Hydrodynamic and Sediment Dispersion Modelling – Results Interpretation

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NORTH FALLS
Offshore Wind Farm

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Glossary of Acronyms

DCO	Development Consent Order
DHI	Danish Hydraulic Institute
DTM	Digital Terrain Model
DWR	Deep Water Route
EIA	Environmental Impact Assessment
ES	Environmental Statement
HD	Hydrodynamic
Hs	Significant Wave Height
KKE	Kentish Knock East
LAT	Lowest Astronomical Tide
MarLIN	Marine Biological Association
MCZ	Marine Conservation Zone
MFE	Mass Flow Excavation System
MLS	Margate and Long Sands
MR	Megaripples
MHWS	Mean High Water Springs
MMO	Marine Management Organisation
MT	Mud transport
NE	Natural England
NFOW	North Falls Offshore Wind Farm Ltd
OCP	Offshore converter platform
ODN	Ordnance Datum Newlyn
OSP	Offshore substation platform
OWF	Offshore Wind Farm
RHDHV	Royal HaskoningDHV
RWE	RWE Renewables UK Swindon Limited
SAC	Special Area of Conservation
SSC	Suspended Sediment Concentration
SSER	SSE Renewables Offshore Windfarm Holdings Limited
SHD	Suction Hopper Dredger
SW	Sandwaves
Tp	Peak Wave Period
WTG	Wind turbine generator

Glossary of Terminology

Array area	The offshore wind farm area, within which the wind turbine generators, array cables, offshore substation platform(s) and/or offshore converter platform will be located.
Array cables	Cables which link the wind turbine generators with each other, the offshore substation platform(s) and/or the offshore converter platform.
Astronomical tide	The predicted tide levels and character that would result from the gravitational effects of the earth, sun and moon without any atmospheric influences
Bedforms	Features on the seabed (e.g. Sandwaves, ripples) resulting from the movement of sediment over it
Current	Flow of water generated by a variety of forcing mechanisms (e.g. waves, tides, wind)
Habitat	The environment of an organism and the place where it is usually found
Hydrodynamic	The process and science associated with the flow and motion in water produced by applied forces
Landfall	The location where the offshore cables come ashore.
Nearshore	The zone which extends from the swash zone to the position marking the start of the offshore zone
Numerical modelling	Refers to the analysis of coastal processes using computational models
Offshore	Area seaward of nearshore in which the transport of sediment is not caused by wave activity
Offshore cable corridor	The corridor of seabed from the array area to the landfall within which the offshore export cables will be located.
Offshore convertor platform	Should an offshore connection to an HVDC interconnector cable be selected, an offshore converter platform would be required. This is a fixed structure located within the array area, containing HVAC and HVDC electrical equipment to aggregate the power from the wind turbine generators, increase the voltage to a more suitable level for export and convert the HVAC power generated by the wind turbine generators into HVDC power for export to shore via a third party HVDC interconnector cable.
Offshore export cables	The cables which bring electricity from the offshore substation platform(s) to the landfall, as well as auxiliary cables.
Offshore substation platform(s)	Fixed structure(s) located within the array area, containing HVAC electrical equipment to aggregate the power from the wind turbine generators and increase the voltage to a more suitable level for export to shore via offshore export cables.
Sand	Sediment particles, mainly of quartz with a diameter of between 0.063mm and 2mm. Sand is generally classified as fine, medium or coarse
Sandwave	Bedforms with wavelengths of 10 to 100m, with amplitudes of 1 to 10m
Sediment	Particulate matter derived from rock, minerals or bioclastic matter
Sediment transport	The movement of a mass of sediment by the forces of currents and waves
Suspended sediment	The sediment moving in suspension in a fluid kept up by the upward components of the turbulent currents or by the colloidal suspension
The Applicant	North Falls Offshore Wind Farm Limited (NFOW)
The Project or 'North Falls'	North Falls Offshore Wind Farm, including all onshore and offshore infrastructure.
Tidal current	The alternating horizontal movement of water associated with the rise and fall of the tide
Tide	The periodic rise and fall of the water that results from the gravitational attraction of the moon and sun acting upon the rotating earth

1 Introduction

1.1 Purpose of this Report

1. This document has been prepared for the North Falls Offshore Windfarm (the Project) and provides an interpretation of the results of hydrodynamic modelling of operation of the Project and sediment dispersion modelling of installation activities along the export cable corridor and in the array area (Supporting Information on Offshore Additional Mitigation, **Document Reference 9.54**).

2. The document provides a summary of the results of the modelling and updates the assessment for Marine Geology, Oceanography and Physical Processes where applicable.

1.2 Hydrodynamic Modelling

3. Hydrodynamic modelling has been completed without the Project in place and with the Project in place using a layout comprising 57 of the smallest turbines and two platforms, and indicative export cable protection along sections of the export cable (Figure 1.1). The smaller turbine layout option is the worst-case scenario. The layout comprising the largest turbines and two platforms comprises only 34 turbines which are wider spaced. The results of the modelling with and without the Project are compared and changes to the tidal current speeds and bed shear stresses (sediment transport potential) assessed. The focus of the interpretation is the results of changes to tidal current speeds and bed shear stresses at peak flood and peak ebb of spring tides as these are the worst case with respect to magnitude.

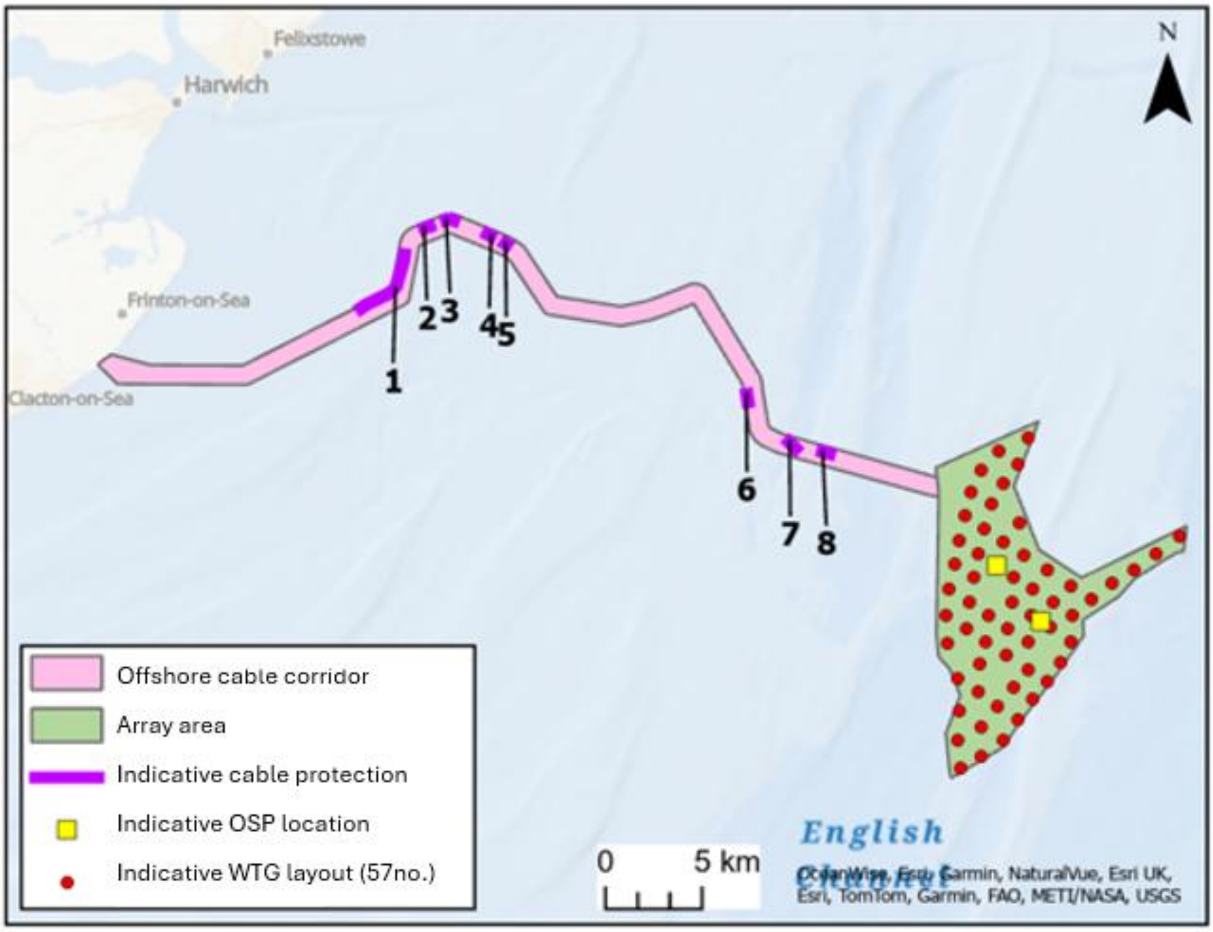

Figure 1.1 Layout of the Project that has been modelled for changes to tidal current speeds and bed shear stresses

1.3 Sediment Dispersion Modelling

4. There are twelve proposed construction activities that are likely to cause suspended sediment release into the water column (Table 1.1). Each activity has been simulated separately.

Table 1.1 Sediment dispersion model simulations (Document Reference 9.54)

ID	LOCATION	ACTIVITY
1	Export Cable Corridor	Levelling of sand waves and megaripples using mass flow excavation (MFE) as a worst case scenario, Sections 6.5 and 7.2 of the Modelling Report
2	Export Cable Corridor	Seabed trenching, Sections 6.6 and 7.3 of the Modelling Report
3	The Sunk Deep Water Route (DWR) part of Export Cable Corridor	Dredging to additional depths as described in Sections 6.7 and 7.4 of the Modelling Report.
4	The Trinity DWR part of Export Cable Corridor	Dredging to additional depths as described in Section 6.8 and 7.5 of the Modelling Report.

ID	LOCATION	ACTIVITY
5	Structure Installation in Array Area	Drilling for 57 of the smallest turbines and platform, Section 6.9 and 7.6 of the Modelling Report.
6	Structure Installation in Array Area	Drilling for 34 of the largest turbines and platform, Sections 6.10 and 7.7 of the Modelling Report.
7	Structure Installation in Array Area	Seabed preparation for 57 of the smallest turbines and platform, Sections 6.11 and 7.8 of the Modelling Report.
8	Structure Installation in Array Area	Seabed preparation for 34 of the largest turbines and platform, Sections 6.12 and 7.9 of the Modelling Report.
9	Array Area Cables	Levelling of sand waves and megaripples, Sections 6.13 and 7.10 of the Modelling Report.
10	Array Area Cables	Seabed trenching, Sections 6.14 and 7.11 of the Modelling Report.
11	Array disposal	Dredged sediment disposal in the array area using sediment size of 'Zones 1 and 3', Sections 6.15 and 7.12 of the Modelling Report.
12	Array disposal	Dredged sediment disposal in the array area using sediment size 'Sand waves', Sections 6.15 and 7.13 of the Modelling Report.

5. The results of the suspended sediment dispersion modelling presented on the figures show summations of the predicted maximum suspended sediment concentrations at individual points near the seabed at any time throughout the simulation. Hence, the maximum concentrations across the plume do not occur at the same time. Maximum suspended sediment concentrations are shown greater than 5mg/l. This value is less than the 15mg/l ambient level defined in the coastal processes EIA chapter.

6. Total seabed level changes are shown that are greater than 5cm (0.05m). This value is the benchmark for a 'light' deposition event as defined by Marine Biological Association (MarLIN).

7. The focus of the interpretation is the results near the seabed (in the bottom water layer) as these are the worst case with respect to both magnitude of concentration and dimensions of the footprint. This suspended sediment is also the closest to the seabed where deposition from the plume takes place.

8. The potential receptors to changes in suspended sediment concentrations and seabed level change are Margate and Long Sands Special Area of Conservation (SAC) and Kentish Knock East Marine Conservation Zone (MCZ).

9. The Margate and Long Sands SAC is located approximately 22km off the Suffolk coast, covering an area of 649km^2. The conservation objective for the SAC is to 'ensure that the integrity of the site is maintained or restored as appropriate, and ensure that the site contributes to achieving the Favourable Conservation Status of its Qualifying Features, by maintaining or restoring: the extent and distribution of qualifying natural habitats; the structure and function (including typical species) of qualifying natural habitats; and the supporting

processes on which the qualifying natural habitats rely'. The North Falls offshore cable corridor lies adjacent to the SAC.

10. The Kentish Knock East MCZ is located approximately 35km off the Essex coast, covering an area of $96km^2$. The conservation objectives for the MCZ's protected features are that they are 'maintained in favourable condition if they are already in favourable condition or recovered to a favourable condition if they are not already in favourable condition'.

2 Construction Phase – Offshore Cable Corridor

2.1 Predicted Changes in Near Seabed Suspended Sediment Concentrations Due to Export Cable Installation

2.1.1 Levelling of Sand Waves and Megaripples

11. During the sand wave and megaripple levelling phase of a single export cable installation, maximum suspended sediment concentrations at any time throughout the simulation are predicted to reach greater than 500mg/l near the seabed up to 10km north-northeast and up to 10km south-southwest of the export cable corridor, along the predominant tidal flow directions (Figure 2.1). The plumes at the seabed that are greater than 5mg/l are predicted to extend 13-20km north-northeast and 7-20km south-southwest. At its maximum extent, the near seabed plume with maximums greater than 5mg/l would interact with part of the Margate and Long Sands SAC but not with the Kentish Knock East MCZ or the coast.

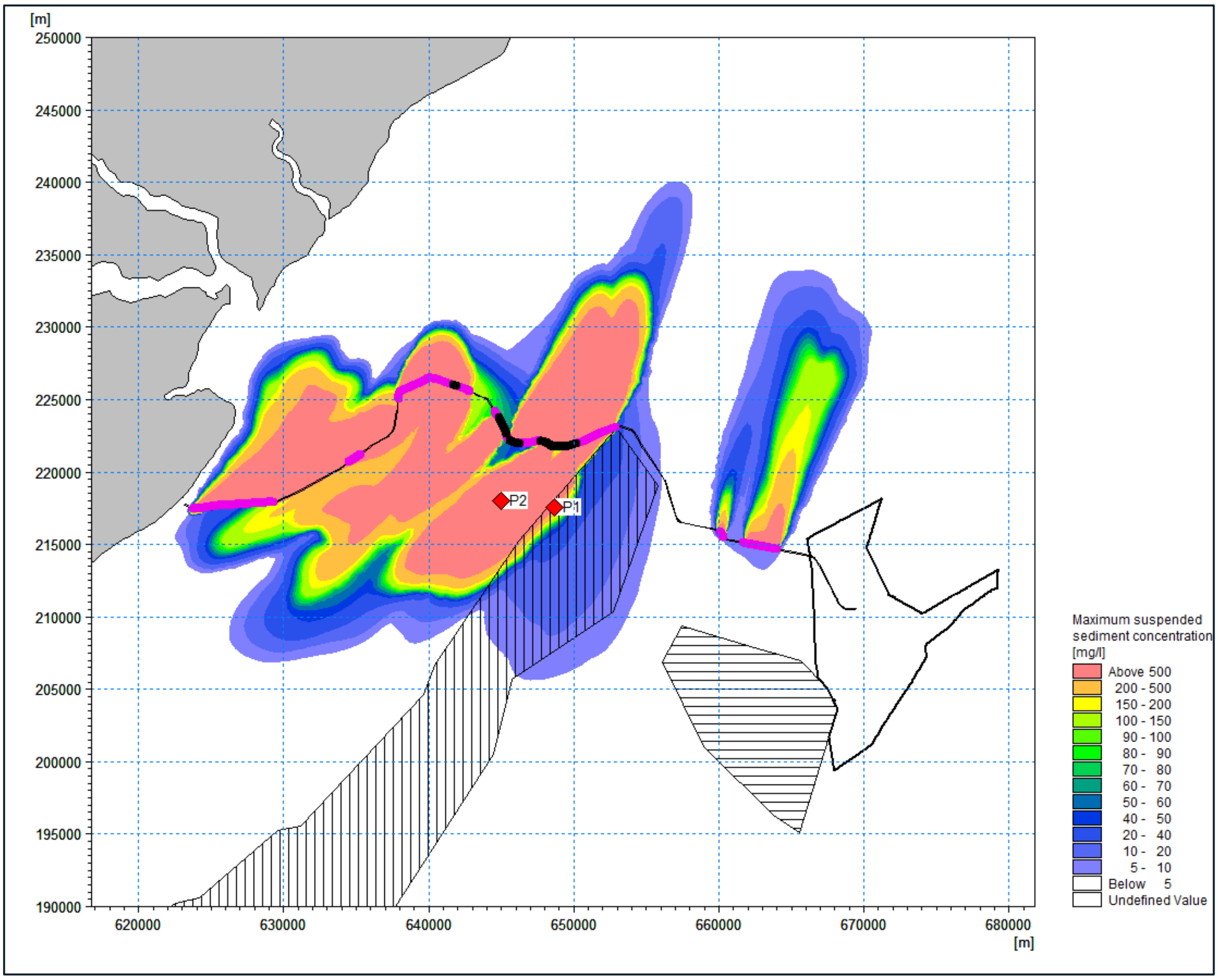

Figure 2.1 Predicted maximum suspended sediment concentrations at the seabed during sand wave and megaripple levelling operations along the export cable corridor (thick purple line = megaripples, thick black line = sand waves, red points = time series extraction points). Vertical hash = Margate and Long Sands SAC. Horizontal hash = Kentish Knock East Marine MCZ

12. Figure 2.2 and Figure 2.3 show the predicted time series of suspended sediment concentrations at the two locations (P1 and P2) shown on Figure 2.1 for a single cable laying activity. Maximum near seabed concentrations of about 400mg/l at P1 and around 4,700mg/l at P2 are predicted (with two modelled peaks), but only for 2-4 hours before returning to less than ambient concentrations (less than 15mg/l). A second cable will be installed several weeks after completion of installation of the first cable, with a similar outcome with respect to generation of suspended sediment concentrations. Given the short period of time that suspended sediment concentrations are above ambient levels for each installation, there will be no interaction of the plumes released by the first and second cables.

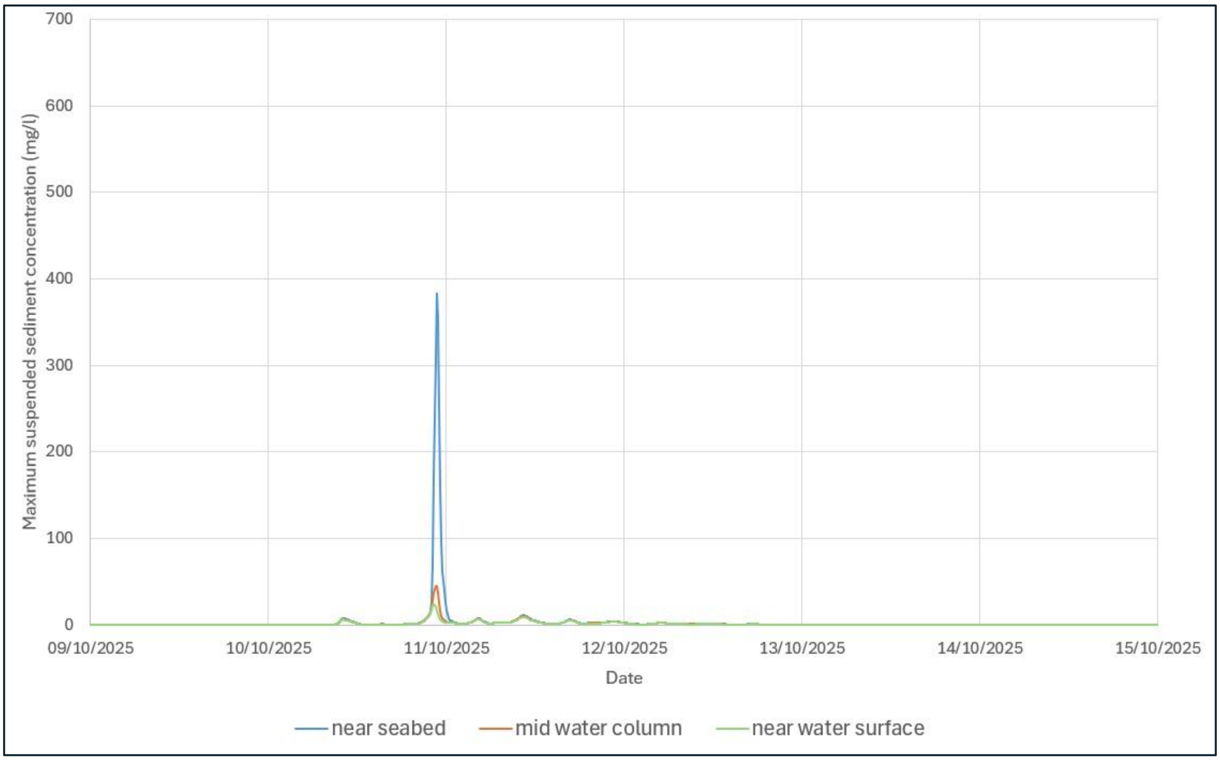

Figure 2.2 Time series of predicted suspended sediment concentrations at P1 (inside Margate and Long Sands SAC) during sand wave and megaripple levelling along the export cable corridor for near seabed, middle of water column and near water surface

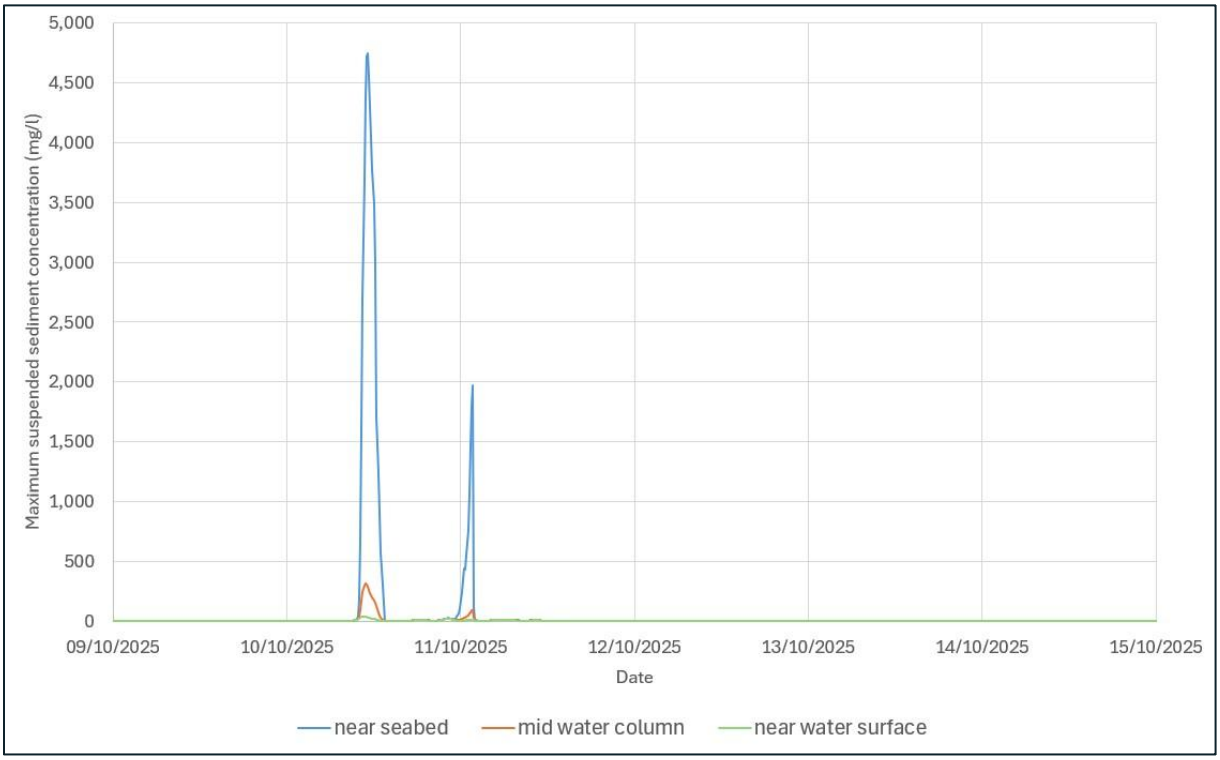

Figure 2.3 Time series of predicted suspended sediment concentrations at P2 (relatively high concentrations along the export cable) during sand wave and megaripple levelling along the export cable corridor for near seabed, middle of water column and near water surface

2.1.2 Seabed Trenching

13. During the trenching phase of a single export cable installation, the magnitude of changes in near seabed suspended sediment concentrations are predicted to be less than sand wave and megaripple levelling. Areas where maximum suspended sediment concentrations are predicted to be greater than about 100mg/l near the seabed are confined to within the export cable corridor or immediately adjacent to it (Figure 2.4). Maximum concentrations along the export cable corridor are predicted to reach 500mg/l in isolated places. The maximum near seabed concentrations in the plume beyond the immediate vicinity of the corridor (up to 7km either side where maximums are greater than 5mg/l) are predicted to be predominantly less than 30mg/l. At its maximum extent, the near seabed plume with maximums greater than 5mg/l would interact with a small part of the Margate and Long Sands SAC but not with the Kentish Knock East MCZ or the coast.

