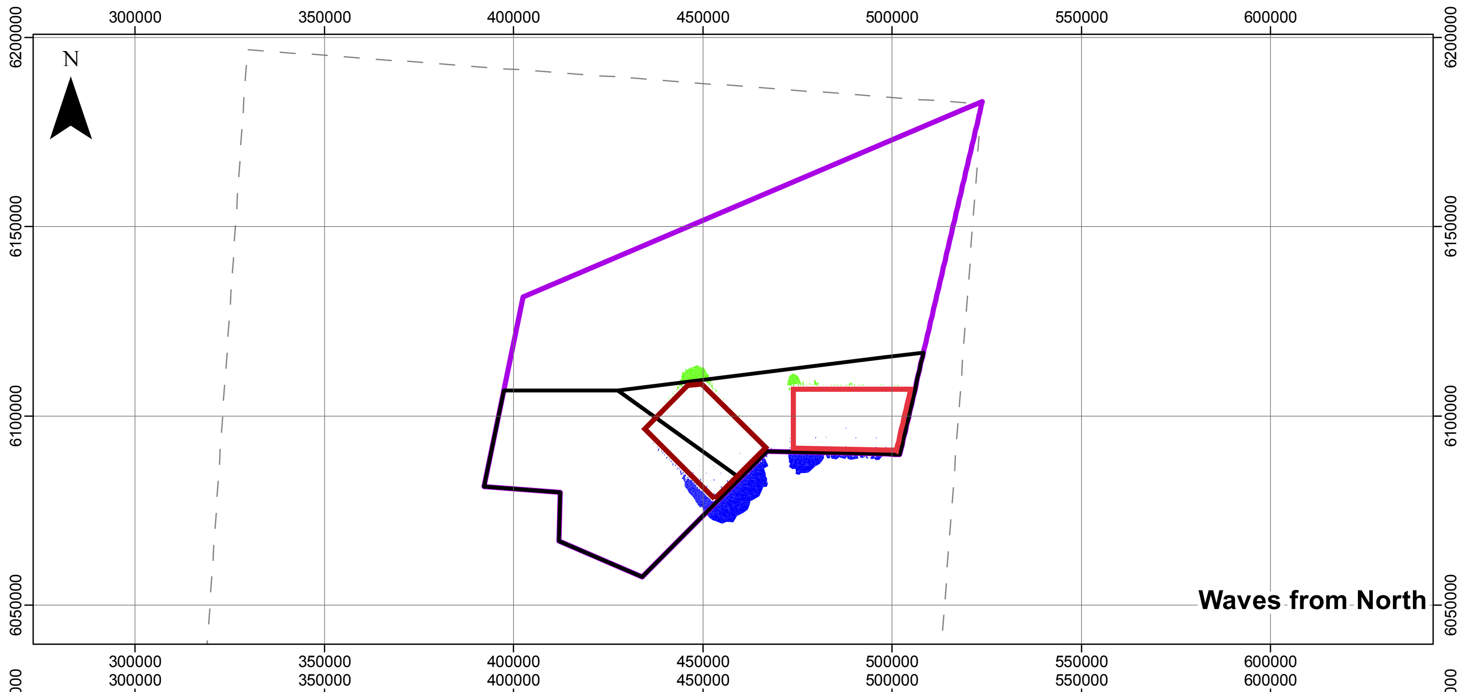
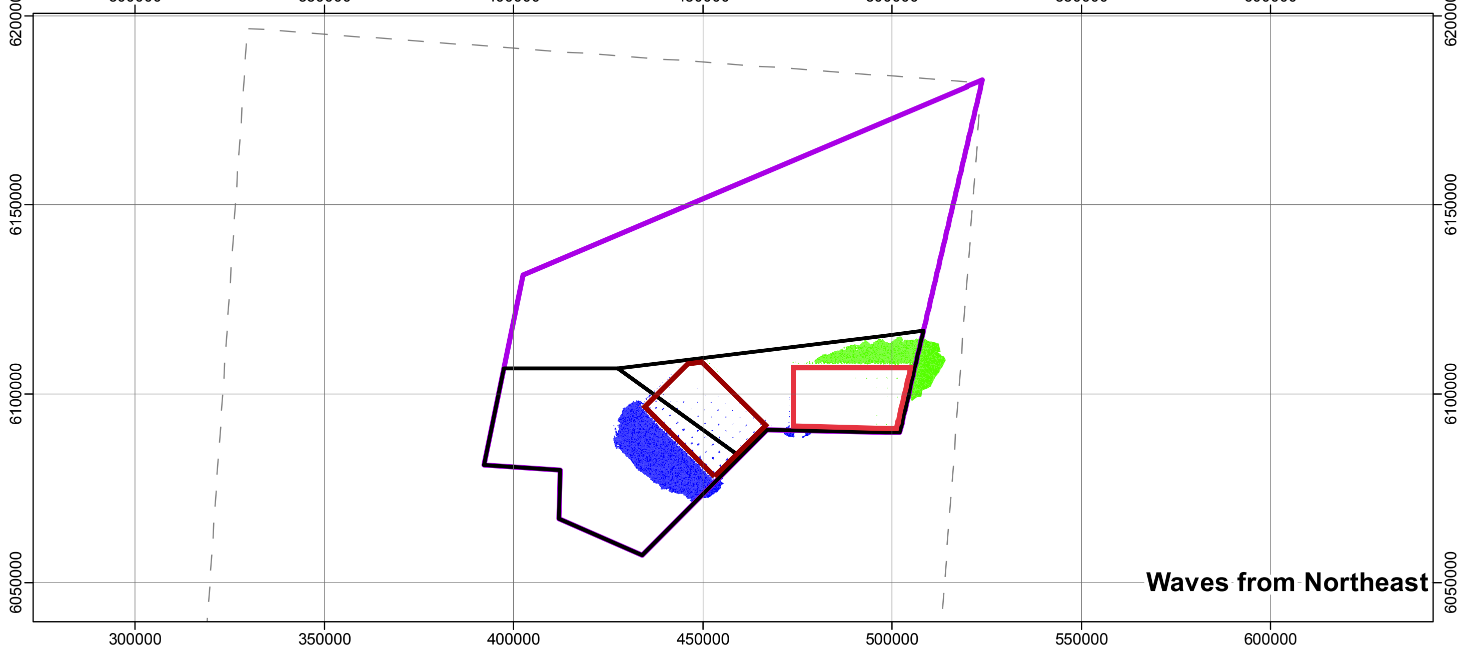
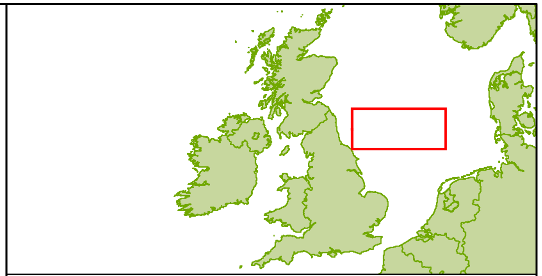






LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Model boundary

Wave height difference (%)

- 1.5 - 2
- 1 - 1.5
- 0.5 - 1
- 0 - 0.5
- -0.5 - 0
- -1.0 - -0.5
- -1.5 - -1.0
- Below - 1.5

0 20 40
Kilometres

Data Source:
Wave height © Royal HaskoningDHV, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 7.5 Percentage change 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-433**

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

FOREWIND

7.3.8 **Figure 7.5** shows that the maximum change in significant wave height for the 6MW conical gravity base foundations is approximately 1% along the southern/south western boundary of Dogger Bank Teesside B (in a band about 12km wide) and the northern boundary of Dogger Bank Teesside A. These percentage changes are within the natural variation of wave height across Dogger Bank and surrounding sea areas and are unlikely to affect the form of recent sediments over and above the natural processes.

7.4 Increase in suspended sediment concentrations as a result of foundations

7.4.1 During the operational phase, scour will occur around the base of the foundations across the project areas, resulting in the liberation of sediment to the water column and formation of sediment plumes. Details of the methodology adopted for the worst case operational scenario are provided in **Appendix 9A**.

7.4.2 The results of the plume dispersion modelling of the operational phase are presented as maximum and average changes in suspended sediment concentration in the bottom layer and sediment thickness deposited from the plume. The worst case results are presented for a run of the model during which all 400 foundations (across Dogger Bank Teesside A & B) (and related infrastructure) are struck by a 50-year storm. The following statistical measures were used:

