The Great Grid Upgrade

Eastern Green Link 3 (EGL 3) and
Eastern Green Link 4 (EGL 4)

Preliminary environmental information report (PEIR)

Volume 2, Part 3, Appendix 3.18.A Fine Sediment Modelling Spreadsheet

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3.18.A. Fine Sediment Modelling Spreadsheet

3.18.A.1 Overview

3.18.A.1.1 The following technical report has been prepared by Port and Coastal Solutions Ltd to inform the preliminary environmental assessments for the development of the English Offshore Scheme.

1. Introduction

The Eastern Green Link (EGL) 3 and EGL 4 are proposed high voltage direct current links between Peterhead/Westfield in Scotland and King's Lynn/West Norfolk in England. The EGL 3 and EGL 4 are separate projects which are independent of one another, but they have a common landfall on the Lincolnshire coastline.

Sediment suspended during installation of the submarine cables could result in temporary increases in suspended sediment concentrations (SSC) which could have an adverse effect on water quality. Subsequent deposition once material re-settles to the bed could also result in smothering.

To inform the Preliminary Environmental Impact Report (PEIR) for the English Offshore Scheme, a spreadsheet based model has been developed and applied to assess the potential adverse effects on water quality and smothering from construction related activities, including sandwave clearance, excavation of HDD exit pits and cable trenching operations.

This technical note is structured as follows:

- details on the baseline characteristics (including sediment properties and flow field) are provided in Section 2.
- details on the methodology are provided in Section 3;
- results are presented in Section 4; and
- a summary is provided in Section 5.

1.1. The Study Area

The Study Area includes the proposed submarine cable corridor for EGL 3 and EGL 4 within English waters (seaward of mean high water springs) plus the draft Order Limits (which are nominally 500 m wide, widening in areas where there are seabed features such as sandwaves, challenging seabed conditions or sensitive habitats to allow for micro-routing) and a 15 km buffer either side. This buffer is informed by the tidal excursion, which varies along the proposed submarine cable corridor. Regional scale modelling tools indicate that the largest tidal excursions occur close to the proposed landfall where they are 10 km on a mean tide (equivalent to around 14 km on a spring tide). Locally, some larger excursions can occur. In other areas of the proposed submarine cable corridor tidal excursions are much shorter, being around 5 km on a mean tide. The adoption of a 15 km buffer throughout provides a precautionary approach.

Kilometre Points (KPs) are used to provide context as to where within the Study Area a feature lies. The KPs are referenced as KP 0 to KP 436 for EGL 3 and KP 0 to KP 422 for EGL 4, with KP 0 defined at the Anderby Creek Landfall.

