Dudgeon and Sheringham Shoal Offshore Wind Farm Extensions

Preliminary Environmental Information Report

Volume 1

Chapter 8 - Marine Geology, Oceanography and Physical Processes

April 2021

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Prepared by:	
Royal HaskoningDHV	
Approved by:	Date:
Magnus Eriksen, Equinor	29th April 2021

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Glossary of Acronyms

3D	Three Dimensional
AWAC	Acoustic Wave and Current Meter
CD	Chart Datum
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CIA	Cumulative Impact Assessment
CPA	Coast Protection Act
DCO	Development Consent Order
DECC	Department of Energy and Climate Change
DEP	Dudgeon Extension Project
DML	Deemed Marine Licence
DOW	Dudgeon Offshore Wind Farm
EEA	European Economic Area
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EIFCA	Eastern Inshore Fisheries and Conservation Authorities
EPP	Evidence Plan Process
ES	Environmental Statement
ETG	Expert Topic Group
FEPA	Food and Environmental Protection Act
GBS	Gravity Base Structure
HAT	Highest Astronomical Tide
HDD	Horizontal Directional Drilling
IFCA	Inshore Fisheries and Conservation Authorities
IPCC	Intergovernmental Panel on Climate Change (IPCC)
IPMP	In-principle monitoring plan
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
MW	Megawatt
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
RCP	Representative Concentration Pathways
s	Second (unit of time)
SMP	Shoreline Management Plan
SAC	Special Area of Conservation
SEP	Sheringham Shoal Extension Project
SOW	Sheringham Shoal Offshore Wind Farm
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 Terms

Amphidromic point	The centre of an amphidromic system; a nodal point around which a standing-wave crest rotates once each tidal period
The Applicant	Equinor New Energy Limited
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 sea bed
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 sea bed (e.g. sand waves, 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 0.002 mm
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 sea bed
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)
Dudgeon Offshore Wind Farm Extension site	The Dudgeon Offshore Wind Farm Extension offshore wind farm boundary
Dudgeon Offshore Wind Farm Extension Project (DEP)	The Dudgeon Offshore Wind Farm Extension site as well as all onshore and offshore infrastructure
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 sea bed 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

Export cable corridor	The corridor of sea bed from the Sheringham Shoal Extension site to the landfall site within which the offshore export cables will be located
Export cables	Cables that transmit electricity from the offshore substation platform to the onshore project substation
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
Infield cables	Cables which link the wind turbine generators to the offshore substation platforms.
Interlink cables	Buried offshore cables which link offshore substation platforms.
Intertidal	Area on a shore that lies between Lowest Astronomical Tide (LAT) and Highest Astronomical Tide (HAT)
Landfall	The point at the coast at which the offshore export cables are brought onshore, connecting to the onshore cables at the transition joint bay above mean high water
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 sand waves 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 substation platform	A fixed structure located within the wind farm area, containing electrical equipment to aggregate the power

	from the wind turbine generators and convert it into a more suitable form for export to shore.
Offshore export cables	The cables which would bring electricity from the offshore substation platform(s) to the landfall.
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
Sand wave	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 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
Sheringham Shoal Offshore Wind Farm Extension site	Sheringham Shoal Offshore Wind Farm Extension offshore wind farm boundary
The Sheringham Shoal Offshore Wind Farm Extension Project (SEP)	The Sheringham Shoal Offshore Wind Farm Extension site as well as all onshore and offshore infrastructure
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 EIA 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.
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
Wavelength	The horizontal distance between consecutive bedform crests

8 MARINE GEOLOGY, OCEANOGRAPHY AND PHYSICAL PROCESSES

8.1 Introduction

1. This chapter of the Preliminary Environmental Information Report (PEIR) describes the potential impacts of the proposed Dudgeon Extension Offshore Wind Farm Project (DEP) and Sheringham Shoal Extension Offshore Wind Farm Project (SEP) on marine geology, oceanography and physical processes. The chapter provides an overview of the existing environment for the proposed offshore development area, followed by an assessment of the potential impacts and associated mitigation for the construction, operation, and decommissioning phases of DEP and SEP.

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 source are the National Policy Statements (NPS). Details of these and the methodology used for the Environmental Impact Assessment (EIA) and Cumulative Impact Assessment (CIA) are presented in **Section 8.4**.

3. The assessment should be read in conjunction with following linked chapters:

   - **Chapter 9 Marine Water and Sediment Quality;**
   - **Chapter 10 Benthic Ecology;**
   - **Chapter 11 Fish and Shellfish Ecology;**
   - **Chapter 14 Commercial Fisheries;** and
   - **Chapter 16 Offshore Archaeology and Cultural Heritage.**

4. Additional information to support the marine geology, oceanography and physical processes assessment includes:

   - Interpretation of survey data specifically collected for DEP and SEP 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 Dudgeon Offshore Wind Farm (DOW) and Sheringham Shoal Offshore Wind Farm (SOW) and their associated Environmental Statement (ES) chapters;
   - Discussion and agreement with key stakeholders; and
   - Application of a conceptual evidence-based assessment by Royal HaskoningDHV.

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**. The key elements to date have included scoping and the ongoing Evidence Plan Process (EPP) via the Seabed Expert Topic Group (ETG) (held in August 2019, June 2020 and February 2021) which includes Natural England, the Marine Management Organisation (MMO), Centre for Environment, Fisheries and Aquaculture Science (Cefas), The Wildlife Trusts, and Eastern Inshore Fisheries and Conservation Authority (Eastern IFCA). Further consultation regarding marine geology, oceanography and physical processes has been conducted through:

- The Dudgeon and Sheringham Shoal Offshore Wind Farm Extensions Scoping Report (Royal HaskoningDHV, 2019); and
- Consultation on the Dudgeon and Sheringham Shoal Offshore Wind Farm Extensions Physical Processes Method Statement submitted to the ETG in April 2020 as part of the 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 (**Appendix 8.1**). Members provided their feedback and agreed the Method Statement via an agreement log which will be provided as part of the Development Consent Order (DCO) application.

6. The feedback received has been considered in preparing the PEIR. **Table 8.1** and **Table 8.2** provide summaries of how the consultation responses received to date have influenced the approach that has been taken.

7. This chapter will be updated following the consultation on the PEIR in order to produce the final assessment that will be submitted with the DCO application. Full details of the consultation process will also be presented in the Consultation Report alongside the DCO application.

Table 8.1: Consultation responses for the Dudgeon and Sheringham Shoal Extension Project Scoping Report

Consultee	Date/ Document	Comment	Project Response
Planning Inspectorate (PINS)	November 2019	The Inspectorate agrees that the potential for the presence of construction plant and offshore infrastructure to impact upon the hydrodynamic regime during the construction phase is unlikely to result in significant effects and can therefore be scoped out of the ES.	Assessment of construction impacts on hydrodynamics are scoped out of the EIA.
PINS	November 2019	The Scoping Report states that "Due to the localised nature of these effects, it is not anticipated that such changes would give rise to significant impacts on sea bed features". The Inspectorate disagrees with this assertion, particularly in relation to the Cromer Shoal Beds Marine Conservation Zone (MCZ) as the geological features cannot reform once damaged. Natural England's consultation response also demonstrates concern in this regard. The Inspectorate considers that the ES [PEIR] should include an assessment of likely significant effects to sea bed features resultant from the Proposed Development.	Consideration of the potential effects on the form and function of bedload sediment transport processes due to foundation and cable installation (particularly in the MCZ) is described in **Section 8.6.5.3, Section 8.6.5.5,** and **Section 8.6.5.6**. The assessment is completed using a conceptual evidence-based approach.
PINS	November 2019	The Scoping Report considers that hydrodynamic and sedimentary impacts would be restricted to near-field change. The Applicant has not provided references to studies to back up this claim, nor has it identified a study area for this aspect chapter within which it considers effects are likely (see below). Nevertheless, having regard to the location of the Proposed Development (a minimum of 100km from any international territory boundary), the nature	Transboundary effects associated with hydrodynamic and sedimentary processes effects are scoped out of the EIA.

Consultee	Date/ Document	Comment	Project Response
		of the likely potential hydrodynamic and sedimentary impacts, the Inspectorate considers that transboundary impacts associated with this matter are unlikely to result in significant effects and can therefore be scoped out of the ES.	
PINS	November 2019	The Scoping Report states "the coast is exposed and dynamic with rapid cliff erosion occurring in places". The potential impacts of landfall work on coastal processes, including erosion and deposition, should be assessed with appropriate cross reference to other technical reports including landscape and visual impacts. The assessment should assess potential impacts associated with climate change during the Proposed Development's operational life and any decommissioning period, as well as the relevant Shoreline Management Plan.	**Section 8.4** discusses the approach to coastal and landfall impacts. These impacts are addressed in the PEIR and cross reference is made, where appropriate, to other technical reports and the Shoreline Management Plan. The United Kingdom Climate Projections 2018 (UKCP18) climate change projections have been applied in the assessment at the coast.
PINS	November 2019	The Scoping Report refers to the use of conceptual methods to assess impacts. No details are provided as to what conceptual methods would be utilised. The ES [PEIR] should provide details of all methods used along with any assumptions and limitations and an explanation of how these have been factored into the assessment.	Justification for using conceptual methods to predict effects is provided in **Section 8.6.3**. 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 impacted by the effect, and the receptor is the receiving entity. The use of numerical modelling is disproportionate to the

Consultee	Date/ Document	Comment	Project Response
			potential effect that would occur. The S-P-R conceptual model is proportionate.
PINS	November 2019	The ES [PEIR] should assess any likely significant effects from changes in current and wave action resulting from introduced scour protection measures.	Several scour protection options are considered and detailed within the PEIR and the effects on hydrodynamics and waves considered.
PINS	November 2019	The Scoping Report refers to ‘previous studies’ however does not reference these. The ES [PEIR] should provide clear references to any studies used to inform the approach and support its conclusions.	Cross references to previous studies are included in this PEIR.
PINS	November 2019	A number of desk-based data sources relating to the existing Sheringham Shoal and Dudgeon offshore wind farms are proposed be used to inform the characterisation of the existing environment. The Inspectorate considers that these will provide useful baseline information, however their limitations in terms of age of data and spatial coverage should be acknowledged within the ES [PEIR]. The Applicant should make efforts to agree with relevant consultation bodies what is an appropriate level of information to inform the baseline characterisation.	A description of new surveys that have collected, including bathymetry, sea bed texture and near-bed geology across the wind farm sites and cable corridors is provided in **Section 8.4.2**. Existing metocean data collected for the existing wind farms is considered appropriate as a baseline for the PEIR due to their proximity to the extensions and likelihood of consistency in metocean conditions across the area occupied by all the wind farms.

Consultee	Date/ Document	Comment	Project Response
PINS	November 2019	It is unclear how the existing suspended sediment concentrations within the application site will be determined based on the existing data sources available (which do not cover the spatial extent of the SEP/DEP) and the proposed baseline surveys (which are for multibeam bathymetry, side-scan sonar and sub-bottom profiling). The ES [PEIR] should clearly identify the data sources used to inform the suspended sediment baseline.	**Section 8.4.2** details how data sources used to inform the suspended sediment concentration baseline will be identified.
PINS	November 2019	The Inspectorate is unclear as to the relevance of the 'Guidance on Environmental Impact Assessment in Relation to Dredging Applications (Office of the Deputy Prime Minister, 2001)', as no dredging has been proposed within the Scoping Report. The Applicant should ensure that all guidance utilised to inform the assessment is relevant and its relationship to the assessment is clearly explained.	All guidance quoted is relevant to the assessment.
PINS	November 2019	The Inspectorate notes that irrespective of the chosen landfall, the offshore cable route would pass through Cromer Shoal Chalk Beds MCZ and the Greater Wash Special Protection Area (SPA). The ES [PEIR] should assess the likely significant effects of changes to hydrodynamic and sedimentary processes on these receptors.	**Section 8.6.5.1** and **8.6.5.2** outline potential impacts on the hydrodynamic and sedimentary processes with regard to the Cromer Shoal Chalk Beds MCZ. A separate study of the sedimentary processes operating in the MCZ has also been carried out (**Appendix 8.2**).

Consultee	Date/ Document	Comment	Project Response
PINS	November 2019	The assessment should take into the effects of climate change. Information from UKCP18 on waves, winds, storm surge and sea level rise, should be incorporated into the future baseline.	The UKCP18 climate change projections are included in the future baseline for physical processes.
Historic England		This section discusses the assessments of the marine geology, oceanography and physical processes. We would recommend that this section includes references to how changes to these factors could impact on the historic environment by exposing or covering heritage assets. For example, it is stated in Section 2.1.2.2 that there is the potential for the development to increase sea bed scour in areas, which could result in the exposure, degradation or loss of vulnerable assets. We note that the impact of changes to the hydrodynamic and sedimentary process regimes on the historic environment are discussed in Section 2.9.2, however we would recommend that heritage is also referenced within this section of the ES.	Part of the assessment covers changes to sedimentary processes which in themselves are not necessarily impacts to which significance can be ascribed. However, such changes may indirectly impact other receptors such as the historic environment and are referenced in the PEIR. The significance of impacts on historic environment are made in the historic environment chapter (**Chapter 16 - Offshore Archaeology and Cultural Heritage**).
MMO	06/11/2019	The applicant proposes that effects on the hydrodynamic regime should be scoped out (Chapter 2.1.2.1), despite noting that there is potential for the physical presence of construction plant and offshore infrastructure to have an impact on the hydrodynamic state. The MMO suggest that the applicant scope this in, as construction activities (such as any changes at the sea bed during cable installation) could have an impact on flow and wave propagation. After	Assessment of the construction impacts on hydrodynamics are scoped out of the PEIR.

Consultee	Date/ Document	Comment	Project Response
		the second ETG meeting in June 2020, and following consultation with our advisers, the MMO can confirm that the impact on the hydrodynamic regime during construction can be scoped out, as the impact of the monopile(s) presence will be assessed in the operational phase of the project.	
Natural England	06/11/2019	The Applicant is considering a proposed cable route through the Cromer Shoal MCZ, which is predominantly designated for subtidal chalk habitat. As stated there is often a veneer of gravelly sand laid on top of the bedrock. In the case of Cromer Shoal Chalk Beds MCZ, this bedrock is chalk. Cabling through chalk could result in losing the unique 3D structures it creates in certain places. Therefore, understanding where these veneers persist and are a suitable thickness for cabling in, would allow the applicant to have greater confidence that the features of the MCZ will not be damaged	Separate reports on sedimentary processes and geology along the export cable corridor in the MCZ covering this issue have been completed (Royal HaskoningDHV, 2020; British Geological Survey, 2021). Royal HaskoningDHV (2020) is appended to the PEIR as supporting documentation (**Appendix 8.2**).
Natural England	06/11/2019	Natural England agrees that the greatest potential impacts from the array upon the hydrodynamic regime would be from the constructed windfarm during operation. Therefore, we are content it can be scoped out of further consideration in relation to the construction phase.	Assessment of construction impacts on hydrodynamics are scoped out of the PEIR.

Consultee	Date/ Document	Comment	Project Response
Natural England	06/11/2019	Natural England disagrees that the wind farm extensions will not give rise to significant impacts on sea bed features. This is particularly relevant to the Cromer Shoal Chalk Beds MCZ and installing cables through it. The geological features that exist in this area are unique and cannot be reformed once damaged, unlike a mobile sediment dominated area. However, the effect on coastal morphology and sediment transport itself will probably be minimal.	A separate study of the sedimentary processes operating in the MCZ has also been carried out (**Appendix 8.2**).
Natural England	06/11/2019	There is currently no reference to specific impacts of suspended sediment concentrations from disposal of dredged material at specific disposal grounds offshore. This needs to be considered further and scoped into the assessment.	Sea-bed levelling will be carried out for interlink cable installation (between SEP and DEP North, between SEP and DEP South, and within DEP North and DEP South array sites). Any excavated sediment due to sand wave levelling for the infield cables would be disposed of within the project sites (the trough would be filled in to create an even sea bed) and therefore there will be no net loss of sand from the site. This impact has been addressed in **Section 8.6.4.7**.
Natural England	06/11/2019	Will wake effects from the turbines be considered further in the assessment?	**Section 8.6.5.2** describes how wakes caused by localised flow accelerations around the foundations and wave shadow effects attributable to individual foundations are assessed in the PEIR.

Consultee	Date/ Document	Comment	Project Response
Natural England	06/11/2019	Increased concentrations of suspended sediments and release of contaminants due to ongoing scour during operation should be scoped vin. This has been recognised by the scoping in of increased suspended sediment concentrations during operation in regard to Benthic and intertidal ecology.	Several scour protection options are considered and detailed within the PEIR and the effects on hydrodynamics and waves considered (**Section 8.6.5.1**and **Section 8.6.5.2**).
Weybourne Parish Council		The Parish Council are keen that Equinor consider the impact of tidal surges in their Environmental Statement. Tidal surges change the nature and character of the coastline and are predicted to increase in frequency and severity.	Tidal surges and their predicted future changes due to climate change are included in the baseline (**Section 8.5**) and are assessed conceptually.

Table 8.2: Consultation responses for Dudgeon and Sheringham Shoal Extension Project Physical Processes Method Statement

Consultee	Date / Document	Comment	Project Response
Natural England	02/06/2020	Project Description - Wind Turbine Generator Foundations This is contradictory as the various documents provided include different foundation types.	When the method statement was drafted, Gravity Base Structure (GBS) foundations had been removed from the Rochdale envelope and were therefore not included. However, this decision has since been reviewed, with the decision to reinstate GBS foundations as an option because they may be necessary for larger turbines that are not currently available in the market, but may be by the time of

Consultee	Date / Document	Comment	Project Response
			construction. The method statement has been revised accordingly.
Natural England	02/06/2020	Project Description - Wind Turbine Generator Foundations Natural England would expect volume and area of scour protection per turbine to be included in ES.	**Section 8.6.5.4** outlines the volume and area of scour protection per Wind Turbine Generator (WTG) foundation.
Natural England	02/06/2020	Operation and Maintenance Strategy It is not clear what the operation life span is, i.e. 25 or 30 years	The operational lifetime of DEP and SEP is assumed to be a minimum of 35 years.
Natural England	02/06/2020	Impact Assessment Methodology - Using the Previous Modelling Results to Support the Conceptual Approach Considering both Dudgeon and Sheringham Shoal Offshore Wind Farm (OWF) are now built, how will the potential impacts on hydrodynamics caused by these projects be taken into consideration given the modelling undertaken for these projects (i.e. before they were built) is suggested to be used?	The existing modelling and assessments are in close proximity to the extensions projects and were very conservative given the larger number of turbines modelled in the existing wind farms compared to the number of turbines in the extensions. Therefore, the modelling results are still considered to be appropriate (presented in **Sections 8.6.5.1– 8.6.5.2**). **Section 8.6.3** provides further justification for use of the previous modelling.

Consultee	Date / Document	Comment	Project Response
Natural England	02/06/2020	Potential Impacts - Impact on Sea Bed Features due to Cable Installation and during decommissioning Natural England welcomes consideration of remove of cable protection at the time of decommissioning and if removal could be achieved, then whilst the impacts would no longer be permanent, they would still last for the lifetime of the infrastructure (25 years) and potentially longer as a residual impact. Therefore, because this impact is lasting/long term and site recovery wouldn't be assured, Natural England's view is that reasonable scientific doubt would likely remain regarding the impact of the proposals on the conservation objectives for the site. Accordingly a precautionary approach is required. Please also be advised that if it is considered that certain types of cable protection could be modified to enable a greater success of recovery/removal at decommissioning, whilst reducing wider designated site impact, then we advise that this would need to be reflected in the DCO/DML to ensure this mitigation is secured.	Noted.
Natural England	02/06/2020	Potential Impacts - Indentations on the Sea Bed due to Installation Vessels Please note that several windfarms (including Norfolk Vanguard and Norfolk Boreas) have recently committed to not using jack-up barges for installation due to the impact that this method has on the seabed. Natural England would therefore recommend re-considering their use at an early stage for all projects.	It is understood that Norfolk Boreas and Norfolk Vanguard have made the commitment not to use jack-up vessels within a Special Area of Conservation (SAC) and will use alternative work vessels in the SAC during the construction and operation of DEP and SEP. This commitment only applies to the export cables, and only within the SAC.

Consultee	Date / Document	Comment	Project Response
			The Applicant will consider this mitigation option for the portion of the export cable corridor that passes through the Cromer Shoal Chalk Beds MCZ.
Natural England	02/06/2020	Potential impacts during O&M - Approach to assessment Please note that existing data should only be used to support site specific data sets.	Noted.
Natural England	02/06/2020	Potential impacts during O&M - Changes to Sediment Transport due to Cable Protection Measures For any proposed cable protection Natural England expects a reasonable estimate of the amount, area impacted and pressure exerted on any designated features within MPAs. Cable protection should be considered as a last resort.	This has been assessed in **Sections 8.6.5.6** and **8.6.5.7**.
MMO	15/07/2020	According to the information presented in the ETG presentation on the 02 June 2020, the MMO agree that the coarse lag is effectively static.	Noted.
MMO	15/07/2020	The MMO confirm that data from planned and past surveys should cover the geological description of the cable corridors adequately.	Noted (see **Section 8.4.2** for Data and Information Sources used to describe offshore geology).
MMO	15/07/2020	The MMO agree that the proposed baseline data collection is adequate in relation to geophysical survey.	Noted.
MMO	15/07/2020	The existing models described refer to OWFs with approximately three times more turbines than the SEP/DEP (so that would cover the worst-case scenario) and the sites have similar characteristics. Furthermore, the expert	**Section 8.6.3** provides further justification for use of the previous modelling. **Sections 8.6.4 – 8.6.6** address potential impacts during the

Consultee	Date / Document	Comment	Project Response
		assessment should identify potential impacts and propose any mitigation measures accordingly.	construction, operation and decommissioning phase of DEP and SEP.
MMO	15/07/2020	As discussed during the ETG, it was identified that the MMO held a conflicting scoping opinion in respect of scoping in or out assessment of impacts on the hydrodynamic regime during construction. Following consultation with our advisers, the MMO can confirm that the impact on the hydrodynamic regime during construction can be scoped out, as the impact of the monopile(s) presence will be assessed in the operational phase of the project.	Noted.
MMO	15/07/2020	The potential projects scoped in for the cumulative impact assessment appear to be appropriate. The MMO note that cumulative impacts have been considered in relation changes to Marine Geology, Oceanography and Physical Processes arising from the proposed project alone and those arising from the proposed project cumulatively or in combination with other offshore wind farm developments and other nearby sea bed activities, including marine aggregate extraction, marine disposal, proposed seaweed farm and construction of Oil and Gas platforms. The full list of ongoing plans or projects to be included in the Environmental Statement (ES) will be developed as part of on-going consultation with technical consultees. The MMO will be able to provide further comments once this is finalised.	Noted.

8.3 Scope

8.3.1 Study Area

8. The DEP North, DEP South and SEP sites are in the southern North Sea. DEP North and DEP South together encompass a sea bed area of approximately 103.5km^2, and SEP approximately 92.6km^2. DEP North and DEP South are adjacent to and north and south of DOW, respectively. SEP is adjacent to and north of SOW. SEP is closest to the coast and is located approximately 13.6km from the nearest point on the coast of Norfolk. An export cable corridor joins the SEP site to the landfall at Weybourne (Muckleburgh Estate). In addition, a project interlink cable corridor has been defined between the DEP and SEP sites and between DEP North and DEP South as there may be a requirement to install cables which link the two sites. The offshore infrastructure required for DEP North, DEP South and SEP sites is outlined in **Section 8.3.2**.

8.3.2 Realistic Worst-case Scenario

9. The detailed design of DEP and SEP (including numbers of wind turbines, layout configuration, requirement for scour protection etc.) has not yet been determined and may not be known until sometime after any DCO has been granted. Therefore, realistic worst-case scenarios in terms of potential impacts/effects on marine geology, oceanography and physical processes are adopted to undertake a precautionary and robust impact assessment.

8.3.2.1 General Approach

10. 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 PINS 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 lesser options will have less impact. Further details are provided in **Chapter 6 EIA Methodology**.

11. The realistic worst-case scenarios for the marine geology, oceanography and physical processes assessment are summarised in **Table 8.3**. These are based on the project parameters described in **Chapter 5 Project Description**, which provides further details regarding specific activities and their durations.

12. In addition to the design parameters set out in **Table 8.3**, consideration is also given to how DEP and SEP will be built out as described in **Section 8.3.2.2** to **Section 8.3.2.4** below. This accounts for the fact that whilst DEP and SEP are the subject of one DCO application, it is possible that either one or both of the projects will be developed, and if both are developed, that construction may be undertaken either concurrently or sequentially.

Table 8.3: Summary of Realistic Worst-case Scenarios

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
Construction				
Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation	Sea bed preparation for 32 conical GBS foundations for 14MW turbines. Total worst case sea bed preparation volume: **530,929m^3**	Sea bed preparation for 24 conical GBS foundations for 14MW turbines. Total worst case sea bed preparation volume: **398,197m^3**	Sea bed preparation for 56 conical GBS foundations for 14MW turbines. Total worst case sea bed preparation volume: **929,126m^3**	The worst-case scenario for a single GBS foundation is for the larger 18+ megawatt (MW) turbine with a 60m base plate diameter, however over the whole project, the worst case volumes are associated with sea bed preparation for the maximum number of 14MW GBS foundations, which has a 45m base plate diameter. Sea bed preparation (dredging using a trailer suction hopper dredger and installation of a bedding and levelling layer) may be required up to a 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. The worst case scenario for DEP and SEP is the same for all DEP and SEP scenarios
Impact 1b: Changes in suspended sediment	Two drilled 14MW	Two drilled 14MW monopile	Four drilled 14MW monopile foundations,	The worst case for a release from an individual wind turbine assumes

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
concentrations due to drill arisings for foundation installation of piled foundations for wind turbines and OSPs	monopile foundations, and one OSP in DEP North. Total worst-case drill arisings: **12,371m^3**	foundations, and one OSP in SEP Total worst-case drill arisings: **12,371m^3**	and two OSPs (one in DEP North and one in SEP) Total worst-case drill arisings: **24,742m^3**	monopile foundation for the 14+ MW wind turbine (13m diameter drill drilling to 45m) releasing a maximum of 5,973m^3 per foundation into the water column. Equinor estimates that the maximum number of foundations requiring drilling would be 5% (1 in 20 foundations). Hence, for the total volume during the construction phase, the worst case scenario for drilling is associated with two 14MW monopiles (per site) and one of eight pin piles per OSP. The worst case scenario for DEP and SEP together assumes DEP (North & South) and SEP are developed in a separated grid option (each having their own OSP).
Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	As Construction Impact 1a	As Construction Impact 1a	As Construction Impact 1a	As Construction Impact 1a.
Impact 2b: Changes in sea bed level due to drill arisings for installation of	As Construction Impact 1b	As Construction Impact 1b	As Construction Impact 1b	As Construction Impact 1b.

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
piled foundations for wind turbines and OSPs				
Impact 3: Changes in suspended sediment concentrations due to export cable installation	One HVAC export cable up to 62km in length. Worst case volume of sediment that would be disturbed: **175,850m^3** (**6,148m^3** of which within the Cromer Shoal Chalk Beds MCZ) • **144,200m^3** for sand wave levelling • **31,000m^3** for export	One HVAC export cable up to 40km in length. Worst case volume of sediment that would be disturbed: **20,650m^3** (**6,148m^3** of which within the Cromer Shoal Chalk Beds MCZ) • No sand wave levelling • **20,000m^3** for export cable trench • **650m^3** for HDD exit point	Two HVAC export cables, totalling up to 102km in length. Worst case volume of sediment that would be disturbed: **195,900m^3** (**11,697m^3** of which within the Cromer Shoal Chalk Beds MCZ) • **144,200m^3** for sand wave levelling • **51,000m^3** for export cable trench • **700m^3** for HDD exit point	Trenching by jetting or ploughing would be required to bury the export cables. However, jetting is considered the worst case scenario due to the greater width of disturbance compared to ploughing. Therefore, the worst case assumes 100% jetting of a v-shaped trench, 1.0m in width and 1.0m depth. The offshore HDD exit location will be approximately 1,000m offshore in the offshore export cable corridor. Sediment displacement assumes a box shaped dimension. The worst case scenario for export cable installation for the DEP and SEP together scenario is where both DEP (North & South) and SEP are developed in in a separated grid option (each having their own OSP and export cable). This is a realistic worst case scenario.