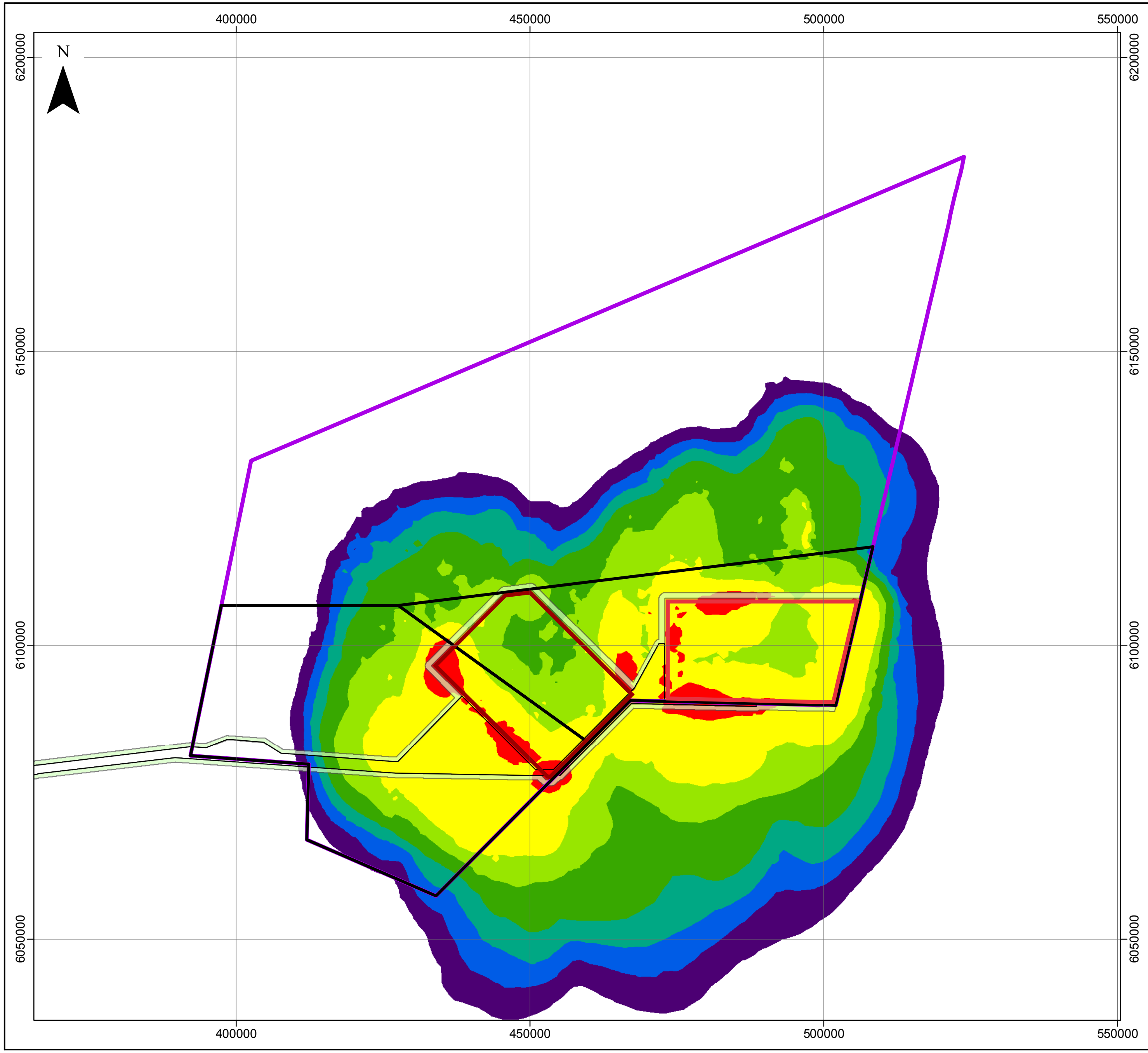
- The maximum values over the 30-day simulation period;
- The average values over the 30-day simulation period; and
- The time over which suspended sediment concentration exceeds 2mg/l.

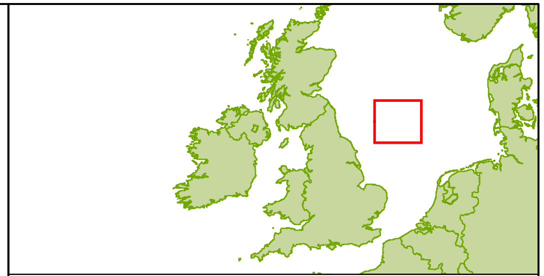
7.4.3 Once the foundations have been scoured to their equilibrium depth, they are unlikely to refill (either partially or fully). Hence, once the scour has reached its equilibrium value for typical conditions (which may take place over a short period of time), then there will be an absence of sediment for further scouring under typical conditions in the future.

Predicted suspended sediment concentrations in the bottom layer

7.4.4 **Figure 7.6** to **Figure 7.8** show maps of suspended sediment concentration in the bottom layer after two years of operation. The concentrations are presented as excesses over the natural background concentration (2mg/l).

7.4.5 **Figure 7.6** shows that maximum suspended sediment concentrations predicted to be greater than 200mg/l occur as up to 20km long, 6km wide patches along the northern and southern boundaries of Dogger Bank Teesside A and the south western boundary of Dogger Bank Teesside B. Across both projects, suspended sediment concentrations are greater than 20mg/l. Suspended sediment concentrations reduce to the background of 2mg/l approximately 40-54km south of the projects southern boundaries and 20-37km north of the northern boundaries.





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

Data Source:
Modelling © Danish Hydraulic Institute, 2013

0 10 20
Kilometres

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

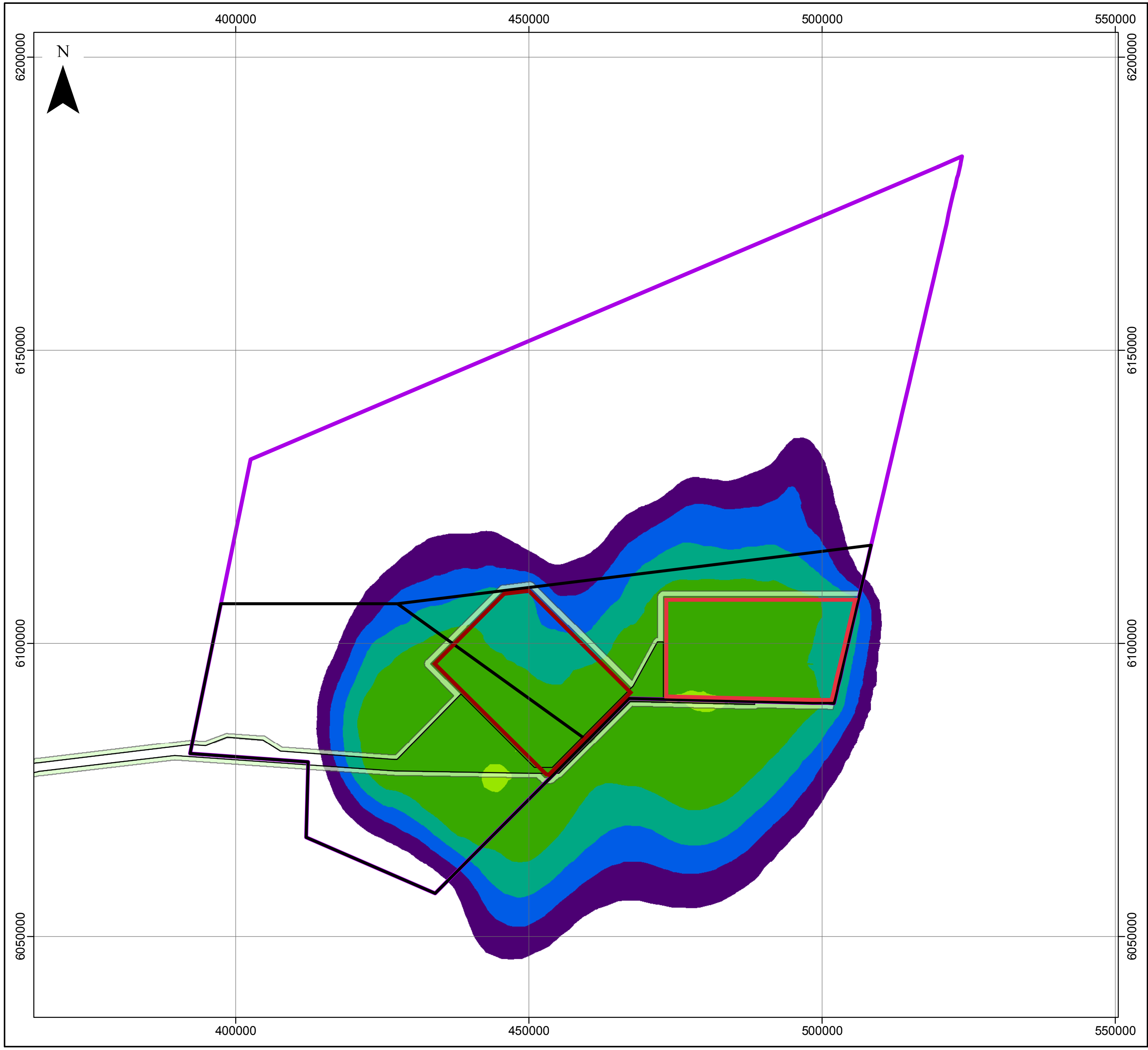
Figure 7.6 Maximum SSC in the bottom layer predicted over the simulation period after two years of operation using the re-suspension of fractions 1 and 2 method

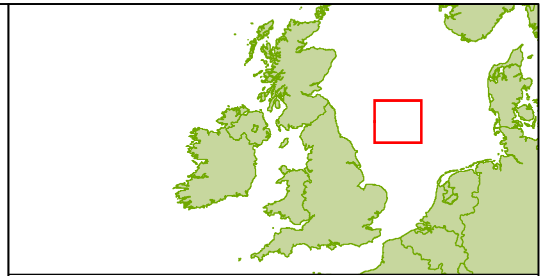
VER	DATE	REMARKS	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	08/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: **F-OFL-MA-434**

SCALE	1:1,000,000	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

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

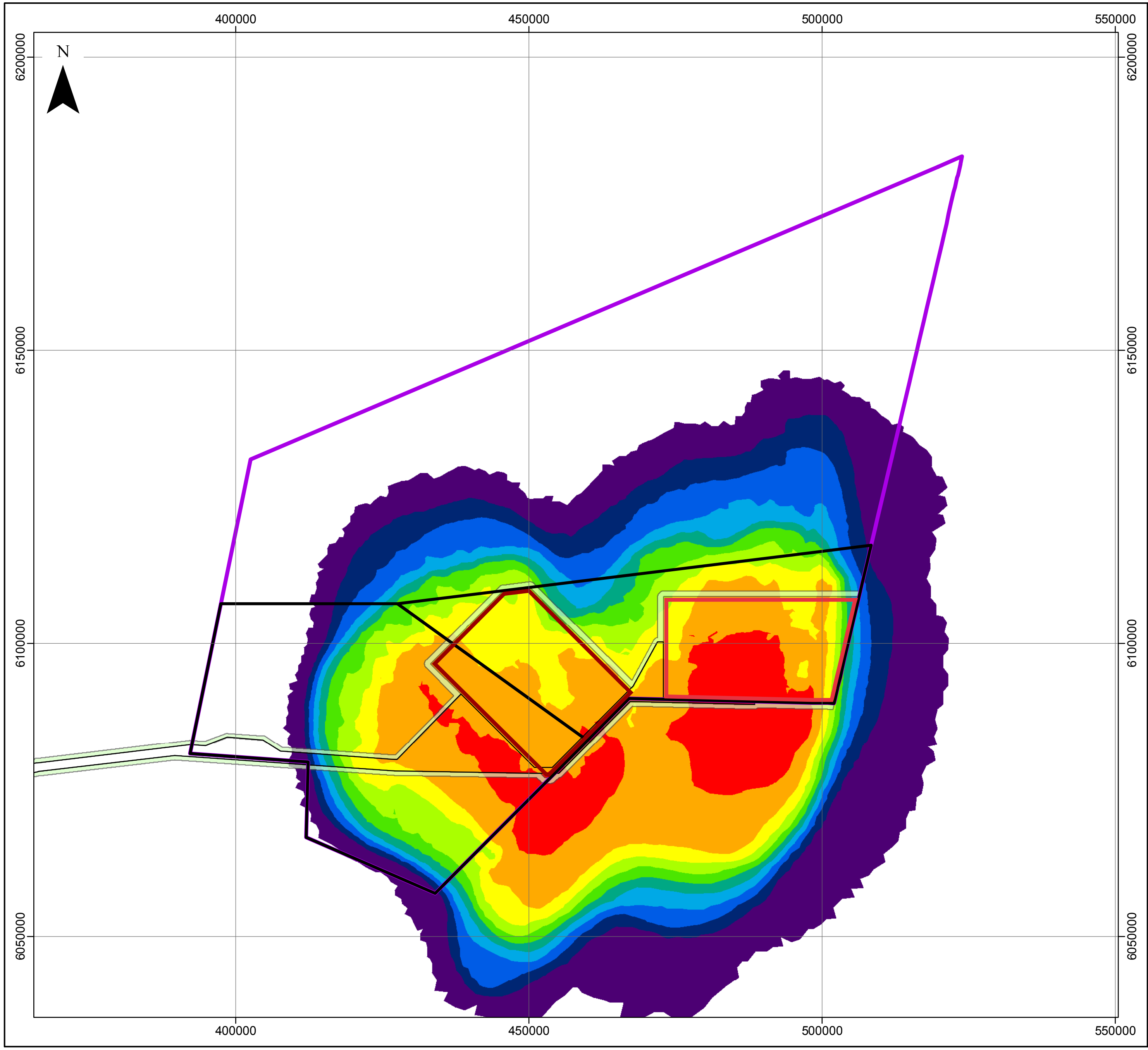
Figure 7.7 Average SSC in the bottom layer predicted over the simulation period after two years of operation using the re-suspension of fractions 1 and 2 method