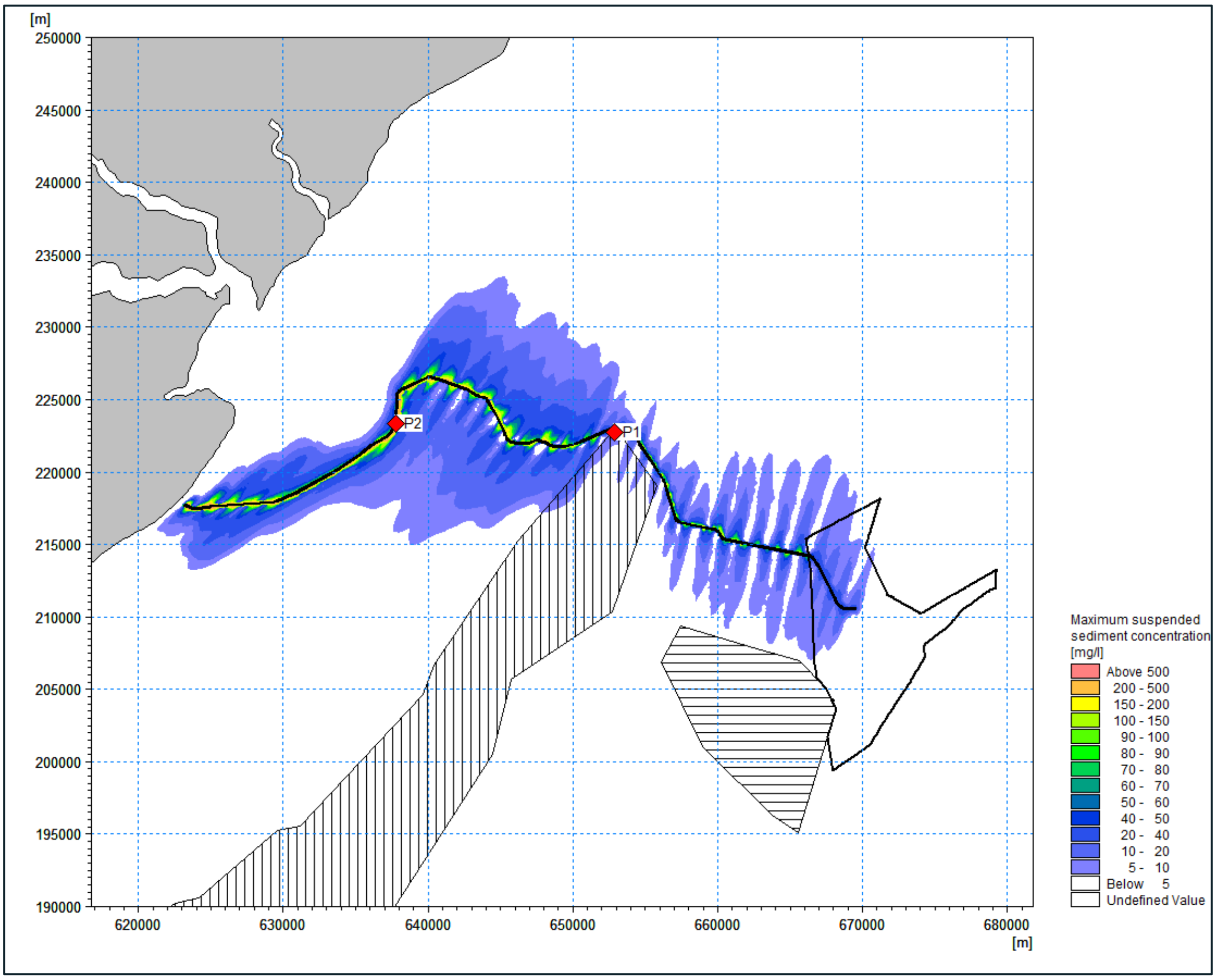

Figure 2.4 Predicted maximum suspended sediment concentrations at the seabed during seabed trenching operations along the export cable corridor (red points = time series extraction points). Vertical hash = Margate and Long Sands SAC. Horizontal hash = Kentish Knock East Marine MCZ

14. Figure 2.5 and Figure 2.6 show the predicted time series of suspended sediment concentrations at the two locations (P1 and P2) shown on Figure 2.4. Maximum near seabed concentrations are predicted to be less than 25mg/l at P1 (with two modelled peaks) and about 400mg/l at P2, but only for 1-8 hours before returning to less than ambient concentrations (less than 15mg/l). A second cable will be installed several weeks after completion of installation of the first cable, with a similar outcome with respect to generation of suspended sediment concentrations. Given the short period of time that suspended sediment concentrations are above ambient levels for each installation, there will be no interaction of the plumes released by the first and second cables.

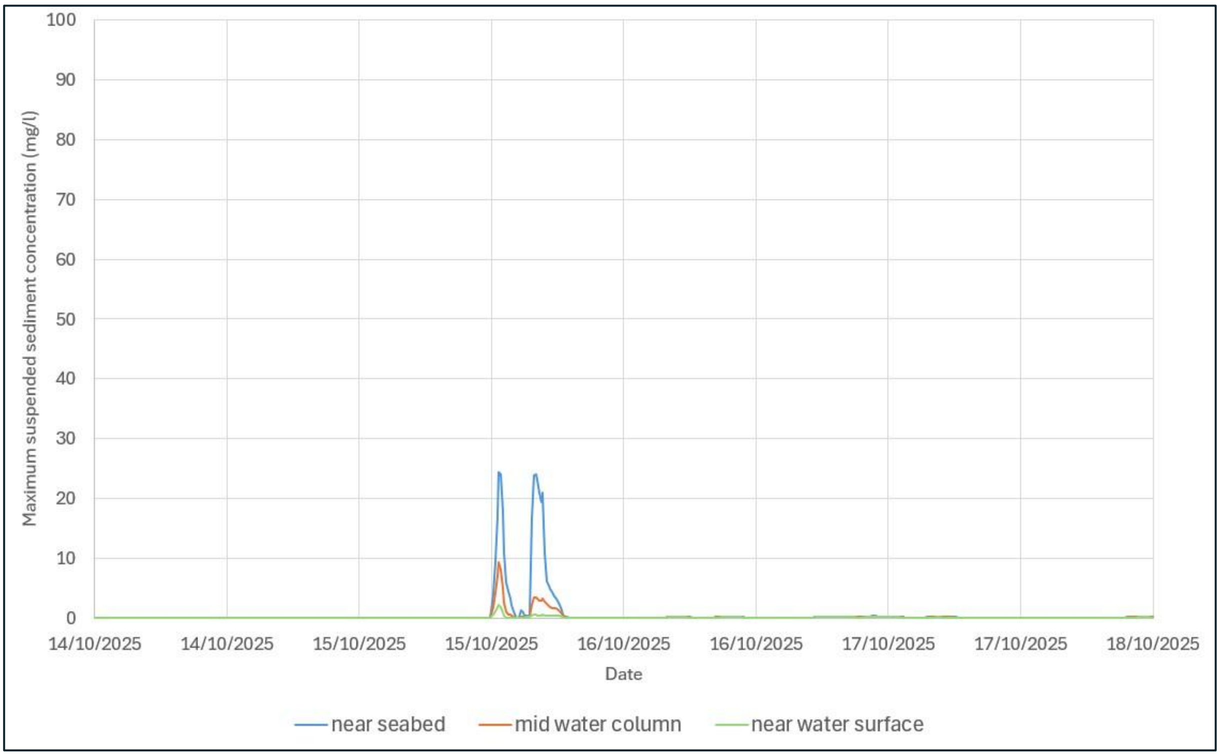

Figure 2.5 Time series of predicted suspended sediment concentrations at P1 (inside Margate and Long Sands SAC) during seabed trenching along the export cable corridor for near seabed, middle of water column and near water surface

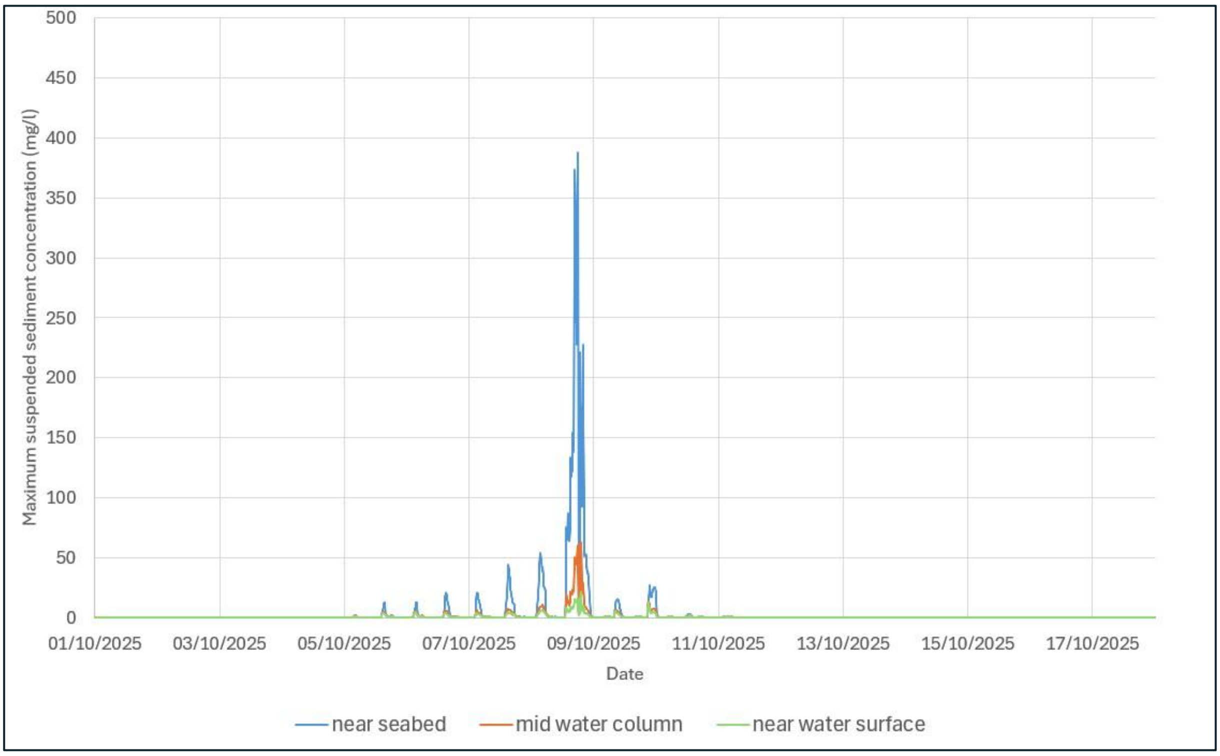

Figure 2.6 Time series of predicted suspended sediment concentrations at P2 (relatively high concentrations along the export cable) during seabed trenching along the export cable corridor for near seabed, middle of water column and near water surface

2.1.3 Dredging at Sunk DWR and Trinity DWR

15. Dredging at Sunk DWR and Trinity DWR is predicted to create spatially restricted sediment plumes (Figure 2.7 and Figure 2.8). The predicted plumes extend to the north and south of the export cable corridor (up to 0.8km for Sunk DWR and 0.5km for Trinity DWR) with predicted concentrations near the seabed below 20mg/l.

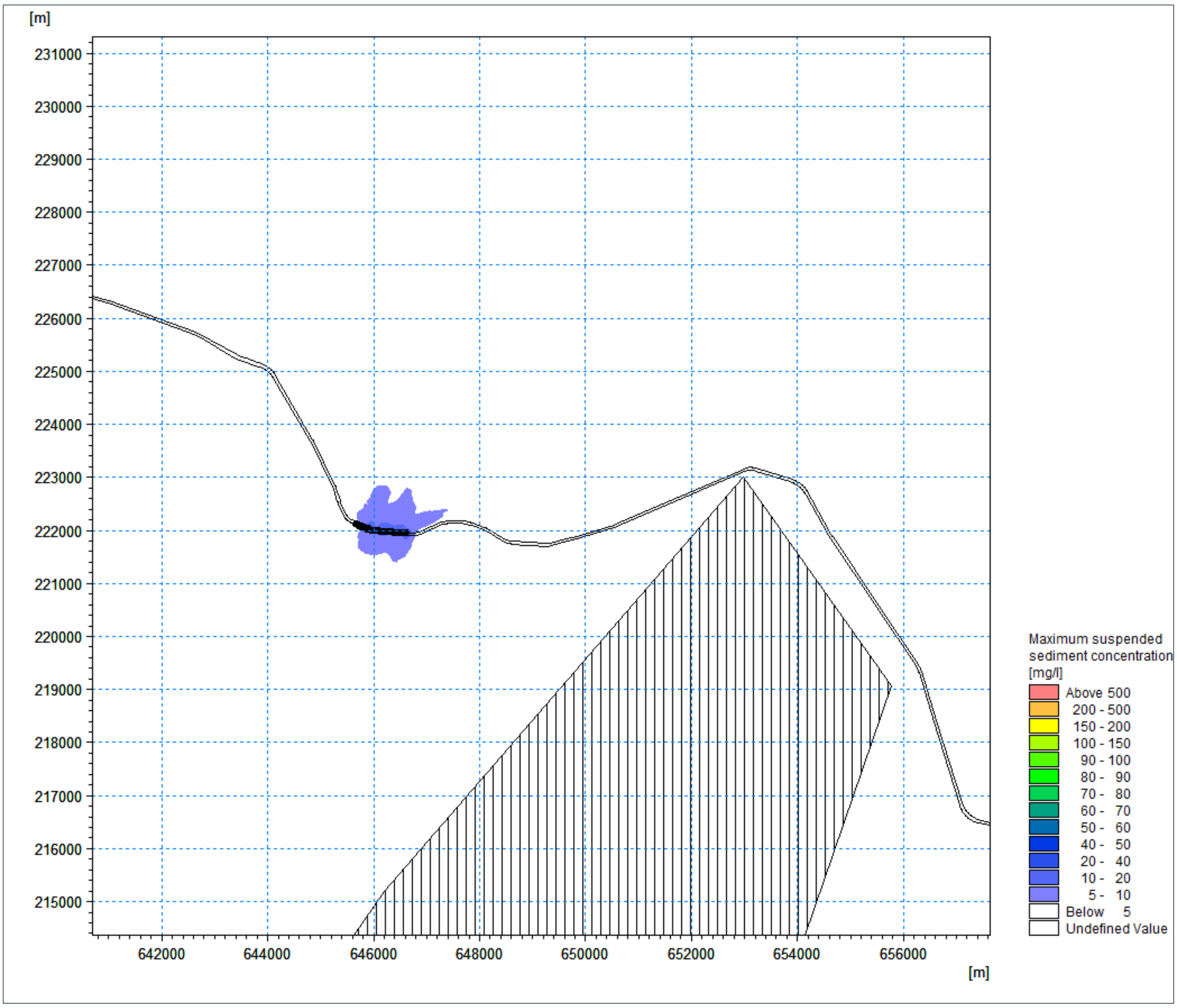

Figure 2.7 Predicted maximum suspended sediment concentrations at the seabed during dredging operations at Sunk DWR. Vertical hash = Margate and Long Sands SAC

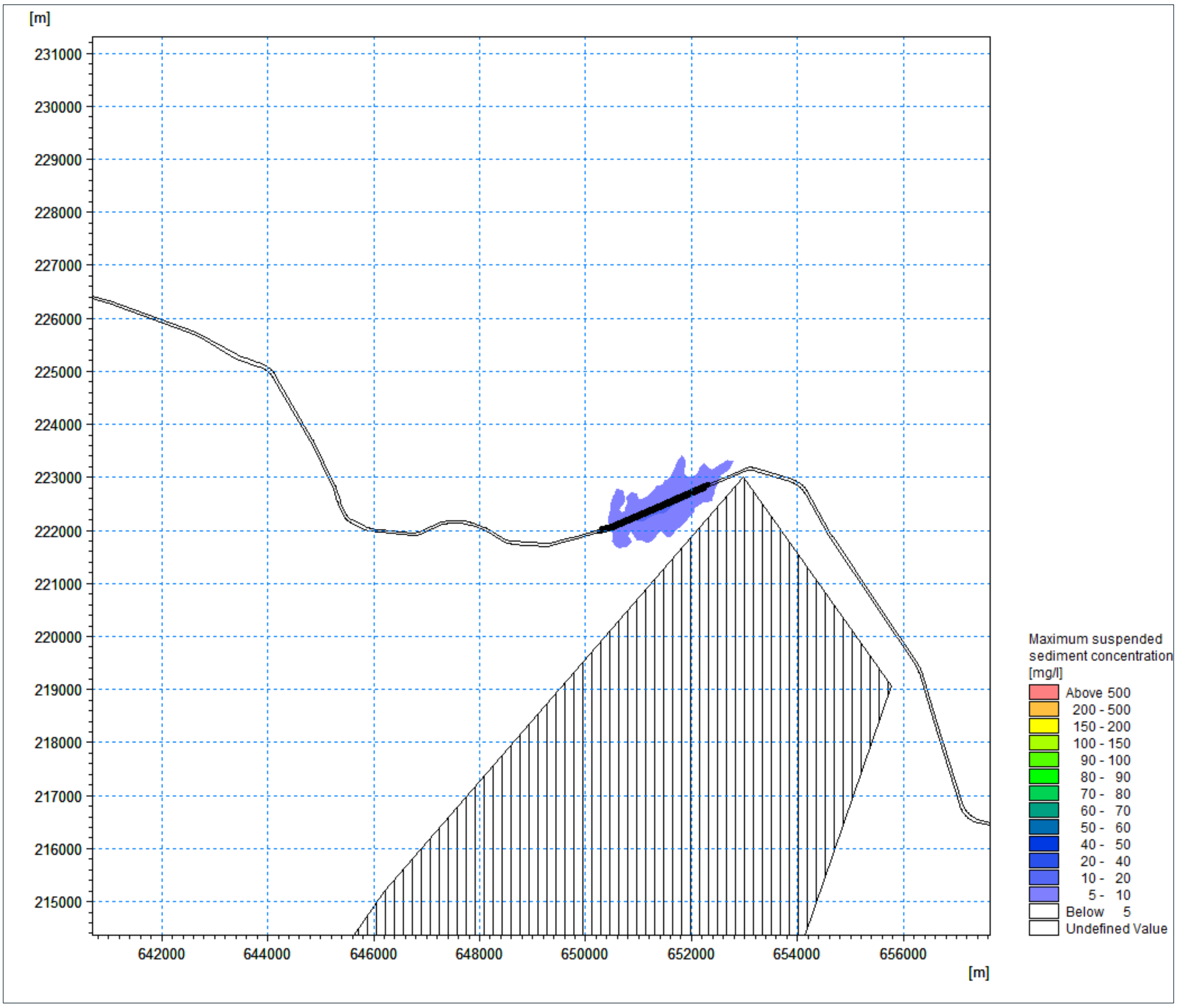

Figure 2.8 Predicted maximum suspended sediment concentrations at the seabed during dredging operations at Trinity DWR. Vertical hash = Margate and Long Sands SAC

2.2 Predicted Changes in Seabed Level Due to Export Cable Installation

2.2.1 Levelling of Sand Waves and Megaripples

16. During sand wave and megaripple levelling for export cable installation, changes in seabed level greater than 5cm (0.05m) are spatially restricted to four northeast to southwest elongate areas, two up to 9km long either side of the export cable corridor (Figure 2.9). Here, changes in seabed level of 5-20cm are predicted. However, the maximum changes are predicted to be at local hotspots along the export cable corridor where changes in seabed level of about 3m are predicted.

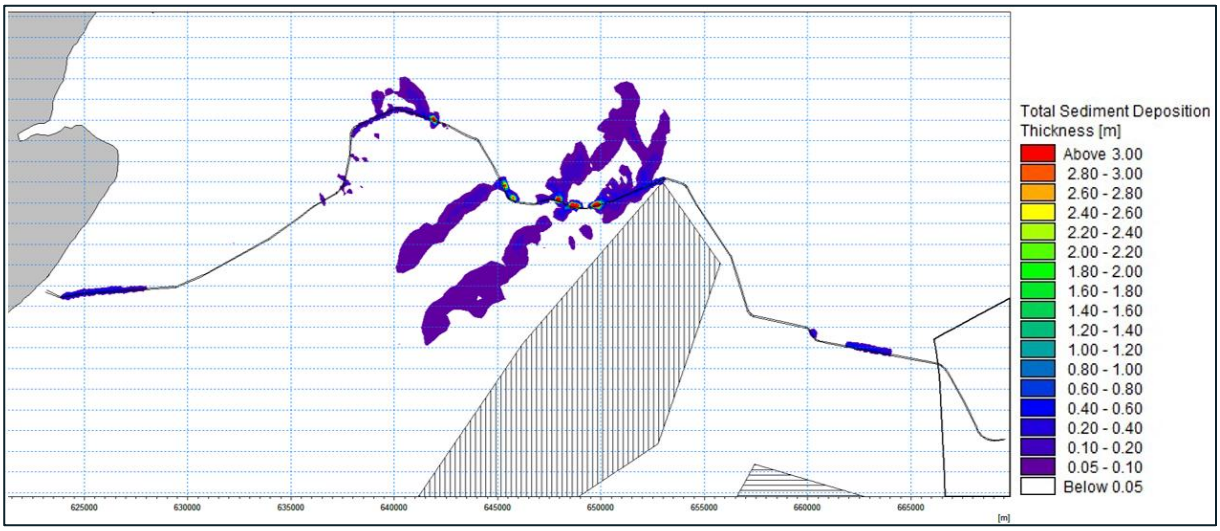

Figure 2.9 Predicted seabed level change during sand wave and megaripple levelling operations along the export cable corridor. Vertical hash = Margate and Long Sands SAC. Horizontal hash = Kentish Knock East Marine MCZ

2.2.2 Seabed Trenching

17. Smaller changes in seabed level due to seabed trenching for export cable installation compared to sand wave and megaripple levelling are predicted. All sediment deposition is predicted to occur within the export cable corridor and is less than 5cm (Figure 2.10).

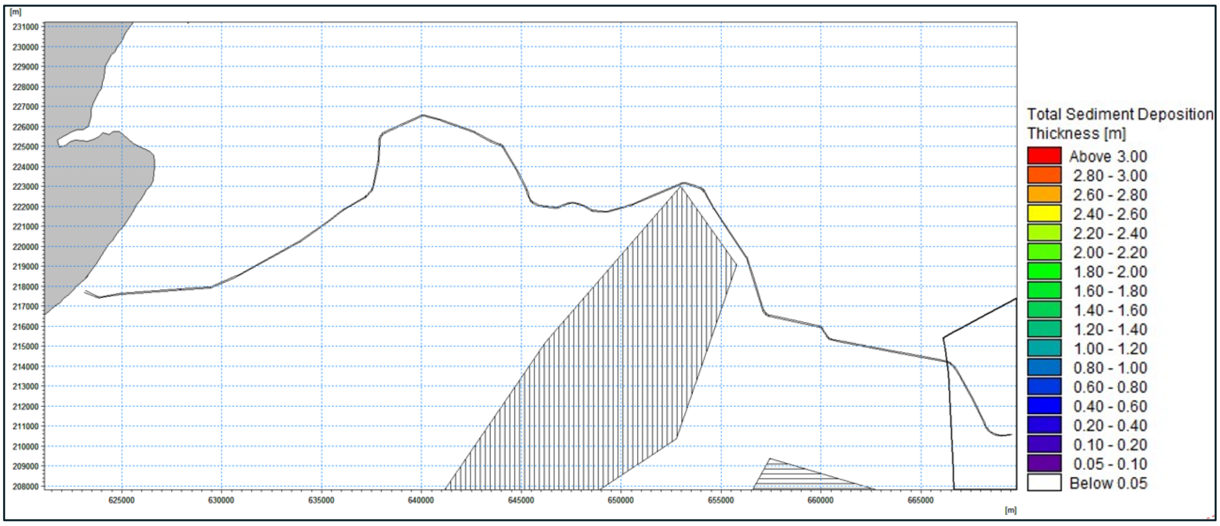

Figure 2.10 Predicted seabed level change during seabed trenching operations along the export cable corridor. Vertical hash = Margate and Long Sands SAC. Horizontal hash = Kentish Knock East Marine MCZ

2.2.3 Dredging at Sunk DWR and Trinity DWR

18. All sediment deposition induced by dredging at the Sunk DWR and Trinity DWR is predicted to occur within the export cable corridor near to the dredging operations with a predicted maximum change of up to 1cm (Figure 2.11).