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
	cable trench - **650m^3** for HDD exit point			
Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor	As Construction Impact 3	As Construction Impact 3	As Construction Impact 3	As Construction Impact 3.

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
Impact 5: Changes in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	Worst case volume of sediment that would be disturbed: **458,325m^3** • Sand wave levelling in infield and interlink cable corridors: **232,200m^3** • 135km of infield cables (DEP North: 90km; DEP South: 45km): **151,875m^3**	Worst case volume of sediment that would be disturbed: **101,250m^3** • 90km of infield cables: **101,250m^3** • No interlink cables • No sand wave levelling	**Worst case scenario**[1]: Worst case volume of sediment that would be disturbed: • Sand wave levelling in infield and interlink cable corridors: **360,200m^3** • Up to 225km of infield cables: **253,125m^3** • Up to seven interlink cables (between DEP North to OSP in SEP) up to 154km total length: **173,250m^3** **Realistic worst case scenario** The realistic worst case volume of sediment that would be disturbed: **774,200m^3**	Sand wave levelling is required in particular areas prior to infield and interlink cable installation. Any excavated sediment due to sand wave levelling would be disposed of within the DEP and SEP wind farm sites, meaning there will be no net loss of sediment from the site(s). The cable burial technique for infield and interlink cables is assumed to be 50% jetting and 50% mechanical cutting. The worst case cable laying technique is considered to be mechanical cutting due to the greater width of disturbance compared to jetting, therefore the assessment considers 100% of cables installed by mechanical cutting. A maximum width of a mechanically cut trench is 1.5m and maximum burial depth of 1.5m for a v-shaped trench is assumed.

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[1] The individual worst case scenarios presented for interlink and infield cables would not represent a developable scenario if taken as a total, therefore a 'realistic' worst case scenario is presented for this and all other activities that vary depending on the development scenario in question. This includes sandwave clearance, number of OSPs and anchors.

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
	- Up to three parallel interlink cables between DEP South and OSP in DEP North: up to 66km in length (combined): **74,250m^3**			**DEP and SEP together worst case scenario** **Sand wave levelling:** Assumes DEP and SEP are developed in an integrated grid option, and DEP North & South and SEP are developed. **Interlink cable:** Assumes DEP and SEP are developed in an integrated grid option, however only DEP North and SEP are developed. **Infield cable:** Assumes DEP and SEP are developed in an integrated grid option, and DEP North & South and SEP are developed. **DEP and SEP together realistic worst case scenario** Assumes DEP and SEP are developed in an integrated grid option, and DEP North & South and SEP are developed.

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)	As Construction Impact 5	As Construction Impact 5	As Construction Impact 5	As Construction Impact 5.
Impact 7: Indentations on the sea bed due to installation vessels	Total footprint: **156,848m^2** (**788m^2** occurs within Cromer Shoal Chalk Beds MCZ) - Up to two jack-up deployments at each turbine/OSP (**32 turbines + one OSP: 79,200m^2**) - Up to eight deployments at HDD exit point (**128m^2**) - Anchoring (**77,520m^2**)	Total footprint of **94,928m^2** (**788m^2** occurs within Cromer Shoal Chalk Beds MCZ) - Up to two jack-up deployments at each turbine/OSP (**24 turbines + one OSP: 60,000m^2**) - Up to eight deployments at HDD exit point (**128m^2**) - Anchoring (**34,800m^2**): Up to 12 lines	**Worst case scenario:** - Up to two jack-up deployments at each turbine/OSP (**56 turbines + two OSPs: 139,200m^2**) - Up to 16 deployments at HDD exit point (**256m^2**) - Anchoring (**149,280m^2**): Up to 12 lines per turbine/OSP location with anchor footprint up to 6m width (**56 turbines + 2 OSPs: 41,760m^2**). Export cable installation vessel anchoring (seven moorings) **42,840m^2**. Interlink cable installation	Worst-case scenario is a jack-up barge with six legs per barge (200m^2 per leg) equating to a total footprint of 1,200m^2 per installation (for turbine and OSPs). A jack-up barge vessel with four legs, each with a 4m^2 spudcan, will be required to install any necessary external cable protection works at the HDD exit point. **<u>DEP and SEP together worst case scenario</u>** **Jack up deployments** - **Turbines/OSP:** Assumes DEP (North & South) and SEP are developed in a separated grid option (each having their own OSP). - **HDD exit point:** Same for all DEP and SEP together scenarios **Anchoring**

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
	: Up to 12 lines per turbine/OSP location with anchor footprint up to 6m width (**32 turbines + 1 OSP: 23,760m^2**). Export cable installation vessel anchoring (seven moorings) **26,040m^2** (62km). Interlink cable installation vessel anchoring (seven	per turbine/OSP location with anchor footprint up to 6m width (**24 turbines + 1 OSP: 18,000m^2**). Export cable installation vessel anchoring (seven moorings) **16,800m^2** (40km).	vessel anchoring (seven moorings) **64,680m^2** **Realistic worst case scenario** The realistic worst case footprint: **276,376m^3** (**1576m^2** occurs within Cromer Shoal Chalk Beds MCZ)	• **Turbines/OSP:** Assumes DEP (North & South) and SEP are developed in a separated grid option (each having their own OSP). • **Export cable:** Assumes DEP (North & South) and SEP are developed in a separated grid option (each having their own OSP). • **Interlink cable:** Assumes DEP and SEP are developed in an integrated grid option, however only DEP North and SEP are developed. **DEP and SEP together realistic worst case scenario** Assumes DEP and SEP are developed in an integrated grid option, however only DEP North and SEP are developed.

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
	moorings) **27,720m^2**			
Operation				
Impact 1: Changes to the tidal regime due to the presence of structures on the sea bed	Worst case obstruction: **459,706m^2** • 32 x 14MW GBS wind turbine foundations (45m base diameter plus scour protection of 135m diameter) with a minimum spacing of 990m: **458,044m^2** • One OSP with four-leg jacket and suction	Worst case obstruction: **345,195m^2** • 24 x 14MW GBS wind turbine foundations (45m base diameter plus scour protection of 135m diameter) with a minimum spacing of 990m: **343,533m^2** • One OSP with four-leg jacket and suction	Worst case obstruction: **804,901m^2** • 56 x 14MW GBS wind turbine foundations (45m base diameter plus scour protection of 135m diameter) with a minimum spacing of 990m: **801,577m^2** • Two OSPs with four-leg jackets and suction buckets (12m diameter per leg) and a maximum bucket spacing of 40m: **3,324m^2**	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 spacing is the worst-case scenario. The worst-case scenario for OSP foundations are suction-buckets given the greater cross-sectional area. 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 from the

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
	buckets (12m diameter per leg) and a maximum bucket spacing of 40m: **1,662m^2**	buckets (12m diameter per leg) and a maximum bucket spacing of 40m: **1,662m^2**		structure. Hence, the effect on tidal currents would be very small. The DEP and SEP worst case scenario assumes DEP (North & South) and SEP are developed in a separated grid option (each having their own OSP).
Impact 2: Changes to the wave regime due to the presence of structures on the sea bed (wind turbines and offshore substation foundations)	As Operational Impact 1	As Operational Impact 1	As Operational Impact 1	GBS are the worst-case foundation types for effects on waves due to the height of the foundation above the sea bed.
Impact 3: Changes to the sediment transport regime due to the presence of structures on the sea bed (wind turbines and offshore substation foundations)	As Operational Impact 1	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 sea bed.
Impact 4: Loss of sea bed area due to the footprint	32 x 14MW GBS wind	24 x 14MW GBS wind turbine	56 x 14MW GBS wind turbine foundations (45m	GBS are the worst-case foundation types for loss of sea bed area due to

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
of wind turbine and offshore substation foundation structures	turbine foundations (45m base diameter plus scour protection of 135m diameter) and one OSP with suction bucket foundations and scour protection Total footprint: **0.46km²** (**0.44%** of the DEP site)	foundations (45m base diameter plus scour protection of 135m diameter) and one OSP with suction bucket foundations and scour protection Total footprint: **0.35km²** (**0.37%** of the SEP site)	base diameter plus scour protection of 135m diameter) and two OSPs with suction bucket foundations and scour protection Total footprint: **0.8km²** (**0.41%** of the DEP and SEP sites)	the size of the base that will be present on the sea bed. The DEP and SEP worst case scenario assumes DEP (North & South) and SEP are developed in a separated grid option (each having their own OSP).
Impact 5: Morphological and sediment transport effects due to cable protection measures within the DEP and SEP	Up to 1,000m of cable protection may be required for	Up to 1,000m of cable protection may be required in the unlikely	Up to 1,000m of cable protection may be required for infield cables, and up to 1,500m may be	Cable protection for unburied cables in the array site and interlink cable corridor will be rock berm protection which will be up to 0.5m in height and

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
sites and interlink cable corridor	infield cables, and up to 1,500m may be required for interlink cables in the unlikely event that cables cannot be buried. Total footprint: **40,300m^2:** - **4,000m^2** for infield cables - **9,000m^2** for interlink cables - **27,300m^2** for 13 crossing protection material for	event that cables cannot be buried Total footprint: **4,000m^2** for infield cable protection. No interlink cable or crossing protection material is required for a SEP in isolation scenario.	required for interlink cables in the unlikely event that cables cannot be buried. Total footprint: **40,300m^2:** - **4,000m^2** for infield cables - **9,000m^2** for interlink cables - **27,300m^2** for 13 crossing protection material for 13 crossings (six interlink crossings, seven infield crossings	4m wide in a trapezoid shape. Cable protection for crossings will be either mattressing or rock dumping. The DEP and SEP worst case scenario is the same for all DEP and SEP together scenarios.

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
	13 crossings (six interlink crossings, seven infield crossing.			
Impact 6: Morphological and sediment transport effects due to cable protection measures along the export cable	Total footprint of export cable and crossing protection: **11,700m²** (**900m²** of cable protection within Cromer Shoal Chalk Beds MCZ): - 0.5km export cable protection (**3,000m²**)	Total footprint of export cable and crossing protection: **11,700m² (900m²** of cable protection within Cromer Shoal Chalk Beds MCZ): - 0.5km export cable protection (**3,000m²**) - Four crossings (**8,400km²**)	Total footprint of export cable and crossing protection: **20,400m²** (**1,800m²** of cable protection within Cromer Shoal Chalk Beds MCZ) - 0.5km export cable protection (**3,000m²**) - Eight crossings (four with Dudgeon cables and four with Hornsea 3 cables) (**16,800m²**) - 200m of HDD exit point cable protection (**600m²**)	Cable protection would be required at crossing locations in the offshore cable corridor. A total of four crossings are required for each cable (up to two cables for a DEP and SEP together scenario). The height of cable crossings would be 0.5m. All crossings will be outside the Cromer Shoal Chalk Beds MCZ. The DEP and SEP worst case scenario is the same for all DEP and SEP together scenarios.

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
	- Four crossings (**8,400m^2**) - 100m of HDD exit point cable protection (**300m^2**)	- 100m of HDD exit point cable protection (**300m^2**)		

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
Impact 7: Cable repairs and reburial	Worst case scenario disturbance footprint: **13,743m^2** on average per year (**481,005m^2** over 35 years) - Up to 10 jack-up deployments per year. Legs / spudcans footprint up to **12,000m²** per year - Cable repair and reburial	Worst case scenario disturbance footprint: **13,170m^2** on average per year (**460,950m^2** over 35 years) - Up to 10 jack-up deployments per year. Legs / spudcans footprint up to **12,000m²** per year - Cable repair and reburial footprint: **1,170m^2**	Worst case scenario disturbance footprint: **28,737m^2** on average per year (**1,005,795m^2** over 35 years) - Up to 20 jack-up deployments per year. Legs / spudcans footprint up to **24,000m²** per year - Cable repair and reburial footprint: **4,737m^2** Worst case scenario disturbance footprint within Cromer Shoal Chalk Beds MCZ: **360m^2** (0.00011% of MCZ)	Maintenance of wind turbine generators and/or cable reburial and maintenance may be required during the operational phase of the project. It is estimated that for repair, up to four cable locations may be visited every ten years which would lead to a total footprint of up to 34,800m^2 per ten years (maximum length of cable repair of 10.0km with a disturbance width of 3m). For reburial, up to four cable locations would be reburied every ten years. This equates to a sea bed footprint of 12,570m^2 per ten years (maximum length of cable reburial 2.25km) with a 3m wide disturbance. For these activities, it is assumed that a dynamically positioned vessel will be used. **DEP and SEP together worst case scenario**

	footprint per year: **1,743m^2** Worst case scenario disturbance footprint within Cromer Shoal Chalk Beds MCZ on average per year: **150m^2** (0.000047% of MCZ)	Worst case scenario disturbance footprint within Cromer Shoal Chalk Beds MCZ: **150m^2** (0.000047% of MCZ)	**Realistic worst case scenario** The realistic worst case disturbance footprint: **28,704m^2** on average per year (**1,004,640m^2** over 35 years)	**Jack up deployments:** Same for all DEP and SEP together scenarios **Cable repair:** Same for all DEP and SEP together scenarios **Cable replacement:** • Export: Same for all DEP and SEP together scenarios • Interlink: Assumes DEP and SEP are developed in an integrated grid option, however only DEP North and SEP are developed. • Infield: DEP and SEP are developed in an integrated grid option, and DEP North & South and SEP are developed / DEP (North & South) and SEP are developed in a separated grid option (each having their own OSP). **DEP and SEP together realistic worst case scenario** Assumes DEP and SEP are developed in an integrated grid option, and DEP North & South and SEP are developed

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
Decommissioning				
Impact 1: Changes in suspended sediment concentrations due to foundation removal	No final decision has yet been made regarding the final decommissioning policy for the offshore project infrastructure. It is also recognised that legislation and industry best practice change over time. However, the following infrastructure is likely 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: • 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. For the purposes of the worst case scenario, it is anticipated that the			Decommissioning arrangements will be detailed in a Decommissioning Plan, which will be drawn up and agreed with the Department for Business, Energy and Industrial Strategy (BEIS) prior to construction.
Impact 2: Changes in sea bed level due to foundation removal				
Impact 3: Changes in suspended sediment concentrations due to removal of parts of the export cable				
Impact 4: Changes in sea bed level due to removal of parts of the export cable				
Impact 5: Changes in suspended sediment				

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
concentrations due to removal of parts of the infield and interlink cables	impacts will be no greater than those identified for the construction phase.			
Impact 6: Changes in sea bed level due to removal due to removal of parts of the infield and interlink cables				
Impact 7: Indentations on the sea bed due to decommissioning vessels				

8.3.2.2 Construction Scenarios

13. The following principles set out the framework for how the projects may be constructed:

- DEP and SEP may be constructed at the same time, or at different times;
- If built at the same time both projects could be constructed in four years, with offshore construction being undertaken over two years (likely years 3 and 4) of the overall construction period;
- If built at different times, either project could be built first;
- If built at different times the first project would require a four-year period of construction, the second project a three-year period of construction including a two year offshore construction period;
- If built at different times, the duration of the gap between the start of construction of the first project, and the start of construction of the second project may vary from two to four years;
- Assuming a maximum construction periods, and taking the above into account, the maximum period over which the construction of both projects could take place is seven years;
- The earliest construction start date is 2024 and the latest is 2028.

14. To determine which construction scenario presents the realistic worst case for each receptor and impact, the assessment considers both maximum duration effects and maximum peak effects, in addition to each project being developed in isolation, drawing out any differences between each of the two projects.

15. The three construction scenarios considered by the marine geology, oceanography and physical processes assessment are therefore:

- Build DEP or build SEP in isolation;
- Build DEP and SEP concurrently – reflecting the maximum peak effects; and
- Build one project followed by the other with a gap of up to two years (sequential) – reflecting the maximum duration of effects. This would result in a maximum gap in offshore construction of one year.

16. Any differences between the two projects, or differences that could result from the manner in which the first and the second projects are built (concurrent or sequential and the length of any gap) are identified and discussed where relevant in the impact assessment section of this chapter (**Section 8.6**). For each potential impact only the worst-case construction scenario for two projects is presented, i.e. either concurrent or sequential. The justification for what constitutes the worst case is provided, where necessary, in **Section 8.6**.

8.3.2.3 Operational Scenarios

17. Operational scenarios are described in detail in **Chapter 5 Project Description**. The assessment considers the following three scenarios:

- Only DEP in operation;

- Only SEP in operation; and
- The two projects operating at the same time, with a gap of up to three years between each project commencing operation.

18. The operational lifetime of each project is expected to be 35 years.

8.3.2.4 Decommissioning Scenarios

19. Decommissioning scenarios are described in detail in **Chapter 5 Project Description**. Decommissioning arrangements will be agreed through the submission of a Decommissioning Plan prior to construction. However, for the purpose of this assessment it is assumed that decommissioning of DEP and SEP could be conducted separately, or at the same time.

8.3.3 Summary of Mitigation Embedded in the Design

20. This section outlines the embedded mitigation relevant to the marine geology, oceanography and physical processes assessment, which has been incorporated into the design of DEP and SEP (**Table 8.4**). Where other mitigation measures are proposed, these are detailed in the impact assessment (**Section 8.6**).

Table 8.4: Embedded Mitigation Measures

Parameter	Mitigation Measures Embedded into the Design of DEP and SEP
Turbine spacing	A minimum separation distance of up to 0.99km has been defined between adjacent wind turbines within each row and between rows, minimising the potential for interaction between adjacent wind turbines with respect to marine physical process.
Foundations	The selection of appropriate foundation designs and sizes at each wind turbine location will be made following pre-construction surveys within the offshore project area.
	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 sea bed preparation prior to foundation installation.
Cables	Cables will be buried where possible, minimising the requirement for cable protection measures and thus effects on sediment transport. Use of external cable protection would be minimised in all cases and in the nearshore is only included for potential use at the HDD exit point.
	Route selection and micro-siting of the cables will be used to avoid areas of sea bed that pose a significant challenge to their installation, including for example areas of sand waves and

Parameter	Mitigation Measures Embedded into the Design of DEP and SEP
	megaripples. This will minimise the requirement for sea bed preparation (levelling) and the associated sea bed disturbance. This is reflected in the allowances that have been made for these works as described in **Table 9.2**, based on the information from the geophysical surveys conducted to date.
Landfall	HDD will be used to install the cables at the landfall, exiting approximately 1,000m offshore. Cables will be buried at sufficient depth to have no effect on coastal erosion. Erosion would continue as a natural phenomenon driven by waves and subaerial processes, which would not be affected by DEP and SEP. Natural coastal erosion throughout the lifetime of the project has been considered within the project design by ensuring appropriate set back distances from the coast for the onshore HDD entry point.

8.4 Impact Assessment Methodology

8.4.1 Policy, Legislation and Guidance

8.4.1.1 National Policy Statements

21. The assessment of potential impacts upon marine geology, oceanography and physical processes has been made with specific reference to the relevant National Policy Statements (NPS). These are the principal decision making documents for Nationally Significant Infrastructure Projects (NSIPs). Those relevant to DEP and SEP are:

- Overarching NPS for Energy (EN-1) (Department of Energy and Climate Change (DECC) 2011a);
- NPS for Renewable Energy Infrastructure (EN-3) (DECC 2011b); and
- NPS for Electricity Networks Infrastructure (EN-5) (DECC 2011c).

22. The specific assessment requirements for marine geology, oceanography and physical processes, as detailed in the NPS, are summarised in **Table 8.5** together with an indication of the section of the PEIR chapter where each is addressed.

Table 8.5: NPS Assessment Requirements

NPS Requirement	NPS Reference	PEIR Reference
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. This was agreed in general terms through the Method Statement and Seabed ETG

NPS Requirement	NPS Reference	PEIR Reference
'the ES [PEIR] 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 are described in **Section 7.6** and **Section 7.7**, respectively DEP and SEP will not affect the Shoreline Management Plan and allowance has been made for predicated erosion rates during DEP and SEP design (further detail is provided in **Chapter 4 Site Selection and Assessment of Alternatives**). Embedded mitigation to minimise potential impacts 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 10 Benthic Ecology**, **Chapter 11 Fish and Shellfish Ecology**, **Chapter 12 Marine Mammal Ecology** and **Chapter 13 Offshore Ornithology.** Effects on recreation are assessed in **Chapter 21 Land Use, Agriculture and Recreation.** As described above DEP and SEP have been designed so that it is not vulnerable to coastal change or climate change.

NPS Requirement	NPS Reference	PEIR Reference
• The vulnerability of the proposed development to coastal change, taking account of climate change, during the Project's operational life and any decommissioning period'		
'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 Cromer Shoal Chalk Beds MCZ and the East Anglian coast. The potential to affect their integrity is assessed with respect to changes in sea bed level caused by foundation and cable installation (**Section 8.6.4.1**–**Section 8.6.4.8**) and interruption to bedload sediment transport by cable protection (**Section 8.6.5.5** and **Section 8.6.5.6**).
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 in **Section 8.6.5.1** – **Section 8.6.5.3** cover the potential magnitude and significance of the physical (waves, tides and sediments) effects upon the baseline conditions resulting from the construction and operation of DEP and SEP. Scour resulting from the proposed development is not assessed because scour protection will be used wherever scour will occur, reducing sediment release to negligible quantities.
'where necessary, assessment of the effects on the subtidal environment should include:	Section 2.6, paragraph 2.6.113	See above for scour. The quantification and potential impact of sea bed loss due to the footprints of DEP and SEP infrastructure is covered in

NPS Requirement	NPS Reference	PEIR Reference
• Loss of habitat due to foundation type including associated sea bed 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 8.6.5.4**. 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 sea bed caused by indentations due to installation vessels is assessed in **Section 8.6.4.9.** The potential increase in suspended sediment concentrations and change in sea bed level is assessed in **Section 8.6.4.1**– **Section 8.6.4.8**. The recoverability of receptors is assessed for all the relevant impacts, particularly those related to changes in sea bed level due to export cable installation (**Section 8.6.4.6**) and morphological and sediment transport effects due to cable protection measures for export cables (**Section 8.6.5.6**).
'an assessment of the effects of installing cable across the intertidal zone should include information, where relevant, about:	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**

NPS Requirement	NPS Reference	PEIR Reference
• 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’		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 10 Benthic Ecology.** 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 8.6.5.6.** The recoverability of the coastal receptor (East Anglian coast) is assessed for morphological and sediment transport effects due to cable protection measures at the coast (**Section 8.6.5.6**).

8.4.1.2 Other

23. 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:

- The Marine Policy Statement (MPS, HM Government, 2011; discussed further in **Chapter 3, Policy and Legislative Context**) 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 East Inshore and the East Offshore Marine Plans (HM Government, 2014; discussed further in **Chapter 3 Policy and Legislative Context**). 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**), 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".*

24. In addition to NPS, MPS and East Inshore and East Offshore Marine Plans, guidance on the generic requirements, including spatial and temporal scales, for marine physical processes studies associated with offshore wind farm developments is provided in seven 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 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).
- East Inshore and East Offshore Marine Plan Areas: Evidence and Issues (MMO, 2012).

25. Further detail where relevant is provided in **Chapter 3 Policy and Legislative Context**.

8.4.2 Data and Information Sources

8.4.2.1 Site specific surveys

26. In order to provide site-specific and up-to-date information on which to base the impact assessment, studies of sedimentary processes and geology in the Cromer Shoal Chalk Beds MCZ were completed by Royal HaskoningDHV (2020) (**Appendix 8.2**) and British Geological Survey (2021), and specifically along the export cable corridor for the DEP and SEP.

27. A geophysical (multibeam echosounder for bathymetry, side-scan sonar for sea bed texture and sub-bottom profiling for shallow geology) survey of the DEP site, SEP site and interlink cable corridor was completed in March to May 2020 (Gardline, 2020a, b). The geophysical survey of the export cable corridor was completed between September and December 2019 (Gardline, 2019). A benthic survey of the project, which collected data on sea bed sediments and particle size, was completed between 11th and 18th August 2020 (Fugro, 2020). The results of these surveys are described in **Table 8.6** and are used to help characterise the existing environment in this chapter.

Table 8.6: Site-specific surveys

Data set	Spatial coverage	Year	Notes
Geophysical survey	DEP North	March to May 2020	High-resolution sea bed bathymetry, sea bed texture, morphological features and shallow geology
Geophysical survey	DEP South	March to May 2020	High-resolution sea bed bathymetry, sea bed texture, morphological features and shallow geology
Geophysical survey	Interlink cable corridor	March to May 2020	High-resolution sea bed bathymetry, sea bed texture, morphological features and shallow geology
Geophysical survey	SEP	March to May 2020	High-resolution sea bed bathymetry, sea bed texture, morphological features and shallow geology
Geophysical survey	Export cable corridor	September to December 2019	High-resolution sea bed bathymetry, sea bed texture, morphological features and shallow geology
Grab sample survey	DEP North	August 2020	16 grab samples and particle size at selected sites
Grab sample survey	DEP South	August 2020	11 grab samples and particle size at selected sites
Grab sample survey	Interlink cable corridor	August 2020	23 grab samples and particle size at selected sites
Grab sample survey	SEP	August 2020	17 grab samples and particle size at selected sites
Grab sample survey	Export cable corridor	August 2020	31 grab samples and particle size at selected sites

8.4.2.2 Other available sources

28. 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 DOW and SOW ESs (HR Wallingford, 2006, 2009) (**Table 8.7**):

- 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 wind farm site and surrounding sea area, along the export cable corridor 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 turbines 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.

29. In addition to the site-specific surveys for DEP and SEP and the data collected for DOW and SOW, a range of other data sources is available including:

- National Tide and Sea Level Forecasting Service;
- Extreme sea levels database (Environment Agency, 2018);
- UK Hydrographic Office (UKHO) tidal diamonds;
- British Oceanographic Data Centre;
- UKCP18 (Met Office, 2018);
- Admiralty Charts and UK Hydrographic Office survey data.
- Southern North Sea Sediment Transport Study; and
- Shoreline Management Plans.

Table 8.7: Existing data sources used in the PEIR

Data source	Date	Data contents
SOW ES and associated technical supporting documents (Scira Offshore Energy)	2006	All marine geology, oceanography and physical processes information and data related to the existing offshore wind farm
SOW: Coastal and sea-bed processes (HR Wallingford)	2006	Hydrodynamic modelling of the existing offshore wind farm
DOW ES and associated technical supporting documents (Dudgeon Offshore Wind)	2009	All marine geology, oceanography and physical processes information and data, including numerical

Data source	Date	Data contents
		modelling, related to the existing wind farm
Post construction geophysical monitoring of SOW	2013-18	Bathymetry and sea-bed character
Post construction environmental monitoring of SOW	2012-20	Sea-bed sediment and particle size
Post construction geophysical monitoring of DOW	2018	Bathymetry and sea-bed character
Post construction environmental monitoring of DOW	2018	Sea-bed sediment and particle size
Post-construction environmental monitoring of the SOW export cables	2013-20	Sea-bed sediment

8.4.3 Impact Assessment Methodology

30. **Chapter 6 EIA Methodology** provides a summary of the general impact assessment methodology applied to DEP and SEP. The following sections confirm the methodology used to assess the potential impacts on marine geology, oceanography and physical processes.

31. 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 receptor impacted by the effect, 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 sea bed (source). This sediment is then transported by tidal currents until it settles back to the sea bed (pathway). The deposited sediment could change the composition and elevation of the sea bed (receptor). Numerical modelling of marine geology, oceanography and physical processes effects of DEP and SEP would be disproportionate to the potential impact and a conceptual evidence-based assessment is preferred (see further details in **Section 8.6.3**).

32. Consideration of the potential effects of DEP and SEP 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 wind farm site and along the export cable corridor; 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).

33. 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 ascribed inherent values, such as chalk reef and other MCZ features, and beaches and sea cliffs (coast).

34. 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 impact.

35. In addition to identifiable receptors, the second type of assessment covers changes to marine geology, oceanography and physical processes which in themselves are not necessarily impacts to which significance can be ascribed. Rather, these changes (such as a change in the wave climate, a change in the tidal regime or a change in suspended sediment concentrations) represent effects which may manifest themselves as an impact upon other receptors, most notably marine water and sediment quality, benthic ecology, and fish and shellfish ecology (e.g. in terms of increased suspended sediment concentrations, or erosion or smothering of habitats on the sea bed). 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 impact is based on an assessment of the sensitivity of the receptor and magnitude of effect by means of an impact significance matrix.
- situations where effects (or changes) in the baseline marine geology, oceanography and physical processes may occur which could manifest as impacts upon receptors other than marine geology, oceanography and physical processes. In this case, the magnitude of effect is determined in a similar manner to the first assessment method but the significance of impacts on other receptors is made within the relevant chapters of the PEIR pertaining to those receptors.

