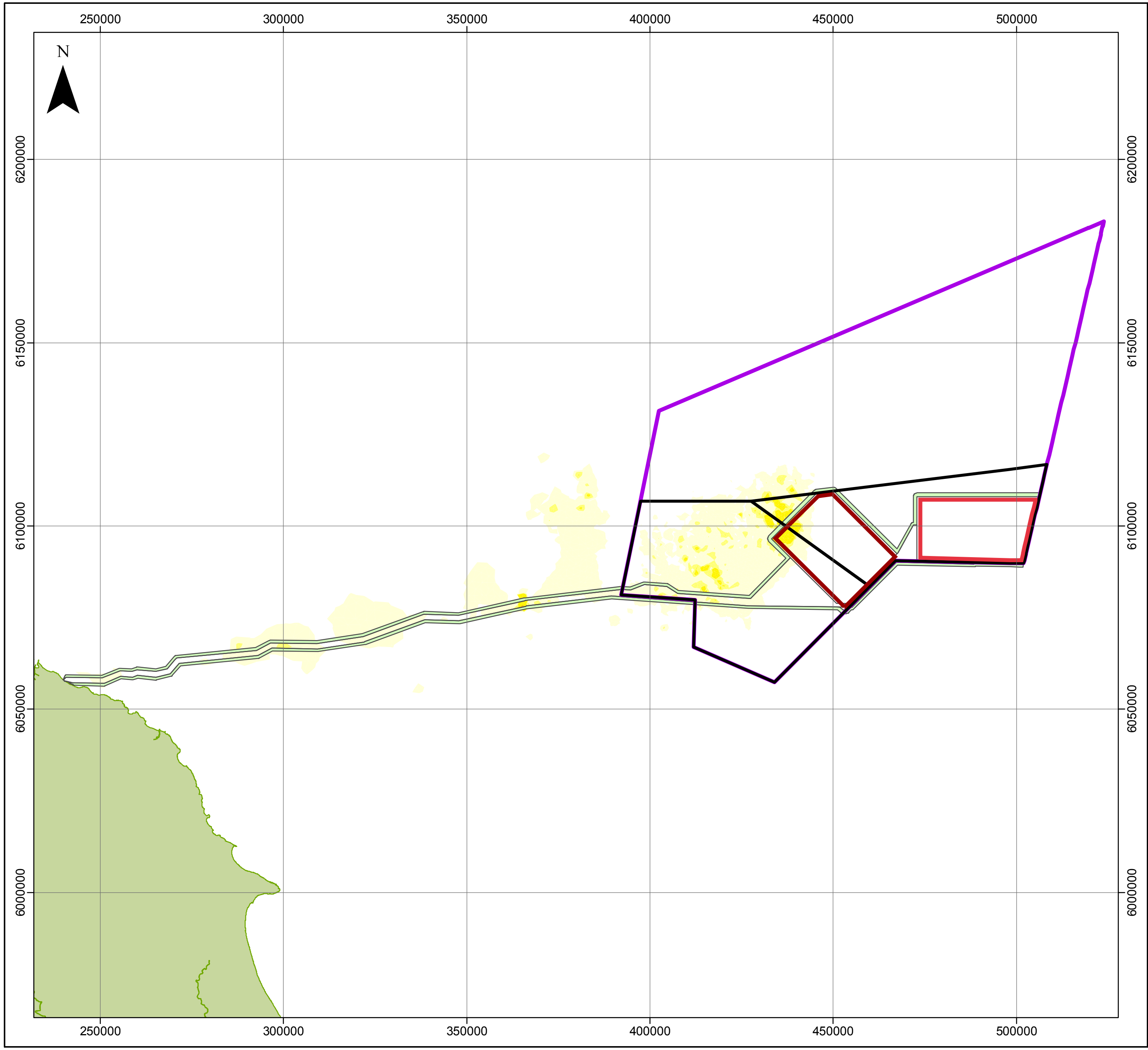
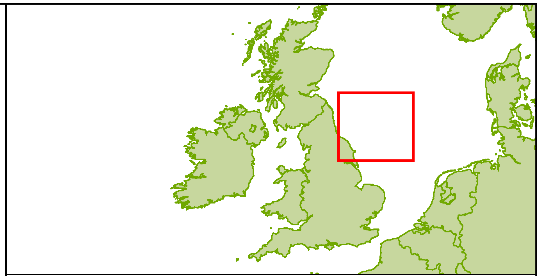




LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Temporary works area

Sediment thickness (m)

- Above 0.1000
- 0.0500 - 0.1000
- 0.0100 - 0.0500
- 0.0050 - 0.0100
- 0.0010 - 0.0050
- 0.0005 - 0.0010
- 0.0001 - 0.0005
- Below 0.0001

0 10 20

Kilometres

Data Source:
Modelling © Danish Hydraulic Institute, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