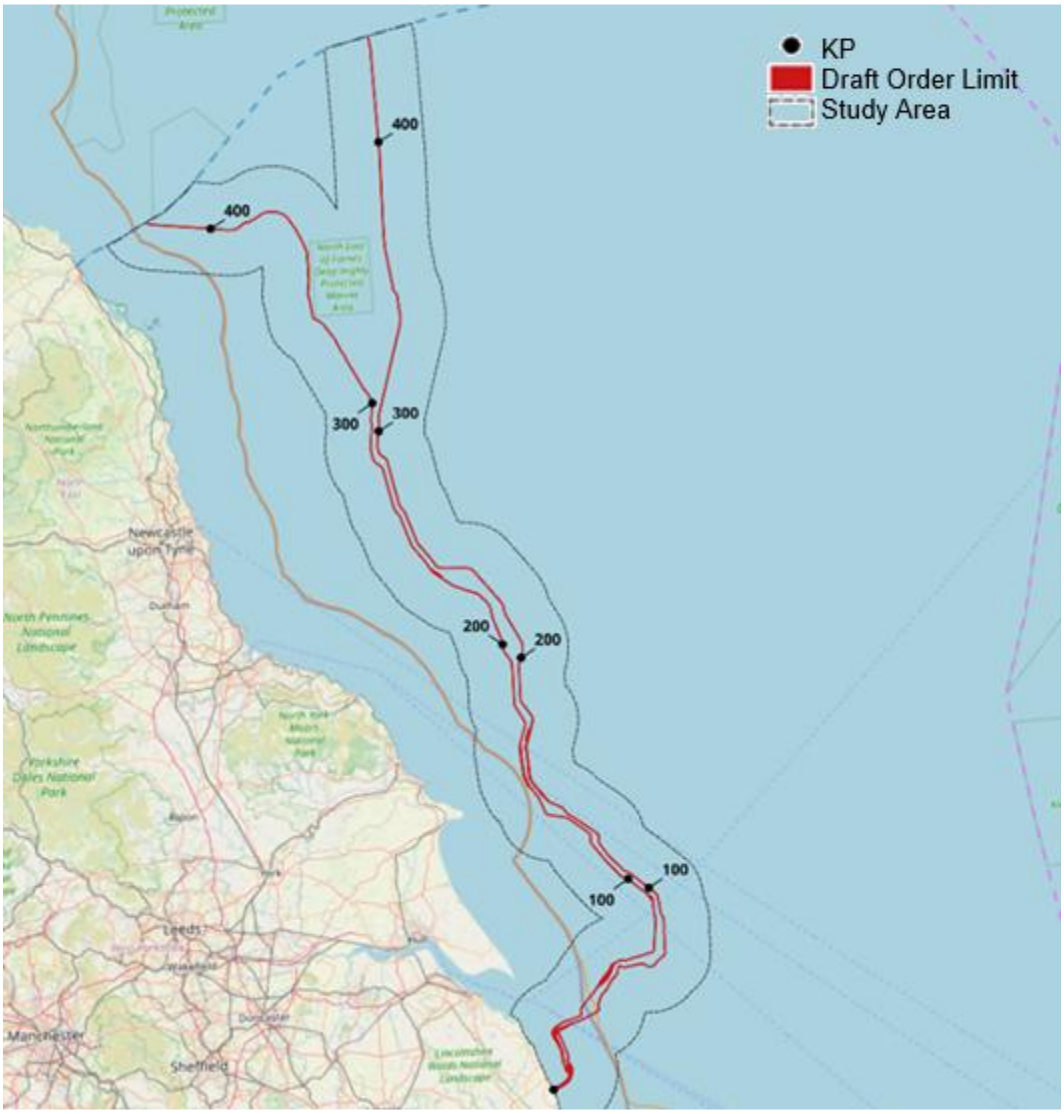

Figure 1. The EGL 3 and EGL 4 proposed submarine cable corridor and Study Area.

2. Baseline Characterisation

A characterisation of the baseline conditions was undertaken to determine the sediment properties (particle size distribution (PSD) and dry sediment density) and hydrodynamic flow conditions along the proposed submarine cable route. Results on sediment properties are presented at a number of KPs in Table 1. KP 3 corresponds to the location of the HDD exit pit excavation, KP 90 corresponds to the location of sandwave clearance and all KPs correspond to the location of trenching.

The PSD varies between samples, the samples were selected to include those with the highest percentages of fines (at KP 10, KP 230 and KP 330) to provide a conservative assessment of the potential area of impact. This is because fine sediment will remain in suspension and disperse, while coarser grain fractions will settle to the bed close to the location of disturbance. Samples at KP 40, KP 150 and KP 200 are more representative of the percentage of fines in the draft Order Limit (with an average of 8.3 % and 10.7% of fines from a total of 149 and 165 surficial sediment samples along the full proposed submarine cable corridor for EGL 3 and EGL 4, respectively).

The dry sediment density was derived from the percentage of fines based on the work of Allersma (1988) as presented in Van Rijn (1993).

Table 1. PSD at locations along the proposed submarine cable corridor.

