Outer Dowsing Offshore Wind

Preliminary Environmental Information Report

Volume 1, Chapter 7: Marine Processes

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OUTER DOWSING OFFSHORE WIND

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Abbreviations

Acronym	Expanded name
BEIS	Department for Business, Energy & Industrial Strategy (now the Department for Energy Security and Net Zero (DESNZ))
BERR	Business Enterprise and Regulatory Reform
BGS	British Geological Survey
BMAPA	British Marine Aggregate Producers Association
BSI	British Standards Institution
CBRA	Cable Burial Risk Assessment
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CIRIA	Construction Industry Research and Information Association
COWRIE	Collaborative Offshore Wind Energy Research into the Environment
CSIP	Cable Specification and Installation Plan
DCO	Development Consent Order
DECC	Department of Energy & Climate Change, now the Department for Energy Security and Net Zero (DESNZ)
DESNZ	Department for Energy Security and Net Zero, formerly Department of Business, Energy and Industrial Strategy (BEIS), which was previously Department of Energy & Climate Change (DECC).
DP	Decommissioning Programme
EA	Environment Agency
ECC	Export Cable Corridor
EEA	European Economic Area
EIA	Environmental Impact Assessment
EMF	Electromagnetic fields
EMP	East Marine Plan
EPP	Evidence Plane Process
ES	Environmental Statement
ETG	Expert Technical Group
EU	European Union
FEPA	Food and Environment Protection Act
FFC	Flamborough and Filey Coast
GBS	Gravity Base Structure
GT R4 Ltd	The Applicant. The special project vehicle created in partnership between Corio Generation (a wholly owned Green Investment Group portfolio company), Gulf Energy Development and TotalEnergies
HADA	Humber Aggregate Dredging Association
HDD	Horizontal Directional Drilling
HPMA	Highly Protected Marine Area
HRA	Habitats Regulation Assessment
IROPI	Imperative Reasons of Overriding Public Interest
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide
MAREA	Marine Aggregate Regional Environmental Assessment

Acronym	Expanded name
MCZ	Marine Conservation Zone
MDS	Maximum Design Scenario
MFE	Mass Flow Excavator
MHWS	Mean High Water Springs
MLWS	Mean Low Water Springs
MMO	Marine Management Organisation
MPA	Marine Protected Area
MPS	Marine Policy Statement
MSFD	Marine Strategy Framework Directive
MSL	Mean Sea Level
NCERM2	National Coastal Erosion Risk Mapping
NPS	National Policy Statement
NRW	National Resources Wales
NSIP	Nationally Significant Infrastructure Project
O&G	Oil and Gas
ODOW	Outer Dowsing Offshore Wind (The Project)
ORCP	Offshore Reactive Compensation Platform
OSS	Offshore Substation
OWF	Offshore Windfarm
PEIR	Preliminary Environmental Information Report
RCP	Representative Concentration Pathway
RIAA	Report to Inform Appropriate Assessment
SAC	Special Area of Conservation
SCI	Site of Community Importance
SoS	Secretary of State
SPA	Special Protection Area
SPM	Suspended Particulate Matter
SPMP	Scour Protection Management Plan
SSC	Suspended Sediment Concentration
SSSI	Site of Special Scientific Interest
TCE	The Crown Estate
TKOWFL	Triton Knoll Offshore Windfarm Ltd
TSHD	Trailer Suction Hopper Dredger
UK	United Kingdom
UXO	Unexploded ordnance
WTG	Wind Turbine Generator
ZoI	Zone of Influence

Terminology

Term	Definition
Array area	The area offshore within the PEIR Boundary within which the generating stations (including wind turbine generators (WTG) and inter array cables), offshore accommodation platforms, offshore transformer substations and associated cabling are positioned.
Baseline	The status of the environment at the time of assessment without the development in place.
Cumulative effects	The combined effect of the Project acting cumulatively with the effects of a number of different projects, on the same single receptor/resource.
Cumulative impact	Impacts that result from changes caused by other past, present or reasonably foreseeable actions together with the Project.
Development Consent Order (DCO)	An order made under the Planning Act 2008 granting development consent for a Nationally Significant Infrastructure Project (NSIP) from the Secretary of State (SoS) for Department for Energy Security and Net Zero (DESNZ).
Effect	Term used to express the consequence of an impact. The significance of an effect is determined by correlating the magnitude of an impact with the sensitivity of a receptor, in accordance with defined significance criteria.
Environmental Impact Assessment (EIA)	A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the Environmental Impact Assessment (EIA) Regulations, including the publication of an Environmental Statement (ES).
EIA Regulations	Infrastructure Planning (Environmental Impact Assessment) Regulations 2017.
Environmental Statement (ES)	The suite of documents that detail the processes and results of the Environmental Impact Assessment (EIA).
Evidence Plan	A voluntary process of stakeholder consultation with appropriate Expert Topic Groups (ETGs) that discusses and where possible agrees the detailed approach to the Environmental Impact Assessment (EIA) and information to support Habitats Regulations Assessment (HRA) for those relevant topics included in the process, undertaken during the pre-application period.
Habitats Regulations Assessment (HRA)	A process which helps determine likely significant effects and (where appropriate) assesses adverse impacts on the integrity of European conservation sites and Ramsar sites. The process consists of up to four stages of assessment: screening, appropriate assessment, assessment of alternative solutions and assessment of imperative reasons of over-riding public interest (IROPI) and compensatory measures.
Impact	An impact to the receiving environment is defined as any change to its baseline condition, either adverse or beneficial.
Intertidal	Area where the ocean meets the land between high and low tides.
Landfall	The location at the land-sea interface where the offshore export cable will come ashore.
Maximum Design Scenario	The maximum design parameters of the combined project assets that result in the greatest potential for change in relation to each impact assessed.

Term	Definition
Mitigation	Mitigation measures, or commitments, are commitments made by the Project to reduce and/or eliminate the potential for significant effects to arise as a result of the Project. Mitigation measures can be embedded (part of the project design) or secondarily added to reduce impacts in the case of potentially significant effects.
National Policy Statement (NPS)	A document setting out national policy against which proposals for Nationally Significant Infrastructure Projects (NSIPs) will be assessed and decided upon.
Offshore Export Cable Corridor (ECC)	The Offshore Export Cable Corridor (Offshore ECC) is the area within the Preliminary Environmental Information Report (PEIR) Boundary within which the export cable running from the array to landfall will be situated.
Offshore Substation (OSS)	Platforms located within the array area which house electrical equipment and control and instrumentation systems. They also provide access facilities for work boats and helicopters.
Offshore Reactive Compensation Station (ORCP)	Platforms located outside the array area which house electrical equipment and control and instrumentation systems. They also provide access facilities for work boats.
Preliminary Environmental Information Report (PEIR)	The PEIR is written in the style of a draft Environmental Statement (ES) and provides information to support and inform the statutory consultation process in the pre-application phase. Following that consultation, the PEIR documentation will be updated to produce the Project's ES that will accompany the application for the Development Consent Order (DCO).
Project Design Envelope	A description of the range of possible elements that make up the Project's design options under consideration, as set out in detail in the project description. This envelope is used to define the Project for Environmental Impact Assessment (EIA) purposes when the exact engineering parameters are not yet known. This is also often referred to as the "Rochdale Envelope" approach.
Receptor	A distinct part of the environment on which effects could occur and can be the subject of specific assessments. Examples of receptors include species (or groups) of animals or plants, people (often categorised further such as 'residential' or those using areas for amenity or recreation), watercourses etc.
PEIR Boundary	The PEIR Boundary is outlined in Figure 3.1 of Volume 1, Chapter 3: Project Description and comprises the extent of the land and/or seabed for which the PEIR assessments are based upon.
Subsea	Subsea comprises everything existing or occurring below the surface of the sea.
The Applicant	GT R4 Ltd. The Applicant making the application for a DCO. The Applicant is GT R4 Limited (a joint venture between Corio Generation, TotalEnergies and Gulf Energy Development (GULF)), trading as Outer Dowsing Offshore Wind. The project is being developed by Corio Generation (a wholly owned Green Investment Group portfolio company), TotalEnergies and GULF.
The Inspectorate	Planning Inspectorate. The agency responsible for operating the planning process for Nationally Significant Infrastructure Projects (NSIPs).

Term	Definition
The Project	Outer Dowsing Offshore Wind including proposed onshore and offshore infrastructure
Transboundary impacts	Transboundary effects arise when impacts from the development within one European Economic Area (EEA) state affects the environment of another EEA state(s).
Trenchless technique	Trenchless technology is an underground construction method of installing, repairing and renewing underground pipes, ducts and cables using techniques which minimize or eliminate the need for excavation. Trenchless technologies involve methods of new pipe installation with minimum surface and environmental disruptions. These techniques may include Horizontal Directional Drilling (HDD), thrust boring, auger boring, and pipe ramming, which allow ducts to be installed under an obstruction without breaking open the ground and digging a trench.
Wind Turbine Generator (WTG)	All the components of a wind turbine, including the tower, nacelle, and rotor.

7 Marine Processes

7.1 Introduction

7.1.1 This chapter of the Preliminary Environmental Information Report (PEIR) presents the results to date of the Environmental Impact Assessment (EIA) process for the potential impacts of Outer Dowsing Offshore Wind ("the Project") on Marine Processes. Specifically, this chapter considers the potential impact of the Project seaward of Mean High Water Springs (MHWS) during the construction, operation and maintenance, and decommissioning phases.

7.1.2 GTR4 Limited (trading as Outer Dowsing Offshore Wind) hereafter referred to as the 'Applicant', is proposing to develop the Project. The Project will be located approximately 54km from the Lincolnshire coastline in the southern North Sea. The Project will include both offshore and onshore infrastructure including an offshore generating station (windfarm), export cables to landfall, onshore cables, and connection to the electricity transmission network, and ancillary and associated development (see Volume 1, Chapter 3: Project Description for full details).

7.1.3 For the purposes of this PEIR, Marine Processes includes the following elements:

- Morphology, including bathymetry, geology, surficial sediments and seabed form;
- Hydrodynamics, including tidal and non-tidal influences, and waves; and
- Sediment transport, including bedload, littoral and suspended sediment transport.

7.1.4 This PEIR chapter should be read in conjunction with the following chapters and appendices:

- Volume 1;
  - Chapter 3: Project Description;
  - Chapter 8: Marine Water Quality;
  - Chapter 9: Benthic and Intertidal Ecology;
  - Chapter 10: Fish and Shellfish Ecology;
  - Chapter 11: Marine Mammals; and
  - Chapter 12: Offshore and Intertidal Ornithology;
- Volume 2;
  - Appendix 7.1: Marine Processes Technical Baseline; and
  - Appendix 7.2: Marine Processes Modelling Report.

7.2 Statutory and Policy Context

7.2.1 The assessment of potential impacts on Marine Processes has been made with specific reference to the relevant legislation, plans and policies. Full details are provided in Volume 1, Chapter 2: Need, Policy and Legislative Context.

7.2.2 In undertaking the assessment, the following policy and legislation has been considered:

- Conservation of Habitats and Species Regulations 2017;
- European Union (EU) Council Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna (the 'Habitats Directive')[1];
- The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017; and
- The Marine Works (Environmental Impact Assessment) Regulations 2007 (as amended).

7.2.3 Guidance on the issues to be assessed for offshore renewable energy developments has been obtained through reference to:

- The Overarching National Policy Statement (NPS) for Energy (NPS EN-1; Department for Energy and Climate Change (DECC), 2011a);
- The NPS for Renewable Energy Infrastructure (NPS EN-3; DECC, 2011b);
- The NPS for Electricity Networks Infrastructure (NPS EN-5; DECC, 2011c); and
- The UK Marine Policy Statement (MPS; HM Government, 2011).

7.2.4 In addition to the current NPS, the draft revised NPSs have been reviewed to determine the emerging expectations and changes from previous iterations of the NPSs. This includes the draft revised:

- Overarching NPS EN-1 (Department for Energy Security and Net Zero (DESNZ, 2023a));
- NPS for Renewable Energy Infrastructure EN-3 (DESNZ, 2023b); and
- NPS for Electricity Networks Infrastructure EN-5 (DESNZ, 2023c).

7.2.5 Other policies of relevance to Marine Processes are the:

- East Inshore and East Offshore Marine Plans (MMO, 2014);
- National Flood and Coastal Erosion Risk Management Strategy for England (Environment Agency, 2020); and
- Marine Strategy Framework Directive (MSFD) (EU, 2008)[2].

7.2.6 Legislation relevant to Marine Processes and details on how they have been addressed in this PEIR chapter are provided in Table 7.1.

[1] The Habitats Directive (Council Directive 92/43/EEC) and certain elements of the Wild Birds Directive (Directive 2009/147/EC) (known as the Nature Directives) were transposed into domestic law by the 2017 Regulations. Following the UK's exit from the EU the Regulations were updated by the Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019 to reflect that the UK was no longer part of the EU. Any references to Natura 2000 in the 2017 Regulations and in guidance now refers to the new national site network.

[2] The MSFD was transposed into UK law under the Marine Strategy Regulations 2010.

Table 7.1: Summary of policy and legislation relevant to Marine Processes

Legislation/policy	Key provisions	Section where comment addressed
Conservation of Habitats and Species Regulations 2017	Maintain or, where appropriate, restore habitats and species listed in Annexes I and II of the Habitats Directive to a favourable conservation status.	The study area overlaps with a number of nationally and internationally designated nature conservation sites, some which are designated on the basis of geological and geomorphological features contained within them. The locations of these sites are shown in Figure 7.10 with an assessment of potential impacts of the Project in Section 7.12 of this PEIR Chapter.
The Habitats Directive (Council Directive 92/43/EEC)	Protects habitats and species of European nature conservation importance through the establishment of a network of designated sites.	The study area overlaps with a number of nationally and internationally designated nature conservation sites, some which are designated on the basis of geological and geomorphological features contained within them. The locations of these sites are shown in Figure 7.10 with an assessment of potential impacts of the Project in Section 7.12 of this PEIR Chapter.
National Policy Statements (DECC, 2011)		
NPS EN-1 (DECC, 2011a)	EN-1, Section 4.8 advises that the resilience of the project to climate change should be assessed in the Environmental Statement accompanying an application.	Potential changes in climate are described in Volume 2, Appendix 7.1 and are considered alongside predicted changes described in the assessment (Section 7.12).
NPS EN-1 (DECC, 2011a)	EN-1, Paragraph 5.5.6: Where relevant, applicants should undertake coastal geomorphological and sediment transfer modelling to predict and understand impacts and help identify relevant mitigating or compensatory measures.	An assessment of the potential impacts of the Project on Marine Processes using the evidence base, project specific baseline characterisation and project specific numerical modelling is provided in Section 7.12 of this PEIR Chapter.
NPS EN-1 (DECC, 2011a)	EN-1, Paragraph 5.5.7: The Environmental Statement 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	A description of the baseline (existing) Marine Processes is provided in Section 7.4 of this PEIR Chapter as well as within Volume 2, Appendix 7.1. The impact of the Project on coastal processes and geomorphology is considered in Section 7.12 of this PEIR Chapter.

Legislation/policy	Key provisions	Section where comment addressed
	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), any relevant Marine Plans…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; and ▪ 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 implications of the Project on strategies for managing the coast are considered in Paragraph 7.12.64 *et seq*. The effects of the Project on marine ecology, biodiversity and protected sites are considered elsewhere in the PEIR within the following chapters: ▪ Volume 1, Chapter 9; ▪ Volume 1, Chapter 10; ▪ Volume 1, Chapter 11; ▪ Volume 1, Chapter 12; and ▪ Report 7.1: Report to Inform Appropriate Assessment (RIAA). The effects of the Project on maintaining coastal recreation sites and features are set out in Volume 1, Chapter 18: Infrastructure and Other Marine Users.
NPS EN-1 (DECC, 2011a)	Paragraph 5.5.9: The applicant should be particularly careful to identify any effects of physical changes on the integrity and special features of Marine Conservation Zones (MCZs), candidate marine Special Areas of Conservation (SACs), coastal SACs and candidate coastal SACs, coastal Special Protection Areas (SPAs) and potential coastal SPAs, Ramsar sites, Sites of Community Importance (SCIs) and Sites of Special Scientific Interest (SSSI).	The locations of designated sites are shown in Figure 7.10 with potential impacts considered in Section 7.12 of this PEIR Chapter. Potential impacts of the Project on Marine Processes are considered in terms of indirect effects (including pathways) on other receptors elsewhere in the PEIR, in particular in Volume 1, Chapter 9 and in Document Reference 7.1.
NPS EN-1 (DECC, 2011a)	EN-1, Paragraph 5.5.11: The decision maker should not normally consent new development in areas of dynamic	This assessment considers the nature of ongoing shoreline change at the landfall and the potential for cables and other

Legislation/policy	Key provisions	Section where comment addressed
	shorelines where the proposal could inhibit sediment flow or have an adverse impact on coastal processes at other locations. Impacts on coastal processes must be managed to minimise adverse impacts on other parts of the coast. Where such proposals are brought forward, consent should only be granted where the decision maker is satisfied that the benefits (including need) of the development outweigh the adverse impacts.	project infrastructure to impact coastal processes in Paragraph 7.12.64 *et seq*. A full description of coastal processes understanding at the landfall is set out in Volume 2, Appendix 7.1.
NPS EN-3 (DECC, 2011b)	EN-3, Paragraph 2.6.81: An assessment of the effects of installing cable across the intertidal zone should include information, where relevant, about: ▪ Any alternative landfall sites that have been considered by the applicant during the design phase and an explanation for the final choice; ▪ Any alternative cable installation methods that have been considered by the applicant during the design phase and an explanation for the final choice; ▪ Potential loss of habitat; ▪ Disturbance during cable installation and removal (decommissioning); ▪ Increased suspended sediment loads in the intertidal zone during installation ; and ▪ Predicted rates at which the intertidal zone might recover from temporary effects.	An assessment of the potential impacts of the Project on Marine Processes is provided in Section 7.12 of this PEIR Chapter. This assessment considers the nature of ongoing shoreline change at the landfall and the potential for cables and other project infrastructure to impact coastal processes in Paragraph 7.12.64 *et seq*. Details regarding alternative landfall sites that have been considered during the design phase and an explanation for the final choice are provided in Volume 1, Chapter 4: Site Selection and Consideration of Alternatives.
NPS EN-3 (DECC, 2011b)	EN-3, Paragraph 2.6.113: Where necessary, assessment of the effects on the subtidal environment should include: ▪ Loss of habitat due to foundation type including associated seabed preparation, predicted scour, scour protection and altered sedimentary processes;	An assessment of the potential impacts of the Project on Marine Processes is provided in Section 7.12 of this PEIR Chapter.

