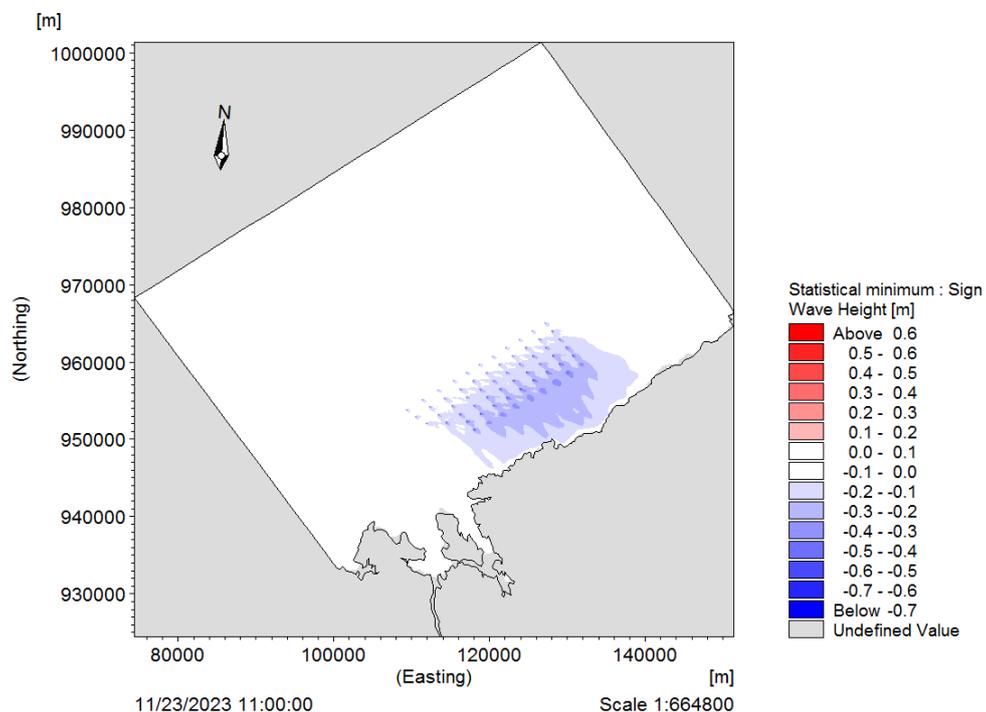
Plate 5-13 Hs difference between post-development and baseline conditions at representative Hs value

11/30/2023 00:30:00   Scale 1:658800
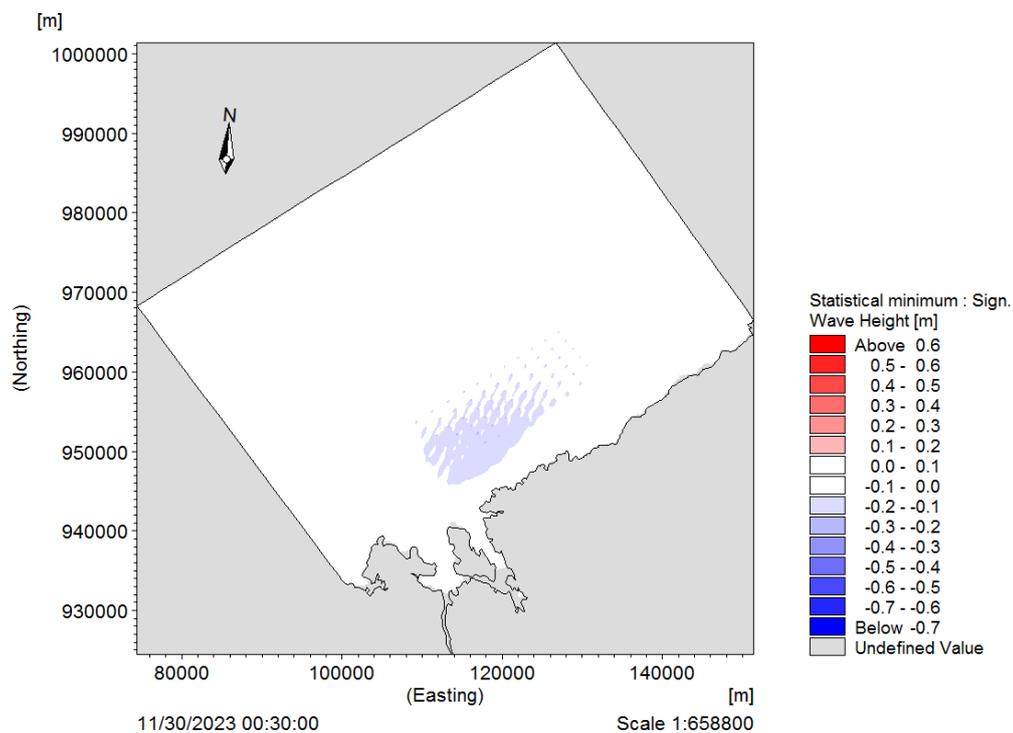
Plate 5-14 Hs difference between post-development and baseline conditions at representative Hs value