Location	Clay to medium silt	Coarse silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse sand and above	% age of fines
KP 3	11.1	0.8	1.7	6.1	38.0	42.3	11.9
KP 10	40.4	2.3	1.3	21.2	26.1	8.7	42.7
KP 40	5.6	0	7.9	47.7	25.6	13.1	5.7
KP 90	9.3	1.2	6.2	13.2	10.3	59.7	10.5
KP 150	5.0	0.1	2.1	25.9	36.1	30.8	5.1
KP 200	8.4	0	8.2	31.6	13.8	38.0	8.4
KP 230	54.5	5.5	21.3	18.0	0.4	0.3	60.0
KP 330	42.1	2.8	6.8	21.5	22.8	4.1	44.9

Tidal currents in the Study Area are generally orientated southwards on the flood tide and northwards on the ebb tide. The currents close to the proposed landfall in the Study Area are bi-directional in nature, aligned with the coast, while currents become slightly more orbital in nature offshore. Fastest currents occur offshore of Spurn Head where peak spring tide current speeds are up to approximately 1.4 m/s. Current speeds reduce inshore and in a northward direction with spring tide current speeds of 1 m/s close to the proposed landfall and of 0.45 m/s at the northern end of the Study Area. Peak neap current speeds are approximately half the quoted peak spring tide current speeds.

There is a slight dominance in the southward flowing flood currents, particularly in the southern part of the Study Area. Superimposed on the regional scale flow pattern, local flow variations can be expected to occur in response to bathymetric features (for example to realign with channel features, or around banks).

The southern North Sea is particularly prone to surge-driven flows during winter months, when intense low-pressure systems, particularly from the North Atlantic, dominate the region. These systems can generate strong easterly and / or northerly winds and heightened sea levels, driving elevated surge flows into the southern North Sea which is relatively shallow compared to the deeper North Sea basins. These flows are accentuated by strong surface winds, occurring at high tide (particularly during a spring tide), topography that funnels flows into narrow channels, and shallow regions of sea bed including coastlines. Elevated surge flows can temporarily lead to an increase in sediment resuspension and transport, particularly in shallow regions and along coastlines (Spencer et al., 2015).

Table 2. Peak spring flow speeds at locations along the proposed submarine cable corridor (ABPmer, 2017).

Location	Peak flow speed (m/s)
KP 3	1.00
KP 10	0.95
KP 40	1.30
KP 90	0.90
KP 150	0.85
KP 200	0.65
KP 230	0.55
KP 330	0.45

3. Method

The key inputs into the model include:

- ambient flow speed;
- sediment release height (which will depend on the construction method);
- sediment fall velocity (which will depend on the sediment properties); and
- sediment release rate (which will depend on the construction method and sediment properties); and

Details on the flow speeds in the Study Area were provided in Section 2. Details on the other model inputs are provided in the Sections 3.1 to 3.3.

The plume concentration was calculated at incremental distances from the source of the sediment release and tracked until the SSC dropped below 10 mg/l (which is unlikely to be discernible from background SSC and SSC variability in the Study Area). Only a single flow speed was applied, irrespective of time or distance from release. In reality flows would vary both spatially and temporally, however the application of the peak spring flow speed and given the fact that the proposed submarine cable corridor passes through the area of highest flows, this assumption will provide a conservative assessment with respect to plume spread. The plume spread was accounted for by the application of a low dispersion (0.2 m^2/s) applied in perpendicular to the direction of travel.

Estimates of sediment thickness of deposited material were calculated from the SSC at the time at which the sediment settled to the bed (based on a single sediment release height and settling velocity per representative grain size) to determine a sediment mass and associated deposit thickness. This approach will provide a conservative assessment of sediment thickness on the bed, since in reality sediment will be released at a range of heights and particles will therefore settle to the bed gradually over the settling period, spreading the sediment more thinly over a wider area.