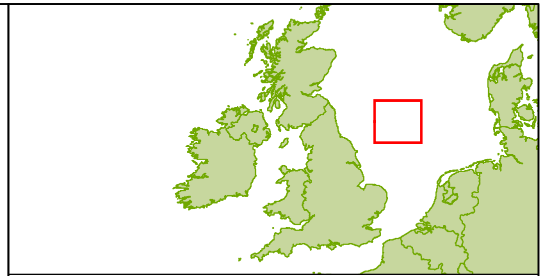
VER	DATE	REMARKS	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	08/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: **F-OFL-MA-435**

SCALE	1:1,000,000	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

Exceedance of 2 mg/l (%)

- Above 90
- 80 - 90
- 70 - 80
- 60 - 70
- 50 - 60
- 40 - 50
- 30- 40
- 20 - 30
- 10 - 20
- 0 - 10
- Below 0

0 10 20
Kilometres

Data Source:
Modelling © Danish Hydraulic Institute, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 7.8 Percentage of time predicted over the simulation period where SSC of 2mg/l is exceeded in the bottom layer after two years of operation 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-436**

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

FOREWIND

7.4.6 The average suspended sediment concentration in the bottom layer predicted over the simulation period is presented in **Figure 7.7**. Suspended sediment concentrations are between 10mg/l and 50mg/l across both projects and for up to approximately 19km to their south. Concentrations reduce to the background of 2mg/l up to approximately 36km south of the projects southern boundaries and up to 26km north of Dogger Bank Teesside A northern boundary.

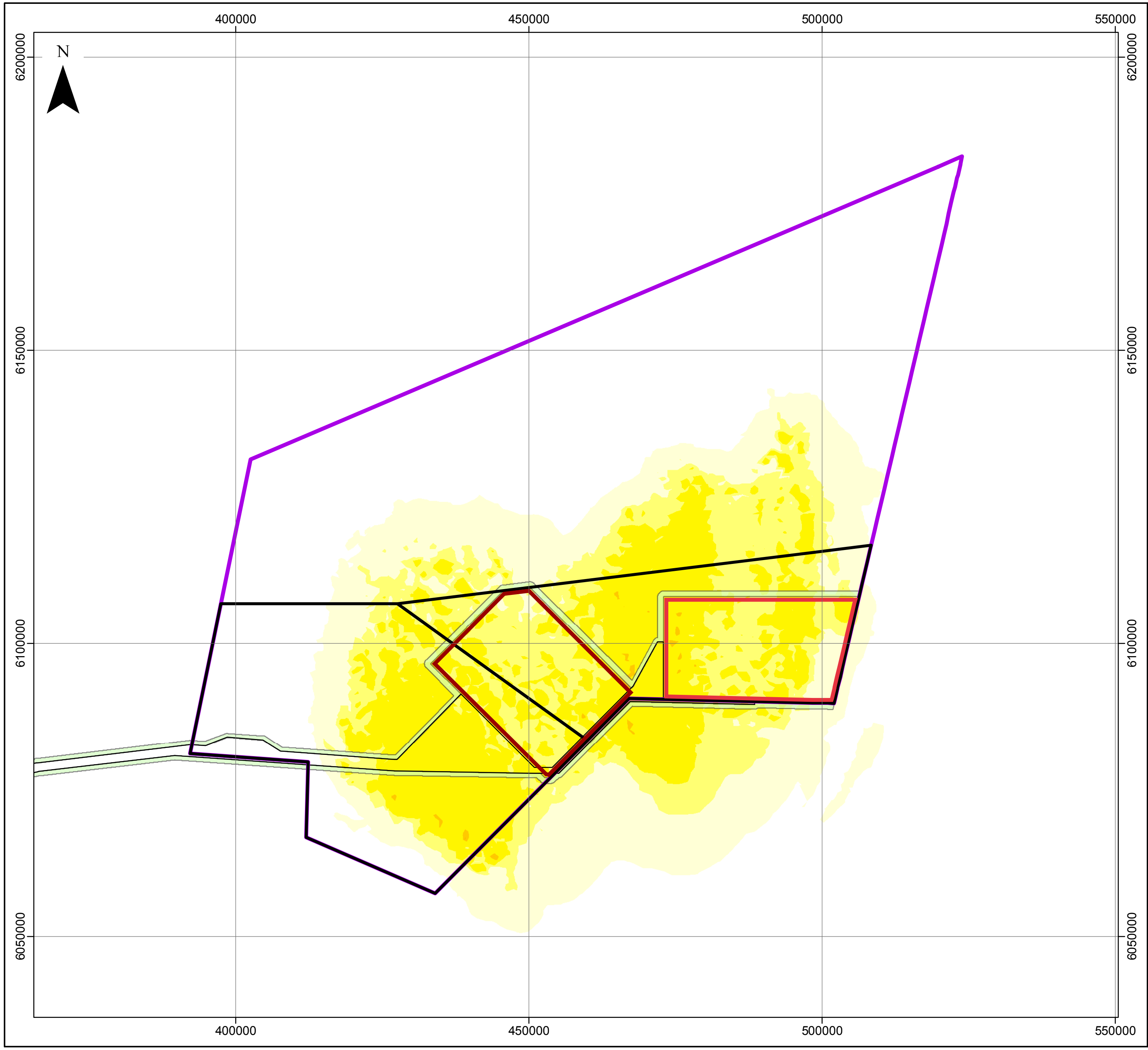
7.4.7 **Figure 7.8** presents the exceedance time during the simulation of the predicted suspended sediment concentration above a chosen limit of 2mg/l. The map shows that 2mg/l is exceeded greater than 90% of the 30-day simulation period in two patches, one to the south of Dogger Bank Teesside B and one within and to the south of Dogger Bank Teesside A, up to 15km south of their southern boundaries. Exceedance is generally greater 70% across both Dogger Bank Teesside A & B.

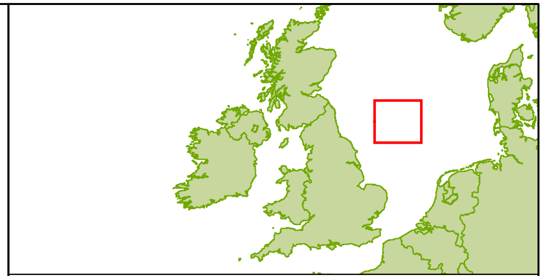
Predicted deposition and re-suspension of dispersed sediment

7.4.8 **Figure 7.9** shows the maximum change in deposition predicted at any time over the 30-day simulation period. The predicted maximum thickness over the simulation period is 5mm with the majority of the project areas subject to maximum deposition between 0.5mm and 5mm. Thicknesses reduce to below 0.1mm approximately 16-30km from the southern boundaries of the projects and 13-35km from the northern boundaries.

7.4.9 Average deposition is predicted to be between 0.5mm and 5mm in a 32km long, 14km wide area located between the two projects (**Figure 7.10**). Elsewhere the maximum average deposition is less than 0.5mm reducing to less than 0.1mm approximately 23km south west of Dogger Bank Teesside B and 19km north of Dogger Bank Teesside A.

7.4.10 **Table 7.1** describes the maximum lengths of time that sediment maintains thicknesses greater than 10mm, 7mm, 3mm and 1mm, based on time series of the plume over the 30-day simulation period at seven selected points (Points R1 to R7 in **Figure 7.11**). **Table 7.1** demonstrates that maximum sediment thickness is 1.7mm at R5. Thicknesses greater than 1mm persist for 72 hours (3.00 days), 70 hours (2.92 days), 32 hours (1.33 days) and 34 hours (1.42 days) at Points, R1, R3, R4 and R5, respectively.