12/11/2023 16:00:00   Scale 1:658800
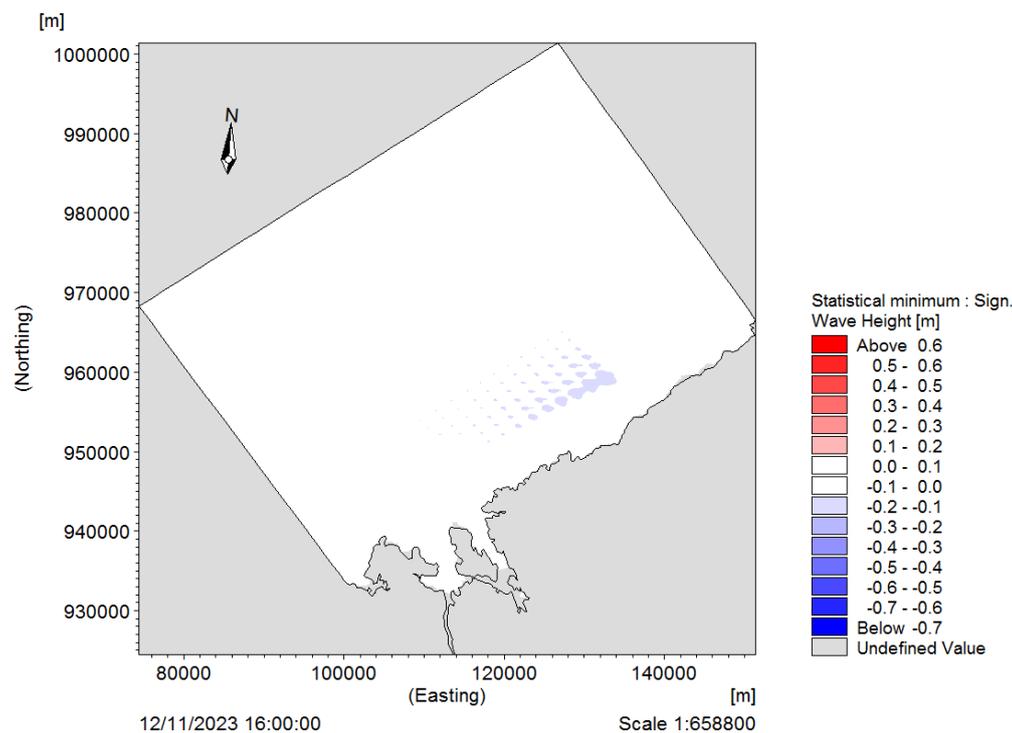
5.3.1.3   Timeseries plots have been extracted at Easting 116997.55554, Northing 960875.77693 and is included in Plate 5-15.

5.3.1.4   The vertical purple lines indicate the locations of the 3 storm Hs values previously included in Plate 5-12 through Plate 5-14. The visible red spike between the first two selected storm values indicates the point of maximum difference in Hs between the baseline and post-development conditions for this point, showing an increase of around 0.5 m in Hs.

5.3.1.5   Increases in Hs are in the form of sudden peaks, in moments where the wave field shows low wave heights and higher wave periods. These are also dependent on the local wind pattern, which rapidly evolves.

5.3.1.6   Given the overall reduction in Hs occurring for the majority of the modelled wave conditions, and the constriction of increases in Hs to instances where initial wave heights are low for the Offshore Project Boundary, the post-development scenario is considered to have the potential to increase Hs only under specific conditions, outside of storm peaks. The main change to wave conditions is a reduction in Hs, with the value of such reductions varying across the Turbine Area based on changes in the wavefield and its incoming direction. Furthermore, specific increases in Hs occur outside of the storm peak and are not able to reach values of Hs that are similar to the peak storm values.

Plate 5-15 Hs timeseries extracted at easting 116998 northing 960876
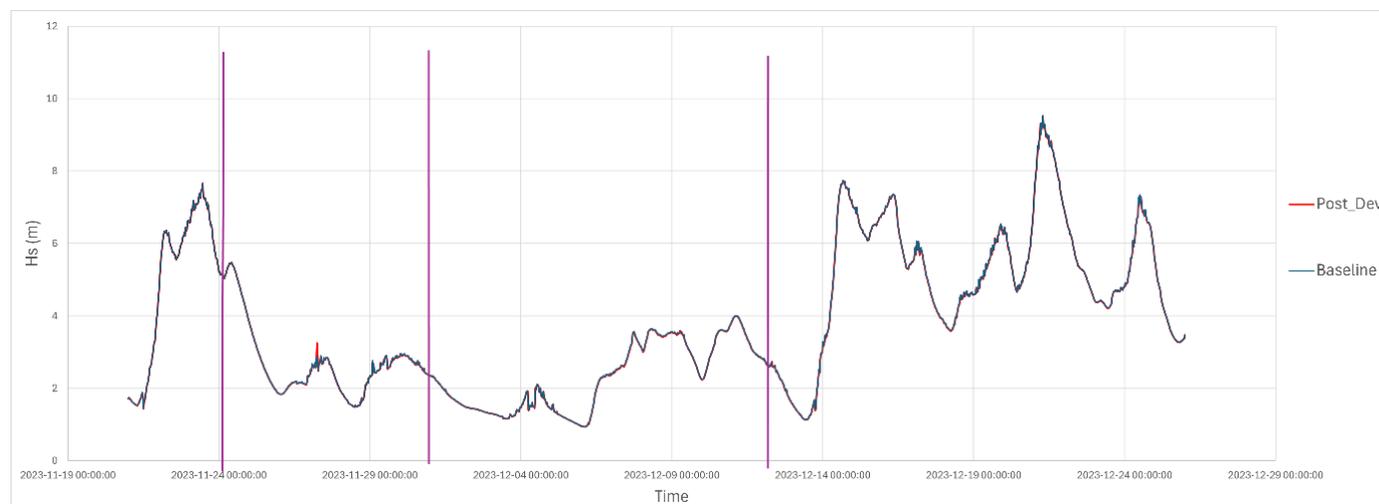
5.3.2   EXTREME EVENTS

5.3.2.1   The impact of structures on the wavefield in the Study Area is shown in Plate 5-16 through Plate 5-23. The following difference plots show the impact of the Turbine Area for 1 in 1 year and 1 in 100 years return period events for each of the 4 directions investigated in the EVA.

5.3.2.2   All difference plots indicate a reduction in significant wave height for both the 1 in 1 year and 1 in 100 year return period events with maximum values between -0.25 m and -0.4 m depending on the return period and storm direction. Due to the layout of the turbines, wave propagation is affected differently for waves incoming from different directions.

5.3.2.3   The impact from the Turbine Area in Hs reduction extends over a larger area for south-westerly (approximately 600 km^2) and westerly waves (approximately 400 km^2). Northerly and north-westerly waves have a reduced area of impact (approximately 280 km^2 and 300 km^2 respectively), also due to the limited distance between the Turbine Area and the coastline to the southeast of the Turbine Area.