For fines (<63 µm) the sediment mass was converted to deposit thickness using an *in situ* density of 135 kg/m^3. This is a low density, representative of freshly deposited sediment with a high *in situ* water content and overtime it is likely that sediment would settle and compact, increasing the *in situ* density and reducing the thickness of the deposit. For sands and coarser sediment fractions an *in situ* density of 1,250 kg/m^3 was applied to convert sediment mass to deposit thickness. This is because sandy sediment is non-cohesive and tends to hold less water than fines and will therefore have a much higher dry sediment density. The application of the faster peak spring tide flows and higher release heights were applied to provide an indication of the maximum distance from the sediment release location that impacts could occur, while application of slower neap tide flows and lower release heights were applied to provide an indication of the maximum thickness of deposits associated with each representative grain size. Sediment thicknesses are therefore quoted as a range.

3.1. Sediment Release Height

The height of release of sediment disturbed was assumed to be 5 m above the bed for cable trenching with a controlled flow excavator (CFE). In reality, the actual height of sediment release for trenching by CFE will be at a range of heights above the bed (from anywhere just above the seabed to several metres above the bed).

For sidecasting during sandwave clearance the height of release of sediment disturbed was assumed to be at 35 m above the bed (close to the water surface in the region where sandwaves are present). In reality the sediment release will be at a range of depths while sidecasting will discharge sediment at the water surface the high sediment concentrations will result in the formation of a dynamic plume which will settle rapidly to the bed with sediment being lost from the plume edges as water is entrained into the plume during it descent to the bed.

The release heights adopted therefore provide a conservative assessment with respect to the impact distance.

3.2. Sediment Fall Velocity

The spreadsheet model calculates the settling times and distances for different grain sizes based on grain size settling velocities of individual grains using the equation from Van Rijn (1984) and a water temperature of 10 °C. The settling distances are calculated by applying the peak flow speed over the settling time. To account for variations in flow speed which would occur over the tide during the period during which fine sediment settles back to the bed, a maximum distance equal to the tidal excursion was applied. The tidal excursion was estimated assuming a sinusoidal flow distribution with a 6 hour cycle (representative of a flood or ebb phase).

Non tidal flow (wind driven and surge driven flow) could result in faster flow speeds and/or the persistence of flows in the same direction for longer than a 6 hour period. However, due to operability constraints, construction would be unlikely to occur during such conditions. In addition, the results (Section 4.1) show that plume concentrations are unlikely to have an impact on water quality at distances of more than approximately half of the spring tidal excursion and therefore the inclusion of non-tidal flows would not be expected to change the results presented.

Typically, it is accepted that the settling velocities are applicable to grains larger than 63 µm. At grain sizes smaller than this, the particles tend to have a more plate-like rather than spherical shape and this affects the settling velocity. In addition, cohesive processes (particularly in the marine environment) result in the formation of flocs (aggregates of smaller particles), further altering the settling velocity. In general, flocs will increase the settling velocity of fine grained sediment and the use of the settling velocity for individual grains will therefore tend to provide a conservative assessment of settling times.

The settling time to the bed for releases at 5 m and 35 m above the bed are provided in Table 3, along with the indicative travel distance for a range of peak spring flow speeds and representative grain sizes.

Table 3. PSD at locations along the proposed submarine cable corridor.

Peak flow (m/s)	Fines (<63 µm)		Very fine sand (125 µm)		Fine sand (250 µm)		Medium sand (500 µm)	
	Settling time (hours)	Settling distance (km)	Settling time (hours)	Settling distance (km)	Settling time (hours)	Settling distance (km)	Settling time (hours)	Settling distance (km)
Release at 5 m above the bed								
1.35	0.5 to 400	2.2 to 17.5	0.1	0.7	<0.1	0.14	<0.01	<0.001
1		1.6 to 12.9		0.5		0.10		
0.5		1.3 to 6.5		0.3		0.05		
0.2		0.3 to 2.6		0.1		0.02		
Release at 35 m above the bed								
1.35	5 to 2850	16 to 17.5	1	4.7	0.2	0.9	0.1	0.3
1		11.7 to 12.9		3.5		0.7		0.2
0.5		5.8 to 6.5		1.8		0.4		0.09
0.2		2.3 to 2.6		0.7		0.1		0.04

3.3. Sediment Release Rates

The rate of fine sediment disturbance was estimated for each activity based on information on project design and results from the environmental surveys (as detailed in the baseline characterisation).