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

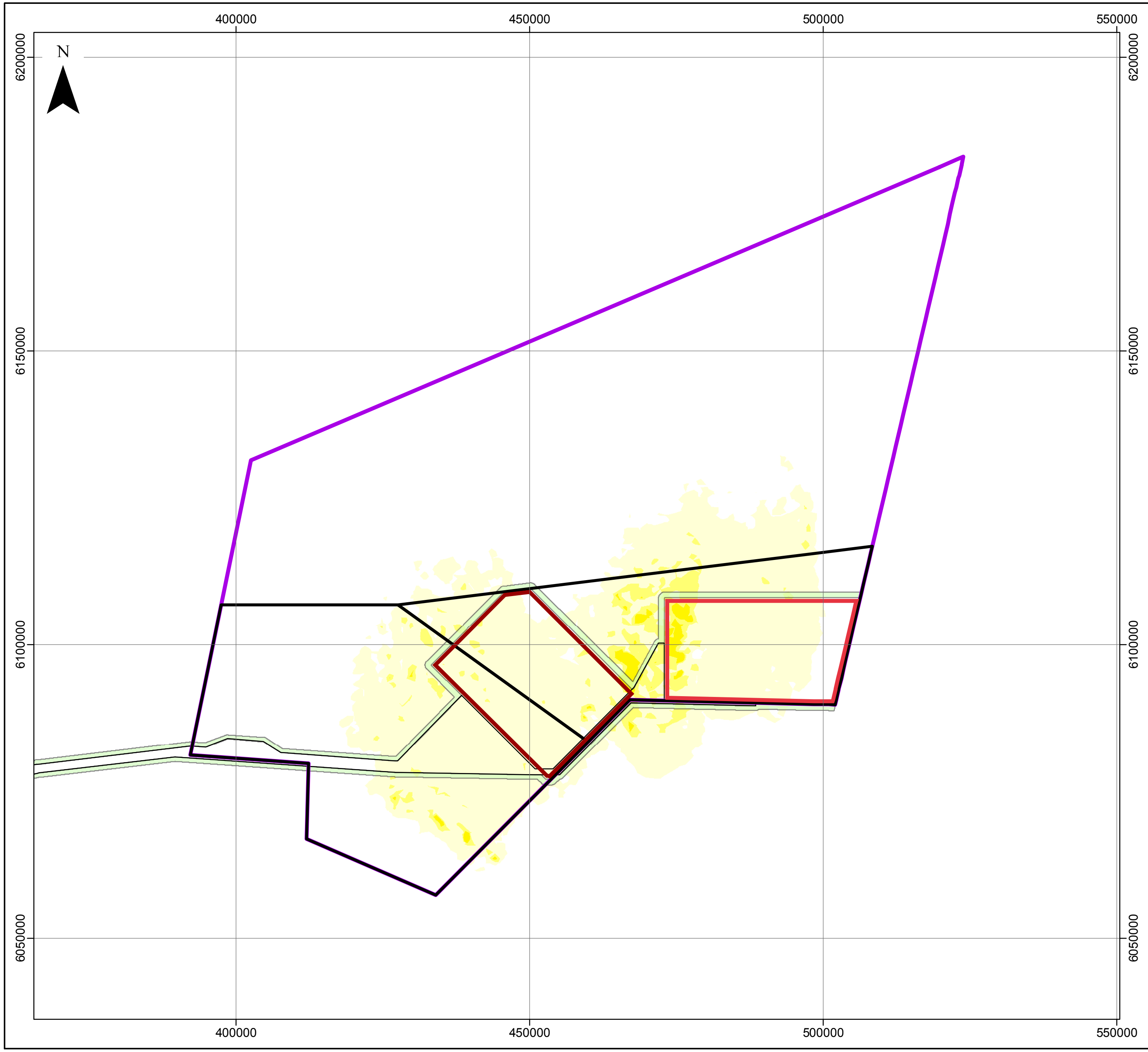
Figure 7.9 Maximum deposition predicted over the simulation period after two years of operation using the re-suspension of fractions 1 and 2 method

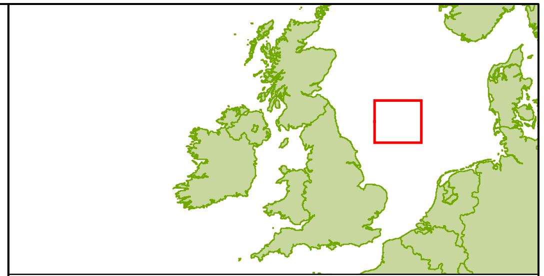
VER	DATE	REMARKS	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	08/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: **F-OFL-MA-437**

SCALE	1:1,000,000	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 (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

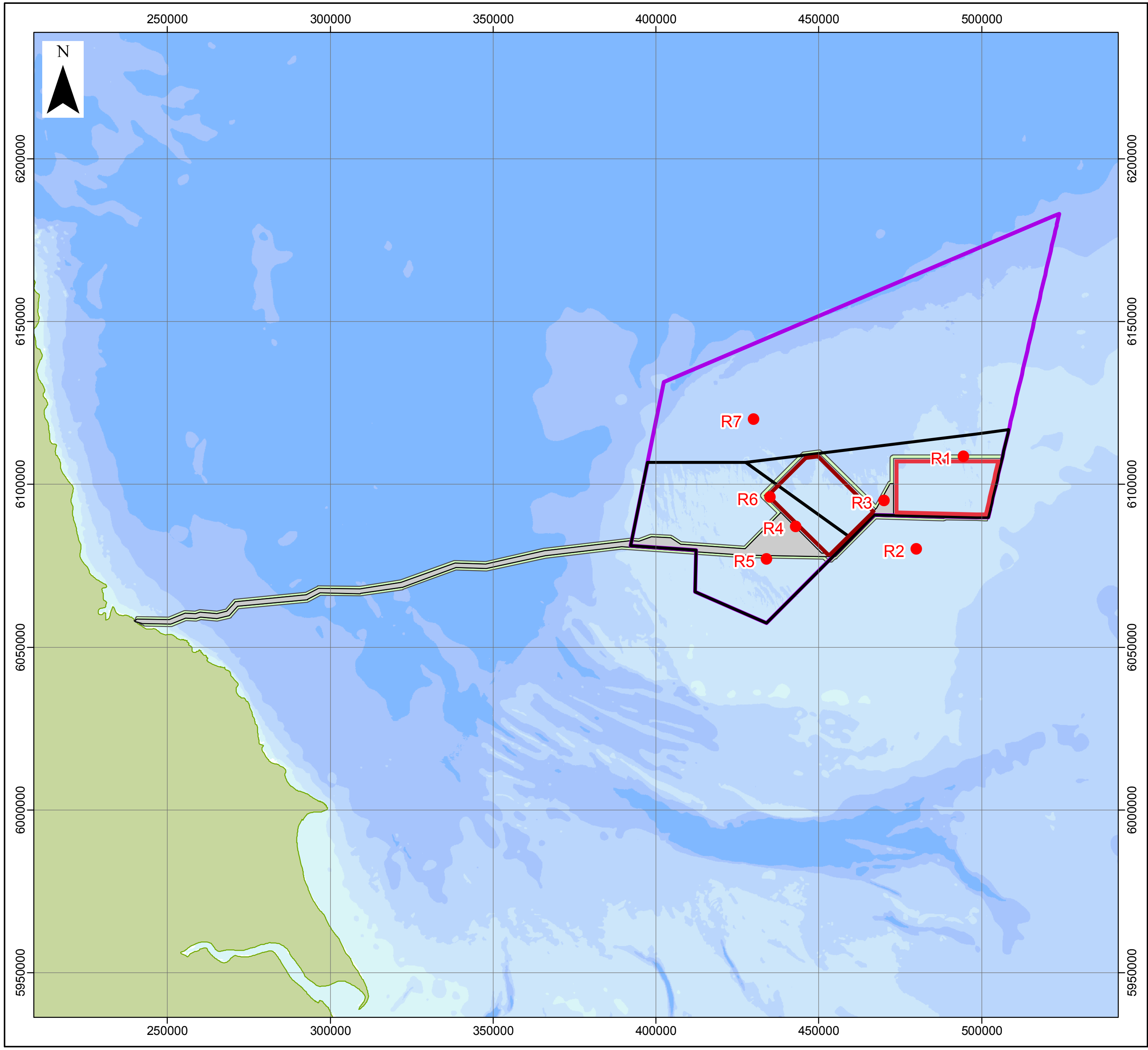
Figure 7.10 Average deposition predicted over the simulation period after two years of operation using the re-suspension of fractions 1 and 2 method

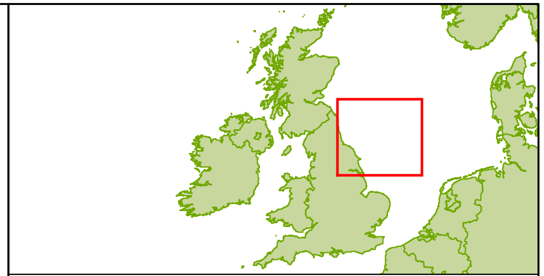
VER	DATE	REMARKS	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	08/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: **F-OFL-MA-438**

SCALE	1:1,000,000	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 7.11 Location of points for sediment thickness time series analysis for the operational phase

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-439**

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

FOREWIND

Table 7.1 Maximum persistency of sediment thickness over the 30-day simulation period after two years of operation

Point	Maximum thickness (mm)	Maximum continuous time of sediment thickness (hours with days in brackets)				Thickness at end of simulation (mm)
		>10mm	>7mm	>3mm	>1mm	
R1	1.62	0	0	0	72 (3.00)	<0.1
R2	0.75	0	0	0	0	<0.1
R3	1.65	0	0	0	70 (2.92)	<0.1
R4	1.06	0	0	0	32 (1.33)	<0.1
R5	1.74	0	0	0	34 (1.42)	<0.1
R6	0.96	0	0	0	0	<0.1
R7	0.21	0	0	0	0	<0.1

Comparison of scour volumes against naturally occurring release of sediment during one-year and 50-year storms

7.4.11 In order to compare the predicted sediment volumes released by the scour process into the context of the scale of natural processes, empirical formulae were used to determine sediment volumes disturbed during a 50-year storm across Dogger Bank without foundations in place.

7.4.12 In order to place the suspended sediment volumes into context, they were referenced to the total volume of sediment that would be suspended within a volume of water around a foundation in the proposed layout. Along the project boundaries the foundations are spaced at 750m centres. Accordingly, the natural suspended sediment volumes were predicted for a body of water with a footprint of 700m x 700m (the water depth was taken as a representative mean value of 27.6m). The total volume of suspended sediment within the associated volume of water was then compared against that which is predicted to be released due to scour around one foundation at the same storm return period.

7.4.13 The suspended volume of sediment was also converted to an equivalent depth of sand released from the seabed and compared against the potentially available sediment in borehole records. Provided that there is sufficient material available on the seabed, then the predicted volume of suspended sediment can occur under natural conditions. **Table 7.2** shows the results of the predictions.