Plate 5-16 South-westerly 1 in 1 year return period
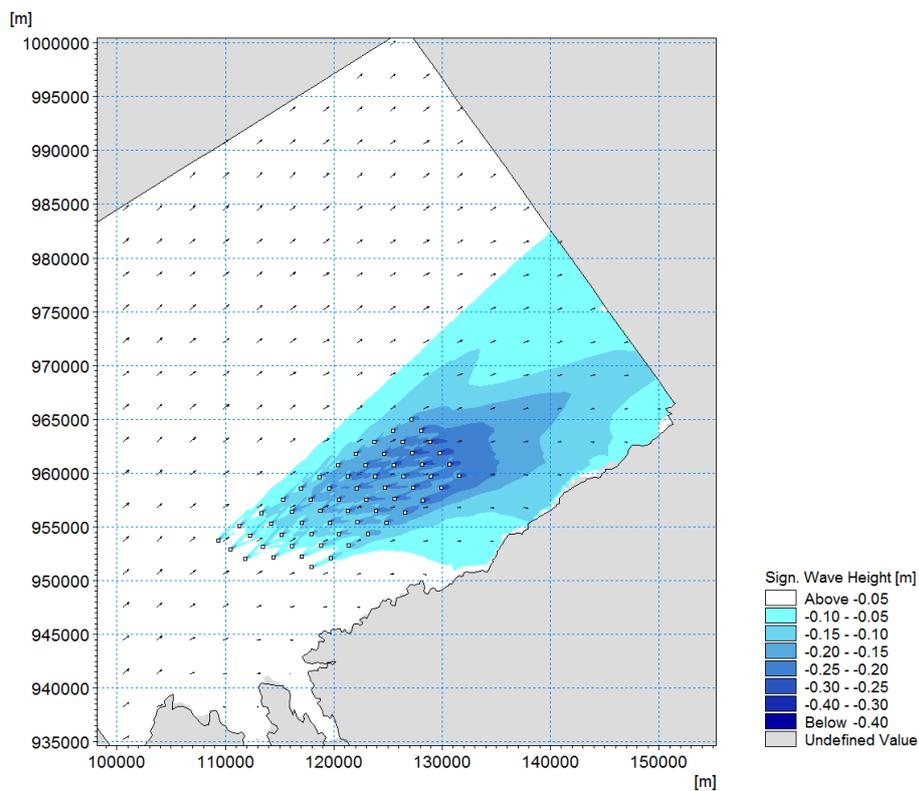
Plate 5-17 South-westerly 1 in 100 year return period
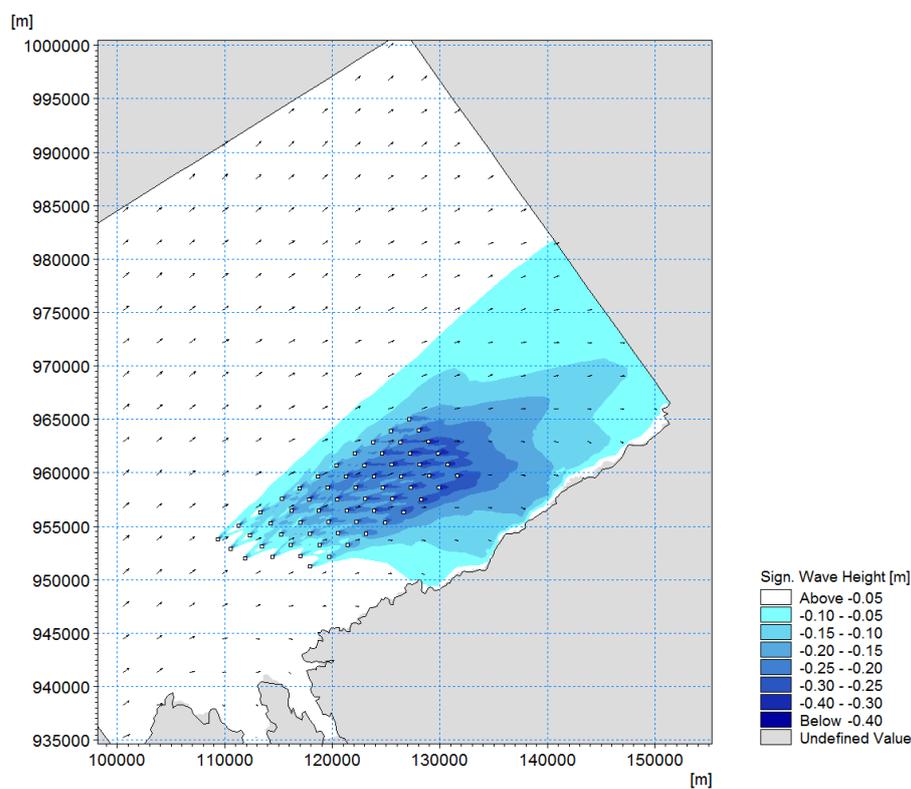
Plate 5-18 Westerly 1 in 1 year return period
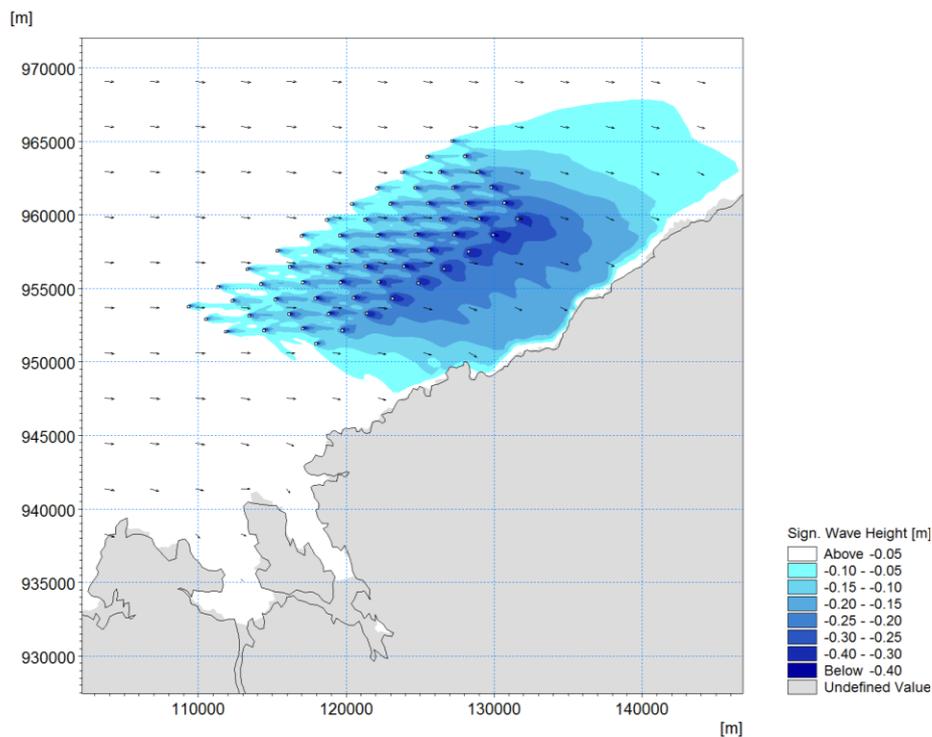
Plate 5-19 Westerly 1 in 100 year return period
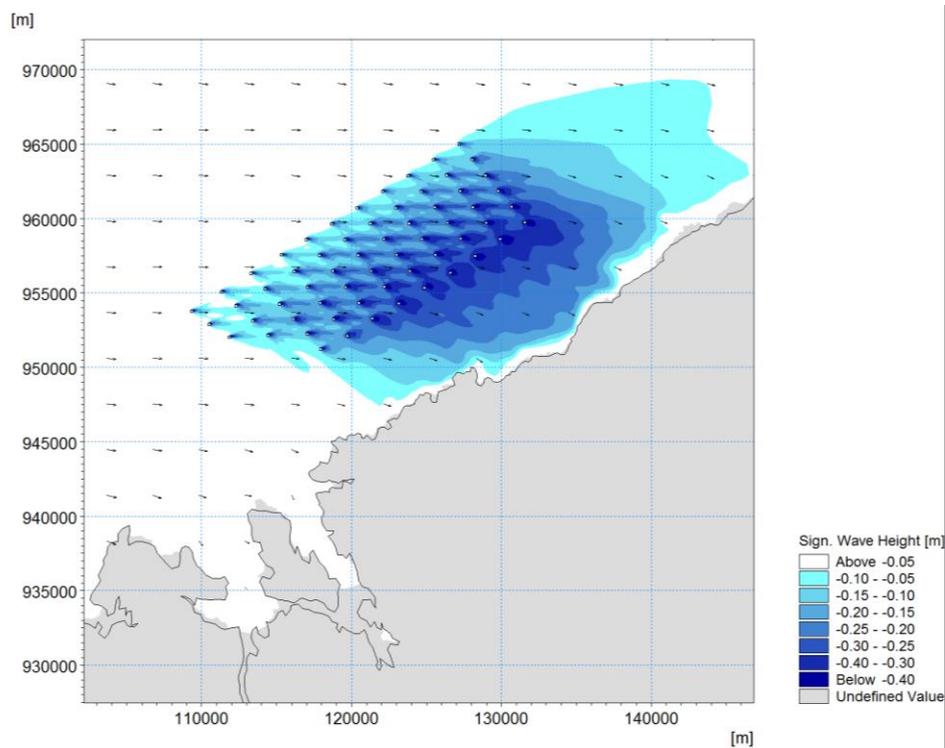