The following assumptions were applied when calculating the release rates:

- for sandwave clearance by dredging, rates assume that 50% of sediment dredged would be released in suspension near the surface (with the rest forming a dynamic plume which would settle straight to the bed). The sediment disturbance from the cutter action on the bed will be less than during trenching (estimated to be 8.2 kg/s) and at a release point closer to the bed (i.e. it will be a lower impact) and as a result this has not been included in the assessment; and
- for HDD exit pit excavation and cable installation, rates are based on a productivity of 1,500 m^3 per hour, assuming that 70% of all sediment disturbed would fall back into or directly adjacent to the trench.

The cable installation speed is expected to be highly variable, with speeds ranging from 100 m/hour to 500 m/hour. The actual speed will depend on the sediment encountered (with lower speeds in sediments with a higher percentage of fines) and the type of plant used. The trench cross sectional area (CSA) has been calculated using the maximum trench width and depth for EGL 4, assuming a v-shaped trench. Achieving these trench dimensions at the expected installation speeds would require a productivity of 1,000 m^3/hour to 5,000 m^3/hour. Values at the lower end of this range provide a more realistic productivity rate that could be achieved, particularly in soils with a higher percentage of fines. The assessment is therefore based on an installation speed of 150 m/hour which is considered to still provide a conservative assessment of productivity rates, particularly where fine sediment fractions are high. Higher installation speeds would be achievable for much smaller trench dimensions, but the overall sediment disturbance rate is unlikely to exceed the values calculated based on the assumptions outlined. The sediment release rates are summarised in Table 4.

Table 4. Estimated rate of fine sediment release associated with different activities.

Location	Percentage Fines (%)	Dry sediment density (kg/m^3)	Release rate (kg/s)
Activity: Sandwave clearance			
KP 90	10	1,450	141.0
Activity HDD exit pit excavation			
KP 3	12	1,436	21.5
Activity: Trenching			
KP 10	42	1,190	62.5
KP 40	12	1,436	21.5
KP 150	5	1,500	9.6
KP 200	8	1,470	15.4
KP 230	60	1,000	75.0
KP 330	45	1,145	64.3

4. Results

Results of the predicted spread of sediment in suspension and the thickness of sediment on the bed are presented in Section 4.1 and Section 4.2, respectively.

4.1. SSC

Results of the predicted SSC from the spreadsheet model are plotted in Figure 2 to Figure 4, for cabling, HDD exit pit excavation and sandwave clearance. Based on the background SSC and natural temporal variability in SSC in the Study Area, increases in SSC of less than 10 mg/l are not expected to be detectable and impacts on receptors are therefore considered to be negligible.

In the near-field (within 5 to 10 m of the activity) sediment disturbed by construction activities will result in very high SSC (several orders of magnitude higher than shown in the plots). These very high SSC will only last while the activity resulting in the sediment disturbance is occurring. A large proportion of this sediment will settle back onto the seabed within the draft Order Limits (or where sediment is released in the case of sidecasting), with the actual amount depending on the grain size characteristics and the flow conditions (see Section 4.2 for additional information on sedimentation).

The distances at which elevated SSC is predicted to reduce to less than 10 mg/l (termed the 'impact distance') are summarised in Table 5. The greatest impact distance is associated with trenching in the area where there was the highest percentage of fines and fastest flow, with peak increases in SSC of more than 10 mg/l occurring up to 8 km from the point of release. Any exceedances of more than 10 mg/l will be of short duration (order of hours or less) beyond the draft Order Limits, due to the variable nature of the flow field and the relatively fast installation speeds.

Table 5. Maximum distance where SSC is greater than 10 mg/l.