Legislation/policy	Key provisions	Section where comment addressed
	▪ Environmental appraisal of inter-array and cable routes and installation methods, including predicted loss of habitat due to predicted scour and scour protection; ▪ Habitat disturbance from construction vessels' extendible legs and anchors; ▪ Increased suspended sediment loads during construction; and ▪ Predicted rates at which the subtidal zone might recover from temporary effects.	Potential impacts of the Project on Marine Processes are considered in terms of indirect effects (including pathways) on other receptors elsewhere in the PEIR, in particular in Volume 1, Chapter 9 and in Document Reference 7.1.
NPS EN-3 (DECC, 2011b)	EN-3, Paragraph 2.6.190: Assessment on the impacts on the physical offshore environment should be undertaken for all stages of the lifespan of the proposed windfarm in accordance with the appropriate policy for offshore windfarm EIAs.	An assessment of the potential impacts of the Project on Marine Processes is provided in Section 7.12 of this PEIR Chapter for all stages of the Project .
NPS EN-3 (DECC, 2011b)	EN-3, Paragraph 2.6.191 and 2.6.192: The Applicant should consult the Environment Agency, Marine Management Organisation (MMO) and Centre for Environment, Fisheries and Aquaculture Science (Cefas) on methods for assessment of impacts on physical processes.	The Applicant has undertaken consultation with the Environment Agency, MMO and Cefas as part of the Evidence Plan Process (EPP) and in Expert Topic Group (ETG) meetings on the approach to assessment for physical processes. Details of the approach to Consultation are provided in Table 7.2.
NPS EN-3 (DECC, 2011b)	EN-3, Paragraph 2.6.193: Geotechnical investigations should form part of the assessment as this will enable design of appropriate construction techniques to minimise any adverse effects.	Geotechnical data will be submitted as part of the Environmental Statement (ES). This will be used alongside the project specific geophysical survey to inform the assessment and project design of the Project.
NPS EN-3 (DECC, 2011b)	EN-3, Paragraph 2.6.194: The assessment should include predictions of the physical effect that will result from the construction and operation of the required infrastructure	An assessment of the potential impacts of the Project on Marine Processes is provided in Section 7.12 of this PEIR Chapter.

Legislation/policy	Key provisions	Section where comment addressed
	and include effects such as the scouring that may result from the proposed development.	
NPS EN-3 (DECC, 2011b)	EN-3, Paragraph 2.6.195: The direct effects on the physical environment can have indirect effects on a number of other receptors. Where indirect effects are predicted, the decision makershould refer to relevant Sections of this NPS and EN 1.	Potential impacts of the Project on Marine Processes are considered in terms of indirect effects (including pathways) on other receptors elsewhere in the PEIR, in particular in Volume 1, Chapter 9 and in Document Reference 7.1.
NPS EN-3 (DECC, 2011b)	EN-3, Paragraph 2.6.196: The methods of construction, including use of materials should be such as to reasonably minimise the potential for impact on the physical environment.	The Project has proposed designs and installation methods that seek to minimise significant adverse effects on the physical environment where possible. Where necessary, the assessment has set out mitigation to avoid or reduce significant adverse effects, as outlined in Table 7.4.
NPS EN-3 (DECC, 2011b)	EN-3, Paragraph 2.6.197: The decision maker should expect applicants to have considered mitigation measures including the burying of cables to a necessary depth, using scour protection techniques around offshore structures to prevent scour effects around them.Applicants should consult the statutory consultees on appropriate mitigation.	The embedded mitigation relating to cable burial and scour are set out in Table 7.4. Consultation is ongoing with statutory consultees and other interested parties.
NPS EN-3 (DECC, 2011b)	EN-3, Paragraph 2.6.189: The construction, operation and decommissioning of offshore energy infrastructure can affect the following elements of the physical offshore environment: ▪ Water quality; ▪ Waves and tides; ▪ Scour effect ▪ Sediment transport; and ▪ Suspended solids.	An assessment of the potential impacts on Marine Processes (including all of those listed in Paragraph 2.6.189 of NPS EN-3) that could arise from the construction, O&M and decommissioning of the Project are presented in Section 7.12 of this PEIR Chapter.

Legislation/policy	Key provisions	Section where comment addressed
NPS EN-5 (DECC, 2011c)	EN-5, Paragraph 2.6.1: Applicants should in particular set out to what extent the proposed development is expected to be vulnerable, and, as appropriate, how it has been designed to be resilient to, among other factors, coastal erosion – for the landfall of offshore transmission cables and their associated substations in the inshore and coastal locations respectively.	The implications of the Project on strategies for managing the coast are considered in Paragraph 7.12.64 *et seq*. A full description of Marine Processes understanding at the landfall is set out Volume 2, Appendix 7.1.
Revised (Draft) National Policy Statements (DESNZ, 2023)		
Revised (Draft) NPS EN-1 (DESNZ, 2023a)	Revised (Draft) EN-1, Section 4.9 advises that the resilience of the project to climate change should be assessed in the Environmental Statement accompanying an application, in addition to taking reasonable steps to maximise the use of nature-based solutions to support climate change adaption.	Potential changes in climate are described in Volume 2, Appendix 7.1 and are considered alongside predicted changes described in the assessment (Section 7.12).
Revised (Draft) NPS EN-1 (DESNZ, 2023a)	Revised (Draft) EN-1, Paragraph 5.6.11: Where relevant, applicants should undertake coastal geomorphological and sediment transfer modelling to predict and understand impacts and help identify relevant mitigating or compensatory measures.	An assessment of the potential impacts of the Project on Marine Processes using the evidence base, project specific baseline characterisation and project specific numerical modelling is provided in Section 7.12 of this PEIR Chapter.
Revised (Draft) NPS EN-1 (DESNZ, 2023a)	Revised (Draft) EN-1, Paragraph 5.6.12: The Environmental Statement should include an assessment of the effects on the coast, tidal rivers and estuaries. 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	A description of the baseline (existing) Marine Processes is provided in Section 7.4 of this PEIR Chapter as well as within Volume 2, Appendix 7.1. The impact of the Project on coastal processes and geomorphology is considered in Section 7.12 of this PEIR Chapter. The implications of the Project on strategies for managing the coast are considered in Paragraph 7.12.64 *et seq*.

Legislation/policy	Key provisions	Section where comment addressed
	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 SMPs, any relevant Marine Plans…and capital programmes for maintaining flood and coastal defences and Coastal Change Management Areas; ▪ The effects of the proposed project on marine ecology, biodiversity, protected sites and heritage assets; ▪ How coastal change could affect flood risk management infrastructure, drainage and flood risk; ▪ The effects of the proposed project on maintaining coastal recreation sites and features; ▪ 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 effects of the Project on marine ecology, biodiversity and protected sites are considered elsewhere in the PEIR within the following chapters: ▪ Volume 1; ▪ Chapter 9; ▪ Chapter 10; ▪ Chapter 11; ▪ Chapter 12; and ▪ Report 7.1: Report to Inform Appropriate Assessment (RIAA). The effects of the Project on maintaining coastal recreation sites and features are set out in Volume 1, Chapter 18: Infrastructure and Other Marine Users.
Revised (Draft) NPS EN-1 (DESNZ, 2023a)	Revised (Draft) EN-1, Paragraph 5.6.14: The applicant should be particularly careful to identify any effects of physical changes on the integrity and special features of Marine Protected Areas (MPAs). These could include MCZs, HRA Sites including Special Areas of Conservation and SPAs with marine features, Ramsar Sites, SCIs, and SSSIs with marine features. Applicants should also identity any effects on the special character of Heritage Coasts.	The locations of designated sites are shown in Figure 7.10 with potential impacts considered in Section 7.12 of this PEIR Chapter. Potential impacts of the Project on Marine Processes are considered in terms of indirect effects (including pathways) on other receptors elsewhere in the PEIR, in particular in Volume 1, Chapter 9 and in Document Reference 7.1.
Revised (Draft) NPS EN-1 (DESNZ, 2023a)	Revised (Draft) EN-1, Paragraph 5.6.18: The decision maker should not normally consent new development in areas of dynamic shorelines where the proposal could	This assessment considers the nature of ongoing shoreline change at the landfall and the potential for cables and other project infrastructure to impact coastal processes in

Legislation/policy	Key provisions	Section where comment addressed
	inhibit sediment flow or have an adverse impact on coastal processes at other locations. Impacts on coastal processes must be managed to minimise adverse impacts on other parts of the coast. Where such proposals are brought forward, consent should only be granted where the decision maker is satisfied that the benefits (including need) of the development outweigh the adverse impacts.	Paragraph 7.12.64 *et seq*. A full description of coastal processes understanding at the landfall is set out in Volume 2, Appendix 7.1.
Revised (Draft) NPS EN-3 (DESNZ, 2023b)	Revised (Draft) EN-3, Paragraph 3.8.125: The construction, operation and decommissioning of offshore energy infrastructure (including the preparation and installation of the cable route) can affect the following elements of the physical offshore environment, which can have knock on impacts on other biodiversity receptors: ▪ Water quality; ▪ Waves and tides; ▪ Scour effect; ▪ Sediment transport ▪ Suspended solids; ▪ Sandwaves; and ▪ Water column.	An assessment of the potential impacts on Marine Processes (including all of those listed in Paragraph 3.8.125 of Revised (Draft) NPS EN-3) that could arise from the construction, O&M and decommissioning of the Project are presented in Section 7.12 of this PEIR Chapter.
Revised (Draft) NPS EN-3 (DESNZ, 2023b)	Revised (Draft) EN-3, Paragraph 3.8.126 and 3.8.127: Applicant assessment are expected to include predictions of the physical effects arising from modifications to hydrodynamics (waves and tides), sediments and sediment transport, and seabed morphology that will result from the construction, operation and decommissioning of the required infrastructure. Assessments should also include effects such as the	An assessment of the potential impacts of the Project on Marine Processes is provided in Section 7.12 of this PEIR Chapter.

Legislation/policy	Key provisions	Section where comment addressed
	scouring that may result form the proposed development and how that might impact sensitive species and habitats.	
Revised (Draft) NPS EN-3 (DESNZ, 2023b)	Revised (Draft) EN-3, Paragraph 3.8.128: Applicants should undertaken geotechnical investigations as part of the assessment, enabling the design of appropriate construction techniques to minimise any adverse effects	Geotechnical data will be submitted as part of the Environmental Statement (ES). This will be used alongside the project specific geophysical survey to inform the assessment and project design of the Project.
Revised (Draft) NPS EN-3 (DESNZ, 2023b)	Revised (Draft) EN-3, Paragraph 3.8.138: Applicant assessment of the effects of installing cable across the intertidal/coastal zone should demonstrate compliance with mitigation measures identified by The Crown Estate in any plan-level HRA produced as part of its leasing round and include information, where relevant, about: ▪ Any alternative landfall sites that have been considered by the applicant during the design phase and an explanation for the final choice; ▪ Any alternative cable installation methods that have been considered by the applicant during the design phase and an explanation for the final choice; ▪ Potential loss of habitat; ▪ Disturbance during cable installation, maintenance/repairs and removal (decommissioning); ▪ Increased suspended sediment loads in the intertidal zone during installation and maintenance/repairs; ▪ Predicted rates at which the intertidal zone might recover from temporary effects, based on existing monitoring data; and ▪ Protected sites.	An assessment of the potential impacts of the Project on Marine Processes is provided in Section 7.12 of this PEIR Chapter. This assessment considers the nature of ongoing shoreline change at the landfall and the potential for cables and other project infrastructure to impact coastal processes in Paragraph 7.12.64 *et seq*. Details regarding alternative landfall sites that have been considered during the design phase and an explanation for the final choice are provided in Volume 1, Chapter 4: Site Selection and Consideration of Alternatives.

Legislation/policy	Key provisions	Section where comment addressed
Revised (Draft) NPS EN-3 (DESNZ, 2023b)	Revised (Draft) EN-3, Paragraph 3.8.166: Applicant assessment of the effects on the subtidal environment should include: ▪ Loss of habitat due to foundation type including associated seabed preparation, predicted scour, scour protection and altered sedimentary processes, e.g. sandwave/boulder/UXO clearance; ▪ Environmental appraisal of inter-array and export cable routes and installation/maintenance methods, including predicted loss of habitat due to predicted scour and scour/cable protection and sandwave/boulder/UXO clearance; ▪ Habitat disturbance from construction and maintenance/repair vessels' extendable legs and anchors; ▪ Increased suspended sediment loads during construction and from maintenance/repairs; ▪ Predicted rates at which the subtidal zone might recover from temporary effects; ▪ Potential impacts from Electromagnetic fields (EMF) on benthic fauna; ▪ Protected sites; and ▪ Potential for invasive/non-native species introduction.	An assessment of the potential impacts of the Project on Marine Processes is provided in Section 7.12 of this PEIR Chapter. Potential impacts of the Project on Marine Processes are considered in terms of indirect effects (including pathways) on other receptors elsewhere in the PEIR, in particular in Volume 1, Chapter 9 and in Document Reference 7.1.
Revised (Draft) NPS EN-3 (DESNZ, 2023b)	Revised (Draft) EN-3, Paragraph 3.8.325 and 3.8.326: Where indirect effects are predicted, the decision maker should refer to relevant sections of this NPS and EN-1.	Potential impacts of the Project on Marine Processes are considered in terms of indirect effects (including pathways) on other receptors elsewhere in the PEIR, in particular in Volume 1, Chapter 9 and in Document Reference 7.1.

Legislation/policy	Key provisions	Section where comment addressed
Revised (Draft) NPS EN-3 (DESNZ, 2023b)	Revised (Draft) EN-3, Paragraph 3.8.327: The design of the windfarm and the methods of construction, including use of materials should be such as to reasonably minimise the potential for impact on the physical environment.	The Project has proposed designs and installation methods that seek to minimise significant adverse effects on the physical environment where possible. Where necessary, the assessment has set out mitigation to avoid or reduce significant adverse effects, as outlined in Table 7.4
Revised (Draft) NPS EN-3 (DESNZ, 2023b)	Revised (Draft) EN-3, Paragraph 3.8.239 and 3.8.240: Applicants are expected to have considered the best ecological outcomes in terms of potential mitigation. These might include: ▪ Avoidance of areas sensitive to physical effects; ▪ Consideration of micro-siting of both the array and cables; ▪ Alignment and density of the array; ▪ Design of foundations; ▪ Ensuring that sediment moved is retained as locally as possible; ▪ The burying of cables to a necessary depth; and ▪ Using scour protection techniques around offshore structures to prevent scour effects or designing turbines to withstand scour, so scour protection is not required or is minimised. Applicants should consult the statutory consultees on appropriate mitigation and monitoring.	The embedded mitigation relating to cable burial and scour are set out in Table 7.4. Consultation is ongoing with statutory consultees and other interested parties.
Revised (Draft) NPS EN-5 (DESNZ, 2023c)	Revised (Draft) EN-5, Paragraph 2.3.2: Applications should in particular set out to what extent the proposed development is expected to be vulnerable and, as appropriate, how it has been designed to be resilient to, among other factors, coastal erosion – for the landfall of offshore transmission cables and their associated	The implications of the Project on strategies for managing the coast are considered in Paragraph 7.12.64 *et seq*. A full description of Marine Processes understanding at the landfall is set out Volume 2, Appendix 7.1.

Legislation/policy	Key provisions	Section where comment addressed
	substations in the inshore and coastal locations respectively.	
UK Marine Policy Statement		
MPS (HM Government, 2011)	Paragraph 2.6.8.1: Coastal change and coastal flooding are likely to be exacerbated by climate change, with implications for activities and development on the coast. These risks are a major consideration in ensuring that proposed new developments are resilient to climate change over their lifetime. Paragraph 2.6.8.6: Account should be taken of the impacts of climate change throughout the operational life of a development including any decommissioning period.	Potential changes in climate are described in Volume 2, Appendix 7.1 and are considered alongside predicted changes identified in the assessment for each stage of the development (Section 7.12).
MPS (HM Government, 2011)	Paragraph 2.6.8.3: Interruption or changes to the supply of sediment due to infrastructure has the potential to affect physical habitats along the coast or in estuaries.	Modifications to sediment supply (pathways) due to the operational presence of the Project infrastructure has been considered in Paragraph 7.12.83 *et seq*. The potential for effects (change/loss) on habitats is considered in Volume 1, Chapter 9.
Marine Plans		
East Marine Plans (EMP) (MMO, 2014).	EMP, Policy BIO2: Where appropriate, proposals for development should incorporate features that enhance biodiversity and geological interests.	Consideration of Marine Net Gain is presented in Supplementary Document 8.3.
EMP (MMO, 2014)	EMP, Policy CC1: Proposals should take account of: ▪ How they may be impacted upon by, and respond to, climate change over their lifetime; and ▪ How they may impact upon any climate change adaptation during their lifetime.	The vulnerability of the project to climate change (and especially change at the coast) is considered in the context of the project design, in Volume 1, Chapter 3. The historical, contemporary and potential future shoreline change at the landfall site is presented in Volume 2,

Legislation/policy	Key provisions	Section where comment addressed
	Where detrimental impacts on climate change adaptation measures are identified, evidence should be provided as to how the proposal will reduce such impacts.	Appendix 7.1. A description of the Marine Processes understanding at the landfall is set out Volume 2, Appendix 7.1. An assessment of the potential impacts of the Project on coastal processes and geomorphology is provided in Paragraph 7.12.64 *et seq.*
EMP (MMO, 2014)	EMP, Policy CAB1: Preference should be given to proposals for cable installation where the method of installation is burial. Where burial is not achievable, decisions should take account of protection measures for the cable that may be proposed by the applicant.	Cables will be buried where possible and cable protection will be applied as and where appropriate according to the cable burial design plan. Indicative design options for cable burial and protection are set out in Volume 1, Chapter 3.
EMP (MMO, 2014)	EMP, Policy ECO1: Cumulative impacts affecting the ecosystem of the East marine plans and adjacent areas (marine, terrestrial) should be addressed in decision-making and plan implementation.	An assessment of the potential for cumulative effects with other projects and activities in the study area is provided in Section 7.13 of this PEIR Chapter.
EMP (MMO, 2014)	EMP, Policy MPA1: Any impacts on the overall Marine Protected Area network must be taken account of in strategic level measures and assessment, with due regard given to any current agreed advice on an ecologically coherent network.	The study area overlaps with a number of nationally and internationally designated nature conservation sites which form part of the Marine Protected Area network. The locations of these sites are shown in Figure 7.10 with an assessment of potential impacts of the Project in Section 7.12 of this PEIR Chapter.
Marine Strategy Framework Directive (MSFD)		
MSFD (EU, 2008)	Descriptors of Good Environmental Status, Descriptor 6: Seafloor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.	Modifications to the seafloor integrity have been considered as pathway effects. The potential for effects (change/loss) on benthic ecosystems are considered in Volume 1, Chapter 9.

Legislation/policy	Key provisions	Section where comment addressed
MSFD (EU, 2008)	Descriptors of Good Environmental Status, Descriptor 7: Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.	Potential impacts on hydrographical conditions that could arise from the construction, O&M and decommissioning of the Project are presented in Section 7.12 of this PEIR Chapter.

7.2.7 The following guidance documents have been used to inform the assessment methodologies used in this PEIR chapter:

- Environmental impact assessment for offshore renewable energy projects (BSI, 2015);
- Coastal Process Modelling for Offshore Windfarm (OWF) Environmental Impact Assessment: Best Practice Guide (Lambkin *et al*., 2009);
- Guidelines in the use of metocean data through the lifecycle of a marine renewable development (ABPmer *et al*., 2008);
- Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects (Cefas, 2011);
- National Resources Wales (NRW) Monitoring Evidence Report No: 243 Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Monitoring Requirements to inform EIA of Major Development Projects (Brooks *et al*., 2018);
- Review of Cabling Techniques and Environmental Effects applicable to the Offshore Windfarm Industry. Department for Business Enterprise and Regulatory Reform in association with Defra (BERR, 2008);
- Offshore wind cabling: ten years experience and recommendations (Natural England, 2018);
- General advice on assessing potential impacts of and mitigation for human activities on Marine Conservation Zone (MCZ) features, using existing regulation and legislation (JNCC and Natural England, 2011);
- Offshore Windfarms: Guidance note for Environmental Impact Assessment in Respect of FEPA and CPA requirements (Cefas, 2004);
- Review of environmental data associated with post-consent monitoring of licence conditions of OWFs. MMO Project No: 1031 (Fugro-Emu, 2014);
- Best Practice Advice for Evidence and Data Standards for offshore renewables projects (Natural England, 2022);
- Further review of sediment monitoring data. (COWRIE ScourSed-09) (ABPmer *et al.*, 2010);
- Review of Round 1 Sediment process monitoring data - lessons learnt. (Sed01) (ABPmer *et al*., 2007);
- Dynamics of scour pits and scour protection - Synthesis report and recommendations. (Sed02) (HR Wallingford *et al*., 2007); and
- Potential effects of offshore wind developments on coastal processes (ABPmer and METOC, 2002).