Plate 5-20 North-westerly 1 in 1 year return period
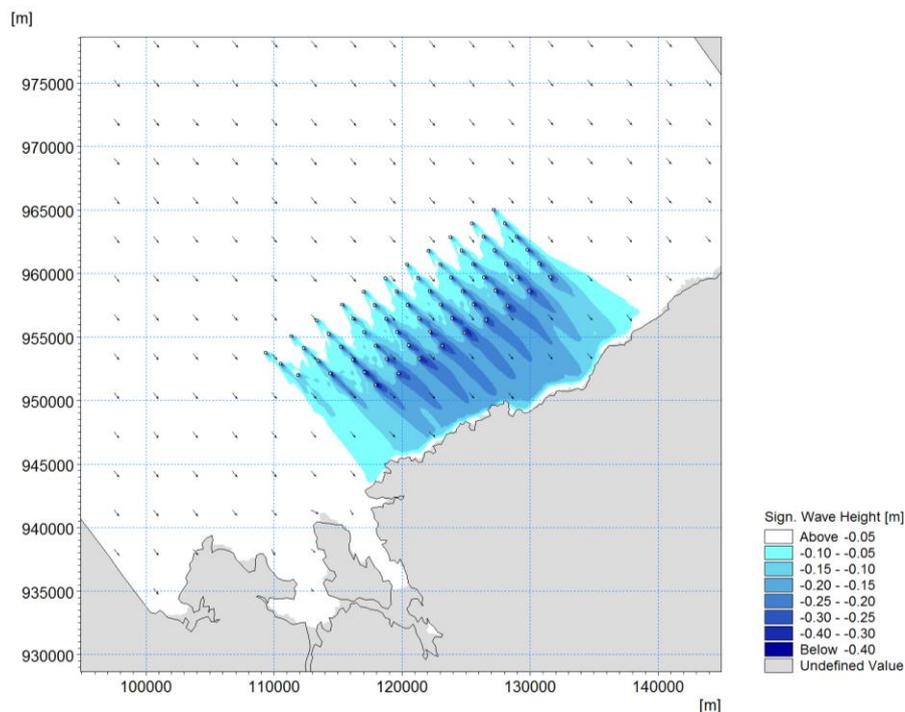
Plate 5-21 North-westerly 1 in 100 year return period
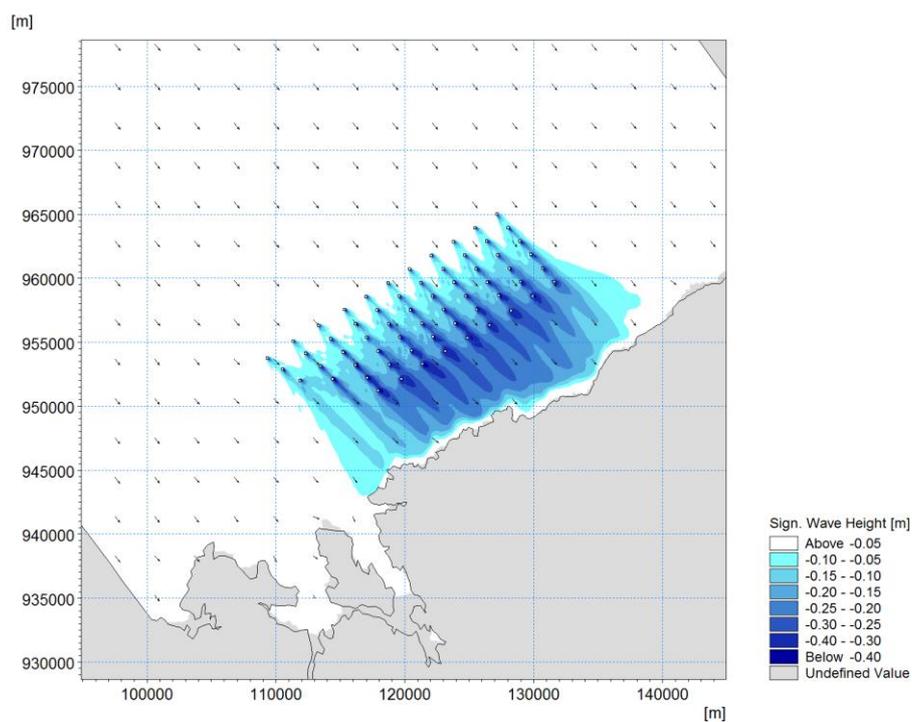
Plate 5-22 Northerly 1 in 1 year return period
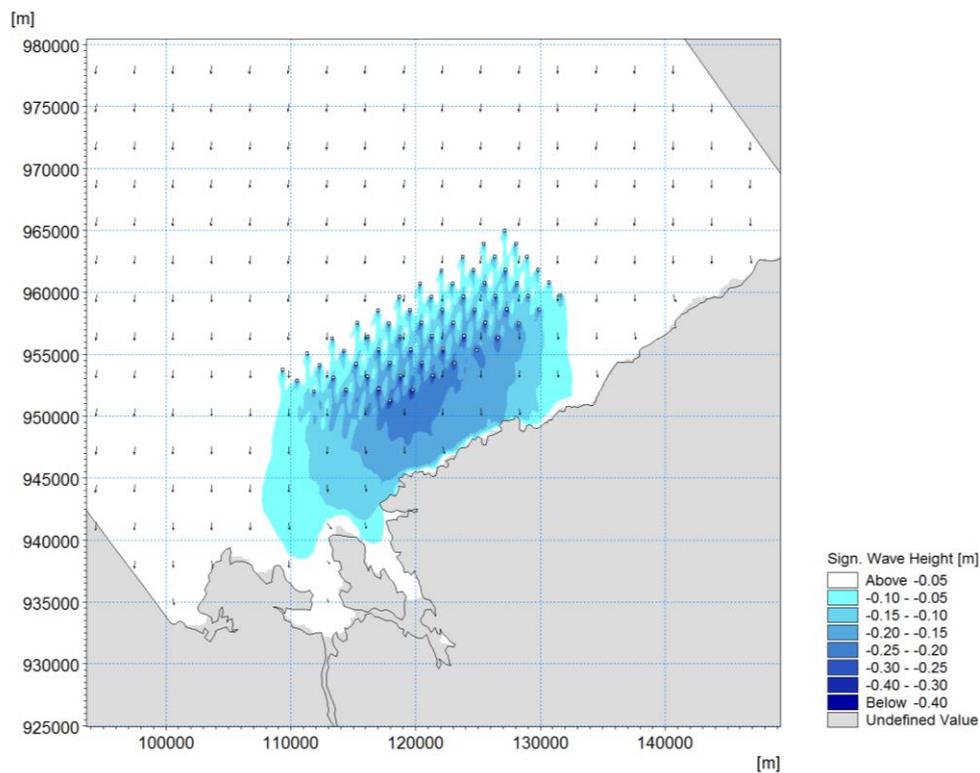
Plate 5-23 Northerly 1 in 100 year return period