8.4.3.1 Definitions

36. For each effect, the assessment identifies receptors sensitive to that effect and implements a systematic approach to understanding the impact pathways and the level of impacts on given receptors. The sensitivity of a receptor is dependent upon its:

- Tolerance to an effect (i.e. the extent to which the receptor is adversely affected by an effect);
- Adaptability (i.e. the ability of the receptor to avoid adverse impacts that would otherwise arise from an effect); and
- Recoverability (i.e. a measure of a receptor's ability to return to a state at, or close to, that which existed before the effect caused a change).

37. In addition, a value component may also be considered when assessing a receptor. This ascribes whether the receptor is rare, protected or threatened. The magnitude of an effect is dependent upon its:

- Scale (i.e. size, extent or intensity);
- Duration;
- Frequency of occurrence; and
- Reversibility (i.e. the capability of the environment to return to a condition equivalent to the baseline after the effect ceases).

38. The sensitivity and value of discrete morphological receptors and the magnitude of effect will be assessed using evidence-based judgement and described with a standard semantic scale. Definitions for each term are provided in **Table 8.8** and **Table 8.9**. These evidence-based judgements of receptor sensitivity, value and magnitude of effect will be closely guided by the conceptual understanding of baseline conditions.

Table 8.8: Definitions of sensitivity for a morphological receptor

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

Table 8.9: 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 local to 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.

8.4.3.2 Impact Significance

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

40. Potential impacts identified within the assessment as major or moderate are regarded as significant in terms of the EIA regulations. 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 impact in order to determine a residual impact upon a given receptor.

Table 8.10: Impact significance 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*	*Minor*	*Negligible*	*Negligible*	*Minor*	*Minor*	*Moderate*
	Negligible	*Minor*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Minor*

Table 8.11: Definition of impact 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.
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 impact, therefore, no change in receptor condition.

8.4.4 Cumulative Impact Assessment Methodology

41. The CIA considers other plans, projects and activities that may impact cumulatively with DEP and SEP. As part of this process, the assessment considers which of the residual impacts assessed for DEP and/or SEP on their own have the potential to contribute to a cumulative impact. **Chapter 6 EIA Methodology** provides further details of the general framework and approach to the CIA.

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

8.4.5 Transboundary Impact Assessment Methodology

43. The transboundary assessment considers the potential for transboundary effects to occur on marine geology, oceanography and physical processes receptors as a result of DEP and SEP; 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** provides further details of the general framework and approach to the assessment of transboundary effects.

44. For marine geology, oceanography and physical processes, the potential for transboundary effects were considered in the Scoping Report and it was concluded that “transboundary impacts are unlikely to occur or are unlikely to be significant” (Royal HaskoningDHV, 2019, PINS, 2019). Therefore, transboundary impacts are scoped out and will not be considered further in this chapter.

8.4.6 Assumptions and Limitations

45. Due to the large amount of data that has been collected for the site-specific surveys, DOW and SOW, 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.

46. Data for the ambient suspended sediment concentrations along the north Norfolk coast are not available, and this assessment is solely based on evidence-based conceptual geomorphological assessment of the likely magnitudes at the coast, based on the perceived energy conditions. Regional suspended sediment data was available from the southern North Sea Sediment Transport Study (HR Wallingford *et al*., 2002), but estimates at the coast are extrapolated from locations further offshore, which were the closest data points to the export cable corridor (near shore section) and landfall. Hence, there is uncertainty as to the validity of this extrapolation inshore where physical conditions are different (e.g. more energetic).

8.5 Existing Environment

8.5.1 Bathymetry and bedforms

8.5.1.1 DEP and SEP

47. Water depths at the DEP and SEP sites range from 14m below Lowest Astronomical Tide (LAT) in the northwest of SEP to 36m below LAT in the northwest of DEP North (**Figure 8.1** and **Figure 8.2**) (Gardline, 2020a, b). The sea bed gradient across DEP and SEP is generally less than 1°, although gradients of greater than 10° are observed on the flanks of sand waves (Gardline, 2020 a,b).

48. Sand waves are prevalent across DEP and SEP, particularly in the northwest of DEP North (Gardline, 2020 a,b). The largest sand waves, commonly trending northeast to southwest, reach heights of approximately 2-4m, although they are more commonly 1-1.5m (Gardline, 2020 a,b).

49. Ripples trending northeast to southwest are present at DEP and SEP and are approximately 0.8m in height, with wavelengths less than 1m. Further minor ripples (less than 0.5m high) are found sporadically across the surveyed areas (Gardline, 2020 a,b).

8.5.1.2 Interlink cable corridors

50. Water depths along the interlink cable corridors are between 10m below LAT and 35m below LAT (**Figure 8.3**) (Gardline, 2020b). The sea bed gradient is generally less than 1° along the routes, although gradients reach greater than 10° on the flanks of megaripples (Gardline, 2020b). The bathymetry shallows moving northwest along the interlink corridor between DEP South and DEP North from approximately 23-24m below LAT to 11-13m below LAT (DOW, 2009).

51. Sand waves oriented northeast to southwest are found predominantly at the northern ends of the SEP to DEP North, and DEP North to DEP South interlink cable corridors, and at the northwestern end of the DEP South to DEP North interlink cable corridor reaching heights of up to 3m (Gardline, 2020b). Minor ripples less than 0.5m high are present along all interlink cable routes (Gardline, 2020b).

8.5.1.3 Export cable corridor

52. Water depths within the offshore portion of the export cable corridor, in the region of the SEP site, are typically 25-27m below LAT (**Figure 8.4**). Water depths decrease progressively to 0m LAT at the coast (Gardline, 2019). The 5m below LAT contour is typically 200-300m from the coast (Gardline, 2019).

53. Superimposed on the general reduction in water depth shoreward is the eastern tip of Sheringham Shoal sand bank, where the bathymetry shallows to about 16m below LAT (Gardline, 2019). Secondary bedforms within the export cable corridor include areas of megaripples (including the flanks of the sand bank) up to 0.5m high with crests typically oriented north-south or north-northeast to south-southwest (Gardline, 2019).

54. The export cable corridor passes through the Cromer Shoal Chalk Beds MCZ. Three geophysical surveys completed across the MCZ for Cefas between 2012 and 2014 provide a general bathymetric overview (**Appendix 8.2**) (Royal HaskoningDHV, 2020). **Appendix 8.2** includes information relevant to an offshore export cable corridor making landfall near Bacton. However, since the report was produced the Weybourne landfall option has been selected as described in **Chapter 4 Site Selection and Assessment of Alternatives.** The bathymetry slopes seaward from about 5m below LAT close to the coast to about 20m below LAT at its seaward boundary (**Figure 8.4**). Details of how variations in bathymetry relate to the underlying geology, sea bed sediment distribution and bedload sediment transport are provided in **Sections 8.5.7.6** and **8.5.8.1**.

8.5.2 Offshore geology

55. The geology of DEP and SEP generally consists of Holocene deposits overlying a series of Pleistocene sands and clays, with a bedrock of Upper Cretaceous Chalk (**Table 8.12**).

Table 8.12: Geological formations present at DEP and SEP, interlink cable corridor and export cable corridor (Gardline, 2020a,b; British Geological Survey, 2020)

Formation	Geophysical description	Expected geological conditions
Botney Cut Formation	Five units varying from chaotic to conformable acoustic facies.	Sand-rich or organic-rich sandy mud channel infills, glaciolacustrine laminated silt and sandy clay, and glaciofluvial sand
Bolders Bank Formation	Three units, typically with a chaotic acoustic character.	Sub-glacial diamicton composed of firm to very stiff clay.
Egmond Ground Formation	Acoustically raised amplitude well layered even reflectors.	Very dense fine sand

Formation	Geophysical description	Expected geological conditions
Sand Hole or Upper Swarte Bank Formation	Two units. Upper unit with conformably-banded horizons with some prograding strata. Lower unit of disturbed conformable reflectors.	Basinal, quiescent (clay-rich) sedimentation (lower unit) and sand-rich deposition (upper unit)
Swarte Bank Formation	Five units of acoustically chaotic/massive reflectors.	Sub-glacial diamicton composed of hard clay with occasional chalk, gravel and flint
Cretaceous Chalk	Acoustically high amplitude very well layered broadly undulating reflections.	Weak to moderately weak low to medium density chalk

8.5.2.1 DEP North

56. The bedrock across DEP North is dominated by Cretaceous Chalk. The top of the formation is between 4m and 80m below the sea bed (Gardline, 2020a). The chalk is incised by large northwest to southeast oriented channels which are infilled by the Swarte Bank Formation.

57. A blanket deposit of the Egmond Ground Formation overlies the Swarte Bank Formation. However, this is extensively incised by channelling and infilling with Botney Cut Formation and Bolders Bank Formation. Bolders Bank Formation overlies the Egmond Ground Formation although much has been removed by Botney Cut channelling (Gardline, 2020a). A significant Botney Cut channel incises the underlying units through to the Chalk at approximately 80m below LAT in the southeast of the site.

58. Holocene deposits are present up to 9m below the sea bed overlying the Botney Cut Formation and in places, the Bolders Bank Formation (Gardline, 2020a). In localised areas, pockets of underlying formations are exposed where Holocene sands are absent (Gardline, 2020a).

8.5.2.2 DEP South

59. The underlying bedrock in DEP South is dominated by Upper Cretaceous Chalk, the top of which is typically in excess of 50m below the sea bed to within 13m of the sea bed in the east and far northwest (Gardline, 2020a). The Chalk is extensively faulted, although vertical displacement rarely exceeds 10m.

60. The chalk is overlain by the Swarte Bank Formation across most of the site, except in the northeast where it has been removed by channelling and infilled with Botney Cut Formation. In the northwest, the chalk is incised by a large channel down to 200m below the sea bed infilled with Swarte Bank Formation. The Swarte Bank Formation is overlain by a thin layer of Egmond Ground Formation, thickening in the east and west and absent through the centre of the site. The Bolders Bank Formation, up to 8m thick, forms a blanket deposit across almost the entire site and is only absent where Botney Cut Formation is present in channels (Gardline, 2020a). A prominent channel filled with Botney Cut Formation is present in the west of the site, extending up to 18m below the sea bed along the channel thalweg (Gardline, 2020a).

61. The Holocene sediment is composed of loose fine to medium sand with shell fragments and is up to 11m thick. The mobile sea bed sediments include a 4m-thick sand bank in the northwest of the site.

8.5.2.3 Interlink Cable Corridor

8.5.2.3.1 SEP to DEP North

62. Progressing north-northeast from SEP towards DEP North, the underlying geology exhibits Bolders Bank Formation up to 10m thick along the majority of the route. This is cut by Botney Cut Formation channels in places (Gardline, 2020b). A large Botney Cut channel infill oriented northeast to southwest is located beneath the Holocene veneer at approximately 16km from SEP (Gardline, 2020b). The Holocene veneer thickens rapidly at 16km (reaching up to 7m), forming a sand bank with superimposed sand waves up to 3m high (Gardline, 2020b).

63. At the DEP North end of the cable corridor, the Botney Cut Formation is up to 30m thick and overlain by a thin (1m) deposit of Holocene sediment (Gardline, 2020b).

8.5.2.3.2 SEP to DEP South

64. Progressing northeast from SEP towards DEP South, conditions are similar to that seen along the SEP to DEP North route; a thin veneer of Holocene sediment overlies the Bolders Bank Formation, which is intermittently cut by Botney Cut Formation channels (Gardline, 2020b).

65. At approximately 11km from SEP, a high-standing feature composed of a well layered sequence of sediments with a flat base is observed. This has been interpreted as the Botney Cut Formation (Gardline, 2020b).

8.5.2.3.3 DEP North to DEP South

66. Progressing northeast from DEP South to DEP North, Holocene sands overlie the Bolders Bank Formation. A minor channel is observed incising into the underlying Bolders Bank Formation infilled with the Botney Cut Formation. In the central survey area, the Bolders Bank Formation is underlain by a sub-crop of the Upper Chalk Formation, whilst in other survey areas it is underlain by the Egmond Ground Formation (Gardline, 2007).

8.5.2.4 SEP

67. The bedrock under SEP is dominated by Upper Cretaceous Chalk, the top of which lies in excess of 180m below the sea bed and as shallow as 3m below the sea bed at the far southeast fringes of the site where the Botney Cut Formation rests directly on the chalk (Gardline, 2020b).The Chalk is incised by large channels filled with Swarte Bank Formation. The base of the largest channel is 180m below the sea bed in the west of the site.

68. The Bolders Bank Formation overlies the Swarte Bank Formation as a blanket deposit across most of the site, although it is frequently cut by Botney Cut Formation in channels. These channels are oriented northeast to southwest and are up to 70m below the sea bed at their bases (Gardline, 2020b).

69. The Holocene sediments are generally up to 1.5m thick, but sand banks are present in the southeast and northwest of the site (Gardline, 2020b).

8.5.2.5 Export Cable Corridor

70. The bedrock along the export cable corridor is dominated by Upper Cretaceous Chalk (Cameron *et al*., 1992; Gardline, 2019; British Geological Survey, 2021). Along most of the southern part of the corridor to south of Sheringham Shoal sand bank, the chalk is either exposed at the sea bed (within the landward 500m of the corridor) or sub-cropping beneath alternating zones of thin gravelly sand/gravel and Holocene sand.

71. About 1-2km from the coast, the chalk is dissected by a deep infilled channel cut through the chalk to -17m LAT filled with Weybourne Channel deposits. These are likely to be a mix of older sand and gravel overlain by laminated silts and sands (Chroston *et al*., 1999).

72. From south of Sheringham Shoal sand bank to the SEP site, the geology is dominated by Pleistocene Botney Cut Formation (and some Swarte Bank Formation) overlying chalk. Where the Botney Cut and Swarte Bank Formations are absent the chalk sub-crops at the sea bed beneath a thin unit of sand and gravel. About 10km from the coast, the Pleistocene units are overlain by the Sheringham Shoal sand bank (and associated megaripples), which is up to 6m thick along the cable corridor.

8.5.2.6 Cromer Shoal Chalk Beds MCZ

73. The export cable corridor passes through the western end of the Cromer Shoal Chalk Beds MCZ. It extends about 10km offshore and covers an area of about 321km^2 (Royal HaskoningDHV, 2020). The bedrock geology across the MCZ is dominated by chalk which is around 400m thick across the site (Cameron *et al*., 1992). In the western part of the MCZ close to the landfall, subtidal chalk is exposed at the sea bed close to the intertidal zone, extending further offshore in the southeast portion of the site (Royal HaskoningDHV, 2020).

74. The sea bed and the shallow sediment layers beneath the sea bed of the Cromer Shoal Chalk Beds MCZ in the vicinity of the proposed cable corridor are characterised geologically and geomorphologically in several different ways (Royal HaskoningDHV, 2020; British Geological Survey, 2021). These are:

    - Outcropping chalk at the sea bed with no overlying sediment;
    - Subcropping chalk covered by a thin lag of coarse sand and gravel;

- Pleistocene glacial sediments covered by a thin lag of coarse sand and gravel;
- Chalk (or chalk with lag) overlain by Holocene sand; and
- Pleistocene glacial sediments overlain by Holocene sand.

75. The Cromer Shoal Chalk Beds MCZ encompasses important sea bed geological features including the best examples of subtidal chalk beds in the North Sea (Royal HaskoningDHV, 2020). The shallow inshore part of the MCZ out to 10m water depth features infralittoral rock which extends for almost the entire length of the site. This area of hard, stable substrate provides a suitable habitat for attached and mobile epifauna. Extending offshore from the infralittoral rock into deeper water is a band of circalittoral rock with more epifauna. The areas of infralittoral and circalittoral rock in the MCZ are comprised of subtidal chalk, as well as other rock types. It is not possible to accurately differentiate between different types of rock using geophysical data, and so areas mapped as the subtidal chalk are likely to overlap with areas mapped as circalittoral and infralittoral rock.

76. Spray and Watson (2011) reported the results of 111 dives to the nearshore sea bed between Cley and Trimingham. Chalk was encountered on every dive with no dives recording only sand or sediment. The exposed chalk has a variety of characters with a continuum from low, irregular plains with scattered flints, through mounded chalk to a rugged sea bed with 1-2m-deep gullies (with partial sediment infill) and ridges, pinnacles and arches. This indicates that where the chalk outcrops at the sea bed it is complex and displays micro-variations in bathymetry (over distances of metres) (Royal HaskoningDHV, 2020).

8.5.2.7 Landfall

77. The coast of north to northeast Norfolk to the east of the landfall is an almost continuous line of glacial till cliffs with a short length of chalk cliffs at Weybourne. The cliffs are fronted by a steep shingle beach. To the west, the cliffs disappear and are replaced by areas of lower ground at Weybourne Gap and Kelling Hard. The beach is formed into a shingle ridge fronting a low-lying coastal fringe with tidal inlets and saltmarsh.

8.5.3 Water Levels

8.5.3.1 Regional Summary

78. The astronomical tidal range in the southern North Sea and along the East Anglian coast varies according to the position of an amphidromic point between East Anglia 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 west across the study area (**Figure 8.5**).

8.5.3.2 DEP North

79. DEP North 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 3.7m at its eastern boundary and 4.1m at its western boundary.

8.5.3.3 DEP South

80. The mean spring tidal range at DEP South ranges from about 3.5m at its eastern boundary to about 3.7m at its western boundary.

8.5.3.4 Interlink Cable Corridor

81. The interlink cable corridors experience a mean spring tidal range of about 3.7m to 4.2m.

8.5.3.5 SEP

82. SEP is in an area subject to a macrotidal regime, with a mean spring tidal range varying from about 4.0m at its eastern boundary to 4.6m at its western boundary.

8.5.3.6 Export Cable Corridor

83. Along the export cable corridor, the tidal range is about 4.0m at its northern end increasing to about 4.7m at the landfall.

8.5.3.7 Cromer Shoal Chalk Beds MCZ

84. The Cromer Shoal Chalk Beds MCZ begins about 200m offshore from the north Norfolk coast with a western boundary just west of Weybourne and an eastern boundary at Happisburgh. This means the tidal range varies from about 3.0m towards its eastern end to about 4.5m towards its western end.

8.5.3.8 Storm Surge

85. The North Sea is particularly susceptible to storm surges, and water levels at DEP and SEP 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 3.15m above MHWS at Weybourne. The 1 in 50-year water levels are predicted to be 4.13m above MHWS at Weybourne.

8.5.4 Tidal Currents

86. DEP and SEP is located adjacent to the existing DOW and SOW. Measured and modelled hydrodynamic data exist for these operational assets and are used here to support the tidal current baseline for DEP and SEP.

8.5.4.1 Regional Summary

87. Regional tidal current velocity and direction are influenced by the presence of the amphidromic point (**Section 8.5.3**) and the anti-clockwise circulation around it. HR Wallingford *et al*. 2002a developed a regional tidal flow model (using TELEMAC), which was used to predict tidal current vectors in the southern North Sea. The model predicted regional spring tide flows closer to the north Norfolk coast that are approximately parallel to the coast turning towards west-northwest (flood tide) and east-southeast (ebb tide) close to DEP and SEP and then northwest and southeast further offshore. Predicted offshore current velocities are around 1m/s reducing to about 0.7m/s closer to the coast.

88. DOW (2009) used the regional TELEMAC model (HR Wallingford *et al*., 2002a), validated against local Acoustic Wave and Current Meter (AWAC) data and information from Admiralty Chart tidal diamonds, to simulate tidal currents at and adjacent to DOW. The simulated data covers the southern area occupied by DEP North, the majority of the area occupied by DEP South and the eastern half of the area occupied by the interlink cable corridor.

89. The predicted peak flood flow and peak ebb flow vectors for spring tides at DOW and shown in **Plate 8-1** and **Plate 8-2**, respectively. Predicted peak flood flow and peak ebb flow vectors for neap tides at DOW are shown in **Plate 8-3** and **Plate 8-4** respectively.

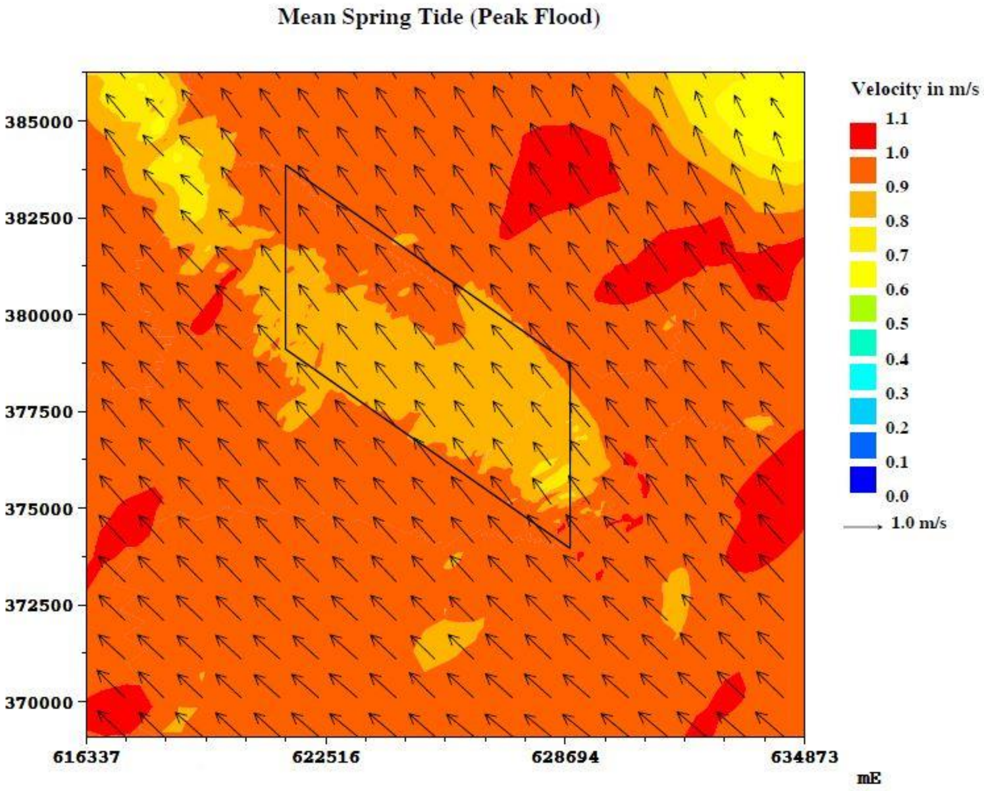

Plate 8-1: Peak flood flow vector for spring tide at DOW (DOW, 2009).

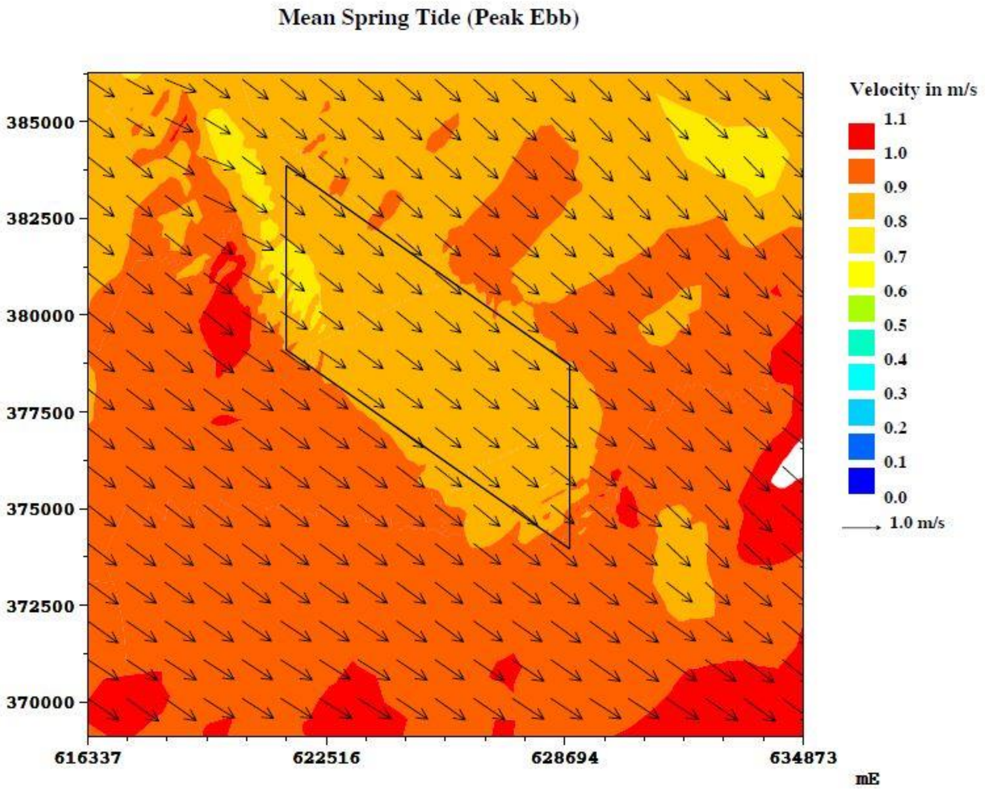

Plate 8-2: Peak ebb flow vector for spring tide at DOW (DOW, 2009).

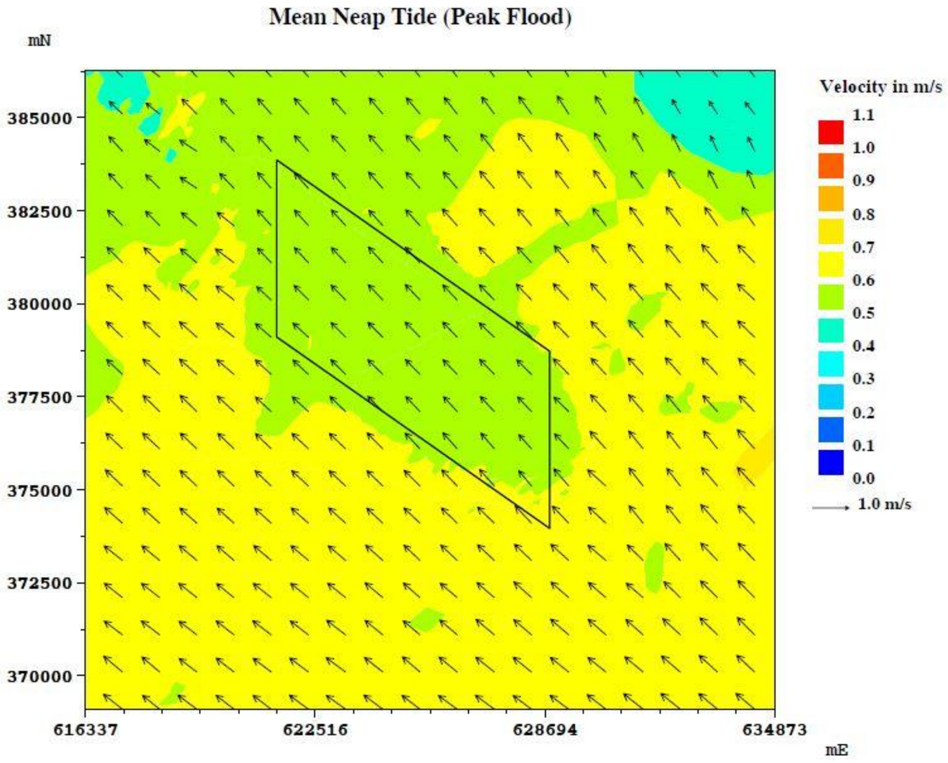

Plate 8-3: Peak flood flow vector for neap tide at DOW (DOW, 2009)

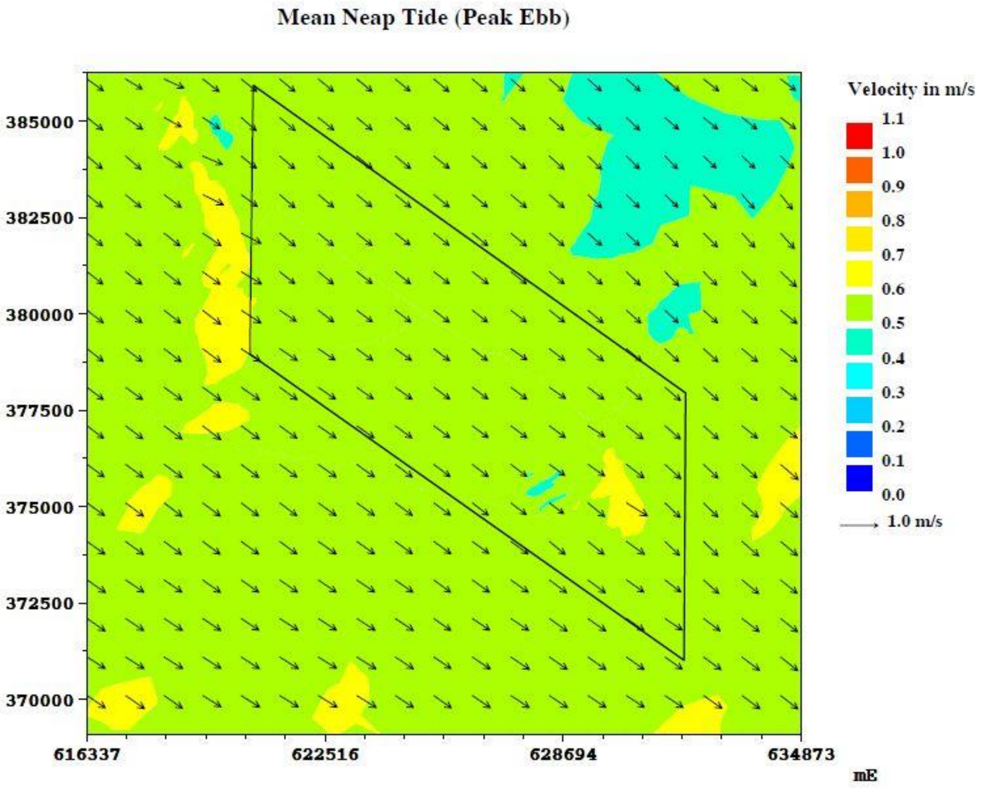

Plate 8-4: Peak ebb flow vector for neap tide at DOW (DOW, 2009)

90. Scira (2006) used the regional TELEMAC model (HR Wallingford *et al*., 2002a), validated against local AWAC data and information from Admiralty Chart tidal diamonds, to simulate tidal currents at and adjacent to SOW. The predicted peak flood flow and peak ebb flow vectors for spring tides are shown in **Plate 8-5** and **Plate 8-6**, respectively. Predicted peak flood flow and peak ebb flow vectors for neap tides are shown in **Plate 8-7** and **Plate 8-8**, respectively. The simulated data covers the area occupied by SEP and also covers the area between the DEP and SEP sites and the coast.