Table 7.2 Natural suspended and GBS scour volumes released during a 50-year storm condition

Storm	Naturally suspended volume (m^3)	Maximum scour volume from GBS (m^3)	Equivalent bed depth released in suspension (mm)
50 year	16,254	2,843	29

7.4.14 **Table 7.2** shows that under a 50-year storm condition, the naturally-occurring volumes of suspended sediment are almost six times greater than those that could arise due to scour predicted to occur around a 6MW conical GBS foundation. In order to sustain the predicted natural suspended sediment volume, only 29mm of sand needs to be lifted off the seabed. There is more than sufficient naturally occurring sediment to sustain the predicted suspended volume at the 50-year return period.

7.5 Effect on nearshore sediment transport of seabed cable protection

7.5.1 During the lifetime of operation, the export cables will be buried below the intertidal zone and cliffs. Therefore, there will be no effects on coastal processes during the operational phase in these areas. However, in the subtidal zone, there is a possibility that up to four export cables will be on the surface and protected by rock armour (or some other form of remedial protection), which could potentially create a partial barrier to sediment transport.

7.5.2 The main reason for the export cables to be surface laid is the absence of surface sand and the proximity of bedrock to the seabed.

7.5.3 As a worst case, remedial protection of the export cable will be 15m wide and stand 1.5m above the surrounding seabed. There is the potential for up to four export cables requiring protection, and hence, four 15m wide (at the base, 5m at the top), 1.5m high structures have been assessed as the worst case scenario.

7.5.4 Interpretation of the nearshore geophysical data by Forewind has provided an estimate of the anticipated amount of remedial protection required in the nearshore area, approaching the Redcar and Cleveland coast. Forewind indicate that no remedial protection will be necessary from the mean low spring tide mark to 350m seaward of this mark. At Marske-by-the-Sea, mean low spring tide (-1.95m OD) is about 400m seaward of the cliffs. This means that from the cliffs to approximately 750m seaward (across the intertidal zone and shallow subtidal zone), the export cables will be buried and have no effect on coastal processes.

7.5.5 Forewind is also confident that burial or trenching of the export cables will be achievable for a minimum of 176.8km of the total 261km length of each cable, leaving a potential maximum of 84.2km of remedial protection per export cable.

7.5.6 For the inter-array cables, the worst case dimensions of the remedial protection are 4.5m wide at the base, 0.5m wide at the top, and 0.7m high. The worst case length of inter-array cables is 1,900km (across both projects), of which 1,536km may be buried leaving a potential maximum of 364km of remedial protection.

7.5.7 The worst case dimensions for the inter-platform cables are the same as the export cables (15m wide at the base, 5m wide at the top and 1.5m high). The worst case length of inter-platform cables is 640km (across both projects), of which 508.8km may be buried leaving a potential maximum of 131.2km of remedial protection.

7.5.8 The key factors in determining the magnitude of the potential effect on bedload sediment transport of remedial protection are the type and aerial extent of transport on the bed. The two main drivers of transport in the nearshore zone are waves approaching the coast predominantly from the northeast and tidal currents further offshore. The aerial extent of transport will depend on the size of the zone in which sediment is actively mobile and the magnitude of transport within this zone. Along the coastline in the vicinity of the landfall, sediment transport takes places under three principal mechanisms (Appendix C of **Appendix 9A**):

- Longshore sediment transport: this transport mechanism occurs along the nearshore seabed as a result of wave-driven processes and occurs primarily as bedload transport. The net longshore sediment transport direction is from north to south but reversals in transport do occur due to local promontories (such as the South Gare Breakwater) and variations in wave climate, such as during storm events from a particular offshore direction.
- Cross-shore sediment transport: this transport mechanism also occurs along the nearshore seabed as a result of wave-driven processes and occurs primarily as bedload transport. However, the sediment is generally transported offshore from the beach to the nearshore during storm events and returned to the beach during more constructive wave conditions.
- Suspended sediment transport: this transport mechanism occurs across the wider seabed of Tees Bay and involves the transportation of sediments in suspension in the water column by the action of tidal currents. Often, wave stirring initiates the mobilisation of seabed sediments.

7.5.9 The placement of cables on the seabed in areas where burial cannot be achieved, and the potential remedial protection of these lengths , could potentially affect the longshore sediment transport processes if placed in the active transport zone. Cables, or cable protection works, would be unlikely to significantly affect cross-shore sediment transport since they would be laid broadly in alignment with the cross-shore transport direction, providing little obstruction to sediment movement. Cables, or cable protection works, would also be unlikely to significantly affect suspended sediment transport since this occurs throughout the water column and not only near to the bed in the layer occupied by cables or protection works.

7.5.10 To investigate the potential effect of remedial protection on the longshore sediment transport regime, it is necessary to define the active littoral zone. Using the Houston formula the active zone is about approximately 2km wide offshore from mean low water spring along the cable route (to about the 10m water depth contour). Consequently, any remedial protection seaward of 2km offshore would have no effect on longshore sediment transport processes.

7.5.11 Within the 2km nearshore zone defined by the closure depth, the main wave activity, and hence wave-driven sediment transport, is in the intertidal and shallow subtidal zones, with most of the sediment transport (although low along this coastline) to the southeast taking place in the intertidal zone. Given that the cables will be buried in the intertidal zone and for 350m seaward of mean low water spring, there will be no barrier to sediment transport and no effect on the highest magnitude longshore sediment transport at the landfall. Hence, there will be no effect on sediment supply to the beaches south of Marske-by-the-Sea and on the coastal geomorphology of adjacent coasts.

7.5.12 The presence of any remedial protection on the seabed, between 350m and 2km offshore from mean low water spring, would provide partial physical barriers to sand transport on, and close to, the seabed. Here, the rate of sediment transport is even lower (driven by tidal currents and lower energy waves) than the already low rates of wave-driven sediment transport along the coastline. Along the coastline, the low rates are manifest in only small sediment build-up on the west side of the Redcar groynes (northwest of the cable corridor). There is, therefore, limited potential for interruption of sediment transport in the 350m to 2km offshore zone. Hence, the magnitude of changes at locations 'downdrift' of the export cables, both locally and further down the sediment transport pathway, are likely to be very small. Larger volumes of sediment are transported in cross-shore directions during storm events, but this mode of transport is not affected by the remedial protection.

7.5.13 The remedial protection along the export cables may also provide a barrier to sand transport driven by tidal current flows. Flows would tend to accelerate over the protection and then decelerate on the 'down-flow' side, returning to baseline values a short distance from the structure. These changes in velocity would occur in a north to south direction on the flood flow and south to north on the ebb flow. The interruption to flows due to the presence of remedial protection could, potentially, have two effects:

- Stop or slow down the bedload transport of sediment across the seabed by acting as a physical barrier; and
- Induce local turbulence in the flow field which could cause unwanted secondary scour in a 'down-flow' direction.

7.5.14 The flood current along the Redcar and Cleveland coastline generally is to the south, flowing parallel to the coast. However, the presence of the Tees Estuary, various maritime structures, headlands and outcrops do locally affect the broader patterns. For example, a localised gyre exists immediately east of the South Gare Breakwater on the flooding tide which has the potential to move sediment transported in suspension in the water column westwards, back towards the mouth of the River Tees estuary.

7.5.15 Also, the majority of this sediment would most likely become entrained in the increased flow path over the protection and be transported from one side to the other, either as near-bed suspended sediment or 'rolled' over the armour as bedload. Any sediment that does become trapped against the cable protection will, eventually (over a long period of time given the volumes), create a 'ramp' across which other sediments can bypass the armouring.

7.5.16 Some sediment would infill the interstices between adjoining rocks within the structure and some would remain on the up-flow side of the armour that would otherwise have been transported beyond this position on the seabed. However, the relatively shallow side-slopes of the armour, about 1 in 4 (14^{o}), are shallower than the critical angle of repose of wet sand (45^{o}) and therefore the 'blocking' effect will be relatively small (compared with, for example, the entrapment against a vertical side slope of a protection structure).

7.5.17 With respect to local turbulence induced in the flow field, this could cause unwanted secondary scour in a ‘down-flow’ direction. However, it is considered to be small in comparison to the potential effects on net bedload transport, and is likely to be local in extent and temporary in nature.

7.5.18 In addition, the flood and ebb currents are different in magnitude, so that there is a net (residual) current. As the flood tide has slightly stronger currents than the ebb tide, the residual current generally is to the south east. Given that the residual current is small, the secondary scour hole created in the down-flow direction on one side of the cable protection would be partially infilled by deposition into the scour on the reverse tide.

8 Assessment of Effects during Decommissioning

8.1 Removal of foundations and cables

8.1.1 The effects are likely to include short-term increases in suspended sediment concentration and sediment deposition from the plume caused by foundation cutting or dredging and seabed disturbance caused by removal of cables and cable protection. The effects during decommissioning of the foundations, inter-array cables and export cables are considered to be less than those described during the construction phase (Section 6). This is because there will be no need for seabed preparation or pile drilling and there is a possibility that cables are left *in situ* with no consequential increase in suspended sediment concentration.

8.2 Removal of landfall infrastructure

8.2.1 A plan for decommissioning the cable at the landfall has yet to be defined, although at the end of its field life it may be dismantled and re-used or decommissioned and left *in situ*, depending on foreseeable cliff erosion. During any decommissioning process, sections of buried cable under the cliff may be removed if there is a potential for exposure due to cliff erosion. If the cable is removed from the beach and intertidal area, there will be temporary local effects of a type and duration likely to be similar to the construction phase activities (Section 6).

9 Inter-relationships

9.1.1 In order to address the environmental impact of the proposed development as a whole, this section establishes the inter-relationships between marine physical processes and other physical, environmental and human receptors. The objective is to identify where the accumulation of residual effects on a single receptor, and the relationship between those effects, gives rise to a need for additional mitigation.

9.1.2 **Table 9.1** summarises the inter-relationships that are considered of relevance to marine physical processes and identifies where they have been considered within the ES.

9.1.3 Although the effects assessed on marine physical processes have the potential to impact a number of other receptors, no inter-relationships have been identified where an accumulation of residual effects on marine physical processes and the relationship between those effects gives rise to a need for additional mitigation.