Location	Maximum distance where SSC> 10 mg/l (km)
Activity: Trenching	
KP 10	8.0
KP 40	6.5
KP 150	2.7
KP 200	2.8
KP 230	5.2
KP 330	4.0
Activity: HDD exit pit excavation	
KP 3	5.0
Activity: Sandwave clearance	
KP 90	7.1

Based on the impact distances, cable trenching and exit pit excavation have the potential to increase SSC at both the Huttoft and Marsh Yard and Anderby bathing waters. However, tidal flows in the nearshore region are predominantly aligned with the coast and given that the excavation of the exit pit and the cable trenching will be constrained to water depths of more than -3 m LAT, any sediment plume will most likely remain offshore of the bathing water sites.

The Environment Agency undertake regular beach renourishment in this region. This activity involves pumping large volumes of sediment and water into the intertidal region. Relative to the renourishment activity any sediment disturbance due to exit pit excavation and cable installation is smaller in scale both spatially and temporally.

KP 330 was selected as an area with a high percentage of fines in close proximity to the North East of Farnes Deep Highly Protected Marine Area (HPMA). The ABPmer tidal renewables atlas shows flows to be orientated north-south in this region so that for the section of the English Offshore Scheme which lies closest to the HPMA, any sediment plume will be advected along the cable route, rather than into the HPMA. For the section of the English Offshore Scheme to the south of the HPMA, some dispersion of the plume into the HPMA would be expected, although elevations would be of short duration (in the order of hours for each trench).