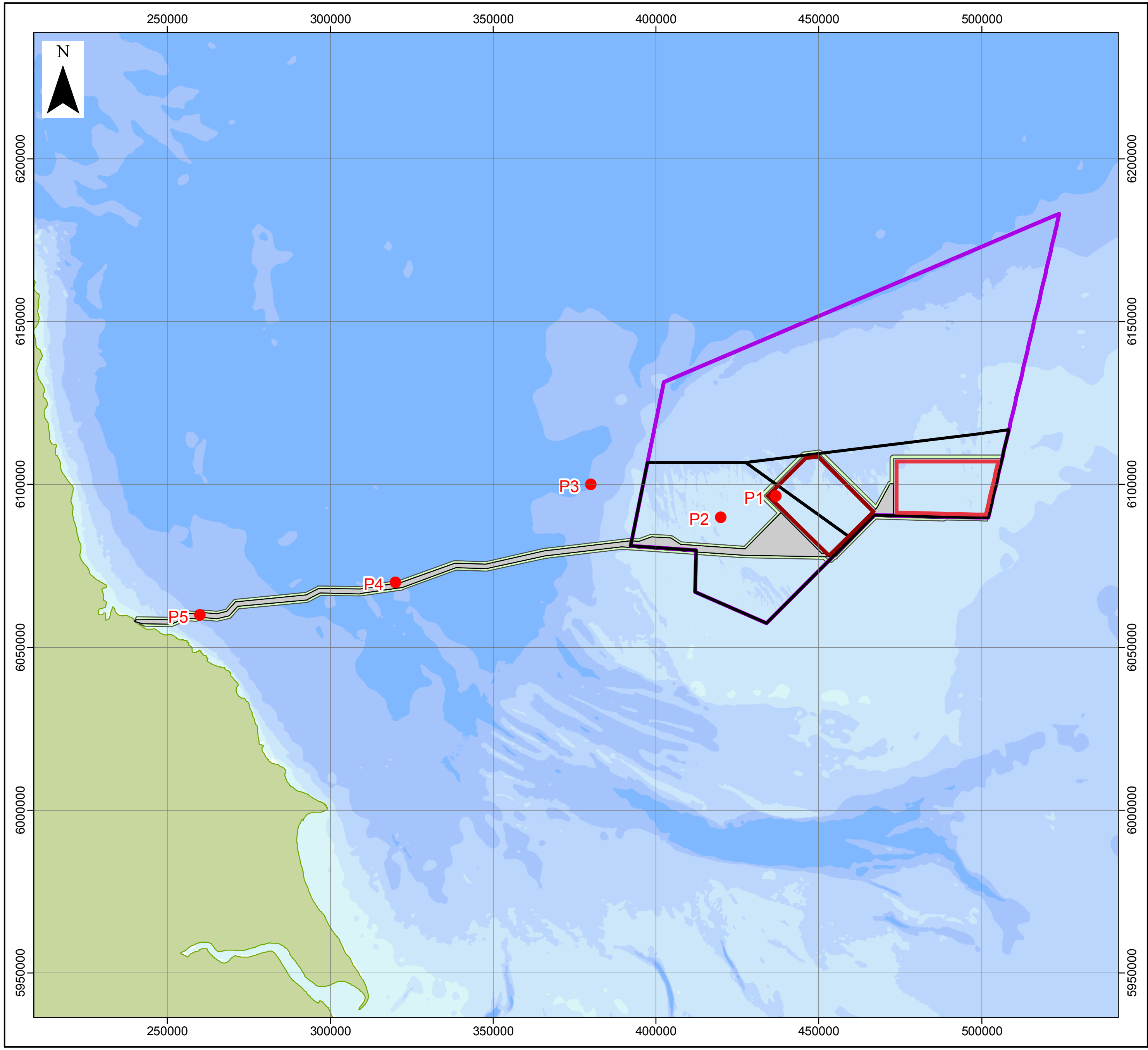
Figure 6.5 Average deposition predicted over the simulation period for the construction phase for 12m monopoles using the re-suspension of fractions 1 and 2 method

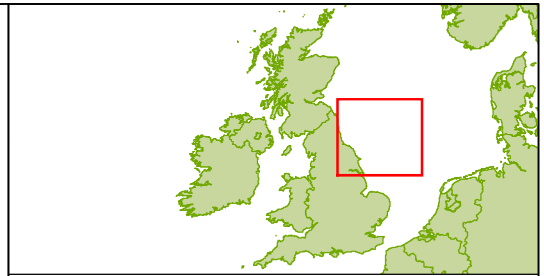
VER	DATE	REMARKS	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	07/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: **F-OFL-MA-425**

SCALE	1:1,600,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Temporary works area
- Sediment thickness time series analysis point

0 20 40
Kilometres

Data Source:
Sediment data from Danish Hydraulic Institute, 2012
Round 3 offshore wind farm boundary © Crown Copyright, 2013
Background bathymetry image derived in part from © TCarta data 2009.

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 6.6 Location of points for sediment thickness time series analysis for the construction phase using the re-suspension of fractions 1 and 2 method

VER	DATE	REMARKS	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	07/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: **F-OFL-MA-426**

SCALE	1:1,800,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND

Predicted suspended sediment concentrations in the surface layer

6.2.16 **Figure 6.7** shows the maximum suspended sediment concentration in the sea surface layer predicted for construction of 12m monopole foundations. **Figure 6.8** compares the maximum suspended sediment concentration at the surface and in the bottom layer, along a north-south section through the middle of the foundation layout. Although concentrations are similar in magnitude to the bottom layer, their spatial extent above background concentrations is limited to within the foundations and less than 8km from their centre.

6.3 Fate of sediment that is not suspended during installation of drilled 12m monopole and GBS foundations

6.3.1 The plume dispersion model assumes that all sediment particles less than 0.18mm in diameter enter the water column in suspension as part of the plume (**Appendix 9A**). Sediment particles larger than 0.18mm are assumed to deposit at the source position.

6.3.2 For installation of a conical GBS, a worst case volume of 3,675m^3 is assumed for the side cast seabed preparation sediment (**Table 5.1**). A conservative particle size distribution for released sediment due to seabed preparation is based on an average from samples collected across Tranche B, with samples with greater than 3% gravel removed. The data shows that on average about 62% of the sediment (2,279m^3) less than 0.18mm is suspended in the plume model and 38% greater than 0.18mm remains (1,396m^3) at the source position as a residual side cast mound.

6.3.3 For installation of a 12m monopole foundation, a worst case volume of 6,220m^3 is estimated for the drill arisings which are released at the sea surface. An estimate of the average particle size characteristics for drill arisings was made by RPS Energy (2012b). Using these data and data from seabed sediment samples shows that about 63% of the sediment (3,919m^3) is suspended in the plume model and 37% (2,301m^3) settles rapidly to the seabed without entering the plume. The deposition of sediment from drill arisings is therefore considered as the worst case scenario.

Potential morphology of the deposited sediment

6.3.4 The results from geotechnical assessments of the surface sediments show that the friction angle of the top 15-20cm of seabed sediment is around 30°, exemplary of that applying to loose granular sand (**Appendix 9A**). Immediately beneath the loose upper layer, the friction angle quickly rises indicatively to 45-50°.

6.3.5 An assumption is made that the non-suspended sediment initially forms a cone on the seabed with a friction angle of 30^o. In its undisturbed state this would produce a 9m high cone with a circular seabed footprint of about 750m^2 (diameter approximately 31m). However, due to subsequent reworking of the sediment pile by waves and tidal currents, it will be reduced in height and distributed over a wider area of seabed.

6.3.6 This is an extremely idealised worst case situation in that an assumption is made that the sand drops vertically through the water column from a point source without the effect of at least some dispersion by tidal currents and waves as it settles through the water column. In reality, as the sediment settles through the column it will be transported horizontally as well as vertically and would not deposit as the idealised cone, but as a flatter and wider based 'mound'. The geometry of this mound would depend on the particle size of the sediment, the settling velocity and the different forces applied to it as it falls through the water column (waves and tidal currents). It is difficult to determine what this shape would be so a cone shape has been chosen, because this was quantifiable.