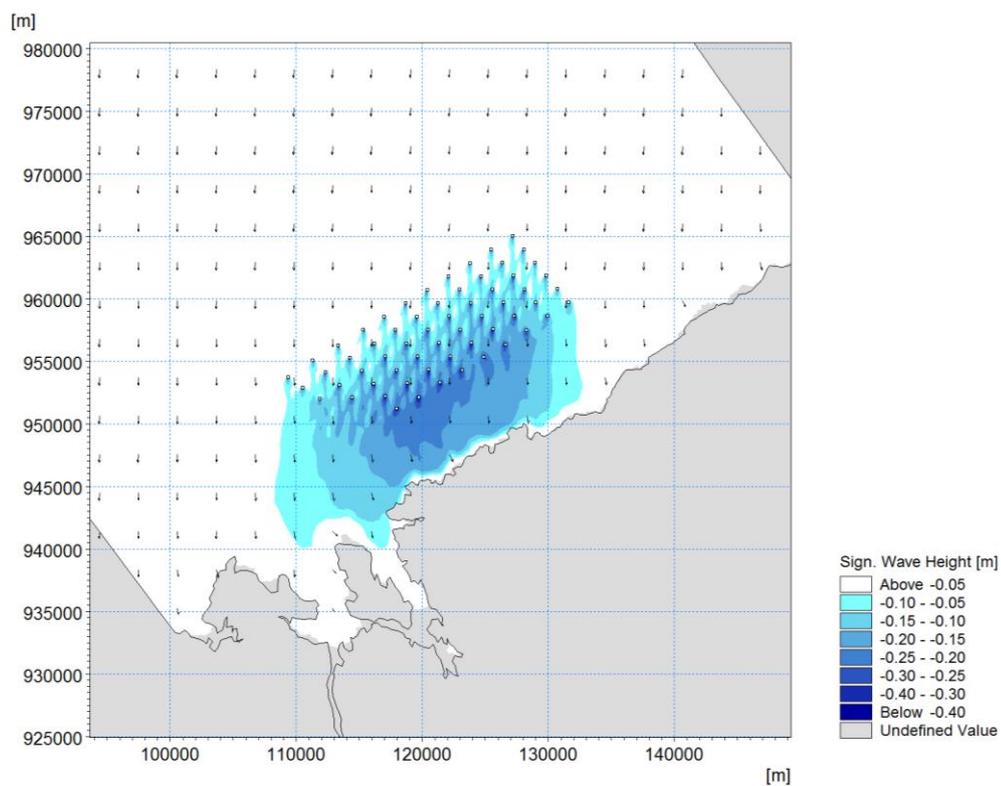
5.3.2.4 EVA outputs are included again in Table 5-1 for reference, alongside the percentage and absolute changes in post-development scenario, obtained from the maximum value within the difference plots. Maximum values are taken outside of the immediate wake impacts to better represent the magnitude of changes to the wavefield.