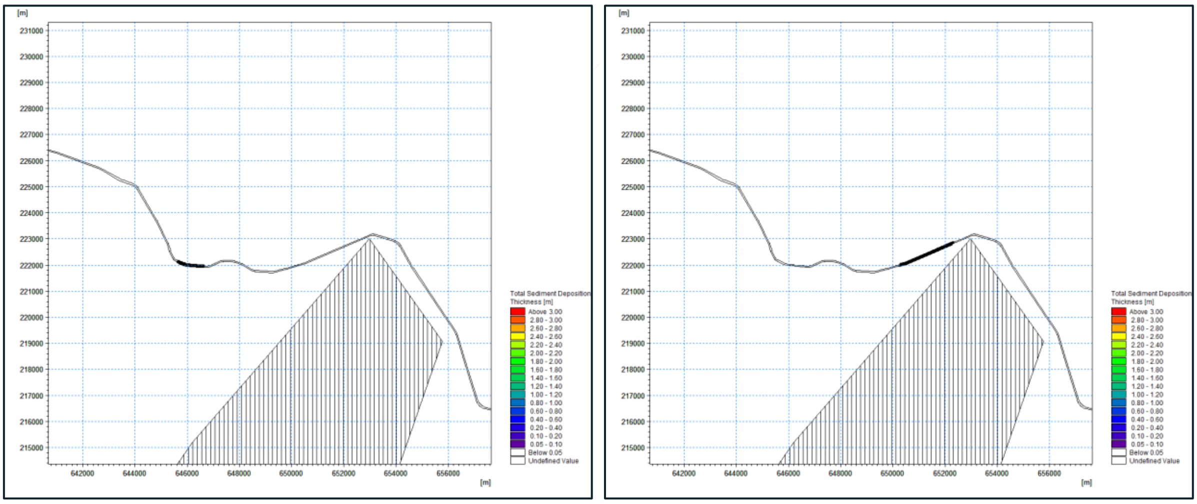

Figure 2.11 Predicted seabed level change during dredging operations at Sunk DWR (left) and Trinity DWR (right). Vertical hash = Margate and Long Sands SAC

2.3 Assessment of the Effects of Export Cable Installation

2.3.1 Worst-case Scenario

19. The worst-case scenario for export cable installation with respect to marine geology, oceanography and physical processes is the sand wave and megaripple levelling phase. This phase is predicted to release the highest concentrations of suspended sediment over the widest geographical area. The plume sediment is then predicted to deposit on the seabed with the greatest thicknesses, also over the widest geographical area. Hence, the modelling results of this construction activity are considered in the assessment of effects for the export cable corridor. The potential effects on marine geology, oceanography and physical processes of seabed trenching for the export cable, dredging at Sunk DWR, and dredging at Trinity DWR, will be less than those for sand wave and megaripple levelling.

20. A summary of the latest worst case scenario parameters for Marine Geology, Oceanography and Physical Processes is provided in Supporting Information on Offshore Additional Mitigation **[Document Reference 9.55]**.

2.3.2 Receptor Sensitivity

21. Due to the nature of the pressure of an increase in suspended sediment concentrations there is no pathway for effect on the marine geology, oceanography and physical processes of the identified receptors (Margate and Long Sands SAC and Kentish Knock East MCZ). Therefore, they are not sensitive to this pressure because the form and function of the SAC and MCZ are dominated by processes that are active along the seabed and not affected by suspended sediment in the water column. Hence, features within these receptors are only potentially sensitive to varying degrees to the potential change in seabed level along the export cable corridor. The value and sensitivity of these receptors to the potential change in seabed level are presented in Table 2.1 based on the definitions provided in Table 8.7 and Table 8.8 of Environmental Statement (ES) Chapter 8 **[APP-022]**.

Table 2.1 Sensitivity and value assessment of the identified receptors for marine geology, oceanography and physical processes

RECEPTOR	TOLERANCE	ADAPTABILITY	RECOVERABILITY	VALUE	SENSITIVITY
Margate and Long Sands SAC	Negligible	Negligible	Negligible	High	Negligible
Kentish Knock East MCZ	Negligible	Negligible	Negligible	High	Negligible

2.3.3 Impact Magnitude

22. The worst-case changes in seabed level due to the installation of the export cable described in Section 2.2.1 are likely to have the magnitudes of impact shown in Table 2.2. It is noted that deposition will not occur in the areas of sensitive habitats. For both the Margate and Long Sands SAC and Kentish Knock East MCZ it is evident (see Figure 2.9, Figure 2.10 and Figure 2.11) that

deposition of measurable scale is not predicted within them and hence there is negligible effect on these features.

Table 2.2 Magnitude of impact on seabed level under the worst-case scenario for export cable installation

LOCATION	SCALE	DURATION	FREQUENCY	REVERSIBILITY	MAGNITUDE OF IMPACT
Near-field	High	Negligible	Negligible	Negligible	Medium
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

*The near-field impacts are confined to a small area likely to be of the order up to 500m from the export cable

2.3.4 Effect Significance

23. The impacts on suspended sediment concentrations due to cable installation do not directly affect the identified receptors for marine geology, oceanography and physical processes (Margate and Long Sands SAC and Kentish Knock East MCZ), so there is no change associated with the Project. No significant effect will occur.

24. The worst-case disturbance effects along the export cable corridor persist in the water column for up to 17 hours, before depositing to form a layer on the seabed (on average about 0.05-0.2m with local hotspots along the export cable route itself of 3m) (Figure 2.9). However, it is anticipated that under the prevailing hydrodynamic conditions, this sediment would be readily re-mobilised by natural processes. The deposited sediment would be continually re-suspended to reduce the thickness even further to a point where it will be effectively zero. This would be the longer-term outcome once the sediment supply from export cable installation has ceased.

25. This means that given these very small magnitude changes in seabed level arising from export cable installation, the effects on the identified receptors would be **not significant**. Hence, the overall significance of the effect of export cable installation activities under a worst-case scenario on seabed level changes for the identified receptors is **negligible adverse** (no significant effect).

26. The magnitude of impact and effect significance are the same as those in Section 8.6.2.5 and Section 8.6.2.6 of the ES Chapter 8 **[APP-022]**.

27. The effects on the benthic ecology of these receptors are discussed in Supporting Information on Offshore Additional Mitigation **[Document Reference 9.55]**.

3 Construction Phase – Array Area

3.1 Predicted Changes in Near Seabed Suspended Sediment Concentrations Due to Foundation Drilling and Seabed Preparation in the Array Area

3.1.1 Drilling for Turbine Foundations

28. The near seabed suspended sediment concentrations generated by drilling for both turbine scenarios (maximum number of smallest turbines and fewer larger turbines) are very low, with predicted maximum concentrations of 5mg/l restricted to the immediate vicinity of each structure that requires drilling.

3.1.2 Seabed Preparation for Turbine Foundations

29. During seabed preparation for either scenario of turbine foundations, maximum suspended sediment concentrations at any time throughout the simulation are predicted to reach greater than 500mg/l within the array area and beyond its boundary (Figure 3.1 and Figure 3.2). The plume maximums at the seabed that are greater than 5mg/l are predicted to extend about 25km north-northeast from the northern boundary of the array area and about 11km south-southwest from the southern boundary of the array area, along the predominant tidal flow directions. At their maximum extents, the near seabed plumes with maximums greater than 5mg/l would interact with a small part of the Kentish Knock East MCZ but not with the Margate and Long Sands SAC.

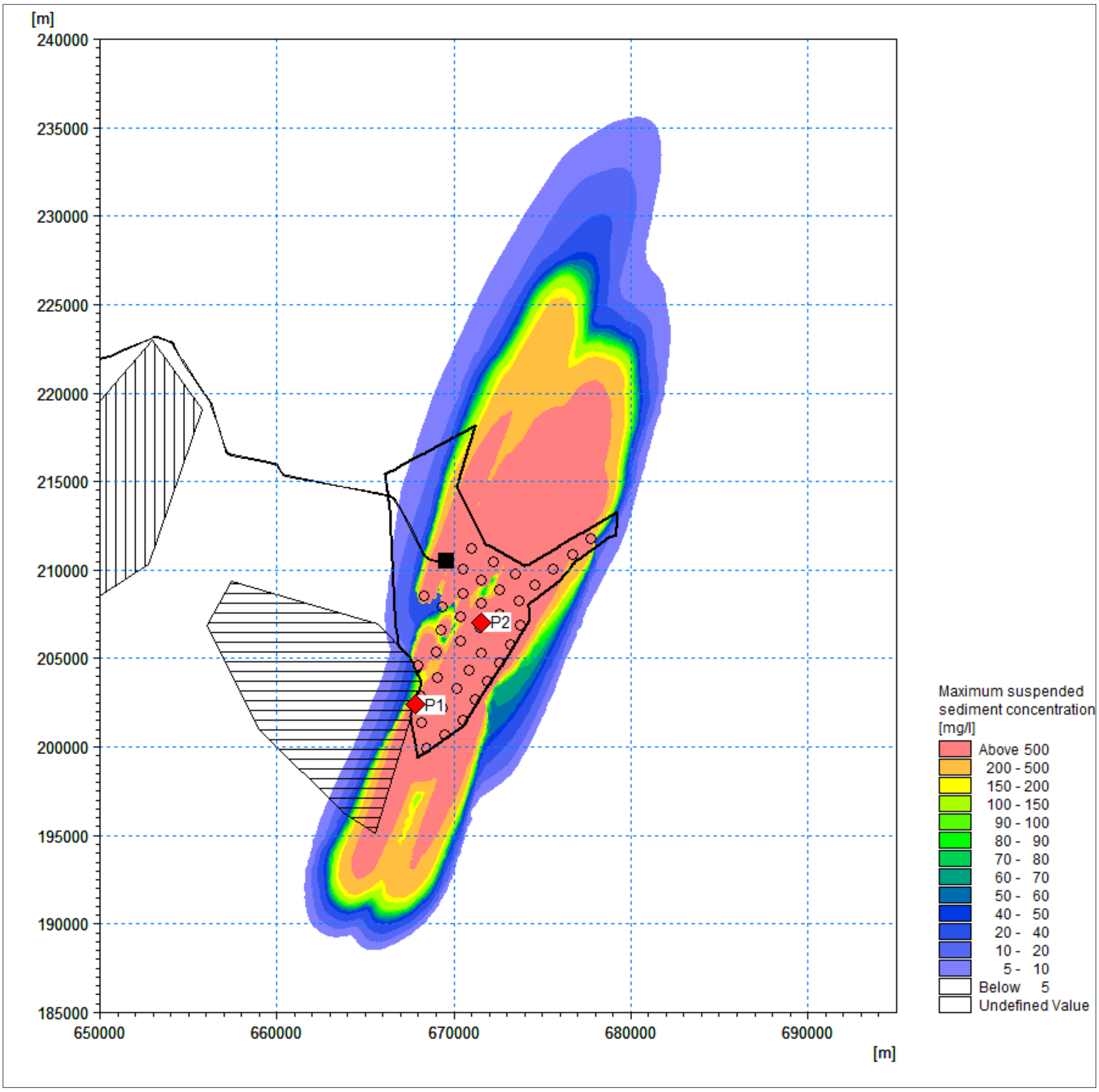

Figure 3.1 Predicted maximum suspended sediment concentrations at the seabed during seabed preparation for smallest turbine foundations (red points = time series extraction points). Vertical hash = Margate and Long Sands SAC. Horizontal hash = Kentish Knock East Marine MCZ

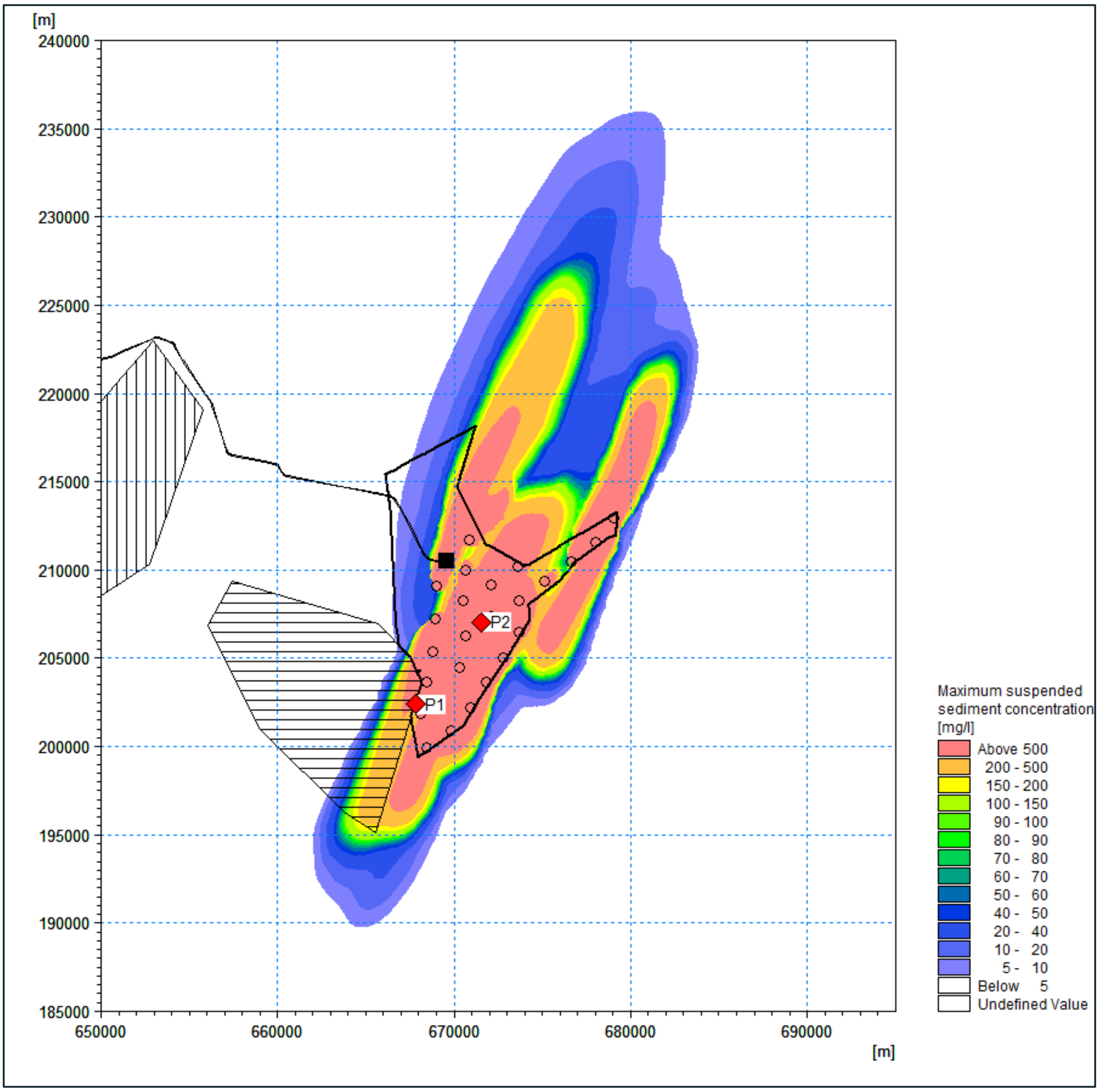

Figure 3.2 Predicted maximum suspended sediment concentrations at the seabed during seabed preparation for largest turbine foundations (red points = time series extraction points). Vertical hash = Margate and Long Sands SAC. Horizontal hash = Kentish Knock East Marine MCZ

30. Figure 3.3 and Figure 3.4 show the predicted time series of suspended sediment concentrations at the two locations (P1 and P2) for the smallest turbine foundations shown on Figure 3.1. Maximum near seabed concentrations are predicted to be around 1,400mg/l at P1, lasting for around four hours before returning to less than ambient concentrations (less than 15mg/l), and about 15,000mg/l at P2, but only for eight hours before returning to less than 15mg/l.

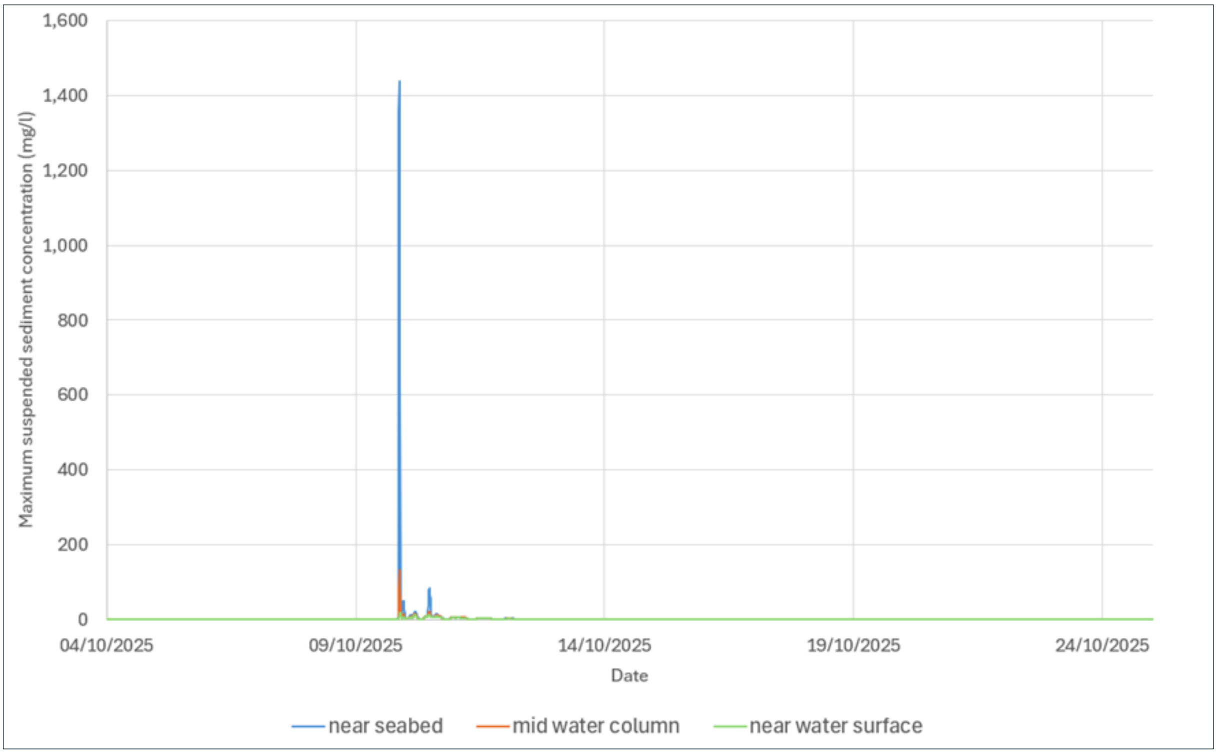

Figure 3.3 Time series of predicted suspended sediment concentrations at P1 (near Kentish Knock East Marine MCZ) during seabed preparation for the smallest turbine foundations for near seabed, middle of water column and near water surface

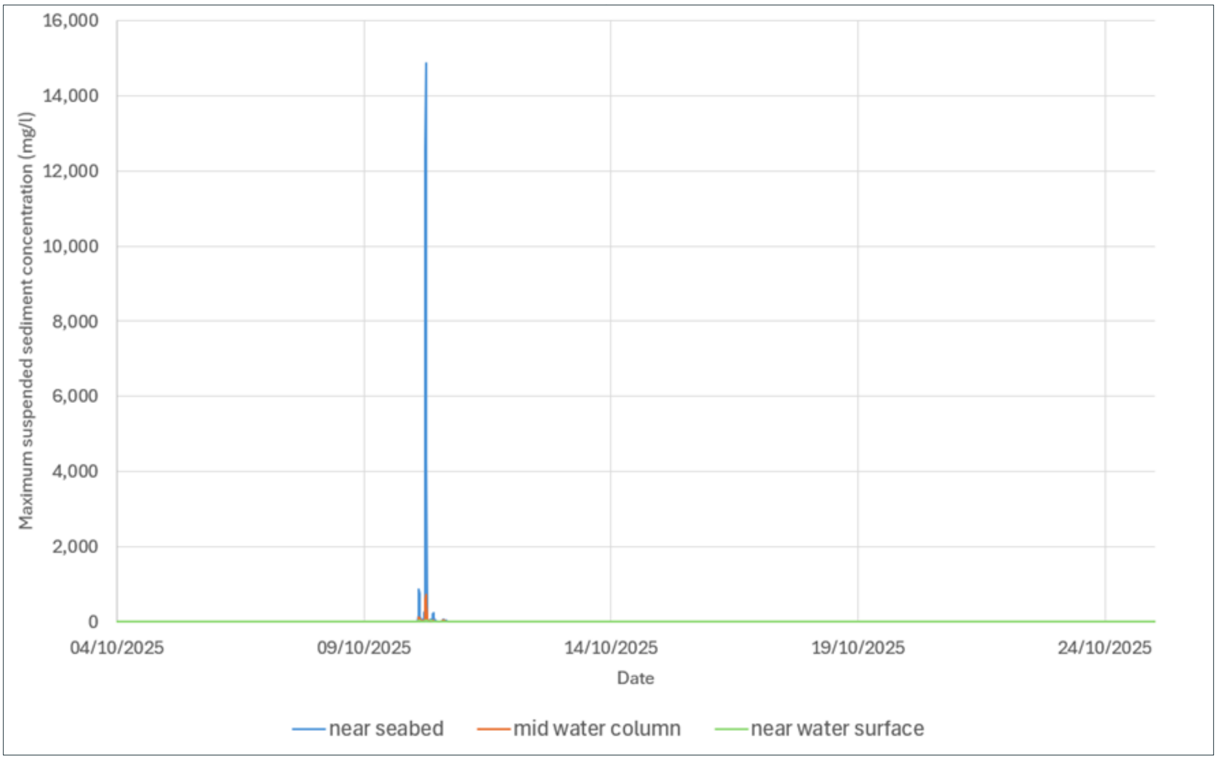

Figure 3.4 Time series of predicted suspended sediment concentrations at P2 (centre of array area) during seabed preparation for the smallest turbine foundations for near seabed, middle of water column and near water surface

31. Figure 3.5 and Figure 3.6 show the predicted time series of suspended sediment concentrations at the two locations (P1 and P2) for the largest turbine foundations shown on Figure 3.2. Maximum near seabed concentrations are predicted to be around 460mg/l at P1 and around 2,500mg/l at P2, but only for 8-21 hours before returning to less than ambient concentrations (less than 15mg/l).