6.3.7 Over time, due to subsequent reworking of the sediment pile, it will be reduced in height and distributed over a wider area of seabed. Given that the predominant driver for sediment transport across Dogger Bank is waves, it is believed conceptually that a cone that stands 9m proud of the seabed would be impacted regularly by waves and the sediment both transported along the bed through this process. The sediment that is initially moved by the waves would also be temporarily entrained close to the seabed by the prevailing tidal currents and transported a short distance by both mechanisms. Over time the gradual erosion of the top of the cone through wave action and its transport would lower the cone height, and its shape would be adapted into some form of low mound with a larger footprint than the original cone.

6.3.8 The shape of the mound would be difficult to determine precisely (and could not be modelled), but given the predominant waves from the north and the predominant north and south tidal current directions, it is assumed that most transport would be north and south forming an elongate north-south mound..

6.3.9 The closest analogy to the mound would be natural sand waves across Tranche A, which have an average wavelength of 100m (range 50-150m) and average crest height of 0.5m (maximum 2m). As a best estimate, if an elongate mound created by installation of a single foundation is assumed to form from 2,301m^3 of sediment (total sediment minus dispersed sediment in the plume), that is 100m in length and 31m wide, it will have a crest height of about 1.5m. The mound footprint will be about 3,100m^2.

Potential particle size of the deposited sediment

6.3.10 The seabed sediments of Dogger Bank are the surface expression of the thicker Holocene sands that sit on top of the Dogger Bank Formation which is predominantly mud. The build-up of these sand bodies has taken place over a long period of time under similar conditions to the present day, and hence they are expected to have similar particle sizes at depth to those on the seabed. Hence, in the modelling of the drill arisings scenario the sand fraction is broken down into its constituent particle sizes based on the surface averages.

6.3.11 The average particle size distribution of the drill arisings (this includes the Holocene sands and the Dogger Bank Formation mud) is described in Table 2.9. It shows that about 41% of the sediment is mud which is predominantly derived from the Dogger Bank Formation. The Holocene sands contain very low quantities of mud. About 55% of the sediment (on average) is sand-sized, with a particle size distribution similar to that of the seabed sediments (Table 2.8). This sand is mainly derived from the Holocene unit.

6.3.12 Sediment particles larger than 0.18mm will deposit at the source position. Table 2.8 shows that a high proportion (87%) of the sand in the drill arisings falls between 0.125 and 0.25mm (fine sand). On average, the sand of the drill arisings contains 60% between 0.125mm and 0.18mm and 27% between 0.18mm and 0.25mm. The 0.125-0.18mm component will be dispersed in the plume, but the 0.18-0.25mm component will deposit at the source position. This means that the median particle size of the disposed sediment will become slightly coarser (i.e. the median will shift towards the coarser part of the 0.125-0.25mm range) but will still remain within the fine sand classification. The particle size distribution of the sediment deposited at the source position will not be significantly different from the surrounding seabed sediments.

6.3.13 The mud fraction and the fraction of sand less than 0.18mm are assumed to disperse in the plume. This means that the sediment deposited at the source position will contain no mud regardless of how much mud the drill arisings contained at the initial time of dispersal. Hence, although there is a large difference between the mud contents of the drill arisings and the surrounding seabed, this variance does not make any difference with respect to the effect on the seabed at the disposal site.

6.4 Temporary changes to suspended sediment concentration at the Cleveland Potash seawater intake

6.4.1 The southern boundary of the nearshore portion of the export cable corridor is approximately 4km north of the Cleveland Potash intake pipe. The sediment plume released during construction of the export cable will impinge on the position of the intake. **Table 6.2** describes the suspended sediment concentrations through the water column at the location of the intake, extracted from the plume dispersion model outputs.

Table 6.2 Maximum suspended sediment concentrations through the water column at the Cleveland Potash intake

Depth of Water from the Sea Surface(m)	Maximum suspended sediment concentration (mg/l)
0	0
1	0
2	0
3	0
4	0
5	0
6	0
7	1
8	1
9	3
10	6
11	22
12	43
13	58
14	72

6.4.2 **Table 6.2** shows that the top 10m of the water column contains very small maximum suspended sediment concentrations at the intake pipe, which are insignificant compared to both background levels nearshore and concentrations developed during storm conditions. Below 10m water depth, maximum suspended sediment concentrations increase to between 22mg/l (11m water depth) and 72mg/l (at the seabed), which are within the range of background levels and smaller than those typically associated with storms.

6.4.3 The suspended sediment concentrations in the bottom layer climb to over 20mg/l about three days before the end of the 30-day simulation. During this time, excavation of the export cable trench is nearing the coast and so a plume that impinges on the location of the seawater intake is created. Values persist above 20mg/l until the end of the simulation. Because the simulation was not continued beyond the end of trenching, it is difficult to ascertain how quickly the suspended sediment concentrations will reduce back to baseline. However, once trenching is completed, the high energy nearshore zone is likely to rapidly disperse (i.e. over a period of hours) the suspended sediment in the absence of any further sediment input.