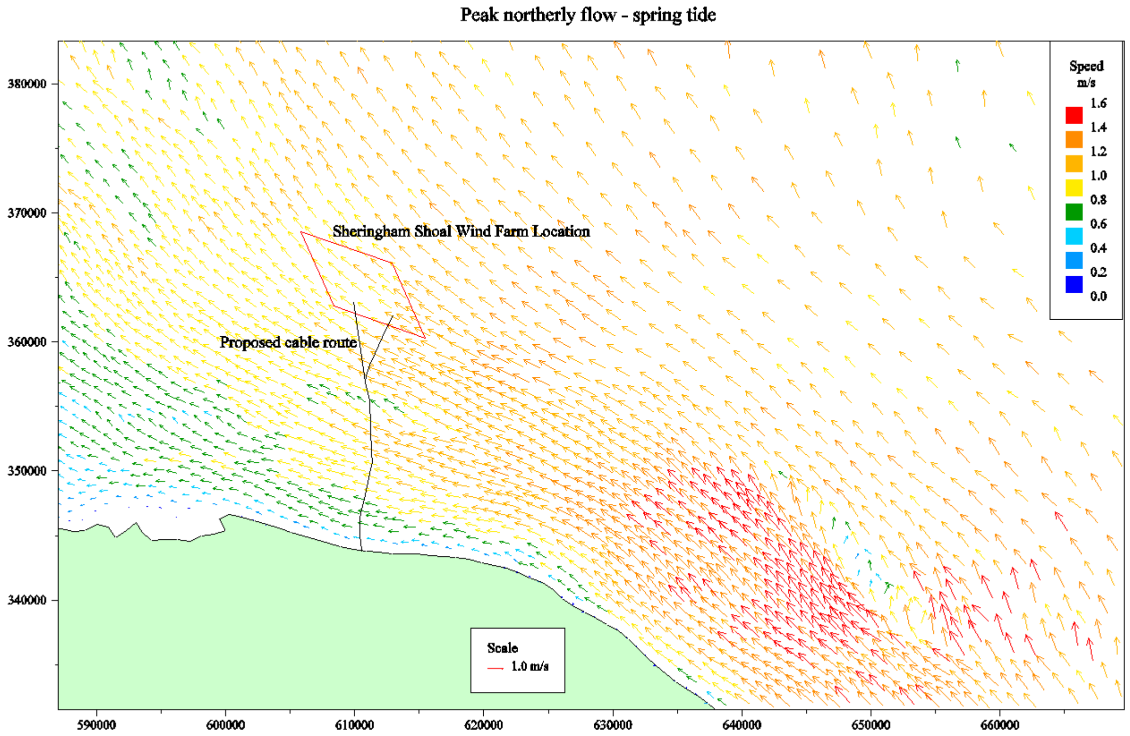

Plate 8-5: Peak flood flow vector for spring tide at SOW (Scira, 2006)

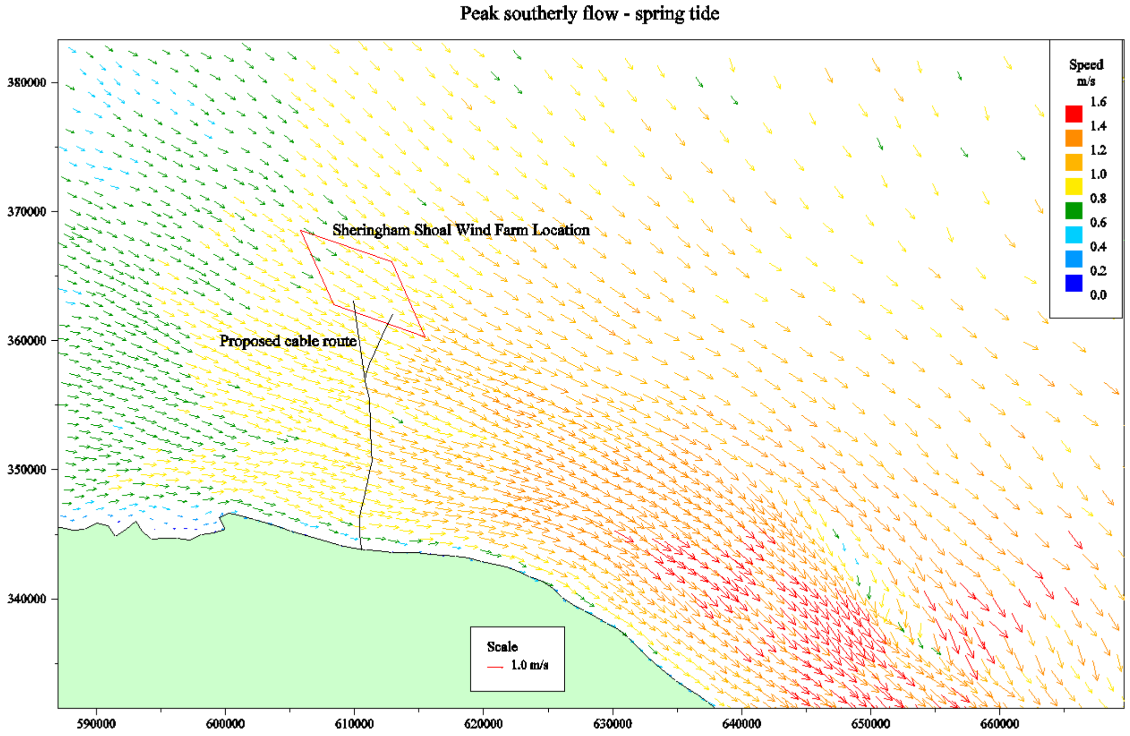

Plate 8-6: Peak ebb flow vector for spring tide at SOW (Scira, 2006)

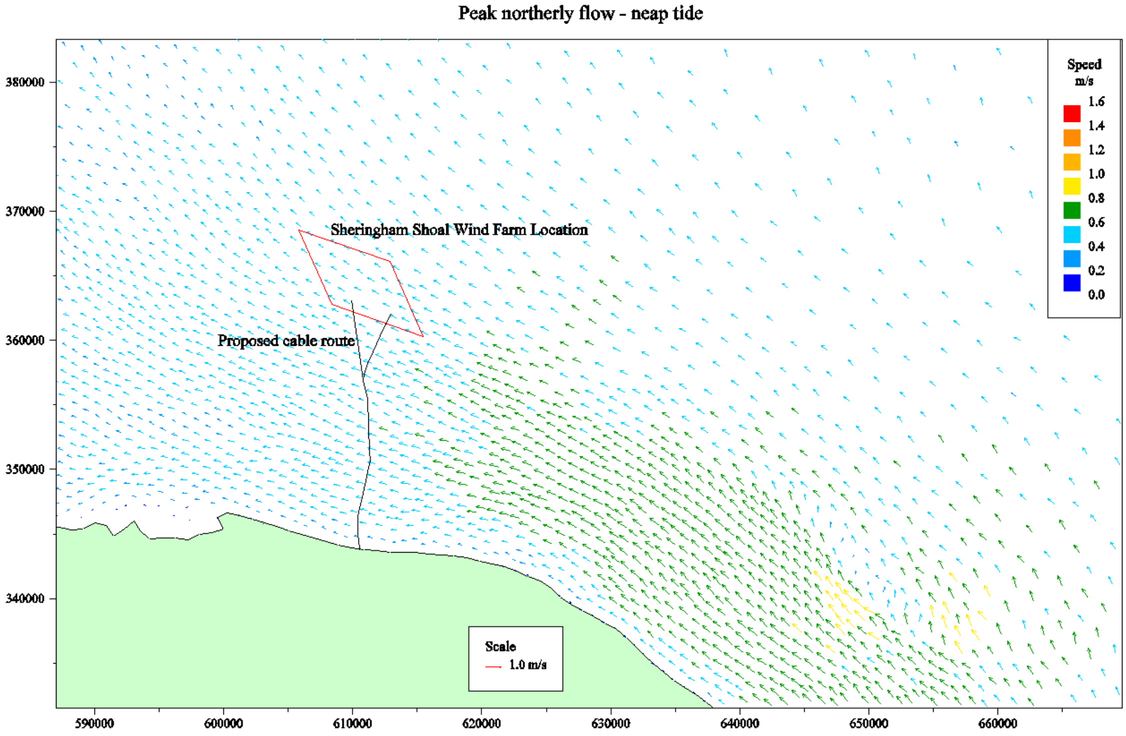

Plate 8-7: Peak flood flow vector for neap tide at SOW (Scira, 2006)

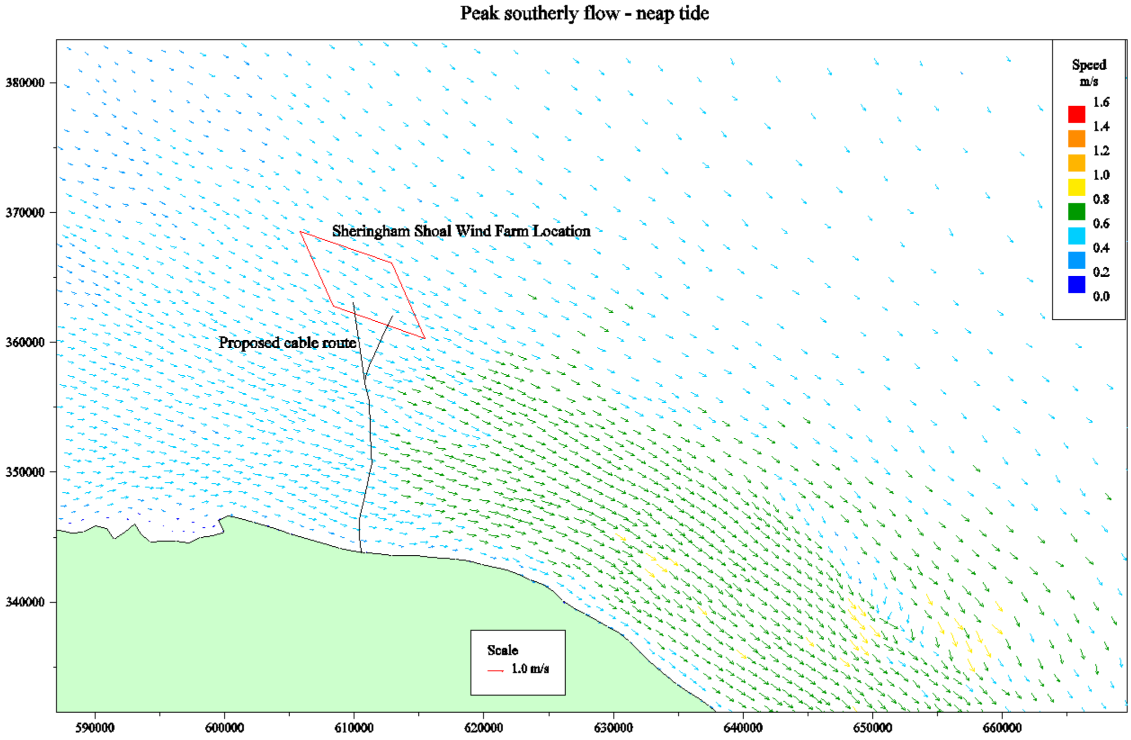

Plate 8-8: Peak ebb flow vector for neap tide at SOW (Scira, 2006)

8.5.4.2 DEP North

91. The spring tide peak flows across DEP North are predicted to be between 0.6m/s and 1.0m/s to the northwest on a flood tide and between 0.8m/s and 1.1m/s to the southeast on an ebb tide. Peak neap tide flows are predicted to be about 0.4-0.7m/s on both flood and ebb tides.

8.5.4.3 DEP South

92. Peak spring tide flows across DEP South are predicted to be about 0.8-1.1m/s on both flood and ebb tides and peak neap tide flows are predicted to be about 0.5-0.7m/s on both flood and ebb tides.

8.5.4.4 Interlink Cable Corridors

93. Peak spring tide flows across the interlink cable corridors are predicted to be about 0.7-1.1m/s on both flood and ebb tides and peak neap tide flows are predicted to be about 0.5-0.7m/s on both flood and ebb tides.

8.5.4.5 SEP

94. The spring tide peak flows across the SEP site are predicted to be between 0.8m/s and 1.2m/s to the northwest on a flood tide and between 0.6m/s and 1.2m/s to the southeast on an ebb tide. Peak neap tide flows are predicted to be about 0.4-0.6m/s on both flood and ebb tides.

8.5.4.6 Export Cable Corridor

95. Along most of the export cable corridor, the spring tide peak current flows are predicted to be 0.8-1.2m/s on both flood and ebb tides. Currents are directed west-northwest on a flood tide and east-southeast on an ebb tide. Neap tide peak current flows are predicted to be 0.4-0.8m/s on both flood and ebb tides. Within 1km of the coast the predicted spring tidal current flows reduce to less than 0.6m/s and re-orient to westerly on a flood tide and easterly on an ebb tide (coast-parallel).

8.5.5 Waves

8.5.5.1 Regional Summary

96. The regional wave climate is composed of a combination of swell waves generated offshore and locally generated wind-waves. Waves from the southwest through northwest with relatively low heights (less than 1m) are most frequent followed by higher waves from the northwest to northeast sector. Offshore waves above 4m are relatively common during winter storms.

97. The wave regimes at the DEP and SEP sites are informed through a desk study undertaken for SOW (Scira, 2006) and relevant data sources from previous studies (e.g. HR Wallingford, 1988, 1990, 2002a, 2002b, 2004) at DOW.

8.5.5.2 DEP North and DEP South

98. DEP North and DEP South are exposed to waves generated across the North Sea but modified by the numerous sand banks present in the Greater Wash SPA area. The most frequent waves are driven by winds from the south and west. However, fetch lengths between the coast and DEP North (38.6m) and DEP South (30.4m) are short, resulting in small waves with maximum significant wave heights of about 2m (DOW, 2009). The largest waves experienced at DEP North and DEP South are from the northwest to northeast sector, however, these waves are less frequent.

8.5.5.3 SEP

99. SEP is exposed to wave conditions generated within the North Sea, with the most severe conditions arriving from the north and northeast due to fetch lengths of over 500km. Significant wave heights greater than 1m are generated from these directions. The most frequent waves are driven by winds blowing over the much shorter fetches from the southwest to northwest sector. Significant wave heights are relatively small (generally less than 1m).

8.5.5.4 Interlink Cable Corridors

100. The interlink cable corridors are located between DEP North and DEP South, DEP North and SEP, and DEP South and SEP. The baseline wave regime is similar to those outlined above.

8.5.5.5 Export Cable Corridor

101. Nearshore wave conditions along the export cable corridor are less severe than the DEP and SEP sites due to the protection afforded by sand banks such as Sheringham Shoal and Pollard Bank. This influence is most apparent at low tide when the shallower water depths over Sheringham Shoal cause significant wave breaking, and a reduction in wave heights from the seaward to landward side of the bank. The other banks and the generally shallower water west from the SEP site also influence wave directions closer to the coast due to refraction. These effects will vary in intensity with wave direction and nearshore location.

8.5.6 Climate Change and Sea-level Rise

102. Historical data show that the global temperature has risen significantly due to anthropogenic influences since the beginning of the 20th century, and predictions are for an accelerated rise, the magnitude of which is dependent on the magnitude of future emissions of greenhouse gases and aerosols.

103. According UKCP18 which draws on the Intergovernmental Panel on Climate Change (IPCCs) Fifth Assessment of Climate Change (Church *et al*., 2013), it is likely (IPCC terminology meaning greater than 66% probability) that the rate of global sea-level rise has increased since the early 20th century. It is very likely (IPCC terminology meaning greater than 90% probability) that the global mean rate was 1.7mm/year (1.5 to 1.9mm/year) between 1901 and 2010 for a total sea-level rise of 0.19m (0.17 to 0.21m). The average long-term trend for the UK is estimated as 1.4mm/year which is slightly lower than the global 1.7mm/year. Between 1993 and 2010, the rate was very likely (IPCC terminology) higher at 3.2 mm/year (2.8 to 3.6mm/year), and this is the historic rate used in this analysis.

104. The rate of global mean sea-level rise during the 21st century is likely to exceed the rate observed between 1993 and 2010. Church *et al*. (2013) developed projections of global sea-level rise for four emissions scenarios of future climate change, called the Representative Concentration Pathways (RCP). In this analysis, the median projection of the worst-case emissions scenario (RCP8.5) is used. For RCP8.5, the rise by 2100 is 0.74m (range 0.52 to 0.98m) with a predicted sea-level rise rate during 2081–2100 of 8 to 16mm/year.

105. As the indicative design life of DEP and SEP is 35 years, and offshore infrastructure is set far enough away from the coast, this rise in sea level will not change significantly through the design life of the project.

106. With respect to waves, climate projections indicate that wave heights in the southern North Sea will only increase by between 0m and 0.05m by 2100. There is predicted to be an insignificant effect on storm surges over the lifetime of DEP and SEP (Lowe *et al*., 2009).

107. One of the most important long-term implications of climate change is the physical response of the coast to future sea-level rise. Predicting coastal erosion rates is critical to forecasting future problem areas. It is likely that the future erosion rate of the cliffs at Weybourne will be affected by the higher rates of sea-level rise than historically. Higher baseline water levels would result in a greater occurrence of waves impacting the toes of the cliffs, increasing their susceptibility to erosion.

8.5.7 Sea Bed Sediment Distribution

8.5.7.1 Regional Summary

108. The regional sea bed 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, sand waves and sand banks.

109. A site-specific grab sampling campaign totalling 98 sea bed samples was completed by Fugro from 11th to 18th August 2020. Samples were recovered from the following areas (**Figure 8.6**):

- DEP (16 samples in DEP North and 11 samples in DEP South);
- SEP (17 samples);
- Interlink cable corridors (nine samples from the part of the interlink cable corridor between DEP North and SEP and 14 samples from the part of the interlink cable corridor between DEP South and SEP); and
- Export cable corridor (31 samples, including 21 samples from within the Cromer Shoal Chalk Beds MCZ).

8.5.7.2 DEP North

110. The dominant sediment type in DEP North is medium sand (23-68% content in all samples) with median particle sizes (d_{50}) between 0.34mm and 0.71mm (medium to coarse sand) (**Plate 8-9**). The mud content is less than 5% in 69% of the samples and less than 10% in 100% of the samples.

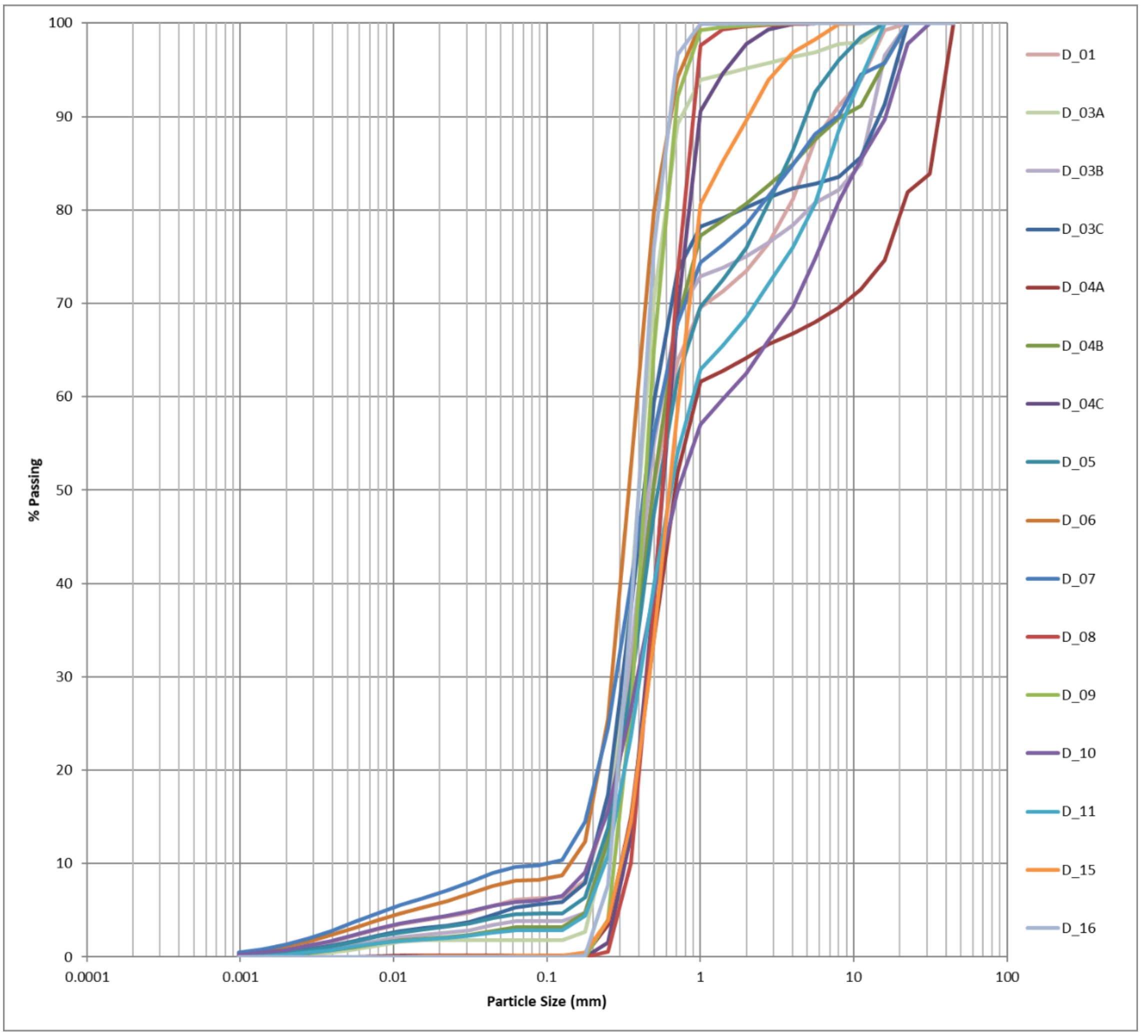

Plate 8-9: Cumulative particle size distribution curves of the 16 sea bed sediment samples collected in DEP North

8.5.7.3 DEP South

111. The dominant sediment type in DEP South is also medium sand (22.2-75.2% content in all samples) with median particle sizes between 0.30mm and 0.81mm (medium to coarse sand) (**Plate 8-10**). Samples from DEP South have a particularly high sand content, with 82% of samples containing greater than 75% sand. Mud content is less than 5% in 82% of the samples and less than 10% in 100% of the samples.

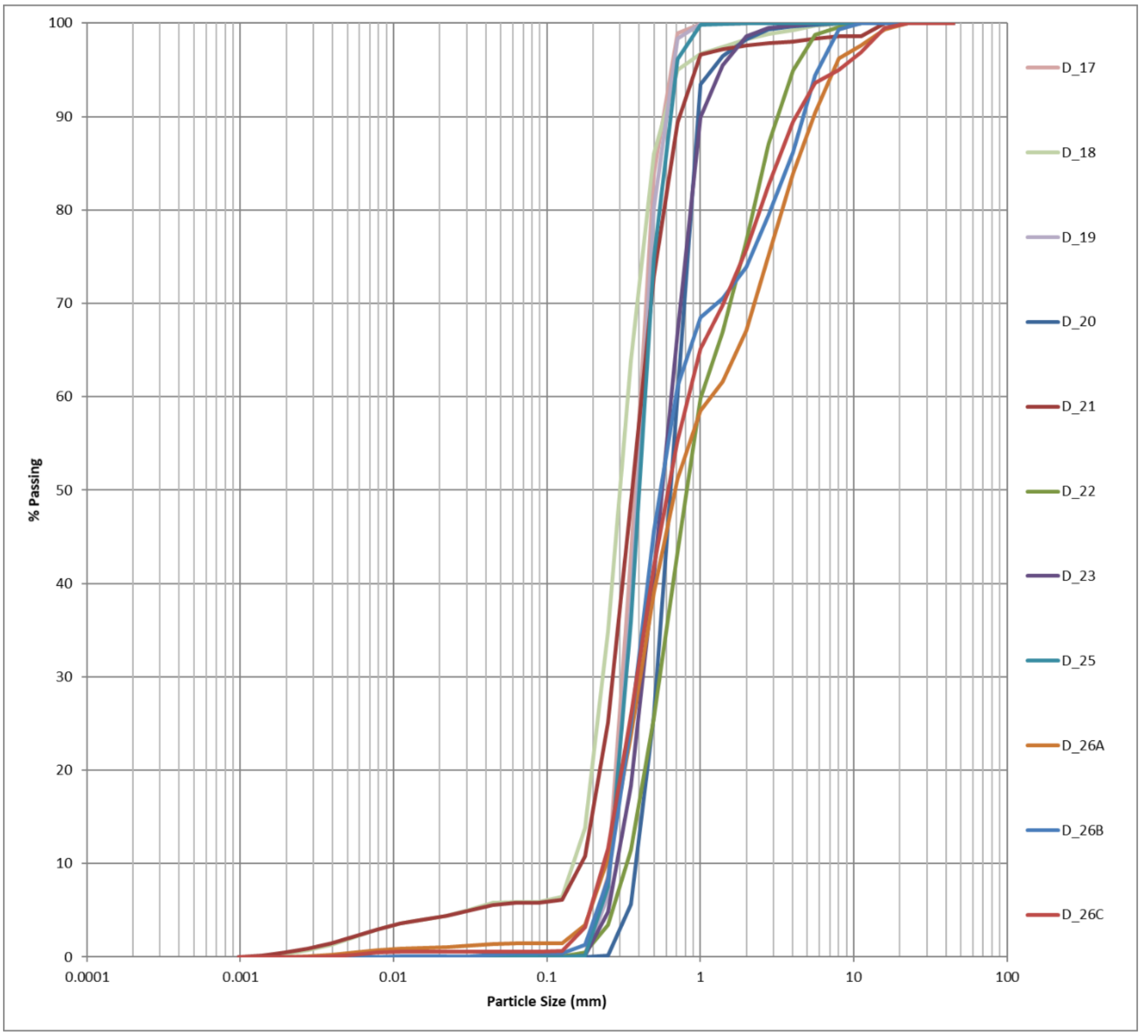

Plate 8-10: Cumulative particle size distribution curves of the 11 sea bed sediment samples collected in DEP South

8.5.7.4 Interlink Cable Corridors

112. The DEP North to SEP part of the interlink cable corridor is characterised by coarser sediment than DEP North and DEP South, with the majority of samples composed primarily of medium to coarse sand (**Plate 8-11**). Three samples located at each end and in the middle of the corridor contain a high percentage of gravel (48-57%). Median particle sizes range between 0.55-4.2mm (coarse sand to fine gravel) and mud content is low (less than 5% in 75% of samples and less than 10% in 100% of samples).