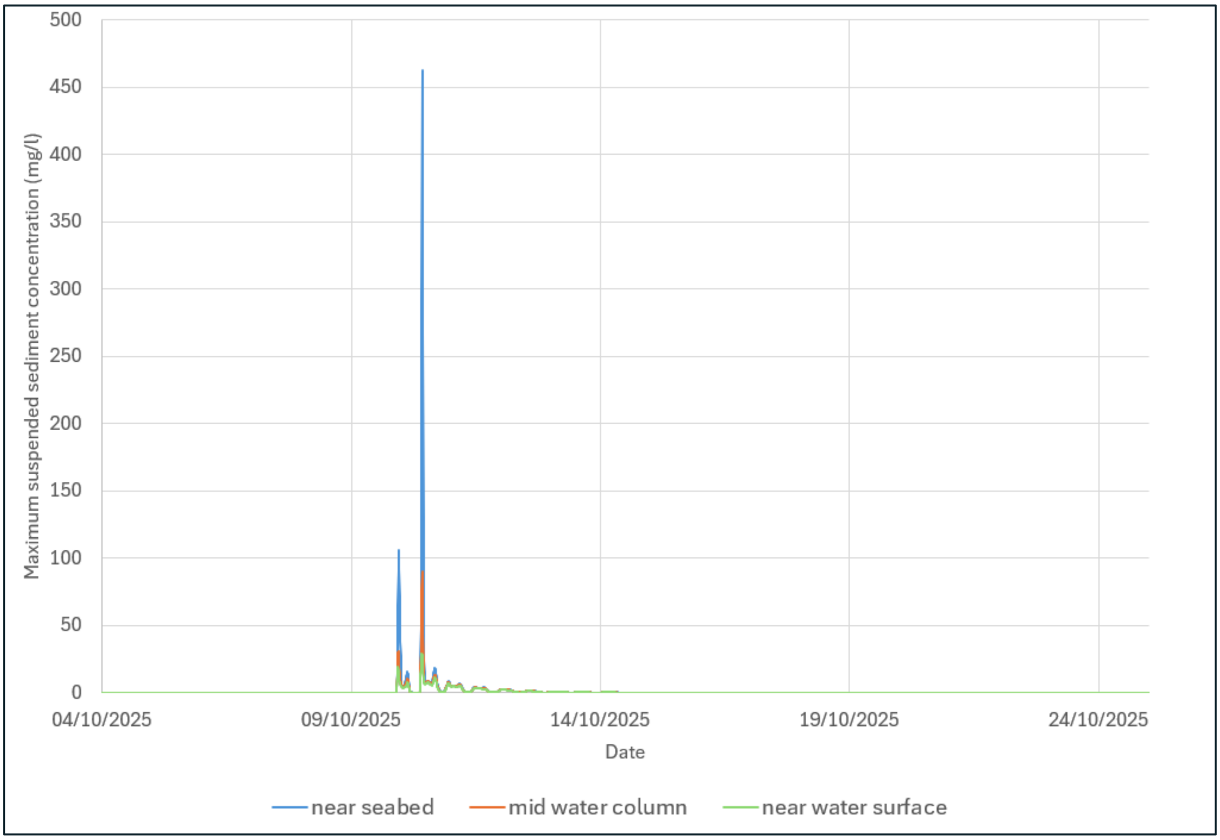

Figure 3.5 Time series of predicted suspended sediment concentrations at P1 (near Kentish Knock East Marine MCZ) during seabed preparation for the largest turbine foundations for near seabed, middle of water column and near water surface

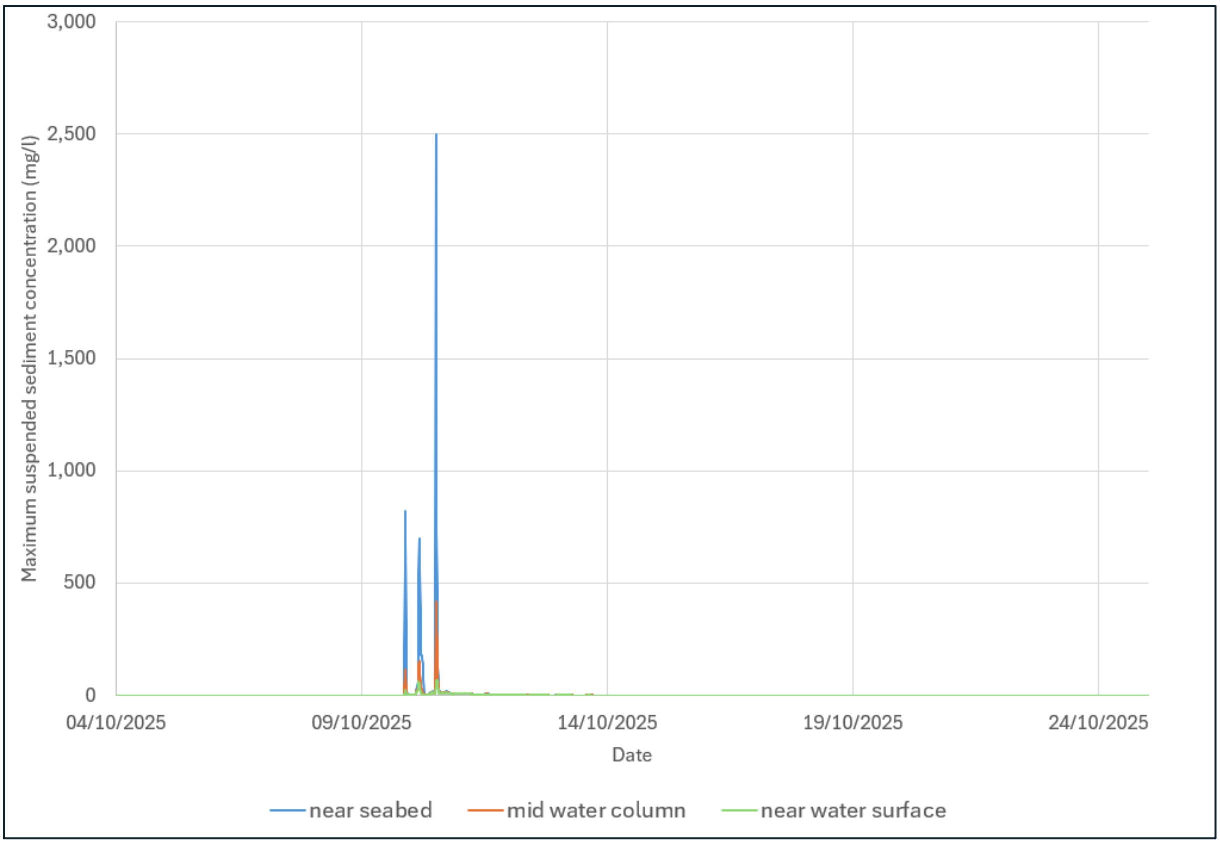

Figure 3.6 Time series of predicted suspended sediment concentrations at P2 (centre of array area) during seabed preparation for the largest turbine foundations for near seabed, middle of water column and near water surface

3.2 Predicted Changes in Seabed Level Due to Foundation Drilling and Seabed Preparation in the Array Area

3.2.1 Drilling for Turbine Foundations

32. All sediment deposition generated by drilling for both scenarios of turbine foundations is predicted to occur within the array area near to the structures that require drilling and is less than 0.5cm.

3.2.2 Seabed Preparation for Turbine Foundations

33. Figure 3.7 and Figure 3.8 show the changes in seabed level greater than 5cm (0.05m) which are predicted to occur during seabed preparation for the smallest and largest turbine foundations, respectively. In both cases, all sediment deposition is predicted to occur within the array area near the structures that require bed preparation. The maximum sediment deposition is 0.6m with the average being around 0.2m.

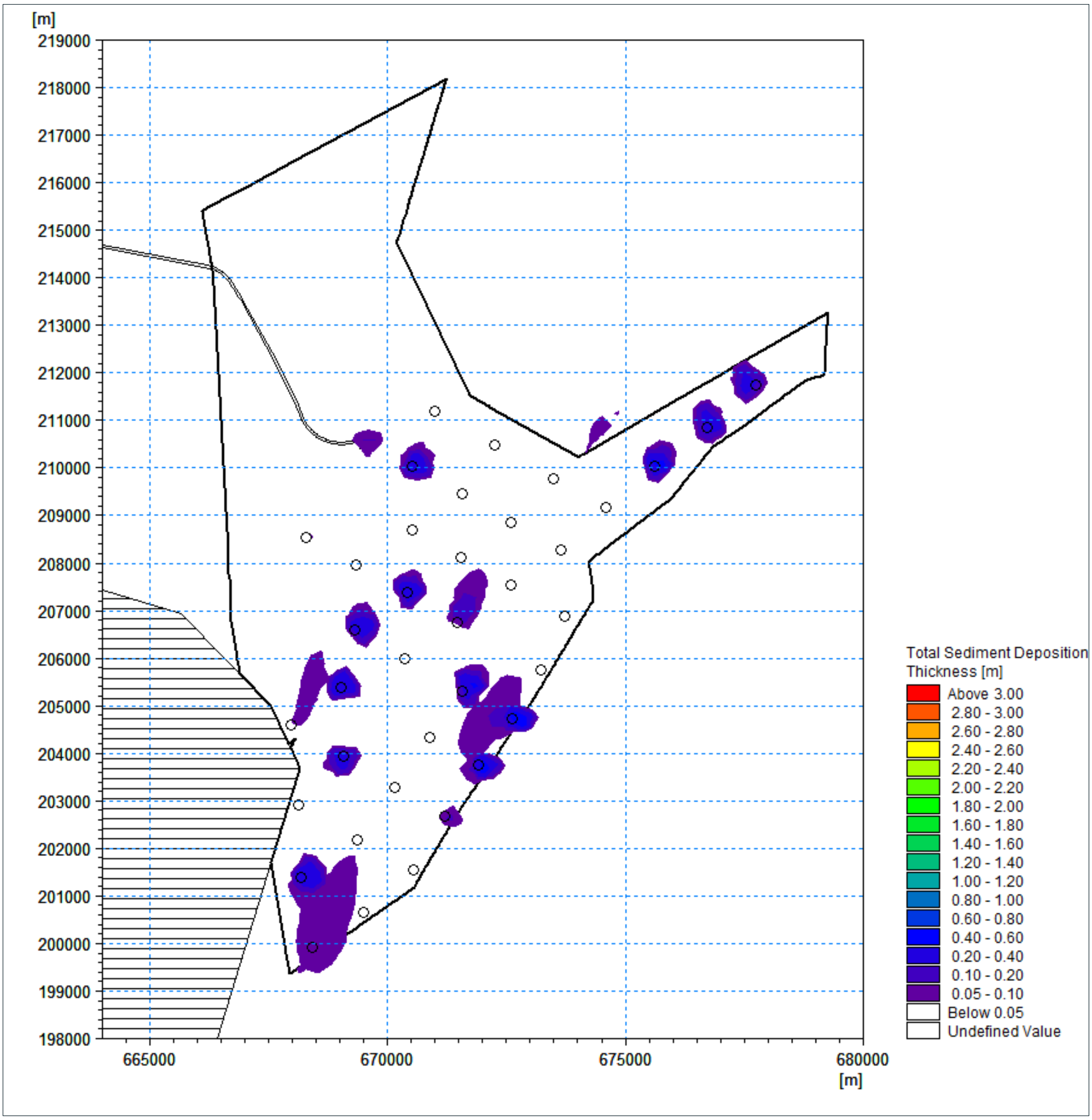

Figure 3.7 Predicted seabed level change during seabed preparation for the smallest turbine foundations. Horizontal hash = Kentish Knock East Marine MCZ

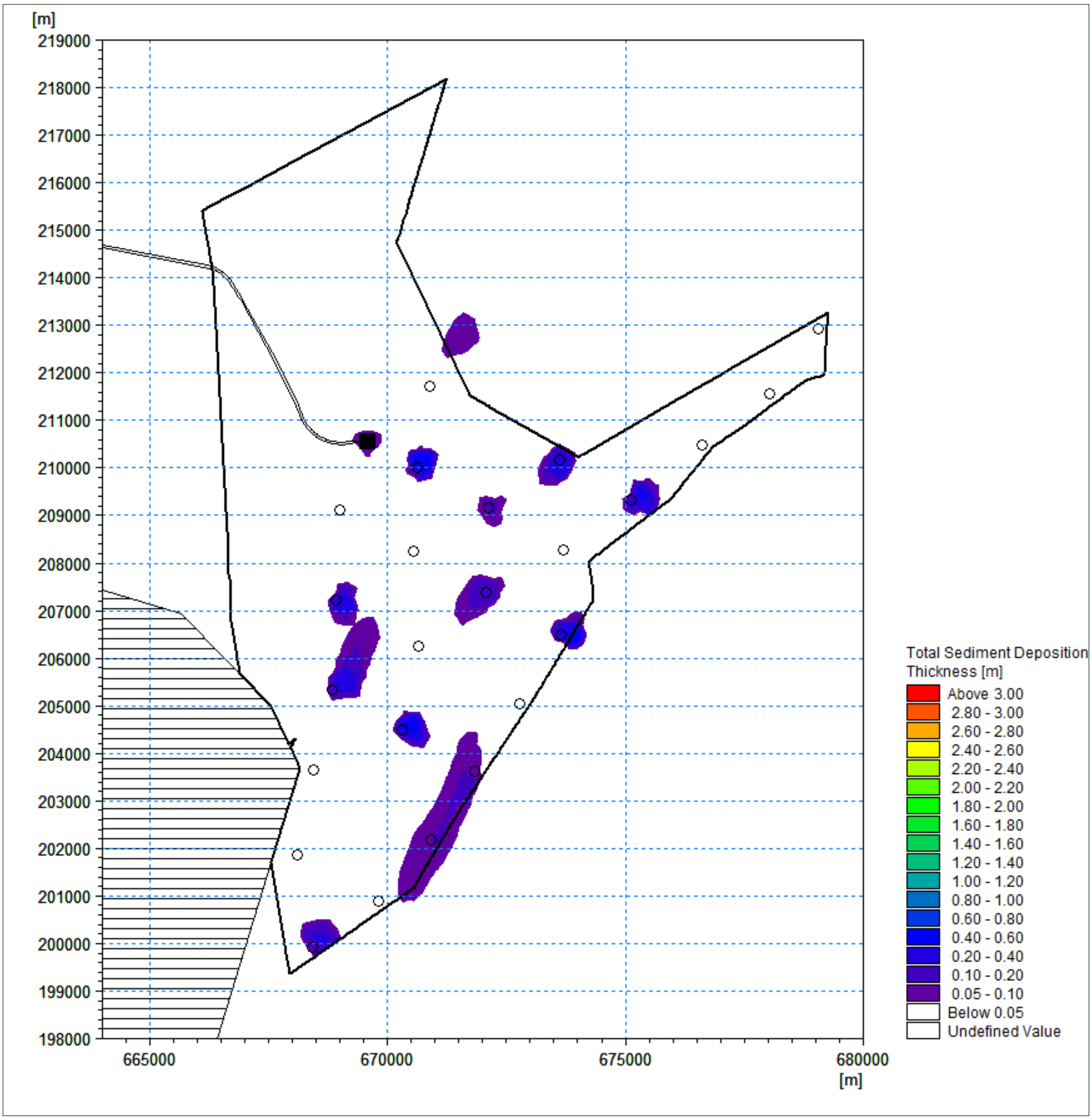

Figure 3.8 Predicted seabed level change during seabed preparation for the largest turbine foundations. Horizontal hash = Kentish Knock East Marine MCZ

3.3 Predicted Changes in Near Seabed Suspended Sediment Concentrations Due to Array Cable Installation

3.3.1 Levelling of Sand Waves and Megaripples

34. During the sand wave and megaripple levelling phase of array cable installation, maximum suspended sediment concentrations at any time throughout the simulation are predicted to reach greater than 500mg/l within the array area and up to 10km beyond its boundary (Figure 3.9). The plume maximums at the seabed that are greater than 5mg/l are predicted to extend about 19km north-northeast from the northern boundary of the array area and about 12km south-southwest from the southern boundary of the array area, along the predominant tidal flow directions. At its maximum extent, the near seabed plume with maximums greater than 5mg/l would interact with part of the Kentish Knock East MCZ but not with the Margate and Long Sands SAC.

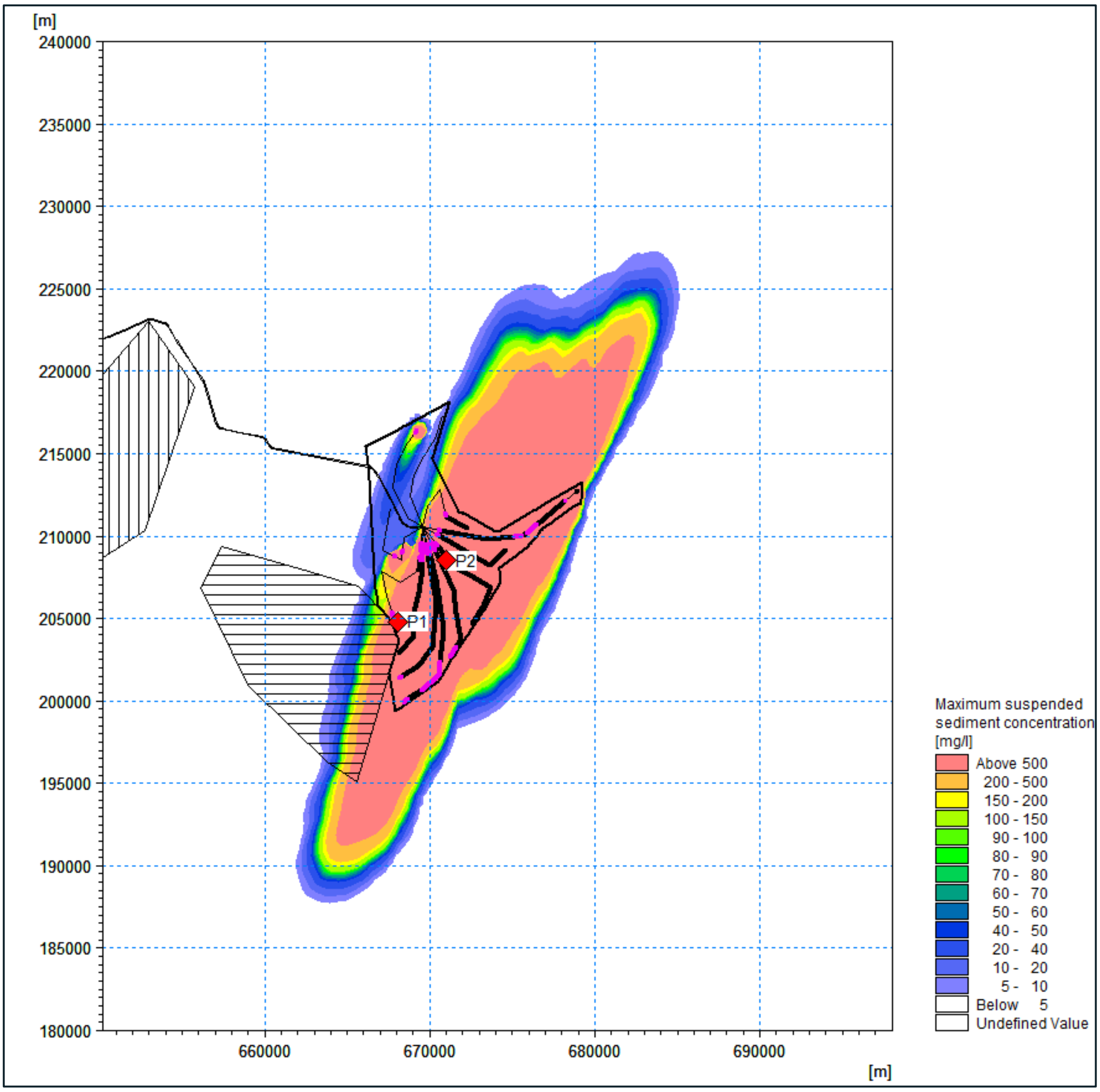

Figure 3.9 Predicted maximum suspended sediment concentrations at the seabed during sand wave and megaripple levelling operations along the array cables (red points = time series extraction points). Vertical hash = Margate and Long Sands SAC. Horizontal hash = Kentish Knock East Marine MCZ

35. Figure 3.10 and Figure 3.11 show the predicted time series of suspended sediment concentrations at the two locations (P1 and P2) shown on Figure 3.9. Maximum near seabed suspended sediment concentrations of about 16,000mg/l at P1 and nearly 9,000mg/l at P2 are predicted, but only for 1-4 hours before returning to less than ambient concentrations (less than 15mg/l). There are also several recurring peaks either side of the highest maximum peak with lower maximum concentrations of up to 5,000mg/l at P2. These peaks also dissipate to ambient suspended sediment concentrations in less than 11 hours.

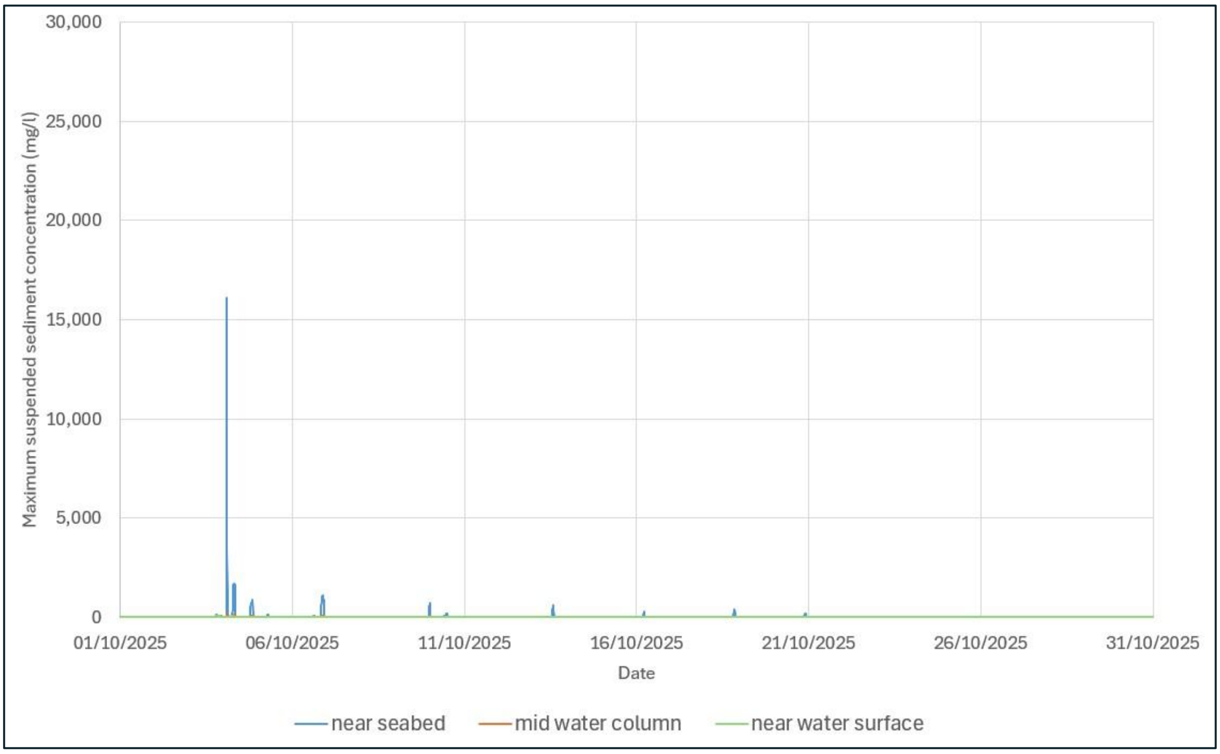

Figure 3.10 Time series of predicted suspended sediment concentrations at P1 (near Kentish Knock East Marine MCZ) during sand wave and megaripple levelling operations along the array cables for near seabed, middle of water column and near water surface

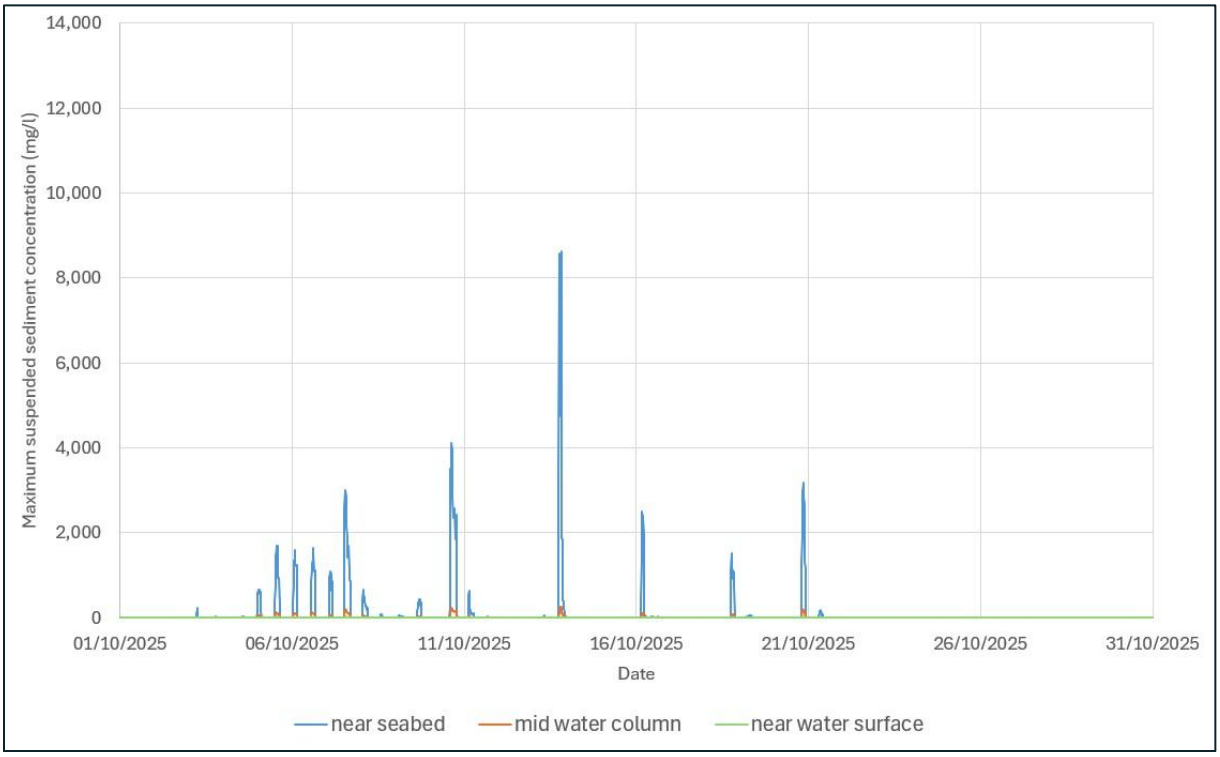

Figure 3.11 Time series of predicted suspended sediment concentrations at P2 (centre of array area) during sand wave and megaripple levelling operations along the array cables for near seabed, middle of water column and near water surface

3.3.2 Seabed Trenching

36. During the trenching phase of array cable installation, the magnitude of changes in near seabed suspended sediment concentrations are predicted to be significantly less than sand wave and megaripple levelling. Areas where maximum suspended sediment concentrations are predicted to be greater than about 100mg/l near the seabed are confined to a few hotspots in the vicinity of the array cables and immediately adjacent to them (Figure 3.12). Most of the plume is predicted to consist of maximum concentrations less than 50mg/l. At its maximum extent, the near seabed plume with maximums less than 5mg/l is predicted to extend about 7km to the north-northeast from the northern boundary of the array area and 4km to the south-southwest from the southern boundary of the array area.