6.5 Interruption of sediment transport as a result of landfall construction activities

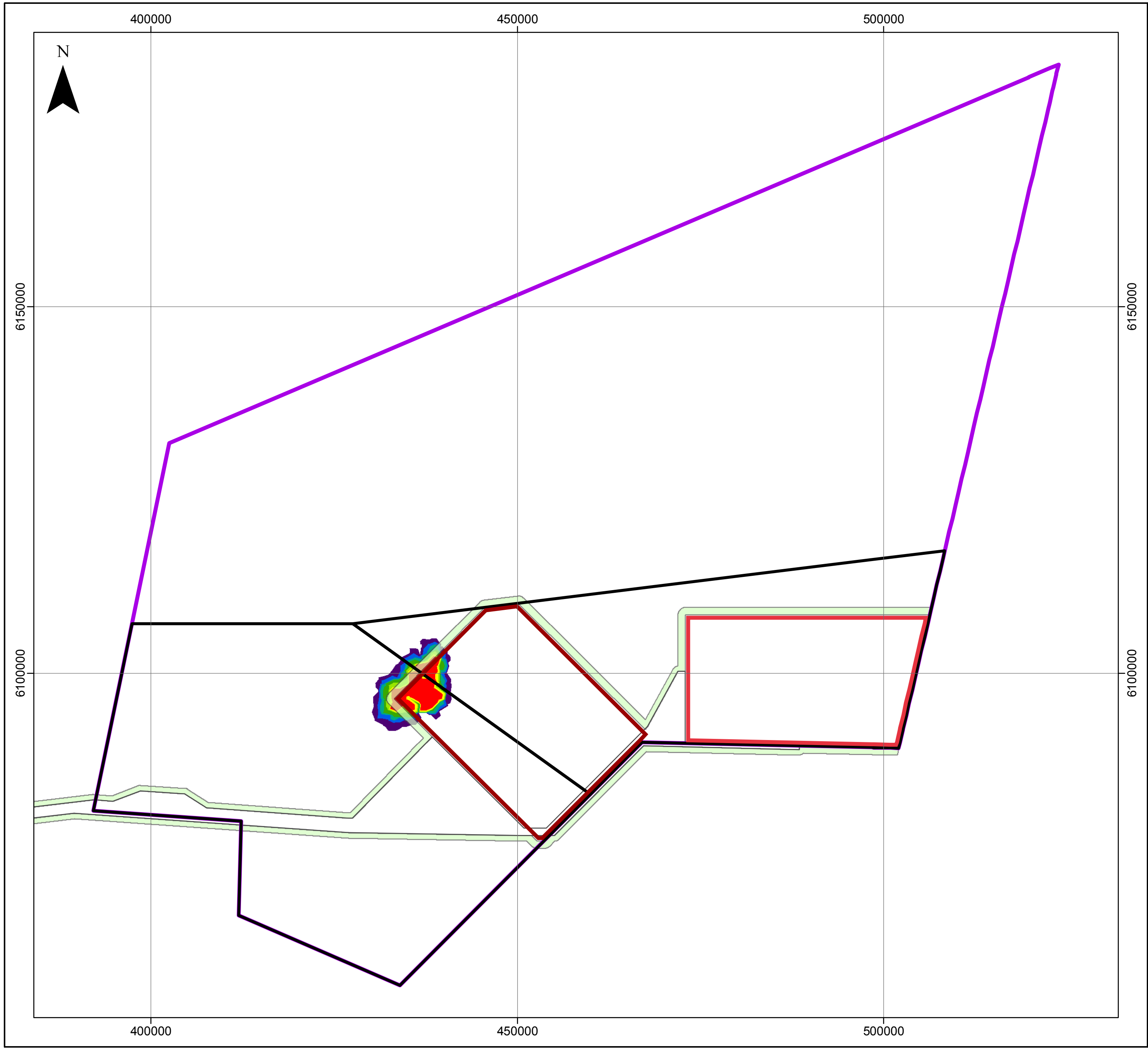
6.5.1 The consideration of the assessment of effects at the landfall site uses the conceptual understanding (Appendix A of **Appendix 9A**) as a baseline against which the potential effects and sensitivities of sediment transport to changes in the system are determined. Sediment transport across the intertidal area has the potential to be affected by the installation and operation of a worst case scenario of two large temporary cofferdams, which would protect excavated trenches within which the export cables will be placed. Each cofferdam comprises a 15m-long cross-shore obstruction to sediment transport stretching seaward from the HDD exit hole.

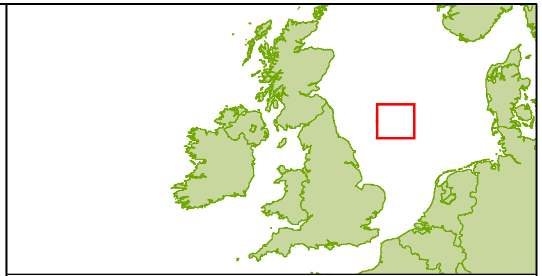
6.5.2 Net sediment transport between Redcar and Marske-by-the-Sea is to the south east, driven by waves approaching predominantly from the north. It is recognised that a cofferdam may intercept mobile sands along its north west side that would otherwise be transported further south east. This would, over time, result in a build-up (accretion) of sediment on the ‘updrift’ (north west) side of the cofferdam and depletion (erosion) of sediment on the ‘downdrift’ (south east) side. As the dominant net transport is south easterly, no effects are anticipated to features north of the landfall due to this process.

6.5.3 For a single small cofferdam, the worst case scenario is that there would be an obstacle of only 10m extending across the intertidal zone. This has the potential to act as a short groyne-like structure, partially interrupting alongshore sediment transport. Assuming the worst case scenario, two cofferdams will be constructed and this will provide an almost continuous barrier to sediment transport for a period of up to 14 weeks. It is likely that the cofferdams will be operational during the summer months when there is relatively low wave action compared to winter, and longshore sediment transport will be at a minimum.

6.5.4 The rate of net annual alongshore transport specifically at the landfall site has not been established. However, only small sediment build-up on the west side of groynes at Redcar indicates that actual longshore sediment transport is low in this area (Appendix C of **Appendix 9A**). This means that whilst the ‘downdrift’ coastline may be affected by construction works, the magnitude of change is likely to be low and temporary. The presence of the cofferdams will not have an effect on natural coastal erosion rates given the short-term nature of the construction programme.

6.5.5 The beach levels on the northwest and southeast sides of the cofferdams will be monitored and bypassing will be implemented if there is evidence for accretion to the northwest coupled with depletion to the southeast.