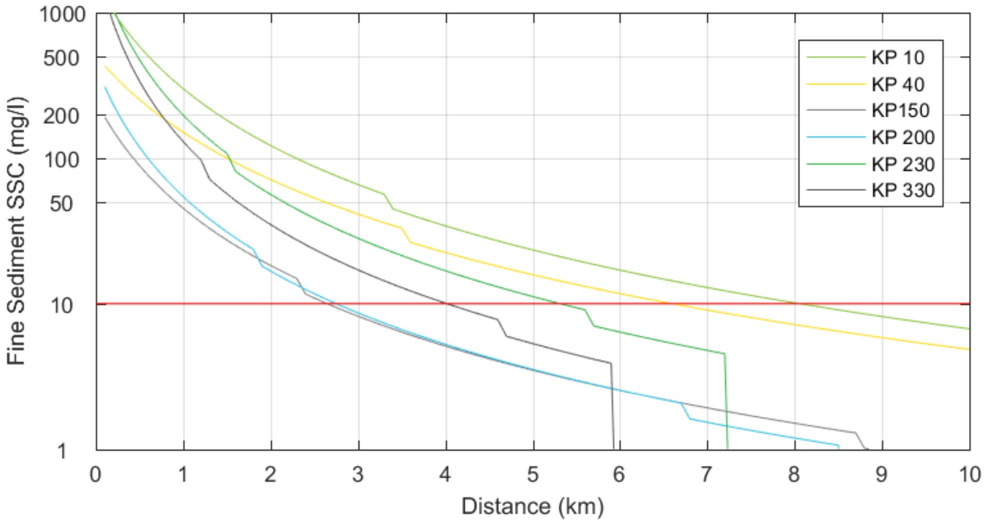

Figure 2. **Fine sediment SSC with distance from release during cabling.**

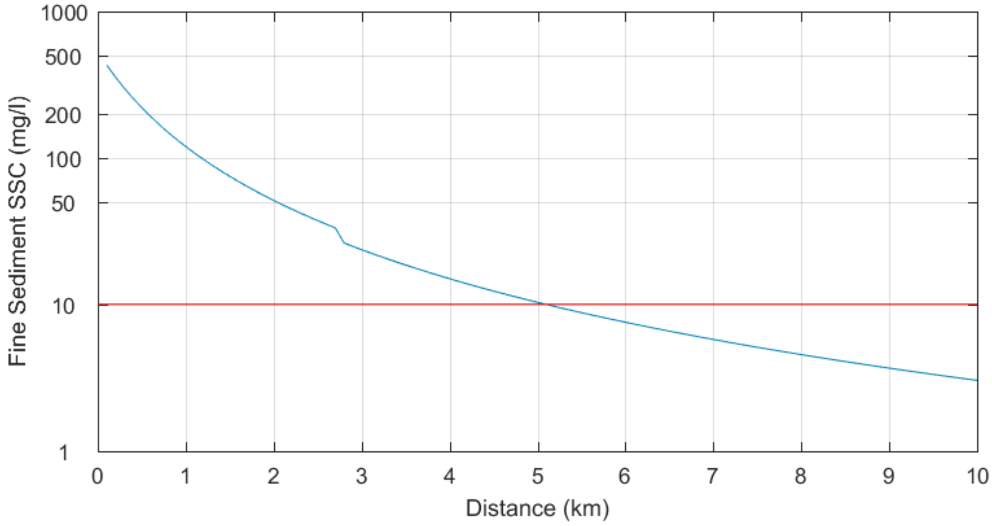

Figure 3. **Fine sediment SSC with distance from release during HDD exit pit excavation.**

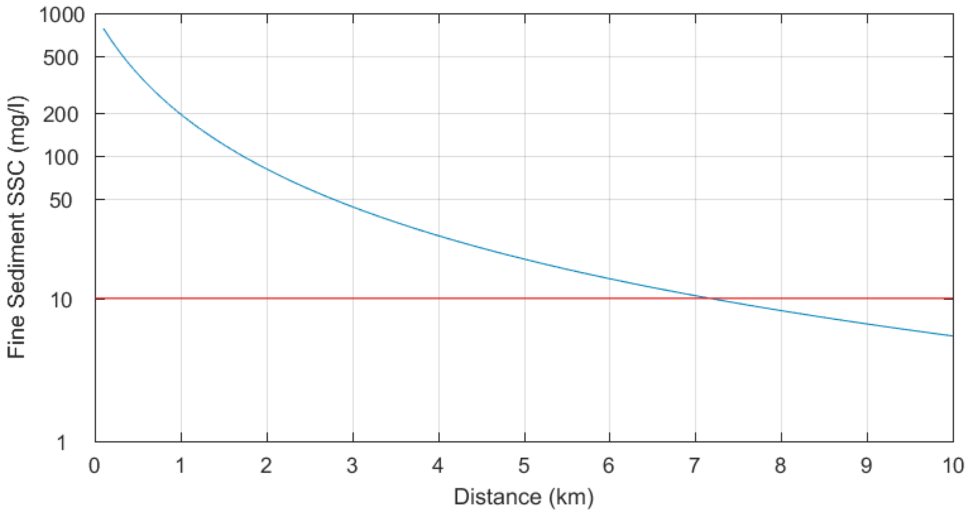

Figure 4. **Fine sediment SSC with distance from release during sandwave clearance.**

4.2. Sedimentation

Estimates of sediment thickness on the bed for different sediment fractions are provided for trenching at KP 10 in Table 6 and at KP 200 in Table 7. Results are given for KP 10 which has a high percentage of fines and fast flow speed (to give an indication of the upper distance of impact) and for KP 200 which has a lower percentage of fines and slower flow speeds (to give an indication of the upper thickness). At both locations estimates of distance of impact and thickness of deposit were made for spring tide flow speeds with a release at 5 m above the bed and for neap tide flow speeds with a release at 2 m above the bed to provide a range of impact distances and sediment thicknesses. The upper distance is associated with the lower range of sediment thickness and the lower distance is associated with the upper range of sediment thickness.

In the near-field (within 5 to 10 m of the activity) sediment thicknesses on the bed will result in higher values than quoted, since the values are based averaging over a 100 m x 100 m area. Results show that within 0.1 km (i.e. within the draft Order Limits) the sediment thickness can be several tens of mm's thick but that beyond the draft Order Limits the sediment thickness is of the order of mm's or less.

It is important to note that the results only consider the 30% of sediment predicted to be ejected out of the trench. The other 70% will either fall back into the trench or be deposited within a couple of metres either side of the trench (as berms), resulting in much thicker deposits in these regions.