7.3 Consultation

7.3.1 Consultation forms an integral part of the Development Consent Order (DCO) process and has been undertaken throughout the Environmental Impact Assessment (EIA) to date, during the scoping phase and within the Evidence Plan Process (EPP) Expert Technical Group (ETG) meetings. Consultation on this PEIR chapter also forms an important part of the process. An overview of the Project consultation process is presented within Volume 1, Chapter 6: Consultation Process.

7.3.2 A summary of the key issues raised during consultation to date, specific to Marine Processes, is detailed in Table 7.2, alongside information on how these issues have been considered in the production of this PEIR.

7.3.3 As identified in Volume 1, Chapter 3: Project Description and Volume 1, Chapter 4: Site Selection and Consideration of Alternatives, the Project design envelope has been refined and will be refined further prior to DCO submission. This process is reliant on stakeholder consultation feedback. Design amendments to cable routing and landfall are of relevance to this PEIR chapter.

Table 7.2: Consultation responses relevant to Marine Processes

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
Evidence Plan Meeting (ETG) held 11th July 2022	No stakeholder queries were raised on the baseline characterisation of the physical marine environment. No stakeholder comments made on the proposed approach.	The Applicant welcomes that there were no disagreements raised nor comments received on these issues following the ETG.
Scoping Opinion (Environment Agency, 9th August 2022)	Updated erosion maps from the National Coastal Erosion Risk Mapping (NCERM2) may be available.	The Applicant notes that the launch of the NCERM2 will provide updates to coastal erosion risk and this will be included as a data source if available at the time of writing. Consideration of historic and contemporary rates of coastal change is provided within Section 7.4 of this PEIR chapter and more fully within Volume 2, Appendix 7.1.
Scoping Opinion (Environment Agency, 9th August 2022)	Although mitigation measures have been proposed to reduce scour and its effects, consideration of scour should remain scoped in to establish the level of mitigation required; although the Applicant should defer to the MMO for final decision on this.	An assessment of potential impacts associated with seabed scouring is provided in Paragraph 7.12.98 *et seq.* with relevant mitigation measures outlined in Table 7.4.
Scoping Opinion (Environment Agency, 9th August 2022)	Cumulative effects/interaction should be considered regarding sediment transport impacts; although the Applicant should defer to the MMO for final decision on this.	An assessment of the potential for cumulative effects with other projects and activities in the study area, including those relating to sediment transport effects, is provided in Section 7.13 of this PEIR chapter.
Scoping Opinion (Environment Agency, 9th August 2022)	Consideration of historic and contemporary rates of coastal change to be made in relation to the operational life and location of the physical landfall site i.e. how deep in the subsurface the cable run should be emplaced and how far inland the landfall junction site should be located.	A consideration of historic and contemporary rates of coastal change, in relation to proposed Project infrastructure is provided within Section 7.4 of this PEIR chapter and more fully within Volume 2, Appendix 7.1.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
Scoping Opinion (the Inspectorate, 9th August 2022)	The Inspectorate notes that scour protection would be installed, thus reducing the risk of scour; however, the Inspectorate has considered the responses of the EA, the Marine Management Organisation (MMO) and Natural England (see Appendix 2 of this Opinion) on this matter and concludes that secondary scour impacts should be scoped into the assessment. The ES should provide details of the anticipated quantities and volumes of scour protection, together with their expected locations. If the ES cannot specify the precise locations, the worst case parameters used for the impact assessment must be presented, together with any assumptions made. No information has been provided regarding the timeframes for installing scour protection. The ES should also provide details regarding timeframes for installing scour protection and either provide assurances that the timeframes for installing scour protection would be sufficient to ensure there would be no likely significant effects or provide an assessment of effects prior to the installation of scour protection, where significant effects are likely to occur.	An assessment of potential impacts associated with seabed scouring, including impacts associated with secondary scour, is provided in Paragraph 7.12.98 *et seq.*, with relevant mitigation measures outlined in Table 7.4. The requirement for scour protection at the foundation locations is currently being assessed and it is currently considered that it will be installed where required for engineering purposes. Details of the anticipated quantities and volumes of scour protection, alongside construction timescales, are provided within Volume 1, Chapter 3, with the worst case scenario outlined and justified in Table 7.3
Scoping Opinion (the Inspectorate, 9th August 2022)	The Scoping Report proposes to scope out cumulative modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime on the basis of available assessments that	An assessment of the potential for cumulative effects with other projects and activities in the study area, including modifications to the wave and tidal regime and

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	suggest modifications to the wave and tidal regime remain within small distances from the foundations. The Scoping Report contains limited evidence at this stage to currently support the scoping out of cumulative modifications to the wave and tidal and associated potential impacts to the sediment transport regime. Therefore, the Inspectorate cannot agree to scope these effects out. The ES should include an assessment of such cumulative effects, where likely significant effects could arise.	consequential impacts on sediment transport, is provided in Section 7.13 of this PEIR chapter.
Scoping Opinion (the Inspectorate, 9th August 2022)	The Scoping Report states that no transboundary impacts on marine physical process pathways are anticipated to occur as a result of the Proposed Development activities during construction, O&M, or decommissioning, as any predicted impacts on these pathways will largely be localised to within the study area and will therefore not give rise to effects on the marine environment beyond UK waters. The Inspectorate agrees that significant effects on an European Economic Area (EEA) State are unlikely to arise as a result of changes to physical process pathways and therefore agrees this matter can be scoped out of further assessment.	The Applicant welcomes that transboundary effects upon marine physical process pathways can be scoped out of the assessment.
Scoping Opinion (the Inspectorate, 9th August 2022)	The Scoping Report states that the study area includes both a nearfield and far-field consideration, the latter being informed through further analysis of the marine physical process pathways. The figures accompanying	The study area is based on the Zone of Influence (ZoI), derived from numerical modelling of sediment plumes and tidal excursions. The study area is shown in Figure 7.1, as well as more fully within Volume 2, Appendix 7.1.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	Chapter 7.1 include a 'study area' boundary around the DCO boundary of a set distance; however, this distance is not specified in the key. The ES should clearly define the study area, based on the Zone of Influence (ZoI) from the Proposed Development, together with a justification for its selection.	
Scoping Opinion (the Inspectorate, 9th August 2022)	The ES should assess the potential significant effects of the Proposed Development on [the Inner Silver Pit] candidate HPMA. Further details can be found at: https://consult.defra.gov.uk/hpma/consultation-on-highlyprotected-marine-areas/	The Applicant notes that this site has not been designated in the initial Highly Protected Marine Area (HPMA) pilot phase (Defra, 2023) and has therefore been excluded from further assessment.
Scoping Opinion (the Inspectorate, 9th August 2022)	The ES should explain the approach to mitigation and address approaches including micro-siting, minimising the number of cables, selection of cable protection materials to match the receiving environment, and avoiding sand wave clearance/levelling where possible in a Marine Protected Area (MPA) (as applicable).	Information pertaining to the mitigation approach is provided in Volume 1, Chapter 3. The mitigation approach may be refined further, and supplementary information will be provided in the subsequent Environmental Statement chapter. Mitigation with direct relevance to Marine Processes is outlined in Table 7.4 and has been included within the Impact Assessment.
Scoping Opinion (the Inspectorate, 9th August 2022)	The ES should include, where possible, figures to show the spatial extent of sediment plumes, suspended sediment concentration (SSC), and deposition thickness in/near the array, and at representative locations along the offshore export cable corridor.	The spatial extent of sediment plumes, Suspended Sediment Concentration (SSC), and deposition thickness is provided in Figures 1.14 to 1.17. Further details are provided in Volume 2, Appendix 7.2.
Scoping Opinion (the Inspectorate, 9th August 2022)	The Scoping Report confirms that specific numerical modelling will be undertaken, such as hydrodynamic (wave and tidal) and sediment plume modelling. The Applicant is advised to agree the detailed assessment methodologies, including modelling, with relevant	Numerical modelling will be presented with the Marine Ecology and Coastal Processes ETG with relevant stakeholders, following submission of the PEIR. Details of the numerical modelling assumptions including the

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	stakeholders represented on the Marine Ecology and Coastal Processes ETG as part of the EPP. The modelling should explain any assumptions made including, the parameters, data sources, and any calibration/validation against previous models. It should also clearly state whether cumulative impacts from other projects have been included.	parameters, data sources and calibration/validation details is provided in Volume 2, Appendix 7.2.
Scoping Opinion (the Inspectorate, 9th August 2022)	The ES should assess the potential effects during construction of the Proposed Development on beach profile and cliff stability, where significant effects are likely to occur.	A description of the baseline environment at the coast is provided in Paragraph 7.4.19 *et seq.* of this PEIR as well as more fully within Volume 2, Appendix 7.1. Potential effects during construction on coastal morphology and processes are provided in Paragraph 7.12.64 *et seq*.
Scoping Opinion (the Inspectorate, 9th August 2022)	The ES should assess the spatial variation in seabed mobility across the study area, specifically in relation to its effect on cable burial and the likely levels of introduced rock or hard substrate that will be required for scour protection, where likely significant effects could occur.	Seabed mobility and its effect on cable burial has been considered as part of the baseline environmental description in Volume 2, Appendix 7.1. Potential effects of cable protection measures have been assessed in Paragraph 7.12.49 *et seq.* and Paragraph 7.12.74 *et seq.*
Scoping Opinion (the Inspectorate, 9th August 2022)	The ES should assess effects on the hydrodynamic regime due to the presence of engineering and installation equipment such as jack-up rigs, cable-laying vessels, and cofferdams etc, where likely significant effects could occur.	The Applicant does not consider that an assessment of the effects of installation vessels is appropriate and in-keeping with best practice - this is not currently assessed within Offshore Windfarm (OWF) or Oil and Gas (O&G) ES's. Cofferdams are currently not being considered within the Project's design statement.
Scoping Opinion (MMO, 9th August 2022)	The data sources as described in Table 7.1.1 are wide ranging and seem sufficient to inform the marine physical processes. There is a large number of desk-based studies which will provide information on	The Applicant welcomes the confirmation that all data sources, pathways, receptors and potential impacts have been identified.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	Metocean data and morphology, and there is mention of geophysical and geotechnical surveys to be carried out which are important and needed. The MMO also agrees that the pathways, receptors and potential impacts that have been provided in Table 7.1.2 are appropriate.	
Scoping Opinion (MMO, 9th August 2022)	Whilst the scoping remains at a high level and appears to be comprehensive, the details of the collected data to be used are not fully provided which makes it difficult to comment on more detail. Furthermore, the details for the geophysical and geotechnical data to be collected are unclear. Table 7.1.1 refers to a spatial coverage area as either full or partial coverage. The MMO has assumed the 'full coverage' is equal to the Physical Processes Study Area in Figures 7.1.1 and 7.1.2, but request that this is confirmed. The data should be collected on a footprint of anywhere that the seabed would be physically altered or disturbed by construction or operation of ODOW. This should also apply to cabling to help determine the best cabling routes.	The Applicant would like to clarify that 'full coverage' relates to the array and ECC in its entirety. Details of the geophysical and geotechnical surveys are presented in the corresponding survey reports of this PEIR document.
Scoping Opinion (MMO, 9th August 2022)	In Table 7.1.3, the two impacts proposed to be scoped out are seabed scouring and cumulative moderations to wave and tidal scheme. The report has also scoped out transboundary impacts. Whilst there is no specific reason to dispute this, the MMO considers that these decisions should be supported with reference to evidence. For example, that wider hydrodynamic	An assessment of potential impacts associated with seabed scouring, including impacts associated with secondary scour, is provided in Paragraph 7.12.98 *et seq*, with relevant mitigation measures outlined in Table 7.4. An assessment of the potential for cumulative effects with other projects and activities in the study area, including modifications to the wave and tidal regime and

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	effects will not arise from the expansion of OWF sites (and the gradual accumulation of local impacts).	consequential impacts on sediment transport, is provided in Section 7.13 of this PEIR chapter.
Scoping Opinion (MMO, 9th August 2022)	The methods used to determine the impacts of those scoped in are sufficient. The method of determining effect signature from receptor sensitivity and impact magnitude, as described in Section 5.7, is appropriate. The assessment will also be determined on the Maximum Design Scenario (MDS), where the project design scenario with the greatest impact shall be used. This will be determined within the ES and should provide a robust assessment.	Full details of the Project MDS are provides within Volume 1, Chapter 3. A summary of project design parameters of relevance to Marine Processes is provided in Table 7.3 of this PEIR Chapter.
Scoping Opinion (MMO, 9th August 2022)	The two types of mitigation mentioned are scour protection and cable protection which are typical measures undertaken for OWF projects. Table 7.1.41 notes that further information is to be included at the Preliminary Environmental Information Report (PEIR) and ES. This should go into significantly more detail as to quantities and volumes, and their expected (or, if not possible, then worst case) locations in respect of the significant coastal systems and processes.	Full details of embedded mitigation measures, including locations, volumes, and areas, where appropriate, are provided within Volume 1, Chapter 3. A summary is provided in Table 7.4 of this PEIR chapter.
Scoping Opinion (MMO, 9th August 2022)	Section 7.1.40 states 'a numerical model will be developed to factor in project specific surveys and a range of representative baseline conditions. The model will be applied to investigate the source-pathway-receptor relationship for those issues scoped in (Table 7.1.2) and based upon the realistic MDS, as provided in Section 3'. The MMO has no specific requirements at this stage, only that full detail of the methodology is to	Details of the numerical modelling assumptions including the parameters, data sources and calibration/validation details is provided in Volume 2, Appendix 7.2.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	be provided. This should include any assumptions, the parameters, data sources and any calibration/validation against previous models. Any consideration to cumulative impacts from other projects should also be stated.	
Scoping Opinion (Natural England, 9th August 2022)	Natural England recommend that offshore ornithology is linked to the Marine Physical Processes chapter, with particular focus to the foraging of FFC SPA seabirds.	An assessment of the potential impacts of the Project on offshore ornithology receptors is provided in Volume 1, Chapter 12: Offshore and Intertidal Ornithology, making use of information provided within this PEIR chapter.
Scoping Opinion (Natural England, 9th August 2022)	Natural England advise including a map showing the regional geology across the study area.	A regional map has been provided as Figure 7.5 within this PEIR chapter, with a comprehensive regional overview provided in Volume 2, Appendix 7.1.
Scoping Opinion (Natural England, 9th August 2022)	Natural England advise that careful consideration be given to the potential impacts due to construction, operation, and maintenance, and decommissioning over the lifetime of the project to these seabed features, for Outer Dowsing OWF alone and in combination with other projects.	An assessment of the potential for cumulative effects with other projects and activities in the study area is provided in Section 7.13 of this PEIR chapter.
Scoping Opinion (Natural England, 9th August 2022)	Natural England would advise that the Applicant should consider how the coast at landfall may alter throughout the lifetime of the project, both in terms of vertical change in beach profile and coastal retreat. In other words, how will cable burial and siting of infrastructure be managed throughout the lifespan of the project?	A consideration of historic and contemporary rates of coastal change, in relation to proposed Project infrastructure is provided within Section 7.4 of this PEIR chapter and more fully within Volume 2, Appendix 7.1. Potential impacts on coastal behaviour at the landfall site has been assessed in Paragraph 7.12.64 *et seq*.
Scoping Opinion (Natural England, 9th August 2022)	Natural England advise that the spatial variation in seabed mobility across the study area should also be considered and assessed specifically in relation to its	Seabed mobility and its effect on cable burial has been considered as part of the baseline environmental description in Volume 2, Appendix 7.1. Potential effects of