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Temporary works area

Suspended sediment concentration kg/m³

- Above 0.200
- 0.100 - 0.200
- 0.050 - 0.100
- 0.020 - 0.050
- 0.010 - 0.020
- 0.005 - 0.010
- 0.002 - 0.005
- Below 0.002

0 10 20
Kilometres

Data Source:
Modelling © Danish Hydraulic Institute, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

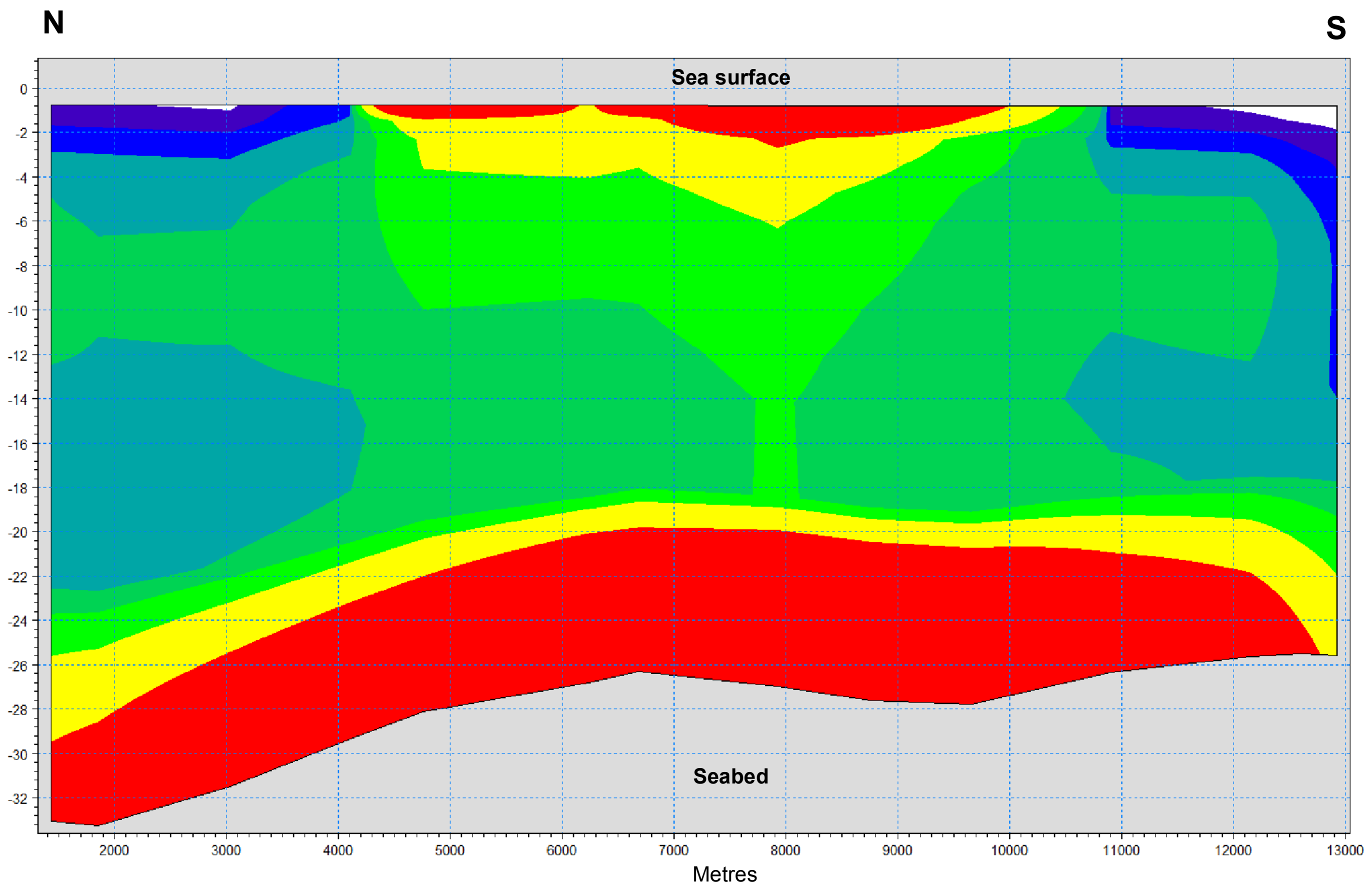
Figure 6.7 Maximum SSC in the surface layer predicted over the simulation period for a 12m monopole using the re-suspension of fractions 1 and 2 method

VER	DATE	REMARKS	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	08/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: **F-OFL-MA-427**

SCALE	1:800,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND



LEGEND

Suspended sediment concentration kg/m³

- Above 0.200
- 0.100 - 0.200
- 0.050 - 0.100
- 0.020 - 0.050
- 0.010 - 0.020
- 0.005 - 0.010
- 0.002 - 0.005
- Below 0.002

Data Source:
Image supplied by Danish Hydraulic Institute, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 6.8 North-south cross-section of maximum SSC for a 12m monopole

VER	DATE	REMARKS	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	08/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: **F-OFL-MA-428**

SCALE	PLOT SIZE	DATUM	PROJECTION
Taken from image	A4		

FOREWIND

6.6 Increased turbidity as a result of landfall construction activities

6.6.1 With respect to turbidity, part of the works in the intertidal area will be confined within the cofferdams and isolated from the marine environment. Sediment removed from the cofferdam would be transferred to a barge for storage before being used for backfilling. No loss of sediment is expected during this exercise.

6.6.2 Excavated sediment would be backfilled into the cofferdam pit by mechanical means (excavator) from the barge, and the beach re-instated. This activity would result in some disturbance to a strip of the beach alongside the pit. Any effect would be localised and short term and this would be assisted by the surface layers of sand replaced into the footprint being similar to that present in undisturbed adjacent areas.

6.6.3 Trenching, stock-piling and backfilling of the open trenches for placement and burial of the cables connecting the landfall to the offshore export cable has the potential to temporarily increase suspended sediment concentrations in the nearshore zone. Some of the sediment displaced during trenching and temporary stock-piling will become mobilised by wave and tidal action, and dispersed across the foreshore or advected by tidal currents in the nearshore zone, where dispersion would be widespread and rapid. Due to the low volumes of sediment displacement and the wide and rapid dispersion, the effects are predicted to be small.

7 Assessment of Effects during Operation

7.1 Introduction

7.1.1 The operational phase of Dogger Bank Teesside A & B equates, at a minimum, to the duration of the lease (nominally 50 years). During this time, the marine physical processes effects of the development are likely to be evident through persistent and direct changes, resulting from wave and tidal current interactions with the foundation structures.

7.1.2 There are anticipated to be no marine physical processes effects during the operation of the inter-array cables or export cables, where they are buried beneath the seabed, or during the operation of the landfall site, because the cables will be buried beneath the shore platform and cliff. However, potential effects to sediment transport may arise across the immediate subtidal area and further offshore, where a cable on the seabed, protected by a variety of methods, including, but not limited to, rock armour, concrete mattressing, pipe, half-pipe or cable clip, is a possibility.

7.2 Effects of foundation structures on tidal currents

7.2.1 As outlined in **Table 5.1**, the worst-case foundation scenario for potential effects on tidal currents is an array of 400 6MW conical GBS[#]1 foundations across Dogger Bank Teesside A & B, spaced 750m apart around their perimeters with a wider internal spacing.