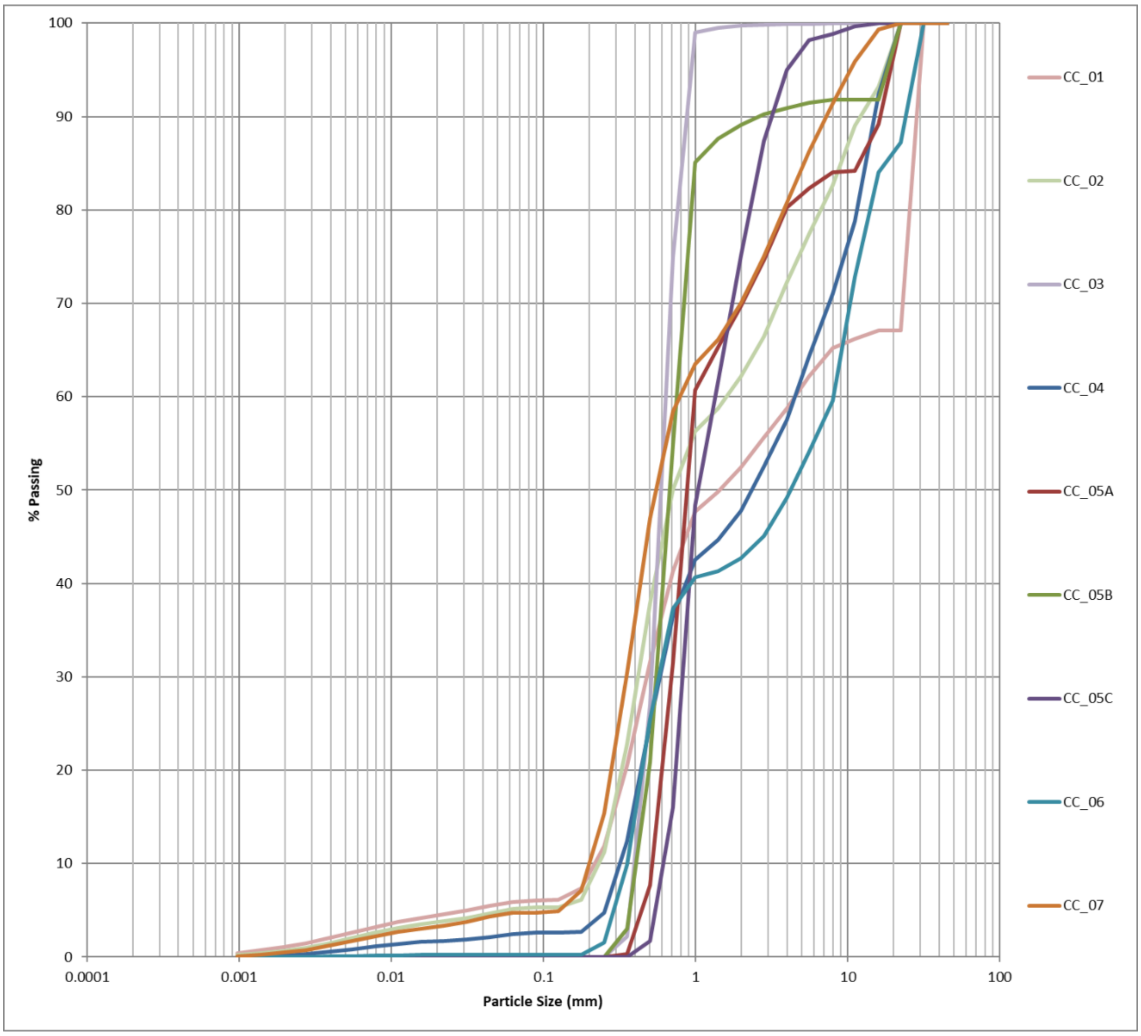

Plate 8-11: Cumulative particle size distribution curves of the nine sea bed sediment samples collected in the northern interlink cable corridor

113. The DEP South to SEP part of the interlink cable corridor is dominated by medium sand (15-71% content in all samples) (**Plate 8-12**). The median particle diameter (d_{50}) falls between 0.27mm and 8.65mm (predominantly medium sand with patches of fine to medium gravel). Mud content is less than 5% in 71% of samples and less than 10% in 100% of samples. Samples from the western portion of the southern corridor have a greater range of sediment size compared to samples in the east, which are more homogenous.

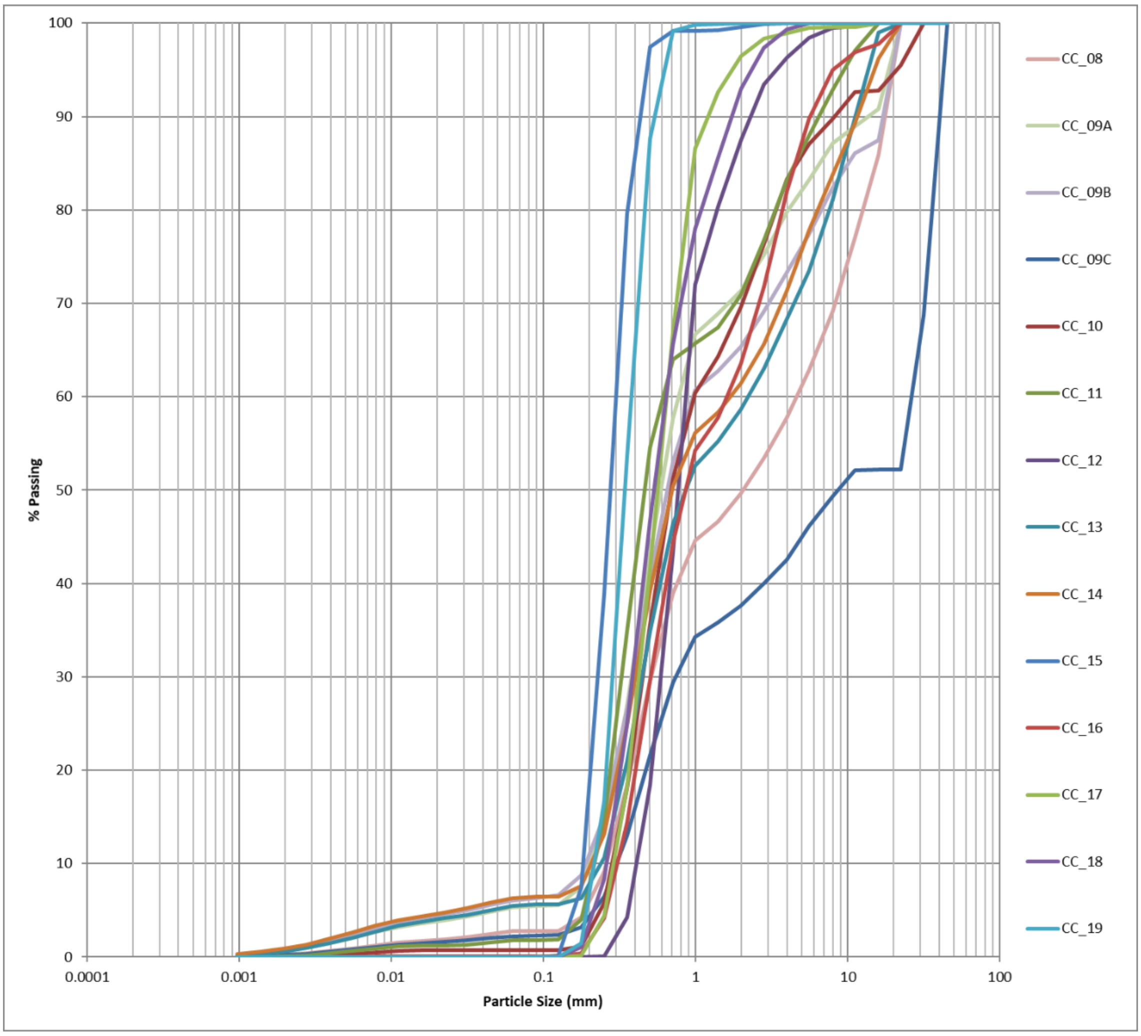

Plate 8-12: Cumulative particle size distribution curves of the 14 sea bed sediment samples collected in the southern interlink cable corridor

114. No sea bed sediment samples were collected in the DEP North to DEP South interlink cable corridor. However, the geophysical survey for DOW characterises the sea bed in the vicinity of the DEP North to DEP South interlink cable corridor as gravelly fine to medium sand (DOW, 2009).

8.5.7.5 SEP

115. The predominant sediment type in SEP is sandy gravel. Median particle sizes (d_{50}) range between 0.54mm and 7.16mm (coarse sand to fine gravel) (**Plate 8-13**). Mud content is less than 5% in 59% of samples and less than 10% in 88% of samples, with two samples in the northwest of SEP containing 17% and 13% mud (SS_19 and SS_23, respectively).

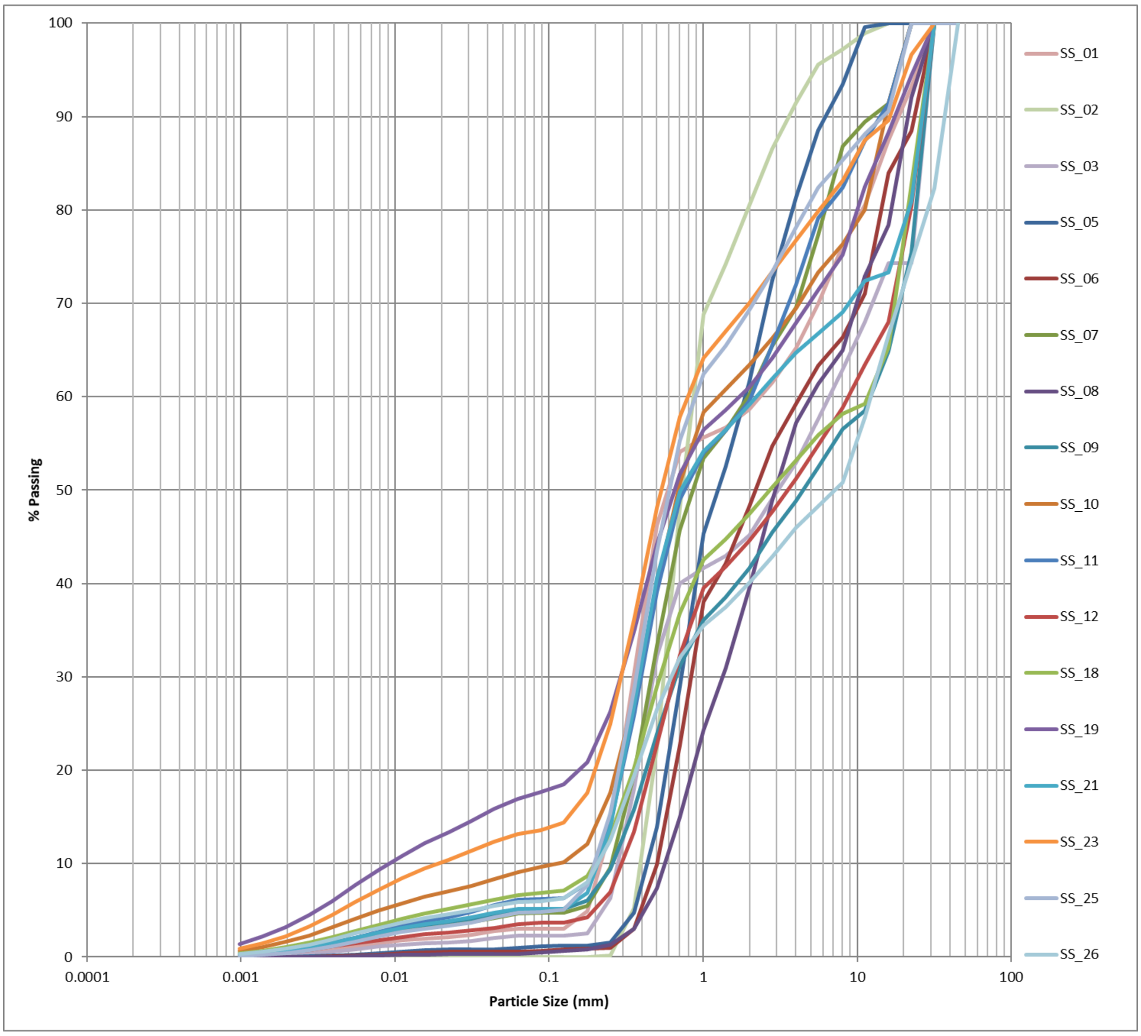

Plate 8-13: Cumulative particle size distribution curves of the 17 sea bed sediment samples collected in SEP

8.5.7.6 Export Cable Corridor

The sea bed of the landward 500m of the export cable corridor is mainly outcropping chalk (**Figure 8.7**) (Royal HaskoningDHV, 2020). This part of the corridor is predominantly chalk at sea bed (with patches of thin sand and gravel in places) potentially sculpted into the complex geo-structures photographed during the nearshore dives of Spray and Watson (2011). This is supported by the complex irregular bathymetry recorded across this area. The seaward boundary of the outcropping chalk is in water depths of about -6m LAT at the western end to -9.5m LAT at the eastern end. The bathymetry of the seaward boundary gradually shallows from east to west. The area of the outcropping chalk within the corridor is about 812,000m^2 (**Figure 8.8**).

116. From 500m to 4.5km offshore along the export cable corridor, the sea bed is composed of alternating zones of gravelly sand/gravel and Holocene sand across a less complex bathymetry than further inshore. The gravelly sand/gravel is interpreted to be a lag deposit created by erosion of Pleistocene units (likely to have been mainly Bolders Bank Formation) that used to overlie the chalk (Royal HaskoningDHV, 2020). It is likely to be less than 1m thick (British Geological Survey, 2021) with sub-cropping eroded chalk (although it is difficult to define the true thickness based on the geophysical data) and not mobile under existing tidal conditions.

117. The Holocene sand is up to 3m thick and rests mainly on chalk and lag. Most of the sand surface is sculpted into megaripples, indicating mobility under existing tidal conditions. If the Holocene sand is mobile, gross migration is likely to be along an approximately east-west axis (given the crest orientations of the bedforms). The smoother bathymetry in this zone indicates that exposed chalk is absent and where it sub-crops it is more regular in elevation.

118. From 4.5km from the coast to SEP the sea bed is gravelly sand or gravel. This wide zone is a continuation of the gravelly sand/gravel sea bed further landward which passes beneath the Holocene sands. The overlying mobile Holocene sands do not occur in this zone. The gradually sloping bathymetry suggests that the sub-cropping chalk surface in this zone is an eroded surface and is relatively flat and regular.

119. About 10km offshore, the sea bed is composed of sand forming the eastern end of Sheringham Shoal sand bank. The bank is up to 6m thick and covered in a field of megaripples (5-10m wavelength with crests oriented north-south).

120. Sediment samples from within the export cable corridor and outside the MCZ show the dominant sediment size is medium sand (19-62% content in all samples) (**Plate 8-14**). Median particle sizes within the export cable corridor outside the MCZ are 0.43-3.39mm (medium sand to very fine gravel). Mud content is less than 5% in 80% of samples and less than 10% in 90% of samples, with one sample (sample EC_16 located approximately 12km from the coast) containing 22% mud.

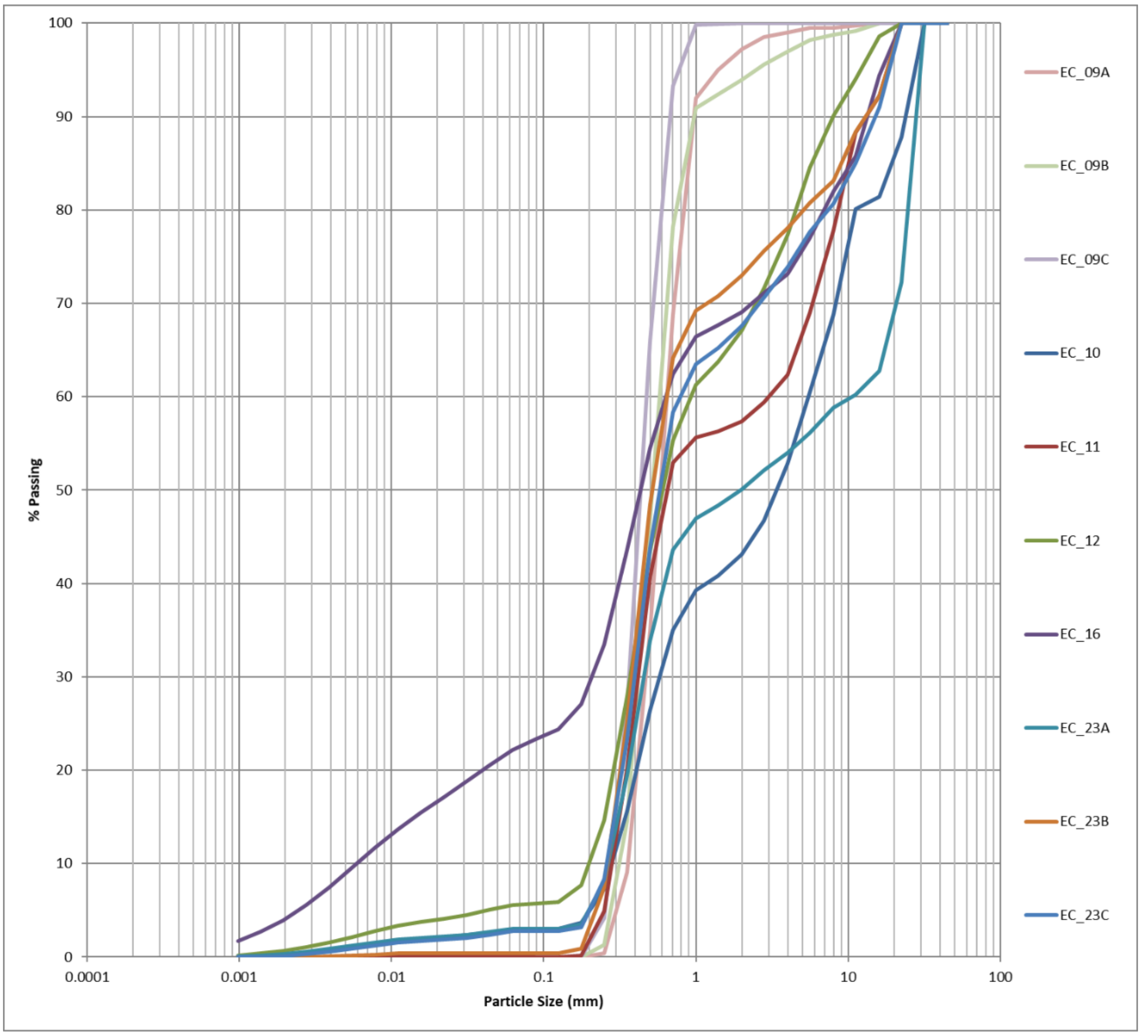

Plate 8-14: Cumulative particle size distribution curves of the ten sea bed sediment samples collected in the export cable corridor outside the MCZ

121. Sediment samples collected within the export cable corridor and inside the MCZ are predominantly composed of medium sand to coarse gravel (**Plate 8-15**). Many samples closer to the coast contain greater than 56% gravel and the majority of samples contain 0% mud.

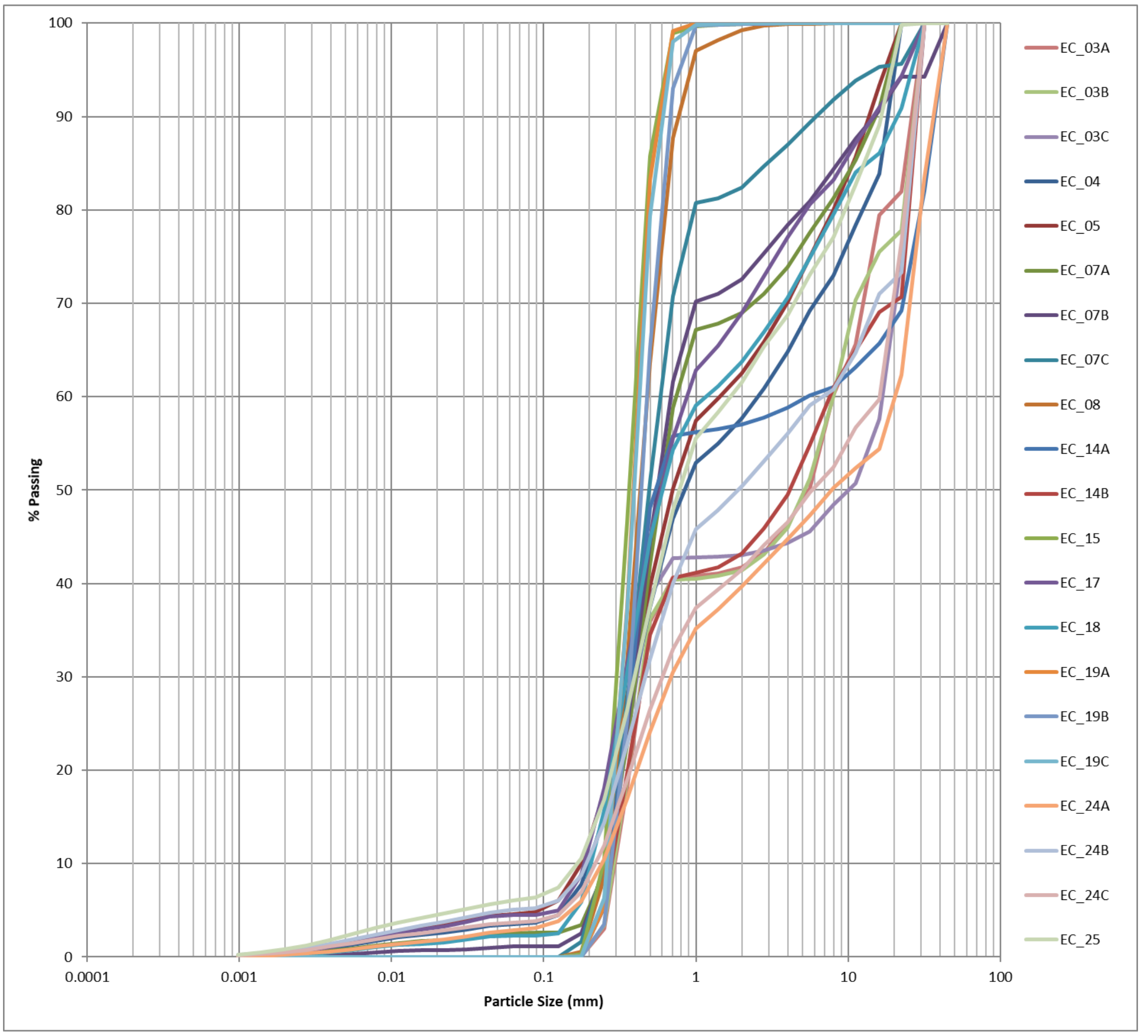

Plate 8-15: Cumulative particle size distribution curves of the 21 sea bed sediment samples collected in the export cable corridor inside the MCZ

122. Sediment sampling has also been completed across the MCZ by Cefas (2014), at 72 stations. Details of the locations of these samples are provided in **Figure 8.9**. The samples describe a variety of sea bed compositions. Similar to the samples recovered by Fugro (2020), most of the samples are composed of sand and gravel. About half the samples contain greater than 25% gravel (25-69%) and are defined as sandy gravel or gravelly sand. About 25% of the samples are greater than 90% sand with four samples predominantly mud (72-90%) with subordinate sand (Royal HaskoningDHV, 2020).

8.5.8 Bedload Sediment Transport

123. 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 east and east-southeast across DEP and SEP and to the west and northwest further offshore. Between these opposing directions of transport is a bedload transport parting. There are very few transport vectors directed to the south either near DEP and SEP or between DEP and SEP, and the coast.

124. Sediment transport pathways within the DEP and SEP sites have been analysed using the orientation of bedforms. Sand waves and ripples are present across parts of DEP North and DEP South (being particularly prevalent in the northern site), SEP, the interlink cable corridors and export cable corridor. Sand waves in these areas exhibit a consistent northeast – southwest orientation that indicates a net direction of transport to the south-east. Tidal currents are the main driving force of sediment transport and as a result, move sediments in a south-easterly direction. The net direction of sediment transport across areas that are not characterised by migrating bedforms will be in the same but at lower rates due to the smaller volumes of sediment available for transport.

8.5.8.1 Cromer Shoal Chalk Beds MCZ

125. Geophysical surveys from 2013 (Fugro, 2014a) and 2018 (MMT, 2018a, b) have been completed along the DOW export cable corridor within the Cromer Shoal Chalk Beds. Where these surveys overlap, they have been used as a basis for comparison to understand potential sediment transport across the MCZ (Royal HaskoningDHV, 2020). Along most of the overlapping cable route, bathymetric change has been less than 0.25m. This is effectively a non-mobile bed given that the vertical accuracy of the multibeam echosounder is +/-0.2m. This supports the interpretation of a predominantly gravelly sand sea bed as a thin static lag deposit resting on chalk. Elevation change greater than 0.25m occurred in two locations where mobile bedforms are present. These are the Holocene sand areas 3.2km to 4.2km offshore along the corridor and at the boundary of the MCZ.

126. A similar comparison was completed for the SOW export cable corridor through the MCZ. A pre-construction survey in 2008 (EMU, 2008) was compared with post-construction surveys in winter 2013 (Fugro EMU, 2014), winter 2015/2016 (Fugro EMU, 2016), and winter 2018 (Fugro, 2019). The main difference in sea bed elevation along the cables is the discontinuous presence of the trenches in which they sit, which persisted through to 2018 (Royal HaskoningDHV, 2020). Preservation of the trenches indicates that in these areas, sediment transport is limited. This is the sea bed occupied by a lag of gravelly sand resting on chalk. Other parts of the trench are filled with sediment indicating transport is active. For example, the trenches were not visible over Pollard Bank or across the inshore 2km of the cable routes to the landfall where mobile sand is present. Apart from the trenches, most of the bathymetric differences recorded between 2008 and 2018 along the export cable corridor were less than 0.25m indicating a non-mobile sea bed. The vertical accuracy of the multibeam echosounder is +/-0.2m.

127. There is a range of sediment transport potentials across the stratigraphic units mapped along the SEP and DEP cable corridor (Royal HaskoningDHV, 2020). The chalk and the Pleistocene geological units that fill channels in the chalk (e.g. Botney Cut Formation and Weybourne Channel Deposits) are static (and can only be eroded), whereas the surface of the Holocene sand is mobile under existing tidal conditions, and so can erode, transport and deposit depending on the physical processes. The mobility of the Holocene sand is supported by the existence of megaripples across its surface in places (mainly along the Weybourne option). This indicates that there is a possibility that movement of this sediment may result in exposure or burial of the underlying geological units. Given the thickness of the Holocene sands, it would only be possible for movement of the feather edges (where the sediment is thin and could all move), to generate new sea bed substrate. In areas where the sand is thicker, the movement of the surface layer would only result in exposure of further sand deeper in the sediment column.

128. Between the chalk or Pleistocene geological units and the sea bed or overlying Holocene sand is a layer of gravelly sand/sandy gravel. This coarse-grained layer is interpreted as a lag deposit created by erosion of Pleistocene units that were originally present on the sea bed (e.g. Bolders Bank Formation). The transport potential of this sediment layer is zero or very low (Royal HaskoningDHV, 2020).

129. There have also been three post-construction benthic surveys of the SOW export cables with a focus on the MCZ; benthic grab sampling in Year 1 (December 2012), Year 2 (April/May 2014) and most recently in August 2020 (video transects of the trenches and adjacent areas in the MCZ). Post-construction geophysical surveys have been completed at least every two years. The benthic monitoring in 2012 and 2014 showed only slight differences in sea bed sediment distribution from the pre-construction sediment distribution. These small variations are likely due to natural inter-annual fluctuations in a dynamic environment.

130. The objective of the 2020 survey was to obtain photographic data to establish whether there is a difference in the sea bed sediments and epifaunal communities between the export cable trenches and adjacent sea bed at ten sites along the cable route within the MCZ. A total of 30 transects, three per survey site, were collected. Each transect was chosen to cross the export cable corridor (described as the impacted area) where trenches were evident and two control areas (control east and control west) located at a minimum of 60m from the noticeable edge of the trenches, to a maximum of 120m. Photographic stills and video were successfully acquired at all proposed transects.