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	effect on cable burial and the likely levels of introduced rock or hard substrate that will be required for cable and turbine base scour protection.	cable protection measures have been assessed in Paragraph 7.12.49 *et seq.* and Paragraph 7.12.74 *et seq.*
Scoping Opinion (Natural England, 9th August 2022)	Once the landfall area is known, Natural England advise that historic and more recent coastal frontage survey data should be gathered, including coverage of the intertidal, in order to inform the baseline characterisation.	Historic and more recent coastal frontage survey data is provided within Volume 2, Appendix 7.1, and has been used to inform the baseline within Section 7.4 of this PEIR chapter.
Scoping Opinion (Natural England, 9th August 2022)	Natural England advise that the mitigation hierarchy should be applied (avoid-reduce-mitigate). Where it is not possible to avoid MPAs in their entirety, the next step is to avoid designated features and areas where the capacity of the feature or site to withstand impacts may be reduced. Furthermore, we advise avoiding areas where there are existing cumulative impacts on sensitive features of MPAs. For example, sandbanks that may have the potential to recover relatively quickly but are already subject to anthropogenic pressures over a considerable amount of their occurrence in MPAs.	The Project has paid full consideration to the presence of designated sites and aims to minimise potential impacts through design. Full details regarding the Project's design are provided in Volume 1, Chapter 3.
Scoping Opinion (Natural England, 9th August 2022)	Natural England encourage the applicant to review consultation documentation relating to the Inner Silver Pit candidate HPMA. It should be noted that Natural England have a 'without prejudice' view that avoidance is likely to be the best approach to managing impacts given the high level of protection envisaged.	The Applicant notes that this site has not been designated in the initial HPMA pilot phase (Defra, 2023) and has therefore been excluded from further assessment.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
Scoping Opinion (Natural England, 9th August 2022)	Natural England advise that other mitigation measures should also be considered.	Mitigation with direct relevance to Marine Processes is outlined in Table 7.4 and has been included within the Impact Assessment. Information pertaining to the mitigation approach is provided in Volume 1, Chapter 3. The mitigation approach may be refined further, and supplementary information will be provided in the subsequent Environmental Statement chapter.
Scoping Opinion (Natural England, 9th August 2022)	Natural England advise that, if possible, maps be provided showing the spatial extent of sediment plumes, suspended sediment concentration, and deposition thickness in/near the array, and at representative locations along the offshore export cable corridor. (It would also be helpful if designated sites could be identified on these maps).	Spatial maps of numerical modelling results are provided within this PEIR chapter as well as within Volume 2, Appendix 7.2.
Scoping Opinion (Natural England, 9th August 2022)	Natural England advise that the assessment needs to consider the effects on the hydrodynamic regime due to the presence of engineering and installation equipment such as jack-up rigs, cable-laying vessels, and cofferdams etc.	The Applicant does not consider that an assessment of the effects of installation vessels is appropriate and in-keeping with best practice - this is not currently assessed within Offshore Windfarm (OWF) or Oil and Gas (O&G) ES's.
Scoping Opinion (Natural England, 9th August 2022)	Natural England advise that the assessment needs to consider the potential impact of beach access ramps and/or construction vehicle traffic on beach profile change or cliff erosion.	Potential impacts on coastal behaviour at the landfall site, including the impact of beach access ramps and construction vehicle traffic, have been assessed in Paragraph 7.12.64 *et seq*.
Scoping Opinion (Natural England, 9th August 2022)	Natural England advise that changes to tidal currents and water levels within and adjacent to the proposed development need to be considered.	Changes to the tidal regime have been assessed through numerical modelling and are presented in Section 7.137 of this PEIR chapter.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
Scoping Opinion (Natural England, 9th August 2022)	Water column features such as the Flamborough Front could also be included in this list (although we note it is quite distant from the array). In addition to the sandbank and sandwave areas, channels/pits could also be considered. We advise that supra-tidal features (e.g., sand dunes) be considered along the coastal frontage, including any designated sites above MHWS that might be affected indirectly by the development (e.g., SSSIs, Ramsar Sites).	The Applicant considers that, given that wake effects resulting from the WTG are localised to the structures and the distance from the array to the Flamborough Front is approximately 24km, that this feature can be scoped out of the Marine Processes assessment. The Applicant advises Natural England that features above MHWS will not be included within the Marine Processes assessment but are rather captured within the onshore aspects of this PEIR. Seabed features which have the potential, using the source-pathway-receptor model, to be impacted by the Project have been assessed in Section 7.12 of this PEIR chapter..
Scoping Opinion (Natural England, 9th August 2022)	To allow a full assessment of potential impacts to the marine environment, decommissioning of the cable should be based on present day techniques/legislation. With regards to cabling, Natural England would like to refer the applicant to our Cabling Lessons Learnt guidance for this chapter, in addition to the Benthic Chapter of the EIA Scoping Report.	The Applicant welcomes the reference to Natural England's Cabling Lessons Learnt guidance. Both this guidance and the EIA Scoping Benthic Chapter have been used for reference within the Marine Processes PEIR chapter.
Scoping Opinion (Natural England, 9th August 2022)	Natural England would advise that considerations need to be made for the potential for secondary scour to develop which is outside the considerations made within the scoping report e.g., the development of scour pits extending away from the edge of any rock protection. Further it is noted that even if scour during operation is scoped out, there will still be a need to provide details on estimates of scour so that	An assessment of potential impacts associated with seabed scouring, including impacts associated with secondary scour, is provided in Paragraph 7.12.98 *et seq.*, with relevant mitigation measures outlined in Table 7.4.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	consideration of the impact from deployment of scour protection can be assessed.	
Scoping Opinion (Natural England, 9th August 2022)	We advise that this impact should be considered and assessed further, alternatively this consideration could provide a robust rationale for scoping it out at a later stage. It may also be necessary to consider including nearby OWFs in the numerical modelling to understand any cumulative wave blockage or transmission effects. It would also be helpful to include a map showing the location of other offshore windfarms (built, planned, and consented) in the vicinity of ODOW and the area of predicted wave and tidal flow changes expected from these windfarms in relation to that of ODOW.	An assessment of the potential for cumulative effects with other projects and activities in the study area, including modifications to the wave and tidal regime and consequential impacts on sediment transport, is provided in Section 7.13 of this PEIR chapter. The location of other offshore windfarm developments in the vicinity of the Project are shown in Figure 7.27. The Applicant considers that, based on the available evidence base, that these impacts will not be significant and these impacts are therefore not included in the numerical modelling.
Scoping Opinion (Natural England, 9th August 2022)	Natural England are broadly in agreement with the data sources identified, however, we would advise that regional geology and sediment mobility should also be considered. Furthermore, once the landfall area has been identified, we advise that historic and more recent coastal frontage survey data should be gathered, including coverage of the intertidal, in order to inform the baseline characterisation and to understand trends.	The full list of data sources used within this PEIR chapter are presented in Volume 2, Appendix 7.1. Consideration of historic and contemporary rates of coastal change is provided within Section 7.4 of this PEIR chapter and more fully within Volume 2, Appendix 7.1.
Scoping Opinion (Natural England, 9th August 2022)	Natural England are also broadly in agreement with the identification of marine physical process receptors and pathways.	The Applicant welcomes that Natural England agree with the identification of marine physical process receptors and pathways.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
Scoping Opinion (Natural England, 9th August 2022)	Natural England advises that there are a number of other projects in the vicinity of the proposed development which could have a cumulative effect on the wave climate in terms of blockage and wave energy transmission. Furthermore, until the foundation design and array layout are refined, the maximum design scenario is not yet known. Which, in turn, leads to greater uncertainty regarding the potential for array-scale blockage effects on waves and flows which could act cumulatively with other nearby projects. Therefore, we advise that this impact should be considered and assessed further in order to provide supporting evidence to justify scoping it out.	An assessment of the potential for cumulative effects with other projects and activities in the study area, including modifications to the wave and tidal regime and consequential impacts on sediment transport, is provided in Section 7.13 of this PEIR chapter. The location of other offshore windfarm developments in the vicinity of the Project are shown in Figure 7.27. The Applicant considers that, based on the available evidence base, that these impacts will not be significant and these impacts are therefore not included in the numerical modelling.
Scoping Opinion (Natural England, 9th August 2022)	We are broadly in agreement with the methods described, however, until the landfall area and OECC are refined, we cannot fully agree owing to the wide Area of Search (AoS) and lack of detailed information.	The study area is based on the Zone of Influence (ZoI), derived from numerical modelling of sediment plume and tidal excursions. The study area is shown in Figure 7.1, as well as more fully within Volume 2, Appendix 7.1.
Scoping Opinion (Natural England, 9th August 2022)	Natural England advise that there are a number of mitigation measures that have not been considered such as: micro-siting, minimising the number of cables, selection of cable protection materials to match the receiving environment, and avoiding sandwave clearance/levelling where possible in an MPA.	Full details of embedded mitigation measures, including locations, volumes, and areas, where appropriate, are provided within Volume 1, Chapter 3. A summary is provided in Table 7.4 of this PEIR chapter.
Scoping Opinion (Natural England, 9th August 2022)	Please see our comment above regarding cumulative interaction between arrays. We advise that the marine physical processes modelling may need to consider potential changes to waves due to the proposed	An assessment of the potential for cumulative effects with other projects and activities in the study area, including modifications to the wave and tidal regime and consequential impacts on sediment transport, is provided in Section 7.13 of this PEIR chapter.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	development alone, and in combination with other nearby developments.	
Evidence Plan Meeting (ETG) held 12th October 2022	Cefas queried if the qualitative effects of cumulative approach will be based on numerical modelling of the specific sites.	Numerical modelling of hydrodynamic, wave and sediment transport processes has been undertaken to inform the Project-specific assessment, provided in Section 1.7 of this PEIR chapter. This has been used to inform the assessment provided in Section 1.8, although modelling of other offshore windfarm projects has not been undertaken.
ETG held 12th October 2022	Post meeting note from Natural England received on 02 November 2022: Natural England advised the Project to contact the Environment Agency for the launch date of NCERM2.	Current timescales for the launch date are late 2023. Should the NCERM2 be made available for the ES, it will be included in the Marine Processes assessments.
ETG held 12th October 2022	Post meeting note from Natural England received on 02 November 2022: Natural England advise that secondary scour around the edge of scour and cable protection should also be considered and assessed.	An assessment of potential impacts associated with seabed scouring, including impacts associated with secondary scour, is provided in Paragraph 1.7.96 *et seq.*, with relevant mitigation measures outlined in Table 1.5.
ETG held 12th October 2022	Post meeting note from Natural England received on 02 November 2022: Natural England advises that any infrastructure used during construction below MHWS but could impact on those features of designated sites above MHWS are considered in both offshore and onshore as any mitigation may be found onshore/offshore.	Potential impacts on coastal behaviour at the landfall site below MHWS has been assessed in Paragraph 1.7.64 *et seq*.
ETG held 12th October 2022	Post meeting note from Natural England received on 02 November 2022: Natural England advise that some supratidal features (e.g., dunes, cliff faces), may be present at landfall which could be affected by	Potential impacts on coastal behaviour at the landfall site below MHWS has been assessed in Paragraph 1.7.64 *et seq*.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	construction or operation of the development. Therefore, supratidal coastal features should remain scoped in.	
ETG held 2nd December 2022	Post meeting note from Natural England received 06 January 2023: Natural England suggested where numerical modelling is presented in the PEIR, it would be helpful to also include visual representation on a map, particularly in relation to the sediment plume modelling.	Visual representation of the numerical modelling results, including that of sediment plume modelling, has been provided in Section 1.7 of this PEIR chapter.
ETG held 2nd December 2022	Post meeting note from Natural England received 06 January 2023: Natural England added it is important that if there are any gaps/limitations in the data, or where data is extrapolated this is clearly acknowledged in the PEIR.	Assumptions and data limitations are presented in Paragraph 1.6.11 *et seq*. of this PEIR chapter.
ETG held 17th March 2023	The Environment Agency suggested that the Project should consider historic rates of erosion in their consideration of landfall siting.	A consideration of historic and contemporary rates of coastal change, in relation to proposed Project infrastructure is provided within Section 7.4 of this PEIR chapter and more fully within Volume 2, Appendix 7.1.
ETG held 17th March 2023	Natural England advise that some supratidal features (e.g., dunes, cliff faces), may be present at landfall which could be affected by construction or operation of the development. Therefore, supratidal coastal features should remain scoped in. Natural England will provide post-meeting comments on this topic.	At the time of writing this PEIR chapter, there were no post-meeting comments received from Natural England.

7.4 Baseline Environment

Study Area

7.4.1 The Marine Processes study area is shown in Figure 7.1. A ZoI has been used to identify those Marine Processes receptors which have the potential to be affected by the Project infrastructure and associated activities. The ZoI (Figure 7.1) has been defined using the outputs from the Project-specific numerical modelling (Volume 2, Appendix 7.2), and has been scaled to conservatively represent the equivalent distance of tidal excursion on a mean spring tide and comprises a distance of between, approximately, 10km (at landfall) and 15km (within the ECC).

7.4.2 A tidal ellipse around the array, comprising a distance of approximately 12km, has been used to define the ZoI for the activities within the array, owing to the plumes generally moving in parallel relative to the coast in less dispersive plumes. This ellipse similarly encapsulates the maximum extent of measurable sediment plumes predicted by the modelling (see Volume 2, Appendix 7.2).

Data Sources

7.4.3 Baseline understanding of Marine Processes within the study area has been developed through consideration of a range of project-specific and existing data sources. These are summarised in Table 7.1 of Volume 2, Appendix 7.1 and include:

- Project-specific geophysical, benthic and oceanographic survey data;
- Data available from a number of marine data portals, including the Atlas of UK Marine Renewable Energy Resources (ABPmer *et al.*, 2008) and the British Geological Society (BGS) Offshore GeoIndex (BGS, 2022);
- Existing marine process investigations from across the study area, including regional characterisations (e.g. Tappin *et al.*, 2011) and Environmental Statements (ES) for other OWF developments (including Triton Knoll OWF, Race Bank OWF, and Dudgeon and Sheringham Shoal Extension projects); and
- Numerical modelling of hydrodynamic, wave and sediment transport processes developed to inform the assessment (Volume 2, Appendix 7.2).

7.4.4 In order to assess the potential effects on the marine physical environment relative to the existing (baseline) environment, a combination of analytical methods has been used. These include:

- Project-specific numerical modelling (outlined in full in Volume 2, Appendix 7.2);
- The 'evidence base' containing monitoring data collected during the construction and O&M of other OWF developments;
- Analytical assessment of Project-specific data; and
- Standard empirical equations describing (for example) the potential for scour development around structures (e.g. Whitehouse, 1998).

Existing Environment

7.4.5 The existing environment across the study area is described in detail within Volume 2, Appendix 7.1, and a summary provided in the following sections of this PEIR chapter. This has been achieved through the combined analysis of project specific survey data (including metocean measurements) and modelled data, information previously collected to inform the construction and operation of nearby OWFs including Triton Knoll and Race Bank (as shown on Figure 7.27), as well as data collected as part of regional coastal and seabed monitoring programmes. Full details are provided in Table 7.1 of Volume 2, Appendix 7.1.

Metocean

Offshore Array

7.4.6 The array area is exposed predominantly to waves originating from the north and north-northwest (Figure 7.2). In the centre of the array area, annual mean significant wave height is 1.3m, with wave heights and peak wave periods increasing with distance offshore (Figure 7.2; MetOceanWorks, 2021a).

7.4.7 Tidal range (Figure 7.3) increases slightly from the northeast to the southwest across the array area, with a transition from a meso-tidal regime[3] in the east, with mean spring and neap ranges of 3.28m and 1.58m, to a macro-tidal regime in the west, with mean spring and neap ranges of 4.14m and 2.00m, respectively (MetOceanWorks, 2021b; 2021d).

7.4.8 Tidal flows are generally to the southeast on the flood tide and to the northwest on the ebb tide. Peak spring tidal current speeds are modelled at approximately 1.0m/s to 1.2m/s across the array area (shown in Figure 7.4). Annual mean surface and near-bed (1m above bed) current speeds in the centre of the array area modelled at 0.53m/s and 0.34m/s, respectively (MetOceanWorks, 2021a; 2021c).

Offshore Export Cable Corridor

7.4.9 Prevailing waves originate from the north in the more offshore parts of the ECC, with a north-eastern component becoming more important closer to the shore (Figure 7.2). Closer to the shore, waves occur most frequently from the north-northeast and northeast, as shown on Figure 7.2, with an annual mean wave height of 0.8m and the most common peak wave period between 4 and 6 seconds.

7.4.10 The mean spring tidal range increases from around 3.6m at the eastern end of the Offshore ECC to approximately 5.5m at the landfall site (ABPmer *et al.*, 2008). In the eastern half of the ECC, east of Inner Silver Pit (see Figure 7.1), tidal flows are generally oriented to the southeast on the flood tide and northwest on the ebb, with comparable current speeds to the array area (Figure 7.4).

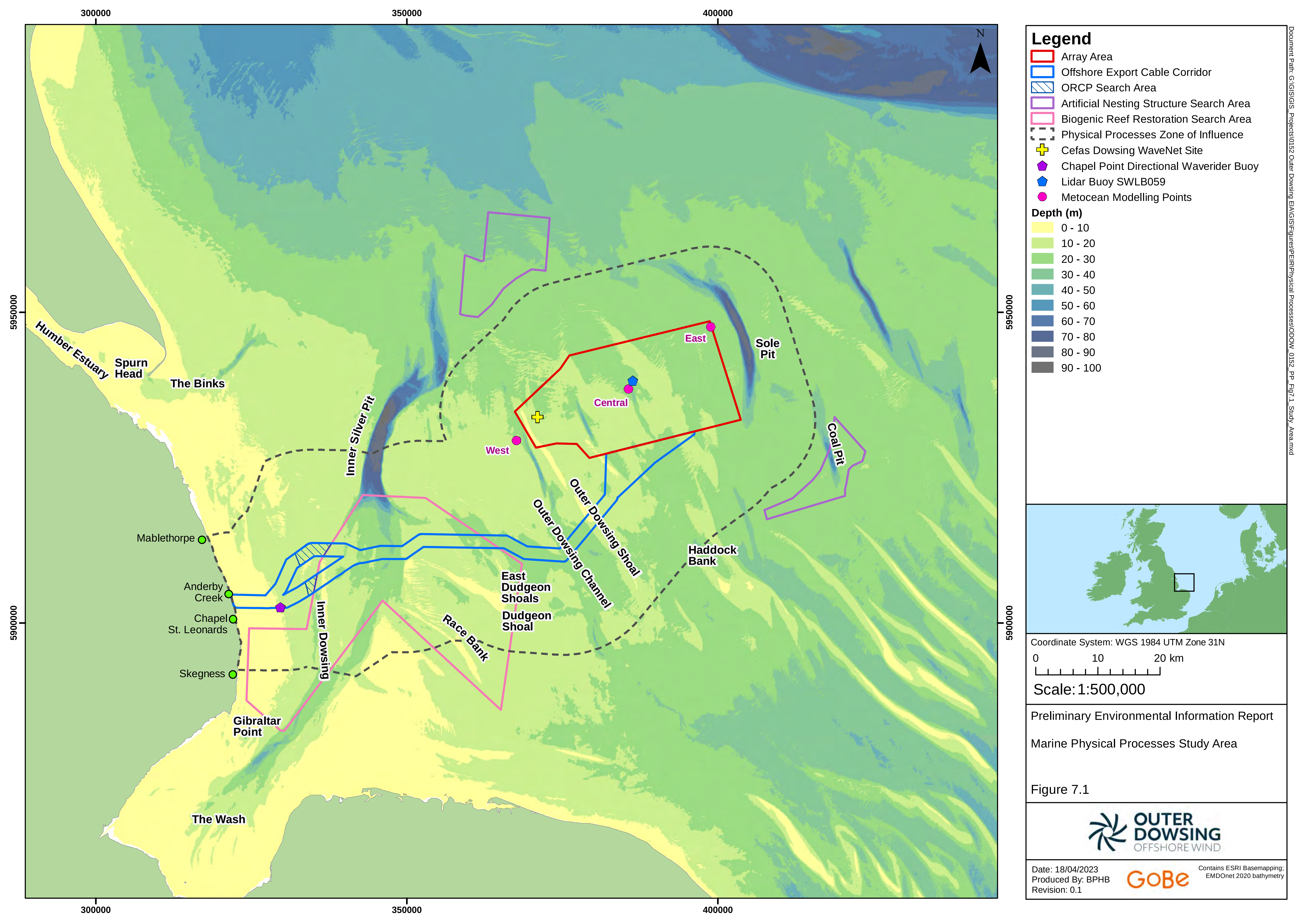
7.4.11 Closer inshore, current speeds generally increase to between 1.2m/s and 1.4m/s, reaching over 1.4m/s south of the Inner Silver Pit, as shown on Figure 7.4. To the south and west of the Inner Silver Pit, tidal flows are oriented north to south, apart from in close proximity to the coast where are they are oriented approximately parallel to the shoreline (ABPmer *et al.*, 2008; MetOceanWorks, 2021c).

[3] Defined by spring tidal range: micro-tidal, tidal range <2m; meso-tidal, tidal range 2 – 4m; macro-tidal, tidal range >4m.

Coast

7.4.12 Waves predominantly arrive on the Lincolnshire coast from the northeast (Figure 7.2), with an annual significant wave height less than 1.0m (ABPmer, 2018). The wave regime exerts the dominant forcing to littoral transport within the nearshore zone (Environment Agency, 2010; 2011).

7.4.13 The landfall area is located within a macro-tidal environment. Peak flow speeds are found to be more than 0.8m/s generally, exceeding 1.0m/s in places, with tidal currents generally following the orientation of the coastline with a flood tide to the south and an ebb tide to the north (Environment Agency, 2013b; TKOWFL, 2015).