Depending where along the route trenching is occurring, the sediment deposited on the bed may or may not subsequently be transported from the bed by natural processes.

Table 6. Estimated sediment thickness from trenching activity at KP 10.

Fraction	Distance from release (km)	Max thickness (mm)
Medium silt to clay	0.5 to 12.3	0.13 to 0.74
Coarse silt	0.3 to 1.6	0.20 to 1.04
Very fine sand	0.1 to 0.5	0.10 to 0.40
Fine sand	<0.1 to 0.1	15.3 to 31.2
Medium Sand	<0.1	46.9 to 61.4
Coarse Sand and above	<0.1	22.0 to 23.8

Table 7. Estimated sediment thickness from trenching activity at KP 200

Fraction	Distance from release (km)	Max thickness (mm)
Medium silt to clay	0.4 to 8.4	0.06 to 0.31
Coarse silt	0.3 to 1.1	0[1]
Very fine sand	0.1 to 0.3	0.66 to 2.62
Fine sand	<0.1 to 0.1	22.75 to 43.43
Medium Sand	<0.1	24.80 to 32.47
Coarse Sand and above	<0.1	96.19 to 103.83
[1] There is no coarse sediment in the sample collected at KP200.		

Results are not provided for HDD exit pit excavation but would be expected to be similar in magnitude to trenching (i.e. order of mm's or less outside of the draft Order Limits).

Estimates of sediment thickness for different sediment fractions are provided for sandwave clearance in Table 8. Estimates of distance of impact and thickness of deposit were made for spring tide flow speeds with a release at 35 m above the bed and for neap tide flow speeds with a release at 15 m above the bed to provide a range of impact distances and sediment thickness. The upper distance is associated with the lower range of sediment thickness and the lower distance is associated with the upper range of sediment thickness.

Note that the reported sediment thickness only accounts for the passive plume (taken to be 50% for the sediment pumped from dredging for sandwave clearance). Accounting for the other 50% from the dynamic plume which settles straight to the bed could result in local deposits of an additional 150 to 200 mm (in addition to the 30 to 40 mm of coarse sand) close to the release location.

The dredger may have to make multiple passes along the same stretch of sandwaves and if so the numbers quoted for the coarser sediment would need multiplying up by the number of passes. For the fines this is not likely to be an issue as the tidal flow will determine where the plume will disperse and settle and it is very unlikely that multiple passes would impact the same location (since the tidal state would vary for repeat passes).

Most of the sediment with any notable thickness on the bed is predicted to settle close to the area of release which is in an area of sandwaves where the bed is mobile and any deposited sediment will therefore be moved either as bedload or in suspension along with the existing sand present on the bed.

Table 8. Estimated sediment thickness from sandwave clearance.

Fraction	Distance from release (km)	Max thickness (mm)
Medium silt to clay	5.8 to 11.7	<0.01
Coarse silt	3.8 to 10.5	<0.01
Very fine sand	1.1 to 3.2	<0.01 to 0.01
Fine sand	0.2 to 0.6	0.22 to 0.40
Medium Sand	0.1 to 0.2	1.37 to 2.07
Coarse Sand and above	<0.1	30.22 to 36.57

5. Summary

The greatest impact distance is predicted to be associated with trenching in the area where there was the highest percentage of fines and fastest flow, with peak SSC of more than 10 mg/l occurring up to 8 km from the point of release. More typically, impact areas are likely to be around half this distance or less, particularly in view of the conservative assumptions applied. Any exceedances of more than 10 mg/l are predicted to be of short duration (order of hours or less) beyond the draft Order Limits due to the relatively fast installation speeds.

A large proportion of sediment dispersed by construction activities are predicted to settle back onto the seabed within the draft Order Limits (or where sediment is released in the case of sidecasting), with the actual amount depending on the grain size characteristics and the flow conditions. Beyond the draft Order Limits, sediment deposits are predicted to be very thin (mm's or less).

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