5.3.2.5 The most significant reductions in the Hs values occur for westerly waves and do not exceed 0.35 m. For waves incoming from the west, results indicate that the turbines act as a barrier, with waves encountering and hitting multiple rows of turbines along their path and causing a wave height reduction at the lee of the Turbine Area (reductions of 0.3 m occur over an approximate distance of approximately 2.7 km). When northwest is the main incoming wave direction, results show the waves crossing the Turbine Area in parallel to the rows of turbines present. The wave height reduction in the lee of each turbine increases as the wave passes through the Turbine Area (from 0.1 m furthest offshore to 0.35 m closest to shore. Where there are no turbines directly obstructing the waves the reduction is lower (between 0 m furthest offshore and 0.25 m closest to shore).

Table 5-1 Maximum percentage and absolute reduction in significant wave height

Direction	Significant wave height (m) for return period (years)					
	1 in 1-year Hs	Max % change	Max absolute change	1 in 100-year Hs	Max % change	Max absolute change
Southwest	6.40	4.69%	0.30	11.61	3.45%	0.40
West	8.01	4.37%	0.35	12.86	3.11%	0.40
Northwest	6.92	3.61%	0.25	11.16	2.69%	0.30
North	6.69	3.74%	0.25	10.48	2.39%	0.25

5.4 SEABED SEDIMENTS

5.4.1.1 The percentage of time that bed shear stresses (due to combined wave and current action) are greater than the threshold for sediment suspension during the spring-neap tidal cycle under O&M conditions is detailed in Table 5-2.

5.4.1.2 The only difference between the baseline conditions (Table 3-3) and operational conditions (Table 5-2) is for the silt sediment fraction in the Southwest of the Turbine Area (22% reduction from 100% to 78%). This represents 36% of the sediment in the top 2 m of the seabed (see Table 2-5) in this area which makes up 30% of the total Offshore Project Boundary. Overall, this means that during a spring-neap tidal cycle there will be 2.4% less sediment mobilisation within the Offshore Project Boundary during the O&M phase of the Offshore Project.

Table 5-2 Percentage of time sediment would be mobile under operational conditions

Location	Sediment	Time that combined wave and current bed shear stress greater than suspension threshold
Southwest of Turbine Area	Silt	78%
	Sand	66%
	Gravel	0%
Northeast of Turbine Area	Silt	69%
	Sand	66%
	Gravel	0%
Middle OCAS	Gravel	0%
HDD Exit Pit	Silt	100%

6 CONCLUSIONS

6.1 OVERVIEW

6.1.1.1 Physical processes baseline characterisation and assessment of construction and operational impacts due to the presence of infrastructure have been carried out. Baseline modelling of hydrodynamics (water depth, current speed, and bed shear stress) and wave conditions (storm event and extreme values) have been combined with seabed sediment survey data to inform the assessment.

6.1.1.2 The conclusions of this report will be used to inform any potential impacts on receptors assessed within:

- Chapter 9, Volume 2a;
- Chapter 10, Volume 2a;
- Chapter 11, Volume 2a;
- Chapter 12, Volume 2a;
- Chapter 15, Volume 2a.

6.1.1.3 The results of the hydrodynamic, spectral wave and sediment plume modelling results define and quantify the Physical Processes impacts associated with construction, O&M and decommissioning phases of the Offshore Project. These results will be interpreted by the above chapters to assess the potential impacts on key receptors. For example, both the temporal and spatial extent, and magnitude of the increased suspended sediment concentrations as a result of construction activities will be used to assess potential effects for the chapters referenced above.

6.2 BASELINE CHARACTERISATION

6.2.1.1 The baseline characterisation indicates that over a spring-neap tidal cycle, water depths within the Turbine Area range from 40-70 m, current speeds range from 0.55 m/s on a spring flood tide to 0.05 m/s on a neap ebb tide, and bed shear stresses range from 2 N/m^2 on a spring flood tide to 0.01 N/m^2 on a neap ebb tide.

6.2.1.2 Seabed sediments modelled within in the Offshore Project Boundary comprised of a mix of clays, sands, and gravels, the properties of which vary spatially and with depth. In general, the southwest Turbine Area has finer sediment than the northeast Turbine Area, and the top 2 m of the OCAS have the largest percentage of gravels.

6.2.1.3 Baseline wave conditions for the measured storm period analysed indicate a maximum Hs of 9.54 m, as well as a further storm peak of 7.7 m, and a variety of other Hs and Tp combinations throughout. The EVA used to assess extreme storm events throughout the domain determined 1 year return period Hs values between 6.4 m and 8.0 m, and 100 year return period Hs between

10.5 m and 12.9 m, depending on incoming wave direction. The highest Hs value for the 1,000-year return period found through the EVA exercise was of 15.3 m.

6.3 SEDIMENT PLUME MODELLING

6.3.1.1 Construction impacts were assessed using sediment PT. Activities included drilling of piles to install WTG foundations, cable burial, drill cutting release from HDD, and HDD exit pit construction. Spatial and timeseries plots of suspended sediment concentrations and sediment deposition thickness demonstrate the potential for the advection and deposition of sediment arising from construction activities. The modelling indicates narrow and mobile plumes due to tidal currents. Results including and excluding sediment resuspension have been presented to provide a conservative and realistic assessment of both suspended sediment concentration (worst-case including resuspension) and sediment deposition thickness (worst-case excluding sediment resuspension).