7.2.2 The effects on tidal currents of the conical gravity base foundations can be divided into two types:

- Local changes in the vicinity of each foundation created by interaction with the currents; and
- Regional changes, which are the overall changes created by the group of foundations in a particular layout pattern.

7.2.3 The regional effects on tidal currents of the foundations have been predicted as changes to depth-averaged current velocity relative to the baseline. The changes were estimated at 30-minute intervals over the 30-day simulation period.

7.2.4 **Figure 7.1** shows the maximum absolute change (increase or decrease) in depth-averaged tidal current velocity, predicted for the 6MW conical gravity base foundation layout. The strongest effect occurs along the project boundaries where the density of the foundations is highest. The maximum change is up to 0.008m/s along the project boundaries reducing to below 0.002m/s up to approximately 8km either side of the boundary. These absolute changes are so small that they are unlikely to affect the form of recent sediments over and above the natural tidal processes.

7.2.5 The maximum change in current velocity is less than 2%, restricted to narrow (up to 3km wide) bands along the boundaries of Dogger Bank Teesside A & B (**Figure 7.2**). This maximum percentage change is within the natural variation of tidal current velocity across Dogger Bank and surrounding sea areas.

7.3 Effects of foundation structures on waves

7.3.1 The simulation for the worst-case foundation layout was run using four different wave conditions, which were commonest directions of approach across Dogger Bank:

- One-year return period waves approaching from the north;
- One-year return period waves approaching from the north east;
- 50-year return period waves approaching from the north; and
- 50-year return period waves approaching from the north east.

7.3.2 The wave model boundary is defined by the rectangle in **Figure 7.3** to **Figure 7.5**, and because there are no results outside this boundary, it is not possible to show any wave effects to the east of the Dogger Bank Zone. However, it is assumed that the wave effects to the east are approximate 'mirror-images' of the effects to the west that occur within the project boundary. Instead of attempting to delineate specific magnitude of effect in these areas, a box has simply been applied to indicate the general location of the potential effects.

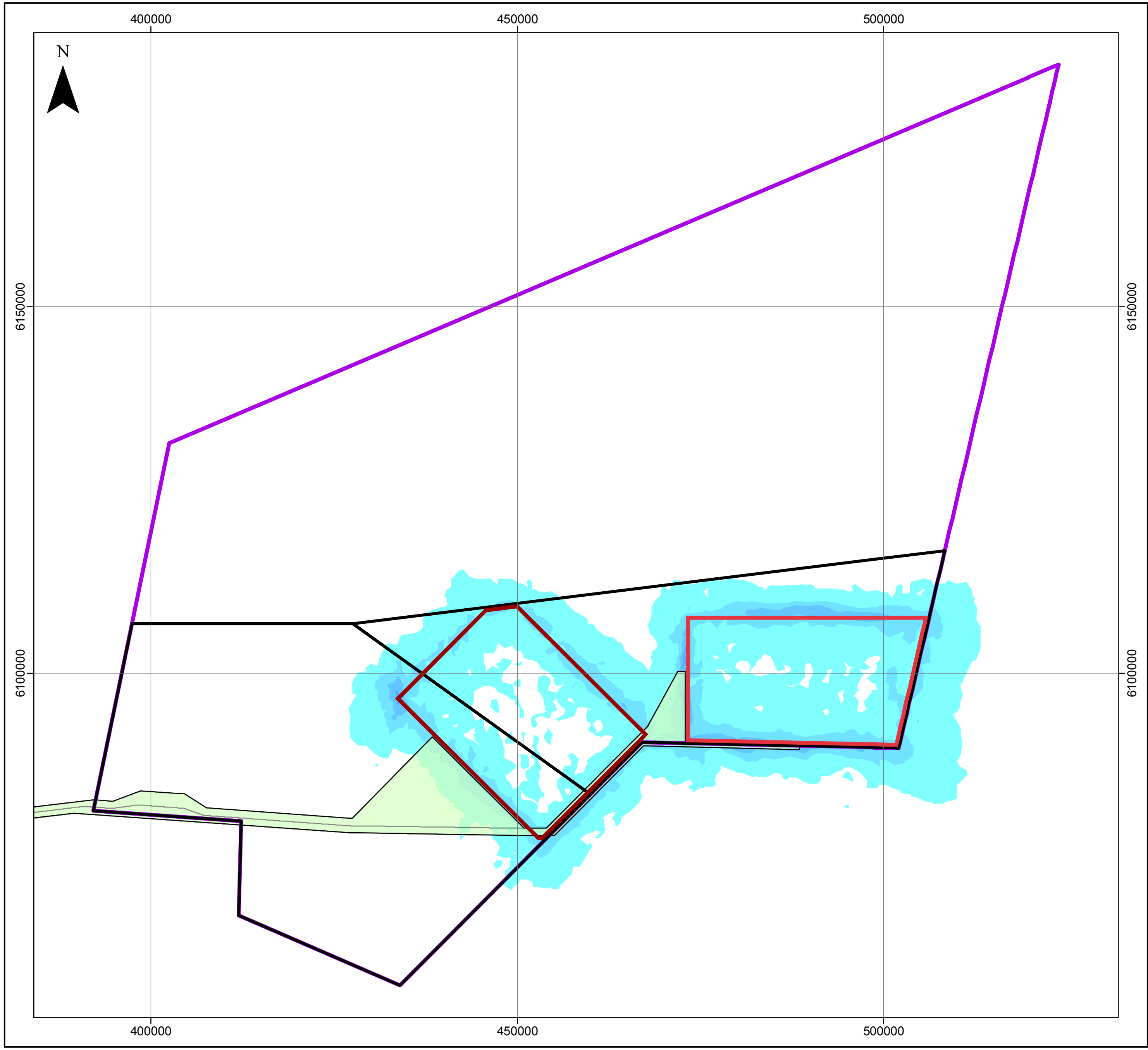
7.3.3 As outlined in **Table 5.1**, the worst-case foundation scenario for potential effects on waves is an array of 400 6MW conical GBS$^{\#}$1 foundations across Dogger Bank Teesside A & B, spaced 750m apart around their perimeters with a wider internal spacing.