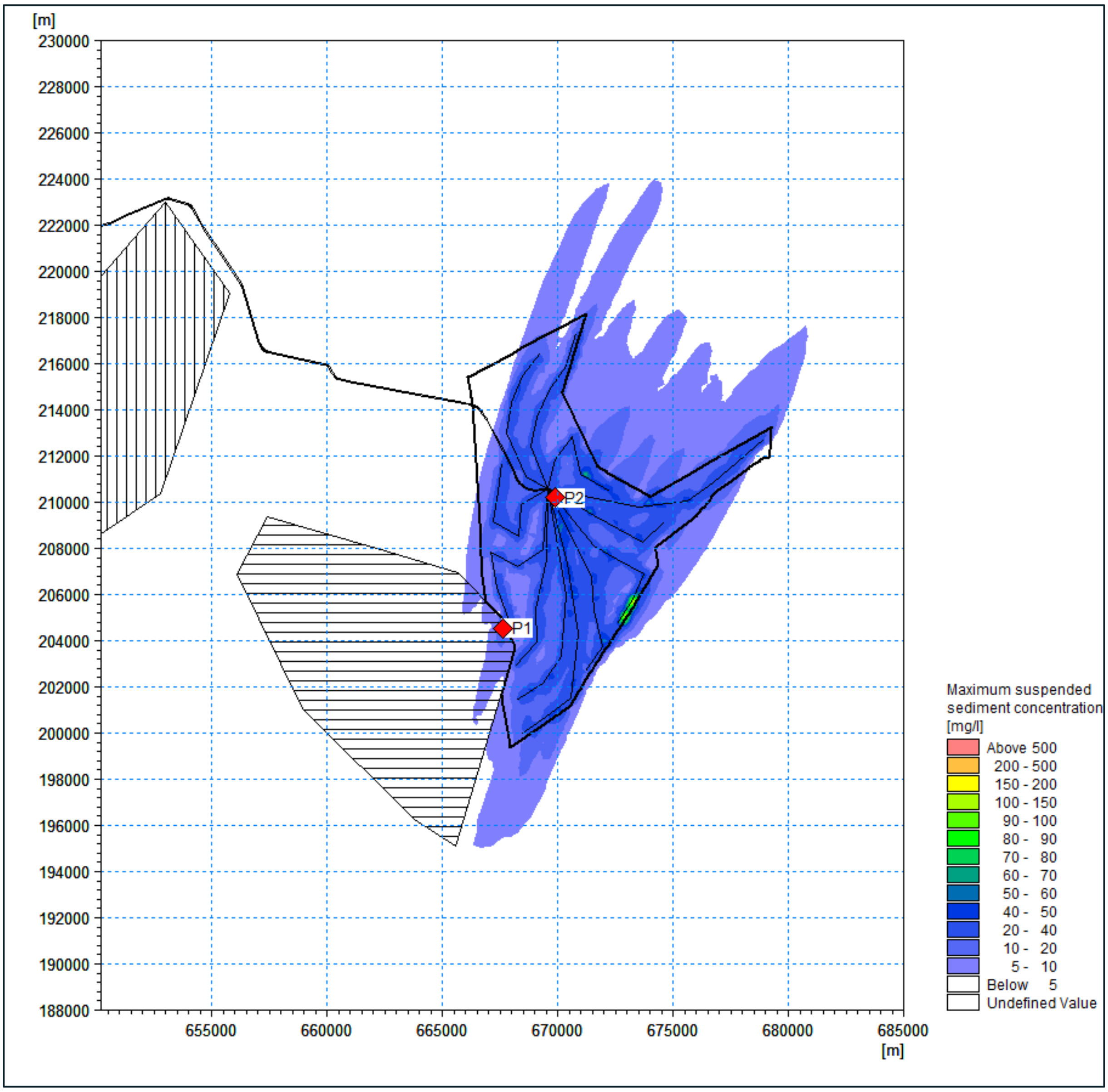

Figure 3.12 Predicted maximum suspended sediment concentrations at the seabed during seabed trenching operations along the array cables (red points = time series extraction points). Vertical hash = Margate and Long Sands SAC. Horizontal hash = Kentish Knock East Marine MCZ

37. Figure 3.13 and Figure 3.14 show the predicted time series of suspended sediment concentrations at the two locations (P1 and P2) shown on Figure 3.12. Maximum near seabed concentrations are predicted to be about 25mg/l at P1 and about 80mg/l at P2, but only for up to one hour before returning to less than ambient concentrations (less than 15mg/l). There are also several recurring peaks either side of the highest maximum peak with lower maximum concentrations of up to 100mg/l at P2. These peaks also dissipate to ambient suspended sediment concentrations in less than two hours.

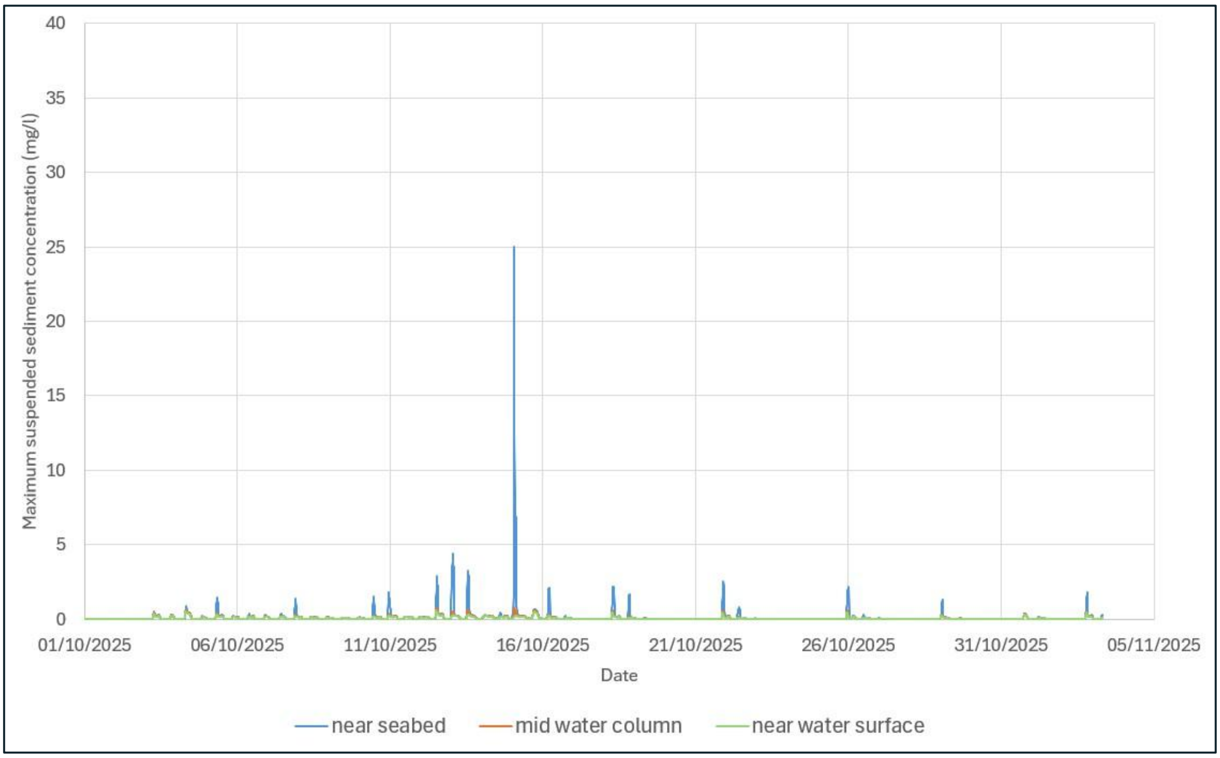

Figure 3.13 Time series of predicted suspended sediment concentrations at P1 (near Kentish Knock East Marine MCZ) during seabed trenching operations along the array cables for near seabed, middle of water column and near water surface

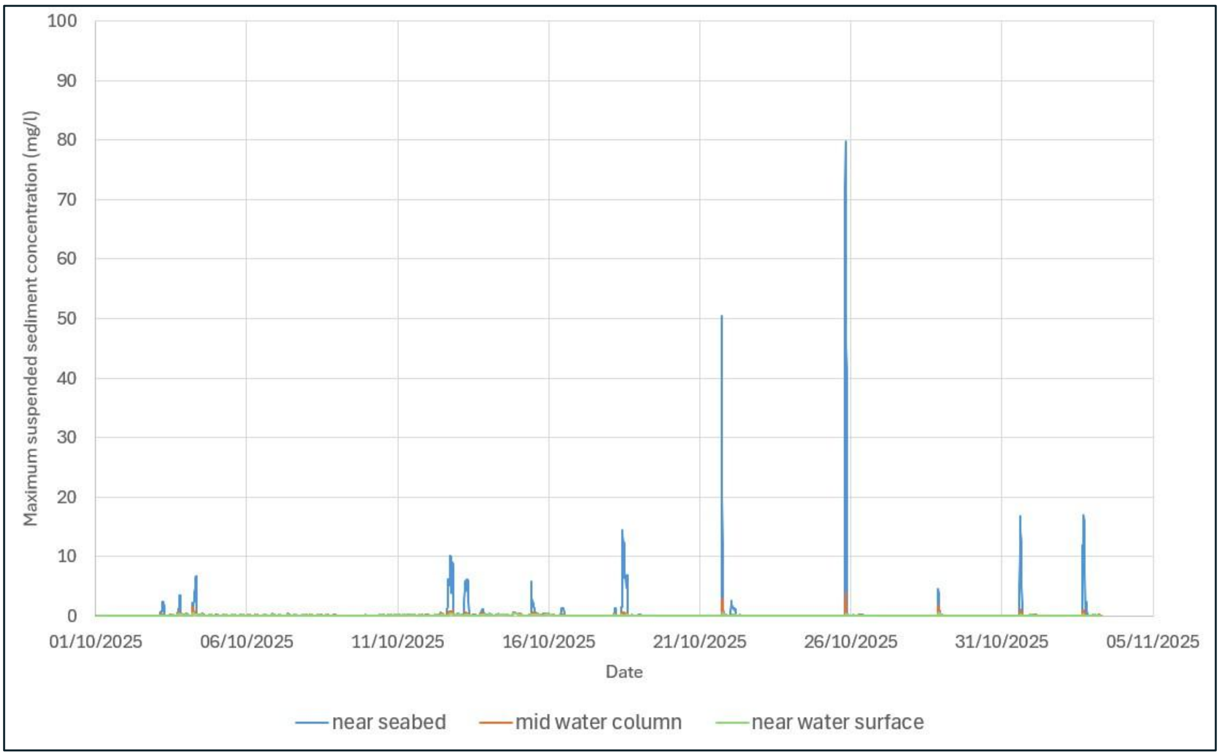

Figure 3.14 Time series of predicted suspended sediment concentrations at P2 (centre of array area) during seabed trenching operations along the array cables for near seabed, middle of water column and near water surface

3.4 Predicted Changes in Seabed Level Due to Array Cable Installation

3.4.1 Levelling of Sand Waves and Megaripples

38. During sand wave and megaripple levelling for the array cables, changes in seabed level greater than 5cm (0.05m) extend 11km to the north-northeast from the northern boundary of the array area and 9km south-southwest from the southern boundary of the array area (Figure 3.15). The greatest changes would occur inside the array area, where 3m of deposition is predicted along the array cables, particularly where they are closer together near the central platform location.

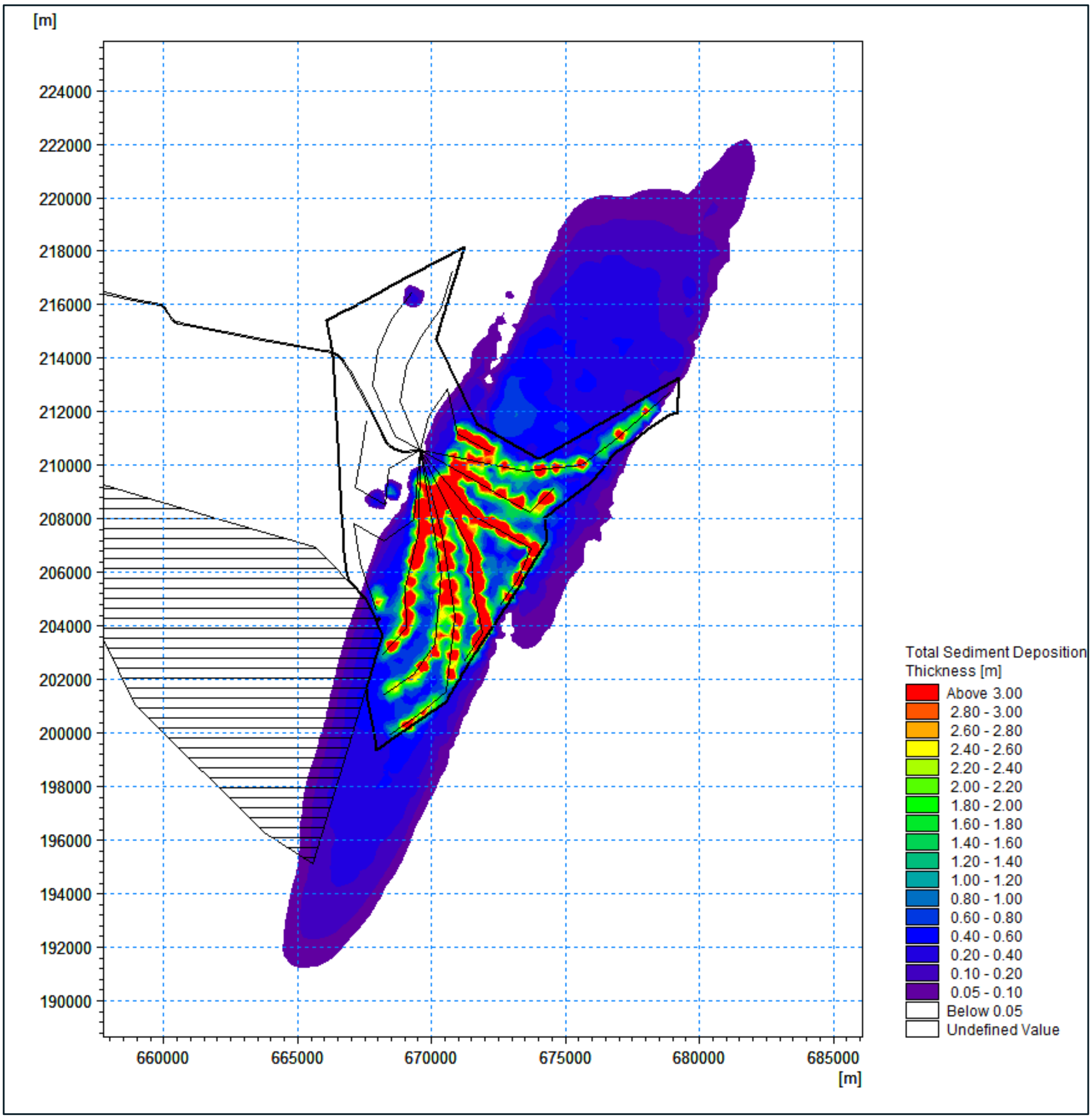

Figure 3.15 Predicted seabed level change during sand wave and megaripple levelling operations along the array cables. Horizontal hash = Kentish Knock East Marine MCZ

3.4.2 Seabed Trenching

39. All sediment deposition induced by seabed trenching along the array cables is predicted to occur within the array area near to the trenching operations. The predicted maximum change is less than 5cm, apart from a small area approximately 500m across, located close to the platform, where the deposition thickness is 5-10cm (Figure 3.16).

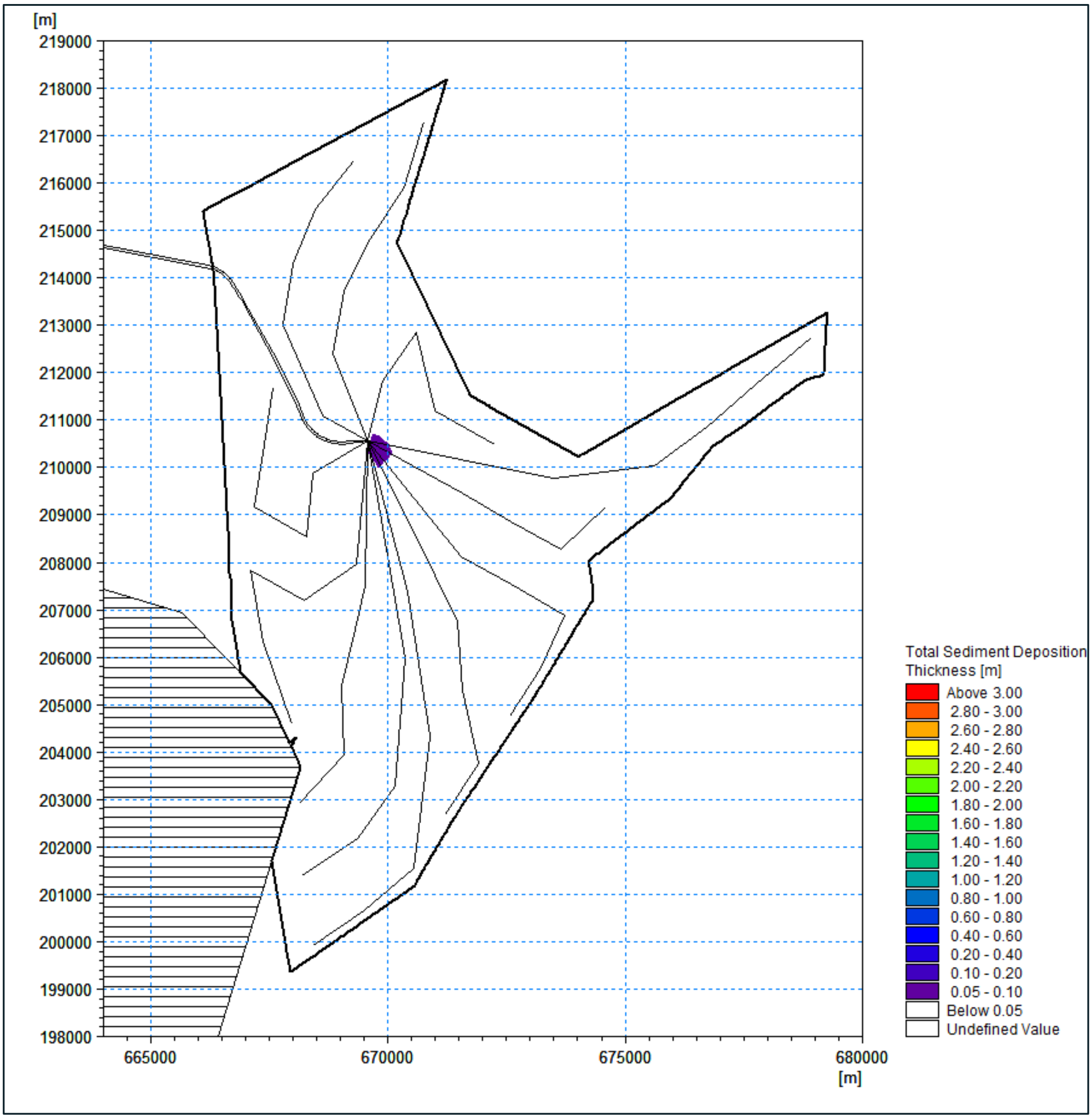

Figure 3.16 Predicted seabed level change during seabed trenching operations along the array cables. Horizontal hash = Kentish Knock East Marine MCZ

3.5 Assessment of the Effects of Installation Activities in the Array Area

3.5.1 Worst-case Scenario

40. The worst-case scenario for installation activities in the array area with respect to marine geology, oceanography and physical processes is sand wave and megaripple levelling for array cable installation. This activity is predicted to release the highest concentrations of suspended sediment over the widest geographical area. The plume sediment is then predicted to deposit on the seabed with the greatest thicknesses, also over the widest geographical area. Hence, the modelling results of this construction activity are considered in the assessment of effects for the array area. The potential effects on marine geology, oceanography and physical processes of seabed trenching for the array cables and activities related to turbine foundation installation (drilling and seabed preparation) will be less than those for sand wave and megaripple levelling.

3.5.2 Receptor Sensitivity

41. Due to the nature of the pressure of an increase in suspended sediment concentrations there is no pathway for effect to the marine geology, oceanography and physical processes for the identified receptor (Kentish Knock East MCZ). Therefore, it is not sensitive to this pressure because the receptor is dominated by processes that are active along the seabed and not affected by suspended sediment in the water column. Hence, marine geology, oceanography and physical processes features within this receptor are only sensitive to varying degrees to the potential change in seabed level induced by the sand wave and megaripple levelling. The value and sensitivity of these receptors to potential changes in seabed level are presented in Table 3.1.

Table 3.1 Sensitivity and value assessment of the identified receptor for marine geology, oceanography and physical processes

RECEPTOR	TOLERANCE	ADAPTABILITY	RECOVERABILITY	VALUE	SENSITIVITY
Kentish Knock East MCZ	Negligible	Negligible	Negligible	High	Negligible

3.5.3 Impact Magnitude

42. The worst-case changes in seabed level due to the installation of the array cables are likely to have the magnitudes of impact shown in Table 3.2. Deposition is predicted to occur across the eastern boundary of Kentish Knock East MCZ (Figure 3.15). Here, the maximum predicted seabed level change is about 0.6m.

Table 3.2 Magnitude of impact on seabed level under the worst-case scenario for array cable installation

LOCATION	SCALE	DURATION	FREQUENCY	REVERSIBILITY	MAGNITUDE OF IMPACT
Near-field*	High	Negligible	Negligible	Negligible	Medium
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

*The near-field impacts are confined to a small area likely to be of the order up to 500m from each array cable

3.5.4 Effect Significance

43. The impacts on suspended sediment concentrations due to cable installation do not directly affect the identified receptor for marine geology, oceanography and physical processes (Kentish Knock East MCZ), so there is no change associated with the Project. No significant effect will occur. However, the impacts on suspended sediment concentrations have the potential to affect the receptor through deposition.