300000
350000
400000
5950000
5900000
N
Humber Estuary
Spurn Head
The Binks
Inner Silver Pit
Mablethorpe
Anderby Creek
Chapel St. Leonards
Skegness
Gibraltar Point
Inner Dowsing
The Wash
Race Bank
East Dudgeon Shoals
Dudgeon Shoal
Outer Dowsing Channel
Outer Dowsing Shoal
West
Central
East
Sole Pit
Haddock Bank
Coal Pit
Legend
Array Area
Offshore Export Cable Corridor
ORCP Search Area
Artificial Nesting Structure Search Area
Biogenic Reef Restoration Search Area
Physical Processes Zone of Influence
Cefas Dowsing WaveNet Site
Chapel Point Directional Waverider Buoy
Lidar Buoy SWLB059
Metocean Modelling Points
Depth (m)
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
Coordinate System: WGS 1984 UTM Zone 31N
0 10 20 km
Scale: 1:500,000
Preliminary Environmental Information Report
Marine Physical Processes Study Area
Figure 7.1
OUTER DOWSING OFFSHORE WIND
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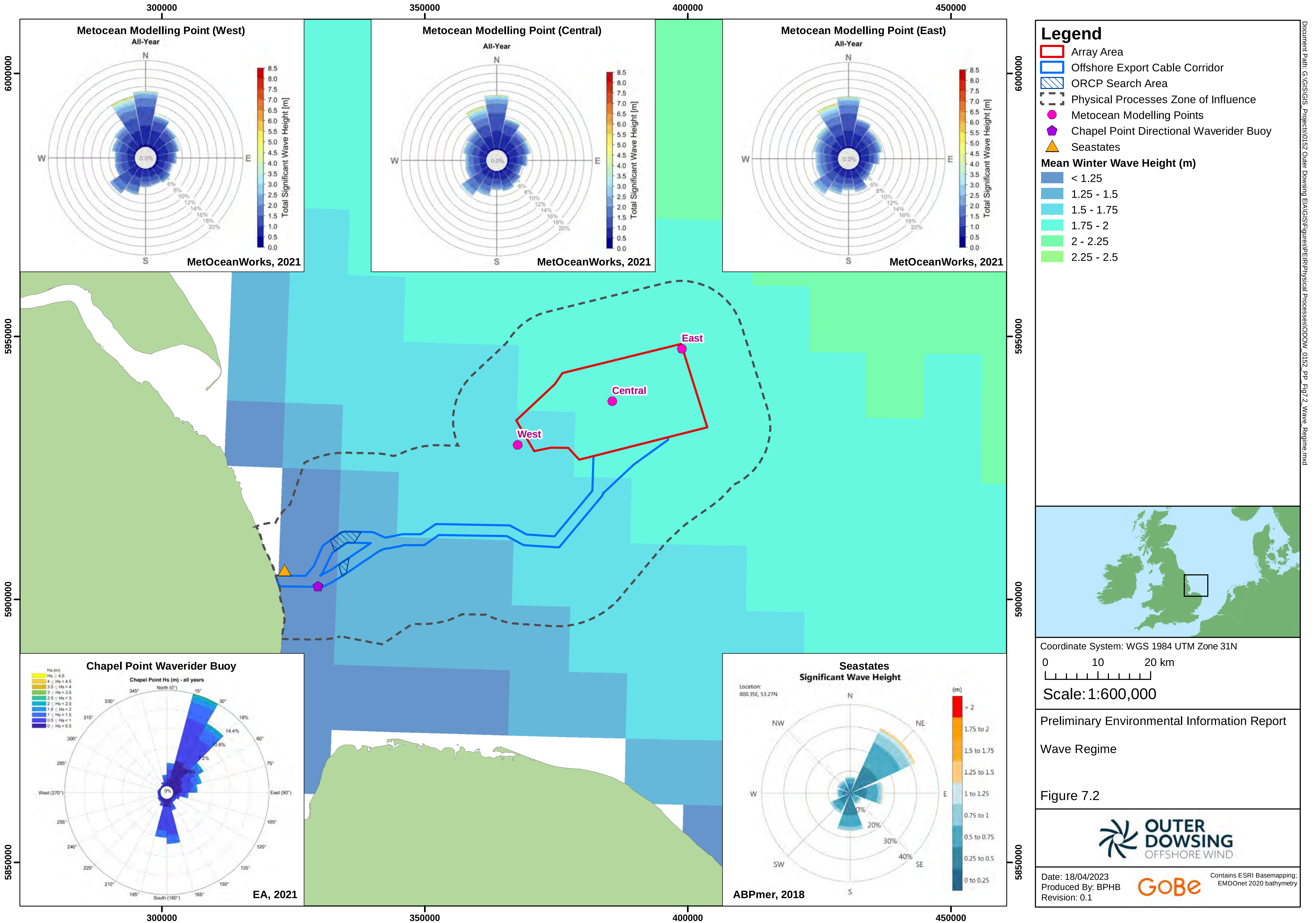
Metocean Modelling Point (West)
All-Year
MetOceanWorks, 2021
Metocean Modelling Point (Central)
All-Year
MetOceanWorks, 2021
Metocean Modelling Point (East)
All-Year
MetOceanWorks, 2021
Total Significant Wave Height [m]
N
E
S
W
East
Central
West
Chapel Point Waverider Buoy
Chapel Point Hs (m) - all years
EA, 2021
Seastates
Significant Wave Height
ABPmer, 2018
300000
350000
400000
450000
6000000
5950000
5900000
5850000
Legend
Array Area
Offshore Export Cable Corridor
ORCP Search Area
Physical Processes Zone of Influence
Metocean Modelling Points
Chapel Point Directional Waverider Buoy
Seastates
Mean Winter Wave Height (m)
< 1.25
1.25 - 1.5
1.5 - 1.75
1.75 - 2
2 - 2.25
2.25 - 2.5
Coordinate System: WGS 1984 UTM Zone 31N
0 10 20 km
Scale: 1:600,000
Preliminary Environmental Information Report
Wave Regime
Figure 7.2
OUTER DOWSING OFFSHORE WIND
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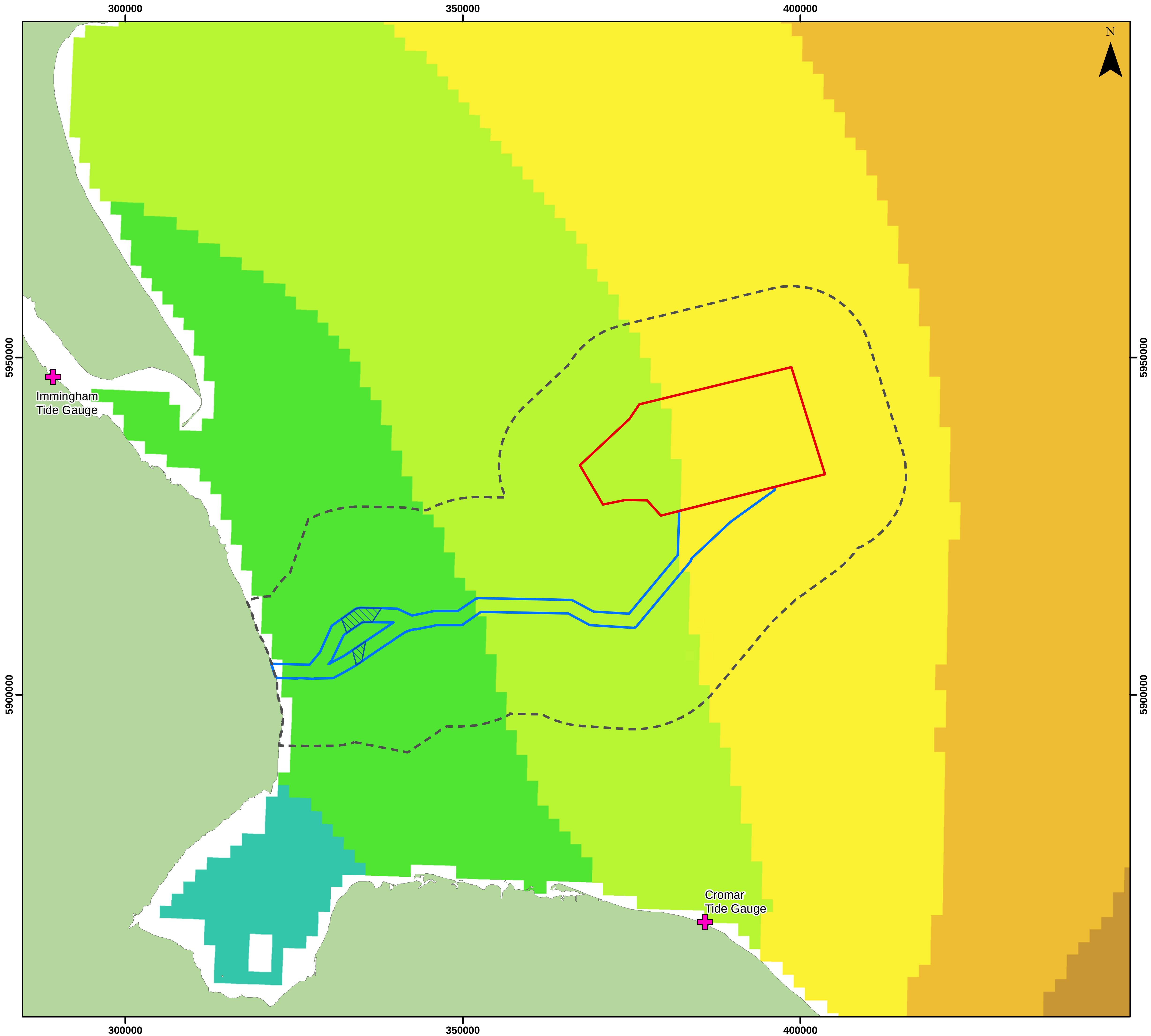
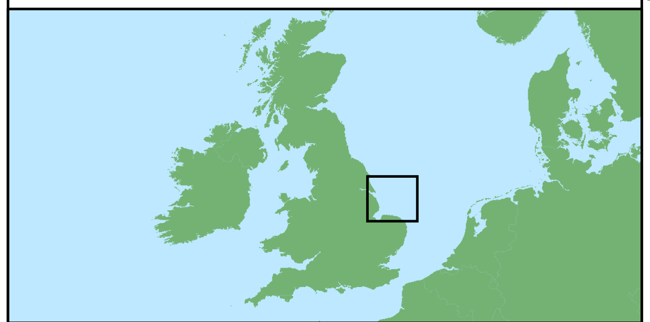


Legend

- Array Area
- Offshore Export Cable Corridor
- ORCP Search Area
- Physical Processes Zone of Influence
- Tide Gauge Location

Mean Spring Tidal Range (m)

- 1.01 - 2
- 2.01 - 3
- 3.01 - 4
- 4.01 - 5
- 5.01 - 6
- 6.01 - 7



Coordinate System: WGS 1984 UTM Zone 31N

0 10 20 km

Scale: 1:525,000

Preliminary Environmental Information Report

Mean Spring Tidal Range
(ABPmer *et al.*, 2008)

Figure 7.3

OUTER DOWSING OFFSHORE WIND

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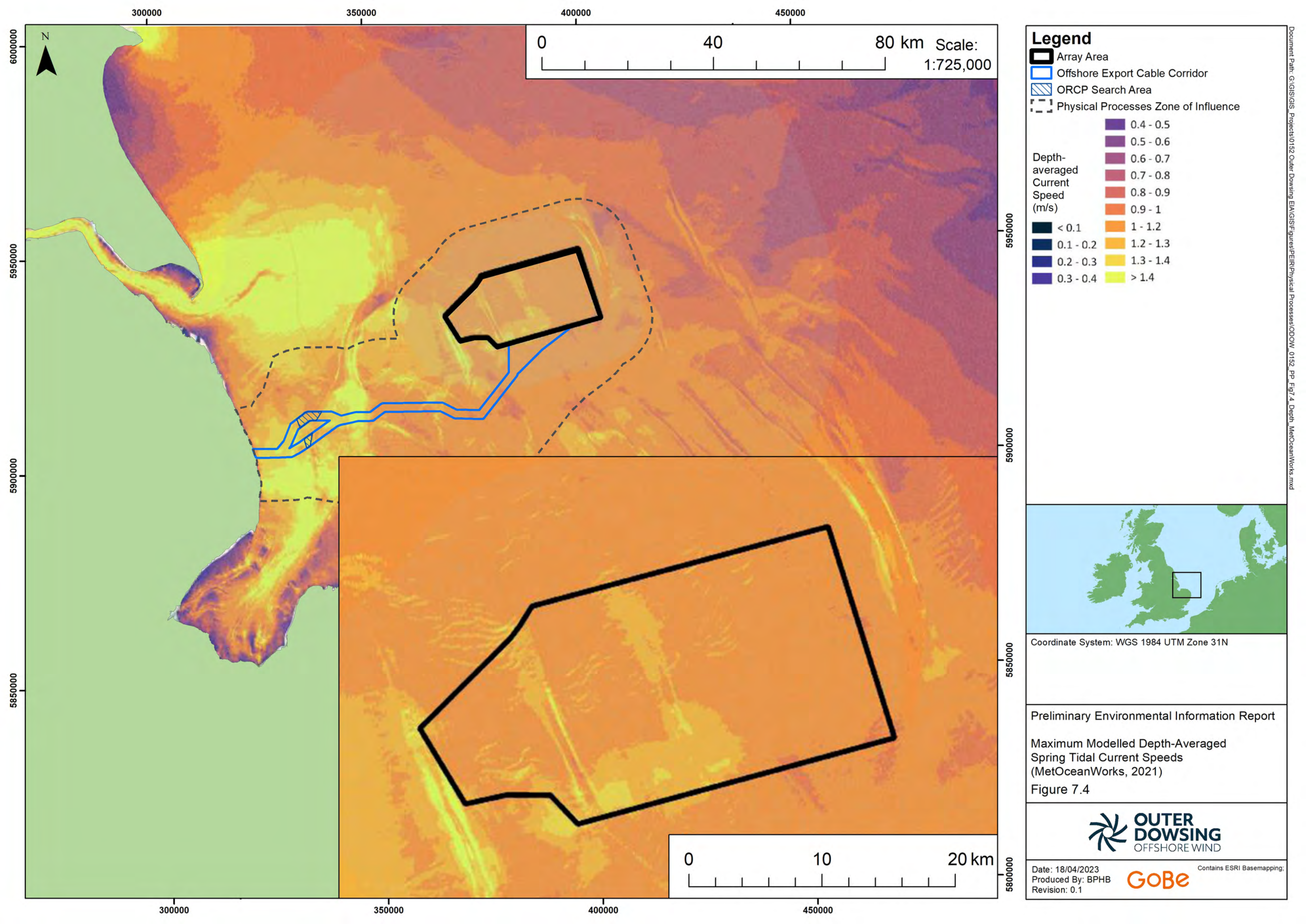
Legend
Array Area
Offshore Export Cable Corridor
ORCP Search Area
Physical Processes Zone of Influence
Depth-averaged Current Speed (m/s)
< 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1
1 - 1.2
1.2 - 1.3
1.3 - 1.4
> 1.4
0 40 80 km
Scale: 1:725,000
0 10 20 km
300000
350000
400000
450000
6000000
5950000
5900000
5850000
5800000
N
Coordinate System: WGS 1984 UTM Zone 31N
Preliminary Environmental Information Report
Maximum Modelled Depth-Averaged Spring Tidal Current Speeds (MetOceanWorks, 2021)
Figure 7.4
OUTER DOWSING OFFSHORE WIND
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Seabed

Offshore Array

7.4.14 The western half of the array area is underlain by Cretaceous Chalk, with mudstones, limestones and sandstones present in the east (Figure 7.5; BGS, 2022). As indicated by the geophysical survey data and regional BGS data, the chalk bedrock is located approximately between 5 and 30m below the seabed and overlain by stiff Pleistocene sediments, primarily the Bolders Bank and Swarte Bank Formation (Cathie, 2021). This is in turn overlain by a layer of Holocene sediments approximately between 0 and 5m thick, with thicker deposits in the east (Enviros, 2022).

7.4.15 Water depths across the array area range from 5 to 47m, with over 90% between 15 and 25m (Lowest Astronomical Tide (LAT)) (Figure 7.6). Surficial seabed sediments within the array area are characterised generally by a mix of sand and gravel (as shown Figure 7.7 and characterised in detail in Volume 2, Appendix 7.1), with a greater proportion of sand at shallower depths associated with sandbank features. The proportion of fines was generally minimal, with a slightly higher content observed at deeper sample points (GEOxyz, 2022a).

Offshore Export Cable Corridor

7.4.16 The Offshore ECC is characterised mainly by Pleistocene deposits present above Cretaceous Chalk bedrock, overlain in turn by a veneer of Holocene sediments. The thickness of sediments overlying the bedrock is highly dependent on morphology, with some parts of the ECC crossing sandbank features with Holocene sediments over 10m thick (Dove *et al.*, 2017). In contrast, south of the Inner Silver Pit the Offshore ECC crosses an area of chalk bedrock close to the surface, with a very thin Holocene sediment layer, as shown on Figure 7.5 (Tappin *et al.*, 2011). Geophysical survey information suggests a thin veneer of Holocene sands of between 1m and 5m across the majority of the ECC (GEOxyz, 2022b).

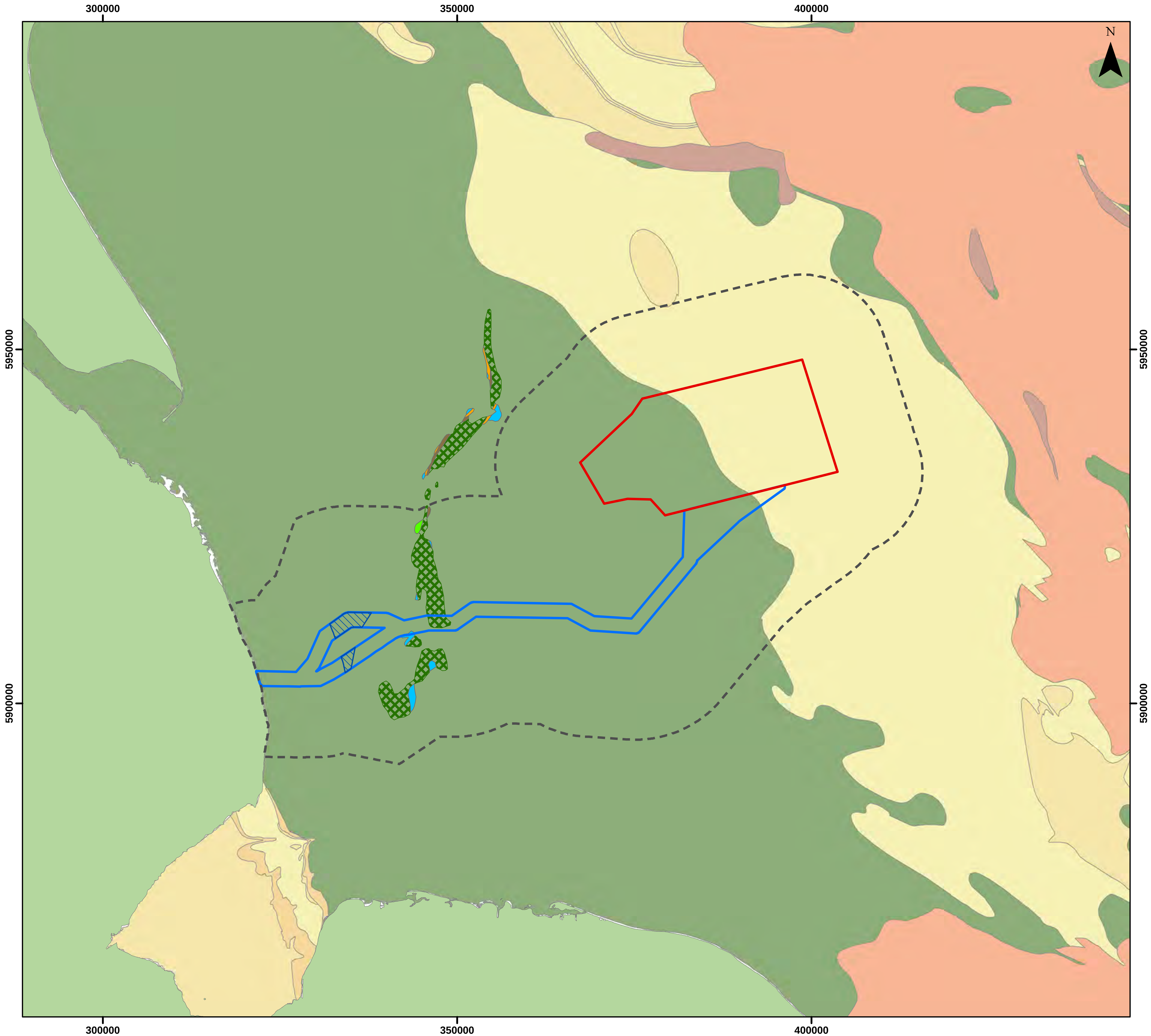
7.4.17 Water depths in the ECC range generally between 10 to 30m (LAT) (see Figure 7.1). From approximately 12km offshore, water depths typically shallow uniformly from circa 14m towards the coast (Figure 7.6; EMODnet, 2022).

7.4.18 Surficial sediments in the Offshore ECC area are characterised mainly by sandy gravel, with some mud component to the south of Inner Silver Pit (Figure 7.7; BGS, 2022). The results of particle size analysis along the Project ECC (GEOxyz, 2022b) indicate a variable sediment type with a general dominance of sand, with higher fines content than the array area, consistent with the BGS data presented in Figure 7.7. Closer to the coast, the proportion of sand generally decreases, with a corresponding increase in gravel and fines content.

Coast

7.4.19 The coastal bedrock geology is composed of Burnham Chalk, overlain by marine sand deposits. Historical borehole data provides no evidence of bedrock within the first 12m (BGS, 2022).

7.4.20 The present form of the Lincolnshire beaches has been directly influenced by the 'Lincshore' annual beach nourishment scheme, outlined further in Paragraph 7.4.27. Analysis of the nourishment material has shown that it can be best described as poorly sorted gravelly sand, although considerable variation was identified within each dredger load and at different locations along the coast (Blott and Pye, 2004).



Legend

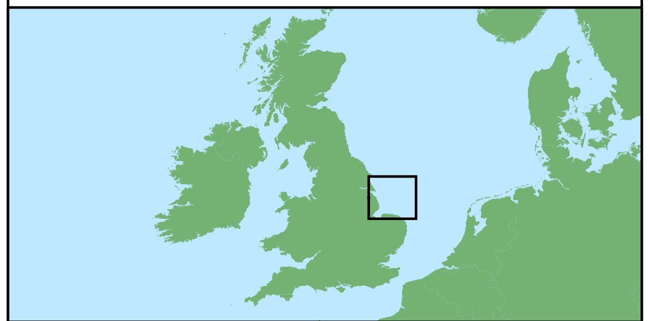
- Array Area
- Offshore Export Cable Corridor
- ORCP Search Area
- Physical Processes Zone of Influence

Pre-Holocene Geology at/near Seabed (Tappin, 2011)

- Mesozoic - Chalk Group - Early to Late Cret.
- Quaternary - Bolders Bank Formation
- Quaternary - Egmond Ground Formation
- Quaternary - Sand Hole Formation
- Quaternary - Swarte Bank Formation

Bedrock Summary Lithologies (BGS)

- Chalk
- Mesozoic interbedded
- Mesozoic mudstones
- Mesozoic sandstones and limestones
- Palaeozoic sedimentary
- Tertiary interbedded



Coordinate System: WGS 1984 UTM Zone 31N

0 10 20 km

Scale: 1:500,000

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Regional Marine Geology

Figure 7.5

OUTER DOWSING OFFSHORE WIND

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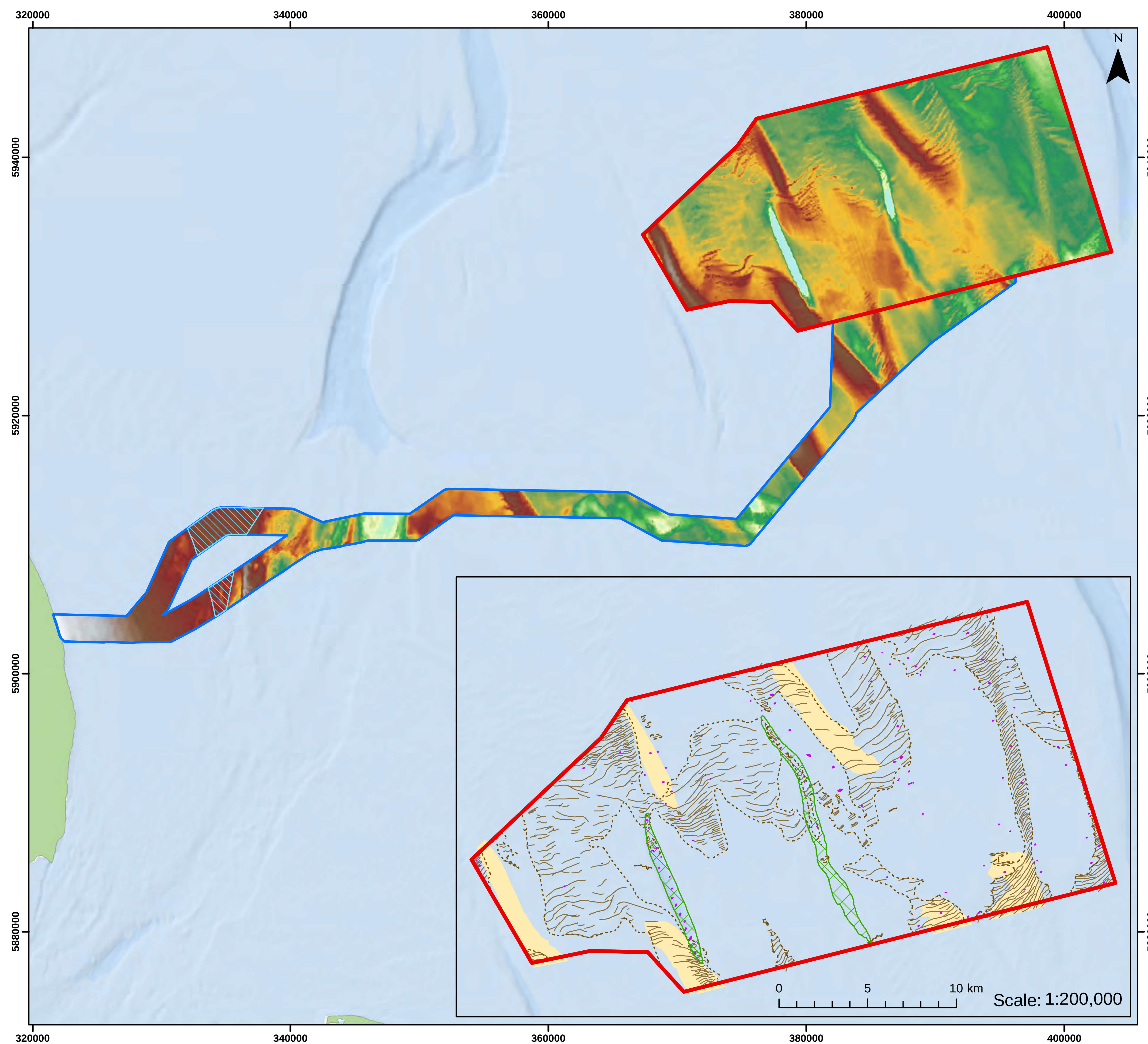


Legend

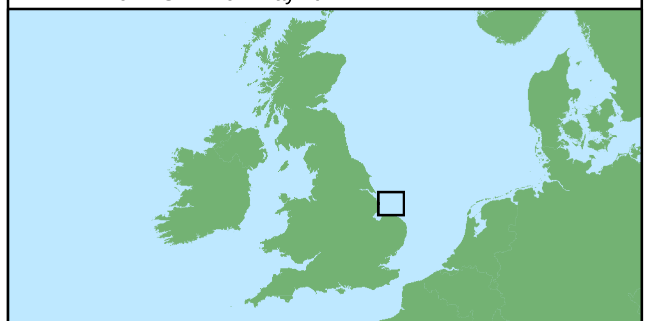
- Array Area
- Offshore Export Cable Corridor
- ORCP Search Area
- Sandwaves Area
- Sandwaves Crest
- Sandbanks
- Megaripples Crest
- Canyon

Depth (m) (EMODnet, 2020)

0

32

Seafloor Morphology data provided by Enviros and is detailed in report 'Outer Dowsing Round 4 Draft Final Report - ENV21-21042-GTR4-04' May 2022



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0 5 10 km

Scale: 1:275,000

Preliminary Environmental Information Report

Morphology of Array Area, Offshore ECC and at Landfall

Figure 7.6

OUTER DOWSING OFFSHORE WIND

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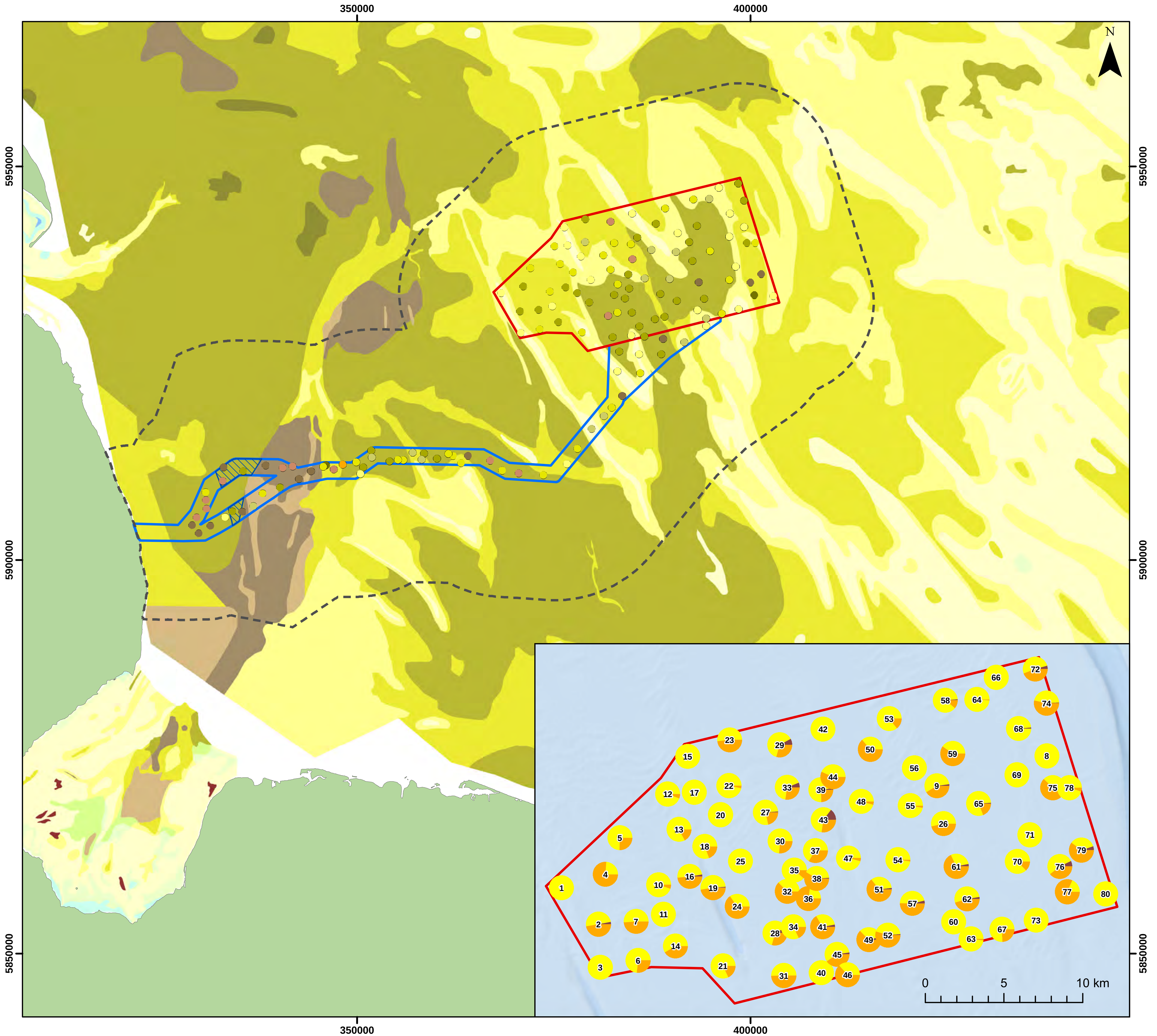

Legend
- Array Area
- Offshore Export Cable Corridor
- ORCP Search Area
- Physical Processes Zone of Influence

Seabed Sediments (FOLK)
- 1.1.1 Mud
- 1.1.2 (gravelly) Mud
- 1.2.1 sandy Mud
- 1.3.1 muddy Sand
- 1.3.2 (gravelly) muddy Sand
- 2.1.1 Sand
- 2.1.2 (gravelly) Sand
- 3.1.1 gravelly Sand
- 3.2.1 sandy Gravel
- 3.3.1 Gravel
- 4.1.1 gravelly Mud
- 4.3.1 gravelly muddy Sand
- 4.4.1 muddy sandy Gravel
- 5. Rock and Boulders

Benthic Samples - Folk Class (GEOxyz, August / November 2022)
- Sand
- Slightly Gravelly Sand
- Slightly Gravelly Muddy Sand
- Gravelly Sand
- Sandy Gravel
- Muddy Sandy Gravel
- Gravelly Muddy Sand
- Gravel

Sediment composition (%)
- Fines
- Sand
- Gravel

Seabed Sediments 1:250 000 – Europe © EMODnet Geology, European Commission, 2016

Coordinate System: WGS 1984 UTM Zone 31N

0 10 20 km

Scale: 1:450,000

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Surficial Seabed Sediments (Folk, 1954)

Figure 7.7

OUTER DOWSING OFFSHORE WIND

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Morphology

Offshore Array

7.4.21 The tidal regime exerts primary control on the sediment transport regime in the offshore environment. Regional-scale assessments identify a net north-westerly direction of bedload transport for the Project array area, which is located seaward of the bedload parting zone, as shown in Figure 7.8 (Kenyon and Cooper, 2005).

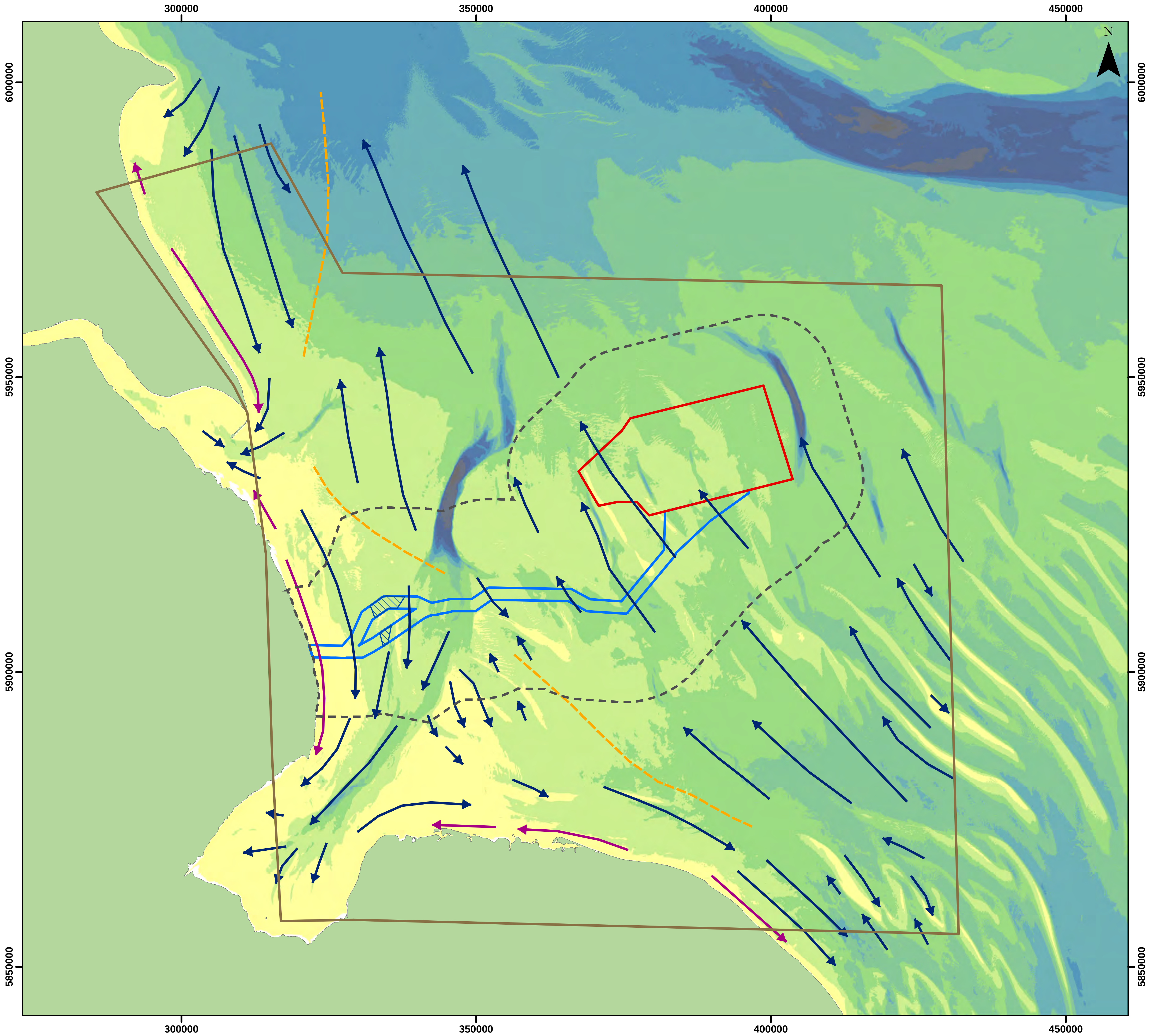
7.4.22 The array area is bound to the eastern (seaward) edge by Sole Pit, and on the western (landward) boundary by the Outer Dowsing Channel (see Figure 7.1). Several non-designated sandbanks are located in the north of the array, with heights from seabed of between 10 and 12m, as well as areas of northwest-facing sand waves with wave heights generally between 2 and 3m, although in places these reach up to 8m (Enviros, 2022).

Offshore Export Cable Corridor

7.4.23 Bedload sediment transport in the most offshore part of the ECC is directed towards the northwest, as in the Project array area (shown on Figure 7.8). The ECC crosses a bedload parting, approximately, 35km offshore, with bedload transport directed to the south. Littoral transport diverges along the Lincolnshire coastline, with a southward transport direction at the landfall site.

7.4.24 The Race Bank – North Ridge – Dudgeon Shoal and Inner Dowsing Annex I sandbank systems are located across the western half of the Offshore ECC. Sediment transport modelling undertaken as part of the Race Bank OWF ES illustrated predominantly north-westerly sediment transport pathways across the majority of the site (Centrica, 2008). The Inner Dowsing sandbank is considered to be a relict feature, although it has experienced some changes in crest level, and is maintained by tidal currents (Centrica, 2007; JNCC, 2010).

7.4.25 Inner Silver Pit, located landward of the array area and on the northern boundary of the Offshore ECC (Figure 7.1), is an elongated, over-deepened and enclosed paleo-valley partly filled with unconsolidated sediments. This bathymetric depression is approximately 38km long, 2.5km wide and 100m deep, with changes in water depth in excess of 60m over 0.5km (Tappin *et al.*, 2011). Erosional processes have exposed bedrock at the seabed within the Inner Silver Pit, with chalk bedrock exposed at the seabed within the feature as well as in the fan to the south (Figure 7.5).



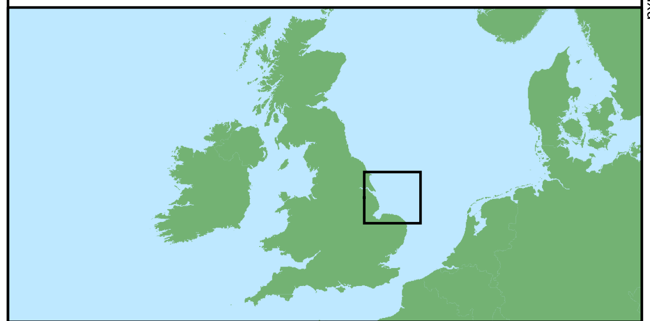
Legend

- Array Area
- Offshore Export Cable Corridor
- ORCP Search Area
- Physical Processes Zone of Influence
- Longshore Transport
- Bed Load Transport
- Bed Load Parting
- SEA Boundary

Depth (m)

- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 100

Longshore Transport, Bed Load Transport and Bed Load Parting from Kenyon and Cooper, 2005



Coordinate System: WGS 1984 UTM Zone 31N

0 10 20 km

Scale: 1:600,000

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Bedload Sediment Pathways
(adapted from Kenyon and Cooper, 2005)

Figure 7.8

OUTER DOWSING OFFSHORE WIND

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Coast

7.4.26 The dominant wave direction along the Lincolnshire coast is from the northeast, which produces a net southerly drift of beach material along the Lincolnshire coast and into the Wash (Figure 7.2; Figure 7.8; HR Wallingford *et al*., 2002; Environment Agency, 2011). The wave regime is the dominant driver of littoral transport in the nearshore zone and is an important determinant of beach morphology in the area.

7.4.27 This coastal section has experience long-term erosion, with an estimated erosion rate of approximately 1.3m/year (HADA, 2012a; TKOWFL, 2015). Much of the surficial beach layer has been removed by contemporary hydrodynamic processes, and an annual beach nourishment scheme has been in operation since 1994, with an average of 500,000m^3 of sediment deposited along the Lincolnshire coast each year (Environment Agency, 2019a; 2019b; 2021b).

7.4.28 The coastal frontage at the proposed landfall site (Wolla Bank) is characterised by the presence of a sandy beach backed by vegetated sand dunes (HADA, 2012a). The beach displays a distinctive seasonal shift in foreshore width, the timing of which is affected by annual nourishment activities, with the beach continuing to erode between nourishment events, particularly in the mid-beach as shown on Figure 7.9 (Environment Agency, 2011; 2013a).

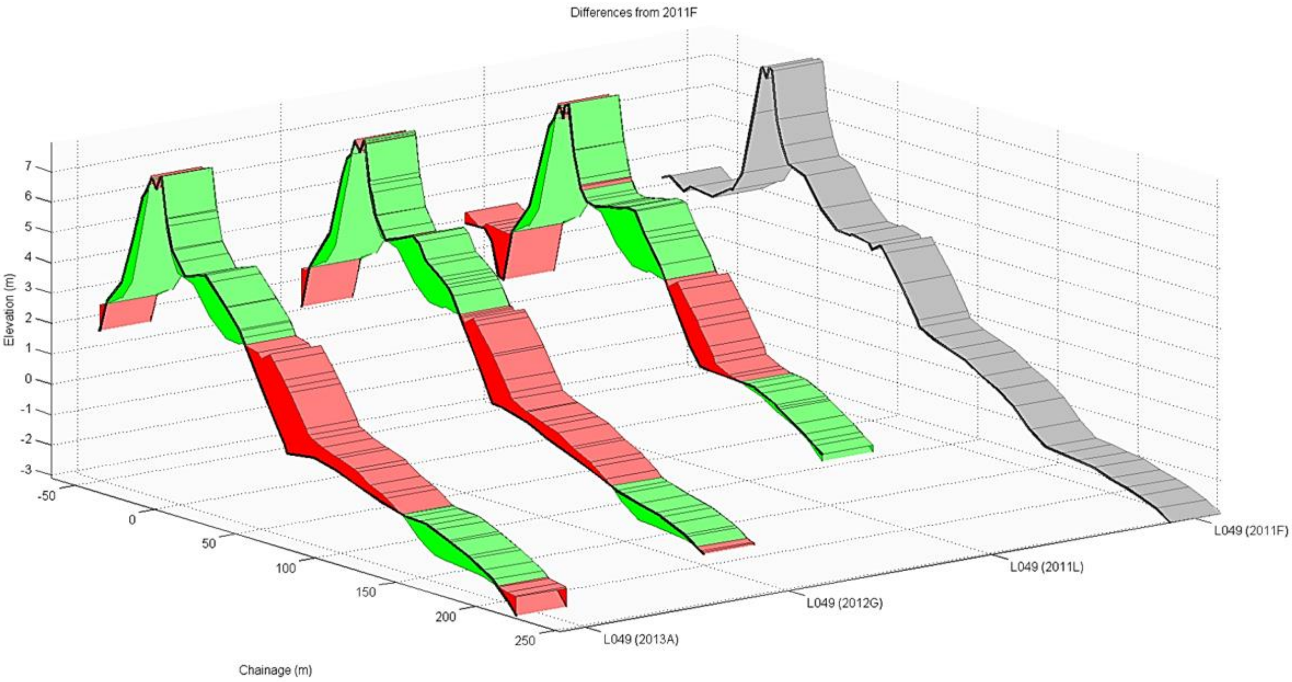


Figure 7.9: Change in beach profile over four surveys between 2011 and 2013. Lowering is shown in red (Environment Agency, 2013a)

Suspended Sediment Concentrations

7.4.29 Suspended sediment in the region is mainly sourced from the eroding Holderness cliffs, which consist of 67% mud (Tappin *et al.*, 2011). As a result of distance from these terrestrial sources, low surface concentrations of up to 5mg/l were recorded in the array area between the period 1998 to 2015 (Cefas, 2016). Higher values will occur during spring tides and storm conditions, with the greatest concentrations encountered close to the bed. Project-specific turbidity data indicated mean near-surface (around 5m below surface) and near-bed spring and summer concentrations of circa 3mg/l and 13mg/l, respectively, between April and November 2022 within the array area (Fugro, 2020).

7.4.30 Surface Suspended Particulate Matter (SPM) levels within the nearshore zone of the Offshore ECC are directly under the influence of terrestrial sources from the Humber Estuary and Holderness Cliffs, such that concentrations reach around 60mg/l, between the period 1998 to 2015 (Cefas, 2016). There is an east to west gradient in SPM throughout the year, although this is most pronounced during the winter.

Compensation Areas

7.4.31 Areas of search for potential compensation measures associated with the Project have been provided in Figure 7.1, with the baseline conditions in these areas provided in Volume 2, Appendix 7.1. The compensation areas will be assessed within the Environmental Statement (ES) following refinement of the proposed areas and once details of the works to be undertaken have been finalised.

7.5 Future Baseline

7.5.1 A consideration of the future baseline, including the associated variation, is provided in the context of the operating lifetime of the Project. For the current purposes of this PEIR chapter, the Representative Concentration Pathway (RCP) 8.5 (high emissions) scenario (Palmer *et al.*, 2018) has been presented.

7.5.2 UKCP18 suggests an increase in Mean Sea Level (MSL) of over 0.7m by 2100 along the Lincolnshire coast (Palmer *et al.*, 2018). This effect would also redefine both tidal levels and extreme water levels, translating the position of high water further landward and increasing the potential of coastal erosion and flooding events. However, the tidal response along this part of the coastline is predicted to be small (less than 5% change in standard deviation of tide) even under a large time-mean sea level increase (Palmer *et al.*, 2018). Future changes in storm surges are predicted to be undistinguishable from background variation (Lowe *et al.*, 2009).

7.5.3 Wave energy is predicted to decrease, such that by 2100 a decrease larger than 10% has been modelled in the North Sea (RCP8.5 scenario; Bonaduce *et al.*, 2019; Meucci *et al.,* 2020). Inter-decadal variability may be largely due to the influence of local weather in the North Sea (EDF ENERGY, 2021).

7.5.4 The preferred management strategy in place along this part of the coast from 2025 to 2055 is to maintain flood defences in their current position and to raise and improve them to counter sea level rise as required (Environment Agency, 2020; 2019a). Beach nourishment is currently ongoing, and it is predicted that the levels and frequency of sand required will increase. The proposed strategy over the next 100 years is therefore to implement a combination of rock structures and beach nourishment. This will be a phased process with beach nourishment continuing in its current form until 2024, with structures to be implemented between 2025 and 2030 (Environment Agency, 2019a).

7.6 Designated Sites and Protected Species

7.6.1 Designated sites in the vicinity of the study area, which are designated for the protection and conservation of marine habitats up to MHWS are shown in Figure 7.10. This includes the following designated sites which are located outside the Marine Processes ZoI, and have therefore not been considered further:

- Haisborough, Hammond and Winterton Special Area of Conservation (SAC);
- Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ);
- The Wash and North Norfolk Coast SAC;
- Humber Estuary SAC;
- Holderness Offshore MCZ; and
- Holderness Inshore MCZ.

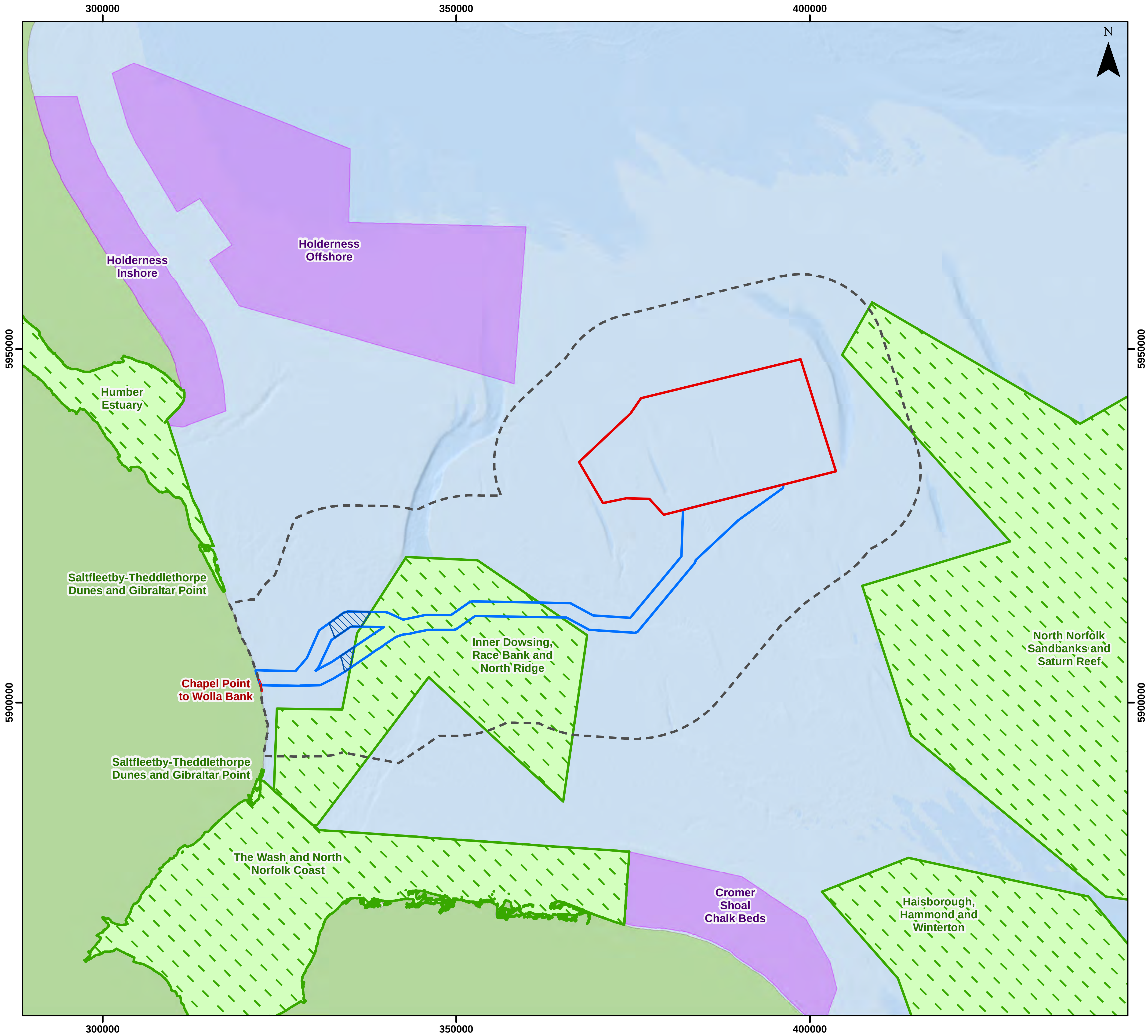
7.6.2 A list of designated sites within the Marine Processes ZoI, with detail of the relevant protected features, is provided below:

- North Norfolk Sandbanks and Saturn Reef SAC:
  - Reefs; and
  - Sandbanks which are slightly covered by sea water all of the time.
- Inner Dowsing, Race Bank and North Ridge SAC:
  - Reefs; and
  - Sandbanks which are slightly covered by sea water all of the time.

7.6.3 One coastal (Sites of Special Scientific Interest (SSSI)) site is also present:

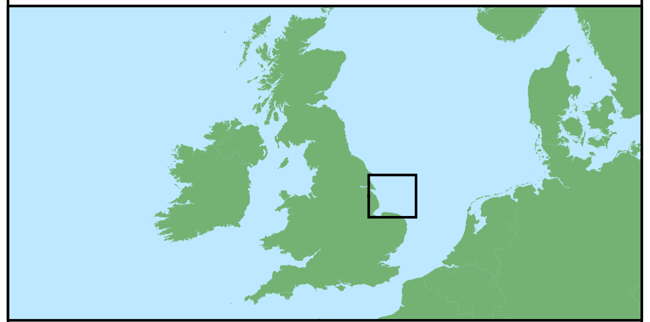
- Chapel Point – Wolla Bank SSSI: national importance in the Geological Conservation Review.

7.6.4 Notably, a standalone Habitats Regulation Assessment (HRA) Report to Inform Appropriate Assessment (RIAA) (Report 7.1) and a Marine Conservation Zone (MCZ) Assessment (Volume 2, Appendix 9.4) will be produced detailing all matters associated with statutory designations.



Legend

- Array Area
- Offshore Export Cable Corridor
- ORCP Search Area
- Physical Processes Zone of Influence
- Marine Conservation Zones
- Special Areas of Conservation
- Site of Special Scientific Interest



Coordinate System: WGS 1984 UTM Zone 31N

0 10 20 km

Scale: 1:500,000

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Designated Sites of relevance to Marine Physical Processes

Figure 7.10

OUTER DOWSING OFFSHORE WIND

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7.7 Basis of Assessment

Scope of the Assessment

Impacts Scoped In for Assessment

7.7.1 The following impacts have been scoped into the assessment:

- Construction:
  - Impact 1: Increases in SSC resulting in elevated turbidity and consequential changes to seabed levels;
  - Impact 2: Potential impacts to seabed morphology (sandbanks, sandwave areas and notable bathymetric depressions); and
  - Impact 3: Modifications to littoral transport and coastal behaviour (erosion), including at landfall.
- Operation and maintenance:
  - Impact 4: Modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime and morphological features; and
  - Impact 5: Seabed scouring.
- Decommissioning:
  - Impact 6: Increases in SSC and consequential changes to seabed levels;
  - Impact 7: Potential impacts to seabed morphology (sandbanks, sandwave areas and notable bathymetric depressions); and
  - Impact 8: Modifications to littoral transport, coastal behaviour (erosion) including at landfall.
- Cumulative:
  - Impact 9: Cumulative increases in SSC and consequential changes to seabed levels;
  - Impact 10: Cumulative impacts to seabed morphology (sandbanks, sandwave areas and notable bathymetric depressions); and
  - Impact 11: Cumulative modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime.

Impacts Scoped Out of Assessment

7.7.2 In line with the Scoping Opinion (The Inspectorate, 2022) and based on the receiving environment, expected parameters of the Project (Volume 1, Chapter 3) and expected scale of impact/potential for a pathway for effect on the environment, the following impacts have been scoped out of the assessment, as discussed through the relevant ETGs (Table 7.2):

- Construction:

- Hydrodynamic impacts from installation vessels such as jack-up rigs, cable laying vessels etc.; and
- Impacts on coastal processes and geomorphology above MHWS.

7.8 Realistic Worst Case Scenario

7.8.1 This section describes the Maximum adverse Design Scenario (MDS) parameters for Marine Processes. This is provided in Table 7.3 for each of the potential effects to be assessed. The MDS is defined by the Project design envelope (outlined in Volume 1, Chapter 3) and includes embedded mitigation measures.

Table 7.3: Maximum design scenario for Marine Processes for the Project alone

Potential effect	Maximum design scenario assessed	Justification
Construction		
Impact 1: Increases in SSC resulting in elevated turbidity and consequential changes to seabed levels.	**Greatest volume of sediment disturbed and released for dredging for seabed preparation prior to foundation installation over the entire array area** ▪ 93 Gravity Base Structure (GBS) Wind Turbine Generator (WTG) foundations, with a total spoil volume of 3,375,900m^3 (36,300m^3 per WTG foundation); ▪ Five offshore platforms within the array area (including four Offshore Substations (OSSs) and one offshore accommodation platform), with a total spoil volume of 242,500m^3 (48,500m^3 per offshore platform foundation); and ▪ Overall total: 3,618,400m^3 (WTG and offshore platform foundations). **Greatest volume of sediment disturbed and released for dredging for seabed preparation prior to foundation installation over the ECC** ▪ Two Offshore Reactive Compensation Platforms (ORCPs) within the ECC, with a total spoil volume of 97,000m^3 (48,500m^3 per offshore platform foundation). **Greatest volume of sediment disturbed and released by drilling as part of foundation installation at a single foundation location**	Defining the MDS for sediment disturbance activities is highly complex as the actual disturbance will be temporally and spatially variable (depending upon the metocean conditions at the time). For sediment plumes, the MDS is intended to be representative in terms of peak concentration, plume extent and plume duration but will not correspond to a single sediment disturbance activity. The same applies for sediment deposition at the bed, where the MDS is a representation of maximum deposit thickness, maximum footprint extent or likely duration. The justification for the MDS is set out in Volume 2, Appendix 7.2. **Dredging for seabed preparation prior to foundation installation** Seabed preparation works would be required prior to installation of certain foundation types, particularly GBS. The use of Trailer Suction Hopper Dredgers (TSHD) is considered to be the realistic worst case option. **Drilling as part of foundation installation** Although the volumes of material released via drilling are less than for seabed preparation via dredging, drilling has the potential to release larger volumes of relatively finer sediment.