131. The analysis showed significant differences between transects reflecting the naturally occurring differences in the sediment composition along the cable route (Royal HaskoningDHV, 2020). However, no significant difference was found in sediment composition between the trenches and the control areas adjacent to the trenches.

8.5.9 Suspended Sediment Transport

132. Typical mean summer suspended sediment concentrations across DEP and SEP are less than 10mg/l whereas mean winter concentrations are 30mg/l, although concentrations may increase significantly during storm events (HR Wallingford *et al*., 2002).

8.5.10 Coastal Processes at the Weybourne (Muckleburgh Estate) Landfall

133. The coast to the east of the landfall is exposed to waves and cliff erosion is occurring in places. The predicted net sediment transport rates in the region range from 160,000m^3/year to 200,000m^3/year (HR Wallingford *et al*., 2002) directed to the west. These transport rates are for sand and are potential rates rather than actual rates).

134. The Shoreline Management Plan (AECOM, 2013) states that the intended management at Weybourne is No Active Intervention (NAI) over the next 100 years. The long-term plan for the frontage is to promote a naturally-functioning coast, with minimal human interference. This will lead to a loss in cliff top land, which includes agricultural land and part of a golf course.

8.5.11 Anticipated Trends in Baseline Conditions

135. 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 sea bed morphology. However, the long-term established performance of these drivers may be affected by environmental changes including climate change driven sea-level rise. This will have the greatest impact at the coast where more waves will impinge on the cliffs, 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.

8.6 Potential Impacts

8.6.1 Impact Receptors

136. 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 DEP and SEP. These are the Cromer Shoal Chalk Beds MCZ and the East Anglian coast (gravel and sand beaches, dunes and cliffs). The projects and interlink cable corridor are located north of the MCZ, but the export cable corridor passes through it, and the landfall is at Weybourne on the north Norfolk coast.

137. The specific features defined within these two receptors as requiring further assessment at the EIA stage for DEP and SEP 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	Distance from DEP and SEP
Cromer Shoal Chalk Beds MCZ (waves, tidal currents and sediment transport)	Weybourne to Happisburgh	Moderate energy infralittoral rock; high energy infralittoral rock; moderate energy circalittoral rock;	Export cable corridor passes through the MCZ

Receptor Group	Extent of Coverage	Description of Features	Distance from DEP and SEP
		high energy circalittoral rock; subtidal chalk; subtidal coarse sediment; subtidal mixed sediments; subtidal sand, peat and clay exposures; and North Norfolk coast (subtidal geological feature)	
East Anglian coast (waves and sediment transport)	King's Lynn to Felixstowe	Gravel and sand beaches, dunes and cliffs	16km from the nearest point of SEP with the export cable making landfall at Weybourne

138. The impact assessment sections (**Sections 8.6.4 and 8.6.5**) assess the significance of potential impacts on the wave and/or current and/or sediment transport regimes on the receptor groups of the sensitive Cromer Shoal Chalk Beds MCZ and East Anglian coast.

8.6.1.1 Cromer Shoal Chalk Beds MCZ

139. Cromer Shoal Chalk Beds MCZ was designated in January 2016. It is located 200m off the north Norfolk coast, covering an area of 321km^2, with maximum depth of about 20m. 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 be brought into favourable condition if they are not already in favourable condition'. The export cable passes through the MCZ.

8.6.1.2 East Anglian Coast

140. The East Anglian Coast, encompassing the landfall at Weybourne, falls under SMP 6 (AECOM, 2013). The cliffs between Kelling Hard and Sheringham has the highest proportion of shingle for the North Norfolk cliffs, representing an important source of shingle to the sediment regime both to the east and west, although some of it remains locally.

141. The beach along this section does not appear to have been affected by the steepening trend seen elsewhere along this frontage (AECOM, 2013). Cliff erosion is linear and gradual but is exacerbated by occasional slumping events. Over the next 100 years, the shoreline is expected to retreat between 10 and 50m (assuming an unconstrained coast), with the shingle ridge at Weybourne likely to roll back due to adjacent cliffline erosion.

8.6.2 Effects

142. As explained in **Section 8.4**, in addition to the receptor groups listed in **Table 8.13**, there are other potential changes (effects) to marine geology, oceanography and physical processes associated with DEP and SEP which may manifest themselves as impacts upon a wider grouping of receptors. These include marine water and sediment quality, benthic ecology, fish and shellfish ecology, commercial fisheries, and offshore archaeology and cultural heritage.

143. In respect of these effects, the marine geology, oceanography and physical processes assessment only defines the magnitude of change. The assessments of the significance of impacts arising from these effects or changes on other receptors are made within the relevant chapters of this PEIR pertaining directly to those receptor types.

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

144. Previous numerical modelling and theoretical work has been undertaken specifically for the DOW and SOW located in close proximity to DEP and SEP to assess the potential effects of the extensions on the marine geology, oceanography and physical processes. 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 O&M effects or impacts of DEP and SEP. The physical basis for using the modelling and theoretical results is that the DOW and SOW designs and marine geology, oceanography and physical processes operating at the sites are like DEP and SEP and therefore provide suitable evidence (and are suitable analogues) to support the assessment of effects or impacts at DEP and SEP.

145. Justification for using the modelling results from DOW and SOW as the principal evidence of potential effects or impacts at DEP and SEP is provided below, which includes the similarities (and dissimilarities) of the existing physical and sedimentary conditions (water depths, tidal currents, waves, sea bed sediments, and suspended sediment) at each of the sites.

146. Water depths at SOW (15-22m below Chart Datum (CD)) and DOW (17-24m below CD) are comparable to those at SEP (14-25m below CD) and DEP (11-23m below CD).

147. Tidal currents demonstrate similar directions and velocities on the flood tide and ebb tide. At all sites, flood and ebb tidal currents flow west-northwest/northwest and east-southeast/southeast, respectively. Spring tide peak current velocities of between 0.6m/s and 1.2m/s occur across all the sites, giving rise to bed transport and the formation of mobile bed features such as sand waves and megaripples. Lower velocities (less than 1.0m/s) occur closer to the coast across the export cable corridors and directions are approximately shore parallel.

148. Predominant waves approach all sites from similar directions. The whole area within which DOW, SOW, DEP and SEP are located is exposed to wave conditions generated within the North Sea, with the most severe conditions arriving from the north and northeast due to long fetch lengths. However, the most frequent waves across all sites are from the southwest to northwest sector, but their fetch lengths are relatively short, and significant wave heights are small (generally between 0.5m and 1.0m). Nearshore wave conditions are less severe due to the protection afforded by Sheringham Shoal sand bank.

149. Sea bed sediments at all sites are similar. The sea beds at DOW and SOW comprise mainly superficial gravelly sands or sandy gravels derived from the reworking of the underlying glacial till. The sea bed sediment across DEP and SEP wind farm sites also comprise a thin veneer of gravelly sand resting on till. Chalk is exposed at the sea bed closer to the coast along the export cable corridor.

150. Regional suspended sediment concentrations vary from typical mean summer values of less than 10 mg/l to typical mean winter values of 30 mg/l. Concentrations may increase significantly during storm events.

151. SOW comprises 88 turbines and DOW comprises 67 turbines, whereas the DEP and SEP sites will have up to 32 and 24 turbines, respectively. Hence, the results of the modelling and theoretical assessments of the DOW and SOW designs are conservative compared to the DEP and SEP designs. 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 DOW and SOW allows for these differences in the effect that may arise due to these factors. In addition, the post-construction geophysical and environmental survey data for DOW and SOW has been used to retrospectively ‘ground-truth’ the pre-construction numerical modelling and theoretical results for the existing wind farms to provide confidence in their use in the assessment of DEP and SEP.

152. The assessments for the existing OWFs were completed when the area occupied by the export cable corridors was not designated as an MCZ. Although the export cable corridor of DEP and SEP now passes through the Cromer Shoal Chalk Beds MCZ (designated in January 2016), the use of conceptual evidence-based assessment is still considered proportionate. This is because the existing modelling of the export cable corridors was conservative and the results are representative of the worst case for DEP and SEP through the MCZ, and are therefore suitable analogies.

8.6.4 Potential Impacts during Construction

153. During the construction phase of DEP or SEP, there is the potential for foundations and cable installation activities to disturb sediment, potentially resulting in changes in suspended sediment concentrations and/or sea bed levels or, in the case of nearshore cable installation, shoreline morphology due to deposition or erosion. These potential effects are considered as construction Impacts 1 to 7.

154. The worst-case layout scenario (discussed in **Section 8.3.2**) is assessed for construction of DEP or SEP in isolation, and DEP and SEP together.

8.6.4.1 Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)

8.6.4.1.1 DEP or SEP in Isolation

155. Sea bed sediments and shallow near-bed sediments within DEP or SEP 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 suspended sediment concentrations both at the point of dredging at the sea bed 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 DEP and SEP sites.

156. 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 8-10 months in total if the projects are built sequentially, or 4-5 months if both projects are built concurrently or in a tandem scenario.

157. The median particle sizes of sea bed sediments are predominantly 0.30mm to 0.81mm (medium to coarse grained sand) across DEP and 0.54mm to 7.16mm (coarse sand to fine gravel) across SEP. Most sea bed samples contained less than 10% mud. As outlined in **Section 8.5.9**, typical mean summer suspended sediment concentrations at DEP and SEP are typically less than 10mg/l, whereas mean winter concentrations are 30mg/l. These concentrations may increase significantly during storm events (HR Wallingford et al., 2002).

158. For the total volume released during the construction phase, the worst-case scenario is associated with the maximum number of 14MW GBS foundations (32 at DEP, 24 at SEP) dredged to 5m (**Table 8.3**).

159. Conceptual evidence-based assessment suggests that, due to the predominance of medium and coarse grained sand across DEP and DEP sites, the sediment disturbed by the drag head of the dredger at the sea bed 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 sea bed as a highly turbid dynamic plume immediately upon its discharge (within a few tens of metres along the axis of tidal flow).

160. 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 sea bed 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 suspended sediment concentrations would extend further from the dredged area, along the axis of predominant tidal flows, the magnitudes would be indistinguishable from background levels.

161. 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 sea bed 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).

8.6.4.1.2 Magnitude of effect

162. The worst-case changes in suspended sediment concentrations due to sea bed preparation for GBS foundation installation are likely to have the magnitudes of effect shown in **Table 8.14**.

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

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

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

8.6.4.1.3 Impact Significance

163. The effects on suspended sediment concentrations due to foundation installation for DEP or SEP do not directly impact upon the identified receptor groups for marine geology, oceanography and physical processes (i.e. the MCZ and East Anglia coast). This is because the designated features of the Cromer Shoal Chalk Beds MCZ (17km southwest of DEP South, and 6.5km south of SEP) are related to processes operating on the sea bed and not in the water column. Also, regional sediment transport directions are directed along a southeast to northwest axis, and so there is no pathway for suspended sediment to reach the East Anglian coast. Hence, there is **no impact** on the identified receptors groups associated with the suspended sediment generated by DEP and SEP. However, the effects have the potential to impact upon other receptors and the assessment of impact significance is addressed within the relevant chapters of this PEIR (**Section 8.9**).

8.6.4.1.4 DEP and SEP Together

164. The worst-case scenario and impacts associated with foundation installation at DEP and SEP together will be comparable to those outlined in **Section 8.6.4.1.1**. Similar to DEP or SEP in isolation, the larger release volume (**Table 8.3**) due to construction of both projects concurrently may combine to result in higher concentrations, but they are likely to still be less than 10mg/l.

8.6.4.1.5 Impact Significance

165. The worst case changes in suspended sediment concentrations due to installation of the maximum number of 14MW GBS foundations across DEP and SEP together will have the same magnitude as those outlined in **Section 8.6.4.1.2**. Hence, there is **no impact** on the identified receptors groups associated with the proposed DEP and SEP together.

8.6.4.2 Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines and OSPs

8.6.4.2.1 DEP or SEP in Isolation

166. Sediments below the sea bed within DEP or SEP would become disturbed during any drilling activities that may be needed at the location of piled foundations. The ambient suspended sediment concentrations across DEP and SEP of less than 10mg/l to about 30mg/l (**Section 8.5.9**) 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 DEP or SEP sites in close proximity to each foundation. The worst case scenario for a release from an individual wind turbine assumes a monopile foundation for the 14MW wind turbine. In this case, a 13m drill diameter would be used from the sea bed to a depth of 45m, releasing a maximum of 5,973m^3 of sediment per foundation into the water column.

167. It is estimated that the maximum number of foundations that would require drilling would be 5% (1 in 20 foundations). Hence, for the total volume released during the construction phase, the worst case scenario for drilling is associated with the maximum number of 14MW monopiles.

168. Piled foundations with 3.5m diameter pin piles would represent the worst case scenario for the OSP. The drill arisings per foundation are 425m^3 of sediment for DEP or SEP (up to one per project). **Table 8.3** summarises the total volume of drill arisings.

169. The drilling process would cause localised and short-term increases in suspended sediment concentrations at the point of discharge of the drill arisings at two 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 suspended sediment concentrations and low changes in sea bed 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 8-10 months in total if the projects are built sequentially, or 4-5 months if both projects are built concurrently or in a tandem scenario.

170. The conceptual evidence-based assessment suggests that away from the immediate release locations, elevations in suspended sediment concentration above background levels for only two 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 northwest or southeast, 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.

8.6.4.2.2 Magnitude of effect

171. The worst case changes in suspended sediment concentrations due to the installation of the maximum number of 14MW monopile foundations (two in each of DEP and SEP and one OSP in each of DEP or SEP) are likely to have the following magnitudes of effect (**Table 8.15**).

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

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

* The near-field effects are confined to a small area likely to be up to a kilometre from each foundation location, and would not cover the DEP or SEP wind farm site.

8.6.4.2.3 Impact Significance

172. The effects on suspended sediment concentrations due to foundation installation for the proposed DEP or SEP projects do not directly impact upon the identified receptor groups for marine geology, oceanography and physical processes, so there is **no impact** associated with the proposed DEP or SEP projects.

173. However, the effects have the potential to impact upon other receptors and the assessment of impact significance is addressed within the relevant chapters of this PEIR (see **Section 8.9**).

8.6.4.2.4 DEP and SEP Together

174. The worst case scenario and impacts associated with foundation installation at DEP and SEP together will be comparable to those outlined in **Section 8.6.4.2.1**. Similar to DEP or SEP in isolation (two foundations in each and two substations), the larger release volume (**Table 8.3**) (but still only four foundations and two substations) may combine to result in larger concentrations above background levels (but likely to still be less than 10mg/l). As outlined in **Section 8.6.4.2.1**, sediment concentrations arising from one foundation installation are unlikely to persist for a sufficiently long period of time for them to interact with subsequent operations, and therefore no cumulative effect is anticipated from multiple installations. Therefore, the construction of DEP and SEP together would not result in a worse impact than DEP or SEP in isolation.

8.6.4.2.5 Impact Significance

175. The worst case changes in suspended sediment concentrations due to installation of the maximum number of 14MW monopile foundations and two substations across DEP and SEP together will have the same magnitude as those outlined in **Section 8.6.4.2.1**. Hence, there is **no impact** on the identified receptors groups associated with the proposed DEP and SEP together.

8.6.4.3 Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation

8.6.4.3.1 DEP or SEP in Isolation

176. The increased suspended sediment concentrations associated with construction Impact 1a (**Section 8.6.4.1**) have the potential to deposit sediment and raise the sea bed elevation slightly.

177. The conceptual evidence-based assessment suggests that coarser sediment disturbed during sea bed preparation would fall rapidly to the sea bed (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.

178. The resulting mound would be a measurable protrusion above the existing sea bed (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 produced mounds would vary across DEP and SEP, 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 sea bed that it has replaced and the surrounding sea bed. The baseline particle size distribution data for DEP North and DEP South shows that the sea bed is dominated by medium sand with overall compositional variations related to the volumes of coarser sand and gravel. Mud content is always less than 10%. This would mean that there would be a small but insignificant change in sea bed sediment type, likely to be caused by differences in the volume of the coarser fraction in the mound compared to the natural sea bed.

179. The sea bed across SEP is dominated by sandy gravel with a wider range of compositions than DEP. However, for the most part, mud content is less than 10%. There is greater likelihood of differences in mound and sea bed composition in SEP. However, the overall composition of the sea bed once the mound has been placed 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 coarse granular sea bed).

180. Also, the overall change in elevation of the sea bed is small compared to the absolute depth of water (up to 36m below LAT in the northwest of DEP North). The change in sea bed elevation is within the natural change to the bed caused by sand waves and sand ridges and hence the blockage effect on physical processes would be negligible.

181. 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.

182. In addition to localised mounds, the very small proportion of mud would form a passive plume and become more widely dispersed before settling on the sea bed. 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 sea bed.

183. This assessment is supported by an extended evidence-base obtained from research into the physical impacts of marine aggregate dredging on sediment plumes and sea bed 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).

8.6.4.3.2 Magnitude of effect

184. The changes in sea bed levels due to foundation installation under the worst-case sediment dispersal scenario are likely to have the magnitudes of effect shown in **Table 8.16**.

Table 8.16: Magnitude of effects on sea bed level changes due to deposition under the worst-case scenario for sediment dispersal following GBS foundation installation

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

*The near-field effects are confined to a small area of sea bed likely to be up to a kilometre from each foundation location and would not cover the whole of DEP or SEP.

8.6.4.3.3 Impact Significance

185. The overall impact of foundation installation activities for the project under a worst-case scenario on sea bed level changes for identified morphological receptor groups (Cromer Shoal Chalk Beds MCZ: 17km southwest of DEP South and 6.5km south SEP, and the East Anglian Coast: 27km southwest of DEP South and 16km south of SEP) is considered to be **negligible adverse impact**. This is because the predicted thickness of sediment resting on the sea bed 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.

186. The worst-case scenario assumes that sea bed 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.

187. The effects on sea bed level have the potential to impact upon other receptors and the assessment of impact significance is addressed within the relevant chapters of this PEIR (see **Section 8.9**).

8.6.4.3.4 DEP and SEP Together

188. The change in sea bed level due to the foundation installation at the wind farm site for a DEP and SEP together scenario will be similar to that outlined for DEP and SEP in isolation (**Section 8.6.4.3.1**).

8.6.4.3.5 Impact Significance

189. The change in sea bed levels due to foundation installation under the worst case sediment dispersal scenario for DEP and SEP together are likely to have the same magnitudes of effect as shown in **Table 8.16**. Hence, the overall impact of foundation installation activities for the project under a worst-case scenario on sea bed level changes for identified morphological receptor groups is considered to be **negligible adverse impact**.

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

8.6.4.4.1 DEP or SEP in Isolation

190. The combined increased in suspended sediment concentrations and creation of aggregated clasts of mud associated with construction Impact 1b (see **Section 8.6.4.2**) have the potential to deposit sediment and raise the sea bed elevation.

191. Drilling of piled foundations could potentially occur through five different geological units (**Table 8.12**); Holocene deposits potentially overlying a series of four Pleistocene units comprised of consolidated clay and sand resting on Upper Cretaceous Chalk. The coarser sediment fractions (medium and coarse sands and gravels) and aggregated ‘clasts’ of mud of the Bolders Bank Formation would settle out of suspension in proximity to each foundation location.

192. The coarser sediment sand/gravel would be deposited near to the point of release up to thicknesses of approximately 3cm over a sea bed area local to each foundation (within 200 metres). For the most part, the deposited sediment layer across the wider sea bed area would be very thin, and confined to a maximum of two foundations in DEP and two foundations in SEP.

193. If the drilling penetrates 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 sea bed (at least initially), rather than being disaggregated into individual fine-grained sediment components immediately upon release. Under this scenario, the worst case scenario assumes that a ‘mound’ would reside on the sea bed near the site of its release.

194. For an individual wind turbine, the worst case is associated with a 14MW monopile and assumes that each mound would contain a maximum volume of 5,973m^3 of sediment (assumes that all the drill arisings are in the form of aggregated clasts).

195. For drill arisings from the DEP or SEP project as a whole, the worst case is for two x 14MW monopile foundations in each of DEP and SEP and one OSP per site (**Table 8.3**). These mounds would be composed of sediment with a different particle size and would behave differently (they would be cohesive) to the surrounding sandy sea bed, and therefore represent the worst-case scenario for mound formation during construction.

196. The method for calculating the footprint of each mound follows that which was developed and agreed with Natural England for earlier major offshore wind 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 sea bed. This was based on simple geometric relationships between volume, height, radius and side-slope angle of a cone. The latter parameter was taken as 30°, which is a suitable representation for an angle of friction of clasts of sediment.
- Calculating 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 sand waves on the sea bed 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 sea bed could then be calculated.

197. Based on this approach, the footprint of an individual 2m-high mound arising from the installation of a 14+MW wind turbine monopile would be 5,973m^2 (or 12,371m^2 for each of DEP and SEP, assuming a worst-case scenario of two 14MW wind turbines in each and one OSP per site is drilled). When compared to the total area of DEP (103.5km^2) or SEP (92.6km^2), the worst-case mound footprints are approximately 0.013% of the sea bed within each of the DEP and SEP wind farm sites.

198. Because of their potential size, 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) 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.

8.6.4.4.2 Magnitude of effect

199. The changes in sea bed levels due to foundation installation under the worst case sediment dispersal scenario and sediment mound scenario are likely to have the magnitudes of effect shown in **Table 8.17** and **Table 8.18**, respectively.

Table 8.17: Magnitude of effects on sea bed level changes due to deposition under the worst-case scenario for sediment dispersal following piled foundation installation

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

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

*The near-field effects are confined to a small area of sea bed likely to be up to a kilometre from each foundation location and would not cover the whole of DEP or SEP.

Table 8.18: Magnitude of effects on sea bed level changes due to deposition under the worst-case scenario for sediment mound creation following piled foundation installation

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

+The near-field effects are confined to a small area of sea bed (likely to be immediately adjacent to each wind turbine location), and would not cover the whole of DEP or SEP.

8.6.4.4.3 Impact Significance

200. As the impacts are restricted to the near field impacts of dispersal and the potential formation of mounds, the overall impact of foundation installation activities for the proposed project under a worst case scenario on sea bed level changes for the identified morphological receptor groups is considered to be **no impact**. This is because there is a separation distance of at least 17km (DEP South) and 6.2km (SEP) between the nearest sediment release point and the Cromer Shoal Chalk Beds MCZ or the East Anglian coast. 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 (MCZ and coast).
201. 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.
202. The effects on sea bed level have the potential to impact upon other receptors and the assessment of impact significance is addressed within the relevant chapters of this PEIR (see **Section 8.9**).

8.6.4.4.4 DEP and SEP Together

203. The change in sea bed level due to the foundation installation at the wind farm site and OSP for a DEP and SEP together scenario will be similar to that outlined for DEP and SEP in isolation (**Section 8.6.4.4.1**).
204. For drill arisings from the DEP and SEP project as a whole, the worst case is for four x 14MW monopile foundations and two OSPs (**Table 8.3**).

205. Based on the approach outlined in **Section 8.6.4.4.1**, the footprint of an individual 2m-high mound arising from the installation of a 14+MW wind turbine monopile would be 5,973m^2. Four foundation installations and two OSPs would have a total mound area of 24,742m^2. When compared to the total area of DEP and SEP combined (196.10km^2), the worst-case mound footprint is only 0.01% of the sea bed within the wind farm area.

8.6.4.4.5 Impact Significance

206. The change in sea bed levels due to foundation installation under the worst case sediment dispersal scenario and sediment mound scenario are likely to have the same magnitudes of effect as shown in **Table 8.17** and **Table 8.18**, respectively.

207. As the impacts are restricted to the near field impacts of the dispersal and the formation of the mounds, the overall impact of foundation installation activities for the proposed project under a worst case scenario on sea bed level changes for the identified morphological receptor groups is considered to be **no impact**. This is because there is a separation distance of at least 6.2km between the nearest sediment release point and the Cromer Shoal Chalk Beds MCZ or the East Anglian coast. 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 (MCZ and coast).

8.6.4.5 Impact 3: Change in suspended sediment concentrations due to export cable installation

208. The assessment of changes in suspended sediment concentrations during export cable installation has been considered separately from those for the infield and interlink cables because parts of the offshore cable corridor are in shallower water and closer to the identified morphological receptor groups.

8.6.4.5.1 DEP or SEP in Isolation

209. 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 62km for DEP and 40km for SEP. The worst case cable laying technique is considered to be jetting due the greater width of disturbance compared to ploughing.

210. Sand wave levelling may be required at the northern end of the export cable corridor at DEP North prior to export cable installation. No sand wave levelling is expected for a SEP in isolation scenario. 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 suspended sediment concentrations both at the point of dredging at the sea bed and, more importantly, at the point of its discharge back into the water column.

211. 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 sand wave levelling would be disposed of within the export cable corridor, meaning there will be no net loss of sand from the site.

212. The installation of the export cables has the potential to disturb the sea bed down to a sediment thickness of up to 1.0m (depending on the area) and a width of up to 1.0m. A trench will also be required at the HDD exit location, located approximately 1,000m offshore. **Table 8.3** summarises the worst case scenario sediment releases.

213. The types and magnitudes of effects that could be caused have previously been assessed within an industry best-practice document on cabling techniques (BERR 2008 and The Crown Estate/RPS, 2019). This document has been used in the conceptual evidence-based assessment of site conditions to inform the below.

214. It is anticipated using conceptual evidence-based assessment and the results from modelling at the DOW export cable corridor that the changes in suspended sediment concentration due to export cable installation would be less than those that have been assessed in relation to the disturbance of near-surface sediments during foundation installation activities (**Section 8.6.4.1** and **Section 8.6.4.2**), although the location of effect would differ as it would be focused along the offshore cable corridor.

215. Also, although suspended sediment concentrations 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 sea bed sediment distribution through re-suspension and re-deposition. They are short-term natural phenomenon that are likely to drive greater changes to the sea bed 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.

216. 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 up to 170mg/l recorded in the vicinity of the coast at Great Yarmouth (ABPmer, 2012).

217. Modelling simulations undertaken for DOW confirm the evidence-based assessment and provided the following quantification of magnitude of change (it should be noted the modelled results are only applicable to the nearshore area where chalk or other competent beds are exposed, or have only a very thin layer of mobile sediment):

- Sand and gravel-sized sediment (which represents most of the disturbed sediment) would settle out of suspension rapidly to the bed in the immediate location of the export cable corridor. Fine sand will most likely remain in the bottom 1-2 m of the water column, and with settling velocities of around 10mm/s, this will ensure the fine sand settles within half an hour or less or become part of the ambient near bed transport (Soulsby, 1997).
- The majority of disturbed sediment will initially resettle within 20m of the export cable, with almost no sand being transported further than 100m of the cable.
- Mud-sized material (which represents only a very small proportion of the disturbed sediment) would be advected a greater distance and persist in the water column for hours to days.
- Chalk dispersion could extend for around 10km to the west and less to the east, with SSCs dropping to less than 1mg/l within a single flood or ebb excursion.

218. In areas where the cable is buried up to 1.0m, the cable would be installed in (mobile) sands only, with no disturbance of underlying chalk or other beds. The amount of fine sediment recorded from samples along the export cable corridor is less than 10% in 90% of samples. Therefore, dispersion from these areas is assumed to be very low.

219. As described in **Section 8.5**, there are similarities in water depth, sediment types and metocean conditions between the offshore export cable corridor for DOW and for the proposed DEP and SEP projects making the earlier modelling studies a suitable analogue for the present assessments.

220. The HDD exit point will be in the subtidal zone approximately 1000m offshore, seaward of the low water mark and at least 9-10m below LAT. 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 suspended sediment concentrations close to shore.

221. During the excavation process the suspended sediment concentrations 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.

222. 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.

8.6.4.5.2 Magnitude of effect

223. The worst case changes in suspended sediment concentrations due to export cable installation at DEP or SEP are likely to have the following magnitudes of effect shown in **Table 8.19**.

Table 8.19: Magnitude of effect on suspended sediment concentrations under the worst case scenario for export cable installation within the offshore cable corridor

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

* The near-field effects 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.

8.6.4.5.3 Impact Significance

224. These effects on suspended sediment concentrations due to export cable installation within the offshore cable corridor would have a **negligible adverse** impact 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 sea bed and are not affected by sediment suspended in the water column. However, there may be impacts arising from subsequent deposition of the suspended sediment on the sea bed and these are discussed under construction Impact 4 (**Section 8.6.4.6**).