Table 9.1 Inter-relationships relevant to the assessment of marine physical processes

Inter-relationship	Section where addressed	Linked chapter
Construction and decommissioning		
Re-suspension of seabed sediments through seabed preparation, drill arisings and scour has the potential to affect water and sediment quality.	Section 6.2 (construction effects on sediment transport)	**Chapter 10 Marine Water and Sediment Quality**
Suspended sediments have the potential to affect other ecological receptors including marine ecology, marine mammals and fish.	Section 6.2 (construction effects on sediment transport)	**Chapter 12 Marine and Intertidal Ecology** **Chapter 13 Fish and Shellfish** **Chapter 14 Marine Mammals**
Suspended sediments have the potential to affect tourism and recreation.	Section 6.2 (construction effects on sediment transport)	**Chapter 23 Tourism and Recreation**
Re-suspension of seabed sediments through seabed preparation, drill arisings and scour has the potential to affect other marine users.	Section 6.2 (construction effects on sediment transport)	**Chapter 17 Other Marine Users**
Re-suspension of seabed sediments through seabed preparation, drill arisings and scour has the potential to affect marine archaeological resources.	Section 6.2 (construction effects on sediment transport)	**Chapter 18 Marine and Coastal Archaeology**
Changes in coastal processes have the potential to affect ecological	Section 6.3 (construction effects at the landfall)	**Chapter 12 Marine and Intertidal Ecology**

Inter-relationship	Section where addressed	Linked chapter
receptors.		
Changes to coastal processes and the physical composition of the coast can affect seascape and visual character.	Section 6.3 (construction effects at the landfall)	**Chapter 20 Seascape and Visual Character**
Scour of the seabed has the potential to result in a change of habitat.	Section 5 (realistic worst case scenario)	**Chapter 12 Marine and Intertidal Ecology**
Operation		
Re-suspension of seabed sediments through scour has the potential to affect water and sediment quality.	Section 7.4 (operational effects on sediment transport)	**Chapter 10 Marine Water and Sediment Quality**
Re-suspension of seabed sediments through scour has the potential to affect other marine users.	Section 7.4 (operational effects on sediment transport)	**Chapter 17 Other Marine Users**
Re-suspension of seabed sediments through scour has the potential to affect marine archaeological resources.	Section 7.4 (operational effects on sediment transport)	**Chapter 18 Marine and Coastal Archaeology**
Suspended sediments and changes in wave and tidal current regime have the potential to affect other ecological receptors including marine ecology and fish.	Sections 7.2 and 7.3 (operational effects on tidal currents and waves, respectively) and Section 7.4 (operational effects on sediment transport)	**Chapter 12 Marine and Intertidal Ecology** **Chapter 13 Fish and Shellfish**
Changes to far-field wave and hydrodynamic conditions have the potential to affect designated habitats.	Sections 7.2 and 7.3 (operational effects on tidal currents and waves, respectively)	**Chapter 8 Designated Sites**

9.1.4 **Chapter 31 Inter-relationships** provides a holistic overview of all of the inter-relationships associated within the proposed development.

10 Cumulative Effects

10.1 Cumulative impact assessment strategy and screening

10.1.1 This section describes the cumulative assessment for marine physical processes, taking into consideration other plans, projects and activities. A summary of the cumulative impact assessment (CIA) is presented in **Chapter 33**.

10.1.2 Forewind has developed a strategy (the 'CIA Strategy') for the assessment of cumulative impacts in consultation with statutory stakeholders including the Marine Management Organisation (MMO), Joint Nature Conservation Committee (JNCC), Natural England and Centre for Environment, Fisheries and Aquaculture Science (Cefas). Details of the approach to CIA adopted for this ES are provided in **Chapter 4 EIA Process**. Although the marine physical processes assessment focusses on describing the effects against the existing environment, rather than defining the impact (see Section 3.3), the general approach taken to the cumulative assessment is the same.

10.1.3 In its simplest form the CIA Strategy involves consideration of:

- Whether impacts on a receptor (or effects) can occur on a cumulative basis between the wind farm project(s) subject to the application(s) and other wind farm projects, activities and plans in the Dogger Bank Zone (either consented or forthcoming); and
- Whether impacts on a receptor (or effects) can occur on a cumulative basis with other activities, projects and plans outwith the Dogger Bank Zone (e.g. other offshore wind farm developments), for which sufficient information regarding location and scale exist.

10.1.4 In this manner, the assessment considers (where relevant) the potential for cumulative impacts in the following sequence:

- With the third phase of development in the Dogger Bank Zone, known as Dogger Bank Teesside C & D;
- With the above, plus any other activities, projects and plans in the Dogger Bank Zone; and
- With all of the above, in addition to any other activities, projects and plans outwith the Dogger Bank Zone.

10.1.5 The strategy recognises that data and information sufficient to undertake an assessment will not be available for all potential projects, activities, plans and/or parameters, and seeks to establish the 'confidence' we can have in the data and information available.

10.1.6 There are two key steps to the Forewind CIA strategy, which both involve 'screening' in order to arrive, ultimately, at an informed, defensible and reasonable list of other plans, projects and activities to take forward in the assessment.

10.1.7 The first step in the cumulative assessment for marine physical processes involved an appraisal of the key effects identified in the assessment of Dogger Bank Teesside A & B (**Table 10.1**). The potential for effects to occur on a cumulative basis has been identified, both within and beyond the Dogger Bank Zone and the confidence in the data and information available to inform the assessment has been appraised (following the methodology set out in **Chapter 4**).

10.1.8 This also identifies where cumulative effects are not anticipated, thereby screening them out from further assessment.

10.1.9 For the purposes of marine physical processes, the effects identified during the construction (Section 6), operation (Section 7) and decommissioning phases (Section 8) of Dogger Bank Teesside A & B that have the potential to result in a cumulative effect, are identified in **Table 10.1**.

10.1.10 On this basis, the potential for any other cumulative effects is screened out from further consideration in the process.

Table 10.1 Potential cumulative effects (impact screening)

Effect	Dogger Bank Zone and Dogger Bank Teesside A & B Export Cable Corridor (within 1km)		Beyond 1km from the Dogger Bank Zone and Dogger Bank Teesside A & B Export Cable Corridor		Rationale for where no cumulative effect is expected
	Potential for cumulative effect	**Data confidence**	**Potential for cumulative effect**	**Data confidence**	
Increase in suspended sediment concentrations and sediment deposition during construction and decommissioning.	Yes	High	Yes	Medium	The nearest development outside the Dogger Bank Zone is approximately 25km away. Construction plumes are unlikely to interact over this distance, although these are screened in to the assessment on a precautionary basis.
Interruption of sediment transport as a result of landfall construction and decommissioning activities.	No	High	No	Medium	No other projects have been identified that would cumulatively effect sediment transport at the landfall site.
Increased turbidity as a result of landfall construction and decommissioning activities.	No	High	No	Medium	No other projects have been identified that would cumulatively effect turbidity (suspended sediment concentration) at the landfall site.
Effects of foundation structures on tidal currents during operation.	No	High	No	Medium	The cumulative effects on tidal currents within the Dogger Bank Zone have been investigated by filling Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D with foundations. The results show that the absolute changes are within the natural variation of tidal current velocity; Outside the Dogger Bank Zone the nearest development with the potential to have operational tidal current effects is 65km away (Hornsea Projects One and Two) and tidal currents will not interact over this distance.
Effect of foundation structures on waves during operation.	No	High	No	Medium	The cumulative effects on waves within the Dogger Bank Zone have been investigated by filling Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside

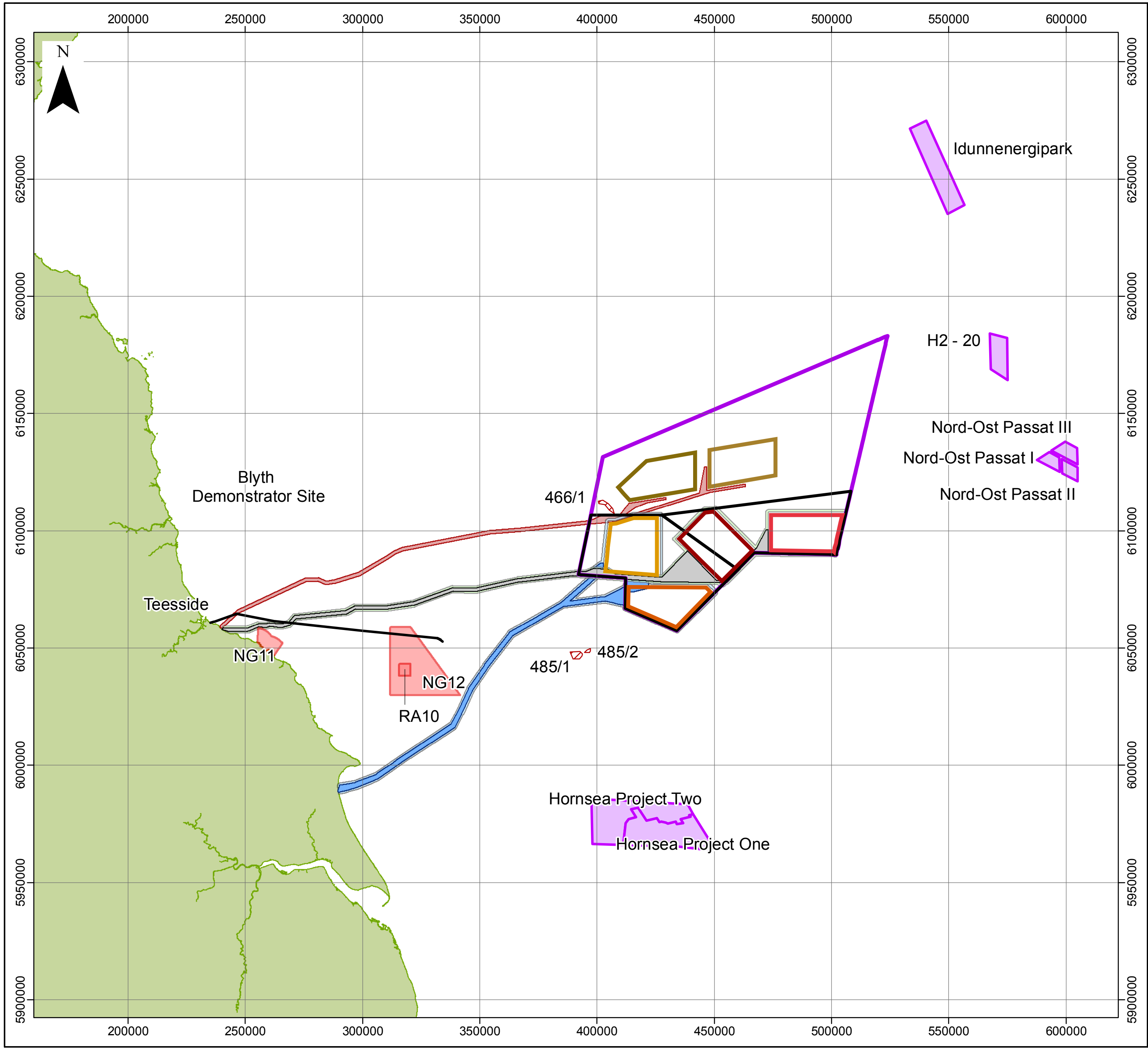
Effect	Dogger Bank Zone and Dogger Bank Teesside A & B Export Cable Corridor (within 1km)		Beyond 1km from the Dogger Bank Zone and Dogger Bank Teesside A & B Export Cable Corridor		Rationale for where no cumulative effect is expected
	Potential for cumulative effect	Data confidence	Potential for cumulative effect	Data confidence	
					C & D with foundations. The results show that the absolute changes are within the natural variation of wave height; Outside the Dogger Bank Zone the nearest development with the potential to have operational wave effects is 65km away (Hornsea Projects One and Two) and waves will not interact over this distance.
Increase in suspended sediment concentrations as a result of scour at foundations during operation.	Yes	High	Yes	Medium	Operational plumes (via release of sediments via scour) from developments outside the Dogger Bank Zone would either be short-lived and relatively small compared to those associated with Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D, or would be at such a large distance that interaction would be unlikely. However, as with construction, these are screened in to the assessment on a precautionary basis.
Effect on nearshore sediment transport of seabed rock armouring during operation.	No	High	No	Medium	No other projects have been identified that would cumulatively effect sediment transport due to rock armouring the export cable.