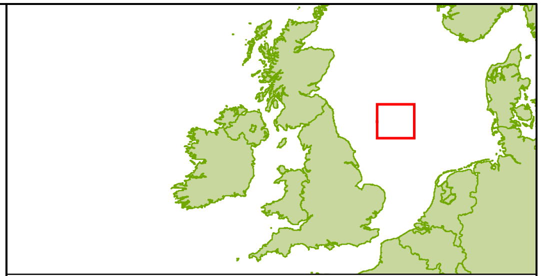
7.3.4 **Figure 7.3** to **Figure 7.5** show the difference in significant wave height between the baseline condition and the layout in place. Changes in significant wave height vary depending on the scenario that was modelled. The differences in wave height under the 50-year return period condition are less than for the one-year return period. This trend is explained in **Appendix 9A**.

7.3.5 Maximum changes in significant wave height are for one-year waves from the north and north east (**Figure 7.3** and **7.4**). The changes are up to +/-0.04m at the southern/south western and northern/north eastern boundaries of Dogger Bank Teesside A & B reducing to less than +/-0.02m up to approximately 22km (waves from the north) and 17km (waves from the north east) from the boundaries. Significant wave height reduces to less than +/-0.01m up to 75km north of Dogger Bank Teesside A & B for waves from the north.

7.3.6 The pattern of decreased and increased wave heights along opposite sides of the project areas is due to simultaneous down-wave blocking and up-wave reflection. The wave energy that is not passing through the foundations is reflected by 180^{o} so that wave height increases on the 'up-wave' side of the projects and decreases on the 'down-wave' side. Between these two areas, within the main confines of each project, the wave reflection and blockage cancel each other out (**Figures 7.3** to **7.4**).

7.3.7 By comparing the change in significant wave height to the baseline condition for the worst case one-year waves, the percentage change has been calculated. **Figure 7.5** shows that the maximum relative change in wave height results from waves from the north and north east.





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Temporary works area

Change in velocity (m/s)

- Above 0.020
- 0.018 - 0.020
- 0.016 - 0.018
- 0.014 - 0.016
- 0.012 - 0.014
- 0.010 - 0.012
- 0.008 - 0.010
- 0.006 - 0.008
- 0.004 - 0.006
- 0.002 - 0.004
- Below 0.002

0 10 20
Kilometres

Data Source:
Modelling © Danish Hydraulic Institute, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

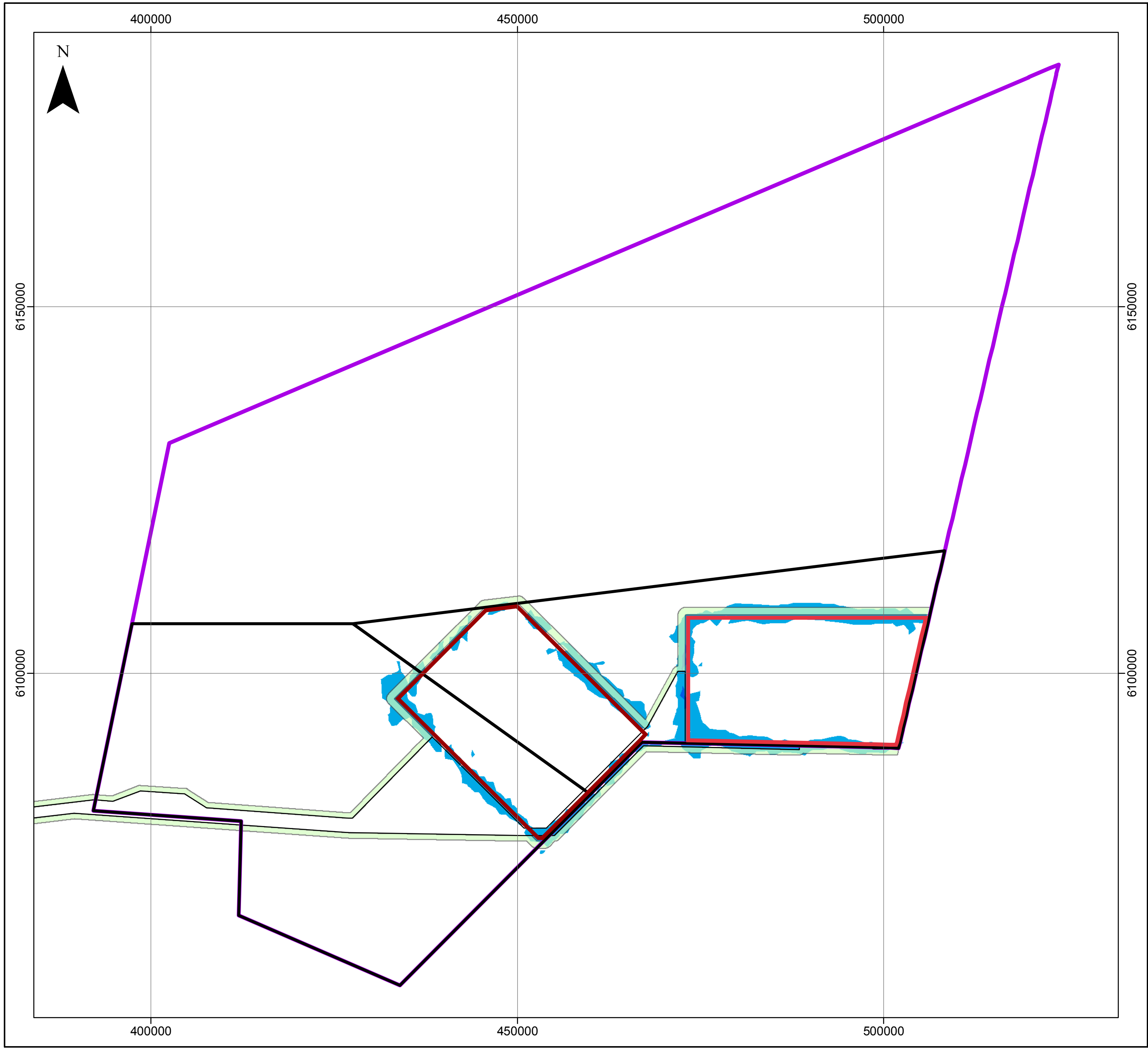
Figure 7.1 Maximum predicted change in depth-averaged tidal current velocity caused by 6MW conical GBS#1 foundations