6.3.1.2 Sediment in the southwest Turbine Area (arising from drilling of piles to install WTG foundations and Array Cables to Final WTG burial) is advected over the largest extent in suspension due to the high proportion of fine sediment. Sediment which is resuspended can be advected up to 15 km over several tidal cycles; during a single tidal cycle the advection distance before deposition is constrained by the tidal ellipse, which is approximately 7 km. Sediment will continue to be advected when resuspended, although peak concentrations generally decrease with each successive resuspension event.

6.3.1.3 Plumes within the buried channel and northeast Turbine Areas as well as the OCAS are more localised (up to 3 km for turbines and less than 1 km for cables). Suspended sediment concentrations reach peak values of several hundred mg/l for very short periods of time (less than an hour) in the immediate vicinity of construction activities.

6.3.1.4 Sediment deposition thickness away from the immediate vicinity of WTG foundation and Array Cables to Final WTG construction activities is generally limited to below 0.002 cm with gravel sediments contributing most to sustained increases in depth as they are not re-mobilised by typical bed shear stresses. Peak sediment deposition thicknesses of up to 30 cm can occur in localised areas in the immediate vicinity of turbines. The extent of sediment deposition is constrained by the distance that suspended sediment is advected; locations that experience the highest suspended sediment concentrations also see the most sediment deposition.

6.3.1.5 Array Cables to Landfall burial causes the most localised increase in suspended sediment concentration and sediment deposition due to the dominant sediment fraction being gravel. The coarser sediment and higher settling velocity limits the distance advected and restricts re-suspension.

6.3.1.6   The modelling of impacts associated with, multiple activities, drilling of piles to install WTG foundations and cable burial indicates that the extent of sediment plumes are mainly constrained to the Turbine Area. Maximum suspended sediment concentrations and sediment deposition thicknesses are highest in the immediate vicinity of construction activities and reduce with distance due to dispersion.

6.3.1.7   Suspended sediment concentrations from drill cutting release from HDD reaches peak values of approximately 650 mg/l for very short periods of time (less than an hour). Sediment deposition arising from drill cutting release of HDD is generally limited to less than 7 mm away from the location of sediment release.

6.3.1.8   HDD exit pit construction was assessed using model outputs from burial of Array Cables to Landfall and drill cutting release from HDD. Maximum suspended sediment concentrations are expected to range between 350 mg/l and 1000 mg/l, returning to baseline conditions within 2 days. Maximum sediment deposition thicknesses are expected to range between 3 cm and 7 mm within 500 m of the HDD exit pit location.

6.3.1.9   Assessment of impacts, from multiple HDD activities (HDD exit pit construction and HDD drill cutting release) concluded that if multiple HDD activities occur within 2 days, then there could be accumulation of suspended sediment within 1 km of the activities. Suspended sediment concentrations are expected to return to baseline conditions within 2 days of a construction activity taking place. This is based on a worst-case assumption that the activities are aligned in the direction of the tidal current.

6.3.1.10 Sediment deposition from multiple HDD activities in a single location, is limited by natural re-mobilisation of sediments by hydrodynamic forces. The maximum deposition thickness is 7 mm for fine sediments, however the fine sediment will be re-mobilised by tidal currents and waves under normal conditions preventing accumulation even where activities overlap. For coarse sediments, combined deposition from multiple HDD activities could reach up to 4 cm.

6.3.1.11 Sediment may accumulate due to multiple HDD activities occurring in multiple locations within the Landfall Exit Pit Area. Sediment deposited due to release of drill cuttings is assumed to be re-mobilised by tidal currents and waves in normal conditions and therefore significant accumulation across different locations is not anticipated. This also applies to fine sediments released by HDD exit pit construction. For coarser sediments released by HDD exit pit construction, sediment could accumulate by up to a maximum of 3 cm per HDD exit pit within 400 m of each other if 100% of the sediment is assumed to be coarse, and the HDD exit pit locations are directly aligned in the direction of the tidal current.

6.4 OPERATIONAL IMPACTS DUE TO PRESENCE OF INFRASTRUCTURE

6.4.1.1 The hydrodynamic operational impact modelling (including the influence of turbine structures) indicates broadly localised changes to water depth, current speed, and bed shear stress. Changes in water depth resulting from the Offshore Project are indistinguishable from natural variation. Current speeds increase between the turbines and decrease in the lee of the turbines with changes of up to ±0.05 m/s. Changes in bed shear stress follow a similar spatial trend with increases between turbines of up to 0.2 N/m^2 and decreases in the lee of the turbines of up to -0.05 N/m^2.

6.4.1.2 Operational impact modelling of the array indicates reductions in Significant Wave Height for both the measured storm events and the extreme storm events analysed. Measured storm events indicated a widespread reduction over time, changing in extent and value depending on incoming wave direction and incoming Hs. Increases in Hs were also present, but these were sudden instances, not showing continuous patterns throughout the run, and occurring at different points within the domain depending on incoming wave direction, Hs, Tp, and wind combinations. These minor increases also occur in moments of relative calm wave conditions and not in storm events, indicating these increases in Hs would not have the ability to worsen impacts of storm events in the Offshore Project Boundary.

6.4.1.3 Extreme event modelling only indicates reductions in Hs throughout the model domain. These increase in magnitude with increasing return periods and differ depending on incoming wave directions due to the changes in wave progression patterns.