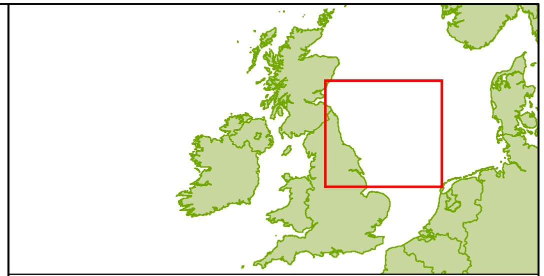
10.1.11 Where the first step has indicated the potential for cumulative effects, the second step in the cumulative assessment for marine physical processes involved the identification of the actual individual plans, projects and activities within those broad industry levels for inclusion in the detailed assessment. In order to inform this, Forewind has produced an exhaustive list of plans, projects and activities occurring within a very large study area encompassing the greater North Sea and beyond (referred to as the 'CIA Project List', see **Chapter 4**). The list has been appraised, based on the confidence Forewind has in being able to undertake an assessment from the information and data available, enabling individual plans, projects and activities to be screened in or out.

10.1.12 The plans, projects and activities relevant to marine physical processes are presented in **Table 10.2** and **Figure 10.1**, along with the results of a further screening exercise that identifies whether there is sufficient confidence to take these forward in a detailed cumulative assessment, or whether they can be screened out on account of distance to (i.e. no interaction with) the receptor in question.

10.1.13 It should be noted that:

- Where Forewind is aware that a plan, project or activity could take place in the future, but has no information on how the plan, project or activity will be executed, it is screened out of the assessment; and
- Existing projects, activities and plans are considered to be a part of the established baseline and are therefore not included in the cumulative assessment.





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside C
- Dogger Bank Teesside D
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Teesside A & B temporary works area
- Dogger Bank Creyke Beck Export Cable Corridor
- Dogger Bank Creyke Beck temporary works area
- Dogger Bank Teesside C & D Export Cable Corridor
- Aggregate application area
- Offshore wind farm
- Breagh pipeline
- Recommended Marine Conservation Zone (NG) & Recommended Reference Area (NG RA)

0 20 40
Kilometres

Data Source:
Breagh pipeline data provided by RWE Dea UK
Designation © Natural England, 2012
UK offshore wind farm & Aggregate areas © The Crown Estate, 2013
European wind farm boundary data supplied by MarineFind, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 10.1 Cumulative effects considered for marine physical processes

VER	DATE	REMARKS	Drawn	Checked
1	21/02/2013	Draft	FK	DB
2	07/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

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SCALE	1:2,500,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

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Table 10.2 Cumulative assessment screening for marine physical processes (project screening)

Type of project	Project title	Project status	Predicted construction and development period	Distance from Dogger Bank Teesside A & B	Confidence in project details	Confidence in project data	Carried forward to cumulative assessment?
Offshore Wind Farm	Dogger Bank Creyke Beck A & B	Pre-consent	Post 2016	5km south west of Dogger Bank Teesside B	High	High	Yes
Offshore Wind Farm	Dogger Bank Teesside C & D	Pre-consent	Post 2017	5km north of Dogger Bank Teesside B	High	Medium	Yes
Offshore Wind Farm	Project One of the Hornsea Zone	Pre-consent	Post 2015	100km south of Dogger Bank Teesside B	High	Medium	Yes
Offshore Wind Farm	Project Two of the Hornsea Zone	Pre-consent	Post 2015	100km south of Dogger Bank Teesside B	Medium	Medium	Yes
Offshore Wind Farm	Teesside Offshore Windfarm	Operational	2012-2013	4km north of Dogger Bank Teesside A & B Export Cable Corridor	High	High	Yes
Offshore Wind Farm	Blyth Demonstration Site (NaREC)	Pre-consent	2014-2016	60km north-north west of Dogger Bank Teesside A & B Export Cable Corridor	Medium	Medium	Yes
Offshore Wind Farm	H2-20	Application submitted	Uncertain	90km north east of Dogger Bank Teesside A	Medium	Medium	Yes
Offshore Wind Farm	Idunn Energipark	Concept / early planning	Uncertain	140km north-north east of Dogger Bank Teesside A	Medium	Medium	Yes
Offshore Wind Farm	Nord-Ost Passat I, II and III	Concept / early planning	Uncertain	85km east of Dogger Bank Teesside A	Medium	Medium	Yes
Aggregate License Area	Area 466/1	Application	Uncertain	30km west-north west of Dogger Bank Teesside B	Medium	Medium	Yes
Aggregate License Area	Area 485 (1 and 2)	Application	Uncertain	60km south west of Dogger Bank Teesside B	Medium	Medium	Yes
Potash Mining	Cleveland Potash	Operational	Ongoing	3km south east of Dogger Bank Teesside A & B Export Cable Corridor	High	High	Yes

10.1.14 Forewind currently has plans to develop four further projects within the Dogger Bank Zone; Dogger Bank Creyke Beck A & B and Dogger Bank Teesside C & D. Project information and boundaries are available for these, shown in **Figure 10.1**.

10.1.15 Forewind has developed a range of potential construction programmes that may apply to Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D. The maximum construction period for each project is six years. The worst case scenario from a physical processes perspective would be for all projects to be constructed at the same time. This would provide the greatest opportunity for interaction of waves, tidal currents and sediment transport during construction and operation of all projects.

10.2 Cumulative effects of construction of Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D

10.2.1 Cumulative construction effects between the six individual projects within the Dogger Bank Zone will be restricted to the potential interaction of sediment plumes that may arise during the construction phases, particularly from foundation installation and cable (export and inter-array) laying activities, and the subsequent deposition of disturbed sediments on the seabed.

10.2.2 The sediment plume and deposition effects arising from the worst case construction scenario adopted for Dogger Bank Teesside B (foundation installation and cable laying activities) are described in Section 6. This assessment considered both conical GBS and 12m pile foundations. The similar effects arising from both of these foundation options for the worst case construction scenario adopted for Dogger Bank Creyke Beck B were similarly assessed and described in the Dogger Bank Creyke Beck Environmental Statement (Forewind 2013). The worst case scenario for cumulative effects would potentially arise if the construction programme for foundation installation and cable laying activities is synchronous across projects and any plumes that are created overlap across project areas.

10.2.3 To assess this worst case, it has been assumed that a similar construction sequence is adopted for foundation installation and cable laying in all other projects at the same time as Dogger Bank Teesside B and Dogger Bank Creyke Beck B. In this scenario, there would be potential for some of the respective plumes to interact, creating a larger overall plume, with higher suspended sediment concentrations and, potentially, a greater depositional footprint on the seabed. However, given that the numerical modelling has identified that the maximum thickness of sediment that would remain deposited on the seabed at the end of the 30-day simulation periods for both Dogger Bank Teesside B and Dogger Bank Creyke Beck B would be less than 0.1mm (for both conical GBS and 12m pile foundation scenarios), it is considered, using expert judgment, that the potential for thick sequences of sediment persistently accumulating on the seabed due to plume interaction from all six projects is low, even if the construction programmes coincide.

10.3 Cumulative effects of operation of Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D

10.3.1 The cumulative effect of operation of two or more projects could occur for one or more of the marine physical processes parameters; tidal currents, waves and/or sediment transport. If Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck are completed at a similar time, and all without scour protection, then there will be cumulative effects. In order to predict the potential cumulative effects, hydrodynamic, wave and sediment plume dispersion models have been run for all six projects simultaneously.

10.3.2 The models have been run for 6MW layouts in each project, on the assumption that in each project they are the worst case for marine physical processes. This is supported by the results of the modelling for Dogger Bank Teesside A & B only which shows that the 6MW layout is the worst case for effects on tidal currents, waves and sediment transport.

Predicted cumulative effects of operation of projects on tidal currents

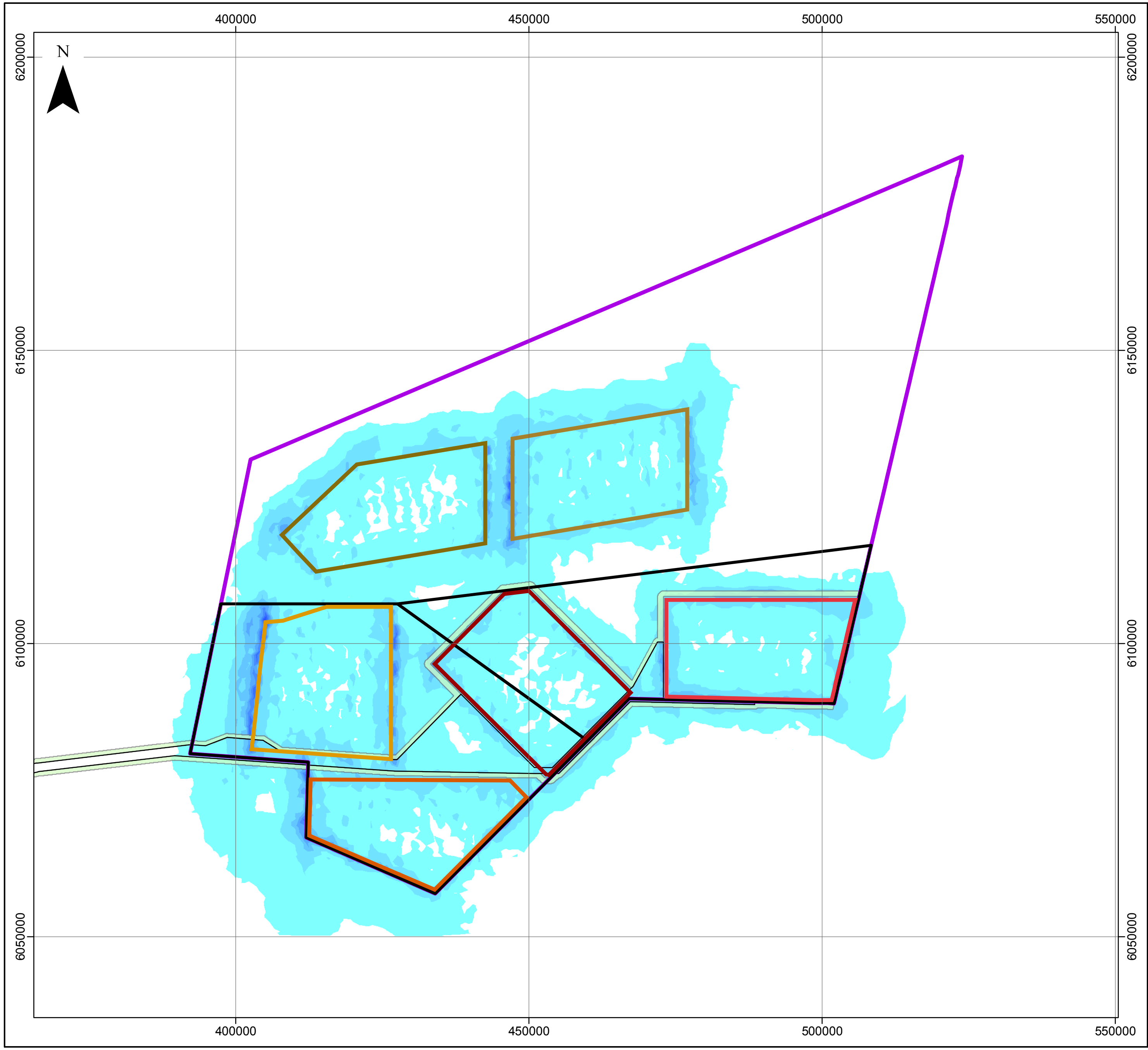
10.3.3 **Figure 10.2** shows the maximum absolute change (increase or decrease) in depth-averaged tidal current velocity over the 30-day simulation period. The strongest effect occurs along the project boundaries where the density of the foundations is highest. The greatest effect is predicted along the western boundaries of Dogger Bank Creyke Beck B and Dogger Bank Teesside D where the maximum change is just over 0.01m/s in small patches less than 1km wide. Maximum changes of up to 0.004m/s occur across most of each project with changes reducing to 0.002m/s up to approximately 17km outside the boundaries.

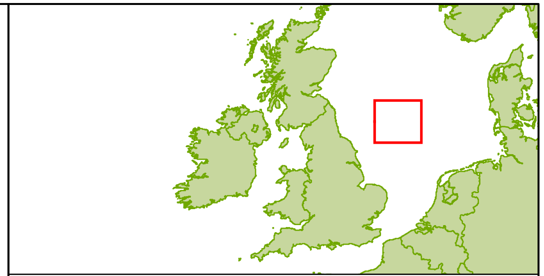
10.3.4 The maximum relative effect is up to approximately 3%, restricted to narrow (up to 2km wide) patches along the western boundaries of Dogger Bank Creyke Beck B and Dogger Bank Teesside D (**Figure 10.3**). This predicted change in tidal current velocities is so small that it is unlikely to affect the form of recent sediments over and above the natural tidal processes. For the worst case scenario, there are no cumulative tidal current interactions with the Hornsea Offshore Wind Farm Zone or the coast.

Predicted cumulative effects of operation of projects on waves

10.3.5 The same four wave conditions that were used to model Dogger Bank Teesside A & B only (Section 7.3) have been applied in the cumulative wave model runs and their description is not repeated here. Maximum changes in significant wave height are for one-year waves from the north and north east (**Figures 10.4**). For one-year waves from the north the changes are up to +/-0.06m at the southern and northern boundaries of all the projects apart from Dogger Bank Creyke Beck B reducing to less than +/-0.02m up to approximately 30km south from the southern boundary of Dogger Bank Creyke Beck A and greater than 60km north from the northern boundaries of Dogger Bank Teesside C & D. For one-year waves from the north east, changes are up to +/-0.05m at the south western and north eastern boundaries of the projects apart from

Dogger Bank Teesside B and Dogger Bank Teesside C reducing to less than +/-0.02m up to approximately 65km south west of the Dogger Bank Creyke Beck south west boundaries and north east of the Dogger Bank Teesside D boundary.





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside C
- Dogger Bank Teesside D
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Teesside A & B 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 10.2 Maximum predicted cumulative change in depth-averaged tidal current velocity caused by 6MW conical GBS#1 foundations

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1	08/04/2013	Draft	FK	DB
2	08/10/2013	PEI3	LW	DB
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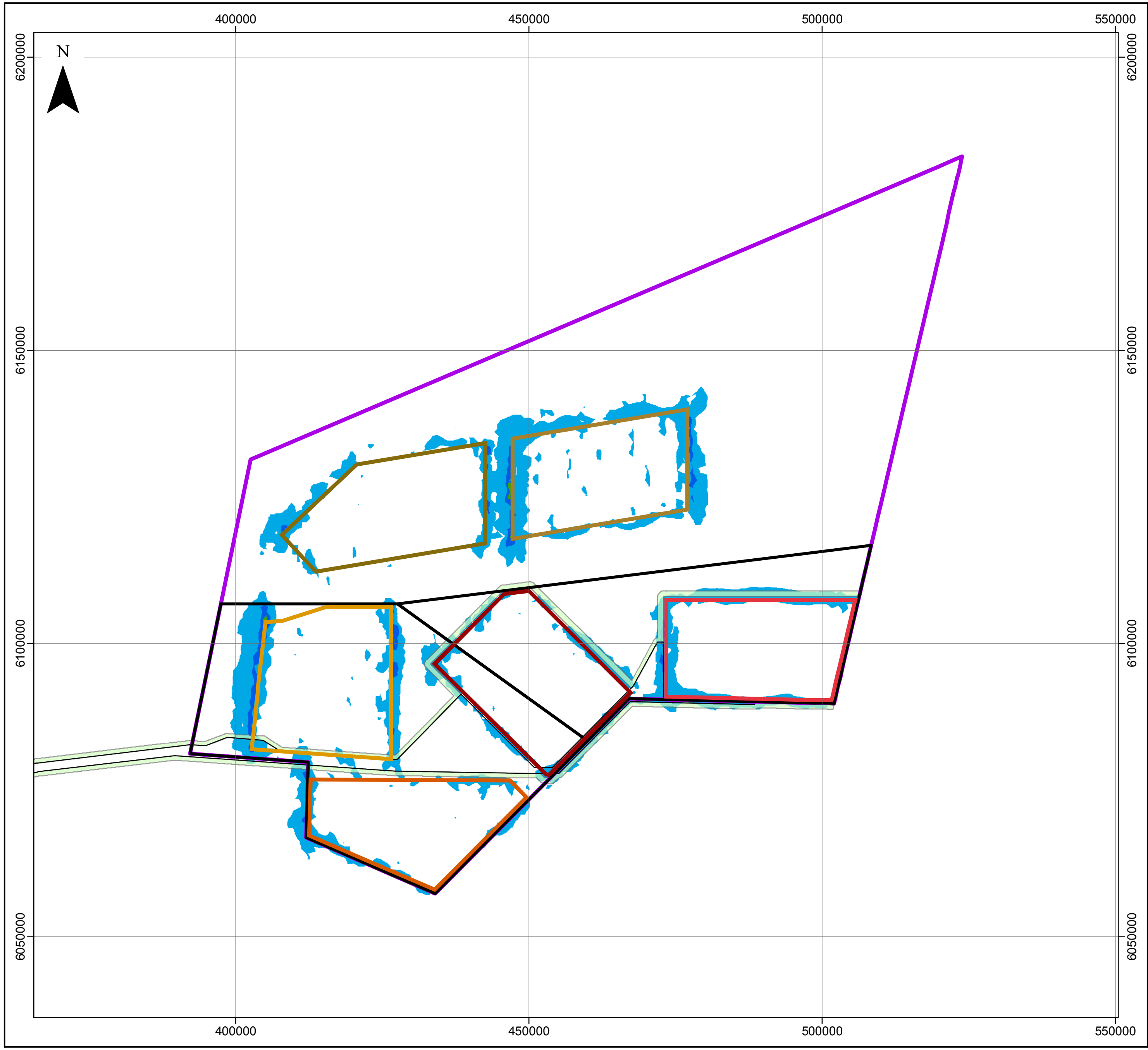
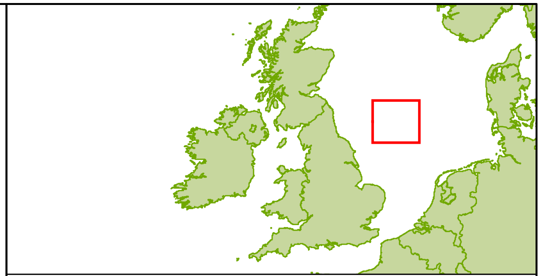
DRAWING NUMBER: **F-OFL-MA-441**

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

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside C
- Dogger Bank Teesside D
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Teesside A & B 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 10.3 Maximum percentage cumulative change in depth-averaged tidal current velocity caused by 6MW conical GBS#1 foundations

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1	08/04/2013	Draft	FK	DB
2	08/10/2013	PEI3	LW	DB
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SCALE	1:1,000,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

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