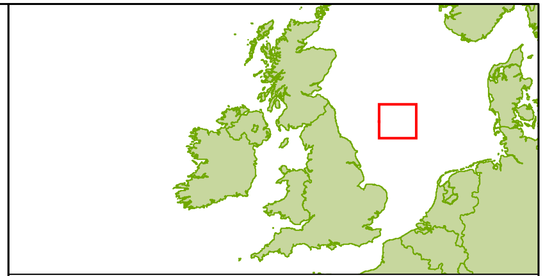
VER	DATE	REMARKS	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	08/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: **F-OFL-MA-429**

SCALE	1:800,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Temporary works area

Change in velocity (%)

- Above 5
- 4 - 5
- 3 - 4
- 2 - 3
- 1 - 2
- Below 1

0 10 20
Kilometres

Data Source:
Modelling © Danish Hydraulic Institute, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

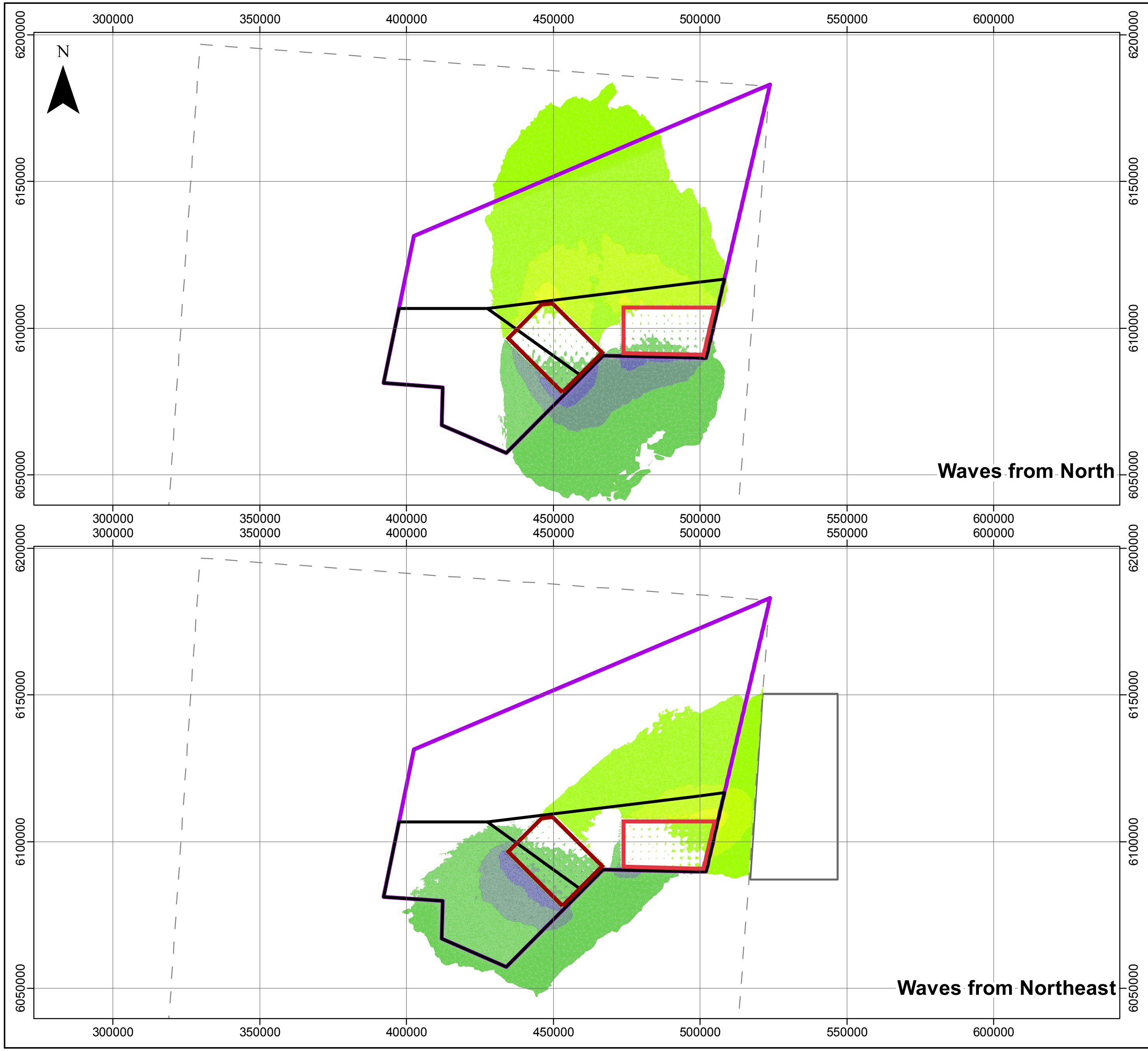
Figure 7.2 Maximum percentage change in depth-averaged tidal current velocity caused by 6MW conical GBS#1 foundations

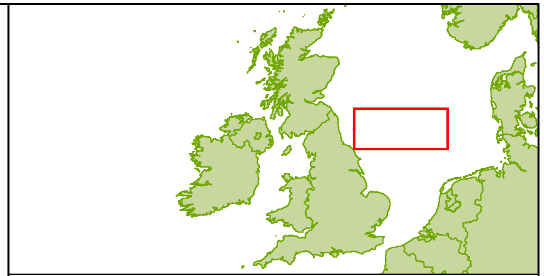
VER	DATE	REMARKS	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	08/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: **F-OFL-MA-430**

SCALE	1:800,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Model boundary
- Potential extent of wave effects into international waters

Change in significant wave height (m)

- Above 0.09
- 0.08 - 0.09
- 0.07 - 0.08
- 0.06 - 0.07
- 0.05 - 0.06
- 0.04 - 0.05
- 0.03 - 0.04
- 0.02 - 0.03
- 0.01 - 0.02
- 0.00 - 0.01
- -0.01 - 0.00
- -0.02 - -0.01
- -0.03 - -0.02
- -0.04 - -0.03
- -0.05 - -0.04
- -0.06 - -0.05
- -0.07 - -0.06
- -0.08 - -0.07
- -0.09 - -0.08
- Below -0.09

0 20 40
Kilometres

Data Source:
Wave height © Royal HaskoningDHV, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 7.3 Changes to significant wave height for one-year waves from the north and northeast caused by 6MW conical GBS#1 foundations

VER	DATE	REMARKS	Drawn	Checked
1	02/04/2013	Draft	FK	DB
2	07/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: **F-OFL-MA-431**

SCALE	1:2,000,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND