NORTH FALLS

Offshore Wind Farm

PRELIMINARY ENVIRONMENTAL INFORMATION REPORT

Chapter 8 Marine Geology, Oceanography and Physical Processes

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Contents

Tables

Plates

Figures (Volume II)

Glossary of Acronyms

3D	Three Dimensional
CD	Chart Datum
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CEA	Cumulative Effect Assessment
CPA	Coast Protection Act
DCO	Development Consent Order
DECC	Department of Energy and Climate Change
EACG	East Anglia Coastal Group
EEA	European Economic Area
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EPP	Evidence Plan Process
ETG	Expert Topic Group
FEPA	Food and Environmental Protection Act
GGOW	Greater Gabbard Offshore Windfarm
GBS	Gravity Base Structure
GWF	Galloper Offshore Windfarm
HAT	Highest Astronomical Tide
HDD	Horizontal Directional Drilling
IFCA	Inshore Fisheries and Conservation Authorities
km	Kilometre
km^2	Kilometre Squared
LAT	Lowest Astronomical Tide
m	Metre
m^2	Metre Squared
m^3	Metre Cubed
m/s	Metres Per Second
MCZ	Marine Conservation Zone
mg/l	Milligrams Per Litre
MHWS	Mean High Water Spring
MLWS	Mean Low Water Spring
mm	Millimetre
MMO	Marine Management Organisation
MPS	Marine Policy Statement
NPS	National Policy Statement
NSIP	Nationally Significant Infrastructure Project

OSP	Offshore Substation Platform
OWF	Offshore Wind Farm
PEIR	Preliminary Environmental Information Report
PINS	Planning Inspectorate
s	Second (unit of time)
SMP	Shoreline Management Plan
SAC	Special Area of Conservation
SPA	Special Protection Area
S-P-R	Source-Pathway-Receptor conceptual model
SSC	Suspended Sediment Concentration
SSSI	Site of Special Scientific Interest
UKCP18	United Kingdom Climate Projections 2018
UKHO	UK Hydrographic Office

Glossary of Terminology

Amphidromic point	The centre of an amphidromic system; a nodal point around which a standing-wave crest rotates once each tidal period
Array areas	The two distinct offshore wind farm areas (including the 'northern array area' and 'southern array area') which together comprise the North Falls offshore wind farm.
Array cables	Cables which link the wind turbine generators with each other and the offshore substation platform(s).
Astronomical tide	The predicted tide levels and character that would result from the gravitational effects of the earth, sun and moon without any atmospheric influences
Bathymetry	Topography of the seabed
Beach	A deposit of non-cohesive sediment (e.g. sand, gravel) situated on the interface between dry land and the sea (or other large expanse of water) and actively 'worked' by present-day hydrodynamic processes (i.e. waves, tides and currents) and sometimes by winds
Bedforms	Features on the seabed (e.g. Sandwaves, ripples) resulting from the movement of sediment over it
Bedload	Sediment particles that travel near or on the bed
Clay	Fine-grained sediment with a typical particle size of less than 0.002mm
Climate change	A change in global or regional climate patterns. Within this chapter this usually relates to any long-term trend in mean sea level, wave height, wind speed etc, due to climate change
Closure depth	The depth that represents the 'seaward limit of significant depth change, but is not an absolute boundary across which there is no cross-shore sediment transport
Coastal processes	Collective term covering the action of natural forces on the shoreline and nearshore seabed
Cohesive sediment	Sediment containing a significant proportion of clays, the electromagnetic properties of which causes the particles to bind together
Crest	Highest point on a bedform or wave
Current	Flow of water generated by a variety of forcing mechanisms (e.g. waves, tides, wind)
Ebb tide	The falling tide, immediately following the period of high water and preceding the period of low water
Erosion	Wearing away of the land or seabed by natural forces (e.g. wind, waves, currents, chemical weathering)
Evidence Plan Process	A voluntary consultation process with specialist stakeholders to agree the approach to the EIA and information to support the HRA
Flood tide	The rising tide, immediately following the period of low water and preceding the period of high water
Glacial till	Poorly-sorted, non-stratified and unconsolidated sediment carried or deposited by a glacier

Gravel	Loose, rounded fragments of rock larger than sand but smaller than cobbles. Sediment larger than 2mm (as classified by the Wentworth scale used in sedimentology)
Habitat	The environment of an organism and the place where it is usually found
High water	Maximum level reached by the rising tide
Holocene	The last 10,000 years of earth history
Hydrodynamic	The process and science associated with the flow and motion in water produced by applied forces
Interconnector cable	Cable between the northern and southern array areas
Interconnector cable corridor	The corridor of the seabed between the northern and southern array areas within which the interconnector cable will be installed
Intertidal	Area on a shore that lies between Lowest Astronomical Tide (LAT) and Highest Astronomical Tide (HAT)
Landfall	The location where the offshore cables come ashore.
Long-term	Refers to a time period of decades to centuries
Low water	The minimum height reached by the falling tide
Mean sea level	The average level of the sea surface over a defined period (usually a year or longer), taking account of all tidal effects and surge events
Megaripples	Bedforms with a wavelength of 0.6 to 10.0m and a height of 0.1 to 1.0m. These features are smaller than sandwaves but larger than ripples
Neap tide	A tide that occurs when the tide-generating forces of the sun and moon are acting at right angles to each other, so the tidal range is lower than average
Nearshore	The zone which extends from the swash zone to the position marking the start of the offshore zone (~20m)
Numerical modelling	Refers to the analysis of coastal processes using computational models
Offshore	Area seaward of nearshore in which the transport of sediment is not caused by wave activity
Offshore cable corridor	The corridor of seabed from array areas to the landfall within which the offshore export cables will be located.
Offshore export cables	The cables which bring electricity from the array areas to the landfall.
Offshore project area	The overall area of the array areas and the offshore cable corridor.
Offshore substation platform(s)	Fixed structure(s) located within the array areas, containing electrical equipment to aggregate the power from the wind turbine generators and convert it into a more suitable voltage for export to shore via offshore export cables.
Pleistocene	An epoch of the Quaternary Period (between about 2 million and 10,000 years ago) characterised by several glacial ages
Quaternary Period	The last 2 million years of earth history incorporating the Pleistocene ice ages and the post-glacial (Holocene) Period
Sand	Sediment particles, mainly of quartz with a diameter of between 0.063mm and 2mm. Sand is generally classified as fine, medium or coarse
Sandwave	Bedforms with wavelengths of 10 to 100m, with amplitudes of 1 to 10m

Scour protection	Protective materials to avoid sediment being eroded away from the base of the wind turbine generator foundations and offshore substation platform foundations as a result of the flow of water.
Sea level	Generally, refers to 'still water level' (excluding wave influences) averaged over a period of time such that periodic changes in level (e.g. due to the tides) are averaged out
Sea-level rise	The general term given to the upward trend in mean sea level resulting from a combination of local or regional geological movements and global climate change
Sediment	Particulate matter derived from rock, minerals or bioclastic matter
Sediment transport	The movement of a mass of sediment by the forces of currents and waves
Shore platform	A platform of exposed rock or cohesive sediment exposed within the intertidal and subtidal zones
Short-term	Refers to a time period of months to years
Significant wave height	The average height of the highest of one third of the waves in a given sea state
Silt	Sediment particles with a grain size between 0.002mm and 0.063mm, i.e. coarser than clay but finer than sand
Spring tide	A tide that occurs when the tide-generating forces of the sun and moon are acting in the same directions, so the tidal range is higher than average
Storm surge	A rise in water level on the open coast due to the action of wind stress as well as atmospheric pressure on the sea surface
Study area	Area where potential impacts from the Project could occur, as defined for each individual PEIR topic
Surge	Changes in water level as a result of meteorological forcing (wind, high or low barometric pressure) causing a difference between the recorded water level and the astronomical tide predicted using harmonic analysis
Suspended sediment	The sediment moving in suspension in a fluid kept up by the upward components of the turbulent currents or by the colloidal suspension
Swell waves	Wind-generated waves that have travelled out of their generating area. Swell characteristically exhibits a more regular and longer period and has flatter crests than waves within their fetch
Thalweg	A line connecting the lowest points of successive cross-sections along the course of a valley or river.
The Applicant	North Falls Offshore Wind Farm Limited (NFOW)
The Project or 'North Falls'	North Falls Offshore Wind Farm, including all onshore and offshore infrastructure.
Tidal current	The alternating horizontal movement of water associated with the rise and fall of the tide
Tidal range	Difference in height between high and low water levels at a point
Tide	The periodic rise and fall of the water that results from the gravitational attraction of the moon and sun acting upon the rotating earth
Wave climate	Average condition of the waves at a given place over a period of years, as shown by height, period, direction etc.

Wave height	The vertical distance between the crest and the trough

8 Marine Geology, Oceanography and Physical Processes

8.1 Introduction

1. This chapter of the Preliminary Environmental Information Report (PEIR) considers the likely significant effects of the North Falls offshore wind farm (hereafter 'North Falls' or 'the Project') on marine geology, oceanography and physical processes. The chapter provides an overview of the existing environment for the proposed offshore project area, followed by an assessment of the likely significant effects for the construction, operation, maintenance and decommissioning phases of the Project.
2. This chapter has been written by Royal HaskoningDHV, with the assessment undertaken with specific reference to the relevant legislation and guidance, of which the primary sources are the National Policy Statements (NPS). Details of these and the methodology used for the Environmental Impact Assessment (EIA) and Cumulative Effects Assessment (CEA) are presented in Section 8.4.
3. The assessment of effects on marine geology, oceanography and physical processes informs the following linked chapters (Volume I):
    - Chapter 9 Marine water and sediment quality;
    - Chapter 10 Benthic and intertidal ecology;
    - Chapter 11 Fish and shellfish ecology;
    - Chapter 14 Commercial fisheries; and
    - Chapter 18 Offshore archaeology and cultural heritage.
4. Information to support the marine geology, oceanography and physical processes assessment includes:
    - Interpretation of survey data specifically collected for North Falls including bathymetry, geophysical (shallow geology) and environmental (sediment particle size) data;
    - The existing evidence base of the effects of offshore wind farm developments on the physical environment;
    - Numerical modelling and theoretical studies undertaken for Galloper Offshore Wind Farm (GWF) and Greater Gabbard Offshore Wind Farm (GGOW) and their associated Environmental Statement (ES) chapters; and
    - Discussion and agreement with key stakeholders.

8.2 Consultation

5. Consultation with regard to marine geology, oceanography and physical processes has been undertaken in line with the general process described in Chapter 6 EIA Methodology (Volume I). The key elements to date have included scoping and the ongoing technical consultation via the Seabed Expert Topic Group (ETG) (including Natural England, the Marine Management Organisation (MMO), Centre for Environment, Fisheries and Aquaculture Science (Cefas),

The Wildlife Trust, and Kent and Essex Inshore Fisheries and Conservation Authority (IFCA)).

6. Further consultation regarding marine geology, oceanography and physical processes has been conducted through consultation on the North Falls Physical Processes Method Statement submitted to the ETG in June 2021 as part of the Evidence Plan Process (EPP). This document provided data requirements and a method for the assessment of potential effects on the baseline marine physical processes due to the proposed project (outlined in Section 8.4.3).

7. The feedback received has been considered in preparing the PEIR. Table 8.1 provides a summary of how the consultation responses received to date have influenced the approach that has been taken.

8. This chapter will be updated following the consultation on the PEIR to produce the final assessment, which will be presented in an ES that will be submitted with the Development Consent Order (DCO) application. Full details of the consultation process will also be presented in the Consultation Report as part of the DCO application.

Table 8.1 Consultation responses

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
Natural England; MMO; The Wildlife Trust; Kent and Essex IFCA; Cefas	05/07/21 Seabed ETG meeting	The Applicant provided an introduction to the project and presented the proposed approach to the EIA and scoping prior to submission of the scoping report to the Planning Inspectorate. Key comments from stakeholders are therefore captured within the scoping opinion described below.	N/A
Essex County Council	20/08/2021 Scoping opinion	In section 2.1.1.3 re Coastal Processes (para 150) it is surprising to find such little attention is paid to the Essex and South Suffolk Shoreline Management Plan (SMP). The preferred policy for this section of coast (Policy Development Zone C2 in the SMP) for Epoch 3 (2055 to 2015) is for Hold the Line / Managed Realignment meaning there is no certainty that this section of frontage will continue to be managed in the same way into the future. It should be noted that even for the earlier periods (present day to 2055) where the current preferred policy is for one of 'Hold The Line', this will only be possible if there is sufficient funding available to undertake the required works. The SMP notes that "in the long term, holding the line at this location will be challenging and that funding may have to come from a variety of sources."	The SMP is discussed in Sections 8.5.9, 8.5.10 and 8.6.1.1. Impacts on the coast are assessed in Sections 8.6.2.9 and 8.6.3.6. The precise landfall location will be determined following PEIR and will be located within the landfall search area.
Essex County Council	20/08/2021 Scoping opinion	There is mention that the defences are under pressure and that Tendring District Council has undertaken works, to stabilise the area (para 135), but further detail is not provided. It is believed that the works referred to here, are the significant works which were undertaken in 2014 to afford protection to a 5km length from Clacton on Sea to just west of the Gunfleet Sailing Club. Whilst this is a scheme designed for 100 years of protection, it is reliant on ongoing maintenance at an estimated cost of £1.2million every 10 years, and it should be noted that it might well be challenging to secure this funding. It should also be noted that the eastern end of this significant scheme is where the coast protection responsibilities of Tendring District Council end, with the remaining and substantive length of the frontage being considered for the onshoring in the scoping study falling under the responsibility of the Environment Agency. The way the scoping report is written is misleading as it implies that Tendring District Council has undertaken works along the whole	

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
		section, which is not the case and yet the whole frontage is under pressure. A more precise location would need to be providing for where the cables will come ashore before it is possible to determine which organisation is responsible for coast protection there.	
Essex County Council	20/08/2021 Scoping opinion	In para 140 (2.1.3.1) the risks of increased suspended sediments and changes to seabed levels are highlighted for during construction. The Paragraph also notes that nearshore cable installation could result in changes to shoreline levels due to deposition or erosion. Para 142 also highlights that effects during operation could occur due to the physical presence of infrastructure (foundations and any cable protection above the seabed) and that these may result in changes to waves / tidal currents which could affect the sediment transport regime and / or seabed morphology. The similar impacts on marine geology and physical processes seen during the construction period are also likely to occur during decommissioning (para 143). With such a significant coast protection scheme having been undertaken in the area in recent years at a total cost of £36 million (including £3 million contribution from Essex County Council) it is vital that any impacts are fully modelled, and results taken into account to ensure that no work is undertaken which could undermine or negatively impact on these previous investments.	Justification for using conceptual methods to predict effects is provided in Section 8.4.6. The assessment is based on a source-pathway-receptor (S-P-R) conceptual model, whereby the source is the initiator event, the pathway is the link between the source and the receptor affected, and the receptor is the receiving entity. The use of numerical modelling is disproportionate to the potential effect that would occur. The MMO consider the approach outlined to assess the potential impacts of the Project on the physical environment to be sufficient (see consultation response from MMO below). Consideration of the risk of increased suspended sediments is described in Section 8.6.2.1 and Section 8.6.2.2. Changes to bed level in Section 8.6.2.3 and 8.6.2.4 and the physical presence of infrastructure during the operation phase in Section 8.6.3.1 and Section 8.6.3.2.
Essex County Council	20/08/2021 Scoping opinion	Para 141 confirms that the EIA will include assessment of the effects of disposal of dredged or drilled material and that a licence application for disposal of dredged material within the wind farm boundary will be included within the DCO application, if required. It is important that the beneficial use options of any dredged material (which can often be used in other coast protection schemes) are fully scoped and where possible, suitable receiving sites identified in a detailed study.	The assessment considers disposal at sea. This is the standard approach for offshore wind farms, however the Applicant is open to considering the feasibility of alternative suggestions by Essex County Council (or others).
Essex County Council	20/08/2021 Scoping opinion	In light of the comments above, studies would need to be undertaken to fully evaluate the impacts of any scheme on coastal processes including the effects on foreshore and structures;	Consideration of the potential effects on the form and function of bedload sediment transport processes due to foundation and cable installation is described in Section 8.6.2.9, Section 8.6.3.3 and Section 8.6.3.5. The assessment is completed using a conceptual evidence-based approach.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
Marine Management Organisation	19/07/2021 Scoping opinion	The MMO consider the approach outlined by The Applicant to assess the potential impacts of the project on the physical environment to be sufficient.	Noted
Marine Management Organisation	19/07/2021 Scoping opinion	The Applicant intends to use bathymetric survey data from 2005.The MMO are unaware of the sediment dynamics in this region, hence it is not possible to comment on the appropriateness of these data. If the region is dynamic, these data could poorly represent the current situation.	A bathymetric survey of the array, interconnector and export cable corridor was undertaken by Fugro between May and September 2021. Results are described in Section 8.5.1.
Marine Management Organisation	19/07/2021 Scoping opinion	The MMO would like to comment that the proposed wave data capture for a relatively short period between November 2004 and March 2005. While these will help characterise modal conditions over the winter period, the short time span will mean they are of limited use when looking at extreme events. This should be considered by The Applicant.	A suite of wave data has been used to inform this assessment – these are outlined in Section 8.4.2 and described in Section 8.5.5.
Marine Management Organisation	19/07/2021 Scoping opinion	The list of activities that could potentially interact with this project are outline in paragraphs 105 and 106 of the Scoping Report. The MMO consider these capture all industries that are likely to interact with the project.	Noted.
Natural England	16/08/2021 Scoping opinion	Marine Geology, Oceanography and Physical Processes Natural England advises that, based on the information provided, there is insufficient information on the baseline conditions, required studies and methodologies, receptors, potential environmental impacts, and approaches to impact assessment. Further information will be needed in the Environmental Statement to form a robust understanding of the worst case design scenario and its impacts during the construction, operation, decommissioning (and repowering) phases of the project.	Section 8.5 provides a detailed description of baseline conditions. Receptors are outlined in Section 8.6.1. Potential environmental impacts are outlined in Section 8.6 – Section 8.9. Approaches to impact assessment are outlined in Section 8.4. The worst case design scenario for marine geology, oceanography and physical processes over the lifespan of the Project is outlined in Section 8.3.2.
Natural England	16/08/2021 Scoping opinion	Section 2.1 Following the review of the existing environment, baseline characteristics and data in this section, the Worst-Case Design Scenario for marine geology, oceanography and physical processes should be presented for the lifespan of the project in the ES. In addition, the range of any mitigation measures	The worst case design scenario for marine geology, oceanography and physical processes over the lifespan of the Project is outlined in Section 8.3.2. Mitigation measures are outlined in Section 8.3.3.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
		captured within the design envelope aimed at minimising environmental effects should be considered.	
Natural England	16/08/2021 Scoping opinion	Section 2.1 Section 2.1 considers 'Marine Geology, Oceanography, and Physical Processes, however, there is little mention of the Marine Geology. Baseline conditions for marine geology should also be included here, including a broad-scale description of the regional geology, contemporary form of the seabed and adjacent coast, their development in response to the last glaciation and sea level rise. In addition, baseline marine geology information should include the geological make-up and surficial sediment cover of the seabed across the Zone of Influence of the proposed development.	Regional geology of the offshore project area is described in Section 8.5.2. Surficial sediment cover of the seabed across the Zone of Influence (ZoI) of the proposed development is described in Section 8.5.6 and shown in Figure 8.15 (Volume II).
Natural England	16/08/2021 Scoping opinion	Section 2.1.1 Storm surges Given that the North Sea is subject to the influence of storm surges, they will need to be considered in the EIA.	Storm surges in the North Sea are considered in Section 8.5.3.6.
Natural England	16/08/2021 Scoping opinion	Section 2.1.1 Sediment Transport Description of suspended and bedload sediment transport across the project area should be included, including the source of sediment across the area, sediment transport pathways, partings, sources and sinks. A map showing these features would be useful. A map of seabed mobility would also be useful in the ES.	Bedload sediment transport and suspended sediment is discussed in Sections 8.5.7 and 8.5.8, respectively. A map of sediment transport pathways is provided in Figure 8.18 (Volume II).
Natural England	16/08/2021 Scoping opinion	Section 2.1.1 Climate change Consideration of climate change impacts over the operational period of North Falls OWF will need to be included in the ES. These impacts will become important if they cause an alteration	Climate change impacts have been considered in Section 8.5.10.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
		in the baseline conditions and become detectable above natural inter-annual variations.	
Natural England	16/08/2021 Scoping opinion	Section 2.1.1.1 Figures 2.1 and 2.2 show Offshore Bathymetry and Offshore Sediment Types. There are no maps showing bedrock geology, or bedforms across the project area. Bedrock geology and seabed morphology mapping should also be included in the ES.	Figure 8.1 and Figure 8.2 (Volume II) show bathymetry and bedforms across the North Falls array areas and export cable corridor.
Natural England	16/08/2021 Scoping opinion	Section 2.1.1.1 Point 133 The Inner Gabbard and The Galloper sandbanks are mentioned in this section, but not identified on Figure 2.2 (or Figure 2.1). These features should be identified in the relevant ES figures.	The Inner Gabbard and Galloper sandbanks are shown in Figure 8.14 (Volume II).
Natural England	16/08/2021 Scoping opinion	Section 2.1.1.1 Point 133 Studies to inform the baseline have been taken from Greater Gabbard OWF (GGOW) from 2005.These studies are now 16 years old. Whilst the GGOW studies provide useful information on seabed sediments within the GGOW project area, site- specific and more recent information for the North Falls OWF project area will also be required to form the baseline.	A site-specific grab sampling campaign totalling 39 seabed samples was completed by Fugro from May to August 2021 (Section 8.5.6). Seabed sediment data from GGOW was used only for comparison.
Natural England	16/08/2021 Scoping opinion	Section 2.1.1.1 Point 134 Typical and maximum significant wave heights of 3.6m and 6.2m, respectively, were recorded [at GGOW, 2005]. The larger waves tended to originate from the north-east. As with the comment above, the GGOW (2005) metocean surveys are now quite old. These surveys pre-date construction of the GGOW and Galloper OWF and thus, more recent and site-specific wave data should also be used to form the baseline for North Falls and in turn, help inform the EIA.	A suite of wave data has been used to inform this assessment – these are outlined in Section 8.4.2 and described in Section 8.5.5.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
Natural England	16/08/2021 Scoping opinion	Section 2.1.2 Table 2.1 & Table 2.2 GGOW geophysical surveys were undertaken in 2004/5, and for Galloper Wind Farm (GWF) in 2009. GGOW geotechnical survey was undertaken (array only) in 2004. GGOW benthic survey was undertaken in 2004/5. GWF benthic survey was undertaken in 2009. GGOW metocean survey (array only) was undertaken in 2004/5. GGOW coastal processes assessment (array only) was carried out in 2005. GWF coastal processes assessment (array only) was carried out in 2011. North Falls geophysical survey, grab sampling and particle size analysis are being carried out in 2021, for both the array and offshore export cable corridor (OECC). We welcome the collection of site-specific contemporary geophysical and sediment sample data for the North Falls OWF project area; however, Table2.2 should state the nature of the geophysical survey (i.e. sub-bottom profiler, side scan sonar, multi beam echo sounder, and magnetometer). There is no mention of further geotechnical surveys following the survey in 2004 for GGOW, yet it is important to ensure that adequate information is collected during the early geophysical and geotechnical survey campaigns to enable careful selection of the cable route and to aid cable burial. Therefore, we advise that additional geotechnical information will be required for North Falls. Similarly, the metocean and coastal processes data listed in Tables 2.1 & 2.2 are old and pre-date the construction of GWF. There is no mention of suspended sediment concentration data measurements, nearshore sediment transport measurements, sediment transport pathways, or sediment cells. These will need to be considered in the ES along with potential impacts on them due to the proposed development. We also advise that hydrodynamic impacts on the wave and current regime will need to be examined through modelling to characterise the wave-current climate across the Zone of Influence and help form an understanding of the potential	A site-specific sediment sampling survey was carried out by Fugro between May to August 2021 and samples were analysed by an MMO accredited laboratory. An outline of the site-specific survey is provided in Table 8.5. A site-specific geotechnical survey will be undertaken post consent to inform the foundation design and cable installation. The worst case scenario, takes into account the range of infrastructure and methods that could be required based on knowledge of geology in the region, including lessons learned from GGOW and GWF. Therefore geotechnical surveys are not required to inform this PEIR chapter. Justification for using conceptual methods to predict effects with regards hydrodynamic impacts on the wave and current regime is provided in Section 8.4.6. The assessment is based on a S-P-R conceptual model, whereby the source is the initiator event, the pathway is the link between the source and the receptor affected, and the receptor is the receiving entity. The use of numerical modelling is disproportionate to the potential effect that would occur. The S-P-R conceptual model is proportionate. The assessment for impacts to the tidal regime and wave regime are presented in Section 8.6.3.1 and Section 8.6.3.2. The MMO consider the approach outlined to assess the potential impacts of the Project on the physical environment to be sufficient (see consultation response from the MMO above). Cumulative effects of hydrodynamic and sediment transport impacts with existing and planned Offshore Wind Farms (OWFs) are assessed in Section 8.8.3.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
		impacts of the project on receptors. To this end, more up- to-date and site-specific data will be needed to characterise the wave-current regime across the Zone of Influence. In turn, this characterisation should consider a range of spatial (near- and far-field) and temporal scales for the entire lifespan of the proposed development. Furthermore, the cumulative effects of hydrodynamic and sediment transport impacts due to the proposed development in combination with existing adjacent offshore windfarms (i.e. GGOW and GWF) and planned OWFs (i.e. Five Estuaries), will need to be investigated. This investigation will need to consider cumulative impacts on the integrity of coastal and offshore receptors.	
Natural England	16/08/2021 Scoping opinion	Section 2.1.2 Point 139 Wave buoy at West Gabbard. West Gabbard 2 waverider buoy is well located for the North Falls OWF project. It might also be useful to incorporate data from the South Knock waverider buoy in the ES as this is further inshore and downwind of the existing GGOW and GWF.	The South Knock and West Gabbard 2 waverider buoys have been included in Section 8.5.5.
Natural England	16/08/2021 Scoping opinion	Section 2.1.2 Point 139 Other data sources. We recommend the EIA utilises the following data sources: Regional geology – BGS Holocene evolution – Shennan et al Sand transport pathways map – Kenyon and Cooper Bedforms – BGS SSC data – Cefas, satellite data etc	The data sources listed are utilised in Section 8.5 and listed in Section 8.4.2.
Natural England	16/08/2021 Scoping opinion	Section 2.1.3.1 Potential impacts during construction Although potential impacts are considered, it is not stated how these potential impacts will be assessed (e.g. seabed morphological change investigations, plume modelling, sediment mobility studies, shoreline profile surveys etc). This information	The assessment of likely significant effects during construction has been completed using a conceptual evidence-based approach. Justification for using conceptual methods with regards hydrodynamic impacts on the wave and current regime is provided in Section 8.4.6.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
		needs to be provided in the ES and should be agreed through the evidence Plan process.	
Natural England	16/08/2021 Scoping opinion	Section 2.1.3.2 Potential impacts during operation and maintenance. As with the comment above, it is not stated how these potential impacts will be assessed (e.g. regional scale hydrodynamic modelling, seabed morphological change and sediment transport process studies, scour prediction modelling, shoreline profile surveys, coastal erosion/accretion analysis.	As above.
Natural England	16/08/2021 Scoping opinion	Section 2.1.3.4 Potential cumulative impacts There is the potential for North Falls to affect sediment transport pathways and downdrift receptors that are susceptible to sediment transport pathway changes. There is also the potential for the proposed development to create a wave sheltering effect when considered in combination with GGOW, GWF, and the planned Five Estuaries project. These potential cumulative impacts will need to be adequately assessed in the ES. Moreover, coastal erosion/accretion and shoreline management implications will also need to be considered due to the in-combination effects.	Cumulative effects are considered in Section 8.6.
Natural England	16/08/2021 Scoping opinion	Section 2.1.3.6 Table 2.3 Summary of potential impacts on marine geology, oceanography and physical processes. This table is too general and non-specific. The ES should consider specific potential effects for each phase of the project lifespan and for both near-field and far- field scales. For example, changes to water levels resulting from installation equipment and construction activity for both the near- and far-field etc. Justification for scoping in/out residual impacts should also be included. Potential effects should be broken down more specifically for consideration in the ES (e.g. for hydrodynamic regime, changes to water levels, tidal currents, and wave height should be considered separately). Seabed	Table 2.3 in the Scoping Report provided a general summary of potential impacts on marine geology, oceanography and physical processes, however the PEIR provides a preliminary assessment of likely significant effects. See Section 8.6.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
		features (bedforms), sediment regime, coastal processes, coastal frontage/landfall should also be considered.	
Natural England	16/08/2021 Scoping opinion	Section 2.1.4 Point 147 "A conceptual evidence-based assessment will draw from the results of the studies outlined above, including modelling undertaken for the GWF, which overlaps with the southern array of North Falls." Please see our comment to Point 2.1.2 above. Model results from the GWF, whilst useful, are pre-construction and do not consider the cumulative effects of the GGOW, GWF, North Falls (and Five Estuaries). Therefore, we advise further hydrodynamic modelling is needed to inform the EIA, with particular regard to establishing changes in wave height reduction, and the potential impacts on sensitive receptors of the North Falls project, both alone and cumulatively.	Justification for using conceptual methods with regards hydrodynamic impacts on the wave and current regime is provided in Section 8.4.6. The assessment is based on a S-P-R conceptual model, whereby the source is the initiator event, the pathway is the link between the source and the receptor affected, and the receptor is the receiving entity. The use of numerical modelling is disproportionate to the potential effect that would occur. The S-P-R conceptual model is proportionate. The assessment of impacts to the tidal regime and wave regime are presented in Section 8.6.3.1 and Section 8.6.3.2. The MMO consider the approach outlined to assess the potential impacts of the Project on the physical environment to be sufficient (see consultation response from the MMO above).
Natural England	16/08/2021 Scoping opinion	Section 2.1.4 Table 2.1.4 Marine geology, oceanography and physical processes receptors A source-pathway-receptor map (both for marine and coastal physical processes receptors as well as other dependent environmental receptors) should be provided in the ES. Offshore sandbanks/sandbank systems and other significant bedforms (designated or otherwise) within or in the vicinity of the development area, should be considered as receptors and included in the impact assessment.	Receptors are detailed in Section 8.6.1 and presented in Figure 8.14 (Volume II).
Natural England	16/08/2021 Scoping opinion	Section 2.13.1.7 Para 391 & 392 Mineral aggregate extraction areas adjacent to/overlapping the array(s) and/or export cable corridor. Further consideration of the cumulative effects of North Falls construction and aggregate extraction activities on the release of suspended sediments into the water column, sediment transport processes and nearby designated sites (e.g. Kentish Knock East MCZ) should be presented in the ES.	Consideration of cumulative effects is presented in Section 8.8.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
Planning Inspectorate	26/08/2021 Scoping opinion	Inter-array cabling and offshore export cables are described as having a target minimum cable depth of 0.5m to 3m where buried; indicative maximum diameters and lengths of cabling are noted but it is stated that the final layout will be determined post consent to fit with the final layout of the WTG. The ES should describe the range of burial depths that have been considered as part of the assessment and the degree of confidence in these parameters. It should establish the parameters likely to result in the maximum adverse effects and include an assessment of these to determine likely significance of effects.	The burial depths that have been used as part of the assessment are presented in Table 8.2. The assessment of the likely significance of effects is presented in Section 8.6.2 for the construction phase, Section 8.6.3 for the operation phase and Section 8.6.3.8 for the decommissioning phase.
Planning Inspectorate	26/08/2021 Scoping opinion	Paragraph 140 of the Scoping Report identifies a potential need for seabed preparation for installation of cables and foundations, including sand wave clearance and boulder removal. The ES should identify the worst case footprint of seabed disturbance that would arise from offshore construction activities, and the maximum footprints of all permanent components should also be identified. Should seabed preparation involve dredging, the ES should identify the quantities of dredged material and likely location for disposal.	The worst case footprint of seabed disturbance that would arise from offshore construction activities, the maximum footprints of all permanent components and volume of dredged material generated during seabed preparation are outlined in Table 8.2.
Planning Inspectorate	26/08/2021 Scoping opinion	Paragraph 86 of the Scoping Report (detailing the overarching assessment methodology for the EIA) states that study areas defined for each receptor are based on the Zone of Influence (ZoI) and relevant characteristics of the receptor (e.g. mobility / range). However, the Inspectorate notes that for many of the aspect chapters included, study areas and ZoIs have not been stated. Where this detail has been provided, it is not clear how these study areas relate to the extent of the impacts and likely significant effects associated with the Proposed Development, how they have been used to determine a ZoI, and what receptors have been identified within the ZoI. The ES should provide a robust justification as to how study areas have been defined and why the defined study areas are appropriate for assessing potential impacts.	The study area for marine geology, oceanography and physical processes is described in Section 8.3.1.
Planning Inspectorate	26/08/2021 Scoping opinion	The Inspectorate understands that areas of search for the landfall and onshore components of the Proposed Development will be refined during the assessment process to identify preferred options, which would be reported in the ES as part of	The landfall location will be refined following PEIR and this comment will be addressed in the ES.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
		any DCO submission. The Inspectorate therefore expects that the DCO boundary is likely to change from the boundary used for scoping. The ES should clearly describe changes that have been made to the DCO boundary from the scoping red line boundary, including reduction or increase in extent, and the reasons for such change. Where changes are made, each aspect chapter of the ES should explain the effect of such changes on the approach to assessment, including where this results in additional matters needing to be scoped into the ES.	
Planning Inspectorate	26/08/2021 Scoping opinion	Some aspect sections of the Scoping Report have identified specific receptors, whereas others identify broad categories of receptors only. Specific receptors should be identified within the ES, alongside categorisation of their sensitivity and value. Section 1.8.2.1 of the Scoping Report explains the generic approach to defining receptor sensitivity in order to assess the potential impacts upon each receptor. The inspectorate expects a transparent and reasoned approach to be applied to assigning receptor sensitivity to be defined and applied across the aspect chapters.	The definition of sensitivity for a morphological receptor is outlined in Table 8.7.
Planning Inspectorate	26/08/2021 Scoping opinion	The ES should include details of difficulties (for example technical deficiencies or lack of knowledge) encountered compiling the required information and the main uncertainties involved.	Assumptions and limitations are presented in Section 8.4.7.
Planning Inspectorate	26/08/2021 Scoping opinion	Section 1.7.2 and Table 1.4 of the Scoping Report explains that an Evidence Plan Process (EPP) with specialist stakeholders commenced in 2021 to agree the 'detailed methodologies for data collection and undertaking the impact assessments' in respect of certain aspects to be scoped into the ES. This approach to agreeing the finer details of the assessment is welcomed. Other aspects, including fisheries, aviation and radar, and shipping and navigation, would fall outside of the EPP but the Applicant has committed to consultation at an early stage of the assessment process. The Applicant should ensure that any agreements reached during EPP or other consultation process are evidenced within the ES.	This table includes a summary of EPP consultation. Agreement/disagreement logs, compiled throughout the EPP will be used to prepare statements of common ground with stakeholders to inform the Examination process.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
Planning Inspectorate	26/08/2021 Scoping opinion	Section 1.9.3 of the Scoping Report sets out the planning policy and legislation context for the Proposed Development. It would be beneficial for the aspect chapters of the ES to also include reference to aspect specific planning policy and legislation, where this has been used to inform the methodology used for assessment.	Topic specific planning policy and legislation is outlined in Section 8.4.1.
Planning Inspectorate	26/08/2021 Scoping opinion	The Scoping Report does not contain a specific section about waste; however, the Inspectorate notes that an assessment of the effects of disposal of dredged or drilled material during offshore construction is scoped into the ES (paragraph 141) and that the scope of the traffic and transport assessment will include construction vehicle movements associated with export of material (paragraph 667). The ES should include information regarding the expected quantities and types of all types of waste that will be produced during construction, operation and decommissioning, including arisings from onshore activity in addition to offshore dredging and drilling. The ES should include an assessment of effects relating to waste in relevant aspect chapters where significant effects are likely to occur, including for example in relation to transport effects as a result of movement of waste.	Information regarding the amount of arisings that will be produced during construction, operation and decommissioning during dredging and drilling is presented in Table 8.2.
Planning Inspectorate	26/08/2021 Scoping opinion	Any mitigation relied upon for the purposes of the assessment should be explained in detail within the ES. The likely efficacy of the mitigation proposed should be explained with reference to residual effects. The ES should also address how any mitigation proposed is secured, with reference to specific dDCO requirements or other legally binding agreements.	A summary of mitigation embedded into the design of the Project is presented in Section 8.3.3.
Planning Inspectorate	26/08/2021 Scoping opinion	Paragraph 142 Table 2.3 Effects on hydrodynamic regime (waves and tidal currents) during construction and decommissioning. The Applicant states that this effect arises as the result of the presence of physical infrastructure (i.e. large foundations and cable protection on the seabed) which is only applicable to the operation phase of the Proposed Development. On the basis that this matter will be assessed within the operation phase assessment, the Inspectorate is satisfied that	Noted.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
		this matter can be scoped out for construction and decommissioning.	
Planning Inspectorate	26/08/2021 Scoping opinion	Paragraph 140 Table 2.3 Effects on seabed level (due to deposition of suspended sediment, and seabed preparation and/or drill arisings) during operation and decommissioning. The Applicant states that seabed level effects will occur only during the construction phase (i.e. during installation activities for cables and foundations) and are not applicable to the operation and decommissioning phases. On the basis that this matter will be assessed within the construction phase assessment, the Inspectorate is satisfied that this matter can be scoped out for construction and decommissioning.	Noted. It is understood the Planning Inspectorate is referring to operation and decommissioning in the final paragraph of this comment.
Planning Inspectorate	26/08/2021 Scoping opinion	Table 2.3 Changes to seabed morphology (due to the presence of foundation structures and cable protection) during construction and decommissioning. The Applicant states that this effect arises as the result of the presence of physical infrastructure (i.e. large foundations and any cable protection on the seabed) which is only applicable to the operation phase of the Proposed Development. On the basis that this matter will be assessed within the operation phase assessment, the Inspectorate is satisfied that this matter can be scoped out for construction and decommissioning.	Noted.
Planning Inspectorate	26/08/2021 Scoping opinion	Paragraph 140 Table 2.3 Indentations on the seabed due to installation vessels during operation and decommissioning. On the basis that this matter applies only to construction and will be assessed within the construction phase assessment, the	Noted.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
		Inspectorate is satisfied that this matter can be scoped out for operation and decommissioning.	
Planning Inspectorate	26/08/2021 Scoping opinion	Paragraph 145 Table 2.3 Transboundary effects. Based on the conclusions of the GWFF in 2011, whose ZoI is stated to be similar to that of the Proposed Development, the Applicant proposes to scope transboundary effects in relation to Marine Geology, Oceanography and Physical Processes out of the assessment. The Proposed Development is also 20km from the Economic Exclusion Zone. The Inspectorate agrees that this matter can be scoped out of the ES.	Noted.
Planning Inspectorate	26/08/2021 Scoping opinion	Study area and assessment The Inspectorate notes that the Scoping Study Area is very large to account for uncertainty surrounding the exact routes of onshore elements of the Proposed Development. The ES should ensure that it is clear where the ongoing assessment work has refined the options and addressed potentially significant effects through design.	This is addressed in Chapter 4 Site Selection and Assessment of Alternatives (Volume I) and embedded mitigation sections of each technical chapter where relevant.
Planning Inspectorate	26/08/2021 Scoping opinion	Para 135 Physical processes baseline The Scoping Report uses information from the Essex and Suffolk Shoreline Management Plan (2010) to provide a baseline for the Tendring Peninsula and notes that since that document was prepared, repairs have been made to the sea defences in the area. The existing physical coastal defences should be described in the ES. Given the likelihood of changes to sea defences, both through ongoing active maintenance and the deterioration of these types of structures that could be expected over time, the ES should review the available information to ensure that it represents a robust basis for the assessment.	The existing physical coastal defences have been described in Section 8.6.1.1 of this PEIR chapter and will be described in the ES.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
Planning Inspectorate	26/08/2021 Scoping opinion	Table 2.1 and 2.2 Para 139 Existing datasets and surveys. The ES should explain how the surveys outlined in Table 2.2 will be used to support the desk-based data that has been collected. The ES should be clear on the reasons for the selection of datasets, with reference to, for example, established guidance, consultee feedback or other evidence and by the choice of an appropriate study area.	Data sources used are described in Section 8.4.2.
Planning Inspectorate	26/08/2021 Scoping opinion	Para 140 Table 2.3 Construction effects The ES should assess the potential for significant effects on coastal processes from the onshore elements of the Proposed Development during both construction and operation. The ES should assess the potential for significant effects from seabed scour during construction and decommissioning activities, in addition to wave and tidal currents.	The Applicant has committed to Horizontal Direction Drilling (HDD) at landfall and the onshore drilling location will be set back, approximately 400m from the coast. The depth profile of the HDD below ground would be designed to ensure there would be no impact on the coastline. Therefore there is no potential pathway for impact between any onshore elements and the coast. Instead, the potential impact of offshore elements, including the HDD exit point, on coastal processes during both construction and operation have been assessed in this PEIR in Section 8.6.2 and Section 8.6.3. The PEIR also considers potential for seabed scour in Section 8.6.3.3 and Section 8.6.3.5.
Planning Inspectorate	26/08/2021 Scoping opinion	Para 139 Approach to assessment The ES should define the aspect specific methodology used to determine significant effects, including defining levels of receptor sensitivity and magnitude of effect. Where modelling is used to predict effects, the ES should ensure that explanation is given as to the choice and selection of models, and how the model and outputs have been verified to provide confidence in the results. The assessment should also define where effects are considered to be significant and not significant, referring back to the use of the methodology.	This is considered standard practice and is outlined in Section 8.4. Further justification for use of the GWF modelling results is provided in Section 8.4.6.

8.3 Scope

8.3.1 Study area

9. The study area for marine geology, oceanography and physical processes has been defined on the basis of both the near-field (within the offshore project area) and far-field (beyond the offshore project area and across the wider regional seabed and coastal) environment.

10. The offshore project area is located in the southern North Sea (Figure 8.1, Volume II). The array areas cover approximately 150km^2 of the seabed (21km^2 in the north array and 129km^2 in the south array) and lie adjacent to GGOW and GWF. An interconnector cable links the northern and southern array areas, and the offshore cable corridor links the southern array to the landfall search area between Clacton-on-Sea and Frinton-on-Sea.

11. The limits of the far-field impacts are based on an understanding of the tidal regime, discussed further in Section 8.6.3.1. Changes associated with the tidal regime would have returned to background levels immediately outside the excursion of one spring tidal ellipse, approximately 15km from the North Falls offshore project area (shown in Figure 8.13, Volume II).

12. For the CEA, a range of 30km from the North Falls offshore project area has been used to provide a conservative search area for the screening of plans and projects which have potential to interact with the impacts of North Falls.

8.3.2 Realistic worst case scenario

13. The final design of North Falls will be confirmed through detailed engineering design studies that will be undertaken post-consent. To provide a precautionary but robust impact assessment at this stage of the development process, realistic worst case scenarios have been defined in terms of the potential effects that may arise. This approach to EIA, referred to as the Rochdale Envelope, is common practice for developments of this nature, as set out in Planning Inspectorate Advice Note Nine (2018). The Rochdale Envelope for a project outlines the realistic worst case scenario for each individual impact, so that it can be safely assumed that all other scenarios within the design envelope will have less impact. Further details are provided in Chapter 6 EIA Methodology (Volume I).

14. The realistic worst case scenarios for the likely significant effects scoped into the EIA for the Marine Geology, Oceanography and Physical Processes assessment are summarised in Table 8.2. These are based on North Falls parameters described in Chapter 5 Project Description (Volume I), which provides further details regarding specific activities and their durations.

Table 8.2 Realistic worst case scenarios

Potential impact	Parameter	Worst case	Notes
Construction			
Impact 1a: Changes in suspended sediment concentrations (SSCs) due to seabed preparation for foundation installation	Volume of sediment disturbed	• Seabed preparation area for GBS of 70m diameter each x 72 wind turbines x average 5m sediment depth = 1,385,440m^3 • Two offshore substation platforms seabed preparation x average 5m sediment depth = 33,185m^3 Worst case scenario volume for seabed preparation for foundation installation = **1.4Mm^3**	Seabed preparation (sandwave levelling) may be required with an average sediment depth of 5m. The worst case scenario assumes that sediment would be dredged and returned to the water column at the sea surface during disposal from the dredger vessel.
Impact 1b: Changes in SSCs due to drill arisings for installation of piled foundations for wind turbines and OSPs	Volume of drill arisings	Drill arisings at 10% of largest wind turbines = **38,133m^3** Drill arisings at 1 x monopile OSPs = **10,688m^3** **Total = 48,820m^3** NB, drill arising would not occur in the event that the GBS is used and therefore this parameter cannot be added to the maximum seabed levelling for GBS described above.	Assumes drilling at up to 10% wind turbine locations (average 42m drill depth, 17m drill diameter). Assumes drilling at one Offshore Substation Platform (OSP) location (42m drill depth, 18m drill diameter).
Impact 2a: Changes in seabed level due to seabed preparation for foundation installation	As Construction Impact 1a	As Construction Impact 1a	As Construction Impact 1a.
Impact 2b: Changes in seabed level due to drill arisings for installation of piled foundations for wind turbines and OSPs	As Construction Impact 1b	As Construction Impact 1b	As Construction Impact 1b.

Potential impact	Parameter	Worst case	Notes
Impact 3: Changes in SSCs due to export cable installation	Volume of sediment disturbed	• Export cable sandwave levelling = 250.8km length with average 24m disturbance width x average 5m sediment depth = 30,096,000 m^3 • Export cable burial = 250.8km length with average 1m trench width x max 1.2m burial depth = 300,960m^3	The offshore HDD exit location will be subtidal in 1 to 8m water depth. Sediment displacement assumes a box shaped dimension.
Impact 4: Changes in seabed level due to deposition from the suspended sediment plume during export cable installation	As Construction Impact 3	As Construction Impact 3	As Construction Impact 3.
Impact 5: Changes in SSCs due to offshore cables installation (array and interconnector cables)	Volume of sediment disturbed	• Cable sandwave levelling = 228km length with average 24m disturbance width x average 5m sediment depth = 27,360,000m^3 • Cable burial = 228km length with average 1m trench width x average 1.2m burial depth = 273,600m^3 Worst case scenario volume due to offshore cable installation = **27,633,600m^3**	Sandwave levelling may be required prior to offshore cable installation. Any excavated sediment due to sandwave levelling would be disposed of within the North Falls offshore project area, meaning there will be no net loss of sediment from the site. Sediment displacement assumes a box shaped dimension.
Impact 6: Changes in seabed level due to offshore cable installation (array and interconnector cables)	As Construction Impact 5	As Construction Impact 5.	As Construction Impact 5.
Impact 7: Interruptions to bedload sediment transport due to	Volume of sediment disturbed	• Cable sandwave levelling = 228km length with average 24m disturbance width x average 5m sediment depth = 27,360,000m^3 Worst case scenario volume due to offshore cable installation = **27,360,000m^3**	The disposal of any sediment that would be disturbed or removed during sandwave levelling would occur within the North Falls offshore project area.

Potential impact	Parameter	Worst case	Notes
sandwave levelling for offshore cable installation (array and interconnector cables)			
Impact 8: Indentations on the seabed due to installation vessels	Seabed disturbance footprint	• Vessel jack up assuming 6 jack up locations per wind turbine (275m^2 per jack up leg x 6 legs x 6 locations) = 712,800m^2 • Jack up vessel footprints for OSPs = 19,800m^2 • Anchoring - 60.7m^2 anchor footprint x 9 anchors per vessel x 264 placements during array/interconnector cable installation = 144,077m^2 • Anchoring – 116.4m^2 anchor footprint x 8 anchors per vessel x 5 placements per wind turbine/OSP installation = 344,529 m^2 • Anchor placement for export cable - 60.7m^2 anchor footprint x 9 anchors per vessel x 545 placements = 297,826m^2 Worst case scenario seabed footprint due to installation vessels = **1.5km^2**	
Operation and maintenance			
Impact 1: Changes to the tidal regime due to the presence of structures on the seabed (array areas)	Cross sectional area within the water column	**Turbines** Total worst case turbine footprint based on 72 x 65m GBS diameter = 238,918m^2 Scour protection - assumes all turbines have scour protection of up to 83,774m^2 (excluding turbine foundation footprint) = 6,031,728m^2 Array cable protection - Up to 45.6km of cable protection may be required in the unlikely event that array cables cannot be buried (based on 20% of the length) x 6m cable protection width = 273,600m^2 Two offshore electrical platforms with scour protection = 149,012m^2 (74,506m^2 each) Worst case scenario total persistent footprint in the array areas = **6.69km^2**	Gravity Based Structures (GBS) are the worst-case foundation types for effects on tidal currents. This is based on GBS having the greatest cross-sectional area within the water column (compared to other foundation types) representing the greatest physical blockage to tidal currents. Therefore, a larger number of GBS with minimum wind turbine and OSP spacing is the worst case scenario. The worst case scenario for changes to the tidal regime does not include effects caused by cable protection. This is because, although flows would tend to accelerate over the protection and then decelerate on the ‘down-flow’ side, they would return to baseline values a very short distance

Potential impact	Parameter	Worst case	Notes
			from the structure. Hence, the effect on tidal currents would be very small.
Impact 2: Changes to the wave regime due to the presence of structures on the seabed (wind turbines and OSP foundations)	Cross sectional area within the water column	72 x GBS wind turbine foundations Wind turbine spacing - a minimum of 5 x the rotor diameter (i.e. 820m for the smallest turbines)	GBS are the worst-case foundation types for effects on waves due to the height of the foundation above the seabed. Wind turbine spacing can be described in general terms at this stage.
Impact 3: Changes to the sediment transport regime due to the presence of structures on the seabed (wind turbines and OSP foundations)	As Operational Impact 1	As Operational Impact 1	GBS are the worst-case foundation types for effects on the sediment transport regime due to the height of the foundation above the seabed.
Impact 4: Loss of seabed area due to infrastructure footprint within the array areas	Loss of seabed area	As Operational Impact 1	GBS are the worst-case foundation types for loss of seabed area due to the size of the base that will be present on the seabed.
Impact 5: Morphological and sediment transport effects due to cable protection measures within the North Falls array areas and interconnector cable corridor	Loss of seabed area	Subsea cable surface protection • Array cable protection - Up to 45.6km of cable protection may be required for cable crossings and/or where array cables cannot be buried (based on 20% of the length) x 6m cable protection width = 273,600m^2 • Cable protection volume = 383,400m^3 (based on height of up to 1.4m)	Cable protection parameters are based on rock berm protection of up to 1.4 m in height and 15.2 m wide in a trapezoid shape. Cable protection could also include mattressing, which would be within these worst case parameters.

Potential impact	Parameter	Worst case	Notes
Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor	Loss of seabed area	Subsea cable surface protection • Export cable protection - Up to 25km of cable protection may be required for cable crossings; at the HDD exit location; and/or where export cables cannot be buried (based on 10% of the length) x 6m cable protection width = 150,480m^2 Cable protection volume = 210,672m^3 (based on height of up to 1.4m)	
Impact 7: Changes in SSC due to cable repairs and reburial	Volume of sediment disturbed	Unplanned repairs and reburial of cables may be required during O&M, the following estimates are included: • Reburial of c. 5km of array/interconnector cable is estimated over the life of the Project (24m disturbance width) = 120,000m^2 • Reburial of c. 5km of export cable is estimated over the life of the Project (24m disturbance width) = 120,000m^2 • Five array/interconnector cable repairs are estimated over the Project life. 600m section removed x 24m disturbance width = 72,000m^2 • Four export cable repairs are estimated over the Project life. 600m section removed x 24m disturbance width = 57,600m^2 Anchored vessels placed during the no. of cable repairs included above = 4,914m^2 Maintenance of offshore infrastructure would be required during O&M. An estimated 180 major component replacement activities may be required per year, using jack up vessels and/or anchoring = 297,000m^2	
Impact 8: Indentations on the seabed due to O&M vessels	Seabed disturbance footprint	Anchored vessels placed during the no. of cable repairs included above = 4,914m^2 Maintenance of offshore infrastructure would be required during O&M. An estimated 180 major component replacement activities may be required per year, using jack up vessels and/or anchoring = 297,000m^2	
Decommissioning			
Impact 1: Changes in SSCs		Cutting of piles below the seabed surface:	No decision has yet been made regarding the final decommissioning arrangements for the

Potential impact	Parameter	Worst case	Notes

due to foundation removal
 	
Impact 2: Changes in seabed level due to foundation removal
	Volume of sediment disturbed	• 300 pin-piles of 3.5m diameter
		  ○ 72 wind turbines x 4 piles
		  ○ 2 OSPs x 6 piles
		Or
		• 74 monopiles of 17m diameter (72 wind turbines + 2 OSPs)
		
		Or
		Removal of largest foundations (GBS):
		• 72 wind turbines x 65m diameter
		• 2 OSPs x 60m diameter
			offshore project infrastructure. It is also recognised that legislation and industry best practice change over time. However, the following infrastructure is likely to be removed, reused or recycled where practicable:
			• Turbines including monopile, steel jacket and GBS foundations;
			• OSPs including topsides and steel jacket foundations; and
			• Offshore cables may be removed or left in situ depending on available information at the time of decommissioning.
			The following infrastructure is likely to be decommissioned in situ depending on available information at the time of decommissioning, however where it represents the worst case scenario (e.g. for disturbance, removal is assessed):
			• Scour protection;
			• Offshore cables may be removed or left in situ; and
			• Crossings and cable protection.
			The detail and scope of the decommissioning works will be determined by the relevant legislation and guidance at the time of decommissioning and will be agreed with the regulator.
			Decommissioning arrangements will be detailed in a Decommissioning Plan, which will be prepared in accordance with the Energy Act 2004.

Impact 3: Changes in SSCs due to removal of parts of the export cable	As Construction Impact 1	• Up to 250.8km of export cable (removal to be determined in consultation with key stakeholders as part of the decommissioning plan)	
Impact 4: Changes in seabed level due to removal of parts of the export cable	As Construction Impact 1		
Impact 5: Changes in SSCs due to removal of parts of the array and interconnector cables	Volume of sediment disturbed	• Up to 228km of array/interconnector cable (removal to be determined in consultation with key stakeholders as part of the decommissioning plan)	
Impact 6: Changes in seabed level due to removal of parts of the array	As Construction Impact 3		

Potential impact	Parameter	Worst case	Notes
and interconnector cables			
Impact 7: Indentations on the seabed due to decommissioning vessels	Volume of sediment disturbed	• Vessel jack up assuming 6 jack up locations per wind turbine (275m^2 per jack up leg x 6 legs x 6 locations) = 712,800m^2 • Jack up vessel footprints for OSPs = 19,800m^2 • Anchoring - 60.7m^2 anchor footprint x 8 anchors per vessel x 264 placements during array/interconnector cable removal (if required) = 144,077m^2 • Anchoring - 116.4m^2 anchor footprint x 9 anchors per vessel x 5 placements per wind turbine/OSP installation = 344,529 m^2 • Anchor placement for export cable removal (if required) = 297,826m^2	

8.3.3 Summary of mitigation embedded in the design

15. This section outlines the embedded mitigation relevant to the Marine Geology, Oceanography and Physical Processes assessment, which has been incorporated into the design of North Falls (Table 8.3). Where other mitigation measures are proposed, these are detailed in the impact assessment (Section 8.6).

Table 8.3 Embedded mitigation measures

Parameter	Mitigation measures embedded into North Falls design
Turbine Spacing	Wind turbine spacing can be described in general terms at this stage. A minimum separation distance 5 x the rotor diameter (i.e. 820m for the smallest turbines) minimising the potential for interaction between adjacent wind turbines with respect to marine physical process.
Foundations	For piled foundation types, such as monopiles and jackets with pin piles, pile-driving will be used in preference to drilling where it is practicable to do so (i.e. where ground conditions allow). This would minimise the quantity of sub-surface sediment released into the water column from the installation process.
	Micro-siting will be used where possible to minimise the requirements for seabed preparation prior to foundation installation.
Cables	Micro-siting will be used where possible to minimise the requirements for seabed preparation prior to cable installation.
	Cables will be buried where possible, minimising the requirement for cable protection measures and thus effects on sediment transport.

8.4 Assessment methodology

8.4.1 Legislation, guidance and policy

8.4.1.1 National Policy Statements

16. The assessment of likely significant effects upon Marine Geology, Oceanography and Physical Processes has been made with specific reference to the relevant NPS. These are the principal decision making documents for Nationally Significant Infrastructure Projects (NSIPs). Those relevant to the Project are:

- Overarching NPS for Energy (EN-1) (Department of Energy and Climate Change (DECC) 2011a);
- NPS for Renewable Energy Infrastructure (EN-3) (DECC 2011b);
- Draft Overarching NPS for Energy (EN-1) (BEIS 2022a);
- Draft NPS for Renewable Energy Infrastructure (EN-3) (BEIS 2022b); and

17. The specific assessment requirements for Marine Geology, Oceanography and Physical Processes, as detailed in the NPS, are summarised in Table 8.4

together with an indication of the section of the PEIR chapter where each is addressed.

18. It is noted that the NPS for Energy (EN-1) and the NPS for Renewable Energy Infrastructure (EN-3) are in the process of being revised. Draft versions were published for consultation in September 2021 (Department for Business Energy and Industrial Strategy (BEIS), 2021a and BEIS 2021b respectively). A review of these draft versions has been undertaken in the context of this PEIR chapter. Any further updates to the NPSs will be considered in the ES.

19. Table 8.4 includes a section for the draft versions of NPS EN-1 and EN-3 in which relevant additional NPS requirements that were not presented within the current versions have been included. References have been provided alongside an explanation of where the requirement has been addressed within this PEIR chapter (or wider PEIR).

20. Minor wording changes within the draft version which do not materially influence the NPS EN-1 and EN-3 requirements have not been reflected in Table 8.4.

Table 8.4 NPS assessment requirements

NPS Requirement	NPS Reference	PEIR Reference (Volume I)
EN-1 NPS for Energy (EN-1)		
'Where relevant, applicants should undertake coastal geomorphological and sediment transfer modelling to predict and understand impacts and help identify relevant mitigating or compensatory measures'	Section 5.5, paragraph 5.5.6	The approach adopted in this PEIR is conceptual and evidence-based using data from GWF and GGOW as a suitable analogue (see Section 8.4.6).
'The ES should include an assessment of the effects on the coast. In particular, applicants should assess: • The impact of the proposed project on coastal processes and geomorphology, including by taking account of potential impacts from climate change. If the development will have an impact on coastal processes the applicant must demonstrate how the impacts will be managed to minimise adverse impacts on other parts of the coast • The implications of the proposed project on strategies for managing the coast as set out in Shoreline Management Plans (SMPs) and any relevant Marine Plans (Objective 10 of the East Inshore and East Offshore Marine Plans is "To ensure integration with other plans, and in the regulation and management of key activities and issues, in the East Marine Plans, and adjacent areas" this therefore refers back to the objectives of the SMPs)… and capital programmes for maintaining flood and coastal defences • The effects of the proposed project on marine ecology, biodiversity and protected sites • The effects of the proposed project on maintaining coastal recreation sites and features	Section 5.5, paragraph 5.5.7	The assessment of potential construction and operation and maintenance impacts and effects are described in Section 8.6.2 and Section 8.6.3, respectively. North Falls will not affect the Shoreline Management Plan and allowance has been made for predicated erosion rates during North Falls design (further detail is provided in Chapter 4 Site Selection and Assessment of Alternatives). Embedded mitigation to minimise likely significant effects at the coast of cable installation and operation are described in Section 8.3.3. Effects on marine ecology biodiversity and protected sites are assessed in Chapter 12 Benthic and Intertidal Ecology, Chapter 13 Fish and Shellfish Ecology, Chapter 14 Marine Mammal Ecology and Chapter 15 Offshore Ornithology. Effects on recreation are assessed in Chapter 34 Tourism and Recreation. As described above, North Falls has been designed so that it is not

NPS Requirement	NPS Reference	PEIR Reference (Volume I)
• The vulnerability of the proposed development to coastal change, taking account of climate change, during the Project's operational life and any decommissioning period'		vulnerable to coastal change or climate change.
'The applicant should be particularly careful to identify any effects of physical changes on the integrity and special features of Marine Conservation Zones, candidate marine Special Areas of Conservation (SACs), coastal SACs and candidate coastal SACs, coastal Special Protection Areas (SPAs) and potential SCIs and Sites of Special Scientific Interest (SSSI)'	Section 5.5, paragraph 5.5.9	The potential receptors to morphological change are the Suffolk coast, Essex coast and designated sites including Margate and Long Sands SAC, Kentish Knock East MCZ, Orford Inshore MCZ and Annex 1 sandbanks. The potential to affect their integrity is assessed with respect to changes in seabed level caused by foundation and cable installation (Section 8.6.2.1– Section 8.6.2.8) and interruption to bedload sediment transport by cable protection (Section 8.6.3.5 and Section 8.6.3.6).
NPS for Renewable Energy Infrastructure (EN-3)		
'The assessment should include predictions of physical effect that will result from the construction and operation of the required infrastructure and include effects such as the scouring that may result from the proposed development'	Section 2.6, paragraph 2.6.193 and 2.6.194	Each of the impacts and effects in Section 8.6.3.1 – Section 8.6.3.3 cover the potential magnitude and significance of the physical (waves, tides and sediments) effects upon the baseline conditions resulting from the construction, operation and maintenance, and decommissioning of North Falls. Scour resulting from the Project is not assessed because scour protection will be used wherever scour is likely to occur, reducing sediment release to negligible quantities.
'Where necessary, assessment of the effects on the subtidal environment should include: • Loss of habitat due to foundation type including associated seabed preparation, predicted scour, scour protection and altered sedimentary processes • Environmental appraisal of inter-array and cable routes and installation methods • Habitat disturbance from construction vessels extendible legs and anchors • Increased suspended sediment loads during construction • Predicted rates at which the subtidal zone might recover from temporary effects'	Section 2.6, paragraph 2.6.113	See above for scour. The quantification and likely significant effect of seabed loss due to the footprints of North Falls infrastructure is covered in Section 8.6.3.4. A worst case scenario of all foundations having scour protection is considered to provide a conservative assessment. The worst case scenario cable-laying techniques are jetting, ploughing or cutting and are considered in all the cable construction assessments. The disturbance to the subtidal seabed caused by indentations due to installation vessels is assessed in Section 8.6.2.10. The potential increase in suspended sediment concentrations and change

NPS Requirement	NPS Reference	PEIR Reference (Volume I)
		in seabed level is assessed in Section 8.6.2.1– Section 8.6.2.8. The recoverability of receptors is assessed for all the relevant impacts, particularly those related to changes in seabed level due to export cable installation (Section 8.6.2.6) and morphological and sediment transport effects due to cable protection measures for export cables (Section 8.6.3.6).
'An assessment of the effects of installing cable across the intertidal zone should include information, where relevant, about: • Any alternative landfall sites that have been considered by the applicant during the design phase and an explanation of the final choice • Any alternative cable installation methods that have been considered by the applicant during the design phase and an explanation of the final choice • Potential loss of habitat • Disturbance during cable installation and removal (decommissioning) • Increased suspended sediment loads in the intertidal zone during installation • Predicted rates at which the intertidal zone might recover from temporary effects'	Section 2.6, paragraph 2.6.81	Landfall Site Selection and Assessment of Alternatives are provided in Chapter 4 Site Selection and Assessment of Alternatives. A range of cable installation methods are required, and these are detailed in Chapter 5 Project Description. The worst case scenario for marine geology, oceanography and physical processes is provided in Section 8.3.2. Potential habitat loss in the intertidal zone is covered in Chapter 12 Benthic and Intertidal Ecology. Assessment of the potential disturbance and increased SSCs in the nearshore (including the intertidal zone) due to cable installation is provided in Section 8.6.3.6. The recoverability of the coastal receptors (Suffolk coast and Essex coast) is assessed for morphological and sediment transport effects due to cable protection measures at the coast (Section 8.6.3.6).
Draft Overarching NPS for Energy (EN-1) (BEIS, 2021a)		
the ES should include an assessment of the effects on the coast. In particular, applicants should assess: • how coastal change could affect flood risk management infrastructure, drainage and flood risk	Section 5.6, paragraph 5.6.7	As described above, North Falls has been designed so that it is not vulnerable to coastal change or climate change. Potential flood risk impacts are considered in Chapter 23 Water Resources and Flood Risk.
Draft NPS for Renewable Energy Infrastructure (EN-3) (BEIS, 2021b)		
Assessment of the effects on the subtidal environment should include: • environmental appraisal of inter-array and export cable corridors and installation/maintenance methods, including predicted loss of habitat due to predicted scour and scour protection	Section 2.30, paragraph 2.30.2	An assessment of likely significant effects of the installation and maintenance of cable infrastructure (including consideration of the potential impact of cable protection measures) is undertaken for the relevant construction and operation

NPS Requirement	NPS Reference	PEIR Reference (Volume I)
• impacts on protected sites (e.g. HRA sites and MCZs) • potential impacts from EMF on benthic fauna		impacts in Section 8.6.2 and 8.6.2.5 respectively. The Margate and Long Sands SAC, Kentish Knock East MCZ and Orford Inshore MCZ have been included as receptors within this chapter and so potential impacts on protected sites has been considered. The topic of EMF is not relevant to marine geology, oceanography and physical processes.
An assessment of the effects of installing cable across the intertidal zone should follow The Crown Estate's cable route protocol and include information, where relevant, about: • disturbance during cable installation, maintenance/repairs and removal (decommissioning) • increased suspended sediment loads in the intertidal zone during installation and maintenance/repairs • Protected sites (e.g. HRA sites, MCZs and SSSIs)	Section 2.27, paragraph 2.27.3	HDD will be used to install the export cables at the landfall and will exit in the subtidal zone. Therefore, there will be no direct impacts on the intertidal zone. Assessment of the potential disturbance and increased suspended sediment concentrations in the nearshore (including the intertidal zone) due to cable installation is provided in Section 8.6.3.6. The recoverability of the coastal receptors (Suffolk and Essex coast) is assessed for morphological and sediment transport effects due to cable protection measures at the coast (Section 8.6.3.6). The Margate and Long Sands SAC, Kentish Knock East MCZ and Orford Inshore MCZ have been included as receptors within this chapter and so likely significant effects on protected sites has been considered.

8.4.1.2 Other legislation, guidance and policy

21. In addition to the NPS, there are a number of pieces of legislation, policy and guidance applicable to the assessment of marine geology, oceanography and physical processes. These include (discussed further in Chapter 3 Policy and Legislative Context, Volume I):

- The Marine Policy Statement (MPS, HM Government, 2011; discussed further in Chapter 3 Policy and Legislative Context, Volume I) provides the high-level approach to marine planning and general principles for decision making that contribute to achieving this vision. It also sets out the framework for environmental, social and economic considerations that need to be considered in marine planning. Regarding the topics covered by this chapter the key reference is in section 2.6.8.6 of the MPS which states:

"…Marine plan authorities should not consider development which may affect areas at high risk and probability of coastal change unless the impacts upon it can be managed. Marine plan authorities should seek to minimise and mitigate any geomorphological changes that an activity or development will have on coastal processes, including sediment movement."

- The MPS is also the framework for preparing individual Marine Plans and taking decisions affecting the marine environment. The Marine Plans relevant to the Project are:
  - the North Falls array areas and offshore section of the offshore cable corridor are located within the remit of the East Inshore and the East Offshore Marine Plans (HM Government, 2014;). Objective 6 "*To have a healthy, resilient and adaptable marine ecosystem in the East Marine Plan areas*" is of relevance to this chapter as this covers policies and commitments on the wider ecosystem, set out in the MPS including those to do with the Marine Strategy Framework Directive and the Water Framework Directive (see Chapter 3 Policy and Legislative Context, Volume I), as well as other environmental, social and economic considerations. Elements of the ecosystem considered by this objective include: "*coastal processes and the hydrological and geomorphological processes in water bodies and how these support ecological features*".
  - The nearshore section of the offshore cable corridor is located within the South-East Inshore Marine Plan (MMO, 2021). Policies SE-CC-2 and SE-CC-3 are of relevance to this chapter:
    - SE-CC-2 – "*Proposals in the south east marine plan area should demonstrate for the lifetime of the project that they are resilient to the impacts of climate change and coastal change."*
    - SE-CC-3 – "*Proposals in the south east marine plan area, and adjacent marine plan areas, that are likely to have significant adverse impacts on coastal change, or on climate change adaptation measures inside and outside of the proposed project areas, should only be supported if they can demonstrate that they will, in order of preference:*

      a) avoid

      b) minimise

      c) mitigate

      - adverse impacts so they are no longer significant."

22. In addition to NPS, MPS and the East Inshore and East Offshore Marine Plans, guidance on the generic requirements, including spatial and temporal scales, for Marine Geology, Oceanography and Physical Processes studies associated with offshore wind farm developments is provided in six main documents:

- Offshore wind farms (OWFs): guidance note for Environmental Impact Assessment in respect of Food and Environmental Protection Act (FEPA) and Coast Protection Act (CPA) requirements: Version 2 (Cefas, 2004).

- Coastal Process Modelling for Offshore Wind Farm Environmental Impact Assessment (Lambkin et al., 2009).
- Review of Cabling Techniques and Environmental Effects applicable to the Offshore Wind Farm Industry (BERR, 2008).
- General advice on assessing potential impacts of and mitigation for human activities on Marine Conservation Zone (MCZ) features, using existing regulation and legislation (JNCC and Natural England, 2011).
- Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects (Cefas, 2011).

23. Further detail is provided in Chapter 3 Policy and Legislative Context (Volume I).

8.4.2 Data sources

8.4.2.1 Site specific

24. To provide site specific and up to date information on which to base the impact assessment, geophysical (multibeam echosounder for bathymetry, side-scan sonar for seabed texture and sub-bottom profiling for shallow geology) surveys of the array areas, interconnector cable corridor and offshore cable corridor were completed between May and August 2021 (Fugro, 2021a, b). A benthic survey of the offshore project area was also undertaken between May and August 2021 (Fugro, 2021c). The results of these surveys are described in Table 8.5 and are used to help characterise the existing environment in this chapter.

Table 8.5 Site-specific data

Data set	Spatial coverage	Year	Notes
Geophysical survey	North array and south array	May to August 2021	High-resolution seabed bathymetry, seabed texture, morphological features and shallow geology
Geophysical survey	Interconnector cable corridor	May to August 2021	High-resolution seabed bathymetry, seabed texture, morphological features and shallow geology
Geophysical survey	Offshore cable corridor	May to August 2021	High-resolution seabed bathymetry, seabed texture, morphological features and shallow geology
Benthic survey	North array and south array	May to August 2021	Grab sampling, particle size analysis and contaminants analysis at three sampling stations (north array) and 16 sampling stations (south array)
Benthic survey	Interconnector cable corridor	May to August 2021	Grab sampling, particle size analysis and contaminants analysis at one sampling station
Benthic survey	Offshore cable corridor	May to August 2021	Grab sampling, particle size analysis and contaminants analysis at 19 sampling stations

8.4.2.2 Other available sources

25. Information to support this PEIR has also been drawn from a series of data collection exercises and associated studies, including desk-top assessment and numerical modelling, which were undertaken to inform the GGOW and GWF ESs (Greater Gabbard Offshore Winds Ltd., 2005, Galloper Wind Farm Limited, 2011) (Table 8.6):

- collection of metocean data (wind, waves, water levels and currents) at the existing wind farms;
- a desk study to determine the existing wave, tidal and sedimentary processes within the GGOW and GWF wind farm sites and surrounding sea area, along their offshore cable corridors and at the adjacent coast;
- an assessment of the effects on the physical environment resulting from the construction, operation and decommissioning of the existing wind farms, including the effects of the turbine foundations on waves, tidal currents and sediment transport; and
- modelling of baseline tidal currents and sediment plume dispersion during cable installation and assessment of foundation scour potential for different areas of the wind farms.

Table 8.6 Other available data and information sources

Data Set	Spatial Coverage	Year
Geophysical survey - bathymetry, seabed features and shallow geology (Titan)	GGOW array area and offshore cable route	June to July 2004
Geophysical survey - bathymetry, seabed features and shallow geology (EMU)	GGOW array area extra seabed after a boundary change	May 2005
Geotechnical survey - sample boreholes, Standard Penetration Tests (SPT) and Cone Penetrometer Test (CPT) at each location (Hydro Soil Services)	GGOW array area - two locations on the Inner Gabbard and two on The Galloper sand banks.	September 2004
Benthic survey – grab samples and particle size analysis (Centre for Marine and Coastal Studies)	GGOW array area and offshore cable route	November 2004 and April 2005
Metocean survey - waves, water levels, currents and SSCs (EMU)	GGOW array area	November 2004 to March 2005
Coastal processes assessment (ABPmer)	GGOW array area	2005
Geophysical survey - bathymetry, seabed features and shallow geology (Osiris)	GWF array area and offshore cable route	August to December 2009
Benthic survey – grab samples and particle size analysis (Centre for Marine and Coastal Studies)	GWF array area and offshore cable route	December 2009
Coastal processes assessments (ABPmer)	GWF array area which includes an area overlapping the North Falls array area	2011

26. In addition to the site-specific surveys for North Falls and the data collected for GGOW and GWF, a range of other data sources are available including:

- Marine Renewable Atlas (BERR, 2008);
- National Tide and Sea Level Forecasting Service;
- United Kingdom Hydrographic Office (UKHO) tidal diamonds and historical charts;
- Numerical modelling studies undertaken by HR Wallingford for the Outer Thames MAREA;
- United Kingdom Climate Projections 2018 (UKCP18) (Palmer *et al.* 2018);
- British Geological Survey 1:250,000 seabed sediment mapping;
- British Geological Survey bathymetric contours and paper maps;
- Admiralty Charts and United Kingdom Hydrographic Office survey data;
- Marine Aggregate Levy Sustainability Fund (MALSF);
- Regional Environmental Characterisation (REC) study for the Outer Thames Estuary (MALSF);
- SeaZone seabed bathymetry data. This data can be used to inform the far-field model domain and to provide base mapping;
- Wavenet Data. On behalf of Defra, CEFAS operates a strategic wave monitoring network for England and Wales that provides a single source of real time wave data from a network of wave buoys located offshore from areas at risk from flooding. One of the buoys is located offshore at West Gabbard;
- TotalTide tidal level data. The TotalTide numerical modelling package can been used to synthetically generate astronomical tidal level data and current speed so that measured data from the metocean surveys can be compared against the model data for an assessment of consistency; and
- Met Office data. Wind and wave time series to provide details on the longer-term offshore wave climate.

8.4.3 Impact assessment methodology

27. Chapter 6 EIA Methodology (Volume I) explains the general impact assessment methodology applied to North Falls. The following sections describe the methods used to assess the likely significant effects on Marine Geology, Oceanography and Physical Processes.

28. The assessment of effects on the marine geology, oceanography and physical processes is predicated on a S-P-R conceptual model, whereby the source is the initiator event, the pathway is the link between the source and the potentially impacted receptor, and the receptor is the receiving entity. An example of the S-P-R conceptual model is provided by cable installation which disturbs sediment on the seabed (source). This sediment is then transported by tidal currents until it settles back to the seabed (pathway). The deposited sediment could change the composition and elevation of the seabed (receptor).

Numerical modelling of marine geology, oceanography and physical processes effects of North Falls would be disproportionate to the potential impacts described in Section 8.6 and a conceptual evidence-based assessment is preferred (see further justification provided in Section 8.4.6).

29. Consideration of the potential effects of North Falls on the marine geology, oceanography and physical processes is carried out over the following spatial scales:

- near-field: the area within the immediate vicinity (tens or hundreds of metres) of the array areas, and along the interconnector and offshore cable corridors; and
- far-field: the wider area that might also be affected indirectly by the Project (e.g. due to disruption of waves, tidal currents or sediment pathways passing through the site).

30. For the effects on marine geology, oceanography and physical processes, the assessment follows two approaches. The first type of assessment is impacts on marine geology, oceanography and physical processes whereby several discrete direct receptors can be identified. These include certain morphological features with an inherent geological or geomorphological value or function which may potentially be affected by North Falls such as Annex 1 sand banks, MCZ features, and beaches and sea cliffs at the coast.

31. The impact assessment incorporates a combination of the sensitivity of the receptor, its value (if applicable) and the magnitude of the change to determine a significance of effect.

32. In addition to identifiable receptors, the second type of assessment covers changes to marine geology, oceanography and physical processes represent impacts which may manifest themselves as an effect upon other receptors, most notably marine water and sediment quality, benthic ecology, and fish and shellfish ecology (e.g. in terms of increased SSCs, or erosion or smothering of habitats on the seabed). Hence, the two approaches to the assessment of marine geology, oceanography and physical processes are:

- Situations where potential impacts can be defined as directly affecting receptors which possess their own intrinsic morphological value. In this case, the significance of the effect is based on an assessment of the sensitivity of the receptor and magnitude of impact, by means of a significance of effect matrix.
- Situations where impacts (or changes) in the baseline marine geology, oceanography and physical processes may occur which could manifest as effects upon receptors other than marine geology, oceanography and physical processes. In this case, the magnitude of impact is determined in a similar manner to the first assessment method but the significance of effects on other receptors is made within the relevant chapters of the PEIR pertaining to those receptors.

8.4.3.1 Definitions

33. For each potential impact, the assessment identifies receptors within the study area which are sensitive to that impact and implements a systematic approach

to understanding the impact pathways and the level of impacts (i.e. magnitude) on given receptors. The definitions of sensitivity and magnitude for the purpose of the Marine Geology, Oceanography and Physical Processes assessment are provided in Table 8.7 and Table 8.9. These expert-based judgements of receptor sensitivity, value and magnitude of impact will be closely guided by the conceptual understanding of baseline conditions.

8.4.3.1.1 Sensitivity

Table 8.7 Definition of sensitivity for a morphological receptor

Sensitivity	Definition
High	Tolerance: Receptor has very limited tolerance of impact Adaptability: Receptor unable to adapt to impact Recoverability: Receptor unable to recover resulting in permanent or long-term (>10 years) change.
Medium	Tolerance: Receptor has limited tolerance of impact Adaptability: Receptor has limited ability to adapt to impact Recoverability: Receptor able to recover to an acceptable status over the medium term (5-10 years).
Low	Tolerance: Receptor has some tolerance of impact Adaptability: Receptor has some ability to adapt to impact Recoverability: Receptor able to recover to an acceptable status over the short term (1-5 years).
Negligible	Tolerance: Receptor generally tolerant of impact Adaptability: Receptor can completely adapt to impact with no detectable changes. Recoverability: Receptor able to recover to an acceptable status near instantaneously (<1 year).

Table 8.8 Definitions of value for a morphological receptor

Value	Definition
High	Value: Receptor is designated and / or of national or international importance for marine geology, oceanography or physical processes. Likely to be rare with minimal potential for substitution. May also be of significant wider-scale, functional or strategic importance.
Medium	Value: Receptor is not designated but is of regional importance for marine geology, oceanography or physical processes.
Low	Value: Receptor is not designated but is of local importance for marine geology, oceanography or physical processes.
Negligible	Value: Receptor is not designated and is not deemed of importance for marine geology, oceanography or physical processes.

8.4.3.1.2 Magnitude

Table 8.9 Definition of magnitude for a morphological receptor

Magnitude	Definition
High	Scale: A change which would extend beyond the natural variations in background conditions. Duration: Change persists for more than ten years. Frequency: The effect would always occur. Reversibility: The effect is irreversible.

Magnitude	Definition
Medium	Scale: A change which would be noticeable from monitoring but remains within the range of natural variations in background conditions. Duration: Change persists for five to ten years. Frequency: The effect would occur regularly but not all the time. Reversibility: The effect is very slowly reversible (five to ten years).
Low	Scale: A change which would barely be noticeable from monitoring and is small compared to natural variations in background conditions. Duration: Change persists for one to five years. Frequency: The effect would occur occasionally but not all the time. Reversibility: The effect is slowly reversible (one to five years).
Negligible	Scale: A change which would not be noticeable from monitoring and is extremely small compared to natural variations in background conditions. Duration: Change persists for less than one year. Frequency: The effect would occur highly infrequently. Reversibility: The effect is quickly reversible (less than one year).

8.4.3.2 Significance of effect

34. The assessment of significance of an effect is a function of the sensitivity of the receptor and the magnitude of the impact (see Chapter 6 EIA Methodology (Volume I) for further details). The determination of significance is guided by the use of a significance of effect matrix, as shown in Table 8.10. Definitions of each level of significance are provided in Table 8.11.

35. Likely significant effects identified within the assessment as major or moderate are regarded within this chapter as significant. Appropriate mitigation has been identified, where possible, in consultation with the regulatory authorities and relevant stakeholders. The aim of mitigation measures is to avoid or reduce the overall significance of effect to determine a residual effect upon a given receptor.

Table 8.10 Significance of effect matrix

		Adverse Magnitude				Beneficial Magnitude			
		High	Medium	Low	Negligible	Negligible	Low	Medium	High
Sensitivity	High	*Major*	*Major*	*Moderate*	*Minor*	*Minor*	*Moderate*	*Major*	*Major*
	Medium	*Major*	*Moderate*	*Minor*	*Minor*	*Minor*	*Minor*	*Moderate*	*Major*
	Low	*Moderate*	*Minor*	*Negligible*	*Negligible*	*Negligible*	*Minor*	*Minor*	*Moderate*
	Negligible	*Minor*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Minor*

Table 8.11 Definition of effect significance

Significance	Definition
Major	Very large or large change in receptor condition, both adverse or beneficial, which are likely to be important considerations at a regional or district level because they contribute to achieving national, regional or local objectives, or could result in exceedance of statutory objectives and / or breaches of legislation.
Moderate	Intermediate change in receptor condition, which are likely to be important considerations at a local level.

Significance	Definition
Minor	Small change in receptor condition, which may be raised as local issues but are unlikely to be important in the decision making process.
Negligible	No discernible change in receptor condition.
No change	No effect, therefore no change in receptor condition.

8.4.4 Cumulative effects assessment methodology

36. The cumulative effects assessment (CEA) considers other plans, projects and activities that may interact cumulatively with North Falls. Chapter 6 EIA Methodology (Volume I) provides further details of the general framework and approach to the CEA.

37. For marine geology, oceanography and physical processes, these activities include construction of other OWFs and large coastal defence/ protection works.

8.4.5 Transboundary effects assessment methodology

38. The transboundary assessment considers the potential for transboundary effects to occur on marine geology, oceanography and physical processes receptors as a result of North Falls; either those that might arise within the Exclusive Economic Zone (EEZ) of European Economic Area (EEA) states or arising on the interests of EEA states e.g. a non UK fishing vessel. Chapter 6 EIA Methodology (Volume I) provides further details of the general framework and approach to the assessment of transboundary effects.

39. For marine geology, oceanography and physical processes, the potential for transboundary effects were considered in the Scoping Report and it was concluded that transboundary effects could be scoped out of assessment. This was based on the findings of the transboundary assessment for GWF (ABPmer, 2011a; Royal Haskoning, 2011) which found no potential for significant transboundary effects. As North Falls is further from the EEZ boundary than GWF and the ZoI from North Falls is likely to be similar to GWF, transboundary effects are scoped out.

8.4.6 Justification for why a conceptual approach is appropriate for the Project

40. Previous numerical modelling and theoretical work has been undertaken specifically for the Greater Gabbard and Galloper offshore wind farms located adjacent to (and east to south-east of) North Falls. The results of this modelling will be used as part of the expert-based assessment and judgement to assess the potential construction and operational effects of North Falls on the identified marine geology, oceanography and physical processes receptors. The results of the modelling and theoretical approaches from the existing OWFs are used as part of the conceptual evidence-based assessment of potential construction and operational impacts and effects of North Falls.

8.4.6.1 Physical environment basis

41. The physical basis for using the modelling and theoretical results is that the GGOW and GWF designs and marine geology, oceanography and physical

processes operating at these sites are like North Falls and therefore provide suitable evidence (and are suitable analogues) to support the assessment of impacts and effects at North Falls. The location of the landfall for North Falls will be the Tendring peninsula (Frinton-on-Sea to Clacton-on-Sea). This is different to the landfall for GGOW and GWF, and so a bespoke desk based assessment of the offshore cable corridor and the landfall search area is provided in Sections 8.6.2.5, 8.6.2.6, 8.6.2.9, 8.6.3.6 and 8.6.3.7.

42. Justification for using the modelling results from GGOW and GWF as the principal evidence of potential impacts and effects at North Falls is provided below, which includes the similarities (and dissimilarities) of the existing physical and sedimentary conditions (water depths, tidal currents, waves, seabed sediments, and suspended sediment) at each of the sites. In addition, the western part of the originally assessed GWF which was not constructed now forms part of the eastern part of North Falls (Figure 8.1, Volume II).

43. Water depths at GGOW and GWF are comparable to those at North Falls (Figure 8.1, Volume II). The two parts of GGOW are located around two north-north-east to south-south-west oriented linear sand banks; the Inner Gabbard to the north and The Galloper to the south. The bathymetry of the northern part of GWF is dominated by the similarly oriented Outer Gabbard sand bank. Although there are no sand banks in the proposed North Falls array arrays, the water depths surrounding the sand banks (which extends into North Falls and includes the western part of the originally assessed GWF) are about 20-50m below Chart Datum (CD) with a maximum depth of about 60m below CD in the south-east part of GWF. These are similar to the water depths at North Falls which range from approximately 10m to 50m below CD.

44. Tidal currents demonstrate similar directions and velocities on the flood tide and ebb tide. For all sites, the main axis for tidal flows are rectilinear and are directed to the north-east during the ebb tide and to the south-west during the flood tide. Modelled current velocities are similar on both states of the tide, ranging from 0.9m/s to 1.3m/s (ABPmer, 2005; PMSS, 2005) (Figure 8.16 and 8.17, Volume II). Six metocean devices were deployed between November 2004 and March 2005 to measure current flows and wave heights and directions for GGOW. Although there was minor variability in current speeds between the different deployments, in general surface currents peaked at approximately 1.8m/s, bed currents were about 0.7 to 1.7m/s, and the currents were aligned with the local seabed topography. Average bed speeds recorded were approximately 0.4m/s at the GGOW offshore wind farm sites, whilst average surface speeds were approximately 0.7m/s. The same data were used to support the Environmental Impact Assessment (EIA) for GWF (ABPmer, 2011a; Royal Haskoning, 2011), and it is anticipated that, given the similar water depths (apart from local variations caused by interactions with the sand banks) the current conditions across North Falls are similar.

45. Predominant waves approach all sites from similar directions. The whole area within which GGOW, GWF and North Falls are located is exposed to wave conditions generated within the North Sea, with the most severe conditions arriving from the north-east due to long fetch lengths. The data collected between November 2004 and March 2005 from GGOW shows that the primary wave direction is from the north-east with a smaller proportion from between

the south-west (ABPmer, 2005; Project Management Support Services (PMSS), 2005) (Plate 8.8). The larger waves normally propagate from the north-east although these are rarely greater than 4m in height. Typical SWHs were about 3.6m. The most common wave heights were between 0.5m and 1.5m approaching along the dominant north-east-south-west axis. The same data was used to support assessment of the existing environment at GWF (ABPmer, 2011a; Royal Haskoning, 2011), and it is anticipated that, given the similar water depths and meteorological conditions, the wave conditions across North Falls are similar.

46. Apart from the Inner Gabbard and Galloper sand banks, the seabed sediments at all sites are broadly similar (Figure 8.9, Volume II). For GGOW grab sampling was undertaken during November 2004 and April 2005. The seabed at GGOW comprises medium sand in the banks surrounded by a more mixed sediment composed of mainly sandy gravel with areas of muddy sandy gravel and gravelly sand. The GWF seabed is dominated by gravelly sand or sandy gravel (which is consistent with the dominant seabed types found at the adjacent GGOW) (ABPmer, 2011a; Royal Haskoning, 2011). Broad-scale sediment mapping by the British Geological Survey shows that the North Falls array areas are dominated by sandy gravel with gravelly sand in the south (Figure 8.9, Volume II).

47. Average baseline SSCs at GGOW and GWF are comparable to those at North Falls (Figure 8.15, Volume II). The average SSC was approximately 10-22mg/l in the vicinity of GGOW and 7-21mg/l in the vicinity of GWF (Cefas, 2016). As described in Section 8.5.8, average SSCs in the vicinity of North Falls was approximately 7-15mg/l at the south array and 20-27mg/l for the north array (Figure 8.15, Volume II).

8.4.6.2 Design basis

48. The modelling for GGOW and GWF assessed 140 wind turbines each with a diameter of 36m and 35m, respectively, for GBS (worst case scenario). Although indicative at this stage, North Falls will comprise up to 72 turbines with GBS foundations of 65m diameter. The larger number of wind turbines assessed in the modelling of the GGOW and GWF provide a conservative proxy for the North Falls assessment. Whilst it is recognised that there are small differences in physical and sedimentary conditions and project parameters between the sites, the conservative nature of the numerical modelling conducted for GGOW and GWF allows for these differences in the effect that may arise due to these factors.

8.4.7 Assumptions and limitations

49. Due to the large amount of data that has been collected for the site-specific surveys for North Falls, and those at GWF and GGOW, as well as other available data, there is a good understanding of the existing marine geology, oceanography and physical processes environment at the Project and its adjacent areas.

8.5 Existing environment

8.5.1 Bathymetry and bedforms

8.5.1.1 North array

50. Water depths in the North array area range from 12.0m below Lowest Astronomical Tide (LAT) in the north-east of the array area where there are some shallow sandwaves, to 59.4m in the south-west of the array area (Figure 8.1, Volume II).

8.5.1.2 South array

51. Water depths in the south array area range from 3.3m below LAT at the site of two large shallow banks in the extreme north-east and south-east of the array area, to 55.6m in the far east of the array area (Figure 8.1, Volume II).

8.5.1.3 Gradient in the array areas

52. The seabed in the west of the array area is predominantly flat and featureless, whilst the east contains large sandwaves with megaripples. The average seabed gradient across the featureless seabed is on average 0.2°, with average gradients of 1.0° observed on the flanks of the megaripples and 3.7° on the flanks of the sandwaves. A maximum gradient of 31.2° was observed on the flank of a sandwave within the array areas.

8.5.1.4 Interconnector cable corridor

53. Water depths along the interconnector cable corridor range between 20.7m below LAT in the south, gradually deepening to 52.5m below LAT in the north (Figure 8.1, Volume II).

54. The seabed of the interconnector cable corridor is predominantly flat and featureless, with an average gradient of 0.2° (Fugro, 2021a).

8.5.1.5 Offshore cable corridor

55. Water depths along the offshore cable corridor are 1.5m above LAT closer to the coast, gradually deepening to 42.4m below LAT in the east (Figure 8.2, Volume II).

56. The west of the offshore cable corridor exhibits outcropping bedrock between flat and featureless seabed (Fugro, 2020b). Towards the centre of the offshore cable corridor, the seabed is characterised by large sandwaves and megaripples (Fugro, 2020b). In the east of the offshore cable corridor, the seabed is flat and featureless with isolated areas of seabed ripples (Fugro, 2020b).

8.5.2 Offshore geology

57. The geology of North Falls is predominantly Eocene to Holocene, generally consisting of Holocene deposits overlying Pleistocene channel complexes and infill deposits, which overlie the London Clay Formation and the Harwich Formation.

58. Table 8.12 outlines each formation, with their geophysical description, expected geological condition and coverage according to Fugro (2021a, b).

Table 8.12 Geological formations present at North Falls array areas, interconnector cable corridor and offshore cable corridor (Fugro, 2021a, b)

Formation	Geophysical description	Expected geological conditions	Coverage
Recent	Low to medium amplitude, discontinuous reflectors.	Includes surficial sediments (veneer of sediment overlying London Clay) and bedforms such as megaripples and Sandwaves.	Throughout project area
Holocene	Distinctive high-amplitude internal reflectors throughout much of the unit	Comprises clay and peat sediments up to 6m thick, rich in woody debris.	South array
Pleistocene	Variety of channel complexes and infill deposits of varying sizes	Very dense, silty gravelly sand and silty sandy gravel, occasionally interbedded with stiff to very stiff sandy gravelly clay.	Throughout project area
London Clay Formation	Low to moderate amplitude subparallel internal reflectors, with occasional prominent fault offsets with throws up to 3 m.	Fine grained, marine, clayey silt, silty clay and silt.	Throughout project area
Harwich Formation	Sequence of high amplitude, chaotic reflectors at the base, passing upwards into a 2-3m thick layer with weak reflectors and finally into a sequence of strong sub-parallel reflectors	Cross-bedded, glauconitic sand and silty facies, varying in depth between 2m below the seabed to more than 78m below the seabed.	Throughout project area

8.5.2.1 North and south array areas and interconnector cable corridor

59. The bedrock across the array areas and interconnector cable corridor is dominated by the Harwich Formation, which is conformably overlain by the London Clay Formation (Plate 8.1) (Fugro, 2021a). The top of the Harwich Formation deepens from approximately 2m below the seabed in the south-west of the south array, to more than 78m below the seabed in the south of the north array (Plate 8.1).

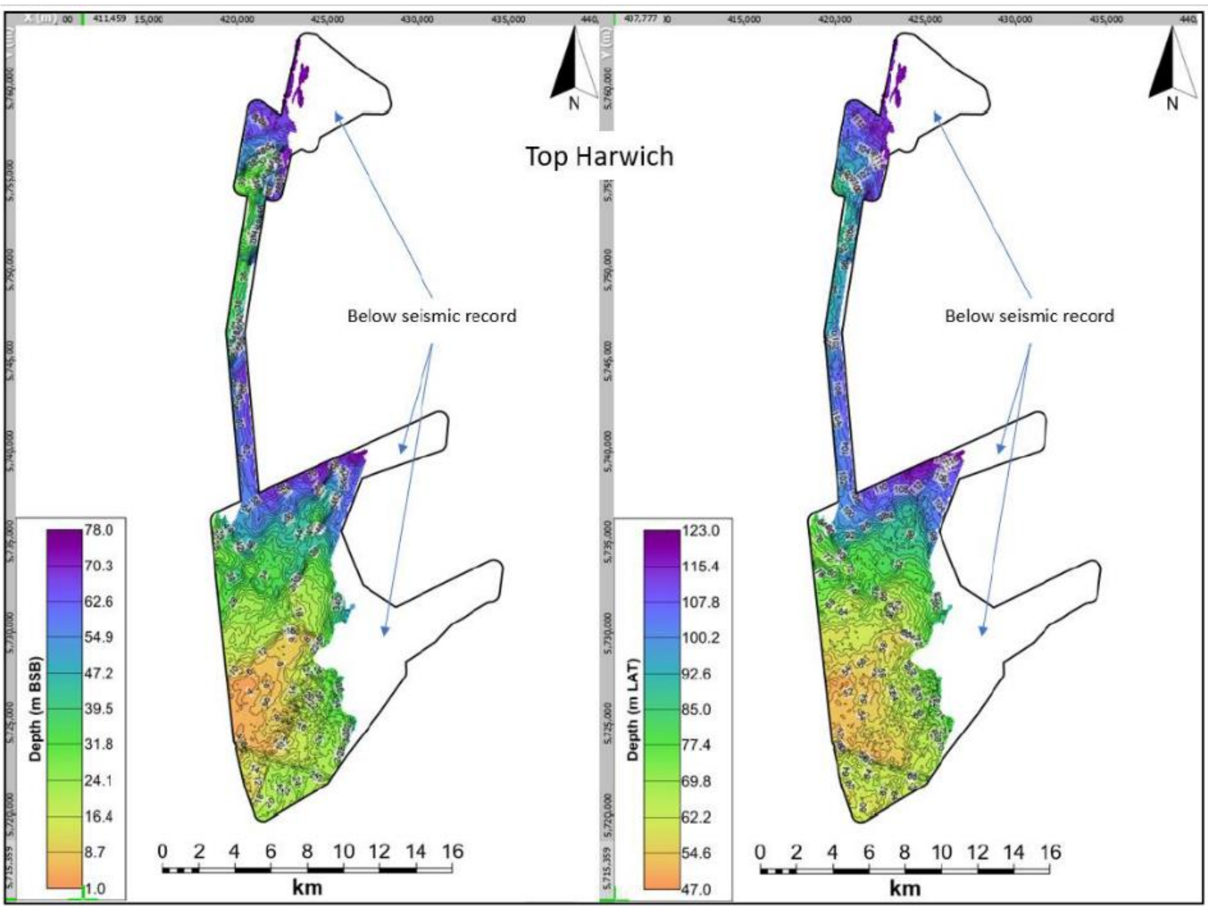

Plate 8.1 Top of Harwich Formation (depth below seabed (left) and depth below LAT (right)) across the north and south array areas and interconnector cable corridor (Fugro, 2021a)

60. London Clay is present below the majority of the seabed, overlain by only a thin veneer of Holocene sediments (Plate 8.2). There are two exceptions to this; in the east of the north and south array areas, where thicker Holocene sediment such as sand banks and sandwaves occur and in locations where the London Clay has been eroded away to expose the underlying Harwich Formation (Fugro, 2021a). The top of the London Clay horizon is 15m deeper in the southern part of the south array than in the north array (Fugro, 2021a).

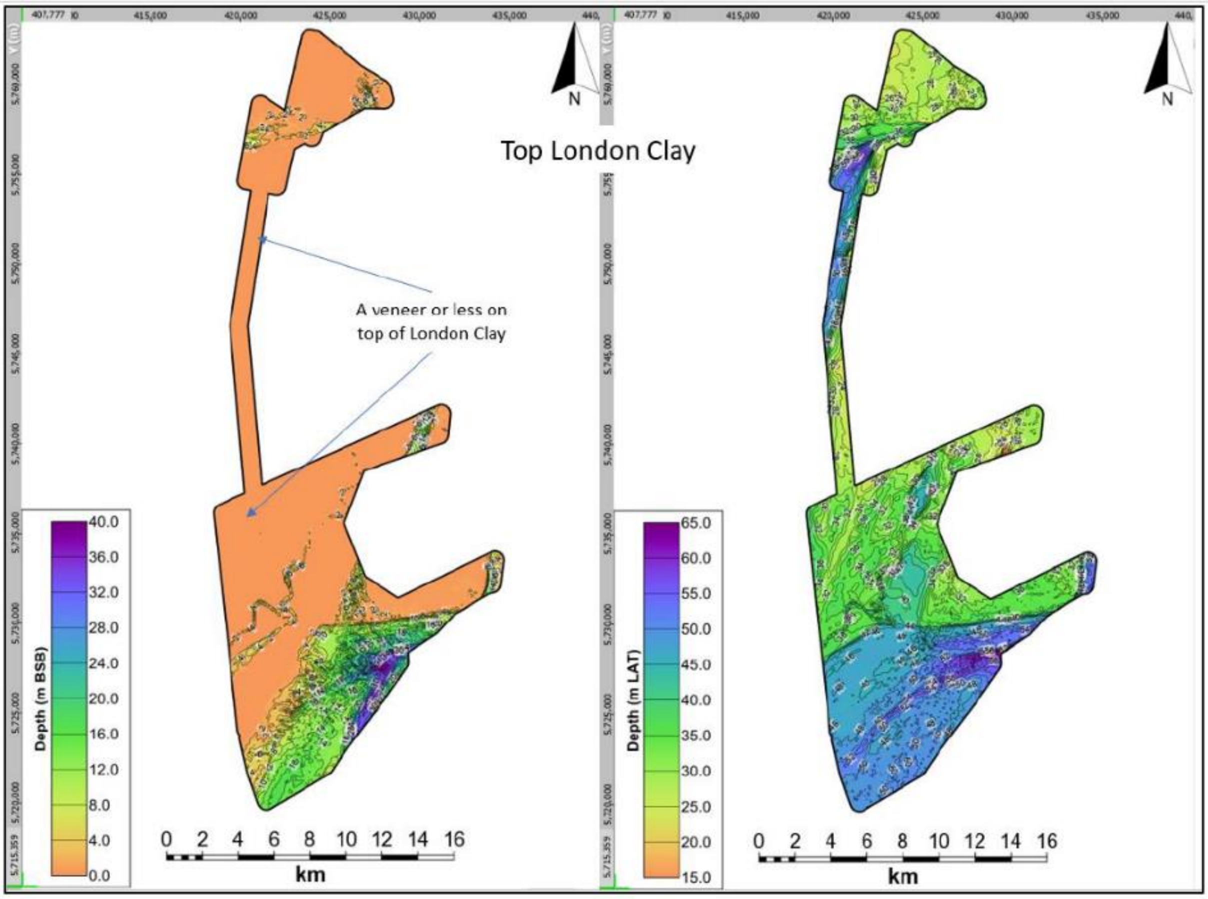

Plate 8.2 Top of London Clay (depth below seabed (left) and depth below LAT (right)) across the north and south array areas and interconnector cable corridor (Fugro, 2021a)

61. The London Clay is overlain by Pleistocene sediments, which are interpreted to be part of a variety of channel complexes and infill deposits of varying sizes where the London Clay Formation has been eroded (Fugro, 2021a). The thickest area of Pleistocene deposits is located in the south of the south array area (up to 20m below the seabed), which coincides with a large channel (Fugro, 2021a). A meandering Pleistocene channel is interpreted in the north-west of the south array and another channel was identified in the north array area (Plate 8.3).

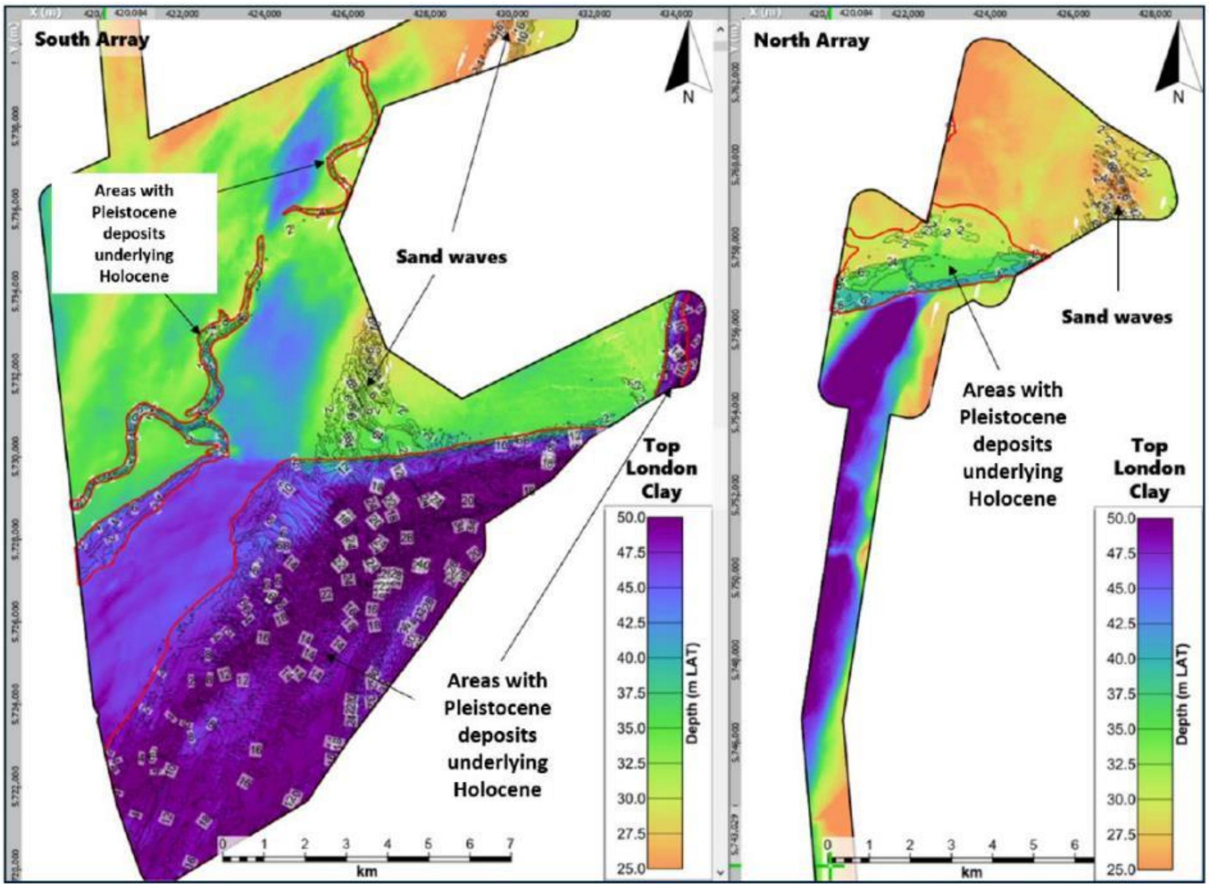

Plate 8.3 Pleistocene deposits in the south array (left) and north array (right) (Fugro, 2021a)

62. The youngest units are associated with the Holocene. They comprise two principal subunits: reworked modern Holocene (Recent) and early Holocene (Fugro, 2021a). A thin veneer of Recent sediment overlies the London Clay throughout the array areas and interconnector cable corridor. This unit is also associated with megaripples and sandwaves (Fugro, 2021a). Reworked Recent sediments occur throughout the array areas and interconnector cable corridor (Fugro 2021a). The early Holocene subunit has only been identified within the south array and is up to 6m thick (Plate 8.4). There is a complex range of seabed sediments present around the outer edges of the early Holocene subunit, caused by the erosion and recent reworking of sediments (Fugro, 2021a).

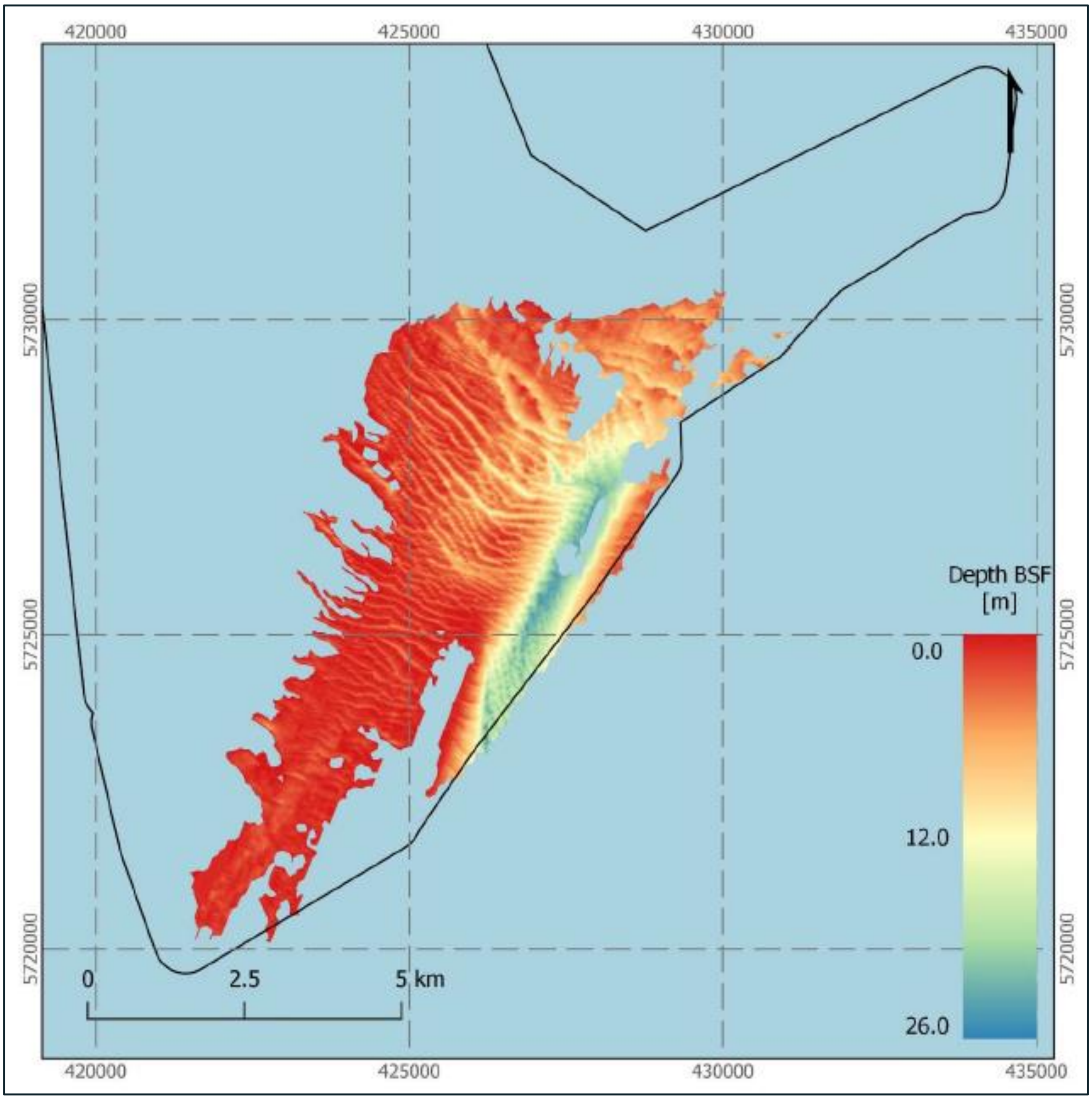

Plate 8.4 The extent of the early Holocene subunit in south array (Fugro, 2021a)

8.5.2.2 Offshore cable corridor

63. The Harwich Formation was interpreted to be present between kilometre posts (KP) 14.00 and 26.00 along the offshore cable corridor (Figure 8.5, Volume II) (Fugro, 2021b). The top of the unit is located between 0 and 14.4m below the seabed, with two outcrops along the cable corridor (Fugro, 2021b).

64. London Clay is present along the entire offshore cable corridor overlying the Harwich Formation (Fugro, 2021b). The depth of the London Clay remains within 2m of the seabed across the majority of the corridor, with deeper areas caused by the cutting of Pleistocene channels where it reaches a maximum depth of 14.4m below the seabed (Fugro, 2021b). There are also several outcrops of London Clay at the seabed (Figure 8.6, Volume II) (Fugro, 2021b).

65. Pleistocene channels of varying sizes are interpreted as cutting through the London Clay Formation (and occasionally the Harwich Formation) along the offshore cable corridor (Fugro, 2021b). Pleistocene channels range from less than 50m wide and 2 – 4m deep, to greater than 1km wide and up to 15m deep (Fugro, 2021b). The base of the Pleistocene unit ranges in depth from 0 to 14.4m below the seabed (Figure 8.7, Volume II) (Fugro, 2021b).

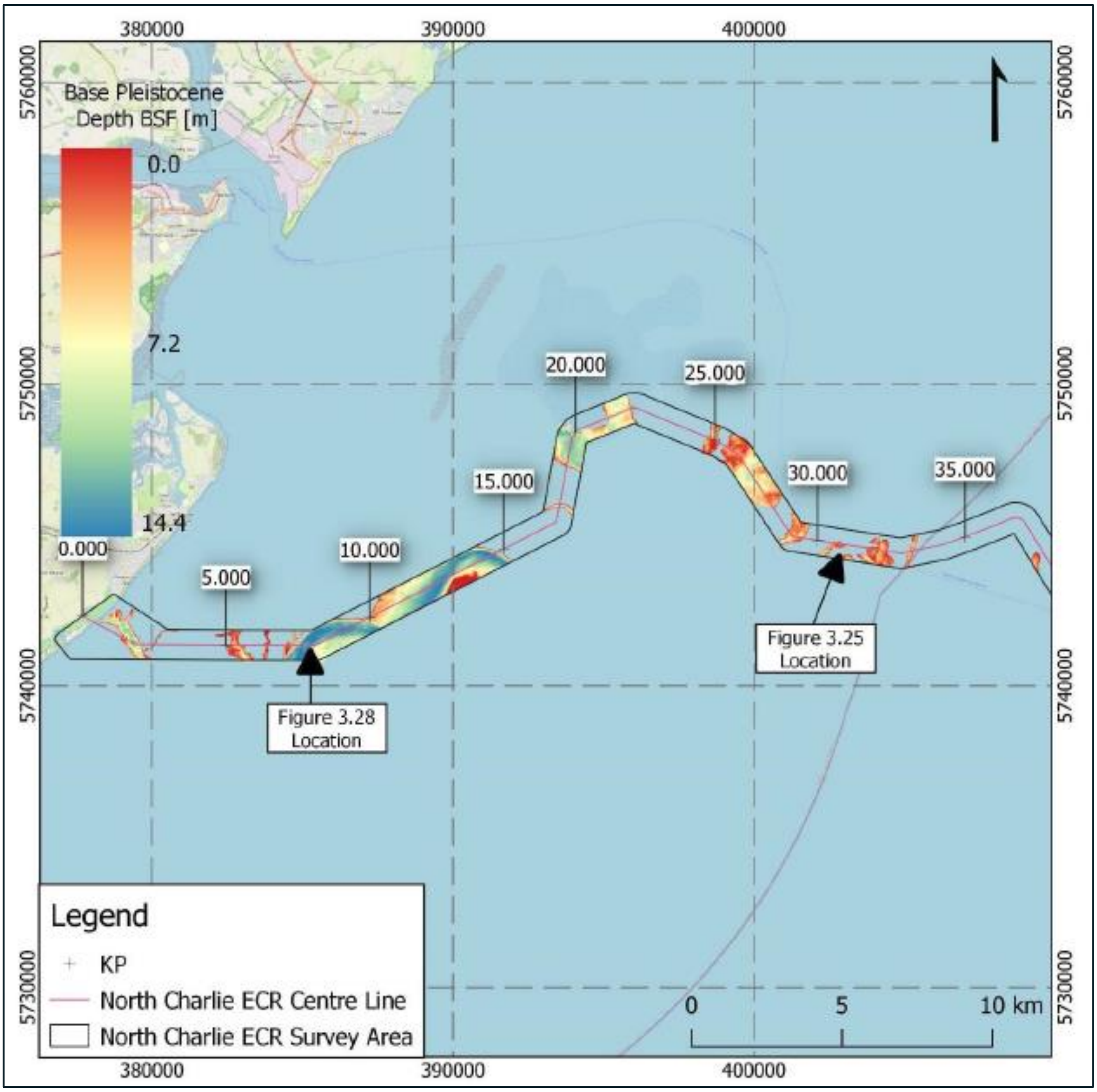

Plate 8.5 The depth below the seabed to the base of the Pleistocene unit along the offshore cable corridor (Fugro, 2021b) (Note: Figure location references refer to figures within the survey report by Fugro and not this chapter)

66. Holocene sediments overlie the London Clay Formation, or the Pleistocene unit in places, along the offshore cable corridor (Fugro, 2021b). An isolated area of unknown origin was observed overlying the Holocene sediments towards the landfall of the offshore cable corridor between KP 0.6 and 1.38 (Fugro, 2021b). The package increases in thickness and lateral extent towards the landfall (Figure 8.8, Volume II). Its extent is delineated by the Base Shore Unit, which

is elevated above the surrounding seabed and is only located on top of Pleistocene channels (Plate 8.6 and Figure 8.8, Volume II). Plate 8.7 illustrates a profile along the offshore cable corridor (Fugro, 2021b).

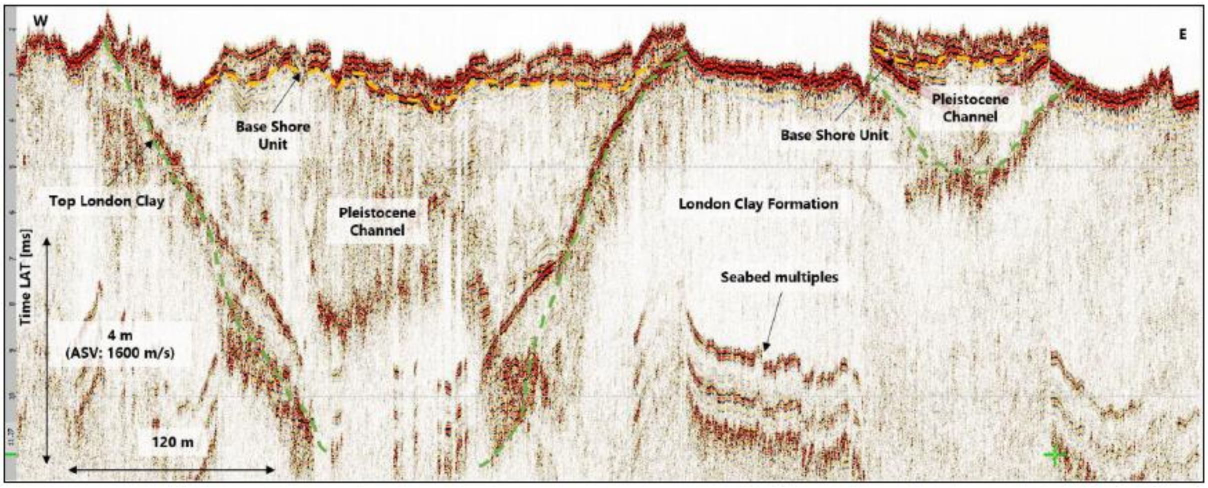

Plate 8.6 Interpreted base short unit observed in the nearshore of the offshore cable corridor

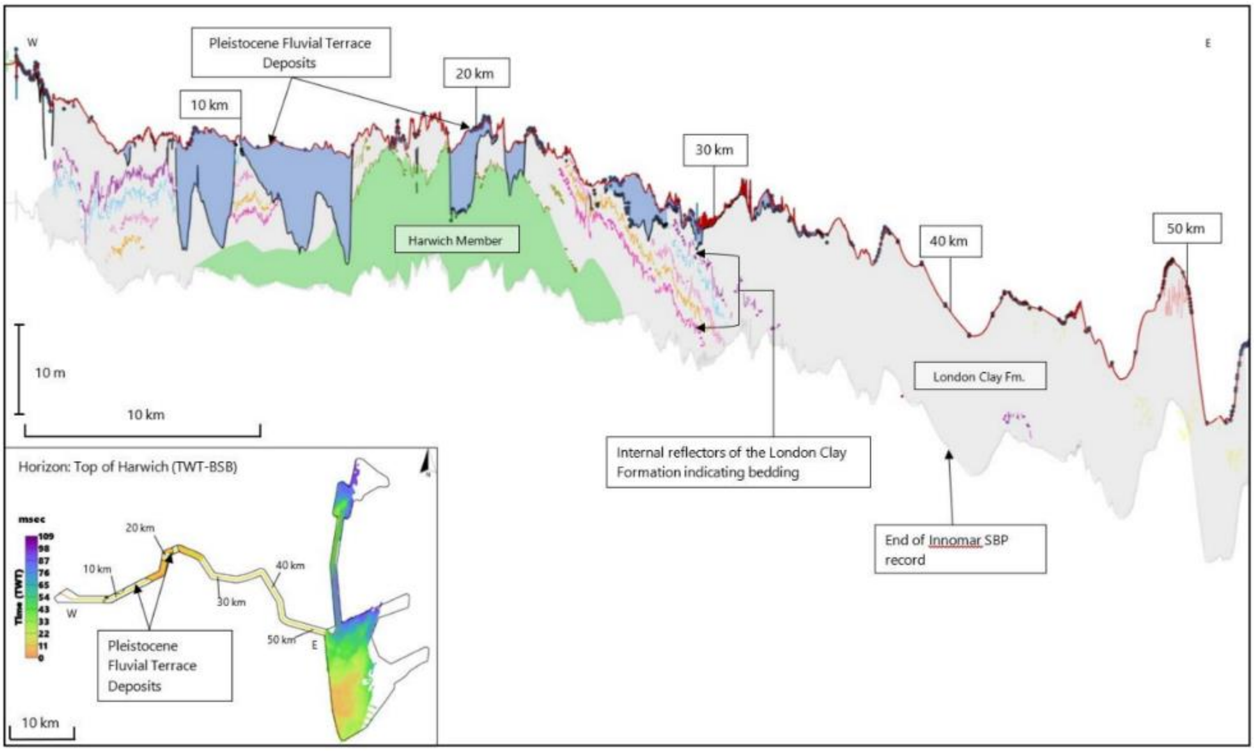

Plate 8.7 Schematic of the shallow geology of the offshore cable corridor (Fugro, 2021b)

8.5.3 Water levels

8.5.3.1 Regional summary

67. The astronomical tidal range in the southern North Sea and along the Essex and Suffolk coast varies according to the position of an amphidromic point between the east of England and the Netherlands. At the amphidromic point,

the tidal range is near zero and then increases with radial distance from this point. Due to the regional tidal regime being influenced by the amphidromic point, the tidal range gradually increases with progression south across the study area (Figure 8.4, Volume II).

8.5.3.2 North array

68. The north array experiences a macrotidal regime with a mean spring tidal range (difference in water levels between mean high water spring (MHWS) and mean low water spring (MLWS)) of about 2.5m (Figure 8.4, Volume II).

8.5.3.3 South array

69. The south array also experiences a macrotidal regime with a mean spring tidal range of about 3.0m at its northern boundary and 3.5m at its southern boundary (Figure 8.4, Volume II).

8.5.3.4 Interconnector cable corridor

70. The interconnector cable corridor experiences a mean spring tidal range of about 3.0m (Figure 8.4, Volume II).

8.5.3.5 Offshore cable corridor

71. Along the offshore cable corridor, the tidal range is about 3.0-3.5m at its eastern end increasing to 3.5-4.0m close to the landfall (Figure 8.4, Volume II).

8.5.3.6 Storm Surge

72. The North Sea is particularly susceptible to storm surges, and water levels at North Falls could become elevated several metres by these meteorological effects. The coast can also be subject to significant surge activity which may raise water levels above those of the predicted tide. Predicted extreme water levels can exceed predicted mean high-water spring levels by more than 1m. Environment Agency (2018) calculated one in one-year water levels of 2.68m above MHWS at Felixstowe. The 1 in 50-year water levels are predicted to be 3.43m above MHWS at Felixstowe.

8.5.4 Tidal currents

73. Previous numerical modelling work has been undertaken specifically for GGOW and GWF located adjacent to (and east to south-east of) North Falls. This data is used here to define the tidal current baseline for North Falls (see Section 8.4.6 for a justification of using this data).

8.5.4.1 Regional summary

74. Tidal currents demonstrate similar directions and velocities on the flood tide and ebb tide. For all sites, the main axes for tidal flows are rectilinear and are directed to the north-east during the ebb tide and to the south-west during the flood tide. Modelled current velocities are similar on both states of the tide, ranging from 0.9m/s to 1.3m/s (ABPmer, 2005; PMSS, 2005) (Figure 8.16 and Figure 8.17, Volume II).

75. Six metocean devices were deployed between November 2004 and March 2005 to measure current flows and wave heights and directions for GGOW. Although there was minor variability in current speeds between the different deployments, in general, surface currents peaked at approximately 1.8m/s and near seabed currents were about 0.7 to 1.7m/s. The currents were aligned with

the local seabed topography. Average recorded near seabed speeds were approximately 0.4m/s for each array area whilst average surface speeds were approximately 0.7m/s.

76. Tidal currents closer to the coast (i.e., Clacton-on-Sea) are approximately 0.26m/s during peak flood spring tide and 0.10m/s during peak ebb spring tide (East Anglia Coastal Group (EACG), 2010).

8.5.5 Waves

77. North Falls is exposed to wave conditions generated within the North Sea, with the most severe conditions arriving from the north-east due to long fetch lengths. Data collected between November 2004 and March 2005 from GGOW shows that the primary wave direction at GGOW is from the north-east, with a smaller proportion from the south-west (ABPmer, 2005; PMSS, 2005) (Plate 8.8).

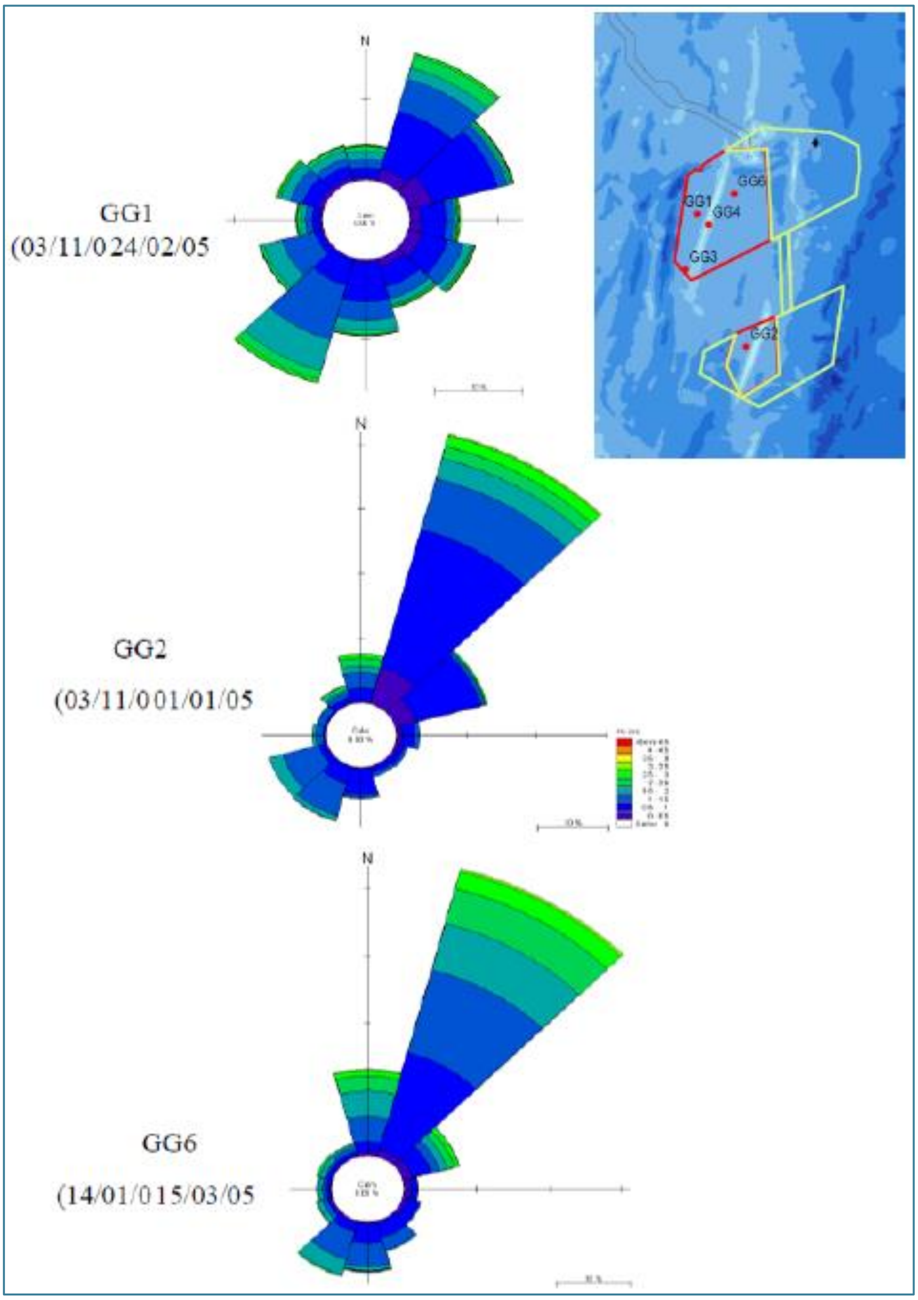

Plate 8.8 Near field wave conditions at GGOW in 2005 (ABPmer, 2011a)

78. The larger waves normally propagate from the north-east although these are rarely greater than 4m in height (ABPmer, 2005; PMSS, 2005). Typical significant wave heights (SWHs) were about 3.6m (ABPmer, 2005; PMSS, 2005). The most common wave heights were between 0.5m and 1.5m approaching along the dominant north-east-south-west axis (ABPmer, 2005; PMSS, 2005). Wave conditions at North Falls array area and interconnector cable corridor are expected to have similar baselines given the proximity to GGOW.

79. Data available from ABPmer (2018) 'SEASTATES' shows the most common waves in the vicinity of North Falls approaching from the south, with secondary waves approaching from the north – northeast (Plate 8.9). The largest SWHs

(greater than 2m) originate from the south, followed by the north-east (Plate 8.9). This data is modelled from long-term (1979), high-resolution wave hindcast databases for the north-western European Continental Shelf and the Baltic Sea (ABPmer, 2018) and was not recorded in the vicinity of North Falls.

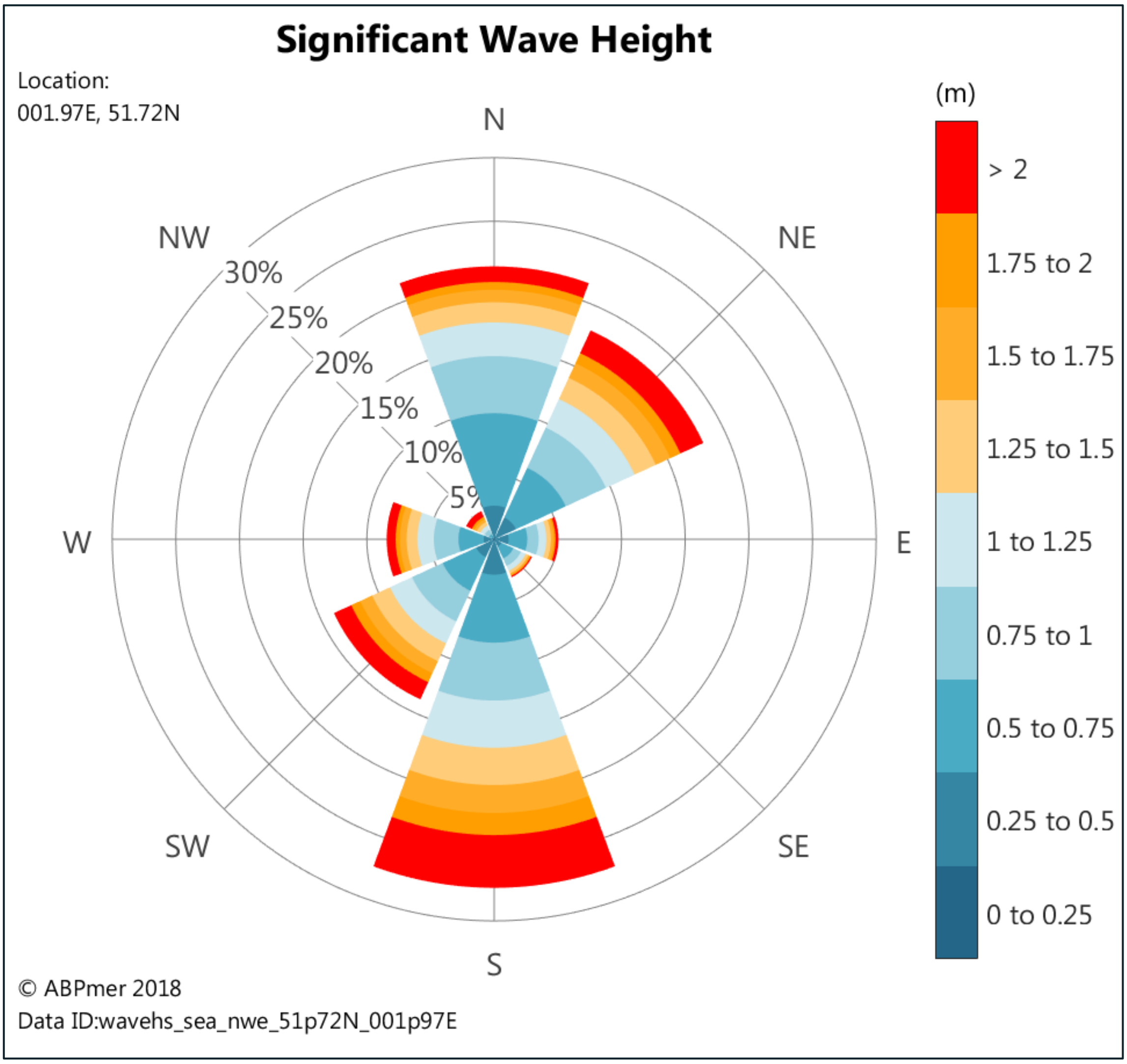

Plate 8.9 Significant wave heights in the vicinity of North Falls array areas (ABPmer, 2018)

80. Cefas' WaveNet, a strategic monitoring network for the United Kingdom, provides real-time wave data from a network of wave buoys located around UK waters. The South Knock wave buoy is located approximately 7km south of the south array. Data recorded between the 1st April 2010 to 1st June 2022 shows an average SWH of 0.8m, with an average predominant wave direction of 143° (south east). The West Gabbard 2 wave buoy is located approximately 50km east of the north array. Data recorded between 10th May 2016 to 1st June 2022 shows an average SWH of 1.1m, with an average predominant wave direction of 126° (south east).

81. Wave conditions towards the landfall will be less severe due to the protection afforded by numerous sand banks and the presence of East Anglia to the north (EACG, 2010). Sand banks can provide a physical barrier or refract incoming waves which reduces the wave energy reaching the coast. A wave rose from

modelled wave hindcast databases shows the most common wave direction close to landfall is from the south-west, followed by the north-east. SWHs range between 0.25 – 0.5m (Plate 8.10) (ABPmer, 2018).

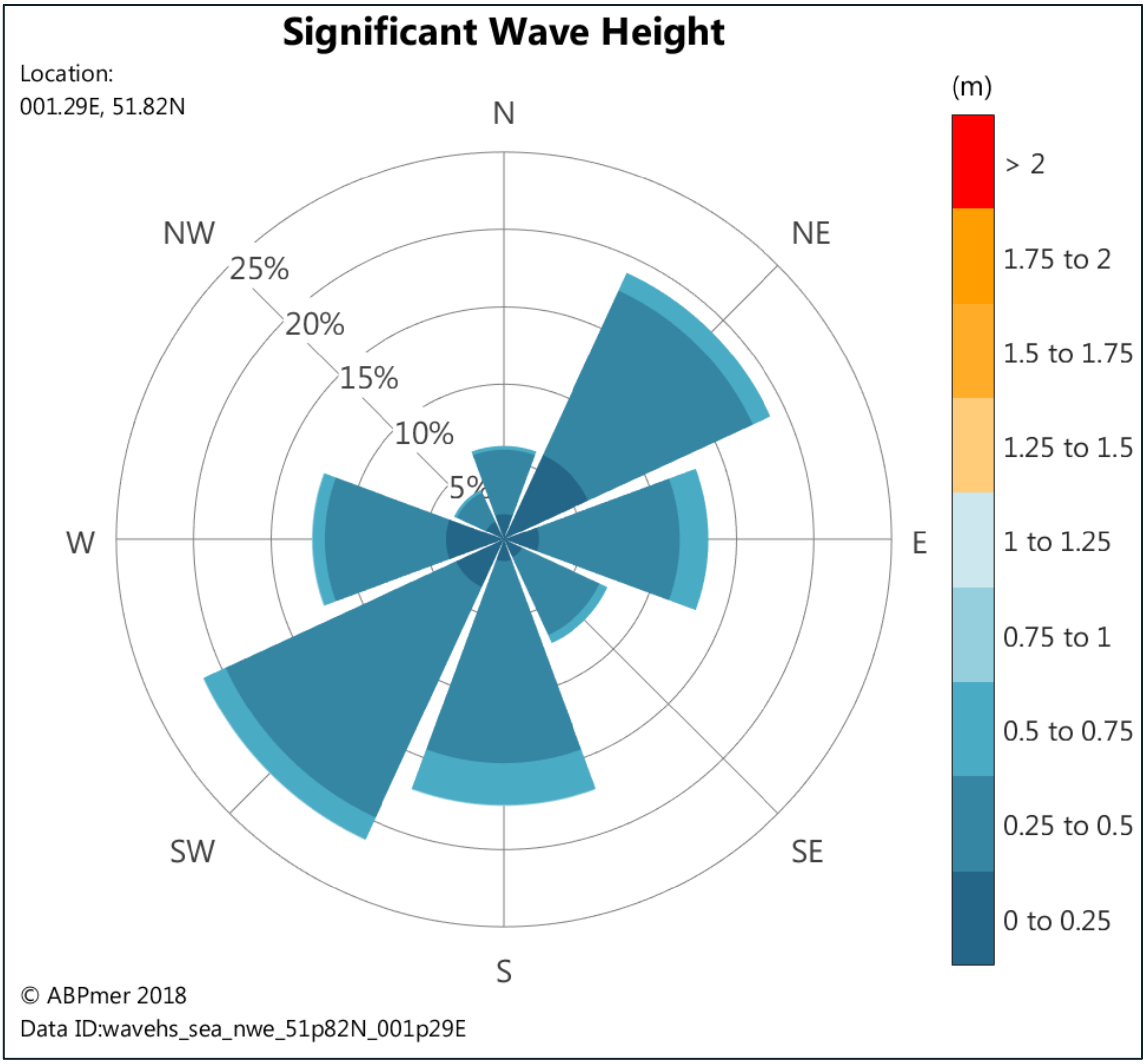

Plate 8.10 Significant wave heights closer to the landfall (ABPmer, 2018)

8.5.6 Seabed sediment distribution

8.5.6.1 Regional summary

82. The regional seabed and coast have been strongly influenced by deposition of sediment during the Pleistocene and Holocene periods (Section 8.5.2). Large quantities of sediment were deposited on the underlying chalk by retreating glaciers and associated rivers. The sediment was reworked by fluvial processes while sea level was low, and then by waves and currents during the Holocene (last 10,000 years) rise in sea level and up to the present day creating numerous bedforms including megaripples, sandwaves and sand banks.

83. A site-specific seabed sediment grab sampling campaign totalling 39 samples was completed by Fugro from May to August 2021 (Fugro, 2021a). Samples were recovered from the following areas:

- North array (three samples);
- South array (16 samples);
- Interconnector cable corridor (one sample); and
- Offshore cable corridor (19 samples).

84. Figures 8.9 and 8.10 (Volume II) provides an overview of the interpreted seabed sediment distribution across the array areas, interconnector cable corridor and offshore cable corridor.

8.5.6.2 North array

85. The dominant sediment type in the north array is coarse sand (6.5-65.7%). Median particle sizes (d_{50}) across the array are between 0.54mm and 0.99mm (coarse sand) (Plate 8.11). The mud content is less than 5% in 67% of the samples and less than 19% in 100% of the samples. Mud is highest at ST28 with 19% content, whereas ST25 has no mud and ST27 had 1.7% mud. Gravel content (47.4%) is highest at ST28 in the south of the north array.

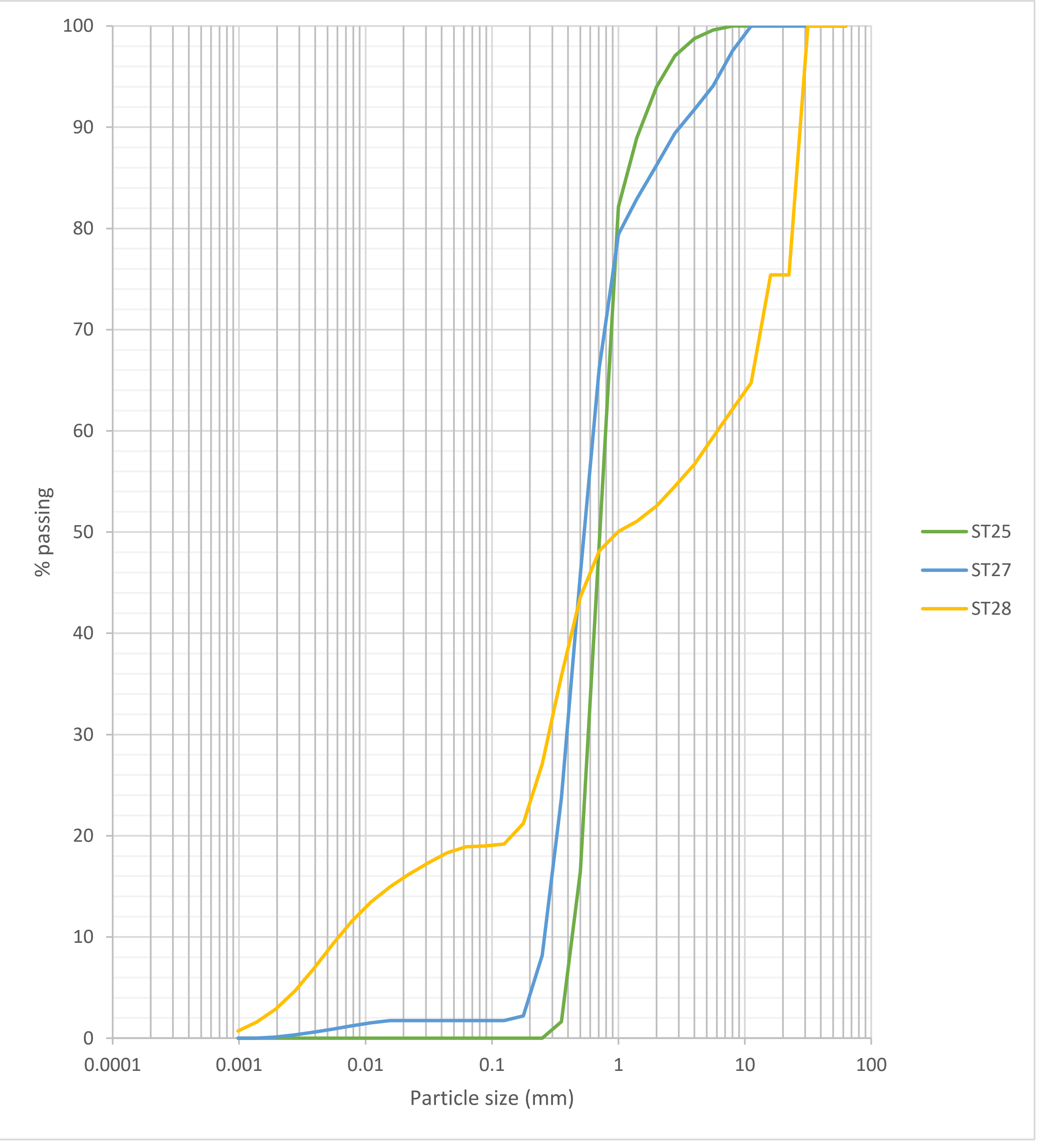

Plate 8.11 Cumulative particle size distribution curves of the three seabed sediment samples collected in the north array

8.5.6.3 South array

86. The dominant sediment type in the south array is medium sand (16-74% in all samples) with median particle sizes (d_{50}) between 0.34mm and 0.92mm (medium to coarse sand) (Plate 8.12). The mud content is less than 5% in 69% of the samples and less than 18% in 100% of the samples. The samples with the highest gravel content (37.1-41.8%) are ST33, ST35, ST36 and ST40 which are all located in the northern part of the south array (Figure 8.3, Volume II). Samples in the south and north-east of the array are dominated by sand.

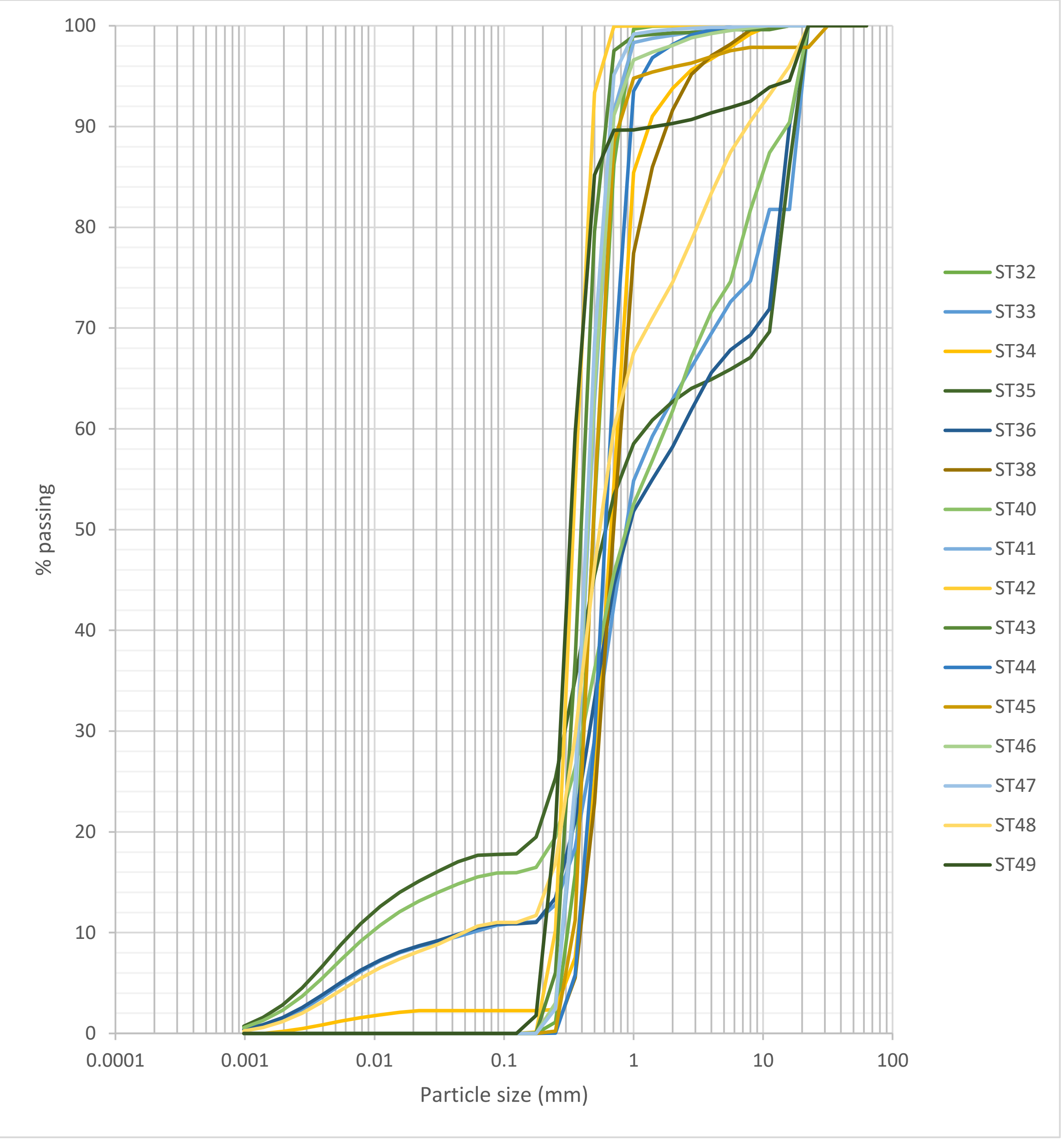

Plate 8.12 Cumulative particle size distribution curves of the 16 seabed sediment samples collected in south array

8.5.6.4 Interconnector cable corridor

87. The sediment type of the sample taken from the interconnector cable corridor, is medium sand (25% content in the sample) with a median particle size (d_{50}) of 0.58mm (coarse sand) (Plate 8.13). The mud content is less than 15% in the sample and gravel accounts for less than 30%, however the dominant sediment type has been interpreted by Fugro as predominantly 'muddy sand' throughout the interconnector cable corridor (Figure 8.9, Volume II).

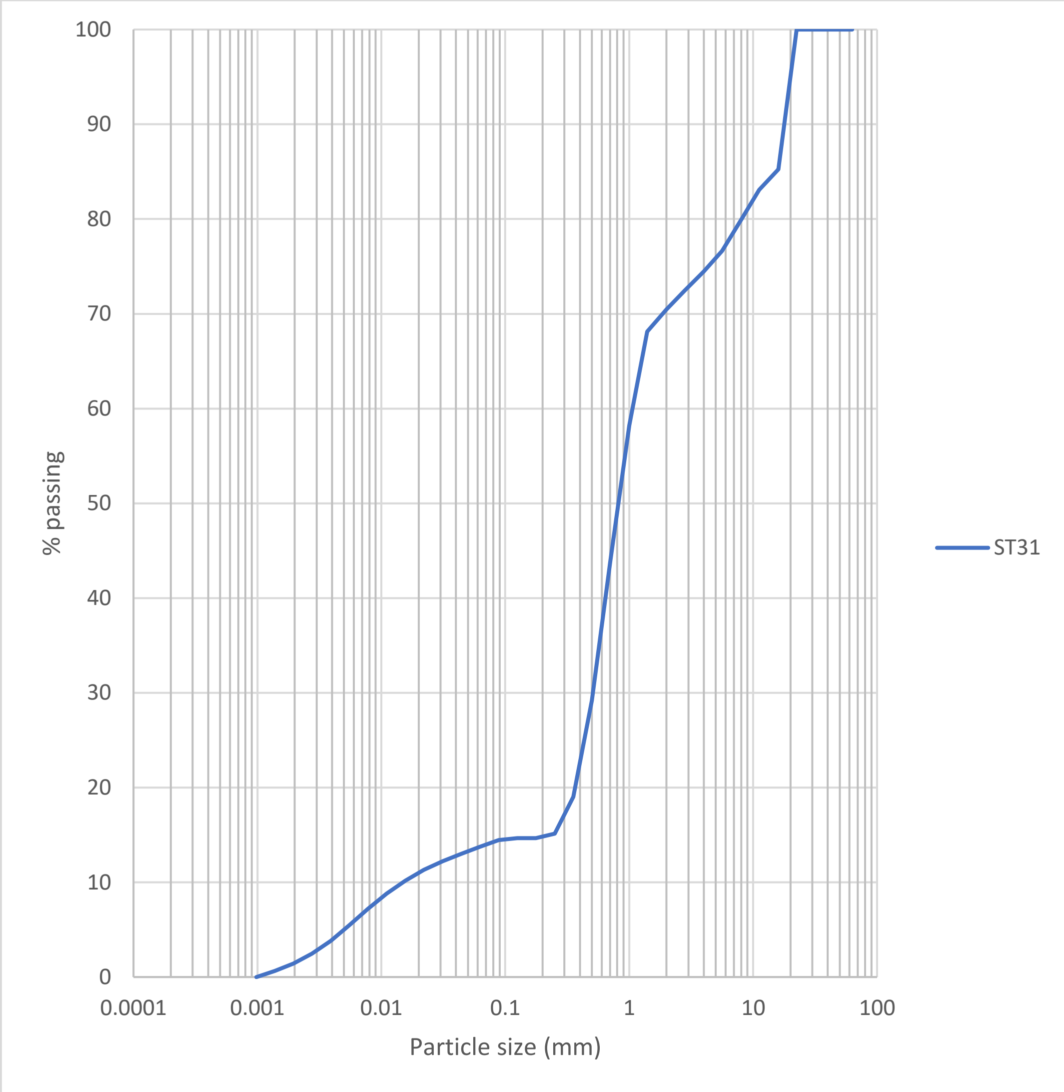

Plate 8.13 Cumulative particle size distribution curves of the one seabed sediment sample collected in the interconnector cable corridor

8.5.6.5 Offshore cable corridor

88. The dominant sediment type in the offshore cable corridor is medium sand (2-51% in all samples) with variable median particle sizes (d_{50}) between 0.012mm and 11.72mm (silt/clay to pebble) (Plate 8.14). The mud content is less than 5% in 26% of the samples and less than 78% in 100% of the samples. The samples with the highest mud content are located at ST02, ST03, ST04 and ST05 with an average of 59.4%. These samples are located closest to the landfall (Figure 8.3, Volume II).

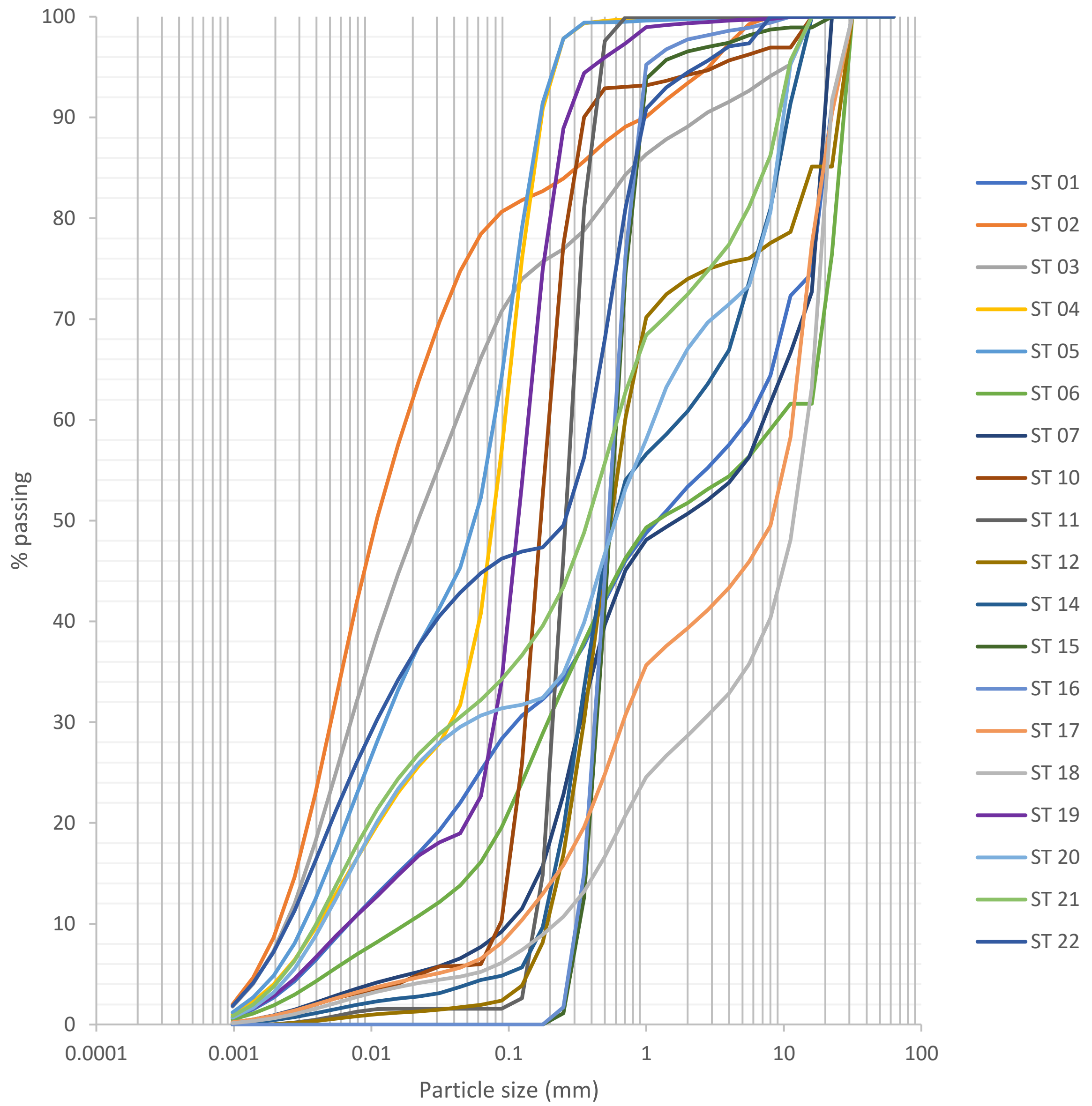

Plate 8.14 Cumulative particle size distribution curves of the 19 seabed sediment samples collected in North Falls offshore cable corridor

8.5.7 Bedload sediment transport

89. Regional bedload sediment transport pathways in the southern North Sea have been investigated by Kenyon and Cooper (2005). They analysed the results of modelling studies and bedform indicators and showed that tidal currents are the dominant mechanism responsible for bedload transport. The dominant regional bedload transport vectors are to the south – south-west across North Falls and to the north – north-east further offshore. Between these opposing directions of transport is a bedload transport parting (Reynaud and Dalrymple, 2012) (Figure 8.18, Volume II).

90. Sediment transport pathways within North Falls have been analysed using the orientation of bedforms. Sandwaves are present across the south, south-east and extreme north-east of the south array, in the east of the north array, and approximately half-way along the offshore cable corridor (Figures 8.11 and 8.12, Volume II). Although sandwaves are not found along the interconnector cable corridor, most of it is occupied by megaripples between 0.3m and 1.5m high.

91. The crests of the sandwaves in these areas exhibit a consistent north-west to south-east orientation that indicates a net direction of transport to the south-west and north-east. Tidal currents are the main driving force of sediment transport across sandwaves and as a result, move sediment in a south-westerly direction during a flow tide and a north-easterly direction during an ebb tide. The net direction of sediment transport across areas that are not characterised by migrating bedforms (adjacent to the sandwaves) is likely to be the same.

8.5.8 Suspended sediment concentrations

92. SSCs were measured at four locations as part of the metocean data collection at GGOW in between 3rd November 2004 – 24th March 2005 The maximum SSC was 85mg/l with a mean concentration of 20mg/l (Emu Ltd, 2005).

93. Cefas (2016) published average SSCs between 1998 and 2015 for the seas around the UK (Figure 8.15, Volume II). The average SSC in the vicinity of the array areas for the period 1998-2015 was approximately 7-15mg/l at the south array and 20-27mg/l for the north array (Figure 8.15, Volume II). The average SSC in the vicinity of the interconnector cable corridor is approximately 14-21mg/l, and the offshore cable corridor is 15mg/l offshore, ranging to 100mg/l close to the landfall location (Figure 8.15, Volume II).

8.5.9 Coastal processes along the Tendring peninsula

94. The exposed coast of the Tendring peninsula, composed of gravel and sand beaches, dunes and cliffs, is shaped by waves approaching from the north-east but is more vulnerable to storms approaching from the east (EACG, 2010). The potential net longshore sediment transport rates in the region range from 1,950m^3/yr to 254,900m^3/yr (Posford Duvivier, 2001, HR Wallingford, 1997) and are directed towards the south-southwest (Plate 8.15). Potential longshore sediment transport rates between Frinton-On-Sea and Clacton-on-Sea range from 16,350-21,000m^3/yr (Posford Duvivier, 2001, Onyett and Simmonds, 1983).

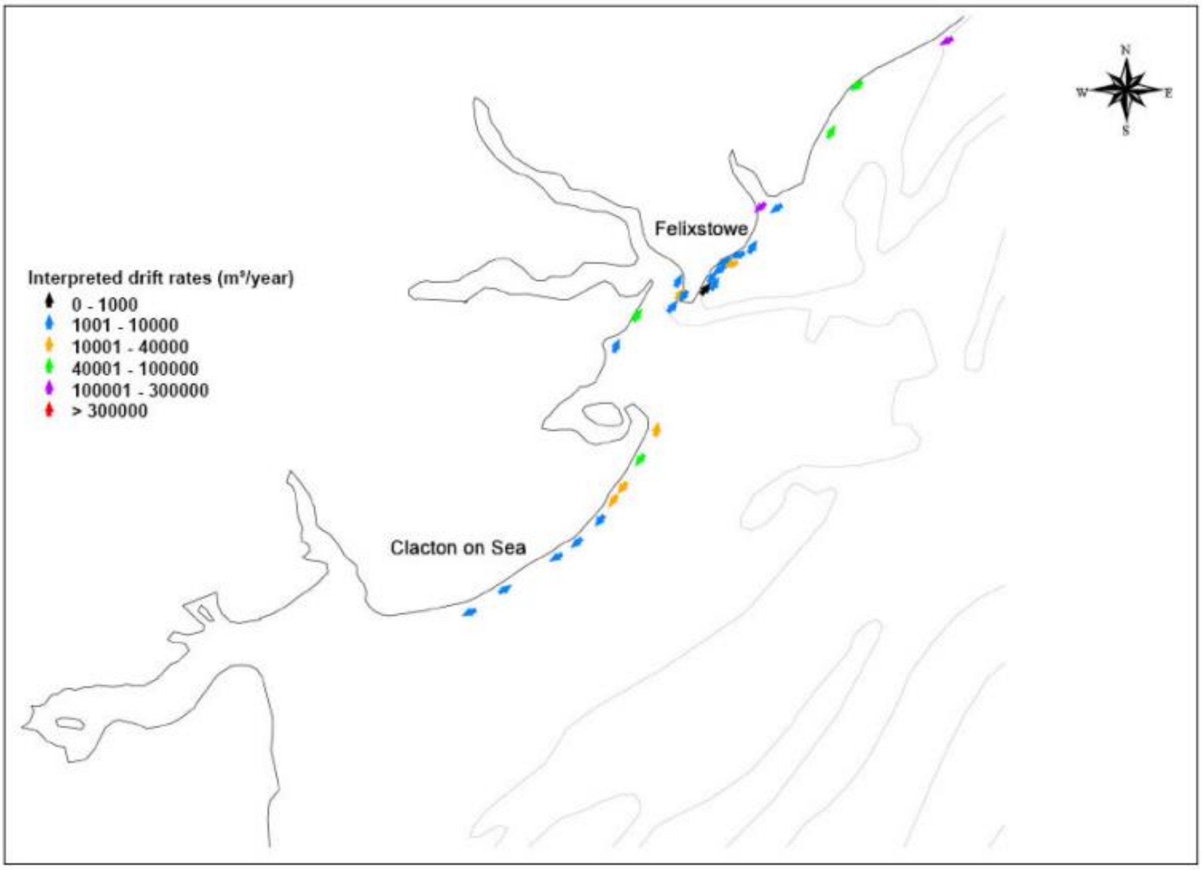

Plate 8.15 Potential longshore sediment transport rates (HR Wallingford et al., 2002)

95. The Shoreline Management Plan (SMP) (EACG, 2010) states that the intended management along this frontage is 'hold the line' and would '*sustain and support its viability of the seaside towns and their communities, tourism and commercial activities*'.

8.5.10 Future trends in baseline conditions

96. The baseline conditions for marine geology, oceanography and physical processes will continue to be controlled by waves and tidal currents driving changes in sediment transport and then seabed morphology. However, the long-term established performance of these drivers may be affected by environmental changes including climate change driven sea-level rise.

97. This will have the greatest impact at the coast where more waves will impinge on the low-lying beaches and estuaries, potentially increasing their rate of erosion. Climate change will have little effect offshore where landscape-scale changes in water levels (water depths) far outweigh the effect of minor changes due to sea-level rise.

98. Trends in coastal erosion will be driven by the shoreline management plan, which is currently to hold the line, however in their response to inform the scoping opinion, Essex County Council state that coastal protection works at Clacton-on-Sea, to the south of the landfall search area, are reliant on ongoing maintenance for which funding may be challenging. Therefore, while the current

shoreline management plan is to hold the line, this could change in future, subject to a revised strategy (the Planning Inspectorate, 2021).

8.6 Assessment of significance

8.6.1 Receptors

99. The principal receptors with respect to marine geology, oceanography and physical processes are those features with an inherent geological or geomorphological value or function which may potentially be affected by North Falls. These are Annex 1 sand banks, Margate and Long Sands SAC, Kentish Knock East MCZ, Orford Inshore MCZ, and the Suffolk and Essex coasts (gravel and sand beaches, dunes and cliffs) (Figure 8.14, Volume II).

100. The specific features defined within these receptors as requiring assessment are listed in Table 8.13.

Table 8.13 Marine geology, oceanography and physical processes receptors relevant to the Project

Receptor Group	Extent of coverage	Description of features	Closest distance from array areas	Closest distance from indicative offshore cable corridor
Suffolk Coast	Southwold to Clacton-on-Sea	Gravel and sand beaches, dunes and cliffs	22.3km	11.1km
Essex Coast (Landfall location)	Clacton-on-Sea to Frinton-on-Sea	Gravel and sand beaches, dunes and cliffs	40.8km	0km
Designated sites and features	Annex 1 Sandbank (Annex 1 Reef will be addressed in the benthic ecology section)	Sublittoral sandbanks permanently submerged, and associated sandwaves	0km (overlapping)	0km (adjacent)
	Margate and Long Sands SAC	Sandbanks which are slightly covered by sea water all the time	9.1km	0km (adjacent)
	Kentish Knock East MCZ	Subtidal sand, subtidal coarse sediment, subtidal mixed sediments	0km (overlapping)	6.2km
	Orford Inshore MCZ	Subtidal mixed sediments	5.6km	12.7km

101. The impact assessment sections (Section 8.6.2 and Section 8.6.3) assess the likely significant effects on the wave, current and sediment transport regimes on the receptor groups outlined in Table 8.13.

8.6.1.1 The Suffolk and Essex coast

102. The Suffolk coast, between Southwold and Clacton-on-Sea, falls under SMP 7 Lowestoft to Felixstowe (Suffolk Coastal District Council, 2010). The Suffolk coast is characterised by soft eroding cliffs, shingle beaches and coastal lagoons, and includes the Blyth, Alde/Ore, Deben, Orwell and Stour estuaries

(Environment Agency, 2011). This coast is predominantly undefended and is therefore prone to roll back in response to wave attack and sea-level rise (Environment Agency, 2011). Features formed by longshore sediment transport dominate much of the Suffolk coast, including Orfordness (a 16km shingle spit) and Benacre Ness (a large mobile shingle beach which is migrating northwards) (Environment Agency, 2011). The two main urban areas along the Suffolk coast are Lowestoft and Felixstowe, which are defended by sea walls and groynes. The SMP notes that there is a lack of sediment supply from the north (EACG, 2010).

103. The Essex coast, encompassing the landfall on the Tendring Peninsula, falls under SMP 8 Essex and South Suffolk (EACG, 2010). The beach frontage along the Tendring Peninsula is composed of a mixture of shingle and/or sand and muddy shores. The erosion of this frontage is primarily due to its vulnerability to wave pressure, orientation and landward constraints imposed by coastal and sea defences (EACG, 2010). It is protected by a combination of sea walls, promenades, wave return walls and a range of other beach control measures including groynes and breakwaters (Plate 8.16). Additional coastal defence works have been undertaken since the SMP, including the following:

- works to reinforce and improve a section of seawall along York Road, Holland on Sea; and
- a major coastal protection scheme covering 5km of coastline between Clacton and Holland on Sea to protect the cliff and promenade. The scheme cost £36M and was opened to the public in 2015 (Tendring Council, undated).

104. The coast at Clacton-on-Sea is important for recreation and tourism and attracts people for its beaches, piers and geological exposures including the Clacton Cliffs and Foreshore SSSI (EACG, 2010).

105. There is a concern that the saltmarsh and mudflats along the Essex and South Suffolk coast and estuaries have been progressively eroding in response to sea-level rise (EACG, 2010). A study of saltmarsh coverage between 1973 and 1998 showed a loss of 1,000 ha in Essex, primarily due to coastal erosion (Cooper et al., 2001).

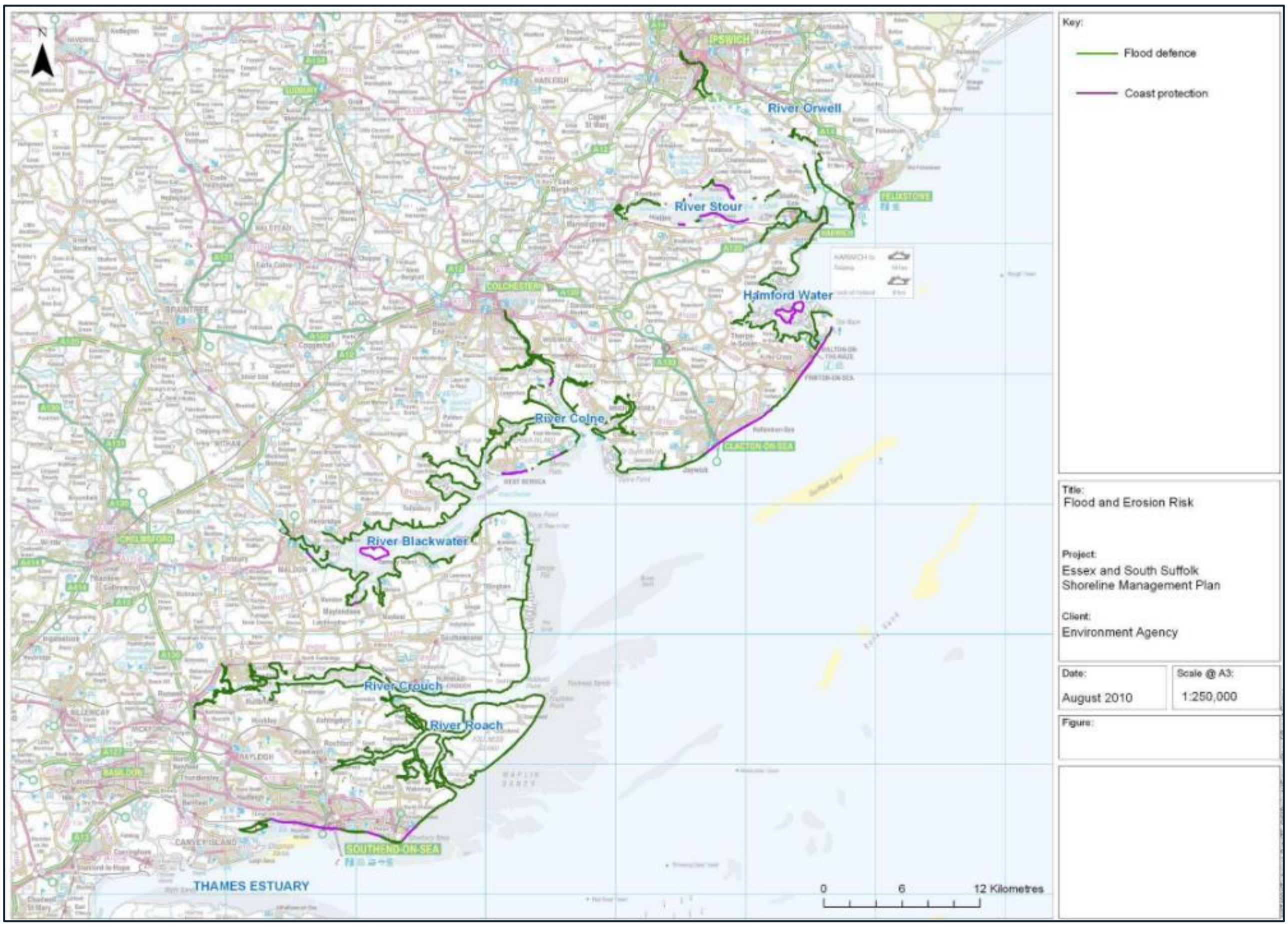

Plate 8.16 Flood defence and coast protection measures in Essex (EACG, 2010)

8.6.1.2 Annex 1 sandbanks

106. Annex I sandbanks are distributed widely around the UK coast. They are characterised as distinct 'banks' (elongate / rounded mounds) associated with horizontal or sloping plains of sand (JNCC, unknown). The 'Annex I' types are associated with areas of horizontal or sloping sandy habitat that are closely associated with the banks. Annex I sandbanks occur on the east of the north and south array areas, adjacent to the offshore cable corridor and parallel to the interconnector cable corridor (Figure 8.14, Volume II).

8.6.1.3 Margate and Long Sands SAC

107. The Margate and Long Sands SAC is located approximately 22km off the Suffolk coast, covering an area of 649km^2. The conservation objective for the SAC is to 'ensure that the integrity of the site is maintained or restored as appropriate, and ensure that the site contributes to achieving the Favourable Conservation Status of its Qualifying Features, by maintaining or restoring:

- the extent and distribution of qualifying natural habitats;
- the structure and function (including typical species) of qualifying natural habitats; and
- the supporting processes on which the qualifying natural habitats rely'.

The North Falls offshore cable corridor lies adjacent to the SAC.

8.6.1.4 Kentish Knock East MCZ

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

8.6.1.5 Orford Inshore MCZ

109. The Orford Inshore MCZ is located approximately 14km off the Suffolk coast, covering an area of 72km^2. The conservation objectives for the MCZ's protected features are that they are 'recovered to a favourable condition if they are not already in favourable condition'. The north array is 5.5km south of the MCZ.

8.6.2 Construction phase

110. During the construction phase of North Falls, there is the potential for foundations and cable installation activities to disturb sediment, potentially resulting in changes in SSCs and/or seabed levels or, in the case of nearshore cable installation, shoreline morphology due to deposition or erosion. These are considered as construction Impacts 1 to 8. The worst-case scenario is discussed in Section 8.3.2.

8.6.2.1 Impact 1a: Changes in SSCs due to seabed preparation for foundation installation (array areas)

111. Seabed sediments and shallow near-bed sediments within the array areas would be disturbed during dredging activities to create a suitable base prior to foundation installation. The worst case scenario assumes that sediment would be dredged and returned to the water column at the sea surface as overflow from a dredger vessel. This process would cause localised and short-term increases in SSCs both at the point of dredging at the seabed and, more importantly, at the point of its discharge back into the water column. The disposal of any sediment that would be disturbed or removed during foundation installation would occur within the offshore project area.

112. Mobilised sediment from these activities may be transported by wave and tidal action in suspension in the water column. The disturbance effects at each wind turbine location are likely to last for no more than a few days, within an overall foundation installation programme of approximately 12 months in total.

113. The median particle sizes of seabed sediments are predominantly 0.54mm to 0.99mm (coarse sand) across the northern array area and 0.34mm to 0.92mm (medium to coarse sand) across the southern array area. Most seabed samples contained less than 5% mud. As outlined in Section 8.5.8, average SSCs at North Falls are up to 15mg/l at the south array and up to 27mg/l at the north array (Cefas, 2016). These concentrations may increase significantly during storm events (HR Wallingford *et al.*, 2002).

114. For the total volume released during the construction phase, the worst case scenario is associated with the maximum number of GBS foundations (72) and two OSPs, with a 70m diameter dredged to 5m (Table 8.2).

115. Conceptual evidence-based assessment suggests that, due to the predominance of medium and coarse-grained sand across North Falls, the sediment disturbed by the drag head of the dredger at the seabed would remain close to the bed and settle back to the bed rapidly. Most of the sediment released at the water surface from the dredger vessel would fall rapidly (minutes or tens of minutes) to the seabed as a highly turbid dynamic plume immediately upon its discharge (within a few tens of metres along the axis of tidal flow).

116. Some of the finer sand fraction from this release and the very small proportion of mud that is present are likely to stay in suspension for longer and form a passive plume which would become advected by tidal currents. Due to the sediment sizes present, this is likely to exist as a measurable but modest concentration plume (tens of mg/l) for around half a tidal cycle (up to six hours). Sediment would eventually settle to the seabed in proximity to its release (within a few hundred metres up to around a kilometre along the axis of tidal flow) within a short period of time (hours to days). Whilst lower SSCs would extend further from the dredged area, along the axis of predominant tidal flows, the magnitudes would be indistinguishable from background levels.

117. This conceptual evidence-based assessment is supported by the findings of a review of the evidence base into the physical impacts of marine aggregate dredging on sediment plumes and seabed deposits (Whiteside et al., 1995; John et al., 2000; Hiscock and Bell, 2004; Newell et al., 2004; Tillin et al., 2011; Cooper and Brew, 2013).

118. Modelling simulations undertaken for the GWF using the Delft3D plume model (ABPmer, 2011b) support the above expert-based assessments of SSCs arising from disturbance of near-surface sediments during seabed preparation for GBS foundations. There are similarities in sediment types and distributions across the North Falls and GWF sites, and water depths for both sites are also similar. Therefore, the modelling studies for the GWF represent a suitable analogue for verifying the conclusions of the more qualitative expert-based assessment described above.

119. For GWF, the simulation was carried out on installation of ten GBS foundations (45m diameter) on the Galloper sandbank, with two foundations installed simultaneously and a seabed sediment release volume of 7,200m^3 (ABPmer, 2011b). Given that the water depths were less than other locations within the GWF array site and that sediment release volumes were more likely to be in the region of 4,750m^3 (following design project optimisation), this was considered a highly conservative scenario.

120. The model results predicted that increased SSCs due to seabed preparation would extend over a larger area for smaller sized sediment given its greater mobility under the tidal regime. Simulations show a maximum dispersion distance of 15km and 11km from the point of release for both coarse silt and fine sand at peak ebb flow (ABPmer, 2011b). Within the passive plume, SSCs were low (less than 0.2mg/l above background levels) and within the range of natural variability. The dispersal of fine-grained sediment retained within the passive plume was in accordance with the main axis of the tidal flow (along a north-east to south-west axis). For larger sized sediment, SSCs are greater close to the point of release (0.5mg/l and 1.4mg/l above background levels for silt and fine sand, respectively at high water) (ABPmer, 2011b). A plume with

concentrations greater than 1mg/l above background levels is isolated to within 2-3km of the point of release, beyond which SSCs are less than 1mg/l (ABPmer, 2011b).

121. Given the similarity in the physical environments of North Falls and GWF, it is expected that effects from installation across the whole of the North Falls array areas would be similar, although with the point of release moving across the site with progression of the construction sequence.

8.6.2.1.1 Magnitude

122. The worst-case changes in SSCs due to seabed preparation for GBS foundation installation are likely to have the magnitudes of impact shown in Table 8.14.

Table 8.14 Magnitude of impact on suspended sediment concentrations under the worst case scenario for GBS foundation installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Near-field*	High	Negligible	Negligible	Negligible	Medium
Far-field	Low	Negligible	Negligible	Negligible	Low

*The near-field impacts are confined to a small area, likely to be up to a kilometre from each foundation location.

8.6.2.1.2 Sensitivity

123. Due to the nature of the pressure (increase in SSCs due to seabed preparation for foundation installation) there is no pathway for impact to all identified receptors so therefore they are not sensitive to this pressure.

8.6.2.1.3 Effect significance

124. The impacts on SSCs due to foundation installation at North Falls do not directly affect the identified receptor groups for marine geology, oceanography and physical processes. This is because the receptors are dominated by processes that are active along the seabed and not affected by suspended sediment in the water column. However, there may be impacts arising from subsequent deposition of the suspended sediment on the seabed and these are discussed under Construction Impact 2a (Section 8.6.2.3). Hence, there is no change on the identified receptors groups associated with the suspended sediment generated by North Falls and no significant effect will occur.

125. The impact on SSCs does have the potential to affect other receptors and therefore the assessment of effect significance is addressed within the relevant chapters of this PEIR (Section 8.10).

8.6.2.2 Impact 1b: Changes in SSCs due to drill arisings for installation of piled foundations for wind turbines and OSPs

126. Sediments below the seabed within North Falls would become disturbed during any drilling activities that may be needed at the location of piled foundations. The ambient SSCs across North Falls of less than 10mg/l to about 27mg/l (Section 8.5.8) mean that the transient impact of sediment plumes arising from installation of the wind farm foundations may be significant (although temporally limited) under specific circumstances. The disposal of any sediment that would be disturbed or removed during foundation installation would occur within the North Falls array areas close to each foundation. The worst case scenario for a release from an individual wind turbine assumes a monopile foundation for the

largest wind turbine. In this case, a 18m drill diameter would be used from the seabed to a depth of 42m, releasing a maximum of 10,688m^3 of sediment per monopile foundation into the water column.

127. It is estimated that the maximum number of foundations that would require drilling would be 10%, based on engineering experience. Taking a precautionary worst case approach it has therefore been assumed that four of the largest wind turbines in North Falls and one OSP would require drilling. The total volume of drill arisings would be up to 48,820m^3 (Table 8.2).

128. The drilling process would cause localised and short-term increases in SSCs at the point of discharge of the drill arisings at four locations only. Released sediment may then be transported by tidal currents in suspension in the water column. Due to the small quantities of fine-sediment released (most of the sediment will be sand or aggregated clasts, see Section 8.5.7), the fine-sediment is likely to be widely and rapidly dispersed. This would result in only low SSCs and low changes in seabed level when the sediments ultimately come to deposit. The disturbance effects at each wind turbine location are only likely to last for a few days of construction activity within the overall construction programme lasting up to 3 years in total.

129. The conceptual evidence-based assessment suggests that away from the immediate release locations, elevations in suspended sediment concentration above background levels for only four foundations would be very low (less than 10mg/l) and within the range of natural variability. Net movement of fine-grained sediment retained within a plume would be to the south-west or north-east, depending on state of the tide at the time of release. Sediment concentrations arising from one foundation installation are unlikely to persist for sufficiently long for them to interact with subsequent operations, and therefore no cumulative effect is anticipated from multiple installations.

8.6.2.2.1 Magnitude

130. The worst case changes in SSCs due to the installation of the maximum number of the largest monopile foundations are likely to have the magnitudes of impact shown in Table 8.15.

Table 8.15 Magnitude of impact on suspended sediment concentrations under the worst case scenario for piled foundation installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Near-field*	Medium	Negligible	Negligible	Negligible	Negligible
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

* The near-field impacts are confined to a small area likely to be up to a kilometre from each foundation location and would not cover the North Falls array areas.

8.6.2.2.2 Sensitivity

131. Due to the nature of the pressure (increase in SSCs due to drill arisings for installation of piled foundations) there is no pathway for effect to any identified receptor so therefore they are not sensitive to this pressure.

8.6.2.2.3 Effect significance

132. The impacts on SSCs due to foundation installation for North Falls do not directly affect the identified receptor groups for marine geology, oceanography

and physical processes, so there is no change associated with the proposed North Falls project. No significant effect will occur. However, the impacts on SSC has the potential to affect other receptors and the assessment of effect significance is addressed within the relevant chapters of this PEIR (see Section 8.10).

8.6.2.3 Impact 2a: Changes in seabed level due to seabed preparation for foundation installation

133. The increased SSCs associated with construction Impact 1a (Section 8.6.2.1) have the potential to deposit sediment and raise the seabed elevation slightly.

134. The conceptual evidence-based assessment suggests that coarser sediment disturbed during seabed preparation would fall rapidly to the seabed (minutes or tens of minutes) as a highly turbid dynamic plume immediately after it is discharged. Deposition of this sediment would form a 'mound' local to the point of release. Due to the coarser sediment particle sizes observed across the site (predominantly medium-grained sand), a large proportion of the disturbed sediment would behave in this manner.

135. The resulting mound would be a measurable protrusion above the existing seabed (likely to be tens of centimetres to a few metres high) but would remain local to the release point. The geometry of each of these mounds would vary across North Falls, depending on the prevailing physical conditions, but in all cases the sediment within the mound would be like (but not exactly the same as) both the seabed that it has replaced and the surrounding seabed. The baseline particle size distribution data for the North Falls array areas show that the seabed is dominated by medium and coarse grained sand with overall compositional variations related to the volumes of coarser sand and gravel. Mud content is always less than 19%. This would mean that there would be a small but insignificant change in seabed sediment type, likely to be caused by differences in the volume of the coarser fraction in the mound compared to the natural seabed.

136. The seabed across the south array is dominated by medium sand with a wider range of compositions than the north array. However, for the most part, mud content is less than 5%. There is greater likelihood of differences in mound and seabed composition in the south array. However, the overall composition of the seabed once the mound has been formed would still be dominated by a mix of medium to coarse sand and gravel (and so would have little effect on the benthic communities that inhabit this type of seabed).

137. Also, the overall changes in elevation of the seabed are small compared to the absolute depth of water (up to 59m below LAT in the south-west of north array). The changes in seabed elevation are within the natural change to the bed caused by sandwaves and sand ridges and hence the effect on physical processes would be negligible.

138. The mound will be mobile and be driven by the physical processes, rather than the physical processes being driven by it. This means that over time the sediment comprising the mound will gradually be re-distributed by the prevailing waves and tidal currents.

139. In addition to localised mounds, the very small proportion of mud that forms the passive plume would become more widely dispersed before settling on the

seabed. The worst-case thickness of sediment deposited from the plume would not likely exceed a maximum of 1mm and be less than 0.1mm over larger areas of the seabed.

140. This theoretical assessment is supported by modelling results for GWF, which shows seabed thickness changes simulated for fine sand of less than 35µm following seabed preparation for ten GBS (equivalent to one grain of fine silt) (ABPmer, 2011b). The maximum area of deposition was between $4km^2$ and $15km^2$ for very fine sand and fine sand, respectively (ABPmer, 2011b).

141. This assessment is further supported by an extended evidence-base obtained from research into the physical impacts of marine aggregate dredging on sediment plumes and seabed deposits (Whiteside et al., 1995; John et al., 2000; Hiscock and Bell, 2004; Newell et al., 2004; Tillin et al., 2011; Cooper and Brew, 2013).

8.6.2.3.1 Magnitude

142. The changes in seabed levels due to foundation installation under the worst-case sediment dispersal scenario are likely to have the magnitudes of impact shown in Table 8.16.

Table 8.16 Magnitude of impact on seabed level changes due to deposition under the worst case scenario for sediment dispersal following GBS foundation installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Near-field*	Medium	Negligible	Negligible	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

*The near-field impacts are confined to a small area of seabed likely to be up to a kilometre from each foundation location and would not cover the whole of North Falls.

8.6.2.3.2 Sensitivity

143. The sensitivity and value of all relevant receptors are presented in Table 8.17.

Table 8.17 Sensitivity and value assessment of sand bank receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Essex coast	Negligible	Negligible	Negligible	High	Negligible
Suffolk coast	Negligible	Negligible	Negligible	High	Negligible
Annex I sandbank	Negligible	Negligible	Negligible	High	Negligible
Margate and Long Sands SAC	Negligible	Negligible	Negligible	High	Negligible
Kentish Knock East MCZ	Negligible	Negligible	Negligible	High	Negligible
Orford Inshore MCZ	Negligible	Negligible	Negligible	High	Negligible

8.6.2.3.3 Effect significance

144. The overall likely effect of seabed preparation for foundation installation activities for North Falls on seabed level changes for the Suffolk coast, Essex coast, Margate and Long Sands SAC and Orford Inshore MCZ is considered to be of negligible adverse significance (no significant effect). This is because there is a separation distance of at least 5.6km between the nearest sediment release point and the receptors noted above.

145. The overall likely effect of seabed preparation for foundation installation activities for the Project under a worst case scenario on seabed level changes on the Annex 1 sandbanks and Kentish Knock East MCZ is considered to be negligible adverse significance (no significant effect). This is because the predicted thickness of sediment resting on the seabed would only amount to a maximum of 1mm. After this initial deposition, this sediment will be continually re-suspended to reduce the thickness even further to a point where it will be effectively zero. This will be the longer-term outcome, once the sediment supply from foundation installation has ceased.

146. The worst case scenario assumes that seabed preparation activities would be the maximum for the given water depth. In practice, the volumes of sediment released would be lower than the worst case at many wind turbine locations because the detailed design process would optimise the foundation type and installation method to the site conditions.

147. The effects on seabed level have the potential to affect other receptors and the assessment of effect significance is addressed within the relevant chapters of this PEIR (Section 8.10).

8.6.2.4 Impact 2b: Changes in seabed level due to drill arisings for installation of piled foundations for wind turbines and OSPs

148. The combined increases in SSCs and creation of aggregated clasts of mud associated with construction Impact 1b (see Section 8.6.2.2) have the potential to deposit sediment and raise the seabed elevation.

149. Drilling of piled foundations could potentially occur through four different geological units (Table 8.12); Holocene deposits (only in the south array), underlying Pleistocene channel complexes and infill deposits, London Clay Formation and the Harwich Formation. The coarser sediment fractions (very dense, silty gravelly sand and silty sandy gravel) of the Pleistocene would settle out of suspension near to the point of release (up to thicknesses of approximately 40mm over a seabed area of 300m). For the most part, the deposited sediment layer across the wider seabed area would be very thin and confined to an area around a maximum of four turbine foundations and eight OSP foundations (see Table 8.2 for worst case drill arisings).

150. If the drilling penetrates the underlying mud deposits, then a worst case scenario is considered whereby the sediment released from the drilling is assumed to be wholly in the form of larger aggregated 'clasts' which would settle rapidly. These clasts would remain on the seabed (at least initially), rather than being disaggregated into their individual fine-grained sediment components immediately upon release. Under this scenario, the worst case scenario assumes that a 'mound' would reside on the seabed near the site of release.

151. These mounds would be composed of sediment with a different particle size and would behave differently (they would be cohesive) to the surrounding sandy seabed, and therefore represent the worst case scenario for mound formation during construction.

152. The method for calculating the footprint of each mound follows that which was developed and agreed with Natural England for earlier major offshore wind farm projects at Dogger Bank Creyke Beck (Forewind, 2013), Dogger Bank Teesside (Forewind, 2014), East Anglia THREE (East Anglia Three Limited (EATL),

2015), Norfolk Vanguard (Royal HaskoningDHV, 2017) and Norfolk Boreas (Royal HaskoningDHV, 2018). The methodology involves the following stages:

- Calculate the maximum potential width of a mound (for the given volume) based on the diameter of an assumed idealised cone on the seabed. This was based on simple geometric relationships between volume, height, radius and side-slope angle of a cone. The latter parameter was taken as a maximum of 30°, which is a suitable representation for an angle of friction of clasts of sediment.
- Calculate the maximum potential length of the mound (for the given volume and maximum potential width). The assumed height of the mound was 'fixed' in the calculation as being equivalent to the average height of the naturally occurring sandwaves on the seabed within the site. This calculation was based on simple geometric relationships between volume, height, width and length and assumed that, when viewed in side elevation, the mound would be triangular in profile but that its length is greater than its width, thus forming a 'ramp' shape.
- Based on the newly calculated width and length of the mound, a footprint area on the seabed could then be calculated.

153. Based on this approach, the footprint of an individual 7m-high mound arising from the installation of the largest wind turbine monopile would be 4,581m^2.

154. Because of their potentially large particle sizes, future transport of the aggregated clasts would be limited, and most would remain static within the mound. However, over time the flow of tidal currents over the mound would gradually winnow (there would be a gradual disaggregation of the clasts into their constituent particle sizes) the topmost clasts and over time the mound would lower through erosion. No specific calculations have been undertaken to understand how long it would take for the mounds to fully erode.

8.6.2.4.1 Magnitude

155. The changes in seabed levels due to foundation installation under the worst case sediment dispersal scenario and sediment mound scenario are likely to have the magnitudes of impact shown in Table 8.18 and Table 8.19, respectively.

Table 8.18 Magnitude of impacts on seabed level changes due to deposition under the worst case scenario for sediment dispersal following piled foundation installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Near-field*	Low	Low-Medium	Low-Medium	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

*The near-field impacts are confined to a small area of seabed likely to be up to a kilometre from each foundation location and would not cover the whole of North Falls.

Table 8.19 Magnitude of impacts on seabed level changes due to deposition under the worst case scenario for sediment mound creation following piled foundation installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Near-field*	Low	Low-Medium	Low-Medium	Medium	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

*The near-field impacts are confined to a small area of seabed (likely to be immediately adjacent to each wind turbine location) and would not cover the whole of North Falls.

8.6.2.4.2 Sensitivity

156. The sensitivity and value of all relevant receptors are presented in Table 8.20.

Table 8.20 Sensitivity and value assessment of relevant receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Essex coast	Negligible	Negligible	Negligible	High	Negligible
Suffolk coast	Negligible	Negligible	Negligible	High	Negligible
Annex I sandbank	Negligible	Negligible	Negligible	High	Negligible
Margate and Long Sands SAC	Negligible	Negligible	Negligible	High	Negligible
Kentish Knock East MCZ	Negligible	Negligible	Negligible	High	Negligible
Orford Inshore MCZ	Negligible	Negligible	Negligible	High	Negligible

8.6.2.4.3 Effect significance

157. The overall effect of foundation installation activities for the proposed project under a worst case scenario on seabed level changes for the Suffolk coast, Essex coast, Margate and Long Sands SAC and Orford Inshore MCZ is considered to be negligible adverse significance. This is because there is a separation distance of at least 5.6km between the nearest sediment release point and the receptors noted above. Also, transport of the aggregated clasts in the mounds would be limited, and so there would be no pathway between the source (mounds) and the receptors (Margate and Long Sands SAC, Orford Inshore MCZ and Essex coast and Suffolk coast).

158. The layout of turbines will be decided post consent, however, in the event that sandbanks (designated as Annex I or Kentish Knock East MCZ) are in proximity to foundation installation, the overall significance of effect associated with sediment dispersal would be negligible adverse as the deposited sediment layer across the wider seabed area (approximately 40mm over a seabed area local to each foundation (within 300m)) could potentially deposit on a sand bank. After this initial deposition, this sediment will be continually re-suspended to reduce the thickness even further to a point where it will be effectively zero. This will be the longer-term outcome, once the sediment supply from foundation installation has ceased. The worst case scenario assumes that piles would be drilled to their full depth for the given water depth. In practice, the volumes of sediment released would be lower than the worst case because the detailed

design process would optimise the foundation type and installation method to the site conditions.

222. Impacts on seabed level have the potential to affect other receptors and the assessment of effect significance is addressed within the relevant chapters of this PEIR (see Section 8.10).

8.6.2.5 Impact 3: Changes in SSCs due to export cable installation

159. The detail of the export cabling is dependent upon the final project design, but present estimates are that the maximum length of export cable could be up to 250.8km (four cables of 62.7km each).

160. Sandwave levelling (pre-sweeping) may be required along the offshore cable corridor prior to installation. The worst case scenario assumes that sediment would be dredged and returned to the water column at the sea surface as overflow from a dredger vessel. This process would cause localised and short-term increases in SSCs both at the point of dredging at the seabed and, more importantly, at the point of its discharge back into the water column.

161. Mobilised sediment from these activities may be transported by wave and tidal action in suspension in the water column. The sediment released at any one time would depend on the capacity of the dredger. Any sediment excavated during sandwave levelling would be disposed of within the North Falls offshore project area, meaning there will be no net loss of sand from the site.

162. The installation of the export cable has the potential to disturb the shallow sub-seabed down to an average of 1.2m (depending on the area) and a width of up to 24m. A trench will also be required at the HDD exit location, which will be located on the seabed at approximately 1-8m depth. Table 8.2 summarises the worst case scenario sediment releases.

163. The types and magnitudes of impacts that could be caused have previously been assessed within industry best-practice documents on cabling techniques (BERR, 2008; The Crown Estate/RPS, 2019). These documents have been used in the conceptual evidence-based assessment of site conditions to inform the assessment.

164. It is anticipated using conceptual evidence-based assessment, that the changes in SSC due to export cable installation would be less than those that have been assessed in relation to the disturbance of seabed sediments during foundation installation activities (Section 8.6.2.1), although the location of effect would differ as it would be focused along the offshore cable corridor.

165. Also, although SSCs will be elevated they are likely to be lower than concentrations that would develop in the water column during storm conditions, including the December 2013 storm surge and other recent events. Storms can rapidly change seabed sediment distribution through re-suspension and re-deposition. They are short-term natural phenomenon that are likely to drive greater changes to the seabed than the changes that would occur due to the presence of the wind farm infrastructure. Also, once jetting is completed, tidal currents are likely to rapidly disperse the suspended sediment (i.e. over a period of a few hours) in the absence of any further sediment input.

166. It is likely that the increase in concentrations would be greatest in the shallowest sections of the offshore cable corridor, but in these locations the background

concentrations are also greater than in deeper waters, with values of greater than 256mg/l recorded in the vicinity of the coast at Orfordness (HR Wallingford et al., 2002).

167. Modelling simulations undertaken for GWF confirm the evidence-based assessment. The model assumed a continuous installation of a 240km export cable (0.5m wide and buried at a depth of 1.5m) by jetting over a 10-day period. Results showed increased SSC up to 14km from the offshore cable corridor. However, SSCs at this distance (14km from the offshore cable corridor) were typically less than 0.2mg/l (ABPmer, 2011b). Over the entire simulation period, SSCs at peak flow were predicted to be less than 0.5mg/l above natural background levels (ABPmer, 2011b). Elevated SSCs were dispersed by tidal currents along the dominant north-east – south-west axis and were a short-term effect. ABPmer (2011b) noted that although this period may be extended to account for poor weather, these events would likely disperse any sediment plumes and restore natural background levels. Elevated SSCs were not expected over a wider coastal area.

168. As described in Section 8.4.6, there are similarities in water depth, sediment types and metocean conditions between the offshore cable corridor for GWF and the proposed North Falls project, as well as the similar length in offshore cable corridor. This makes the GWF modelling study a suitable analogue for the present assessment.

169. The HDD exit point will be in the subtidal zone seaward of the low water mark. The cable exit point would require excavation of a trench to bury the nearshore portion of the offshore cable on the seaward side of the landfall HDD. This excavation has the potential to increase SSCs close to shore.

170. During the excavation process the SSCs will be elevated above prevailing conditions, but are likely to remain within the range of background nearshore levels (which will be high close to the coast because of increased wave activity) and lower than those concentrations that would develop during storm conditions. Also, once jetting is completed, the high energy nearshore zone is likely to rapidly disperse the suspended sediment (i.e. over a period of a few hours) in the absence of any further sediment input.

171. Excavated sediment would be backfilled into the trench by mechanical means (within a few days of excavation) and the nearshore zone re-instated close to its original morphology. This activity would result in some localised and short-term disturbance to the beach and nearshore zone, but there would be no long-term effect on sediment transport processes.

8.6.2.5.1 Magnitude

172. The worst case changes in SSCs due to export cable installation are likely to have the magnitudes of impact shown in Table 8.21.

Table 8.21 Magnitude of impacts on SSCs under the worst case scenario for export cable installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Near-field* (nearshore)	Low	Negligible	Negligible	Negligible	Negligible
Near-field* (offshore)	Low	Negligible	Negligible	Negligible	Negligible

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

* The near-field impacts are confined to a small area likely to be of the order up to a kilometre from the offshore cable corridor, and would not cover the whole offshore cable corridor.

8.6.2.5.2 Sensitivity

173. Due to the nature of the pressure (increase in SSCs due to export cable installation) there is no pathway for effect to all identified receptors so therefore they are not sensitive to this pressure.

8.6.2.5.3 Effect significance

174. The effects on SSCs due to export cable installation would have no change upon the identified receptors groups for marine geology, oceanography and physical processes and no significant effect will occur. This is because the receptors are dominated by processes that are active along the seabed and are not affected by sediment suspended in the water column. However, there may be effects arising from subsequent deposition of the suspended sediment on the seabed and these are discussed under construction Impact 4 (Section 8.6.2.6).

175. The impact on SSC does have the potential to affect other receptors and therefore the assessment of effect significance is addressed within the relevant chapters of this PEIR (see Section 8.10).

8.6.2.6 Impact 4: Changes in seabed level due to deposition from the suspended sediment plume during export cable installation

176. The assessment of changes in seabed level due to offshore export cable installation has been considered separately from those for the array and interconnector cables.

177. The increases in SSCs associated with offshore export cable installation have the potential to result in changes in seabed level as the suspended sediment deposits.

178. The plume modelling simulations undertaken for export cable installation for GWF indicated that the larger sediment sizes (fine sand) would result in the greatest bed thickness changes, although the maximum seabed thickness change simulated is less than 15µm (0.015mm) (ABPmer, 2011b). The sand was deposited over an area of less than 30m^2 (ABPmer, 2011b). Should any sediment deposition occur along the coast, it will be rapidly dispersed by wave action. As there is already significant ambient sand transport in the vicinity, the small amounts of additional resettled sand will not significantly change the local transport. The coarse sediment observed across the interconnector and offshore cable corridor would behave in this manner.

179. The mud-sized sediment present along the offshore cable corridor close to shore and at the eastern end of the offshore cable corridor close to the south array (Section 8.5.6) would be advected a greater distance and persist in the water column for hours to days, before depositing to form a thin a layer on the seabed. However, it is anticipated that under the prevailing hydrodynamic conditions, this sediment would be readily re-mobilised, especially in the shallow inshore area where waves would regularly agitate the bed. Accordingly, outside the immediate vicinity of the offshore cable trench, bed level changes

and any changes to seabed character are expected to be not measurable in practice.

8.6.2.6.1 Magnitude

180. The worst case changes in seabed level due to export cable installation are likely to have the magnitudes of impact described in Table 8.22.

Table 8.22 Magnitude of impact on seabed level changes due to export cable installation under the worst case scenario for SSCs

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Near-field*	Low	Negligible	Negligible	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

*The near-field impacts are confined to a small area of seabed likely to be up to a kilometre from each foundation location and would not cover the whole of North Falls.

8.6.2.6.2 Sensitivity

181. The sensitivity and value of all relevant receptors are presented in Table 8.23.

Table 8.23 Sensitivity and value assessment of relevant receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Essex coast	Negligible	Negligible	Negligible	High	Negligible
Suffolk coast	Negligible	Negligible	Negligible	High	Negligible
Annex I sandbanks	Negligible	Negligible	Negligible	High	Negligible
Margate and Long Sands SAC	Negligible	Negligible	Negligible	High	Negligible
Kentish Knock East MCZ	Negligible	Negligible	Negligible	High	Negligible
Orford Inshore MCZ	Negligible	Negligible	Negligible	High	Negligible

8.6.2.6.3 Effect significance

182. Based on the GWF plume modelling simulations, conceptual evidence-based assessment of deposition from the plume generated from cable installation indicates that the changes in seabed elevation are effectively immeasurable within the accuracy of any numerical model or bathymetric survey. This means that given these very small magnitude changes in seabed level arising from offshore export cable installation, the effects on the identified morphological receptors would not be significant. Hence, the overall effect of offshore cable installation activities under a worst case scenario on seabed level changes for the identified morphological receptor groups is considered to be negligible adverse (no significant effect) for Essex coast, Margate and Long Sands SAC, Annex I sandbanks and Kentish Knock East MCZ receptors. Given the bedload sediment transport direction is to the south-west (Section 8.5.7), and the distances between the closest sediment release point and the Orford Inshore MCZ (12.7km) and Suffolk coast (11.1km), there is considered to be no change on these receptors.

183. In many parts of the offshore cable corridor, export cable installation is unlikely to result in the release of the volumes of sediment considered under this worst case scenario. In addition, the optimisation of the offshore cable route selection

within the corridor, depth and installation methods during detailed design would ensure that effects are minimised.

184. The impacts on seabed level also have the potential to affect other receptors and therefore the assessment of effect significance is addressed within relevant chapters of this PEIR (see Section 8.10).

8.6.2.7 Impact 5: Changes in SSCs due to array and interconnector cable installation

185. Sandwave levelling (pre-sweeping) may be required for the array/interconnector cable prior to installation. The worst case scenario assumes that sediment would be dredged and returned to the water column at the sea surface as overflow from a dredger vessel. This process would cause localised and short-term increases in SSCs both at the point of dredging at the seabed and more importantly, at the point of its discharge back into the water column. Table 8.2 summarises the worst case scenario volume of sediment disturbed.

186. Mobilised sediment from these activities may be transported by wave and tidal action in suspension in the water column. The disturbance effects at each location are likely to last for no more than a few days. The sediment released at any one time would depend on the capacity of the dredger. Any sediment excavated during sandwave levelling would be disposed of within the North Falls offshore project area, meaning there will be no net loss of sand from the site.

187. The types and magnitudes of impacts that could be caused have previously been assessed within an industry best practice document on cabling techniques (BERR, 2008). This document has been used to support the evidence-based assessment of site conditions to inform the below.

188. Conceptual evidence-based assessment indicates that the changes in SSCs due to array and interconnector cable installation would be similar to those that have been assessed in relation to the disturbance of near-surface sediments during foundation and export cable installation activities (see Construction impact 1a – Section 8.6.2.1).

189. Modelling simulations for array and interconnector cabling were not undertaken for GWF. Given the similar area of sediment release for the array and interconnector cables as the foundations, it was considered that modelling of GBS foundation installation provided a highly conservative worst case scenario in terms of increases in SSC. Therefore, it was considered that any impact associated with array and interconnector cabling would be less than that associated with GBS installation (ABPmer, 2011b).

8.6.2.7.1 Magnitude

190. The worst case changes in SSCs due to the installation of the array and interconnector cables are likely to have the magnitudes of impact shown in Table 8.24.

Table 8.24 Magnitude of impact on suspended sediment concentrations under the worst case scenario for array and interconnector cable installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Near-field*	Medium	Negligible	Negligible	Negligible	Negligible

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

* The near-field impacts are confined to a small area likely to be up to a kilometre from the cable and would not cover the entirety of the seabed within the North Falls array areas.

8.6.2.7.2 Sensitivity

191. Due to the nature of the pressure (increase in SSCs due to array and interconnector cable installation) there is no pathway for effect to all identified receptors so therefore they are not sensitive to this pressure.

8.6.2.7.3 Effect significance

192. The effects on SSCs due to array and interconnector cable installation (including that from any seabed preparation) will have no change (i.e. no significant effect) upon the identified receptors groups for marine geology, oceanography and physical processes. This is because the receptors are dominated by processes that are active along the seabed and are not affected by sediment suspended in the water column. However, there may be effects arising from subsequent deposition of the suspended sediment on the seabed and these are discussed under construction Impact 6 (Section 8.6.2.8).

193. The impact on SSC does have the potential to affect other receptors and therefore the assessment of effect significance is addressed within the relevant chapters of this PEIR (see Section 8.10).

8.6.2.8 Impact 6: Changes in seabed level due to the deposition from the suspended sediment plume during array and interconnector cable installation

194. The increases in SSCs associated with construction Impact 5 (Section 8.6.2.7) have the potential to result in changes in seabed levels as the suspended sediment deposits.

195. The evidence-based assessment suggests that coarser sediment disturbed during cable installation would fall rapidly to the seabed (minutes or tens of minutes) as a highly turbid dynamic plume immediately after it is discharged. Deposition of this sediment would form a linear mound (likely to be tens of centimetres high) parallel to the cable as the point of release moves along the excavation. The coarse sediment particle sizes observed across the array and interconnector areas would behave in this manner and be similar in composition to the surrounding seabed. This would mean that there would be no significant change in seabed sediment type.

196. The mud sized sediment would also be released to form a passive plume and become more widely dispersed before settling on the seabed. The conceptual evidence-based assessment suggests that due to the dispersion by tidal currents, and subsequent deposition and re-suspension, the deposits across the wider seabed would be very thin (millimetres).

197. This theoretical assessment is supported by modelling results for GBS foundation installation for GWF (considered a highly conservative worst case scenario), which shows bed thickness changes of 0.03mm (ABPmer, 2011b). This is considered to be within the natural variation in bed level change for the area.

8.6.2.8.1 Magnitude

198. Evidence-based assessment indicates that changes in seabed level due to array and interconnector cable installation (including any deposition arising from sandwave levelling) would be minor and are likely to have the magnitudes of impact shown in Table 8.25.

Table 8.25 Magnitude of impact on seabed level changes due to deposition under the worst case scenario for sediment dispersal following array and interconnector cable installation (including sandwave levelling)

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Near-field*	Low	Negligible	Negligible	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

*The near-field impacts are confined to a small area of seabed likely to be up to a kilometre from the cable and would not cover the whole of North Falls.

8.6.2.8.2 Sensitivity

199. The sensitivity and value of all relevant receptors are presented in Table 8.26.

Table 8.26 Sensitivity and value assessment of relevant receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Essex coast	Negligible	Negligible	Negligible	High	Negligible
Suffolk coast	Negligible	Negligible	Negligible	High	Negligible
Annex I sandbanks	Negligible	Negligible	Negligible	High	Negligible
Margate and Long Sands SAC	Negligible	Negligible	Negligible	High	Negligible
Kentish Knock East MCZ	Negligible	Negligible	Negligible	High	Negligible
Orford Inshore MCZ	Negligible	Negligible	Negligible	High	Negligible

8.6.2.8.3 Effect significance

200. The impact on seabed level is considered highly unlikely to have the potential to directly affect the identified receptor groups for marine geology, oceanography and physical processes. Any impacts will be of lower magnitude than those seabed level impacts already considered for the installation of foundations. Consequently, the overall effect significance of array and interconnector cable installation on seabed level changes for the Essex coast, Suffolk coast, Margate and Long Sands SAC is considered to be negligible adverse (no significant effect) due to the separation distance between these receptors and the array and interconnector cables. The overall effect significance of array and interconnector cable installation under a worst case scenario on seabed level changes for Annex I sand banks, Kentish Knock East MCZ and Orford Inshore MCZ is also considered to be negligible adverse (no significant effect).

201. The impacts on seabed level also have the potential to affect other receptors and the assessment of impact significance is addressed within the relevant chapters of this PEIR (see Section 8.10).

8.6.2.9 *Impact 7: Interruptions to bedload sediment transport due to sandwave levelling for offshore cable installation*

202. Sandwave levelling (pre-sweeping) may be required prior to offshore cable installation.

203. The removal of sandwaves could potentially interfere with sediment transport pathways that supply sediment to the local sand bank systems, including those designated under the Margate and Long Sands SAC.

204. Any excavated sediment due to sandwave levelling for offshore cables would be disposed of within the North Falls offshore project area and therefore there will be no net loss of sand from the site. Tidal currents would, over time, re-distribute the sand back over the levelled area (as re-formed sandwaves). The extent of sandwave levelling required and specific disposal locations within the offshore project area would be determined post consent following detailed geophysical surveys. However, given the relatively low volumes of sand likely to be affected, the overall effect of changes to the seabed would be minimal.

205. The dynamic nature of the sandwaves in this area means that any direct changes to the seabed associated with sandwave levelling are likely to recover over a short period of time due to natural sand transport pathways. This conceptual evidence-based assessment is supported by the findings of a review of the evidence base into the recovery of sandwaves at the similarly dynamic areas of Race Bank and Haisborough Hammond and Winterton SAC (ABPmer, 2018b).

206. To install parts of the array and export cables for Race Bank Offshore Wind Farm, the crests of sandwaves were reduced in elevation. Ørsted (2018) reported the results of multibeam echosounder monitoring of pre- (2015/2016), during (2017) and post- (2018) sandwave levelling (pre-sweeping) to assess the level of disturbance and the rate of natural recovery (restoration) of seabed morphology. Nine areas were chosen (seven array cables routes and two areas along the offshore cable corridors) where significant sediment mobility was expected. The results showed that along most of the nine study areas, the seabed had completely or nearly completely recovered to pre-construction levels (greater than 75% recovery of sandwaves in all areas).

207. ABPmer (2018b) completed a sandwave study in relation to cable installation activities in the Haisborough, Hammond and Winterton SAC which has informed the impact assessments for the Norfolk Projects. They showed that the cable corridor is in an active and highly dynamic environment governed by current flow speeds, water depth and sediment supply, all of which are conducive to the development and maintenance of sand banks. Therefore, despite the disturbance to sandwaves intersecting the cable corridor, the Haisborough, Hammond and Winterton SAC sand bank system would remain undisturbed as new sandwaves will continue to be formed. They concluded that the overall form and functioning of any sandwave, or the SAC sandbank system, is not disrupted by levelling of the sandwaves.

8.6.2.9.1 Magnitude

208. The worst-case changes in bedload sediment transport due to sandwave levelling within the offshore cable corridors are likely to have the magnitudes of impact described in Table 8.27.

Table 8.27 Magnitude of impact on bedload sediment transport under the worst case scenario for sandwave levelling within the offshore cable corridors

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Near-field*	Medium	Negligible	Negligible	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

*The near-field impacts are confined to a small area of seabed (likely to be of the order of several hundred metres up to a kilometre from the cable corridors) and would not cover the whole cable corridors.

8.6.2.9.2 Sensitivity

209. The sensitivity and value of all relevant receptors are presented in Table 8.28.

Table 8.28 Sensitivity and value assessment of relevant receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Essex coast	Negligible	Negligible	Negligible	High	Negligible
Suffolk coast	Negligible	Negligible	Negligible	High	Negligible
Annex I sandbanks	Negligible	Negligible	Negligible	High	Negligible
Margate and Long Sands SAC	Negligible	Negligible	Negligible	High	Negligible
Kentish Knock East MCZ	Negligible	Negligible	Negligible	High	Negligible
Orford Inshore MCZ	Negligible	Negligible	Negligible	High	Negligible

8.6.2.9.3 Effect significance

210. Keeping the dredged sand within the sand bank system enables the sand to become re-established within the local sediment transport system by natural processes and encourages the re-establishment of the bedforms. Given the local favourable conditions that enable sandwave development, the sediment would be naturally transported back into the levelled area within a short period of time. The levelled area will naturally act as a sink for sediment in transport and will be replenished in the order of a few days to a year. The overall effect significance of sandwave levelling activities within the offshore cable corridors on the Suffolk coast, Kentish Knock East MCZ and Orford Inshore MCZ is considered to be no change due to the separation distance between these receptors and offshore cable corridors. The overall effect significance of sandwave levelling activities on the Essex coast, Annex I sand banks and Margate and Long Sands SAC is considered to be negligible adverse (no significant effect).

292. The impacts on bedload sediment transport also have the potential to affect other receptors and therefore the assessment of effect significance is addressed within relevant chapters of this PEIR (see Section 8.10).

8.6.2.10 Impact 8: Indentations on the seabed due to installation vessels

211. There is potential for certain vessels used during installation of foundations and cable infrastructure to directly impact the seabed. This applies for those vessels

that utilise jack-up legs or several anchors to hold station and to provide stability for a working platform. Where legs or anchors (and associated chains) have been inserted into the seabed and then removed, there is potential for an indentation to remain, proportional to the dimensions of the object. The worst case scenario is considered to correspond to the use of jack-up vessels, since the depressions would be greater than the anchor scars.

212. As the leg is inserted, the seabed sediments would primarily be compressed vertically downwards and displaced laterally. This may cause the seabed around the inserted leg to be raised in a series of concentric pressure ridges. As the leg is retracted, some of the sediment would return to the hole via mass slumping under gravity until a stable slope angle is achieved. Over the longer term, the hole would become shallower and less distinct due to infilling with mobile seabed sediments. Post-construction monitoring of indentations on the seabed caused by jack-ups during the installation of Dudgeon Offshore Wind Farm (DOW) indicate that natural processes are restoring local areas of seabed affected by the construction works.

213. A six-legged jack-up barge used for the installation of turbines/OSPs would have a footprint of 1,650m^2. Each leg could penetrate 5 to 15m into the seabed and may be cylindrical, triangular, truss leg or lattice. The worst case scenario assumes that six jack-up events will be required at each turbine/OSP (Table 8.2).

214. Vessels may also require to anchor during turbine and OSP installation. 116.4m^2 anchor footprints are assumed, with eight anchors per vessel and five placements per turbine/OSP. The total footprint of anchoring is during turbine/OSP installation is 344,529m^2 (Table 8.2).

215. Cable installation vessels will also be required to anchor. 60.7m^2 anchor footprints are assumed, with nine anchors per vessel and 264 placements during array and interconnector cable installation and 545 during export cable installation, therefore the total footprint of anchoring is 441,903m^2 (Table 8.2).

8.6.2.10.1 Magnitude

216. The worst-case changes in terms of indentations on the seabed due to installation vessels are likely to have the magnitudes of impact described in (Table 8.29).

Table 8.29 Magnitude of impact on seabed level changes under the worst case scenario for installation vessels

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Near-field (footprint of leg/anchor)	High	Negligible	Negligible	Medium	Medium
Near-field (beyond the footprint of leg/anchor)	No change	-	-	-	No change
Far-field	No change	-	-	-	No change

8.6.2.10.2 Sensitivity

217. The sensitivity and value of all relevant receptors are presented in Table 8.30.

Table 8.30 Sensitivity and value assessment of relevant receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Essex coast	Negligible	Negligible	Negligible	High	Negligible
Suffolk coast	Negligible	Negligible	Negligible	High	Negligible
Annex I sandbanks	Negligible	Negligible	Negligible	High	Negligible
Margate and Long Sands SAC	Negligible	Negligible	Negligible	High	Negligible
Kentish Knock East MCZ	Negligible	Negligible	Negligible	High	Negligible
Orford Inshore MCZ	Negligible	Negligible	Negligible	High	Negligible

8.6.2.10.3 Effect significance

218. The footprint of jack-ups and mooring lines used during the installation of turbines/OSPs and interconnector cables would not extend beyond the direct footprint. Therefore, there is no change from these activities on the Suffolk coast or Orford Inshore MCZ since these receptors are located remotely from the zone of potential effect.

219. The layout of turbines and offshore cables will be decided post consent, however, in the event that it is not possible for jack-up vessel legs or cable installation vessel anchors to avoid sandbanks, there is potential for indentations to occur. However, any disturbance footprint would be limited in scale (see Table 8.2) and any impacts would be temporary in nature with indentations infilling through natural processes over the course of a few days to months. ’Therefore, the likely effect of these activities is considered to be negligible adverse which is not significant on Margate and Long Sands SAC, Annex I sandbanks and Kentish Knock East MCZ.

220. Installation of the export cable and cable protection measures at the HDD exit point may involve an anchor footprint. These activities will be localised and temporary and therefore a negligible adverse effect which is deemed to be not significant will occur on the Essex coast

304. The significance of the effects on other receptors is addressed within the relevant chapters of this PEIR (see Section 8.10).

8.6.3 Operation phase

221. During the operational phase, there is potential for the presence of foundations to cause changes to the tidal and wave regimes due to physical blockage effects. These changes could potentially affect the sediment regime and/or seabed morphology. These potential effects are considered as operational Impacts 1 to 6. In addition, there is potential for disturbance of the seabed during maintenance activities. These potential effects are considered as operational Impact 7.

8.6.3.1 Impact 1: Changes to the tidal regime due to the presence of structures on the seabed (wind turbines and OSP foundations)

222. The presence of the worst case GBS wind turbine foundations and two suction bucket OSP foundation structures on the seabed within North Falls has the potential to alter the baseline tidal regime, particularly tidal currents. Any changes in the tidal regime have the potential to contribute to changes in seabed morphology due to alteration of sediment transport patterns (see operational Impact 3, Section 8.6.3.3).

223. The conceptual evidence-based assessment suggests that each foundation would present an obstacle to the passage of currents locally, causing a small modification to the height and/or phase of the water levels and a wake in the current flow. This latter process involves a deceleration of flow immediately upstream and downstream of each foundation and an acceleration of flow around the sides of each foundation. Current speeds return to baseline conditions with progression downstream of each foundation and generally do not interact with wakes from adjacent foundations due to the separation distances.

224. The assessment of tidal currents at the adjacent GWF, which has a conservative design compared to the North Falls design (Section 8.4.6), concluded that there would be no significant changes to the broad-scale flow regime, with a reduction in the overall flow within the wind farm boundary of 5% at peak flood and 4% at peak ebb, and an increase in flow between the turbine rows (ABPmer, 2011). The changes modelled only last a maximum of 10 minutes at one time (ABPmer, 2011). No significant impact on the tidal current regime was predicted for GWF, and the same conclusion (based on the similarities between GWF and North Falls, see Section 8.4.6) is drawn for North Falls.

225. In addition, there is a pre-existing scientific evidence base which demonstrates that changes in the tidal regime due to the presence of foundation structures are both small in magnitude and localised in spatial extent. This is confirmed by existing guidance documents (ETSU, 2000, 2002; Lambkin et al., 2009) and numerous ESs for a range of existing and planned OWFs.

8.6.3.1.1 Magnitude

226. The worst case changes to tidal currents due to the presence of GBS turbine foundations and two suction bucket OSPs are likely to have the magnitudes of impact shown in Table 8.31.

Table 8.31 Magnitude of impact on tidal currents under the worst case scenario for the presence of GBS foundations and suction bucket OSPs

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Near-field	Low	High	Medium	Negligible	Low
Far-field	Negligible	High	Medium	Negligible	Negligible

227. The effects on the tidal regime have been translated into a ‘zone of potential influence’ based on an understanding of the tidal ellipses. The zone of potential influence is based on the knowledge that effects arising from wind turbine and

OSP foundations on the tidal regime are relatively small in magnitude, and local. It is expected that changes to the tidal regime would have returned to background levels immediately outside the excursion of one tidal ellipse, and this threshold has been used to produce the maximum 'zone of potential influence' on the tidal regime, as presented in Figure 8.13 (Volume II).

228. The ZoI (Figure 8.13, Volume II) overlaps with the Kentish Knock East MCZ, Orford Inshore MCZ and Annex sandbanks. It does not overlap the Suffolk coast, Essex coast or Margate Long Sands SAC.

8.6.3.1.2 Sensitivity

229. The sensitivity and value of all relevant receptors are presented in Table 8.32.

Table 8.32 Sensitivity and value assessment of relevant receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Suffolk coast	Medium	Low	Negligible	Medium	Negligible
Essex coast	Medium	Low	Negligible	Medium	Negligible
Annex 1 sandbanks	Negligible	Negligible	Negligible	High	Negligible
Margate and Long Sands SAC	Negligible	Negligible	Negligible	High	Negligible
Kentish Knock East MCZ	Negligible	Negligible	Negligible	High	Negligible
Orford Inshore MCZ	Negligible	Negligible	Negligible	High	Negligible

8.6.3.1.3 Effect significance

230. The Suffolk coast, Essex coast and Margate Long Sands receptor groups for marine geology, oceanography and physical processes are remote from the zone of potential influence on the tidal regime. Due to this, no pathway exists between the source and this receptor, so in terms of effects on this receptor groups there is no change associated with North Falls.

231. The predicted ZoI for North Falls encompasses Annex I sandbanks, Kentish Knock East MCZ and Orford Inshore MCZ. As outlined in Section 8.6.3.1, no significant impact on the tidal current regime is anticipated for North Falls and therefore the effect on the Annex I sandbanks, Kentish Knock East MCZ and Orford Inshore MCZ is anticipated to be negligible adverse (not significant).

8.6.3.2 Impact 2: Changes to the wave regime due to the presence of structures on the seabed (wind turbine and OSP foundations)

232. The presence of GBS wind turbine foundations and suction bucket OSP foundation structures on the seabed within North Falls has the potential to alter the baseline wave regime, particularly in respect of wave heights and directions. Any changes in the wave regime may contribute to changes in seabed morphology due to alteration of sediment transport patterns (see operational Impact 3, Section 8.6.3.3).

233. The evidence-based assessment suggests that each foundation would present an obstacle to the passage of waves locally, causing a small modification to the

height and / or direction of the waves as they pass. Generally, this causes a small wave shadow effect to be created by each foundation. Wave heights return to baseline conditions with progression downstream of each foundation and generally do not interact with effects from adjacent foundations due to the separation distances.

234. An assessment of waves at the adjacent GWF, which has a conservative design compared to the North Falls design (Section 8.4.6), modelled changes to wave height, period and direction from waves originating from the most common directions (north-east, south-west and south) over three return periods (10 in 1 year, 1 in 1 year and 1 in 10 year). The results (ABPmer, 2011) concluded that:

- Changes to SWHs for southwesterly waves for a 1 in 10 year event showed a reduction in height of less than 0.35m, occurring within 1km of the wind farm boundary. Reductions in SWH beyond 1km were typically no greater than 0.25m and smaller reductions of 0.1m were observed up to 10km north of the GWF boundary. In the context of baseline conditions, the model predicted that the largest reduction in SWH was at the centre of the array (between 5% and 10%) for all wave directions.
- Wave period reductions from waves originating from the south and south-west were restricted to the centre of the wind farm and were typically less than 0.45s. In the context of baseline conditions, the model predicted that the majority of changes to the wave period were less than 1% of the baseline value. The largest reductions in wave period were at the centre of the array, where maximum changes of 4 – 5% were observed for waves from the south and south-west.
- Changes to wave direction were typically restricted to ±2°. However, slightly larger changes in wave direction of ±3° were predicted for waves arriving from the south for all the return periods simulated. In the context of baseline values, the majority of directional changes were less than 1% of the baseline value (with a maximum predicted change of 3% in the centre of the array for waves arriving from the south-west) (ABPmer, 2011).

235. No significant effect on the wave regime or the coast was anticipated for GWF, and so the same conclusion (based on GWF as an analogy, Section 8.4.6) is drawn for North Falls.

236. In addition to the bespoke assessments at GWF, there is a strong evidence base which demonstrates that changes in wave regime due to the presence of foundation structures, even under a worst case scenario of the largest diameter GBS, are relatively small in magnitude (typically less than 10% of baseline wave heights in close proximity to each wind turbine, reducing with greater distance from each wind turbine). Effects are localised in spatial extent, extending as a shadow zone typically up to several tens of kilometres from the site along the axis of wave approach, but with low magnitudes (only a few percent change across this wider area). This is confirmed by a review of modelling studies from around 30 wind farms in the UK and European waters (Seagreen, 2012), existing guidance documents (ETSU, 2000; ETSU, 2002; Lambkin et al., 2009), published research (Ohl et al., 2001) and post-installation monitoring (Cefas, 2005).

8.6.3.2.1 Magnitude

237. The worst case changes to the wave regime due to the presence of GBS foundations are likely to have the magnitudes of impact shown in Table 8.33.

Table 8.33 Magnitude of impact on the wave regime under the worst case scenario for the presence of GBS foundations

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Low	High	Medium	Negligible	Low
Far-field	Negligible	High	Medium	Negligible	Negligible

8.6.3.2.2 Sensitivity

238. The sensitivity and value of all relevant receptors are presented in Table 8.34.

Table 8.34 Sensitivity and value assessment of relevant receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Suffolk coast	Medium	Low	Negligible	Medium	Negligible
Essex coast	Medium	Low	Negligible	Medium	Negligible
Annex 1 sandbank	Negligible	Negligible	Negligible	High	Negligible
Margate and Long Sands SAC	Negligible	Negligible	Negligible	High	Negligible
Kentish Knock East MCZ	Negligible	Negligible	Negligible	High	Negligible
Orford Inshore MCZ	Negligible	Negligible	Negligible	High	Negligible

8.6.3.2.3 Effect significance

239. These effects on the wave regime have been translated into a ‘zone of potential influence’ based on an understanding of the wave roses, previous numerical modelling of effect, and using expert-based assessment.

240. Plate 8.8 shows the near field wave conditions at GGOW in 2005 (ABPmer, 2011a) and describes that waves that are likely to be aligned north-east to south-west. It should be noted that predominant wave direction in Plate 8.9 indicates that waves originate from the south, followed by the north-east. This data is modelled using wave hindcast databases for the north-western European Continental Shelf and the Baltic Sea (ABPmer, 2018a) and was not recorded in the vicinity of North Falls. Therefore, a north-east to south-west axis of greatest potential influence at the array areas is considered appropriate.

241. In addition, wave modelling of the effect of GWF on the wave regime has been used as an analogue for delineating the ‘zone of potential influence’. In that previous modelling assessment, the greatest changes along the defined axis of greatest potential influence arose under a 1:10 return period. The spatial extent of measurable changes under such an event was mapped and superimposed over the North Falls array areas. The resulting ‘zone of influence’ on the wave regime is presented in Figure 8.13 (Volume II).

242. The Essex coast, Suffolk coast and Margate and Long Sands SAC receptor groups for marine geology, oceanography and physical processes are remote from the zone of influence. Due to this, no pathway exists between the source and the receptor in these areas, and so in terms of effects on these receptor groups there is no change associated with the Project.

243. However, the zone of influence encroaches onto the Orford Inshore MCZ, Kentish Knock East MCZ and Annex I sandbank receptor groups. The change in wave height would only be a few percent within these zones of encroachment. Hence the effect significance on these receptor groups would be negligible adverse.

8.6.3.3 Impact 3: Changes to the sediment transport regime due to the presence of structures on the seabed (wind turbine and OSP foundations)

244. Modifications to the tidal regime and/or the wave regime due to the presence of the foundation structures during the operational phase may affect the sediment transport regime. This section addresses the broader patterns of suspended and bedload sediment transport across, and beyond, the North Falls site and sediment transport at the coast.

245. The predicted reductions in tidal regime (operational Impact 1) and wave regime (operational Impact 2) associated with the presence of the worst case GBS foundation structures would result in a reduction in the sediment transport potential across the areas where such changes are observed. Conversely, the areas of increased tidal flow around each wind turbine would result in increased sediment transport potential.

246. These changes to the marine geology, oceanography and physical processes would be both low in magnitude and largely confined to local wake or wave shadow effects attributable to individual wind turbine foundations and, therefore, would be small in geographical extent. In the case of wave effects, there would also be reductions due to a shadow effect across a greater seabed area, but the changes in wave heights across this wider area would be notably lower (typically less than 1%) than the changes local to each wind turbine foundation.

247. ABPmer (2011) assessed the potential impact to regional bedload transport processes caused by changes in flow vectors (speed and direction) and bed shear stress as a result of the installation of GWF. The numerical model showed that neither speed nor direction of the flow regime was greatly affected by the installation of the windfarm.

248. A comparison of bed shear stress values before and after the GWF installation was undertaken during times of peak flow within the study area (ABPmer, 2011). Changes in bed shear stress values were typically restricted to within the GWF boundary, with some changes occurring to the north and south of the boundary depending on the tidal direction. Changes outside the array were restricted to within 0.5km of the GWF boundary and were of the order -0.1 N/m^2. The centre of the array was subject to local reductions in bed shear stress, whilst there were marginal increases (less than 0.25N/m^2) in the east and west of the GWF array. It was considered unlikely that the changes simulated would result in a change in seabed form (ABPmer, 2011).

249. The main concern with respect to seabed morphology was the potential change to the form and function of the Outer Gabbard Bank. This was also raised as a concern during the GGOW consultation process (with respect to the Galloper and Inner Gabbard sand banks), which resulted in the development of an exclusion zone around these sandbanks (ABPmer, 2011). The position of these sand banks with respect to North Falls is shown in Figure 8.14 (Volume II).

250. Numerical modelling predictions showed that reductions in bed shear stress occurred along and adjacent to the Outer Gabbard bank during flood and ebb tidal conditions (ABPmer, 2011). Changes only occurred in the lee of the turbines, with no bed shear stress changes noted alongside the main axis of flow through the GWF array. The maximum reduction in bed shear stress ($1N/m^2$) occurred in the shallow reaches of the Outer Gabbard bank during both ebb and flood tides, having a larger spatial extent during peak ebb tide. This may reduce the potential for mobilisation of larger sand fractions during the neap tidal period but was not expected to be reduced during the spring tidal period.

251. The largest changes to bed shear stress were located at the GBS structures on the Outer Gabbard bank and therefore an exclusion zone was placed around the bank. The layout of turbines for North Falls will be decided post consent.

252. A scour assessment was undertaken for GWF (ABPmer, 2011) which assessed monopile, jacket and GBS foundations. The predicted sediment volume released from scour development was found to be smaller than that released through seabed preparation activities for foundation installation ($4,163m^3$ compared to a maximum of $7,200m^3$ for a 45m GBS structure) (ABPmer, 2011). As shown in Section 8.6.2.1 and Section 8.6.2.3, the potential effects of changes in suspended sediment and changes in seabed level associated with seabed preparation was considered negligible. Therefore, it is considered that the magnitude of sediment released through scour development is also negligible. Although the area of seabed effected by scour is increased due to scour, it is still considered a small proportion of the overall array areas.

8.6.3.3.1 Magnitude

253. Since it is expected that the changes in tidal flow and wave heights during the operational phase of North Falls would have no significant far-field impacts, then the changes in sediment transport would be similar, with the likely magnitudes of impact shown in Table 8.35.

Table 8.35 Magnitude of effects on the sediment transport regime under the worst case scenario for the presence of GBS foundations

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Near-field	Low	High	Medium	Negligible	Low
Far-field	Negligible	High	Medium	Negligible	Negligible

8.6.3.3.2 Sensitivity

254. The sensitivity and value of all relevant receptors are presented in Table 8.36.

Table 8.36 Sensitivity and value assessment of relevant receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Suffolk coast	Medium	Low	Negligible	Medium	Negligible
Essex coast	Medium	Low	Negligible	Medium	Negligible
Annex 1 sandbank	Negligible	Negligible	Negligible	High	Negligible
Margate and Long Sands SAC	Negligible	Negligible	Negligible	High	Negligible
Kentish Knock East MCZ	Negligible	Negligible	Negligible	High	Negligible
Orford Inshore MCZ	Negligible	Negligible	Negligible	High	Negligible

8.6.3.3.3 Impact significance

255. Sediment transport in the nearshore is controlled by the wave climate.

256. As outlined in Section 8.6.3.1 and Section 8.6.3.2, no significant effect on the wave or tidal regime is anticipated for North Falls and therefore the effect on the Suffolk coast, Essex coast, Annex I sandbanks, Margate and Long Sands SAC, Kentish Knock East MCZ and Orford Inshore MCZ is anticipated to be negligible adverse (not significant).

8.6.3.4 Impact 4: Loss of seabed area due to infrastructure within the array areas

257. The seabed would be directly impacted by the footprint of each foundation structure and array cable protection on the seabed within the North Falls array areas. This would constitute a loss in natural seabed area during the operational life of the Project.

258. This direct footprint due to the presence of foundation structures could occur in one of two ways; without and with scour protection. Scour protection will be installed at locations where required, as determined by pre-construction surveys. A worst case scenario of all foundations and up to 20% of array cable length having scour protection is considered to provide a conservative assessment.

259. Under the worst case scenario, the seabed would be further occupied by material that is 'alien' to the baseline environment, such as concrete mattresses, fronded concrete mattresses, rock dumping, bridging or positioning of gravel bags.

260. The worst case is associated with the maximum number of 72 GBS turbine foundations and scour protection, two GBS OSP foundations with scour protection, and up to 20% of array cable protection (45.6km) (Table 8.2). This constitutes a seabed loss of 4.56% of the array areas.

261. The layout of turbines will be decided post consent, however, it is possible that turbines could be located within the Kentish Knock East MCZ. The worst case scenario assumes that seven GBS foundations (diameter of 65m plus scour protection) and array cable protection (4.6km of array cable protection length within the MCZ, with a 6m width) could be located within the Kentish Knock East MCZ. This would constitute a seabed loss within the Kentish Knock East MCZ, resulting in habitat loss of 0.67% of the MCZ. Table 8.2 outlines the worst case scenario footprints. Magnitude

262. The worst-case loss of seabed due to the presence of foundation structures with scour protection and array cable protection is likely to have the magnitudes of impact shown in Table 8.37. It is likely that any secondary scour effects associated scour protection would be confined to within a few meters of the direct footprint of that scour protection.

Table 8.37 Magnitude of impacts on seabed morphology under the worst case scenario for the footprint of foundations and scour protection

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Near-field*	High	High	High	Negligible	High
Far-field	No change	-	-	-	No change

*The near-field impacts are confined to within the footprint of each foundation structure

8.6.3.4.1 Sensitivity

263. The sensitivity and value of all relevant receptors are presented in Table 8.38.

Table 8.38 Sensitivity and value assessment of relevant receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Suffolk coast	Medium	Low	Negligible	Medium	Negligible
Essex coast	Medium	Low	Negligible	Medium	Negligible
Annex 1 sandbank	Negligible	Negligible	Negligible	High	Negligible
Margate and Long Sands SAC	Negligible	Negligible	Negligible	High	Negligible
Kentish Knock East MCZ	Negligible	Negligible	Negligible	High	Negligible
Orford Inshore MCZ	Negligible	Negligible	Negligible	High	Negligible

8.6.3.4.2 Impact significance

264. The near-field impacts are confined to the footprint of each foundation structure, and therefore have no pathway to the Essex coast, Suffolk coast, Margate and Long Sands SAC and Orford Inshore MCZ receptors. There is therefore no change.

265. A loss of seabed will have a negligible adverse effect on sandbanks (and associated sandwaves) as sand will continue to be transported around the turbine foundation and over any scour protection due to the dynamic nature of the area. There is therefore a negligible adverse effect on Annex I sandbanks receptors which is not significant.

266. A loss of seabed within the Kentish Knock East MCZ, designated for subtidal sand, subtidal coarse sediment and subtidal mixed sediments, will represent a relatively small loss of seabed compared to the footprint of the Kentish Knock East MCZ. Sediment will continue to be transported around the turbine foundations and over any scour protection. There is therefore a minor adverse effect on the Kentish Knock East MCZ which is not significant.

267. The significance of the effects on other receptors is addressed within the relevant chapters of this PEIR (see Section 8.10).

8.6.3.5 Impact 5: Morphological and sediment transport effects due to cable protection measures within the North Falls array areas and interconnector cable corridor

268. As a worst case scenario, if the array or interconnector cables cannot be buried, they would be surface-laid and protected in some manner, and cable protection would also be required at any cable crossings. Cable protection will take the form of rock or concrete mattresses.

269. The impacts that such works may have on marine geology, oceanography and physical processes primarily relate to the potential for interruption of sediment transport processes and the footprint they present on the seabed. In areas of active sediment transport, any linear protrusion on the seabed may interrupt bedload sediment transport processes. There is unlikely to be any significant impact on suspended sediment processes since armoured cables or cable protection works (including where the cable crosses other sub-marine infrastructure such as pipelines and other cables) are relatively low above the seabed (a maximum of 1.4m).

270. The worst case scenario area of cable protection for the array and interconnector cables and crossings is 273,600m^2 (Table 8.2).

271. The presence of sandwaves across the north and south array areas indicates that some bedload sediment transport exists, with a net direction south-west to north-east (see Section 8.5.7). Protrusions from the seabed are unlikely to significantly affect the migration of sandwaves, since their heights (typically between 1m and 15m, with average wavelengths of between 25m and 37m (Fugro, 2021a)) would exceed the height of cable protection works and pass over them. There may be localised interruptions to bedload transport in other areas, but the gross patterns of bedload transport across the North Falls array areas would not be affected significantly.

272. Secondary scour may occur around the edge of cable protection, dependent upon the cable protection material. Once scour has developed, the long-term suspension of sediments is unlikely. It is considered unlikely that any impacts on sediment transport as a result of scour around cable protection will occur.

8.6.3.5.1 Magnitude

273. The worst case changes to the seabed morphology and sediment transport due to cable and crossing protection measures for array and interconnector cables are likely to have the magnitudes of impact shown in Table 8.39.

Table 8.39 Magnitude of impacts on seabed morphology and sediment transport under the worst case scenario for cable and crossing protection measures for array and interconnector cables

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	High	High	High	Negligible	High
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

* The near-field impacts are confined to a small area (likely to be within the footprint of cable protection works), and would not cover the whole North Falls

8.6.3.5.2 Sensitivity

274. The sensitivity and value of all relevant receptors are presented in Table 8.40.

Table 8.40 Sensitivity and value assessment of relevant receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Suffolk coast	Medium	Low	Negligible	Medium	Negligible
Essex coast	Medium	Low	Negligible	Medium	Negligible
Annex 1 sandbank	Negligible	Negligible	Negligible	High	Negligible
Margate and Long Sands SAC	Negligible	Negligible	Negligible	High	Negligible
Kentish Knock East MCZ	Negligible	Negligible	Negligible	High	Negligible
Orford Inshore MCZ	Negligible	Negligible	Negligible	High	Negligible

8.6.3.5.3 Impact significance

275. The effects on seabed morphology and sediment transport arising from the presence of array and interconnector cables and crossing protection measures would not extend far beyond the direct footprint. Therefore, there is no change associated with the proposed project on the Essex coast, Suffolk coast, Margate and Long Sands SAC and Orford Inshore MCZ since these are located remotely from this zone of potential impact. If cable protection does present an obstruction to bedload transport, then it is likely that sandwaves would pass over them. Gross patterns of bedload transport would therefore not be affected significantly, and therefore there would be a negligible adverse effect on Annex I sand banks (and associated sandwaves) and Kentish Knock East MCZ which is not significant.

276. The significance of the effects on other receptors is addressed within the relevant chapters of this PEIR (see Section 8.10).

8.6.3.6 Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor

277. As a worst case scenario, it has been assumed that burial of the export cables would not practicably be achievable within some areas of the offshore cable corridor and, instead, cable protection measures would need to be provided to surface-laid cables in these areas. The locations where cable protection measures are most likely to be required are areas of cable crossings and in areas of seabed characterised by exposed bedrock. An estimate of 10% of the cable length requiring cable protection is included in the worst case scenario (Table 8.2). Cable protection may take the form of rock or concrete mattresses.

278. The impacts that export cable protection may have on marine geology, oceanography and physical processes primarily relate to the potential for interruption of sediment transport processes and the footprint they present on the seabed.

279. In areas of active sediment transport, any linear protrusion on the seabed may interrupt bedload sediment transport processes during the operational phase. There is likely to be a difference in impact depending on whether the cable protection works are in 'nearshore' or 'offshore' areas within the offshore cable

corridor. Any works in areas closest to the coast have the potential to affect longshore sediment transport processes and circulatory pathways across any nearshore banks.

280. The seaward limit which marks the effective boundary of wave-driven sediment transport is called the 'closure depth' and is estimated to be approximately 1.5km from the coast, within 5m water depth.

281. Any protrusions from the seabed associated with cable protection measures could potentially have an effect on sediment transport in the nearshore and along the coast. Any interruptions to sediment transport locally within this zone could, in turn, affect the morphological response of wider areas (e.g. frontages along the sediment transport pathway) due to reductions in sediment supply to those areas.

282. The potential magnitude of the impact will depend on the local sediment transport rates; a lower rate would reduce the potential effect on sediment supply to wider areas. There are likely to be a range of sediment transport potentials across the export cables. If Pleistocene geological units are exposed at the seabed or covered by a thin lag, then they are static and have zero transport potential (i.e. no mobile sediment). If the cable protection is laid in these areas, then sediment transport is not an issue as no sediment is being transported.

283. Where the seabed is composed of mobile sand, it can be transported under existing tidal conditions. If the cable protection does present an obstruction to this bedload transport the sediment would first accumulate one side or both sides of the obstacle (depending on the gross and net transport at that location) to the height of the protrusion. With continued build-up, it would then form a 'ramp' over which sediment transport would eventually occur by bedload processes, thereby bypassing the protection. The gross patterns of bedload transport across the export cables would therefore not be impacted significantly.

284. In recognition of these potential impacts, the site selection process will consider an appropriate landfall location and offshore cable corridor which aims to minimise the need for cable protection and therefore sediment transport effects will be minimised, as far as practicably possible.

285. The presence of cable protection works on the seabed would represent the worst case in terms of a direct loss of seabed area (Table 8.2).

286. A commitment has been made to install the export cable at the landfall using HDD techniques, thus avoiding direct disturbance in the intertidal zone.

8.6.3.6.1 Magnitude

287. The worst case changes to the seabed morphology and sediment transport due to cable protection measures for export cables would have the magnitudes of impact shown in Table 8.41.

Table 8.41 Magnitude of impact on seabed morphology and sediment transport under the worst case scenario for cable protection measures for export cables

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Landfall intertidal zone	Negligible	High	High	Negligible	Negligible

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Shallower than 5m water depth	Medium	High	High	Negligible	Medium
Deeper than 5m water depth	Low	High	High	Negligible	Low

8.6.3.6.2 Sensitivity

288. The sensitivity and value of all relevant receptors are presented in Table 8.42.

Table 8.42 Sensitivity and value assessment of relevant receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Suffolk coast	Medium	Low	Negligible	High	Medium
Essex coast	Medium	Low	Negligible	High	Medium
Annex 1 sandbank (outside SACs)	Negligible	Negligible	Negligible	High	Negligible
Margate and Long Sands SAC	Negligible	Negligible	Negligible	High	Negligible
Kentish Knock East MCZ	Negligible	Negligible	Negligible	High	Negligible
Orford Inshore MCZ	Negligible	Negligible	Negligible	High	Negligible

8.6.3.6.3 Impact significance

289. Offshore of the closure depth, the effects on seabed morphology and sediment transport arising from the presence of export cable protection measures would not extend far beyond the direct footprint. Therefore, there is no change associated with the proposed project on the Suffolk coast, Kentish Knock East MCZ, Annex 1 sandbanks outside SACs and the Orford Inshore MCZ since these receptors are located remotely from this zone of potential impact.

290. The Margate and Long Sands SAC is adjacent to the offshore cable corridor and therefore within the zone of influence. The low impact magnitude and negligible sensitivity outlined above would result in a negligible effect significance on the physical processes of the Margate and Long Sands SAC. The significance of effects on the biological receptors of the SAC are assessed in Chapter 10 Benthic and intertidal ecology (Volume I).

291. Inshore of the closure depth, the placement of cable protection could result in a medium impact magnitude within the zone of influence (the Tendring Peninsula). While the sensitivity of the Essex coastline is predominantly medium, the presence of coastal protection along the Tendring Peninsula means that changes to the sediment transport regime would have an effect of negligible significance on the Tendring coast. In reality, cable protection could form a similar beneficial function to the existing groynes, which are aimed at restricting the flow of sediment to protect the coastline.

292. The significance of the effects on other receptors is addressed within the relevant chapters of this PEIR (see Section 8.10).

8.6.3.7 Impact 7: Changes in SSC due to cable repairs and reburial

293. Cable repairs and reburial could be needed over the operational lifetime of North Falls.

294. The maximum disturbance area for a cable repair is predicted to be 0.014km^2 (based on 24m width and 600m repair length). Four repairs of the array and interconnector cables and four repairs of the export cables are estimated over the Project life. The location of these repairs is unknown.

295. As a worst case scenario, it is estimated that 5km of the array, interconnector and export cables could require reburial over the Project life. The disturbance width of reburial would be 24m.

296. The sediment volumes arising from repair and reburial would be small in magnitude and cause an insignificant impact in terms of enhanced SSCs and deposition elsewhere.

297. There is potential for the temporary physical disturbance associated with maintenance and repair operations to be located within the Kentish Knock East MCZ in the south array and/or Annex I sandbanks in the north and south array. In addition, export cable repairs and/or reburial could be adjacent to the Margate and Long Sands SAC.

8.6.3.7.1 Magnitude

298. The worst-case changes in terms of indentations on the seabed due to maintenance vessels and cable repair and reburial footprints would have the magnitudes of impact shown in Table 8.43.

Table 8.43: Magnitude of impact on the seabed under the worst case scenario for maintenance vessels

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Near-field	Low	Negligible	Negligible	Negligible	Negligible
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

8.6.3.7.2 Sensitivity

299. Due to the nature of the pressure (increase in SSCs due to cable repairs or reburial) there is no pathway for effect to all identified receptors so therefore they are not sensitive to this pressure.

8.6.3.7.3 Impact significance

300. The assessment indicates that temporary physical disturbance may occur to Kentish Knock East MCZ (Table 8.2). Although temporary physical disturbance may occur, this area is a very small part of the MCZ (0.02%) and the need for cable repairs and/or reburial is likely to be intermittent in nature. In addition, no sediment would be removed from the MCZ during maintenance activities. Due to the short duration and small scale of any maintenance works (if required) there will be no effect on the form or function of the site. Therefore, the significance is assessed as negligible adverse (not significant).

8.6.3.8 Impact 8: Indentations on the seabed due to O&M vessels

301. For cable repair and reburial, anchor placement may be required with a total footprint of 4,914 m^2.

302. Wind turbines and OSP maintenance may also need to be carried out, requiring the use of jack up or anchored vessels. The worst case scenario disturbance areas during maintenance are presented in Table 8.2.

303. Where legs or anchors are temporarily placed on the seabed, there is potential for an indentation to remain proportional in size to the dimensions of the object. There is also potential for local effects on waves, tides and sediment transport and for local scour-hole formation around the legs or anchors while they remain in place for the duration of the maintenance works.

304. There is potential for the temporary physical disturbance associated with maintenance and repair operations to be located within the Kentish Knock East MCZ in the south array and/or Annex I sandbanks in the north and south array. All other receptors listed in Table 8.13 are beyond the zone of influence of seabed indentations from O&M vessels.

8.6.3.8.1 Magnitude

305. The worst-case changes in terms of indentations on the seabed due to maintenance vessels would have the magnitudes of impact shown in Table 8.43.

Table 8.44: Magnitude of impact on the seabed under the worst case scenario for maintenance vessels

Location	Scale	Duration	Frequency	Reversibility	Magnitude
Near-field (footprint of leg/anchor)	High	Negligible	Negligible	Medium	Medium
Near-field (beyond the footprint of the leg/anchor)	No change	-	-	-	No change
Far-field	No change	-	-	-	No change

8.6.3.8.2 Sensitivity

306. The sensitivity and value of all relevant receptors are presented in Table 8.45.

Table 8.45 Sensitivity and value assessment of relevant receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Annex 1 sandbank	Negligible	Negligible	Negligible	High	Negligible
Kentish Knock East MCZ	Negligible	Negligible	Negligible	High	Negligible

8.6.3.8.3 Impact significance

307. The near-field impacts are confined to the footprint of each vessel, and therefore have no pathway to the Essex coast, Suffolk coast, Margate and Long Sands SAC and Orford Inshore MCZ receptors. There is therefore no change.

308. The assessment indicates that temporary physical disturbance may occur to Kentish Knock East MCZ (Table 8.2). Although temporary physical disturbance

may occur, this area is a very small part of the MCZ (0.3%) and the need for cable repairs is likely to be intermittent in nature. In addition, no sediment would be removed from the MCZ during maintenance activities. Due to the short duration and small scale of any maintenance works (if required) there will be no effect on the form or function of the site. Therefore, it is assessed as negligible adverse effect (not significant).

309. Due to the dynamic nature of sand banks and sandwaves in this area, it is not known whether cable repair and reburial will directly impact on this receptor during the operation phase. However, due to the short duration and small-scale nature of any maintenance works (if required) it is anticipated that if they are present within the area at the time of cable repairs and reburial there will be a negligible adverse effect to Annex I sandbanks which is not significant.

310. The significance of the effects on other receptors is addressed within relevant chapters of this PEIR (see Section 8.10).

8.6.4 Decommissioning phase

311. The scope of the decommissioning works would most likely involve removal of the accessible installed components. This is outlined in Section 5.5.16 of Chapter 5 Project Description (Volume I) and the detail would be agreed with the relevant authorities at the time of decommissioning. Offshore, this is likely to include removal of all the wind turbine components and part of the foundations (those above seabed level). Some or all of the array cables, interconnector cables, and export cables may also be removed. Scour and cable protection would likely be left in situ. Table 8.2 provides an indicative worst case scenario for decommissioning.

312. During the decommissioning phase, there is potential for wind turbine foundation and cable removal activities to cause changes in SSCs and/or seabed or shoreline levels because of sediment disturbance effects. The types of effect would be comparable to those identified for the construction phase:

- Impact 1 Changes in SSCs due to foundation removal;
- Impact 2 Changes in seabed level due to foundation removal;
- Impact 3 Changes in SSCs due to removal of parts of the export cable;
- Impact 4 Changes in seabed level due to removal of parts of the export cable;
- Impact 5 Changes in SSCs due to removal of parts of the array and interconnector cables;
- Impact 6 Changes in seabed level due to removal of parts of the array and interconnector cables; and
- Impact 7 Indentations on the seabed due to decommissioning vessels.

313. The magnitude of impacts would be comparable to or less than those identified for the construction phase. Accordingly, given the construction phase assessments concluded “no change” or “negligible adverse effects” for marine geology, oceanography and physical processes receptors, it is anticipated that

the same would be valid for the decommissioning phase regardless of the final decommissioning methodologies.

314. The significance of effects on other receptors is addressed within relevant chapters of this PEIR (Chapter 9 Marine Water and Sediment Quality, Chapter 12 Benthic and Intertidal Ecology, Chapter 12 Fish and Shellfish Ecology, Chapter 14 Marine Mammals and Chapter 15 Offshore Ornithology, Volume I).

8.7 Potential monitoring requirements

315. No further monitoring is proposed in relation to marine geology, oceanography and physical processes. This is on account of the outcomes of the assessment, which has concluded that all of the potential impacts considered will result in either no change or, at worse, negligible adverse effects (i.e. no significant effects). The conclusions can be made with a high degree of certainty on account of an accumulation of evidence from a range of studies and other existing wind farms (details in Section 8.4.2). However, as is typical for development projects of this nature, a range of geophysical surveys will be carried out both before and after construction both for engineering / asset integrity purposes and to feed into the requirements for other environmental topics such as benthic ecology and archaeology.

8.8 Cumulative effects

8.8.1 Identification of potential cumulative effects

316. The first step in the CEA process is the identification of which residual effects assessed for North Falls on their own have the potential for a cumulative effect with other plans, projects and activities. This information is set out in Table 8.46. Only potential impacts assessed in Section 8.6.2 as negligible adverse or above are included in the CEA (i.e. those assessed as 'no impact' are not taken forward as there is no potential for them to contribute to a cumulative impact).

Table 8.46 Potential cumulative effects

Impact	Potential for cumulative effect	Rationale
Construction		
Construction Impact 2a: Changes in seabed level due to seabed preparation for foundation installation	Yes	Although there is not a sufficient level of information known at this stage, there is a potential temporal overlap in installation activities for the NeuConnect Interconnector, which bisects the North Falls offshore cable corridor and interconnector cable corridor, and the construction of cables and foundations for North Falls. Depending on their construction programmes, there is also a potential temporal overlap in construction of Five Estuaries and East Anglia TWO offshore windfarms.
Construction Impact 2b: Changes in seabed level due to drill arisings for installation of piled foundations for wind turbines and OSPs		
Construction Impact 4: Changes in seabed level due to deposition from the suspended sediment plume during export cable installation		

Impact	Potential for cumulative effect	Rationale
[negligible adverse effect applies to Essex coast, Margate and Long Sands SAC, Annex I sandbanks and Kentish Knock East MCZ receptors only]		
Construction Impact 6: Changes in seabed level due to the deposition from the suspended sediment plume during array and interconnector cable installation		
Construction Impact 7: Interruptions to bedload sediment transport due to sandwave levelling for offshore cable installation [negligible adverse effect applies to Essex coast, Annex I sand banks and Margate and Long Sands SAC receptors only]	No	Impacts occur at discrete locations for a time-limited duration and are local in nature with a low impact magnitude.
Construction Impact 8: Indentations on the seabed due to installation vessels [negligible adverse effect applies to Margate and Long Sands SAC, Annex I sandbanks and Kentish Knock East MCZ receptors only]		
Operation		
Operational Impact 1: Changes to the tidal regime due to the presence of structures on the seabed (wind turbines and OSP foundations)	Yes	Impacts could occur potentially coalesce with those arising from other windfarms.
Operational Impact 2: Changes to the wave regime due to the presence of structures on the seabed (wind turbine and OSP foundations)		
Operational Impact 3: Changes to the sediment transport regime due to the presence of structures on the seabed (wind turbine and OSP foundations)		
Operational Impact 4 Loss of seabed area due to infrastructure within the array areas [negligible adverse effect applies to Annex I sandbanks and Kentish Knock East MCZ receptors only]	No	Impacts occur at discrete locations within the North Falls array areas and therefore there will be no cumulative impact.

Impact	Potential for cumulative effect	Rationale
Operational Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor [negligible adverse effect applies to Margate Long Sands SAC only]	No	Impacts occur at discrete locations within the North Falls offshore cable corridor and therefore there will be no cumulative impact.
Operational Impact 7 Cable repairs and reburial [negligible adverse effect applies to Annex I sandbanks and Kentish Knock East MCZ receptors only]	No	Impacts will be highly localised around the foundations and cables and therefore there will be no cumulative impact.
Decommissioning		
Decommissioning Impact 2 Changes in seabed level due to foundation removal	No	Impacts occur at discrete locations for a time-limited duration and negligible adverse in magnitude.
Decommissioning Impact 4 Changes in seabed level due to removal of parts of the export cable		
Decommissioning Impact 6 Changes in seabed level due to removal of parts of the array and interconnector cables		
Decommissioning Impact 7 Indentations on the seabed due to decommissioning vessels		

8.8.2 Other plans, projects and activities

317. The second step in the cumulative assessment is the identification of the other plans, projects and activities that may result in cumulative effects for inclusion in the CEA (described as 'project screening'). This information is set out in Table 8.47 below, together with a consideration of the relevant details of each, including current status (e.g. under construction), planned construction period, closest distance to North Falls, status of available data and rationale for including or excluding from the assessment.

318. The project screening has been informed by the development of a CEA project list which forms an exhaustive list of plans, projects and activities within the study area (Section 8.3.1) relevant to North Falls. The list has been appraised, based on the confidence 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.

Table 8.47 Summary of projects considered for the CEA in relation to marine geology, oceanography and physical processes (project screening)

Plan or project	Status	Construction period	Closest distance from the Project	Closest distance from the offshore cable corridor	Confidence in Data	Included in the CEA (Y/N)	Rationale
NeuConnect Interconnector	Pre-construction	2022-2028	0 km	0 km	High	Yes, subject to available information	The NeuConnect Interconnector bisects the North Falls export cable corridor and interconnector cable corridor and there is potential for temporal overlap of cable installation activities.
BritNed Interconnector	Operational since 2009	N/A	0 km	10.86 km	High	No	The BritNed Interconnector passes through the south of the south array but has been operational since 2009. There is therefore no potential for cumulative impact on the identified receptors.
Nautilus	Early planning	Unknown	Cable route currently unknown		Low	Yes (Subject to available information)	The offshore study area for Nautilus intersects with the North Falls offshore project area, Therefore, there is potential for cumulative effects, subject to the final location and programme for the interconnector.
South & East Anglia (SEA) Link	Early planning	Unknown	Cable route currently unknown		Low	Yes, for offshore construction effects only (Subject to available information)	The emerging preferred and alternative routes for Sea Link intersect with the North Falls offshore cable corridor. Therefore, there is potential for cumulative effects, subject to the final location and programme for the interconnector.
Tarchon Energy Ltd – EA Green Interconnector	Early planning	Unknown	Cable route currently unknown		Low	Yes (Subject to available information)	Interconnector between UK and Germany with potential to be in proximity to the North Falls offshore project area.

Plan or project	Status	Construction period	Closest distance from the Project	Closest distance from the offshore cable corridor	Confidence in Data	Included in the CEA (Y/N)	Rationale
Greater Gabbard offshore wind farm	Operational since 2012	N/A	0 km	5.6 km	Medium	Yes	Potential cumulative effect on wave and tidal regime, and from ongoing maintenance activities.
Galloper offshore wind farm	Operational since 2018	N/A	0 km	8.5 km	Medium	Yes	
Five Estuaries offshore wind farm	In Planning	Unknown	0 km (0.04m)	14.8 km	Medium	Yes	Potential for some interaction between the dredging plumes from the cable/foundation installation from these projects with North Falls. Following construction, there is potential for cumulative effect on wave and tidal regime, and from ongoing maintenance activities.
East Anglia TWO offshore wind farm	Consent granted	Construction planned mid 2020s	14.8 km	37.2 km	High	No	Construction phases unlikely to overlap. Any ongoing effects of maintenance activity from these offshore wind farms will be highly localised and therefore, given the distance from the North Falls offshore project area, there is no pathway for significant cumulative effects.
Thanet offshore wind farm	Operational since 2010	N/A	24.4 km	36.2 km	Medium	No	Any ongoing effects of maintenance activity from these offshore wind farms will be highly localised and therefore, given the distance from the North Falls offshore project area, there is no pathway for significant cumulative effects.
London Array offshore wind farm	Operational since 2013	N/A	19.4 km	15.5 km	Medium		

Plan or project	Status	Construction period	Closest distance from the Project	Closest distance from the offshore cable corridor	Confidence in Data	Included in the CEA (Y/N)	Rationale
Gunfleet Sands offshore wind farm	Operational since 2010	N/A	43.3	10.3 km	Medium		This approach is in keeping with the Galloper EIA, where it was agreed with Cefas and Defra that no assessment of cumulative effects was required with other Round 2 sites in the Thames strategic area (except GGOW).
Outer OTE aggregate exploration and option area 528/2	Unknown	N/A	8.4 km	14 km	Low	Yes, subject to available information	There is potential for some interaction between the dredging plumes from the aggregate exploration and option areas and plumes from cable/foundation installation / decommissioning and operation and maintenance activities.
East Orford Ness aggregate exploration and option area 1809	Unknown	N/A	2 km	24.8 km	Low	Yes, subject to available information	
Thames D aggregates production agreement area 524	Production agreement secured 2022	2022-2036	0 km	12.5 km	Low	Yes, subject to available information	

Plan or project	Status	Construction period	Closest distance from the Project	Closest distance from the offshore cable corridor	Confidence in Data	Included in the CEA (Y/N)	Rationale
Southwold East aggregates production agreement area 430	Operational since 2012	N/A	27.3 km	48.4 km	Medium	No	Sites which were operational at the time of the North Falls characterisation surveys are a component of the baseline environment.
North Inner Gabbard aggregate production agreement area 498	Operational since 2015	N/A	1.7 km	24 km	Medium	No	
Shipwash aggregate production agreement area 507	Operational since 2016	N/A	0.2 km	9.8 km	Medium	No	
Longsand aggregate production agreement area 508	Operational since 2014	N/A	11.7 km	5.8 km	Medium	No	
Longsand aggregate production agreement area 509	Operational since 2015	N/A	11.7 km	2.1 km	Medium	No	
Longsand aggregate	Operational since 2015	N/A	7.3 km	3.5 km	Medium	No	

Plan or project	Status	Construction period	Closest distance from the Project	Closest distance from the offshore cable corridor	Confidence in Data	Included in the CEA (Y/N)	Rationale
production agreement area 510							
North Falls East production agreement area and option area 501	Operational since 2017	N/A	13.2 km	27.5 km	Medium	No	

8.8.3 Assessment of cumulative impacts

8.8.3.1 Cumulative impacts with the Interconnectors

319. The NeuConnect Interconnector bisects the North Falls offshore cable corridor and interconnector cable corridor and there is potential for temporal overlap of cable installation activities.

320. The cable routes of the Nautilus, Tarchon Energy and Sea Link Interconnectors are not yet known and therefore these will be considered further in the ES, if sufficient information is available.

321. The worst case scenario from a marine geology, oceanography and physical processes perspective would be for the Interconnector and North Falls to be constructed at the same time. This would provide the greatest opportunity for interaction of sediment plumes and a larger change in seabed level during their construction. The combined change in seabed level from foundation and/or cable installation could have a greater spatial extent and be greater in a vertical sense than both individual projects, however in the context of the study area this would be of negligible magnitude.

322. As for North Falls alone, the majority of suspended sediment arising from foundation and array cable installation would fall rapidly to the seabed after the start of construction and therefore the potential cumulative impact would be of negligible magnitude.

323. The receptor sensitivity would also be negligible and therefore it is considered that the cumulative effect of both projects constructing in this area at the same time would be negligible adverse which is not significant.

8.8.3.2 Cumulative impacts with adjacent windfarms

324. The effects of the foundation and offshore cable installation and decommissioning activities (including works at the landfall) on the identified receptors were identified of negligible adverse effect for North Falls alone.

325. The construction programme of Five Estuaries may overlap with North Falls construction programme and North Falls construction is likely to follow sequentially to East Anglia TWO construction.

326. The worst case scenario from a marine geology, oceanography and physical processes perspective would be for all projects to be constructed have some overlap in their construction phases. This would provide the greatest opportunity for interaction of sediment plumes and a larger change in seabed level during their construction. The combined change in seabed level sediment plume from foundation and cable installation could have a greater spatial extent and be greater in a vertical sense than each individual project.

327. As for North Falls alone, the majority of suspended sediment arising from each project would fall rapidly to the seabed after the start of construction and therefore the potential cumulative impact would be of negligible magnitude. The receptor sensitivity would also be negligible and therefore it is considered that the cumulative effect of two or three projects constructing in this area at the same time would be negligible adverse which is not significant.

8.8.3.3 Cumulative impacts with adjacent wind farms

328. From an operation and maintenance perspective, Figure 8.13 (Volume II) shows the likely maximum zone of influence arising from the proposed North Falls project with GWF and GGOW based on the direction of the predominant waves. It was agreed that no assessment of cumulative effects was required for GWF with other Round 2 sites in the Thames strategic area and therefore they are not considered for North Falls (ABPmer, 2011).

329. The overlap of the ‘zones of influence’ effectively represents the enlargement of three separate zones into a single ‘zone of influence’ of a much larger windfarm. In this respect, the pre-existing scientific evidence base and the results of the GWF modelling (Sections 8.6.3.1 and 8.6.3.2), which demonstrate that changes in tidal currents and waves due to the presence of foundation structures are both small in magnitude and localised in spatial extent, applies cumulatively. Hence, the potential cumulative effect between GWF, GGOW offshore windfarm and North Falls is considered to be negligible adverse.

330. This is supported by modelling undertaken for East Anglia ONE North and TWO (located approximately 15m north east of the North Falls north array), which demonstrated no significant impact on the wave or tidal regime as a result of the windfarms.

331. Increases in suspended sediment caused by maintenance activities over the operational lifespan of North Falls, GWF and GGOW will be minimal and considerably less than during construction. The majority of suspended sediment arising from each maintenance activity would fall rapidly to the seabed after the start of construction and therefore the potential cumulative impact would be of negligible magnitude. The receptor sensitivity would also be negligible and therefore it is considered that the cumulative effect of maintenance activities of three projects in this area at the same time would be negligible adverse which is not significant.

8.8.3.4 Cumulative impacts with marine aggregate dredging

332. To assess the potential for cumulative effects between the installation of offshore cable and marine aggregate dredging activities in adjacent areas of the seabed, reference has been made to the GWF EIA and supporting technical appendix by ABPmer (2011). Although the cable corridor route is different the results provide a useful and appropriate analogy for North Falls.

333. The CEA for GWF determined that based on previous modelling investigations undertaken for dredging areas (which were closer to GGOW), no cumulative impact was predicted. This was supported by results from monitoring of plume dispersal from dredging activities undertaken by Oakwood Environmental (1999) and numerical modelling studies undertaken for the Outer Thames MAREA, which concluded that SSCs outside the licensed dredging areas were less than 20mg/l above background levels (except at the boundary, where they were within the range of natural variability) (HR Wallingford, 2010). It was considered that due to the similar physical conditions of GWF and GGOW, an assessment of ongoing dredging activities and foundation/cable installation for GWF was not necessary (ABPmer, 2011).

334. Given the similarity in the physical environments of North Falls and GWF (outlined in Section 8.4.6), an assessment of cumulative effects of ongoing

dredging activities and foundation/cable installation for North Falls is not necessary.

335. The Outer Thames MAREA found that changes in current speeds of greater than 5% did not extend outside the boundaries of the aggregate dredging areas (HR Wallingford, 2010). Changes in seabed morphology following aggregate dredging would be limited to very restricted parts of the seabed adjacent to the licenced or proposed dredging areas (HR Wallingford, 2010). Therefore, given the distance of the majority of the aggregate dredging areas (Table 8.47), no cumulative impacts and effects are expected during the operation phase.

336. The 'Thames D aggregates production agreement area 524' is located less than 0.5km from the array areas and therefore there is potentially a cumulative effect on the hydrodynamic regime. Given the impact on the hydrodynamic regime from aggregate dredging is restricted to the boundaries of the licenced or proposed dredge area, the cumulative effect is expected to be minimal. Therefore, the significance is still considered negligible adverse which is not significant.

8.8.4 Summary of cumulative impacts

337. Given the localised nature of the impacts described above, the overall cumulative effect significance is predicted to remain negligible (not significant).

8.9 Transboundary impacts

338. Given that there will be no change to the hydrodynamic and sedimentary regime as a result of North Falls, transboundary impacts are unlikely to occur, or are unlikely to be significant, and therefore transboundary impacts are scoped out of further assessment in accordance with the scoping opinion (Planning Inspectorate, 2021).

8.10 Inter-actions

339. There are clear inter-actions between the marine geology, oceanography and physical processes topic and several other topics that have been considered within this PEIR. Table 8.48 provides a summary of the principal inter-actions and sign-posts to where those issues have been addressed in the relevant chapters.

Table 8.48 Marine Geology, Oceanography and Physical Processes inter-relationships

Topic and description	Related chapter (Volume I)	Where addressed in this chapter	Rationale
Construction			
Effects on water column (suspended sediment concentrations)	Chapter 9 Marine Water and Sediment Quality Chapter 13 Fish and Shellfish Ecology	Section 8.6.2.1 and Section 8.6.2.2 (foundation installation) Section 8.6.2.5 (export cable installation)	Suspended sediment could be contaminated and could cause disturbance to fish and benthic species through smothering.

Topic and description	Related chapter (Volume I)	Where addressed in this chapter	Rationale
	Chapter 16 Commercial Fisheries Chapter 12 Benthic and Intertidal Ecology	Section 8.6.2.7 (array and interconnector installation)	
Effects on seabed (morphology / sediment composition)	Chapter 12 Benthic and Intertidal Ecology Chapter 13 Fish and Shellfish Ecology Chapter 16 Commercial Fisheries Chapter 17 Shipping and Navigation Chapter 18 Offshore Archaeology and Cultural Heritage	Section 8.6.2.1 and Section 8.6.2.2 (foundation installation) Section 8.6.2.5 (export cable installation) Section 8.6.2.7 (array and interconnector installation) Section 8.6.2.10 (installation vessels)	Disruption to seabed morphology and sediment composition could affect these receptors by altering the existing sedimentary environment, however this is unlikely to be to levels which are significant.
Operation			
Effects on shoreline (morphology / sediment transport / sediment composition)	Chapter 12 Benthic and Intertidal Ecology Chapter 23 Water Resources and Flood Risk Chapter 31 Seascape and Visual Impact Assessment Chapter 32 Landscape and Visual Amenity		Disruption to shoreline morphology could potentially impact on these chapters through a change to the existing shoreline environment which could have implications for the receptors associated with these chapters.
Effects on seabed (sediment transport processes / morphology)	Chapter 12 Benthic and Intertidal Ecology Chapter 13 Fish and Shellfish Ecology Chapter 16 Commercial Fisheries Chapter 17 Shipping and Navigation Chapter 18 Offshore Archaeology and Cultural Heritage	Section 8.6.3.3 (sediment transport regime) Section 8.6.3.4 (loss of seabed area) Section 8.6.3.5 (array and interconnector cable protection) Section 8.6.3.6 (export cable protection in the offshore zone)	Disruption to sediment transport processes or loss of seabed area could affect these receptors by altering the existing sedimentary environment, however this is unlikely to be to levels which are significant.
Decommissioning			

Topic and description	Related chapter (Volume I)	Where addressed in this chapter	Rationale
Inter-relationships for impacts during the decommissioning phase will be the same as those outlined above for the construction phase.			

8.11 Inter-relationships

340. The impacts identified and assessed in this chapter have the potential to inter-relate with each other. The areas of potential inter-relationships between impacts are presented in Table 8.49. This provides a screening tool for which impacts have the potential to interrelate. Table 8.49 provides an assessment for each receptor (or receptor group) as related to these impacts.

341. Within Table 8.50 the impacts are assessed relative to each development phase (i.e. construction, operation or decommissioning) to see if (for example) multiple construction impacts affecting the same receptor could increase the significance of effect upon that receptor. Following this, a lifetime assessment is undertaken which considers the potential for impacts to affect receptors across all development phases (Table 8.50).

342. The impacts listed in Table 8.49 are expressed on the following receptors in Table 8.50:

- Essex coast;
- Suffolk coast;
- Annex I sandbanks;
- Margate and Long Sands SAC;
- Kentish Knock East MCZ; and
- Orford Inshore MCZ.

Table 8.49 Inter-relationships between impacts – screening

Construction										
	Impact 1a: Changes in SSCs due to seabed preparation for foundation installation (array areas)	**Impact 1b: Changes in SSCs due to drill arisings for installation of piled foundation for wind turbines (array areas)**	**Impact 2a: Changes in seabed level due to seabed preparation for foundation installation**	**Impact 2b: Changes in seabed level due to drill arisings for installation of piled foundations**	**Impact 3: Changes in SSCs due to export cable installation**	**Impact 4: Changes in seabed level due to deposition from the suspended sediment plume during export cable installation**	**Impact 5: Changes in SSCs due to offshore cables installation (array and interconnector cables)**	**Impact 6: Changes in seabed level due to offshore cables installation (array and interconnector cables)**	**Impact 7: Interruptions to bedload sediment transport due to sandwave levelling for offshore cable installation (array and interconnector cables)**	**Impact 8: Indentations on the seabed due to installation vessels**
Impact 1a: Changes in SSCs due to seabed preparation for foundation installation (array areas)	-	No	Yes	No	Yes	Yes	Yes	Yes	No	No
Impact 1b: Changes in SSCs due to drill arisings for installation of piled foundations for wind turbines (array areas)	No	-	No	Yes	Yes	Yes	Yes	Yes	No	No
Impact 2a: Changes in seabed level due to seabed preparation for foundation installation	Yes	No	-	No	Yes	Yes	Yes	Yes	No	Yes

Construction	Impact 1a: Changes in SSCs due to seabed preparation for foundation installation (array areas)	Impact 1b: Changes in SSCs due to drill arisings for installation of piled foundation for wind turbines (array areas)	Impact 2a: Changes in seabed level due to seabed preparation for foundation installation	Impact 2b: Changes in seabed level due to drill arisings for installation of piled foundations	Impact 3: Changes in SSCs due to export cable installation	Impact 4: Changes in seabed level due to deposition from the suspended sediment plume during export cable installation	Impact 5: Changes in SSCs due to offshore cables installation (array and interconnector cables)	Impact 6: Changes in seabed level due to offshore cables installation (array and interconnector cables)	Impact 7: Interruptions to bedload sediment transport due to sandwave levelling for offshore cable installation (array and interconnector cables)	Impact 8: Indentations on the seabed due to installation vessels
Impact 2b: Changes in seabed level due to drill arisings for installation of piled foundations	No	Yes	No	-	Yes	Yes	Yes	Yes	No	Yes
Impact 3: Changes in SSCs due to export cable installation	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	No	No
Impact 4: Changes in seabed level due to deposition from the suspended sediment plume during export cable installation	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	No	Yes
Impact 5: Changes in SSCs due to offshore	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes	No	No

Construction	Impact 1a: Changes in SSCs due to seabed preparation for foundation installation (array areas)	Impact 1b: Changes in SSCs due to drill arisings for installation of piled foundation for wind turbines (array areas)	Impact 2a: Changes in seabed level due to seabed preparation for foundation installation	Impact 2b: Changes in seabed level due to drill arisings for installation of piled foundations	Impact 3: Changes in SSCs due to export cable installation	Impact 4: Changes in seabed level due to deposition from the suspended sediment plume during export cable installation	Impact 5: Changes in SSCs due to offshore cables installation (array and interconnector cables)	Impact 6: Changes in seabed level due to offshore cables installation (array and interconnector cables)	Impact 7: Interruptions to bedload sediment transport due to sandwave levelling for offshore cable installation (array and interconnector cables)	Impact 8: Indentations on the seabed due to installation vessels
cables installation (array and interconnector cables)										
Impact 6: Changes in seabed level due to offshore cables installation (array and interconnector cables)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes
Impact 7: Interruptions to bedload sediment transport due to sandwave levelling for offshore cable installation (array and interconnector cables)	No	No	No	No	No	No	No	Yes	-	No

Construction	Impact 1a: Changes in SSCs due to seabed preparation for foundation installation (array areas)	Impact 1b: Changes in SSCs due to drill arisings for installation of piled foundation for wind turbines (array areas)	Impact 2a: Changes in seabed level due to seabed preparation for foundation installation	Impact 2b: Changes in seabed level due to drill arisings for installation of piled foundations	Impact 3: Changes in SSCs due to export cable installation	Impact 4: Changes in seabed level due to deposition from the suspended sediment plume during export cable installation	Impact 5: Changes in SSCs due to offshore cables installation (array and interconnector cables)	Impact 6: Changes in seabed level due to offshore cables installation (array and interconnector cables)	Impact 7: Interruptions to bedload sediment transport due to sandwave levelling for offshore cable installation (array and interconnector cables)	Impact 8: Indentations on the seabed due to installation vessels
Impact 8: Indentations on the seabed due to installation vessels	No	No	Yes	Yes	No	Yes	No	Yes	No	-

Operation	Impact 1: Changes to the tidal regime due to the presence of structures on the seabed (wind turbines and OSP foundations)	Impact 2: Changes to the wave regime due to the presence of structures on the seabed (wind turbines and OSP foundations)	Impact 3: Changes to the sediment transport regime due to the presence of structures on the seabed (wind turbines and OSP foundations)	Impact 4: Loss of seabed area due to the footprint of wind turbine and OSP foundation structures	Impact 5: Morphological and sediment transport effects due to cable protection measures within the North Falls array areas and interconnector cable corridor	Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor	Impact 7: Cable repairs and reburial
Impact 1: Changes to the tidal regime due to the presence of structures on the seabed (wind turbines and OSP foundations)	-	Yes	No	No	No	No	No
Impact 2: Changes to the wave regime due to the presence of structures on the seabed (wind turbines and OSP foundations)	Yes	-	No	No	No	No	No
Impact 3: Changes to the sediment transport regime due to the presence of structures on the seabed (wind turbines and OSP foundations)	No	No	-	No	Yes	Yes	No
Impact 4: Loss of seabed area due to the footprint of wind turbine and OSP foundation structures	No	No	No	-	No	No	No
Impact 5: Morphological and sediment transport effects due to cable	No	No	Yes	No	-	Yes	No

Operation	Impact 1: Changes to the tidal regime due to the presence of structures on the seabed (wind turbines and OSP foundations)	Impact 2: Changes to the wave regime due to the presence of structures on the seabed (wind turbines and OSP foundations)	Impact 3: Changes to the sediment transport regime due to the presence of structures on the seabed (wind turbines and OSP foundations)	Impact 4: Loss of seabed area due to the footprint of wind turbine and OSP foundation structures	Impact 5: Morphological and sediment transport effects due to cable protection measures within the North Falls array areas and interconnector cable corridor	Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor	Impact 7: Cable repairs and reburial
protection measures within the North Falls array areas and interconnector cable corridor							
Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor	No	No	Yes	No	Yes	-	No
Impact 7: Cable repairs and reburial	No	No	No	No	No	No	-

Decommissioning	Impact 1 Changes in SSCs due to foundation removal	Impact 2 Changes in seabed level due to foundation removal	Impact 3 Changes in SSCs due to removal of parts of the export cable	Impact 4 Changes in seabed level due to removal of parts of the export cable	Impact 5 Changes in SSCs due to removal of parts of the array and interconnector cables	Impact 6 Changes in seabed level due to removal of parts of the array and interconnector cables	Impact 7 Indentations on the seabed due to decommissioning vessels
Impact 1 Changes in SSCs due to foundation removal	-	No	No	No	Yes	Yes	Yes

Decommissioning	Impact 1 Changes in SSCs due to foundation removal	Impact 2 Changes in seabed level due to foundation removal	Impact 3 Changes in SSCs due to removal of parts of the export cable	Impact 4 Changes in seabed level due to removal of parts of the export cable	Impact 5 Changes in SSCs due to removal of parts of the array and interconnector cables	Impact 6 Changes in seabed level due to removal of parts of the array and interconnector cables	Impact 7 Indentations on the seabed due to decommissioning vessels
Impact 2 Changes in seabed level due to foundation removal	No	-	No	No	Yes	Yes	Yes
Impact 3 Changes in SSCs due to removal of parts of the export cable	No	No	-	Yes	No	No	Yes
Impact 4 Changes in seabed level due to removal of parts of the export cable	No	No	Yes	-	No	No	Yes
Impact 5 Changes in SSCs due to removal of parts of the array and interconnector cables	Yes	Yes	No	No	-	Yes	Yes
Impact 6 Changes in seabed level due to removal of parts of the array and interconnector cables	Yes	Yes	No	No	Yes	-	Yes
Impact 7 Indentations on the seabed due to decommissioning vessels	Yes	Yes	Yes	Yes	Yes	Yes	-

Table 8.50 Inter-relationships between impacts – phase and lifetime assessment

Receptor		Highest significance level Construction	 Operation	 Decommissioning	Phase assessment	Lifetime assessment
Suffolk Coast	Southwold to Clacton-on- Sea	Negligible	Negligible	Negligible	No greater impact than individually assessed impact. The impacts are considered to have negligible adverse magnitude of impact on the receptor. Given that that each impact will be managed with standard and best practice methodologies it is considered that there would either be no interactions or that these would not result in greater impact than assessed individually.	No greater than individually assessed impact
Essex Coast (Landfall location)	Coast between Clacton-on-Sea and Frinton-on-Sea, Essex	Negligible	Negligible	Negligible	No greater impact than individually assessed impact. The impacts are considered to have negligible adverse magnitude of impact on the receptor. Given that that each impact will be managed with standard and best practice methodologies it is considered that there would either be no interactions or that these would not result in greater impact than assessed individually.	No greater than individually assessed impact
Designated sites and features	Annex 1 Sandbank (Annex 1 Reef will be addressed in the benthic ecology section)	Negligible	Negligible	Negligible	No greater impact than individually assessed impact. The impacts are considered to have negligible adverse magnitude of impact on the receptor. Given that that each impact will be managed with standard and best practice methodologies it is considered that there would either be no interactions or that these would not result in greater impact than assessed individually.	No greater than individually assessed impact
	Margate and Long Sands SAC	Negligible	Negligible	Negligible	No greater impact than individually assessed impact. The impacts are considered to have negligible adverse magnitude of impact on the receptor. Given that that each impact will be managed with standard and best practice methodologies it is considered that there would either be no interactions or that these would not result in greater impact than assessed individually.	No greater than individually assessed impact
	Kentish Knock East MCZ	Negligible	Negligible	Negligible	No greater impact than individually assessed impact. The impacts are considered to have negligible adverse magnitude of impact on the receptor. Given that that each	No greater than individually

Receptor		Highest significance level Construction	Operation	Decommissioning	Phase assessment	Lifetime assessment
					impact will be managed with standard and best practice methodologies it is considered that there would either be no interactions or that these would not result in greater impact than assessed individually.	assessed impact
	Orford Inshore MCZ	Negligible	Negligible	Negligible	No greater impact than individually assessed impact. The impacts are considered to have negligible adverse magnitude of impact on the receptor. Given that that each impact will be managed with standard and best practice methodologies it is considered that there would either be no interactions or that these would not result in greater impact than assessed individually.	No greater than individually assessed impact

8.12 Summary

343. This chapter has provided a characterisation of the existing environment for marine geology, oceanography and physical processes based on both existing and site-specific survey data, which has established that the effects on the identified receptors during construction, operation and decommissioning phases of North Falls are considered 'negligible adverse' or 'no change' and therefore not significant.

344. The specific receptors that have been identified in relation to this topic are Annex 1 Sandbanks, Margate and Long Sands SAC, Kentish Knock East MCZ, Orford Inshore MCZ, and the Suffolk and Essex coasts.

345. The impacts that have been assessed are mostly anticipated to result in no change to the above-mentioned receptors because they are located remotely from the zones of influence and no pathway has been identified that can link the source to the receptor. A summary of impacts to these receptors are listed in Table 8.51.

Table 8.51 Summary of potential impacts on Marine Geology, Oceanography and Physical Processes topic

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation significance	Additional mitigation measures proposed	Residual significance
Construction						
Impact 1a: Changes in suspended sediment concentrations due to seabed preparation for foundation installation (array areas)	Essex coast	N/A	Medium (near-field) Low (far-field)	No change	N/A	No change
	Suffolk coast	N/A	Medium (near-field) Low (far-field)	No change	N/A	No change
	Annex 1 sandbanks	N/A	Medium (near-field) Low (far-field)	No change	N/A	No change
	Margate and Long Sands SAC	N/A	Medium (near-field) Low (far-field)	No change	N/A	No change
	Kentish Knock East MCZ	N/A	Medium (near-field) Low (far-field)	No change	N/A	No change
	Orford Inshore MCZ	N/A	Medium (near-field) Low (far-field)	No change	N/A	No change
Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines and OSPs	Essex coast	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change
	Suffolk coast	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change
	Annex 1 sandbanks	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change
	Margate and Long Sands SAC	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change
	Kentish Knock East MCZ	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation significance	Additional mitigation measures proposed	Residual significance
	Orford Inshore MCZ	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change
Impact 2a: Changes in seabed level due to seabed preparation for foundation installation	Essex coast	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Suffolk coast	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Annex 1 sandbanks	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Margate and Long Sands SAC	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Kentish Knock East MCZ	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Orford Inshore MCZ	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
Impact 2b: Changes in seabed level due to drill arisings for installation of piled foundations for wind turbines and OSPs	Essex coast	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Suffolk coast	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Annex 1 sandbanks	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Margate and Long Sands SAC	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Kentish Knock East MCZ	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation significance	Additional mitigation measures proposed	Residual significance
	Orford Inshore MCZ	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
Impact 3: Changes in suspended sediment concentrations due to export cable installation	Essex coast	N/A	Negligible (near-field (nearshore)) Negligible (near-field (offshore)) Negligible (far-field)	No change	N/A	No change
	Suffolk coast	N/A	Negligible (near-field (nearshore)) Negligible (near-field (offshore)) Negligible (far-field)	No change	N/A	No change
	Annex 1 sandbanks	N/A	Negligible (near-field (nearshore)) Negligible (near-field (offshore)) Negligible (far-field)	No change	N/A	No change
	Margate and Long Sands SAC	N/A	Negligible (near-field (nearshore)) Negligible (near-field (offshore)) Negligible (far-field)	No change	N/A	No change
	Kentish Knock East MCZ	N/A	Negligible (near-field (nearshore)) Negligible (near-field (offshore)) Negligible (far-field)	No change	N/A	No change
	Orford Inshore MCZ	N/A	Negligible (near-field (nearshore))	No change	N/A	No change

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation significance	Additional mitigation measures proposed	Residual significance
			Negligible (near-field (offshore)) Negligible (far-field)			
Impact 4: Changes in seabed level due to deposition from the suspended sediment plume during export cable installation	Essex coast	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Suffolk coast	Negligible	Low (near-field) Negligible (far-field)	No impact	N/A	No impact
	Annex 1 sandbanks	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Margate and Long Sands SAC	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Kentish Knock East MCZ	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Orford Inshore MCZ	Negligible	Low (near-field) Negligible (far-field)	No change	N/A	No change
Impact 5: Changes in suspended sediment concentrations due to offshore cables installation (array and interconnector cables)	Essex coast	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change
	Suffolk coast	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change
	Annex 1 sandbanks	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change
	Margate and Long Sands SAC	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change
	Kentish Knock East MCZ	N/A	Negligible (near-field)	No change	N/A	No change

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation significance	Additional mitigation measures proposed	Residual significance
			Negligible (far-field)			
	Orford Inshore MCZ	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change
Impact 6: Changes in seabed level due to offshore cable installation (array and interconnector cables)	Essex coast	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Suffolk coast	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Annex 1 sandbanks	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Margate and Long Sands SAC	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Kentish Knock East MCZ	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Orford Inshore MCZ	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
Impact 7: Interruptions to bedload sediment transport due to sandwave levelling for offshore cable installation (array and interconnector cables)	Essex coast	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Suffolk coast	Negligible	Low (near-field) Negligible (far-field)	No change	N/A	No change
	Annex 1 sandbanks	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Margate and Long Sands SAC	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation significance	Additional mitigation measures proposed	Residual significance
	Kentish Knock East MCZ	Negligible	Low (near-field) Negligible (far-field)	No change	N/A	No change
	Orford Inshore MCZ	Negligible	Low (near-field) Negligible (far-field)	No change	N/A	No change
Impact 8: Indentations on the seabed due to installation vessels	Essex coast	Negligible	Medium (near field (footprint of leg/anchor)) No change (near field (beyond the footprint of leg/anchor)) No change (far field)	Negligible	N/A	Negligible
	Suffolk coast	Negligible	Medium (near field (footprint of leg/anchor)) No change (near field (beyond the footprint of leg/anchor)) No change (far field)	No change	N/A	No change
	Annex 1 sandbanks	Negligible	Medium (near field (footprint of leg/anchor)) No change (near field (beyond the footprint of leg/anchor)) No change (far field)	Negligible	N/A	Negligible
	Margate and Long Sands SAC	Negligible	Medium (near field (footprint of leg/anchor))	Negligible	N/A	Negligible

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation significance	Additional mitigation measures proposed	Residual significance
			No change (near field (beyond the footprint of leg/anchor)) No change (far field)			
	Kentish Knock East MCZ	Negligible	Medium (near field (footprint of leg/anchor)) No change (near field (beyond the footprint of leg/anchor)) No change (far field)	Negligible	N/A	Negligible
	Orford Inshore MCZ	Negligible	Medium (near field (footprint of leg/anchor)) No change (near field (beyond the footprint of leg/anchor)) No change (far field)	No change	N/A	No change
Operation						
Impact 1: Changes to the tidal regime due to the presence of structures on the seabed (wind turbines and OSP foundations)	Essex coast	Negligible	Low (near-field) Negligible (far-field)	No change	N/A	No change
	Suffolk coast	Negligible	Low (near-field) Negligible (far-field)	No change	N/A	No change
	Annex 1 sandbanks	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Margate and Long Sands SAC	Negligible	Low (near-field) Negligible (far-field)	No change	N/A	No change

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation significance	Additional mitigation measures proposed	Residual significance
	Kentish Knock East MCZ	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Orford Inshore MCZ	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
Impact 2: Changes to the wave regime due to the presence of structures on the seabed (wind turbines and OSP foundations)	Essex coast	Negligible	Low (near-field) Negligible (far-field)	No change	N/A	No change
	Suffolk coast	Negligible	Low (near-field) Negligible (far-field)	No change	N/A	No change
	Annex 1 sandbanks	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Margate and Long Sands SAC	Negligible	Low (near-field) Negligible (far-field)	No change	N/A	No change
	Kentish Knock East MCZ	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Orford Inshore MCZ	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
Impact 3: Changes to the sediment transport regime due to the presence of structures on the seabed (wind turbines and OSP foundations)	Essex coast	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Suffolk coast	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Annex 1 sandbanks	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Margate and Long Sands SAC	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation significance	Additional mitigation measures proposed	Residual significance
	Kentish Knock East MCZ	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Orford Inshore MCZ	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible
Impact 4: Loss of seabed area due to the footprint of wind turbine and OSP foundation structures	Essex coast	Negligible	High (near-field) No change (far-field)	No change	N/A	No change
	Suffolk coast	Negligible	High (near-field) No change (far-field)	No change	N/A	No change
	Annex 1 sandbanks	Negligible	High (near-field) No change (far-field)	Negligible	N/A	Negligible
	Margate and Long Sands SAC	Negligible	High (near-field) No change (far-field)	No change	N/A	No change
	Kentish Knock East MCZ	Negligible	High (near-field) No change (far-field)	Minor	N/A	Minor
	Orford Inshore MCZ	Negligible	High (near-field) No change (far-field)	No change	N/A	No change
Impact 5: Morphological and sediment transport effects due to cable protection measures within the North Falls array areas and interconnector cable corridor	Essex coast	Negligible	High (near-field) Negligible (far-field)	No change	N/A	No change
	Suffolk coast	Negligible	High (near-field) Negligible (far-field)	No change	N/A	No change
	Annex 1 sandbanks	Negligible	High (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Margate and Long Sands SAC	Negligible	High (near-field) Negligible (far-field)	No change	N/A	No change

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation significance	Additional mitigation measures proposed	Residual significance
	Kentish Knock East MCZ	Negligible	High (near-field) Negligible (far-field)	Negligible	N/A	Negligible
	Orford Inshore MCZ	Negligible	High (near-field) Negligible (far-field)	No change	N/A	No change
Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor	Essex coast	Medium	Negligible (landfall) Medium (shallower than 5m) Low (deeper than 5m)	Negligible	N/A	Negligible
	Suffolk coast	Medium	Negligible (landfall)	No change	N/A	No change
	Annex 1 sandbanks	Negligible	Medium (shallower than 5m)	No change	N/A	No change
	Margate and Long Sands SAC	Negligible	Low (deeper than 5m)	Negligible	N/A	Negligible
	Kentish Knock East MCZ	Negligible	Negligible (landfall)	No change	N/A	No change
	Orford Inshore MCZ	Negligible	Medium (shallower than 5m)	Negligible	N/A	Negligible
Impact 7: Changes in SSC due to cable repairs and reburial	Essex coast	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change
	Suffolk coast	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change
	Annex 1 sandbanks	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change
	Margate and Long Sands SAC	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation significance	Additional mitigation measures proposed	Residual significance
	Kentish Knock East MCZ	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change
	Orford Inshore MCZ	N/A	Negligible (near-field) Negligible (far-field)	No change	N/A	No change
Impact 8: Indentations on the seabed due to O&M vessels	Essex coast	N/A	High (near-field (footprint of leg/anchor)) No change (near-field (beyond the footprint of the leg/anchor)) No change (far-field)	No change	N/A	No change
	Suffolk coast	N/A	High (near-field (footprint of leg/anchor)) No change (near-field (beyond the footprint of the leg/anchor)) No change (far-field)	No change	N/A	No change
	Annex 1 sandbanks	Negligible	High (near-field (footprint of leg/anchor)) No change (near-field (beyond the footprint of the leg/anchor)) No change (far-field)	Negligible	N/A	Negligible
	Margate and Long Sands SAC	N/A	High (near-field (footprint of leg/anchor))	No change	N/A	No change

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation significance	Additional mitigation measures proposed	Residual significance
			No change (near-field (beyond the footprint of the leg/anchor)) No change (far-field)			
	Kentish Knock East MCZ	Negligible	High (near-field (footprint of leg/anchor)) No change (near-field (beyond the footprint of the leg/anchor)) No change (far-field)	Negligible	N/A	Negligible
	Orford Inshore MCZ	N/A	High (near-field (footprint of leg/anchor)) No change (near-field (beyond the footprint of the leg/anchor)) No change (far-field)	No change	N/A	No change
Decommissioning						
The effects during the decommissioning phase would be comparable to those identified for the construction phase. Accordingly, given that no significant impact was assessed for the identified marine geology, oceanography and physical processes receptors during the construction phase, it is anticipated that the same would be valid for the decommissioning phase.						

8.13 References

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