225. The effects do have the potential to impact upon other receptors and therefore the assessment of impact significance is addressed within the relevant chapters of this PEIR (see **Section 8.9**).

8.6.4.5.4 DEP and SEP Together

226. In a DEP and SEP together scenario, the worst case scenario for the export cable is where both DEP and SEP are developed with a separated grid option (each having their own offshore substation and export cable) (**Table 8.3**). Therefore, there will be two export cables (62km + 40km).

227. The potential change in suspended sediment concentrations due to export cable installation for DEP and SEP together scenario (including sand wave levelling and trenching at the HDD exit point) is similar to that of DEP in isolation (**Table 8.3**). Although suspended sediment concentrations will be elevated, they are likely to be lower than concentrations that would develop in the water column during storm conditions. 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.

228. Therefore, the overall impact of export cable installation under a worst case scenario on suspended sediment concentrations for the identified morphological receptor groups is considered to be of **negligible adverse** significance.

8.6.4.6 Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor

229. The assessment of change in sea bed level due to export cable installation has been considered separately from those for the infield and interlink cables because parts of the offshore cable corridor are in shallower water and closer to the identified morphological receptor groups.

8.6.4.6.1 DEP or SEP in Isolation

230. The increases in suspended sediment concentrations associated with export cable installation have the potential to result in changes in sea bed level as the suspended sediment deposits.

231. The plume modelling simulations for DOW indicate that sand-sized material would settle out of suspension within less than 20m from the point of installation within the offshore cable corridor and persist in the water column for less than half an hour. Due to the coarse sediment particle sizes observed across the site (predominantly medium-grained sand), a large proportion of the disturbed sediment would behave in this manner.

232. The low amount of mud-sized material present at DEP and SEP (**Section 8.5**) 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 sea bed. 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 sea bed character are expected to be not measurable in practice. Also, as outlined in **Section 8.6.4.5.1**, although chalk plumes may extend some distance, there is no evidence that the very low levels of suspended load have any impact on marine habitats or species (DOW, 2009).

8.6.4.6.2 Magnitude of effect

233. The worst case changes in sea bed levels due to export cable installation within the offshore cable corridor are likely to have the magnitudes of effect described in **Table 8.20**.

Table 8.20: Magnitude of effects on sea bed level changes due to export cable installation within the offshore cable corridor under the worst case scenario for suspended sediment concentrations

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

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

234. Importantly, the offshore cable corridor passes through the Cromer Shoal Chalk Beds MCZ and will be close to the East Anglian coast. The sensitivity and value of both receptors are presented in **Table 8.21**.

Table 8.21: Sensitivity and value assessment of East Anglian coast and Cromer Shoal Chalk Beds MCZ

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
East Anglian Coast	Negligible	Negligible	Negligible	High	Negligible
Cromer Shoal Chalk Beds MCZ	Negligible	Negligible	Negligible	High	Negligible

8.6.4.6.3 Impact Significance

235. Based on the DOW plume modelling simulations, conceptual evidence-based assessment of deposition from the plume generated from cable installation indicates that the changes in sea bed elevation are effectively immeasurable within the accuracy of any numerical model or bathymetric survey. This means that given these very small magnitude changes in sea bed level arising from export cable installation, the impacts on the Cromer Shoal Chalk Beds MCZ and East Anglian coast receptors would not be significant. Hence, the overall impact of offshore cable installation activities under a worst case scenario on bed level changes for the identified morphological receptor groups is considered to be **no impact** for East Anglian Coast and **negligible adverse impact** for Cromer Shoal Chalk Beds MCZ.

236. In many parts of the offshore cable corridor the 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 impacts are minimised.

237. The effects on sea bed level also have the potential to impact upon other receptors and therefore the assessment of impact significance is addressed within relevant chapters of this PEIR.

8.6.4.6.4 DEP and SEP Together

238. The potential change in sea bed level due to export cable installation for DEP and SEP together will be similar to that outlined for DEP in isolation (see **Section 8.6.4.5.1** and **Table 8.3**). Hence, the overall impact of offshore cable installation activities under a worst case scenario on bed level changes for the identified morphological receptor groups is considered to be **no impact** for East Anglian Coast and **negligible adverse impact** for Cromer Shoal Chalk Beds MCZ.

8.6.4.7 Impact 5: Change in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)

239. As the interlink cables between DEP North and SEP, DEP South and SEP, and DEP North and DEP South will only be constructed in a DEP in isolation or DEP and SEP together scenario, changes in suspended sediment concentrations due to interlink cable installation are not considered within a SEP in isolation scenario.

8.6.4.7.1 DEP or SEP in Isolation

240. The details of the infield and interlink cabling are dependent upon the final project design (**Table 8.3**). There are no interlink cables for a SEP in isolation scenario. The cable burial technique for infield and interlink cables is assumed to be 50% jetting and 50% mechanical cutting. The worst case cable laying technique is considered to be mechanical cutting due the greater width of disturbance compared to jetting, and so the assessment below considers 100% of infield and interlink cables installed by mechanical cutting.

241. Sand wave levelling may be required in DEP North, DEP South and adjacent sections of offshore cable corridors prior to infield and interlink cable installation. No sand wave levelling is expected for a SEP in isolation scenario. 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 suspended sediment concentrations both at the point of dredging at the sea bed and, more importantly, at the point of its discharge back into the water column. **Table 8.3** summarises the worst case scenario volume of sediment disturbed for both scenarios.

242. 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 sand wave levelling would be disposed of within the DEP wind farm sites and export cable corridor, meaning there will be no net loss of sand from the sites.

243. The types and magnitudes of effects 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.

244. Conceptual evidence-based assessment indicates that the changes in suspended sediment concentration due to infield and interlink cable installation would be similar to those that have been assessed in relation to the disturbance of near-surface sediments during foundation installation activities (see Construction impact 1a).

8.6.4.7.2 Magnitude of effect

245. The worst case changes in suspended sediment concentrations due to infield and interlink cable installation are likely to have the following magnitudes of effect (**Table 8.22**).

Table 8.22: Magnitude of effect on suspended sediment concentrations under the worst case scenario for infield and interlink cable installation

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

* The near-field effects are confined to a small area likely to be up to a kilometre from the cable, and would not cover the entirety of the sea bed area within the DEP or SEP wind farm site.

8.6.4.7.3 Impact Significance

246. The effects on suspended sediment concentrations due to infield and interlink cable installation (including that from any sea bed preparation) will have **no impact** 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 sea bed and are not affected by sediment suspended in the water column. However, there may be impacts arising from subsequent deposition of the suspended sediment on the sea bed and these are discussed under construction Impact 6 (**Section 8.6.4.8**).

247. The effects do have the potential to impact upon other receptors and therefore the assessment of impact significance is addressed within the relevant chapters of this PEIR (see **Section 8.9**).

8.6.4.7.4 DEP and SEP Together

248. The details of the infield and interlink cabling are dependent upon the final project design (**Table 8.3**).

249. The cable burial technique for infield and interlink cables is assumed to be 50% jetting and 50% mechanical cutting. The worst case cable laying technique is considered to be mechanical cutting due the greater width of disturbance compared to jetting, therefore the assessment below considers 100% of infield cables installed by mechanical cutting.

250. Sand wave levelling is required prior to interlink and infield cable installation at the north end of the corridor between SEP and DEP North, between DEP North and DEP South, and within DEP North and DEP South wind farm sites. Any excavated sediment due to sand wave levelling preparation for the infield and interlink cables would be disposed of within the DEP and SEP wind farm sites. This means there will be no net loss of sand from the site. **Table 8.3** summarises the worst case volume of sediment affected due to infield and interlink cable installation, including sand wave levelling.

251. It is anticipated using evidence-based assessment that the changes in suspended sediment concentration due to infield and interlink cable installation would be similar to those arising from the disturbance of near-surface sediments during foundation installation activities including sea bed preparation (see construction impact 1a).

8.6.4.7.5 Impact Significance

252. The worst case changes in suspended sediment concentrations due to infield and interlink cable installation for DEP and SEP together are likely to have the same magnitudes of effect as those outlined in **Table 8.20**. Hence, there will be **no impact** on the identified receptors groups associated with the suspended sediment generated by the proposed DEP and SEP projects together.

8.6.4.8 Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)

253. The increases in suspended sediment concentrations associated with construction Impact 5 (**Section 8.6.4.7**) have the potential to result in changes in sea bed levels as the suspended sediment deposits.

254. Given that interlink cables will only be required in a DEP in isolation or DEP and SEP together scenario, changes in sea bed level due to interlink cable installation are not assessed for SEP in isolation.

8.6.4.8.1 DEP or SEP in Isolation

255. As discussed in **Section 8.6.4.7**, sand wave levelling is only required for a DEP in isolation scenario. No sand wave levelling is expected for a SEP in isolation scenario. The dynamic nature of the sand waves in this area means that any direct changes to the sea bed associated with sand wave levelling are likely to recover over a short period of time due to natural sand transport pathways.

256. Any excavated sediment due to sand wave levelling for the interlink and infield cables would be disposed of within the DEP and SEP wind farm sites 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 sand waves). The extent of sand wave levelling required and specific disposal locations within the project sites 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 sea bed would be minimal.

257. The evidence-based assessment suggests that coarser sediment disturbed during cable installation would fall rapidly to the sea bed (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. 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 and be similar in composition to the surrounding sea bed. This would mean that there would be no significant change in sea bed sediment type.

258. A very small proportion of mud would also be released to form a passive plume and become more widely dispersed before settling on the sea bed. 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 sea bed would be very thin (millimetres).

8.6.4.8.2 Magnitude of effect

259. Evidence-based assessment indicates that changes in sea bed level due to infield and interlink cable installation (including any deposition arising from spilled sediment from sand wave levelling) would be minor and are likely to have the magnitudes of effect shown in **Table 8.23**.

Table 8.23: Magnitude of effect on sea bed level changes due to deposition under the worst case scenario for sediment dispersal following infield cable installation (including sand wave levelling)

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

*The near-field effects are confined to a small area of sea bed likely to be up to a kilometre from the cable, and would not cover the whole of DEP or SEP.

8.6.4.8.3 Impact Significance

260. These effects on sea bed level are considered highly unlikely to have the potential to impact directly upon the identified receptor groups for marine geology, oceanography and physical processes. Any impacts will be of lower magnitude than those sea bed level impacts already considered for the installation of foundations. Consequently, the overall impact of infield and interlink cable installation under a worst case scenario on sea bed level changes for identified morphological receptor groups is therefore considered to be **negligible** for DEP or SEP in isolation.

261. The effects on sea bed level also have the potential to impact upon other receptors and the assessment of impact significance is addressed within the relevant chapters of this PEIR (see **Section 8.9**).

8.6.4.8.4 DEP and SEP Together

262. Although the volume of sediment disturbed for DEP and SEP together will be greater than DEP in isolation (**Section 8.6.4.7.4** and **Table 8.3**), evidence-based assessment suggests that the change in sea bed level due to infield and interlink cable installation would be less than that arising from the change in sea bed level during foundation installation activities including sea bed preparation. This is because the overall sediment release volumes would be low and confined to near the sea bed (rather than higher in the water column) along the alignment of the cables, and the rate at which sediment is released from the mechanical cutting process would be relatively slow.

8.6.4.8.5 Impact Significance

263. The worst case change in sea bed level due to infield and interlink cable installation for DEP and SEP together are likely to have the same magnitude of effects as those outlined in **Table 8.23**.

264. Consequently, the overall impact of infield and interlink cable installation activities under a worst case scenario on sea bed level changes for identified morphological receptor groups is therefore considered to be **negligible adverse** for DEP and SEP together.

8.6.4.9 Impact 7: Indentations on the sea bed due to installation vessels

8.6.4.9.1 DEP or SEP in Isolation

265. There is potential for certain vessels used during installation of DEP or SEP and cable infrastructure to directly impact the sea bed. 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 sea bed 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.

266. As the leg is inserted, the sea bed sediments would primarily be compressed vertically downwards and displaced laterally. This may cause the sea bed 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 sea bed sediments. Indeed, post-construction monitoring of DOW indicates that natural processes are restoring local areas of sea bed affected by the construction works.

267. A six-legged jack-up barge used for the installation of turbines/OSPs would have a footprint of 1,200m^2. Each leg could penetrate 5 to 15m into the sea bed and may be cylindrical, triangular, truss leg or lattice. The worst-case scenario assumes that two jack-up deployments will be required at each turbine/OSP, with up to 12 temporary mooring lines required (**Table 8.3**). The export and interlink cable installation vessels will require seven mooring lines. Cable protection measures at the HDD exit point will require jack-up deployments with a footprint of 128m^2 (**Table 8.3**).

8.6.4.9.2 Magnitude of effect

268. The worst-case changes in terms of indentations on the sea bed due to installation vessels are likely to have the magnitudes of effect described in (**Table 8.24**).

Table 8.24: Magnitude of effect on sea bed level changes under the worst case scenario for installation vessels

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field (immediate vicinity of leg)	High	Negligible	Negligible	Medium	Medium

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field (beyond immediate vicinity of leg)	No change	-	-	-	No change
Far-field	No change	-	-	-	No change

269. The footprint of jack-ups and mooring lines used during the installation of turbines/OSPs and interlink cables would not extend beyond the direct footprint. Therefore, there is **no impact** from these activities associated with DEP or SEP in isolation on the Cromer Shoal Chalk Beds MCZ or East Anglian coast since these receptors are located remotely from this zone of potential effect.

270. However, installation of the export cable and cable protection measures at the HDD exit point will involve a small jack-up and anchor footprint within the Cromer Shoal Chalk Beds MCZ. These activities will not impact the East Anglian coast as they are at least 1,000m offshore. Given this, the sensitivity and value of this receptor is presented in **Table 8.25**.

Table 8.25: Sensitivity and value assessment for the Cromer Shoal Chalk Beds MCZ

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Cromer Shoal Chalk Beds MCZ	Negligible	Negligible	Negligible	High	Negligible

8.6.4.9.3 Impact Significance

271. The extremely small footprints of the jack-ups and anchors (**Table 8.3**) associated with the installation of the export cable and cable protection measures at the HDD exit point would have a **negligible adverse impact** on the Cromer Shoal Chalk Beds MCZ.

272. The significance of these effects on other receptors is addressed within the relevant chapters of this PEIR (see **Section 8.9**).

8.6.4.9.4 DEP and SEP Together

273. Under a DEP and SEP together scenario, the construction phase would occur over 48 months. Therefore, the assessment of significance previously made for DEP or SEP in isolation is the same for DEP and SEP together. As such, there is **no impact** under a worst case scenario on the identified receptor groups during turbine/OSP and interlink cable installation since they are remote from the immediate vicinity of each leg, and a **negligible adverse impact** associated with export cable installation and installation of cable protection measures at the HDD exit point within the Cromer Shoal Chalk Beds MCZ (**Table 8.3**).

8.6.5 Potential Impacts during Operation

274. During the operational phase of DEP or SEP, 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 sea bed morphology. These potential effects are considered as operational Impacts 1 to 6. In addition, there is potential for disturbance of the sea bed during maintenance activities. These potential effects are considered as operational Impact 7.

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

8.6.5.1.1 DEP or SEP in Isolation

275. The presence of the worst case GBS wind turbine foundation and suction bucket OSP foundation structures on the sea bed within DEP or SEP 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 the sea bed morphology due to alteration of sediment transport patterns (see operational Impact 3, **Section 8.6.5.3**).

276. 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.

277. 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; ETSU, 2002; Lambkin *et al*., 2009) and numerous ESs for a range of existing and planned OWFs. Also, post-construction monitoring of DOW demonstrates that changes to sea bed sediment distribution due to the presence of the turbines are minimal, implying that changes to tidal currents (and waves) are local and not have a significant effect on sediment transport further afield.

278. Tidal currents in the vicinity of DEP and SEP are rectilinear, with peak speeds of 0.8-1.0m/s on mean spring tides and 0.5-0.6m/s on mean neap tide (Scira, 2006, DOW, 2009). A theoretical assessment of impacts to the tidal regime at SOW considered a worst case scenario of 108 large structures set out with spacings of 660m in the approximate direction of the strongest currents (west-northwest to east-southeast) and 570m in the approximate direction of largest waves (north-northeast to south-southwest). No significant changes to the broad scale flow regime were concluded, with a reduction in the overall flow within SOW of 1-2% and an increase in flow locally around each structure (Scira, 2006). These changes were considered to be insignificant within SOW. The substation location and foundation types were not considered in the theoretical assessment. However, it was concluded that this would still not result in a significant reduction in overall flow (Scira, 2006).

279. At SEP, a worst case scenario of 24 x 14MW GBS foundations set out with a spacing of 990m (the layout of the wind turbines will be defined post consent) and one OSP with four legs of 12m diameter) is being considered. The results of the theoretical assessment of the SOW design are conservative compared to the SEP design.

280. A theoretical assessment of impacts to the tidal regime at DOW considered a worst case scenario of 168 GBS foundations separated at least 360m in the dominant flow direction. A previous assessment of large GBS foundations for a similar area of the Greater Wash SEA area (HR Wallingford, 2006) showed a reduction in average flow speed of 1-2%. Therefore, any change to the flow regime was anticipated to be negligible.

281. At DEP, a worst case scenario of 32 x 14MW GBS foundations set out with spacings of 990m (the layout of the wind turbines will be defined post consent) and one OSP with four legs of 12m diameter is being considered. The results of the theoretical assessment of the DOW design are conservative compared to the DEP design.

8.6.5.1.2 Magnitude of effect

282. The worst case changes to tidal currents due to the presence of GBS foundations are likely to have the following magnitudes of effect (**Table 8.26**).

Table 8.26: Magnitude of effects on tidal currents 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

283. These 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 substation 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 8.10**.

8.6.5.1.3 Impact Significance

284. The identified 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 the receptor, so in terms of impacts on these receptor groups there is **no impact** associated with DEP or SEP in isolation.

8.6.5.1.4 DEP and SEP Together

285. **Figure 8.10** shows that the zones of potential influence for DEP and SEP do not overlap, and the combined effect on tidal currents would be the same as the two sites individually. Hence, the worst case changes to tidal currents due to the presence of GBS foundations (56 wind turbines) and suction bucket foundations (eight legs at two OSPs) at DEP and SEP together will be similar to those outlined for DEP or SEP in isolation. No pathway exists between the source and the receptor, so there is **no impact** on the identified receptor groups associated with the proposed DEP and SEP together.

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

8.6.5.2.1 DEP or SEP in Isolation

286. The presence of foundation structures within DEP or SEP and the OSP 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 the sea bed morphology due to alteration of sediment transport patterns (see operational Impact 3, **Section 8.6.5.3**).

287. 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.

288. A theoretical assessment of impacts to the wave regime at SOW considered a worst case scenario of 108 large structures set out with spacings of 660m in the approximate direction of the strongest currents (west-northwest to east-southeast) and 570m in the approximate direction of largest waves (north-northeast to south-southwest). It was shown that there would be some local scattering and some down-wave sheltering effects, but the effects were considered insignificant beyond the boundaries of the wind farm site (Scira, 2006). It was considered that given the dimensions of the proposed GBS at SOW, that only large waves during storm conditions would be affected. Wave breaking was not predicted to occur at high water over deeper parts of the array site. At mid-tide levels and with depths more typical of SOW, wave breaking was only anticipated when significant wave height is greater than 6.5m (a return period of around ten years) (Scira, 2006).Therefore, no significant impact on the wave regime or along the East Anglian coast was anticipated.

289. At SEP, water depths are similar to SOW. The worst case scenario is 24 x 14MW GBS foundations set out with spacings of 990m (the layout of the wind turbines will be defined post consent). The results of the theoretical assessment of the SOW design are conservative compared to the SEP design.

290. The theoretical assessment undertaken for DOW determined that larger GBS foundations (greater than 40m) could cause shoaling, breaking, refraction and frictional dissipation of longer period waves. However, only large waves during storm conditions would be affected. It was concluded that even if DOW as a whole had a minor adverse cumulative impact on the wave climate, the effect would be small and insignificant with regard to potential changes to coastal processes at the East Anglian coast (32km away). This assessment was based on a worst case scenario of 168 turbines spaced at least 360m apart. The result of the theoretical assessment of the DOW design is conservative compared to the DEP design.

291. In addition to the bespoke assessments at SOW and DOW, there is a strong evidence base which demonstrates that the changes in the wave regime due to the presence of foundation structures, even under a worst case scenario of the largest diameter GBS, are both 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 relatively 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). Also, post-construction monitoring of DOW demonstrates that changes to sea bed sediment distribution due to the presence of the turbines are minimal, implying that changes to waves (and tidal currents) are local and not have a significant effect on sediment transport further afield.

8.6.5.2.2 Magnitude of effect

292. The worst case changes to the wave regime due to the presence of GBS foundations are likely to have the following magnitudes of effect (**Table 8.27**).

Table 8.27: Magnitude of effect 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

8.6.5.2.3 Impact Significance

293. The identified receptor groups for marine geology, oceanography and physical processes are remote from the zone of effect arising from changes in the baseline wave regime. Due to this, no pathway exists between the source and the receptor, so in terms of impacts on these receptor groups there is **no impact** associated with the proposed DEP or SEP projects in isolation.

8.6.5.2.4 DEP and SEP Together

294. The evidence-based assessment shows that wave heights over a wide area for DEP and SEP individually would only change by a few percent. There is potential for these zones of change to overlap across their distal parts, but given the large distance between DEP and SEP (about 10km at the closest points), the combined effect will be minimal and similar to the effect for each individual site. Hence, the worst case changes to waves due to the presence of GBS foundations at DEP and SEP together will be similar to those outlined for DEP or SEP in isolation. No pathway exists between the source and the receptor, so there is **no impact** on the identified receptor groups associated with the proposed DEP and SEP together.

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

8.6.5.3.1 DEP or SEP in Isolation

295. 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 regime. This section addresses the broader patterns of suspended and bedload sediment transport across, and beyond, the DEP or SEP site and sediment transport at the coast.

296. 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.

297. 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 sea bed 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.

298. Based on the results of the theoretical assessment of impacts to the tidal regime (outlined in **Section 8.6.5.1**) and the wave regime (outlined in **Section 8.6.5.2**) at SOW, it was concluded that there would be no impact on overall sediment transport across SOW due to large, closely spaced GBS foundations (Scira, 2006). However, it was shown that sediment transport processes would be altered in the immediate vicinity of each GBS base on the sea bed, with potential for local scour and sediment deposition downstream. The depositional area was not anticipated to extend as far as adjacent foundations (Scira, 2006).

299. In addition to the evidence from theoretical studies, there is a post-construction benthic survey of the DOW array site carried out in 2018 (MMT, 2019). Grab samples were recovered from three zones. The primary impact zone during the pre-construction survey included locations within the proposed infield site, which were expected to be subjected to direct impacts. The secondary impact zones during the pre-construction survey included locations within the maximum tidal extent of the site, and thus were allocated to areas of indirect impacts. The reference areas during pre-construction survey, included locations outside the tidal excursion of the wind farm.

300. Comparison of the pre-construction and post-construction particle size data showed that there have been no significant changes in sea bed sediment composition, indicating that sediment composition has remained unaffected by the development of the wind farm. What little changes there have been are a small reduction in mud content and a small increase in gravel content. Overall, mean mud content reduced from 4.5% to 2.6%, and gravel content increased from 24.8% to 27.0%. Both of these changes over the four-year period, are within the bounds of change expected under natural processes. Indeed, the secondary impact zones and reference areas had the greatest shift in sediment composition compared to the primary impact zone, indicating that natural variation due to natural processes is having a greater effect on sea bed character than the presence of the wind turbine foundations.

301. The results of the geophysical survey describe only minor and localised effects remaining from the wind farm construction, with evidence of natural processes acting to restore any local areas of sea bed affected by the construction works to the pre-construction condition. The overall topography of the sea bed within DOW has not greatly changed.

8.6.5.3.2 Magnitude of effect

302. Since it is expected that the changes in tidal flow and wave heights during the operational phase of DEP and SEP would have no significant far-field effects, then the changes in sediment transport would be similar, with the likely following magnitudes of effect (**Table 8.28**).

Table 8.28: 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 of Effect
Near-field	Low	High	Medium	Negligible	Low
Far-field	Negligible	High	Medium	Negligible	Negligible

8.6.5.3.3 Impact Significance

303. The impacts on the sediment transport regime would not extend beyond the zones of influence previously illustrated for the changes to the tidal (**Figure 8.10**) and wave regimes and therefore, there is **no impact** on the marine geology, oceanography and physical processes receptor groups.

8.6.5.3.4 DEP and SEP Together

304. **Figure 8.10** shows that the tidal current zones of potential influence for DEP and SEP do not overlap, and conceptual evidence-based assessment indicates the combined influence of waves would be similar to DEP and SEP individually. Hence, the combined effect on sediment transport would be the same as the two sites individually. Hence, the worst case changes to sediment transport due to the presence of GBS foundations at DEP and SEP together will be similar to those outlined for DEP or SEP in isolation. No pathway exists between the source and the receptor, so there is **no impact** on the identified receptor groups associated with the proposed DEP and SEP together.

8.6.5.4 Impact 4: Loss of sea bed area due to the footprint of wind turbine and OSP foundation structures

8.6.5.4.1 DEP or SEP in Isolation

305. The sea bed would be directly impacted by the footprint of each foundation structure on the sea bed within the DEP or SEP sites. This would constitute a loss in natural sea bed area during the operational life of the project.

306. 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 having scour protection is considered to provide a conservative assessment.

307. Under the worst case scenario of scour protection being provided for all foundations, the sea bed 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.

308. The worst case is associated with the maximum number of 14MW GBS turbine foundations, with scour protection and an OSP with suction bucket foundations and scour protection (**Table 8.3**).

8.6.5.4.2 Magnitude of effect

309. The worst-case loss of sea bed due to the presence of foundation structures with scour protection is likely to have the following magnitudes of effect (**Table 8.29**). 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 material.

Table 8.29: Magnitude of effects on sea bed morphology under the worst-case scenario for the footprint of foundations and scour protection

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

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

8.6.5.4.3 Impact Significance

310. The near-field effects are confined to the footprint of each foundation structure, and therefore have no pathway to the relevant impact receptors. There is therefore **no impact** for DEP or SEP in isolation.

311. The significance of these effects on other receptors is addressed within the relevant chapters of this PEIR (see **Section 8.9**).

8.6.5.4.4 DEP and SEP Together

312. The maximum footprint on the sea bed from GBS foundations and scour protection for each wind turbine and suction bucket OSP foundations with scour protection is larger than that of DEP or SEP in isolation (**Table 8.3**), however any near-field effects are confined to the footprint of each foundation structure. The impacts associated with DEP and SEP together would be the same as those outlined for DEP or SEP in isolation (**Section 8.6.5.4.1**).

313. The worst case changes to the sea bed morphology due to the presence of foundation structures at DEP and SEP together would have the same magnitudes of effect as those outlined for DEP or SEP in isolation.

8.6.5.5 Impact 5: Morphological and sediment transport effects due to cable protection measures within the DEP and SEP sites and interlink cable corridor

314. Given that interlink cables will only be required in a DEP in isolation or DEP and SEP together scenario, morphological and sediment transport effects due to cable protection for interlink cables are not assessed for SEP in isolation.

8.6.5.5.1 DEP or SEP in Isolation

315. As a worst case scenario, if infield or interlink 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 placement.

316. The effects 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 sea bed.

317. In areas of active sediment transport, any linear protrusion on the sea bed may interrupt bedload sediment transport processes during the operational phase of the proposed project. There is unlikely to be any significant effect 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 sea bed (a maximum of 0.5m).

318. The worst case scenario of cable protection for the infield and interlink cables, and crossings is rock berm protection (**Table 8.3**).

319. The presence of sand waves across both DEP and SEP indicates that some bedload sediment transport exists, with a net direction towards the southeast (see **Section 8.5.8**). There are also megaripples present across the sites. Protrusions from the sea bed are unlikely to significantly affect the migration of sand waves, since sand wave heights (up to 4m) in most areas would exceed the height of cable protection works, and would pass over them. There may be localised interruptions to bedload transport in other areas, but the gross patterns of bedload transport across the DEP and SEP array sites would not be affected significantly.

320. The presence of cable and crossing protection works on the sea bed would represent the worst case in terms of a direct loss of sea bed area, but this footprint is likely to be lower than that of the foundations (and associated scour protection works) within DEP or SEP.

8.6.5.5.2 Magnitude of effect

321. The worst case changes to the sea bed morphology and sediment transport due to cable and crossing protection measures for infield and interlink cables are likely to have the following magnitudes of effect (**Table 8.30**).