44. The worst-case disturbance effects along the array cables persist in the water column for up to 21 hours, before depositing to form a layer on the seabed (less than 1m with local hotspots along the array cable routes themselves of 3m) (Figure 3.15). However, it is anticipated that under the prevailing hydrodynamic conditions, this sediment would be readily re-mobilised. The deposited sediment would be continually re-suspended to reduce the thickness even further to a point where it will be effectively zero. This would be the longer-term outcome once the sediment supply from array cable installation has ceased.

45. This means that given these very small magnitude changes in seabed level arising from array cable installation, the effects on the identified receptors would be **not significant**. Hence, the overall significance of the effect of export cable installation activities under a worst-case scenario on seabed level changes for the identified receptors is **negligible adverse** (no significant effect).

3.6 Predicted Changes in Near Seabed Suspended Sediment Concentrations Due to Disposal in the Array Area

46. The sediment for disposal has been released in the model at a worst case location for sediment dispersion along the northeast boundary of the array area at four states of the tide: slack water near high water during neap tide, slack water near low water during neap tide, peak flood during spring tide, and peak ebb during spring tide. Particle size data using sediment size of ‘Zones 1 and 3’ and ‘Sand waves’ have been modelled at each of these tidal states.

47. The worst-case scenario for disposal in the array area with respect to marine geology, oceanography and physical processes is disposal using sediment size of ‘Zones 1 and 3’. This phase is predicted to release the highest concentrations of suspended sediment over the widest geographical area. Hence, the modelling results of this disposal activity are considered here.

48. During slack water near high water during neap tide, maximum suspended sediment concentrations greater than 5mg/l at any time throughout the simulation are predicted to extend about 12km northeast from the release point across a footprint about 4km wide (Figure 3.17). The highest concentrations greater than 500mg/l are close to the release point.

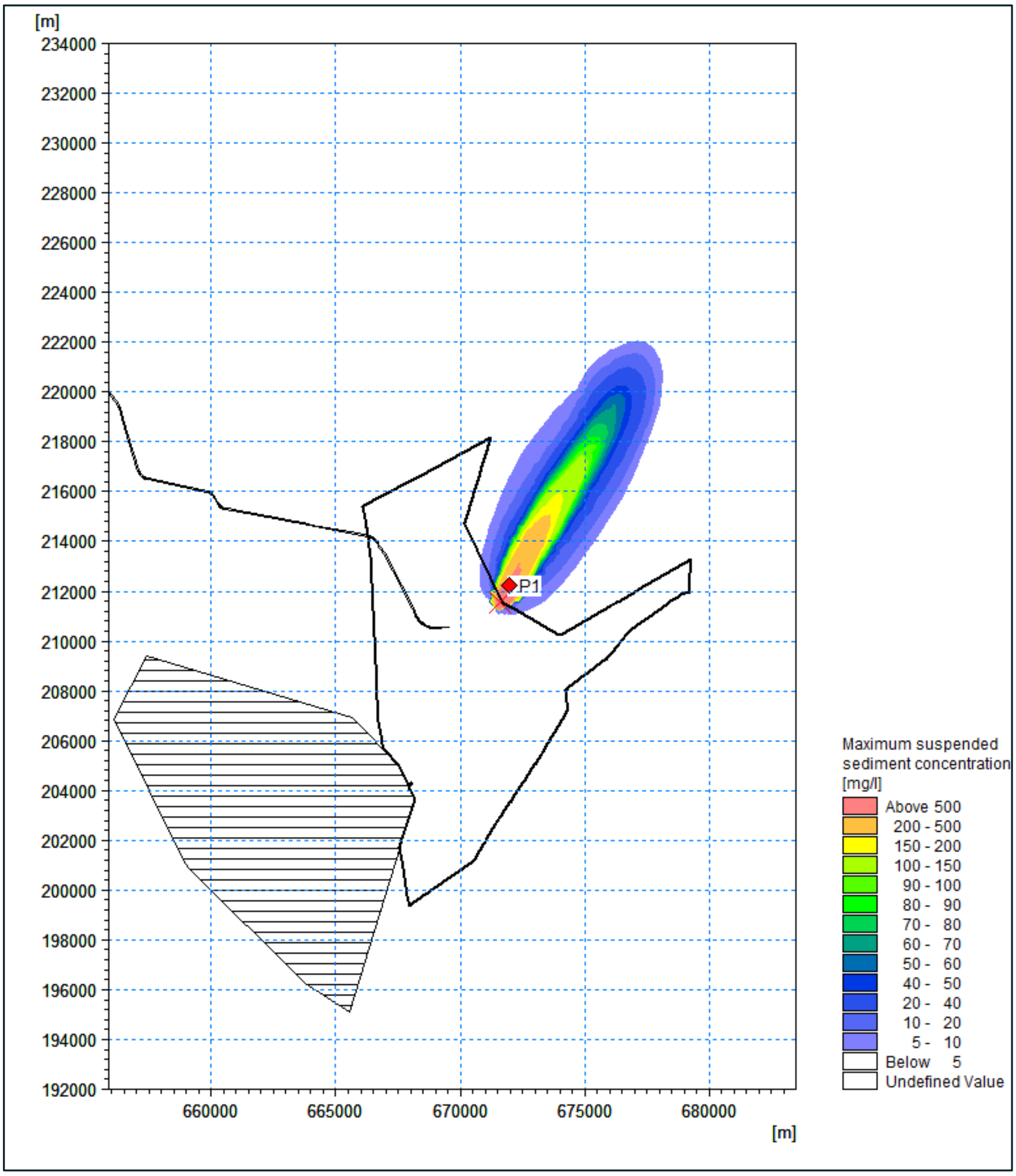

Figure 3.17 Predicted maximum suspended sediment concentrations at the seabed during disposal at slack water near high water during neap tide (red point = time series extraction point). Horizontal hash = Kentish Knock East Marine MCZ

49. Figure 3.18 shows the predicted time series of suspended sediment concentrations at location P1 shown on Figure 3.17. Maximum near seabed concentrations are predicted to be about 2,200mg/l, but only for two hours before returning to less than ambient concentrations (less than 15mg/l).

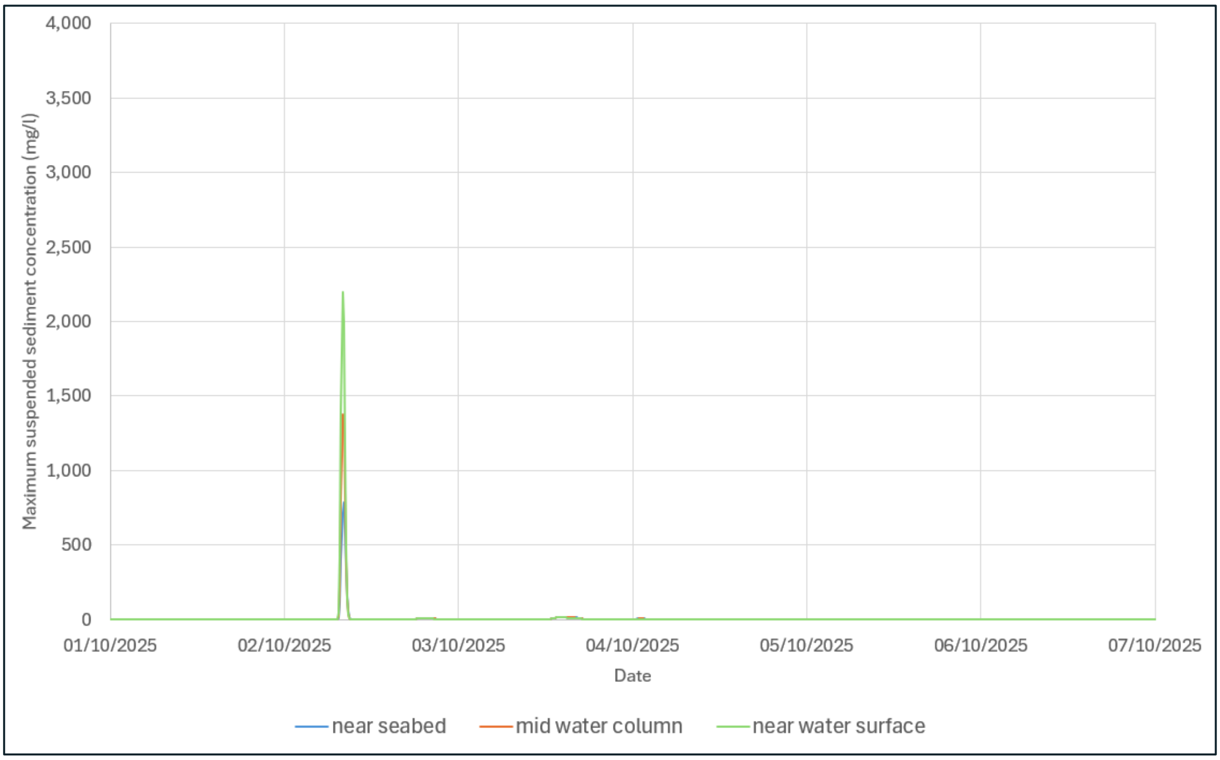

Figure 3.18 Time series of predicted suspended sediment concentrations at P1 (near the release point) during disposal at slack water near high water during neap tide for near seabed, middle of water column and near water surface

50. During slack water near low water during neap tide, maximum suspended sediment concentrations at any time throughout the simulation are predicted to reach greater than 500mg/l local to release point (Figure 3.19). The plume maximums at the seabed that are greater than 5mg/l are predicted to extend south-southeast across the array area for about 12km across a footprint about 4km wide. A smaller area of maximums greater than 5mg/l is predicted to extend north-northeast for about 3km from the release point.

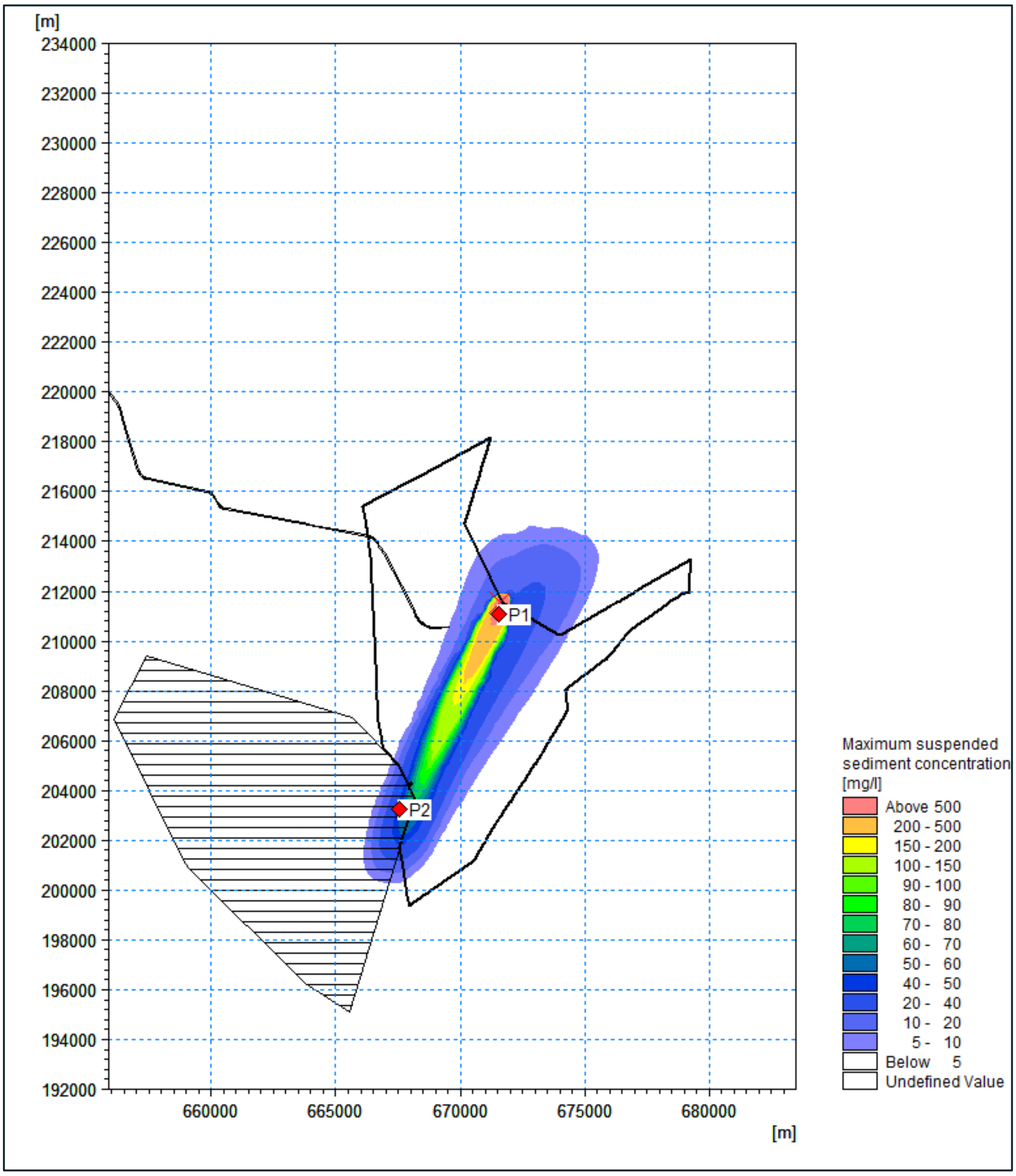

Figure 3.19 Predicted maximum suspended sediment concentrations at the seabed during disposal at slack water near low water during neap tide (red points = time series extraction points). Horizontal hash = Kentish Knock East Marine MCZ

51. Figure 3.20 and Figure 3.21 show the predicted time series of suspended sediment concentrations at the two locations (P1 and P2) shown on Figure 3.19. Maximum near seabed suspended sediment concentrations of about 4,300mg/l at P1 and 45mg/l at P2 are predicted, but only for 2-4 hours before returning to less than ambient concentrations (less than 15mg/l).

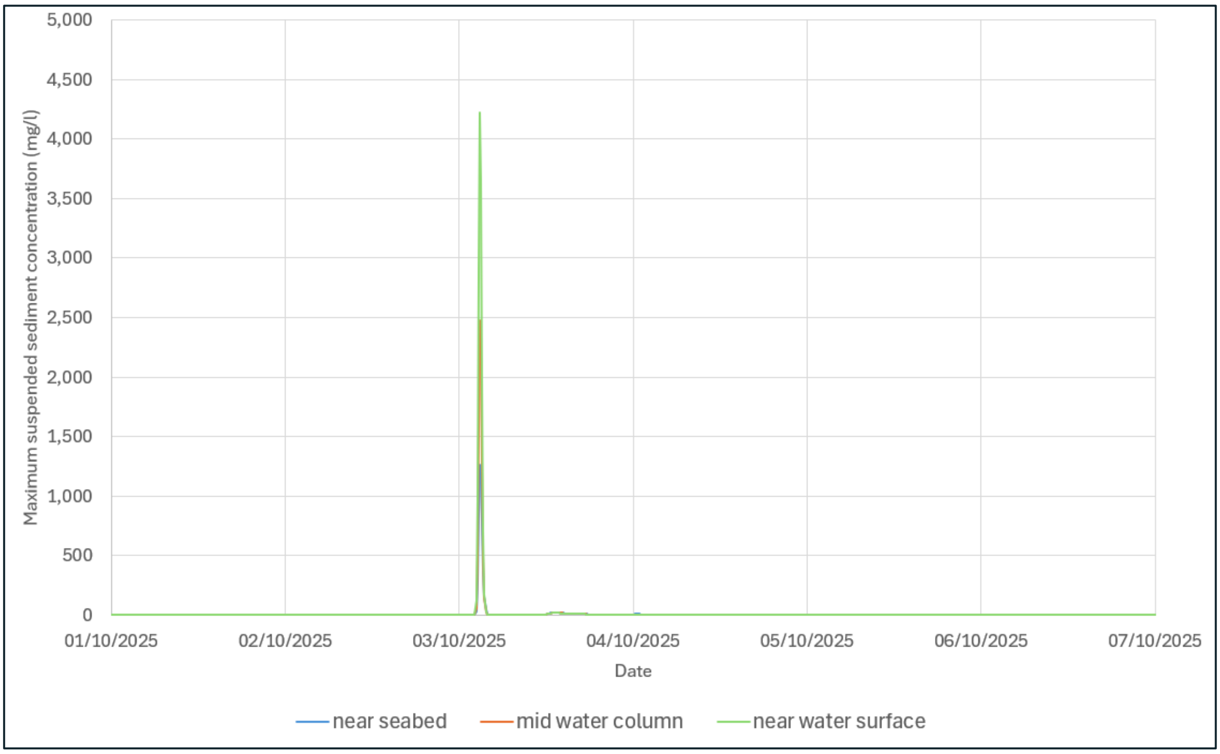

Figure 3.20 Time series of predicted suspended sediment concentrations at P1 (near the release point) during disposal at slack water near low water during neap tide for near seabed, middle of water column and near water surface

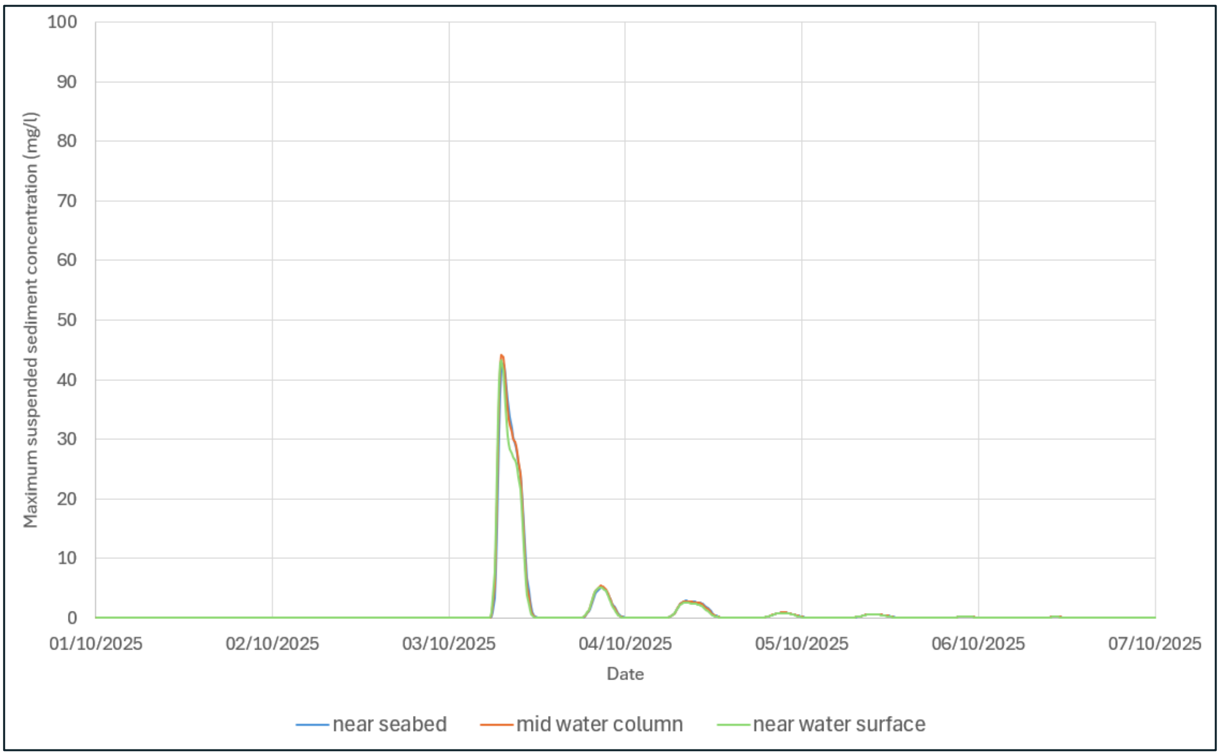

Figure 3.21 Time series of predicted suspended sediment concentrations at P2 (near Kentish Knock East Marine MCZ) during disposal at slack water near low water during neap tide for near seabed, middle of water column and near water surface

52. During the peak flood current of the spring tide, maximum suspended sediment concentrations at any time throughout the simulation are predicted to reach greater than 500mg/l local to release point and south-southeast across the array area for about 5km (Figure 3.22). The plume maximums at the seabed that are greater than 5mg/l are predicted to extend south-southeast across the array area for about 9.5km across a footprint about 4km wide. The maximum concentrations greater than 5mg/l also extend about 14km north-northeast from the release point (6km wide), although the maximum concentrations are less than 40mg/l.

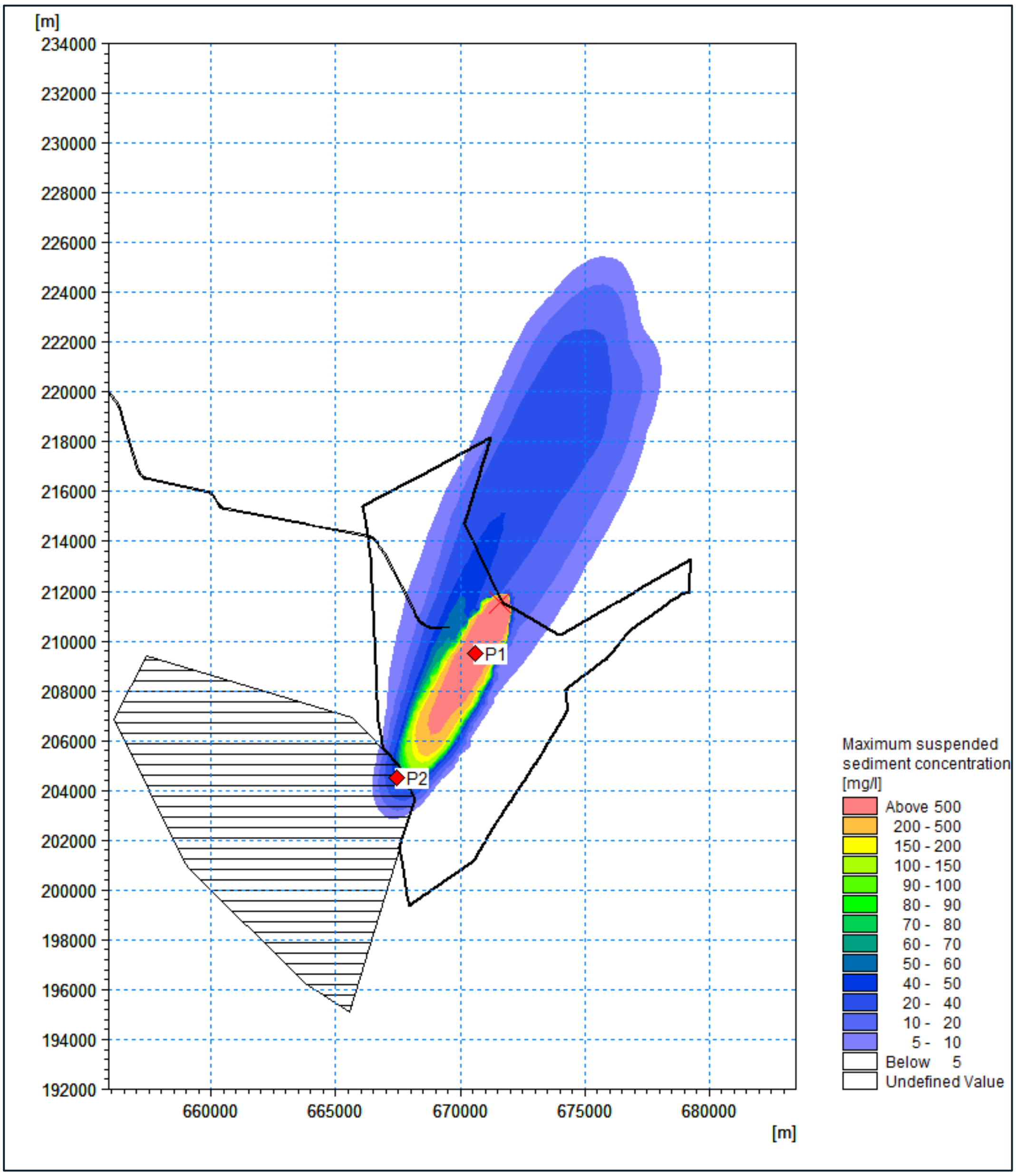

Figure 3.22 Predicted maximum suspended sediment concentrations at the seabed during disposal at peak flood current of spring tide (red points = time series extraction points). Horizontal hash = Kentish Knock East Marine MCZ

53. Figure 3.23 and Figure 3.24 show the predicted time series of suspended sediment concentrations at the two locations (P1 and P2) shown on Figure 3.22. Maximum near seabed suspended sediment concentrations of about 3,000mg/l at P1 and 45mg/l at P2 are predicted, but only for two hours before returning to less than ambient concentrations (less than 15mg/l).