7 GLOSSARY OF TERMS AND ABBREVIATIONS

7.1.1.1   A list of key terms and acronyms used in this Appendix are provided in Table 7-1 and Table 7-2.

Table 7-1 Acronyms and abbreviations

Term	Definition
~	Approximately
>	Greater-than
<	Less-than
%	Per cent
±	Plus-minus
cm	Centimetres
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EVA	Extreme Value Analysis
HD	Hydrodynamic
HDD	Horizontal Directional Drilling
Hr	Hour
Hs	Significant Wave Height
MHWS	Mean High Water Springs
MIKE	Water modelling software produced by Danish Hydraulic Institute (DHI)
Kg/m^3	Kilogram per cubic metre
Kg/s	Kilogram per second
km	Kilometres
km^2	Square Kilometre
m	Metres
m^2	Metres squared
m^3	Metres cubed
m/hr	Metres per hour
mg/l	Milligrams per litre
mm	Millimetres
m/s	Metres per second
N/m^2	Newton per square metre
O&M	Operational and Maintenance
OCAS	Offshore Cable Area of Search
OSP	Offshore Substation Platform
OWF	Offshore Wind Farm
PPCC	Probability Plot Correlation Coefficient
PT	Particle Tracking
SW	Spectral Wave
Tp	Wave period
WTG	Wind Turbine Generator

Table 7-2 Glossary

Term	Meaning
the Applicant	Spiorad na Mara Limited (the Project owner).
Array Area	The offshore area within which the offshore wind turbine generators (WTGs), associated foundations, Offshore Cables, and Offshore Substation Platform (OSP) (if required), will be located. This area encompasses the Turbine Area that will contain all above water surface infrastructure (WTGs/OSP) and an additional area within which further below water infrastructure (foundations and cables) may also be located.
Array Cables	The offshore electrical and communication cables that connect infrastructure located within the Array Area, for: • Scenario 1: Array Cables will used to connect Wind Turbine Generators (WTGs) to each other, and to connect WTGs to the OSP; • Scenario 2: Array Cables will used to connect WTGs to each other.
Array Cables to Landfall	The offshore electrical and communication cables located in the Array Area and Offshore Cables Area of Search (OCAS) that connect the wind turbine generators (WTGs) directly to Landfall for Scenario 2.
Baseline	Existing conditions as represented by the latest available data, whether from literature or survey and used as a benchmark for making comparisons to assess the impact of a development or project.
Bed shear stress	Stress exerted by water on the seabed surface.
Buried Channel	A buried channel refers to an ancient river or streambed that has been covered by sediment over time and now lies beneath the seabed. These channels are significant in geophysical studies because they can indicate past geological events, composition of seabed strata and influence seabed stability.
d_{50}	Median sediment particle size
Depth-averaged current	The average velocity, over a vertical profile, in a given location.
Ebb tide	Tide flowing to the southwest.
Effect	Term used to express the consequence of an impact. The significance of an effect is determined by correlating the magnitude of the impact with the importance, or sensitivity, of the receptor or resource in accordance with defined significance criteria.
Environmental Impact Assessment Report (EIAR)	The Environmental Impact Assessment Report (EIAR) prepared to assess the likely significant effects of the Offshore Project on the environment.
Extreme value analysis	Statistical technique used to predict the likelihood of extreme values based on a data set.
Flood tide	Tide flowing to the northeast.
Hindcast wave data	Predictions of surface waves during a past event.
Horizontal Directional Drill (HDD)	A trenchless crossing engineering technique using a drill steered underground without the requirement for open trenches. This method is able to carry out the underground installation of pipes and cables with minimal surface disruption.

Term	Meaning
Horizontal Directional Drill (HDD) Exit Pit	Represents one exit pit that will be located within the Landfall Exit Pit Area.
Hydrodynamic	The movement and forces exerted by water.
Hydrological effects	Impacts relating to water and its interaction with land/ sediment.
Impact	Change that is caused by an action; for example, foundation installation (action) during construction which results in habitat loss (impact).
Landfall	This consists of works from offshore Horizontal Directional Drill (HDD) exit pits (located below MLWS) to onshore at the Transition Joint Bays (TJB) (located above MHWS). The infrastructure and installation methods associated with the Landfall involves both onshore and offshore components.
Landfall Exit Pit Area	The offshore area in which all HDD Exit Pits will be located within.
Mass flux	Rate of release of sediment (mass per unit time).
Metocean conditions	Changes to the seabed (deepening or raising) leading to changes in tidal current flows and/ or wave conditions (height/ direction).
Metocean data	Meteorological and oceanographic data including wind, currents, and waves.
Offshore Cables	Electrical and communication cables located within the Offshore Cable Area of Search and Array Area. The Offshore Cables consist of Array Cables, Array Cables to Landfall, and Export Cables.
Offshore Cable Area of Search (OCAS)	The area within which the offshore electrical and communication cables between the Array Area and Landfall up to Mean High Water Springs (MHWS) will be located.
Offshore Project	The offshore components of the Spiorad na Mara offshore wind farm (the Project) located seaward of Mean High Water Springs (MHWS).
Offshore Project Boundary	The 'red line boundary' encompassing the Offshore Project.
Offshore Substation Platform (OSP)	The optional offshore substation located within the Turbine Area. Includes the platform and associated components which allows the voltage to be increased to meet onward transmission requirements.
Physical processes	Processes such as metocean conditions, seabed geology/morphology, sediment transport, and water quality which could be impacted by the Offshore Project.
Post-development	Conditions after the Offshore Project has been constructed.
Project	The Spiorad na Mara offshore wind farm development. This term describes the whole development, including all offshore and onshore components.
Project Design Envelope	A description of the range of possible components that make up the Project design options under consideration when the exact engineering parameters are not yet known.
Scour protection	The protection of sediment against localised erosion e.g. by placing rock.
Sediment deposition thickness	Height of sediment deposited on the seabed averaged over the area of a model element.

Term	Meaning
Sediment disturbance	Disturbing/displacing sediment (contaminated or uncontaminated).
Sediment fractions	Subsets of sediment in a location with different properties (e.g. grain size).
Sediment plume	A mobile area of increased suspended sediment concentration, usually generated by activities such as construction or dredging.
Sediment resuspension	The suspension of sediment after it has settled to the seabed (not due to initial suspension from construction activities).
Settling velocity	The speed at which sediment particles fall through the water column.
Significant wave height	Average height of the largest 1/3 of waves.
Suspended sediment concentration	Concentration of sediment particles entrained within the water column.
Turbine Area	A reduced area within the Array Area where above water surface infrastructure would be located i.e. Wind Turbine Generators (WTG) or Offshore Substation Platform (OSP) (if required). This area has been developed and refined through stakeholder engagement and environmental assessment.
Wind Turbine Generator (WTG)	The wind turbines that generate electricity consisting of tubular towers and blades attached to a nacelle housing mechanical and electrical generating equipment.

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