Table 8.30: Magnitude of effects on sea bed morphology and sediment transport under the worst-case scenario for cable and crossing protection measures for infield and interlink 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 effects are confined to a small area (likely to be within the footprint of cable protection works), and would not cover the whole DEP or SEP sites

8.6.5.5.3 Impact Significance

322. The effects on sea bed morphology and sediment transport arising from the presence of infield and interlink cable and crossing protection measures would not extend far beyond the direct footprint. Therefore, there is **no impact** associated with the proposed project on the identified marine geology, oceanography and physical processes receptor groups since these are located remotely from this zone of potential effect.

323. The significance of these effects on other receptors is addressed within the relevant chapters of this PEIR (see **Section 8.9**).

8.6.5.5.4 DEP and SEP Together

324. The footprint of sea bed impacted by cable and crossing protection measures would be the same as DEP in isolation scenario. Gross patterns of bedload transport would not be affected significantly since sand wave heights (up to 4m) in most areas would exceed the height of cable protection works and would pass over them. Therefore, impacts associated with DEP and SEP together would be the same as those outlined for DEP or SEP in isolation (**Table 8.3** and **Section 8.6.5.5.1**).

325. The worst case changes to the sea bed morphology and sediment transport due to protection measures for infield and interlink cables, and crossings for DEP and SEP together would have the same magnitudes of effect as DEP or SEP in isolation, as the effects would not extend far beyond the direct footprint. Therefore, there is **no impact** associated with DEP and SEP on the identified marine geology, oceanography and physical processes receptor groups since these are located remotely from this zone of potential effect.

8.6.5.6 Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor (export cables)

8.6.5.6.1 DEP or SEP in Isolation

326. 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 sea bed characterised by exposed bedrock (**Table 8.3**).

327. Cable protection may take the form of concrete mattresses, fronded concrete mattresses, or uraduct shell. Equinor has committed to not using loose rock placement within the MCZ.

328. The effects 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 sea bed.

329. In areas of active sediment transport, any linear protrusion on the sea bed may interrupt bedload sediment transport processes during the operational phase. There is likely to be a difference in effect 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 alongshore sediment transport processes and circulatory pathways across any nearshore banks.

330. The seaward limit which marks the effective boundary of wave-driven sediment transport is called the ‘closure depth’ and can be calculated using the methods of Hallermeier (1978). For the sea bed offshore from the landfall, this would typically be located in around 5m of water.

331. Any protrusions from the sea bed 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 etc.) due to reductions in sediment supply to those areas.

332. The potential magnitude of the effect will depend on the local sediment transport rates; a lower rate would reduce the potential effect on sediment supply to wider areas. There would be a range of sediment transport potentials across the export cables. If chalk or Pleistocene geological units are exposed at the sea bed 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.

333. Where the sea bed is composed of mobile sand, it can be transported under existing tidal conditions. If the 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 (up to 0.5m in most cases). 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 affected significantly.

334. The presence of cable protection works on the sea bed would represent the worst case in terms of a direct loss of sea bed area, but this footprint would be lower than that of the wind turbine foundations (and associated scour protection works) within the DEP and SEP sites (**Table 8.3**).

335. In recognition of these potential effects, considerable effort has been given to selecting an appropriate landfall location and export cable corridor to minimise sediment transport effects as far as practicably achievable. The most important marine geological and geomorphological features present in the nearshore and at the landfall are those associated with the Cromer Shoal Chalk Beds MCZ. Royal HaskoningDHV (2020) showed that potential bedload sediment transport rates are low to non-existent in areas where cable protection is most likely to be required within the MCZ (**Appendix 8.2**). These areas consist of chalk overlain by a thin static lag of sand and gravel.

336. A commitment has also been made to install the export cable at the landfall using HDD techniques, thus minimising disturbance and avoiding the need for cable protection in the intertidal and shallowest nearshore zones. It is likely that the HDD pop-out location would be in water depths of approximately 9-10m below LAT, which is seaward of the 5m closure depth. Hence, there would be no interruption to sediment transport pathways close to the coast because the export cables would be buried.

337. Also, a commitment has been made to only use cable protection at the HDD exit point and up to a maximum of 100m for each of the two export cables inside the MCZ.

338. As a consequence of this embedded mitigation, the proposed HDD method and pop-out location would:

- Minimise direct physical disruption to the Cromer Shoal Chalk Beds MCZ;
- Avoid disturbance to the alongshore sediment transport processes; and
- Reduce the risk of suspended sediment (during construction) affecting the MCZ.

339. Based on a Hornsea Project Three construction start in 2021 and offshore export cable corridor construction in years 3 and 4 (2023-2024), and possibly also years 8 and 9 in a two-phase development (2028-2029), temporal overlap of export cable construction is not expected. Similarly, it is unlikely that cable maintenance activities would take place at the same time during operation of the wind farm export cables, and concurrent decommissioning is not expected.

8.6.5.6.2 Magnitude of effect

340. The worst case changes to the sea bed morphology and sediment transport due to cable protection measures for export cables are likely to have the following magnitudes of effect (**Table 8.31**).

Table 8.31: Magnitude of effect on sea bed morphology and sediment transport under the worst-case scenario for cable protection measures for export cables

Location	**Scale**	**Duration**	**Frequency**	**Reversibility**	**Magnitude of Effect**
Landfall	Negligible	High	High	Negligible	Negligible
Shallower than 9m water depth (excluding landfall)	No change	-	-	-	No change
Deeper than 9m water depth	Low	High	High	Negligible	Low

341. Offshore of the closure depth, the effects on sea bed 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 impact** in these locations associated with the proposed project on the East Anglian coast since this receptor is located remotely from this zone of potential effect.

342. However, inshore of the closure depth, these effects could potentially affect the Cromer Shoal Chalk Beds MCZ or indirectly affect parts of the East Anglian coast. Given this, the sensitivity and value of these receptors are presented in **Table 8.32**.

Table 8.32: Sensitivity and value assessment for the Cromer Shoal Chalk Beds MCZ and East Anglian coast

Receptor	**Tolerance**	**Adaptability**	**Recoverability**	**Value**	**Sensitivity**
Cromer Shoal Chalk Beds MCZ	Medium	Low	Negligible	High	Medium

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
East Anglian coast	Medium	Low	Negligible	High	Medium

8.6.5.6.3 Impact Significance

343. It is considered that the extremely small areas associated with cable protection (**Table 8.3**) would have no significant effect on the sediment transport processes in the MCZ. Therefore, there would be **negligible adverse** impact on the Cromer Shoal Chalk Beds MCZ.

344. As no cable protection will be used landward of the HDD exit point in the nearshore area (about 1,000m from the coast) of the offshore cable corridor, no morphological effects would take place and so there would be **no impact** on coastal morphology at the cable landfall during the operational phase of DEP or SEP.

345. The significance of these effects on other receptors is addressed within the relevant chapters of this PEIR (see **Section 8.9**).

8.6.5.6.4 DEP and SEP Together

346. As outlined above in **Section 8.6.5.6.1**, the detail of the export cabling is dependent upon the final project design (**Table 8.3**).

347. The morphological and sediment transport effects due to cable protection measures along the export cable for DEP and SEP together will be the same as those outlined in **Section 8.6.5.6.1**. Given the extremely small areas of cable protection, **no impact** is anticipated on the East Anglian coast. Due to the small area of rock berm present within Cromer Shoal Chalk Beds MCZ (0.0006%) associated with the proposed DEP and SEP together scenario, an impact of **negligible adverse** significance is anticipated on the Cromer Shoal Chalk Beds MCZ.

8.6.5.7 Impact 7: Cable repairs and reburial

8.6.5.7.1 DEP or SEP in Isolation

348. Cable repairs and reburial could be needed over the operational lifetime of DEP or SEP. Turbine repairs may also need to be carried out as required. The disturbance areas for reburial and repairs of cables are extremely small in comparison to construction. For cable repair and reburial, it is assumed that a dynamically positioned vessel will be used.

349. There is potential for temporary physical disturbance to the Cromer Shoal Chalk Beds MCZ in the offshore export cable corridor due to cable maintenance and repair operations. The maximum disturbance area for cable repair and reburial inside the MCZ is estimated as 1500m^2 (for both DEP or SEP) every ten years. This equates to 0.00047% of the total area of the MCZ (321km^2). This is estimated from 400m per cable pair within the MCZ, with a disturbance width of 3m. If reburial is required, this would be for up to 100m per cable pair with a disturbance width of 3m (300m^2 for DEP or SEP in isolation) within the Cromer Shoal Chalk Beds MCZ.

350. There is potential for certain vessels used during the maintenance of the wind turbines to directly impact the sea bed during the operational phase. 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 are temporarily placed on the sea bed, 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.

351. The worst-case scenario is considered to correspond to the use of jack-up vessels for wind turbine repairs since the depressions and potential for effects on marine geology, oceanography and physical processes and scour-hole formation would be greater than the anchor scars. The worst case scenario is presented in **Table 8.3**.

352. The sediment volumes arising from repair and reburial would be small in magnitude and cause an insignificant effect in terms of enhanced suspended sediment concentrations and deposition elsewhere.

8.6.5.7.2 Magnitude of effect

353. The worst-case changes in terms of indentations on the sea bed due to maintenance vessels and cable repair and reburial footprints are likely to have the magnitudes of effect shown in **Table 8.33**.

Table 8.33: Magnitude of effect on the sea bed under the worst-case scenario for maintenance vessels

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field (immediate vicinity of leg)	High	Negligible	Negligible	Medium	Medium
Near-field (beyond immediate vicinity of leg)	No change	-	-	-	No change
Far-field	No change	-	-	-	No change

8.6.5.7.3 Impact Significance

354. There is **no impact** under a worst-case scenario on the East Anglian coast receptor since it is remote from the immediate vicinity of each leg.

355. The sensitivity and value of the Cromer Shoal Chalk Beds MCZ to disturbance is shown in **Table 8.34**.

Table 8.34: Sensitivity and value assessment of Cromer Shoal Chalk Beds MCZ

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Cromer Shoal Chalk Beds MCZ	Negligible	Negligible	Negligible	High	Negligible

356. The assessment indicates that temporary physical disturbance may occur within the Cromer Shoal Chalk Beds MCZ (**Table 8.3**). Although temporary physical disturbance may occur, this area is a very small part of the MCZ, 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 impact**.

357. The significance of these effects on other receptors is addressed within relevant chapters of this PEIR.

8.6.5.7.4 DEP and SEP Together

358. The maximum disturbance area for a DEP and SEP together scenario would be larger than DEP or SEP in isolation (**Table 8.3**), however, the disturbance areas for reburial and repairs of cables, and associated jack-up footprint are still small in comparison to construction.

359. It is possible that different areas would be affected in each year of the operational phase. There is **no impact** under a worst-case scenario of DEP and SEP together on the East Anglian coast receptor since it is remote from the immediate vicinity of each leg.

360. Given the short duration and small scale of any maintenance works (if required) there will be **negligible adverse** impact on the form or function of the site. The magnitude of effects are expected to be the same as those outlined above in **Table 8.33** and **Table 8.34**.

8.6.6 Potential Impacts during Decommissioning

361. The scope of the decommissioning works would most likely involve removal of the accessible installed components. This is outlined in **Section 5.4.12** of **Chapter 5 Project Description** 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, part of the foundations (those above sea bed level), removal of some or all of the infield cables, interlink cables, and export cables. Scour and cable protection would likely be left *in situ,* other than in the MCZ where it may be removed.

362. During the decommissioning phase, there is potential for wind turbine foundation and cable removal activities to cause changes in suspended sediment concentrations and/or sea bed 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 suspended sediment concentrations due to foundation removal;

- Impact 2 Changes in sea bed level due to foundation removal;
- Impact 3 Changes in suspended sediment concentrations due to removal of parts of the export cable;
- Impact 4 Changes in sea bed level due to removal of parts of the export cable;
- Impact 5 Changes in suspended sediment concentrations due to removal of parts of the infield and interlink cables;
- Impact 6 Changes in sea bed level due to removal due to removal of parts of the infield and interlink cables; and
- Impact 7 Indentations on the sea bed due to decommissioning vessels.

363. The magnitude of effects would be comparable to or less than those identified for the construction phase. Accordingly, given the construction phase assessments concluded "**no impact**" or "**negligible adverse** impacts" 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. The magnitude of effects will be the same for DEP or SEP in isolation and for DEP and SEP together.

364. The significance of effects on other receptors is addressed within relevant chapters of this PEIR (**Chapter 9 Marine Water and Sediment Quality**, **Chapter 10 Benthic Ecology**, **Chapter 11 Fish and Shellfish Ecology**, **Chapter 12 Marine Mammal Ecology** and **Chapter 13 Offshore Ornithology**).

8.7 Cumulative Impacts

8.7.1 Identification of Potential Cumulative Impacts

365. The first step in the CIA process is the identification of which residual impacts assessed for DEP and/or SEP on their own have the potential for a cumulative impact with other plans, projects and activities (described as 'impact screening'). This information is set out in **Table 8.35** below, together with a consideration of the confidence in the data that is available to inform a detailed assessment and the associated rationale. Only potential impacts assessed in **Section 8.6** as negligible adverse or above are included in the CIA (i.e. those assessed as 'no impact' are not taken forward as there is no potential for them to contribute to a cumulative impact).

366. **Table 8.35** concludes that in relation to marine geology, oceanography and physical processes, no cumulative impacts are anticipated during the construction, operation or decommissioning phases and therefore cumulative impacts are screened out of further assessment.

Table 8.35: Potential Cumulative Impacts (impact screening)

Impact	Potential for Cumulative Impact	Data Confidence	Rationale
Construction			
Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	No	High	Impacts occur at discrete locations for a time-limited duration and are negligible adverse in magnitude. This applies to DEP or SEP in isolation, and DEP and SEP together. Based on a Hornsea Project Three construction start in 2021 and offshore export cable corridor construction in years 3 and 4 (2023-2024), and possibly also years 8 and 9 in a two-phase development (2028-2029), temporal overlap of export cable construction is not expected.
Impact 3: Change in suspended sediment concentrations due to export cable installation	No	High	
Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor *[negligible adverse impact applies to Cromer Shoal Chalk Beds MCZ only]*	No	High	
Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink)	No	High	
Impact 7: Indentations on the sea bed due to installation vessels	No	High	
Operation			
Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor (export cables) *[negligible adverse impact applies to Cromer Shoal Chalk Beds MCZ only]*	No	High	The combined effects of changes to the sediment transport regime as a result of the export cables in combination with the cables of DOW and SOW.

Impact	Potential for Cumulative Impact	Data Confidence	Rationale
Impact 7: Cable repairs and reburial *[negligible adverse impact applies to Cromer Shoal Chalk Beds MCZ only]*	No	High	Impacts will be highly localised around the foundations and cables and therefore there will be no cumulative impact.
Decommissioning			
Impact 3: Change in suspended sediment concentrations due to removal of parts of the export cable	No	High	Impacts occur at discrete locations for a time-limited duration and negligible adverse in magnitude. This applies to DEP or SEP in isolation, and DEP and SEP together.
Impact 4: Change in sea bed level due to removal of parts of the export cable	No	High	
Impact 5: Changes in suspended sediment concentrations due to removal of parts of the infield and interlink cables	No	High	
Impact 6: Changes in sea bed level due to removal due to removal of parts of the infield and interlink cables	No	High	

8.8 Transboundary Impacts

367. Given that there will be no impact to the hydrodynamic and sedimentary regime as a result of DEP and SEP (in isolation and together), transboundary impacts are unlikely to occur, or are unlikely to be significant (PINS, 2019), and therefore transboundary impacts are scoped out of further assessment.

8.9 Inter-relationships

368. There are clear inter-relationships between the marine geology, oceanography and physical processes topic and several other topics that have been considered within this PEIR. **Table 8.36** provides a summary of the principal inter-relationships and sign-posts to where those issues have been addressed in the relevant chapters.

Table 8.36: Marine geology, oceanography and physical processes inter-relationships

Topic and description	**Related chapter**	**Where addressed in this chapter**	**Rationale**
Construction			
Effects on water column (suspended sediment concentrations)	**Chapter 9 Marine Water and Sediment Quality** **Chapter 11 Fish and Shellfish Ecology** **Chapter 14 Commercial Fisheries** **Chapter 10 Benthic Ecology**	**Section 8.6.4.1** and **Section 8.6.4.2** (foundation installation) **Section 8.6.4.7** (infield cables installation) **Section 8.6.4.5** (export cables installation)	Suspended sediment could be contaminated and could cause disturbance to fish and benthic species through smothering.
Effects on sea bed (morphology / sediment composition)	**Chapter 10 Benthic Ecology** **Chapter 11 Fish and Shellfish Ecology** **Chapter 14 Commercial Fisheries** **Chapter 15 Shipping and Navigation** **Chapter 16 Offshore**	**Section 8.6.4.3** and **Section 8.6.4.4** (foundation installation) **Section 8.6.4.8** (infield cables installation) **Section 8.6.4.6** (export cables) **Section 8.6.4.9** (installation vessels)	Disruption to sea bed 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.

Topic and description	Related chapter	Where addressed in this chapter	Rationale
	Archaeology and Cultural Heritage **Chapter 18 Other Marine Users**		
Operation			
Effects on shoreline (morphology / sediment transport / sediment composition)	**Chapter 10 Benthic Ecology** **Chapter 20 Water Resources and Flood Risk** **Chapter 27 Seascape and Visual Impact Assessment** **Chapter 28 Landscape and Visual Amenity**	**Section 8.6** (export cable protection in nearshore and intertidal zone)	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 sea bed (sediment transport processes / morphology)	**Chapter 10 Benthic Ecology** **Chapter 11 Fish and Shellfish Ecology** **Chapter 14 Commercial Fisheries**	**Section 8.6.5.3** (sediment transport regime) **Section 8.6.5.4** (loss of sea bed area) **Section 8.6.5.5** (infield and interlink cable protection) **Section 8.6.5.6** (export cable	Disruption to sediment transport processes or loss of sea bed area could affect these receptors by altering the existing sedimentary environment, however this is unlikely to be to levels which are significant.

Topic and description	Related chapter	Where addressed in this chapter	Rationale
	Chapter 15 Shipping and Navigation **Chapter 16 Offshore Archaeology and Cultural Heritage**	protection in offshore zone)	
Decommissioning			
Inter-relationships for impacts during the decommissioning phase will be the same as those outlined above for the construction phase.			

8.10 Interactions

369. The impacts identified and assessed in this chapter have the potential to interact with each other. The areas of potential interaction between impacts are presented in **Table 8.37**. This provides a screening tool for which impacts have the potential to interact. **Table 8.37** provides an assessment for each receptor (or receptor group) as related to these impacts.

370. Within **Table 8.37** the impacts are assessed relative to each development phase (‘phase assessment’, i.e. construction, operation or decommissioning) to see if (for example) multiple construction impacts affecting the same receptor could increase the level of impact upon that receptor. Following this, a ‘lifetime assessment’ is undertaken which considers the potential for impacts to affect receptors across all development phases (**Table 8.38**).

371. The impacts listed in **Table 8.37** are only expressed on the following two receptors in **Table 8.38**:

- East Anglian Coast; and
- MCZ.

Table 8.37: Interaction between impacts - screening

Potential Interaction between Impacts									
Construction									
	Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)	Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines (wind farm site)	Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations	Impact 3: Change in suspended sediment concentrations due to export cable installation	Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor	Impact 5: Change in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)	Impact 7: Indentations on the sea bed due to installation vessels
Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)	-	No	Yes	No	Yes	Yes	Yes	Yes	No

Potential Interaction between Impacts									
Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines (wind farm site)	No	-	No	Yes	Yes	Yes	Yes	Yes	No
Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	Yes	No	-	No	Yes	Yes	Yes	Yes	Yes
Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations	No	Yes	No	-	Yes	Yes	Yes	Yes	Yes
Impact 3: Change in suspended sediment concentrations due to export cable installation	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	No

Potential Interaction between Impacts									
Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes
Impact 5: Change in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes	No
Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes
Impact 7: Indentations on the sea bed due to installation vessels	No	No	Yes	Yes	No	Yes	No	Yes	-

Potential Interaction between Impacts									
Operation									
	Impact 1: Changes to the tidal regime due to the presence of structures on the sea bed (wind turbines and OSP foundations)	Impact 2: Changes to the wave regime due to the presence of structures on the sea bed (wind turbines and OSP foundations)	Impact 3: Changes to the sediment transport regime due to the presence of structures on the sea bed (wind turbines and OSP foundations)	Impact 4: Loss of sea bed 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 DEP and SEP sites and interlink cable corridor	Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor (export cables)	Impact 7: Cable repairs and reburial		
Impact 1: Changes to the tidal regime due to the presence of structures on the sea bed (wind turbines and OSP foundations)	-	Yes	No	No	No	No	No		

Potential Interaction between Impacts									
Impact 2: Changes to the wave regime due to the presence of structures on the sea bed (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 sea bed (wind turbines and OSP foundations)	No	No	-	No	Yes	Yes	No		
Impact 4: Loss of sea bed area due to the footprint of wind turbine and OSP foundation structures	No	No	No	-	No	No	No		

Potential Interaction between Impacts									
Impact 5: Morphological and sediment transport effects due to cable protection measures within the DEP and SEP sites and interlink cable corridor	No	No	Yes	No	-	Yes	No		
Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor (export cables)	No	No	Yes	No	Yes	-	No		
Impact 7: Cable repairs and reburial	No	No	No	No	No	No	-		
Decommissioning									
The magnitude of effects would be comparable to those identified for the construction phase. Accordingly, given that no significant impacts were 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.									

Table 8.38: Interaction between impacts – phase and lifetime assessment

	Highest significance level				
Receptor	**Construction**	**Operation**	**Decommissioning**	**Phase assessment**	**Lifetime assessment**
East Anglian coast	Negligible	No impact	Negligible	**No greater than individually assessed impact** The impacts are considered to have no impact to negligible adverse magnitude of effect on the receptor. Given that the magnitudes are none to negligible adverse and 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**
Cromer Shoal Chalk Beds MCZ	Negligible	Negligible	Negligible	**No greater than individually assessed impact** The impacts are considered to have a negligible adverse impact on the receptor. Given that the magnitudes are negligible adverse and that 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**

8.11 Potential Monitoring Requirements

372. Monitoring requirements will be described in the in-principle monitoring plan (IPMP) submitted alongside the DCO application and further developed and agreed with stakeholders prior to construction based on the IPMP and taking account of the final detailed design of DEP and SEP. 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 or, at worse, negligible adverse impacts. 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 8.6**). 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.

8.12 Assessment Summary

373. 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 impacts on the identified receptors during construction, operation and decommissioning phases of DEP and SEP (in isolation and together) are considered ‘negligible adverse’ or ‘no impact’.

374. The specific receptors that have been identified in relation to this topic are the sensitive ‘East Anglian’ coast and Cromer Shoal Chalk Beds MCZ.

375. The effects that have been assessed are mostly anticipated to result in no impact 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 8.39**.

Table 8.39: Summary of potential impacts on marine geology, oceanography and physical processes

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Construction						
Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)	East Anglian coast	N/A	Medium (near-field) Low (far-field)	**No impact**	N/A	**No impact**
	Cromer Shoal Chalk Beds MCZ	N/A	Medium (near-field) Low (far-field)	**No impact**	N/A	**No impact**
Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines and OSPs	East Anglian coast	N/A	Negligible (near-field) Negligible (far-field)	**No impact**	N/A	**No impact**
	Cromer Shoal Chalk Beds MCZ	N/A	Negligible (near-field) Negligible (far-field)	**No impact**	N/A	**No impact**
	East Anglian coast	Negligible	Low (near-field) Negligible (far-field)	**Negligible**	N/A	**Negligible**

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	Cromer Shoal Chalk Beds MCZ	Negligible	Low (near-field) Negligible (far-field)	**Negligible**	N/A	**Negligible**
Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations for wind turbines and OSPs	East Anglian coast	N/A	Low (near-field) Negligible (far-field)	**No impact**	N/A	**No impact**
	Cromer Shoal Chalk Beds MCZ	N/A	Low (near-field) Negligible (far-field)	**No impact**	N/A	**No impact**
Impact 3: Change in suspended sediment concentrations due to export cable installation	East Anglian coast	N/A	Negligible (near-field (nearshore)) Negligible (near-field (offshore)) Negligible (far-field)	**Negligible**	N/A	**Negligible**
	Cromer Shoal Chalk Beds MCZ	N/A	Negligible (near-field (nearshore)) Negligible (near-field (offshore)) Negligible (far-field)	**Negligible**	N/A	**Negligible**

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor	East Anglian coast	Negligible	Low (near-field) Negligible (far-field)	**No impact**	N/A	**No impact**
	Cromer Shoal Chalk Beds MCZ	Negligible	Low (near-field) Negligible (far-field)	**Negligible**	N/A	**Negligible**
Impact 5: Change in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	East Anglian coast	N/A	Medium (near-field) Low (far-field)	**No impact**	N/A	**No impact**
	Cromer Shoal Chalk Beds MCZ	N/A	Medium (near-field) Low (far-field)	**No impact**	N/A	**No impact**
Impact 6: Change in sea bed level due to offshore cable installation (infield, and interlink cables)	East Anglian coast	N/A	Low (near-field) Negligible (far-field)	**Negligible**	N/A	**Negligible**
	Cromer Shoal Chalk Beds MCZ	N/A	Low (near-field) Negligible (far-field)	**Negligible**	N/A	**Negligible**
	East Anglian coast	N/A	Medium (near field (immediate vicinity of leg)	**No impact**	N/A	**No impact**

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 7: Indentations on the sea bed due to installation vessels			No change (near field (beyond immediate vicinity of leg) No change (far field)			
	Cromer Shoal Chalk Beds MCZ	N/A	Medium (near field (immediate vicinity of leg) No change (near field (beyond immediate vicinity of leg) No change (far field)	**Negligible impact**	N/A	**Negligible impact**
Operation						
Impact 1: Changes to the tidal regime due to the presence of structures on the sea bed (wind turbines and OSP foundations)	East Anglian coast	N/A	Low (near-field) Negligible (far-field)	**No impact**	N/A	**No impact**
	Cromer Shoal Chalk Beds MCZ	N/A	Low (near-field) Negligible (far-field)	**No impact**	N/A	**No impact**
	East Anglian coast	N/A	Low (near-field) Negligible (far-field)	**No impact**	N/A	**No impact**

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 2: Changes to the wave regime due to the presence of structures on the sea bed (wind turbines and OSP foundations)	Cromer Shoal Chalk Beds MCZ	N/A	Low (near-field) Negligible (far-field)	**No impact**	N/A	**No impact**
Impact 3: Changes to the sediment transport regime due to the presence of structures on the sea bed (wind turbines and OSP foundations)	East Anglian coast	N/A	Low (near-field) Negligible (far-field)	**No impact**	N/A	**No impact**
	Cromer Shoal Chalk Beds MCZ	N/A	Low (near-field) Negligible (far-field)	**No impact**	N/A	**No impact**
Impact 4: Loss of sea bed area due to the footprint of wind turbine and OSP foundation structures	East Anglian coast	N/A	High (near-field) No change (far-field)	**No impact**	N/A	**No impact**
	Cromer Shoal Chalk Beds MCZ	N/A	High (near-field) No change (far-field)	**No impact**	N/A	**No impact**
	East Anglian coast	N/A	High (near-field) Negligible (far-field)	**No impact**	N/A	**No impact**

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 5: Morphological and sediment transport effects due to cable protection measures within the DEP and SEP sites and interlink cable corridor	Cromer Shoal Chalk Beds MCZ	N/A	High (near-field) Negligible (far-field)	**No impact**	N/A	**No impact**
Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor (export cables)	East Anglian coast	Medium	Negligible (landfall) No change (Shallower than 9m) Low (deeper than 9m)	**No impact**	N/A	**No impact**
	Cromer Shoal Chalk Beds MCZ	Medium	Negligible (landfall) No change (Shallower than 9m) Low (deeper than 9m)	**Negligible**	N/A	**Negligible**
Impact 7: Cable repairs and reburial	East Anglian coast	N/A	Medium (near-field (immediate vicinity of leg)) No Change (near-field (beyond immediate vicinity of leg))	**No impact**	N/A	**No impact**

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
			No change (far-field)			
	Cromer Shoal Chalk Beds MCZ	Negligible	Medium (near-field (immediate vicinity of leg)) No Change (near-field (beyond immediate vicinity of leg)) No change (far-field)	**Negligible**	N/A	**Negligible**
Decommissioning						
The impacts 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.						

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