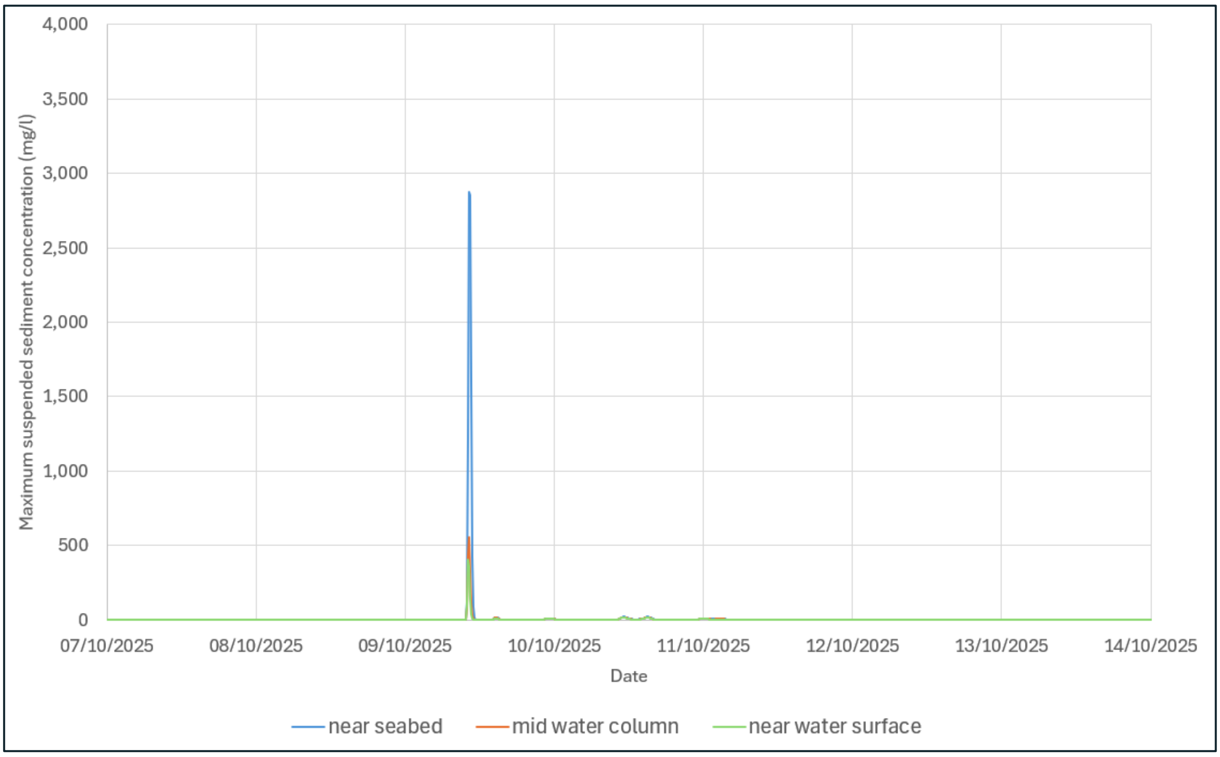

Figure 3.23 Time series of predicted suspended sediment concentrations at P1 (near the release point) during disposal at peak flood current of spring tide for near seabed, middle of water column and near water surface

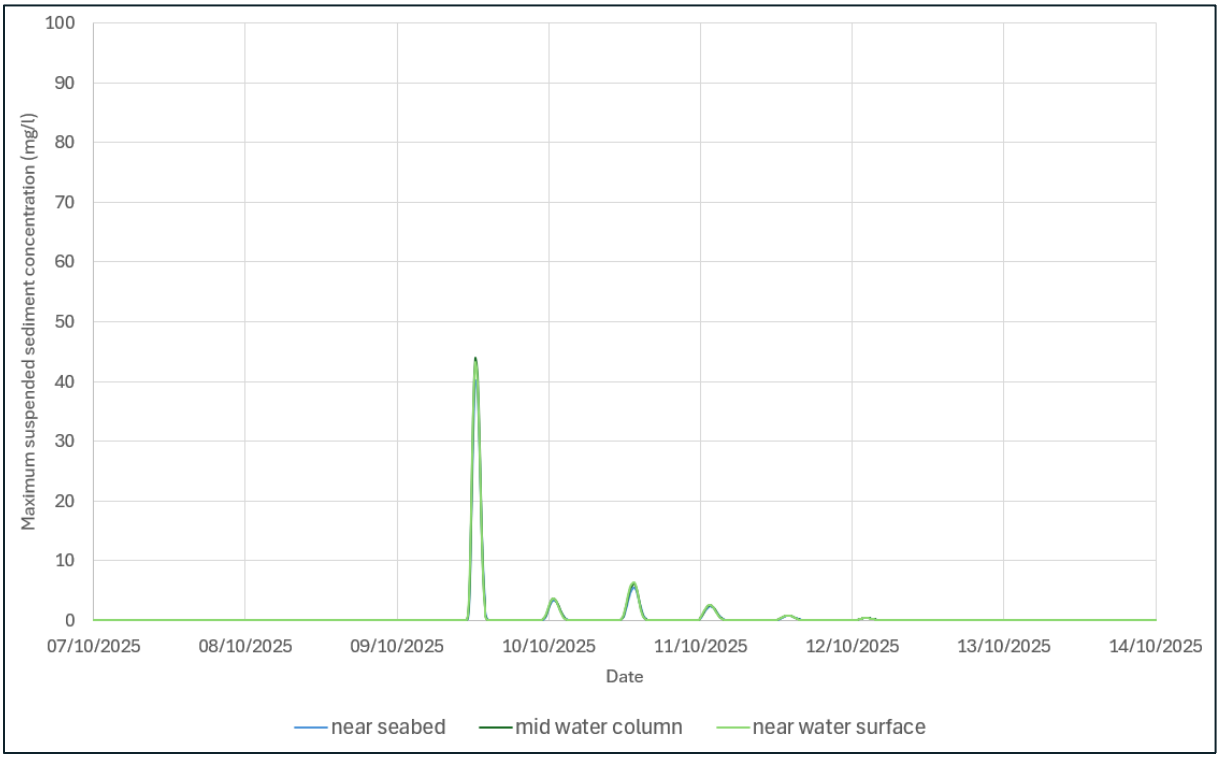

Figure 3.24 Time series of predicted suspended sediment concentrations at P2 (near the release point) during disposal at peak flood current of spring tide for near seabed, middle of water column and near water surface

54. During the peak ebb current of the spring tide, maximum suspended sediment concentrations at any time throughout the simulation are predicted to reach greater than 500mg/l local to release point and north-northeast for about 7km (Figure 3.25). The plume maximums at the seabed that are greater than 5mg/l are predicted to extend north-northeast for about 16km from the release point across a footprint about 8km wide. The maximum concentrations greater than 5mg/l also extend about 9km south-southeast across the array area from the release point (5.5km wide), although the maximum concentrations are less than 40mg/l.

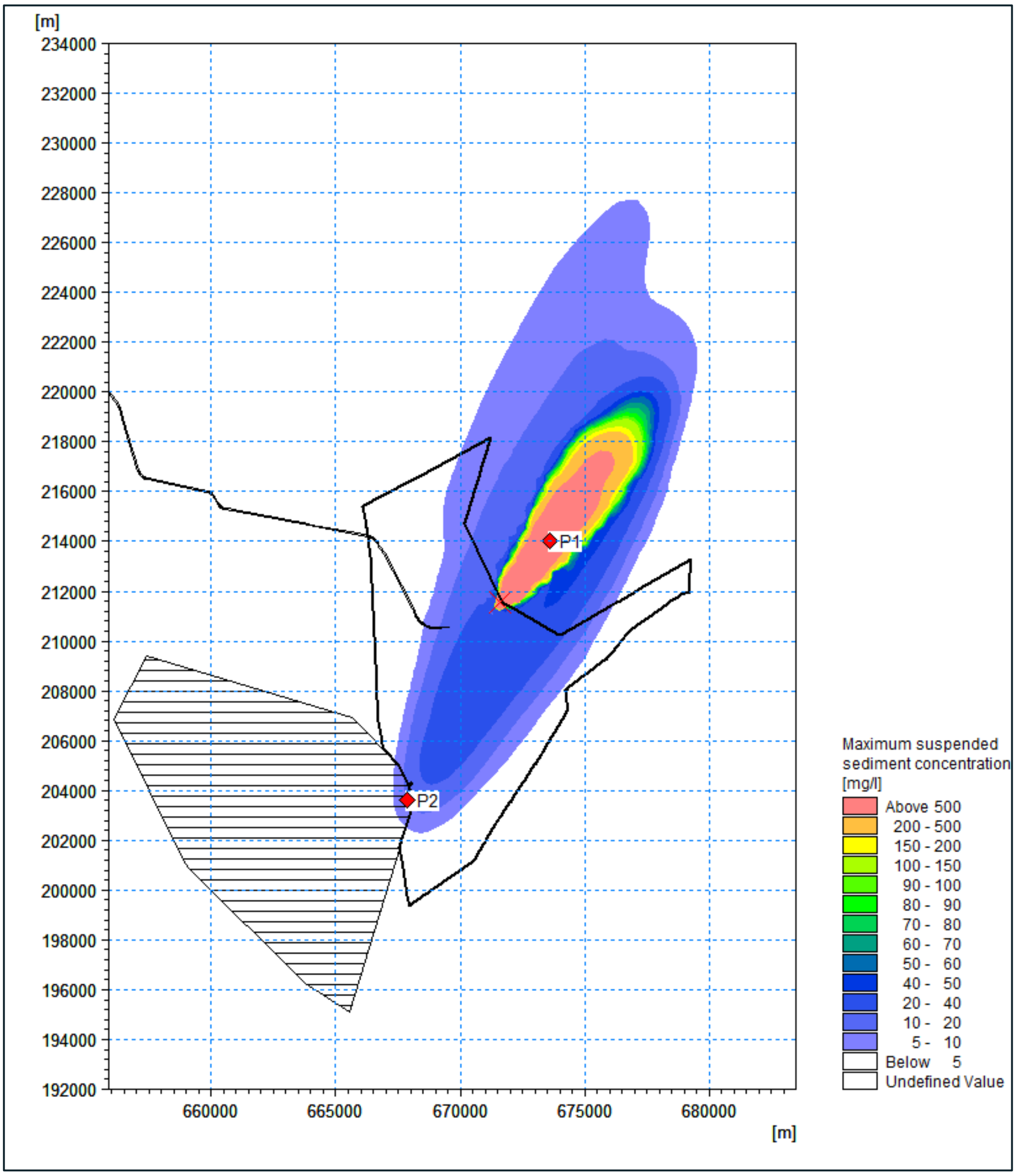

Figure 3.25 Predicted maximum suspended sediment concentrations at the seabed during disposal at peak ebb current of spring tide (red points = time series extraction points). Horizontal hash = Kentish Knock East Marine MCZ

55. Figure 3.26 and Figure 3.27 show the predicted time series of suspended sediment concentrations at the two locations (P1 and P2) shown on Figure 3.25. Maximum near seabed suspended sediment concentrations of about 3,000mg/l at P1 and 22mg/l at P2 are predicted, but only for 1-2 hours before returning to less than ambient concentrations (less than 15mg/l).

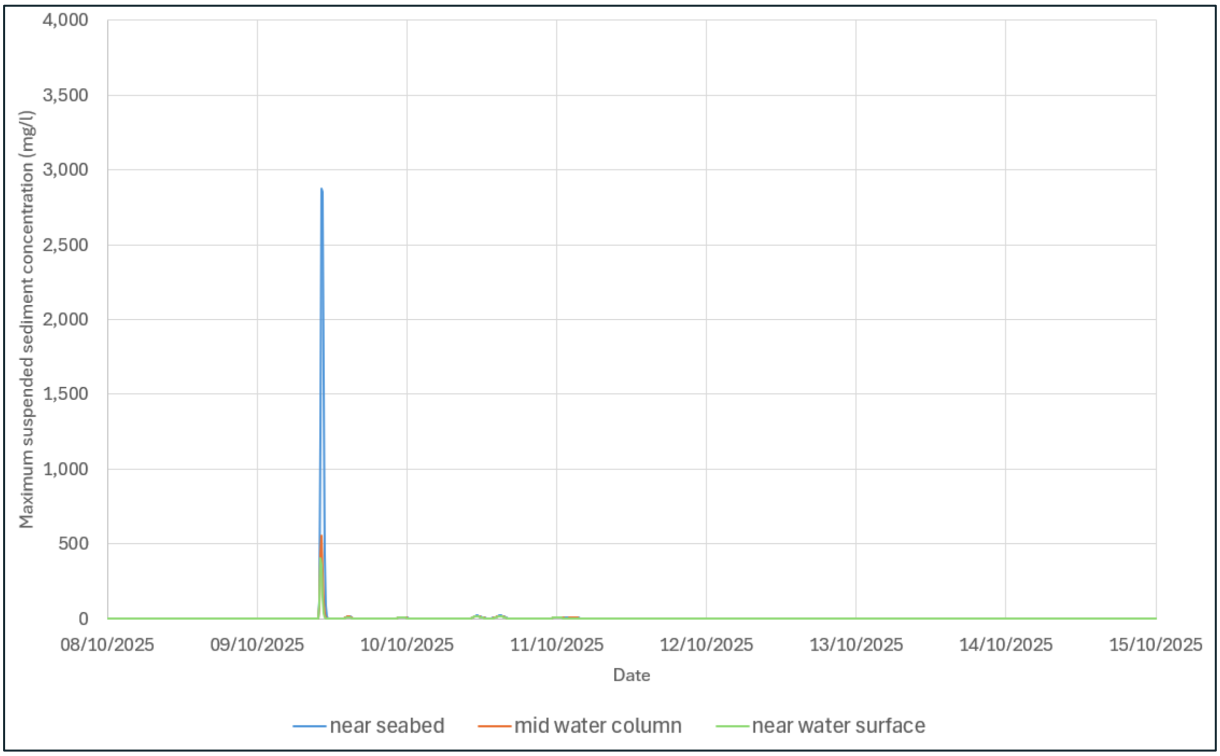

Figure 3.26 Time series of predicted suspended sediment concentrations at P1 (near the release point) during disposal at peak ebb current of spring tide for near seabed, middle of water column and near water surface

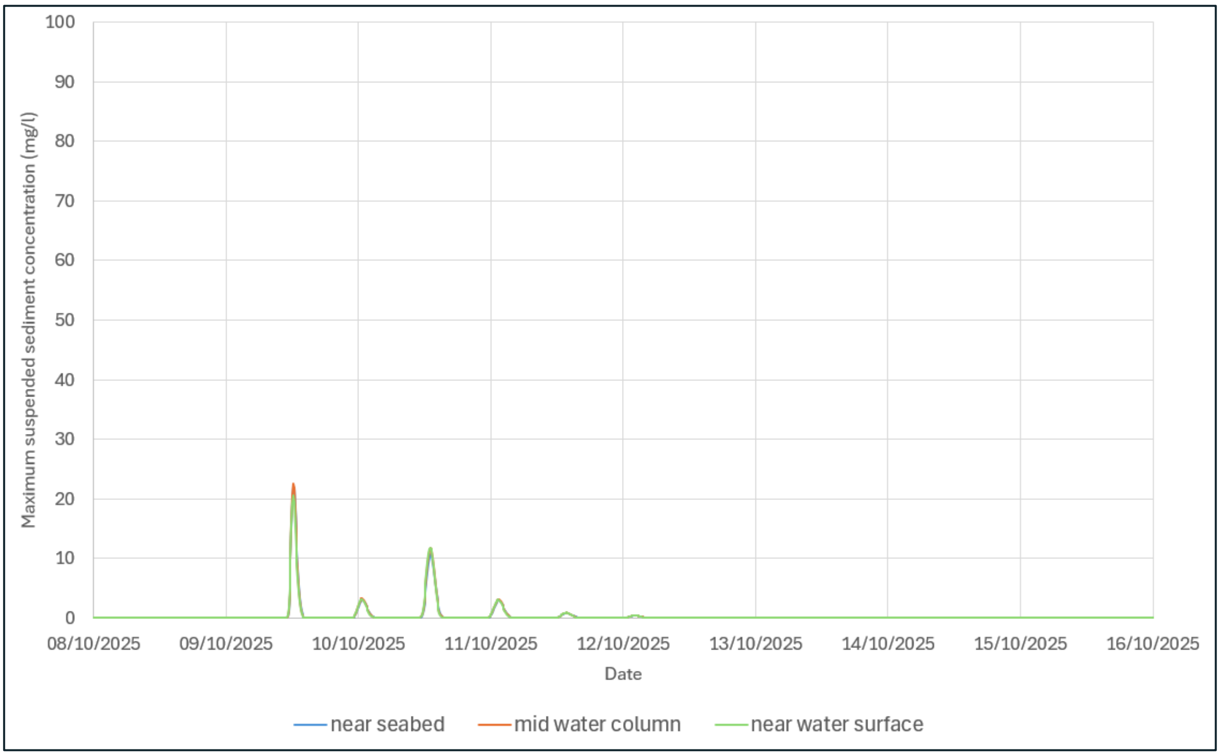

Figure 3.27 Time series of predicted suspended sediment concentrations at P2 (near the release point) during disposal at peak ebb current of spring tide for near seabed, middle of water column and near water surface

3.7 Predicted Changes in Seabed Level Due to Disposal in the Array Area

56. Figure 3.28 and Figure 3.29 show the changes in seabed level greater than 5cm (0.05m) which are predicted to occur during sediment disposal during slack water near high water and low water, respectively, during neap tide. In both cases, all sediment deposition is local to the release point extending no further than 750m in diameter with concentrations less than 0.5m.

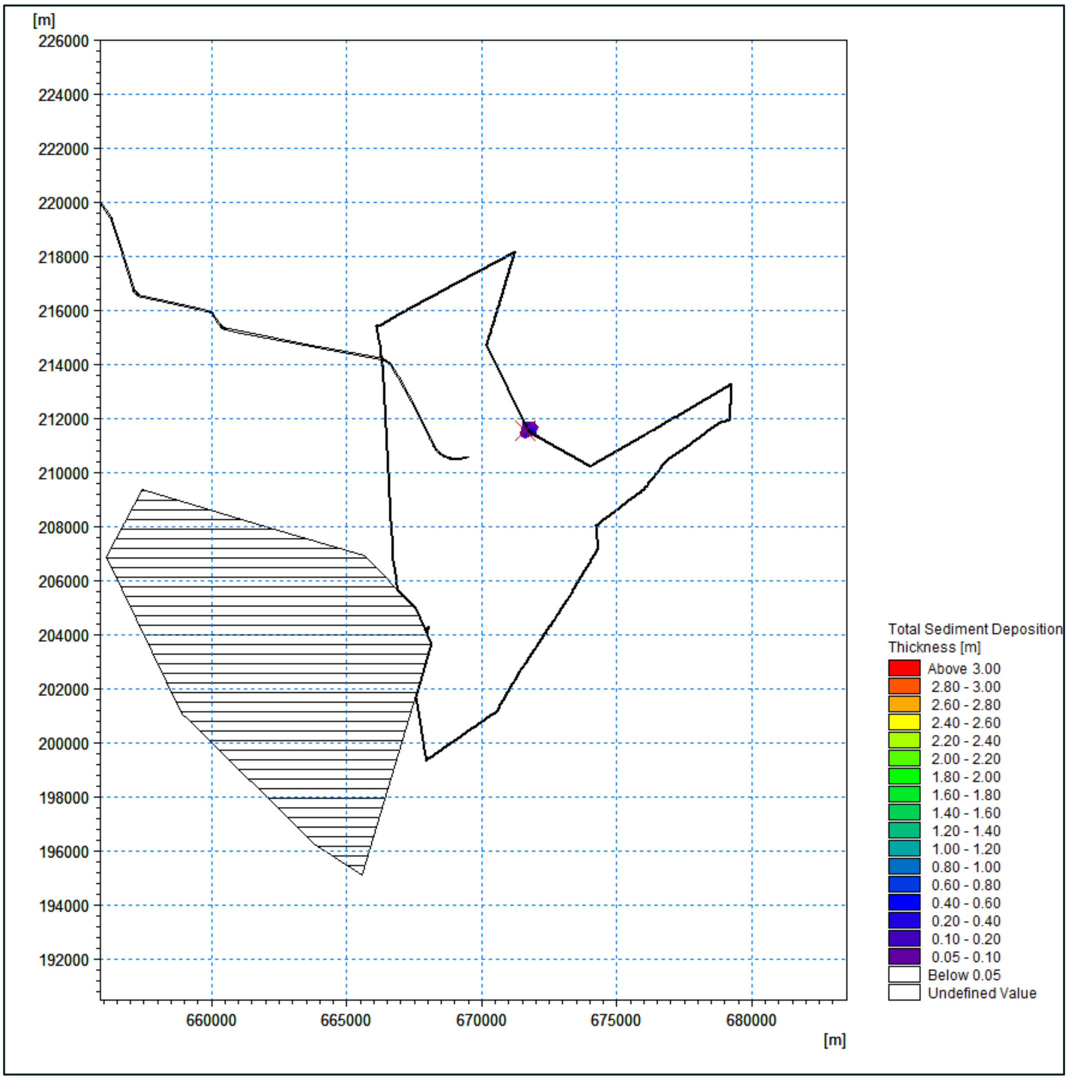

Figure 3.28 Predicted seabed level change during disposal at slack water near high water during neap tide. Horizontal hash = Kentish Knock East Marine MCZ

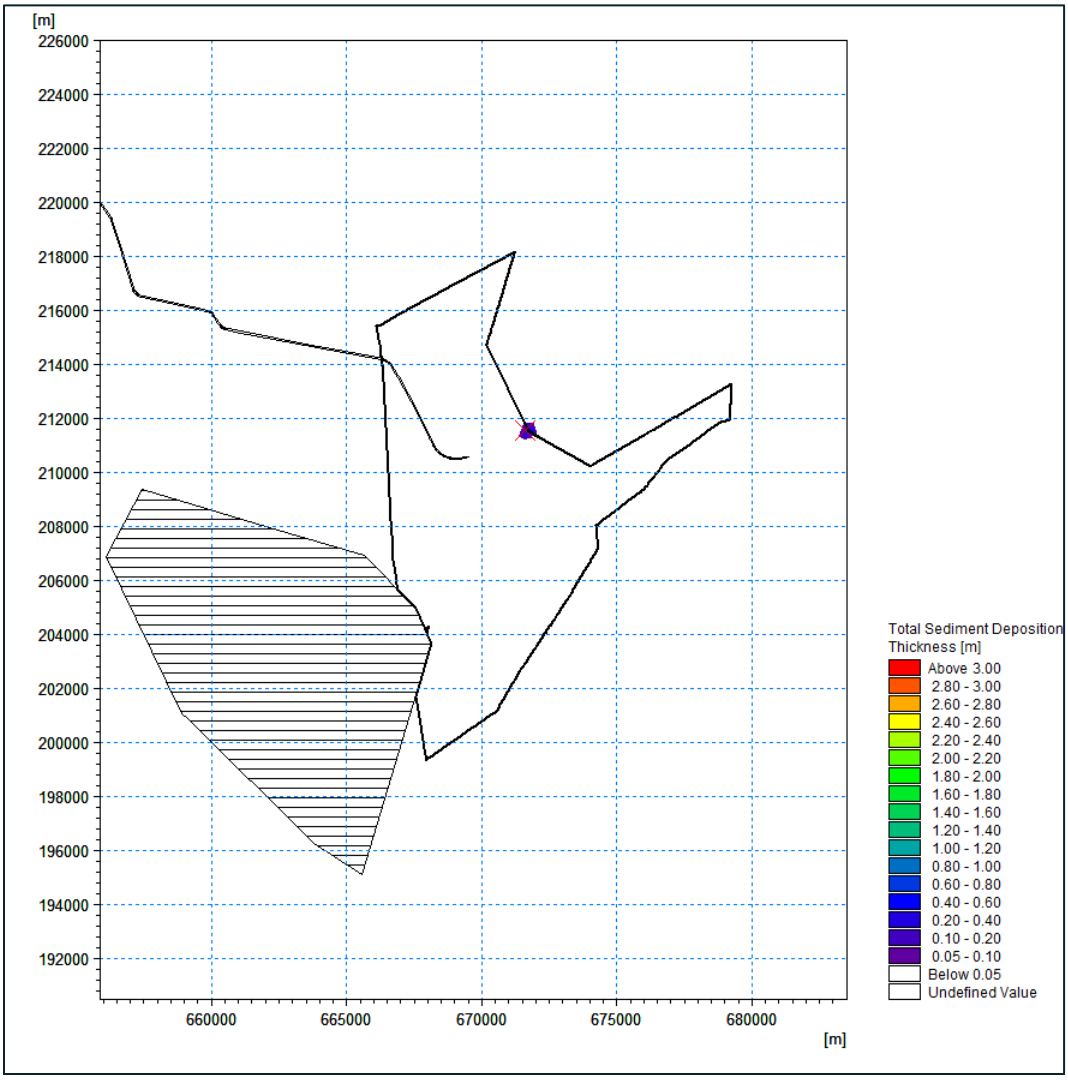

Figure 3.29 Predicted seabed level change during disposal at slack water near low water during neap tide. Horizontal hash = Kentish Knock East Marine MCZ

57. Figure 3.30 and Figure 3.31 show the changes in seabed level greater than 5cm (0.05m) which are predicted to occur during sediment disposal during peak flood current and peak ebb current, respectively, during spring tide. In both cases, sediment deposition is predicted to be less than 5cm.

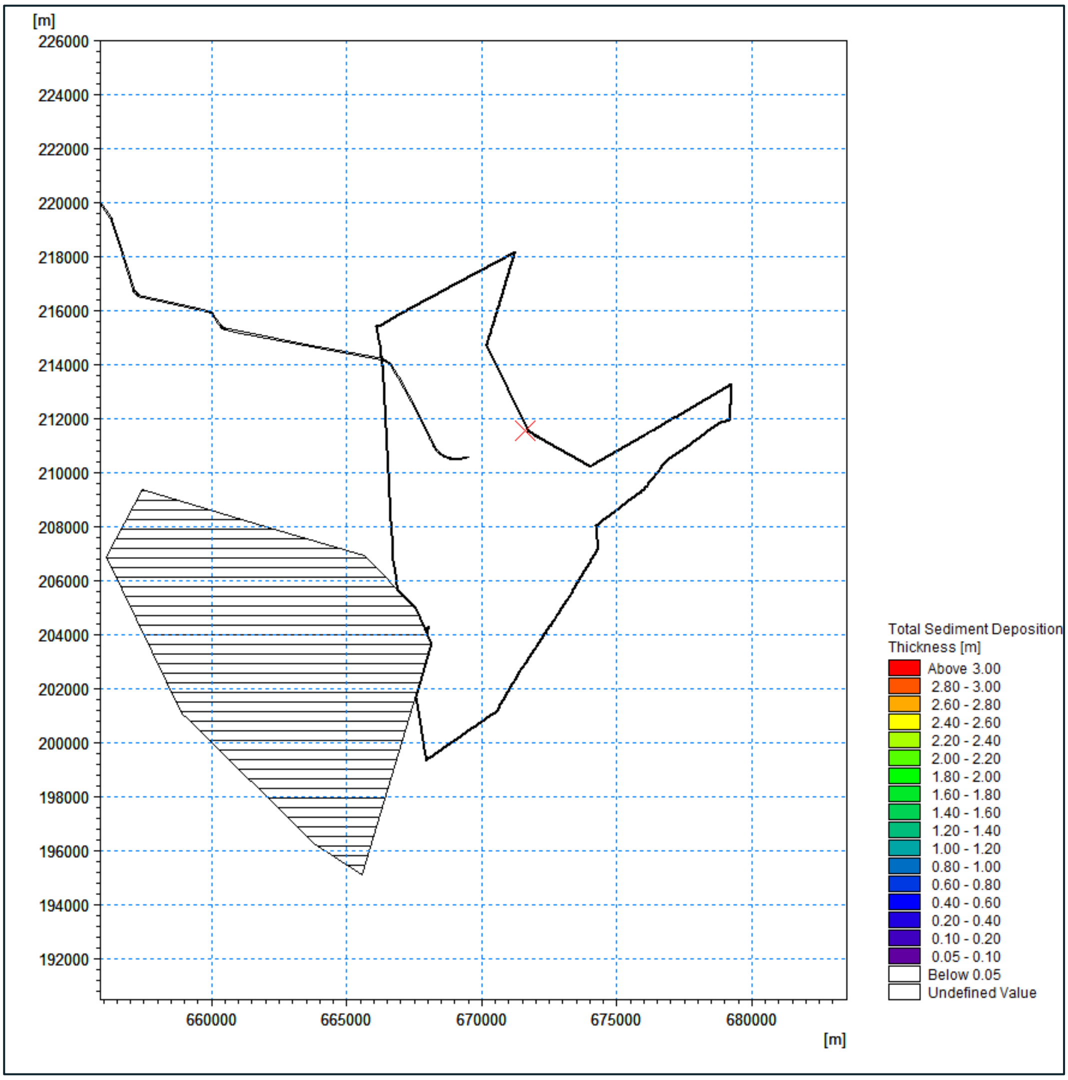

Figure 3.30 Predicted seabed level change during disposal at peak flood current of spring tide. Horizontal hash = Kentish Knock East Marine MCZ

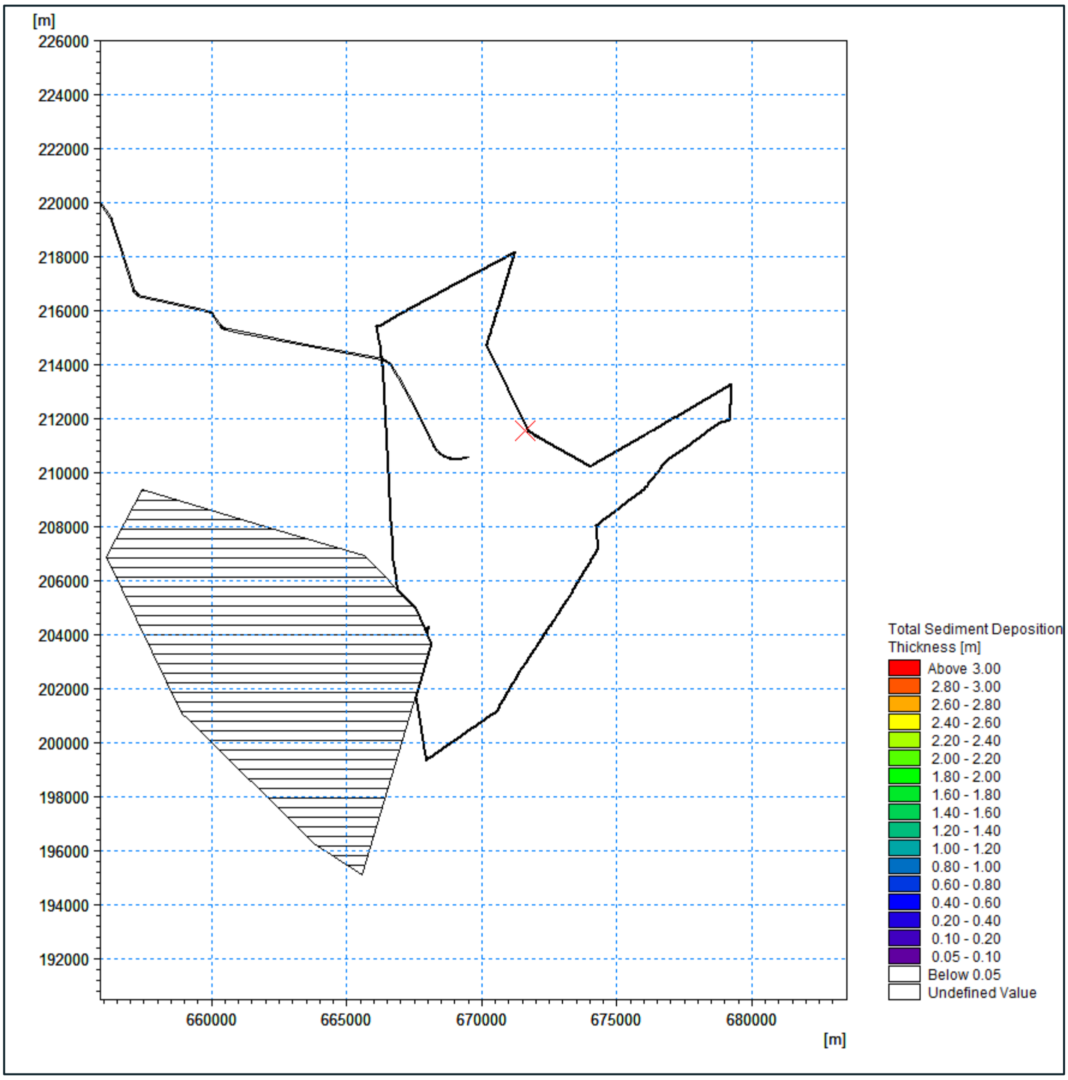

Figure 3.31 Predicted seabed level change during disposal at peak ebb current of spring tide. Horizontal hash = Kentish Knock East Marine MCZ

3.8 Assessment of the Effects of Disposal in the Array Area

58. The worst-case scenario for disposal in the array area with respect to marine geology, oceanography and physical processes is less than the worst case scenario for sand wave and megaripple levelling using mass flow excavation (Sections 3.1.2 and 3.3.1). If mass flow excavation is used, sediment disposal is not required. Hence, the assessment of effects of installation activities in the array area, described in Section 3.5represents the worst case scenario.

4 Operational Phase – the Project

4.1 Predicted Changes in Tidal Current Speeds and Bed Shear Stresses Due to the Presence of Turbines

4.1.1 Predicted Changes in Tidal Current Speeds

59. The predicted changes in tidal current speeds due to the presence of the smallest turbines and two platforms during spring tides are less than +/-0.08m/s. This translates to less than 3% of the baseline values of current speed (Figure 4.1 and Figure 4.2).

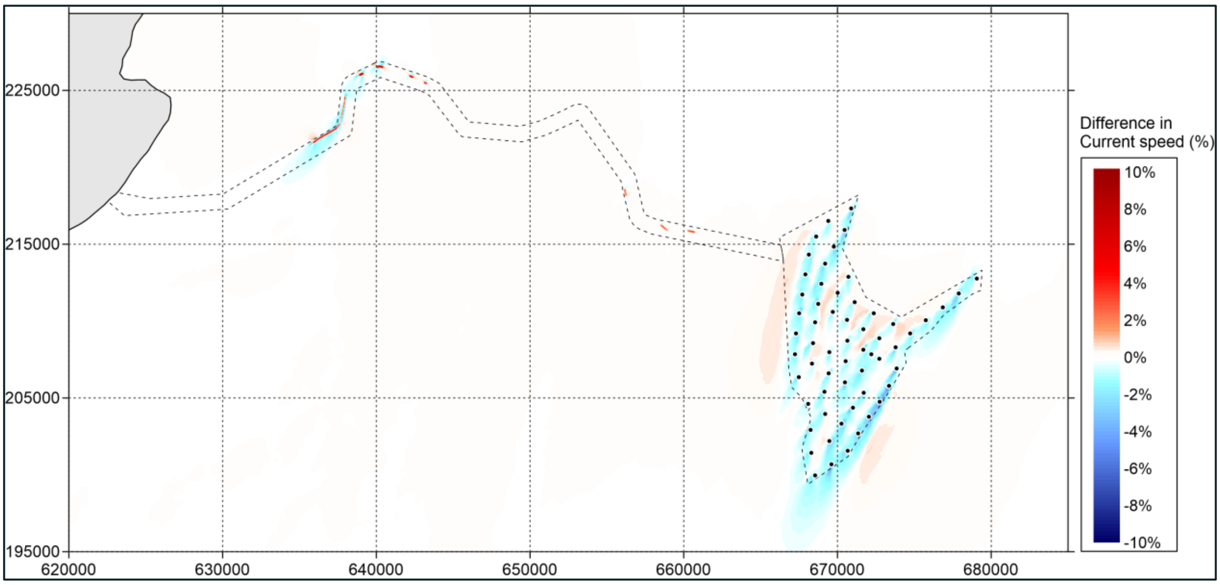

Figure 4.1 Predicted percentage change in current speeds due to the Project during peak flood of spring tide (positive indicates an increase in current speed and negative indicates a decrease in current speed)

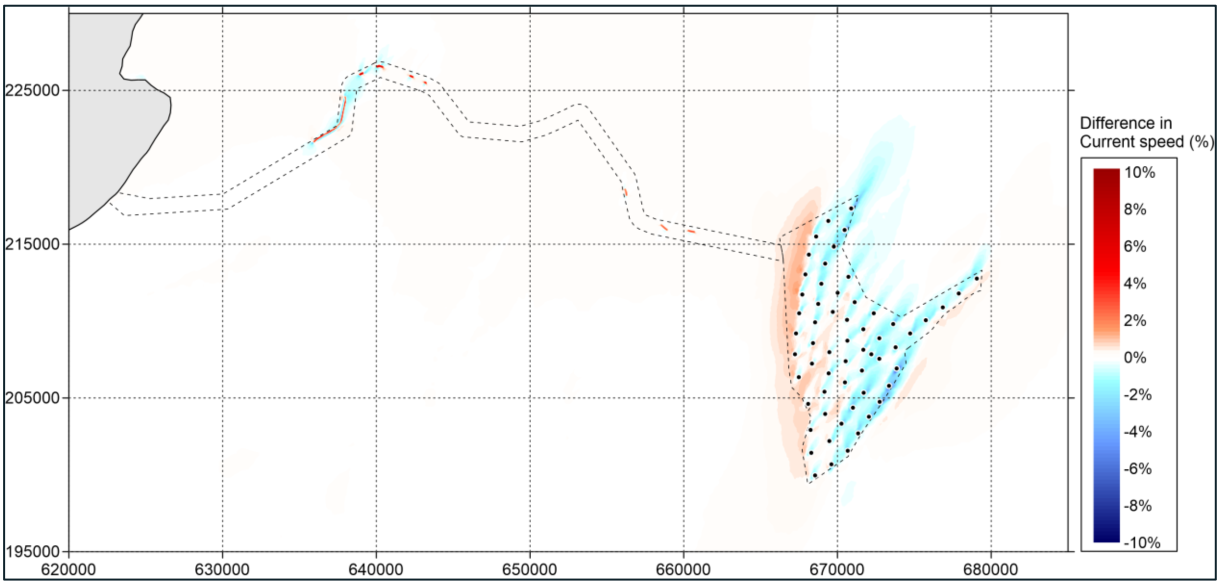

Figure 4.2 Predicted percentage change in current speeds due to the Project during peak ebb of spring tide (positive indicates an increase in current speed and negative indicates a decrease in current speed)

4.1.2 Predicted Changes in Bed Shear Stresses

60. The predicted changes in bed shear stresses (sediment transport potential) due to the presence of the smallest turbines and two platforms during spring tides are less than +/-0.5N/m^2. This translates to less than 5% of the baseline values of bed shear stress (Figure 4.3 and Figure 4.4).

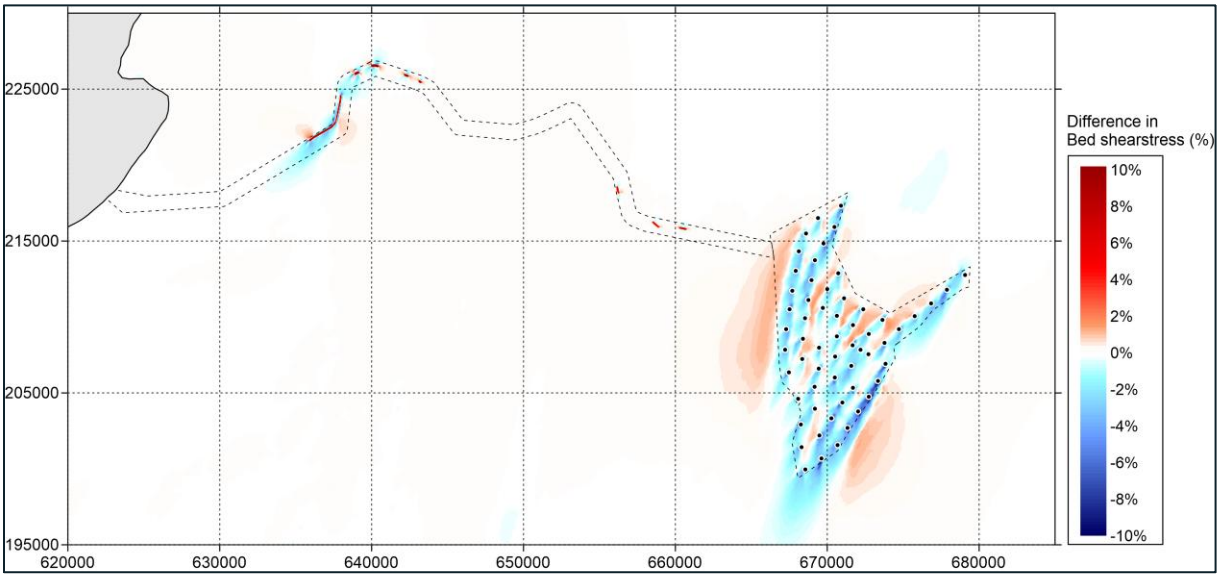

Figure 4.3 Predicted percentage change in bed shear stresses due to the Project during peak flood of spring tide (positive indicates an increase in current speed and negative indicates a decrease in current speed)

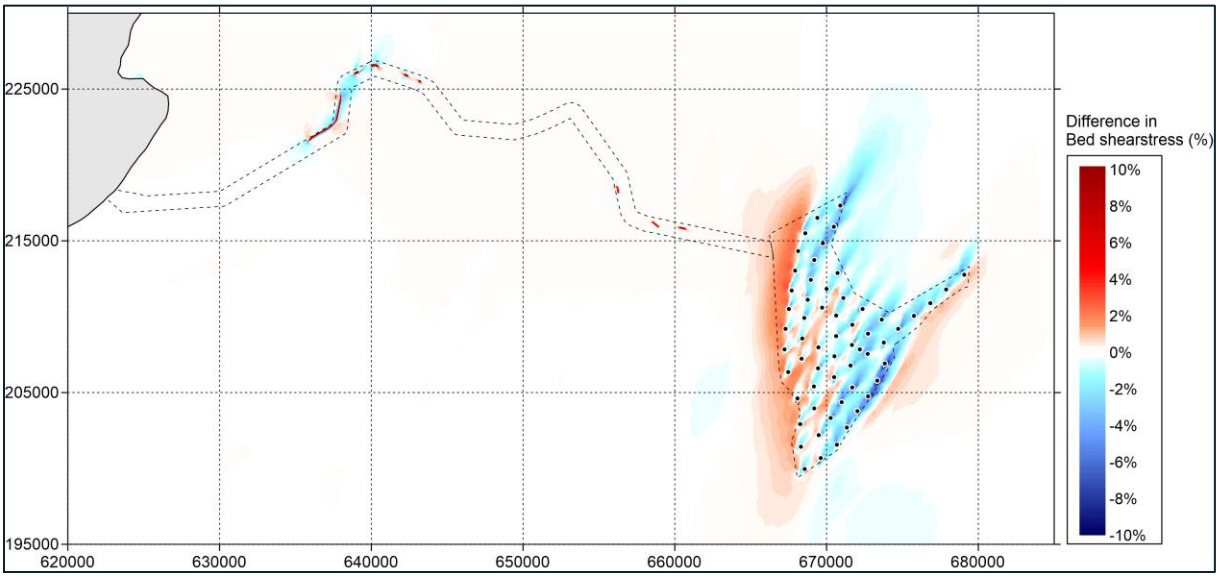

Figure 4.4 Predicted percentage change in bed shear stresses due to the Project during peak ebb of spring tide (positive indicates an increase in current speed and negative indicates a decrease in current speed)

4.2 Predicted Changes in Tidal Current Speeds and Bed Shear Stresses Due to the Presence of Export Cable Protection

4.2.1 Predicted Changes in Tidal Current Speeds

61. The predicted changes in tidal current speeds due to the presence of the cable protection during spring tides are less than 2% of the baseline values of current speed across all cable protection sections (Figure 4.1 and Figure 4.2).

4.2.2 Predicted Changes in Bed Shear Stresses

62. The predicted changes in bed shear stresses (sediment transport potential) due to the presence of the cable protection during spring tides varies at each section are modelled. Along cable protection section 1 (Figure 1.1), bed shear stresses are predicted to reduce by up 4% up to 2.5km south of the protection (Figure 4.3, Figure 4.3 and Figure 4.4). Over the cable protection a 10% increase in bed shear stresses are predicted due to the increase in local tidal current speed over the structure where the water depth reduces. At cable protection sections 2 to 8 (Figure 1.1), the increase in bed shear stresses is less than 2%.

4.3 Assessment of the Effects on Tidal Current Speeds and Bed Shear Stresses

4.3.1 Worst-case Scenario

63. The worst-case scenario for operation with respect to potential changes to tidal current speeds and bed shear stresses is a Project comprising 57 of the smallest turbines and two platforms, and indicative export cable protection along sections of the export cable (Figure 1.1).

64. A summary of the latest worst case scenario parameters for marine geology, oceanography and physical processes is provided in Supporting Information on Offshore Additional Mitigation **[Document Reference 9.55]**.

4.3.2 Receptor Sensitivity

65. The value and sensitivity of the identified receptors (Margate and Long Sands SAC and Kentish Knock East MCZ) are presented in Table 4.1.The value and sensitivity of the identified receptors (Margate and Long Sands SAC and Kentish Knock East MCZ) are presented in Table 4.1.

Table 4.1 Sensitivity and value assessment of the identified receptors for marine geology, oceanography and physical processes

RECEPTOR	TOLERANCE	ADAPTABILITY	RECOVERABILITY	VALUE	SENSITIVITY
Margate and Long Sands SAC	Negligible	Negligible	Negligible	High	Negligible
Kentish Knock East MCZ	Negligible	Negligible	Negligible	High	Negligible

4.3.3 Impact Magnitude

66. The worst case changes to tidal current speeds and bed shear stresses due to the presence of the Project are likely to have the magnitudes of impact shown in Table 4.2. The worst case changes to tidal current speeds and bed shear stresses due to the presence of the Project are likely to have the magnitudes of impact shown in Table 4.2. The changes overlap the Kentish Knock East MCZ but not the Margate and Long Sands SAC.

Table 4.2 Magnitude of impact on tidal current speeds and bed shear stresses under the worst-case scenario for operation

LOCATION	SCALE	DURATION	FREQUENCY	REVERSIBILITY	MAGNITUDE OF IMPACT
Near-field (turbines)*	Low	High	Medium	Negligible	Medium
Near-field (cable protection)	Negligible	High	Medium	Negligible	Low
Far-field	Negligible	High	Medium	Negligible	Low

*These near-field impacts are confined to a small area, likely to be up to a kilometre from each turbine location

4.3.4 Effect Significance

67. The Margate and Long Sands SAC receptor is remote from the zone of influence on tidal current speeds and bed shear stresses. Due to this, no pathway exists between the source and the receptor in this area, and so in terms of effects on this receptor there is no change associated with the Project. However, the changes encroach onto the Kentish Knock East MCZ receptor. The change in tidal current speeds and bed shear stresses would only be a few percent within this zone of encroachment.

68. This means that given these very small magnitude changes in tidal current speeds and bed shear stresses (sediment transport potential) arising from the presence of the Project, the effects on the identified receptors would be **not significant**. Hence, the overall significance of the effect of the Project under a worst-case scenario on tidal current speeds and bed shear stresses for the identified receptors is **negligible adverse** (no significant effect).

69. The magnitude of impact and effect significance are the same as those in Section 8.6.3.1 of ES Chapter 8 **[APP-022]**.

70. The effects on the benthic ecology of these receptors are discussed in Supporting Information on Offshore Additional Mitigation **[Document Reference 9.55]**.

HARNESSING THE POWER OF NORTH SEA WIND

North Falls Offshore Wind Farm Ltd

A joint venture company owned equally by SSE Renewables and RWE.

To contact please email contact@northfallsoffshore.com