Potential effect	Maximum design scenario assessed	Justification
	▪ 25 or 30MW jacket foundation WTG with pin-piles, embedment depth = 125m, drill volume per location (Area 1) = 9,825m^3 (2,456m^3 per pin pile). See Volume 2, Appendix 7.2 for further details. **Greatest volume of sediment disturbed and released by drilling as part of the foundation installation over the entire array area** ▪ Average drill spoil volume for 16MW WTG monopile foundations = 2,850m^3; ▪ Total estimated drilling volume for 93 x 16MW monopile foundations: 93 x 2,850 = 265,050m^3; ▪ Average drill spoil volume for a jacket offshore platform foundation with pin-piles = 16,500m^3; ▪ Total estimated drilling volume for five offshore platform foundations = 82,500m^3; ▪ Total estimated drilling volume for WTGs and offshore platforms = 347,550m^3. **Greatest volume of sediment disturbed and released by drilling as part of foundation installation over the ECC** ▪ Average drill spoil volume for a jacket ORCP foundation with pin-piles = 16,500m^3; ▪ Total estimated drilling volume for two ORCP foundations = 33,000m^3. **Installation of inter-array cables** ▪ Total length: 351km;	Two maximum adverse scenarios are identified, corresponding to the greatest volume of sediment disturbance locally (from a single foundation) and across the entire array (from all foundations). The greatest volume of drill arisings from a single foundation location is associated with jacket foundations with pin-piles and the greatest volume of drill arisings for the entire array area is associated with a layout comprising of monopiles. **Cable Installation** Cable installation may require some combination of (e.g.) jetting, ploughing, trenching and/or cutting type installation techniques. The realistic worst case option is represented by the use of Mass Flow Excavator (MFE) trenching, developing the largest amount of displaced sediment into the water column, with the fastest trenching rate of 300m/hr representing the highest release rate of sediments and operating in locations with the largest contribution of fine sediments. **Horizontal Directional Drilling (HDD) Operations** Although other trenchless installation technologies are available, HDD is the established solution and has therefore been identified as the realistic worst case option. HDD operations are expected to have localised and short-term effects on SSC concentrations due to the potential release of bentonite during punch-out in the

Potential effect	Maximum design scenario assessed	Justification
	▪ V-shaped trench; seabed width = 18m, depth = 3m; ▪ Assume 100% of material is forced into suspension to a height of, approximately, 2m above the seabed; ▪ Total volume of disturbance: 351,000 x 18 x 3 x 0.5 x 100% = 9,477,000m^3; ▪ Installation method: MFE; and ▪ Assumed installation rate of up to 300m/hr. **Installation of interlink cables** ▪ Total length: 123.75km; ▪ V-shaped trench; seabed width = 18m, depth = 3m; ▪ Assume 100% of material is forced into suspension to a height of, approximately, 2m above the seabed; ▪ Total volume of disturbance: 123,750 x 18 x 3 x 0.5 x 100% = 3,341,250m^3; ▪ Installation method: MFE; and ▪ Assumed installation rate of up to 300m/hr. **Installation of export cables** ▪ Total length of (4) export cables = 514.8km, each up to 128.7km in length from array area to landfall; ▪ V-shaped trench; seabed width = 18m, depth = 3m; ▪ Assume 100% of material is forced into suspension to a height of approximately 2m above the seabed; ▪ Total volume of disturbance: 514,800 x 18 x 3 x 0.5 x 100% = 13,899,600m^3;	nearshore exit pit. The period of release for bentonite is estimated to be 12 hours to accommodate both initial punch-out and the subsequent reaming processes. Accordingly, the release rate has been estimated at 3,195g/s over this period.

Potential effect	Maximum design scenario assessed	Justification
	▪ Installation method: MFE; and ▪ Assumed installation rate of up to 300m/hr. **Sandwave clearance via dredging (array cables)** ▪ Total length inter-array cables and interlink cables = 474.75km, up to 60% requiring sandwave clearance; ▪ Dredged corridor up to 30m seabed width and 2m deep. ▪ Sandwave clearance volume (for 93 x 16MW WTGs):13,672,800m^3; and ▪ Material disposed of within the Project array area and Offshore ECC. **Sandwave clearance via dredging (export cable)** ▪ Total length of up to four export cables; ▪ Dredged corridor up to 30m seabed width and 2m deep. ▪ Sandwave clearance volume: 7,413,120m^3; and ▪ Material disposed of within the Project array area and Offshore ECC. **HDD drilling fluid release** ▪ Maximum volume and mass of drilling fluid released per HDD conduit: 773m^3 fluid (138,000kg bentonite); and ▪ Period of release: 12 hours with estimated release rate of 3,195g/s.	
Impact 2: Potential impacts to seabed	See **Impact 1**.	During the construction phase, the primary means by which sandbanks and sandwaves could be impacted is

Potential effect	Maximum design scenario assessed	Justification
morphology (sandbanks, sandwave areas and notable bathymetric depressions)		through the interruption of sediment transport patterns via sandwave clearance and other seabed preparation activities.
Impact 3: Modifications to littoral transport and coastal behaviour (erosion), including at landfall	**Horizontal Directional Drilling (HDD)** ▪ Punch-out location for HDD: Subtidal; ▪ Six HDD exit pits (allowing for two failures), excavated to a depth of up to 5m over a total area = 1,000m^2; ▪ Estimated maximum excavated material volume = 5,000m^3 per pit and total = 30,000m^3; and ▪ Duration exit pits remain open: up to twelve months and then backfilled on completion.	The primary means by which the landfall morphology could potentially be impacted during the construction phase is through sediment disturbance during the HDD exit pit excavation within the subtidal area, resulting in associated changes to bed levels and modification of hydrodynamic/ sediment transport processes.
Operation and Maintenance		
Impact 4: Modifications to the wave and tidal regime and associated potential impacts to morphological features	**Foundations** ▪ 93 x 16 MW GBS slab-based WTG foundations, base height up to 13m; and ▪ Up to five slab-based GBS offshore platform foundations. **Cable protection** ▪ Standard options include rock placement, concrete mattresses, flow dissipation devices, protective aprons, bagged protection, etc.; ▪ Rock berm protection with crest height = 2m, crest width = 2m, side slopes = 1:3 gradient and width at seabed = 16m(including a provision for 1m buffer either side);	The greatest total in-water column blockage to currents, waves and sediment transport processes is presented by an array comprising the largest number (93) of gravity base foundations.

Potential effect	Maximum design scenario assessed	Justification
	▪ Total length of cables which may potentially require seabed protection anticipated to be up to, approximately, 25% of array cable length and 25% of export cable length, including 20 crossings; and ▪ Maximum area of 1,899,000m ^{2} for the inter-array cables and 2,059,200m^2 for the export cable.	
Impact 5: Seabed scouring.	Maximum adverse scenario is defined on the basis of the scour assessment.	Each foundation type may produce different scour patterns therefore monopiles and GBS have been considered. The foundation type, size and number producing the greatest area and/or volume of influence cannot be identified in advance of the assessment.
Decommissioning		
Impact 6: Increases in SSC and consequential changes to seabed levels.	▪ Array comprising the largest number of foundations (93 WTG, five OSS); ▪ Buried cables to be cut and left *in situ* (but to be determined in consultation with key stakeholders as part of the decommissioning plan and following best practice at the time); ▪ Scour and cable protection left *in situ*; and ▪ Decommissioning activities lasting approximately three years.	When removing foundations, the greatest disturbance will be associated with the layout containing the greatest number of structures.
Impact 7: Potential impacts to seabed morphology (sandbanks, sandwaves and notable bathymetric depressions).	▪ Removal of export cables from trenches within intertidal/ shallow subtidal; ▪ Filling of HDD ducts; and ▪ Decommissioning activities lasting approximately three years.	Maximum disturbance of seabed/intertidal and change in blockage resulting from infrastructure removal.

7.9 Embedded Mitigation

7.9.1 Mitigation measures that were identified and adopted as part of the evolution of the Project design (embedded into the project design) and that are relevant to Marine Processes are listed in Table 7.4. General mitigation measures, which would apply to all parts of the Project, are set out first. Thereafter mitigation measures that would apply specifically to Marine Process issues associated with the array, ECC and landfall are described separately.

Table 7.4: Embedded mitigation relating to Marine Processes

Parameter	Mitigation measures embedded into the project design
General	
Definition of development boundaries	The development boundary selection was made following a series of constraints analyses, with the array area and Offshore ECC route selected to ensure the impacts on sensitive environmental receptors are minimised.
Construction	
Offshore cables	A cable burial risk assessment (CBRA) will be undertaken to inform front end engineering works. Cable burial will be the preferred option for cable protection, and this will minimise any impacts associated with habitat loss.
Offshore cables	Where possible, subsea cable burial will be the preferred option for cable protection. Cable burial will be informed by the cable burial risk assessment (CBRA) – which will take account of the presence of designated sites - and detailed within the Cable Specification and Installation Plan (CSIP). An outline CSIP will be prepared in support of the Application, which will be finalised post-consent.
Landfall	In the intertidal zone, no permanent rock protection will be employed. The installation of the offshore export cables at landfall will be undertaken by HDD or other trenchless methods. Any rock protection utilised within the subtidal zone will not exceed LAT.
Landfall	Trenchless punchout will avoid the coastal SSSIs.
Foundations and offshore cable	Dredged material will be deposited within an area of similar sediment characteristics, in close proximity to the dredge location in order to retain sediment within the sediment transport system.
Operation and Maintenance	
Project Design	The installation of scour protection around windfarm infrastructure where required for engineering purposes.
Decommissioning	
Decommissioning Programme	Development of, and adherence to, a Decommissioning Programme (DP).

7.10 Assessment Methodology

7.10.1 The assessment methodology for Marine Processes has, in accordance with best practice, adopted the '*source-pathway-receptor*' approach. This allows a study area to be identified which includes all the marine locations of project activities which may create potential sources of effects, in addition to all the pathways which create a linkage between the source and environmental receptors.

7.10.2 The baseline and assessment works have been undertaken using an evidence-based approach, supported by Project specific surveys and numerical modelling as appropriate.

7.10.3 For the most part Marine Processes are not in themselves receptors but are instead 'pathways'. However, changes to Marine Processes have the potential to indirectly impact other environmental receptors (Lambkin *et al.*, 2009). An example is the creation of sediment plumes which may result in settling of material onto benthic habitats. The potential significance of this particular change is assessed in Volume 1, Chapter 9. This distinction between the assessments of pathways and receptors is summarised in Table 7.5, for each of the potential impacts/changes considered within the assessment section.

Table 7.5: Potential impacts/changes classified as pathways and/or receptors

Potential effect	Pathway/receptor
Construction	
Impact 1: Increases in SSC resulting in elevated turbidity and consequential changes to seabed levels.	Pathway
Impact 2: Potential impacts to seabed morphology (sandbanks, sandwave areas and notable bathymetric depressions).	Pathway/receptor
Impact 3: Modifications to littoral transport and coastal behaviour (erosion), including at landfall.	Pathway/receptor
Operation and Maintenance	
Impact 4: Modifications to the wave and tidal regime and associated potential impacts to morphological features.	Pathway
Impact 5: Seabed scouring.	Pathway/receptor
Decommissioning	
Impact 6: Increases in SSC and consequential changes to seabed levels.	Pathway
Impact 7: Potential impacts to seabed morphology (sandbanks, sandwaves and notable bathymetric depressions).	Pathway/receptor

7.10.4 Whilst Marine Processes can largely be considered as pathways, there are a small number of features which have been identified as potentially sensitive Marine Process receptors. These features, as presented in Figure 7.10, are:

- The shoreline, including the Chapel Point – Wolla Bank SSSI;
- Nearby designated offshore sand banks (including North Norfolk Sandbanks and Saturn Reef SAC and Inner Dowsing, Race Bank and North Ridge SAC); and
- Seabed areas contained within nationally or internationally important sites.

7.10.5 These receptors have been identified and the potential effects assessed on the basis of:

- Professional judgement, local and regional specialist experience;
- The Scoping Opinion (The Inspectorate, 2022);
- Outcomes from the consultation process completed to date; and
- Reference to best practice guidance.

7.10.6 Where these receptors have the potential to be affected by changes to physical processes, a full impact assessment (i.e. assigning sensitivity, magnitude and significance) has been carried out.

7.10.7 This assessment is consistent with the EIA methodology presented in Volume 1, Chapter 5: EIA Methodology. The approach for determining the significance of effects is a two-stage process that involves defining the sensitivity of the receptors and the magnitude of the impacts against set criteria. This section describes the criteria applied in this PEIR chapter to assign values of sensitivity to the receptors and determine the magnitude of potential impacts.

7.10.8 The magnitude of impact describes the extent or degree of change that is predicted to occur to a receptor. This has been assessed using expert judgment and described qualitatively with a standard semantic scale. Definitions for each term are provided in Table 7.6.

Table 7.6: Impact magnitude definitions

Magnitude	Description/reason
High	Permanent changes across the near- and large parts of the far-field to key characteristics or features of the particular environmental aspect's character or distinctiveness.
Medium	Permanent changes, over the near- and parts of the far-field, to key characteristics or features of the particular environmental aspect's character or distinctiveness.
Low	Noticeable, temporary (for part of the Project duration) change, or barely discernible change for any length of time, restricted to the near-field and immediately adjacent far-field areas, to key characteristics or features of the particular environmental aspect's character or distinctiveness.
Negligible	Changes which are not discernible from background conditions.

7.10.9 The sensitivity/importance of the receptor is defined in Table 7.7. The sensitivities (or importance) of Marine Process receptors are defined by both its capacity to accommodate change in addition to its socioeconomic importance.

Table 7.7: Sensitivity/importance of the environment

Receptor sensitivity/importance	Definition
High	Very low or no capacity to accommodate the proposed form of change; and/or receptor designated and/or of international level importance. Likely to be rare with minimal potential for substitution. May also be of very high socioeconomic importance.

Receptor sensitivity/importance	Definition
Medium	Moderate to low capacity to accommodate the proposed form of change; and/or receptor designated and/or of regional level importance. Likely to be relatively rare. May also be of moderate socioeconomic importance.
Low	Moderate to high capacity to accommodate the proposed form of change; and/or receptor not designated but of district level importance.
Negligible	High capacity to accommodate the proposed form of change; and/or receptor not designated and only of local level importance.

7.10.10 The significance of the effect on Marine Processes is determined by correlating the magnitude of the impact and the sensitivity of the receptor. The method employed for this assessment is described in Table 7.8. Where a range of significance of effect is presented, the final assessment for each effect is based upon expert judgement. For this assessment, any effects with a significance level of minor or less have been concluded to be not significant in terms of the EIA Regulations.

Table 7.8: Matrix to determine effect significance

		Magnitude of impact			
		Negligible	*Low*	*Medium*	*High*
Sensitivity of receptor	*Negligible*	Negligible (Not significant)	Negligible (Not significant)	Minor (Not significant)	Minor (Not significant)
	Low	Negligible (Not significant)	Minor (Not significant)	Minor (Not significant)	Moderate (Significant)
	Medium	Minor (Not significant)	Minor (Not significant)	Moderate (Significant)	Major (Significant)
	High	Minor (Not significant)	Moderate (Significant)	Major (Significant)	Major (Significant)

7.11 Assumptions and Limitations

7.11.1 Whilst many of the baseline characteristics are well understood, in some instances, data sources or assumptions are less well studied and/or quantified for the study area. This section seeks to identify areas of uncertainty and potential data gaps.

7.11.2 Grab sampling provides detailed information (sediment; fauna) as data points which must be interpretated alongside other relevant datasets. Existing surveys which have included for grab samples have been conducted in the wider area and show good validation against the regional data (Figure 7.7). The seabed morphology and sediments in the area are well studied and surveyed. As such, the available evidence base is considered sufficiently robust to underpin the assessment presented here and an overall high confidence is placed in the baseline characterisation.

7.11.3 There is some uncertainty associated with the sediment plume assessment and accompanying bed level changes due to Project related activities and analogous developments. This arises due to the uncertainty regarding how the seabed geology will respond to drilling and jetting. There are a number of factors which determine the exact sediment volume that is entrained into the water column; including the type of drilling/ cable installation equipment used, the variability of the forcing conditions at the installation time (i.e. the waves and tidal conditions) and the mechanical properties of the geological units. In the absence of this detailed information, a series of potential release scenarios have been considered in below assessment. Together, these scenarios capture the worst case impacts in terms of the highest concentration and persistent suspended sediment plumes, the maximum and greatest spatial extent of changes in bed level elevation.

7.11.4 Where a modelled activity occurs within the resolution of one model cell, the behaviour of the sediment plume can be considered to occur at a sub-grid scale. Therefore, it is not appropriate to draw conclusions for the size or concentration of the plume within the cell in which the activity occurs. Therefore, this has been supplemented with information based on expert judgement and analogous projects to allow meaningful interpretation.

7.11.5 The availability of robust data relevant for the characterisation and assessment of Marine Processes is such that, despite some data limitations, it is considered that a thorough and meaningful characterisation for the purposes of EIA can be undertaken. As such, the available evidence base is sufficiently robust to underpin the assessment presented here and an overall high confidence is placed on the assessment.

7.12 Impact Assessment

Construction

Impact 1: Increases in SSC Resulting in Elevated Turbidity and Consequential Changes to Seabed Levels

7.12.1 During Project construction, sediment will be disturbed and released into the water column. This will give rise to suspended sediment plumes and localised changes in bed levels as material settles out of suspension. Those Project activities which will result in the greatest disturbance of seabed sediments are:

- Pre-lay cable trenching using a Mass Flow Excavation (MFE) tool at the seabed;
- Seabed preparation (including both seabed levelling for WTG foundations and sandwave clearance) including spoil disposal via a Trailer Suction Hopper Dredger (TSHD);
- Foundation installation using drilling techniques; and
- Drilling fluid release during Horizontal Directional Drilling (HDD), or other trenchless technique, operations.

7.12.2 The MDS used for each of these scenarios is provided in Table 7.3 and each has been considered using numerical modelling both within the array area and along the ECC, for both spring and neap tides.

7.12.3 The release events that have been simulated within the numerical model, as described in Volume 2, Appendix 7.2, have been specifically designed to capture the full range of realistic worst case outcomes in terms of:

- Sediment plume concentrations;
- Sediment plume extent;
- Vertical deposition depth (bed level change); and
- Horizontal extent of deposition (spatial extent (area) of bed level change).

7.12.4 The methodology applied to assess the characteristics of sediment plumes and associated changes in bed level arising from settling of material is set out in Volume 2, Appendix 7.2. The findings are presented below.

Conceptual Understanding of Change

7.12.5 The actual magnitude and extent of change in SSC and bed levels will depend in practice on a range of factors, such as the actual total volumes and rates of sediment disturbance, the local water depth and current speed at the time of the activity, the local sediment type and grain size distribution, the local seabed topography and slopes, etc. There will be a wide range of possible combinations of these factors and so it is not possible to predict specific dimensions with complete certainty. To provide a robust assessment, a range of realistic combinations have been considered, based on conservatively representative location (environmental) and Project (MDS) specific information, including a range of water depths, heights of sediment ejection/initial resuspension, and sediment types.

7.12.6 The maximum distance and as such the overall spatial extent that any resultant plume might be reasonably experienced can be estimated as the spring tidal excursion distance. Any location beyond the tidal excursion distance is unlikely to experience any measurable change in SSC from a sediment plume. Given the temporary nature of the sediment disturbance, any impacts are also anticipated to be short-lived, with any deposited material likely to be re-worked on subsequent tides. Further discussion on the predicted impacts from each of the seabed disturbance activities is provided in following sections.

7.12.7 The tidal excursion distance is the approximate distance over which water (or a section of plume with elevated SSC) is advected during one flood or ebb tide. The tidal excursion distance will vary in relation to the peak current speed on a given tide. Therefore, this distance may be smaller than shown during the smaller than average spring, intermediate and neap conditions, and only very occasionally may be larger than shown during larger than average spring conditions. The high spring and low neap model scenarios provided below represent the top and bottom 0.5% of current speeds, with events exceeded approximately three times per year.

7.12.8 The path followed by a tidal ellipse is not the same on every tide. As such, it is unlikely that the same seabed area will be affected by the higher SSC more localised plume, for more than one or two consecutive tides. Consequential deposition areas are also unlikely to be affected by deposition from suspended material over more than one or two tides.

7.12.9 Any disturbed sediment will be transported away from the activity at a faster rate during spring tidal conditions. As such, the sediment mass will be dispersed over a larger area and water volume which consequentially results in the plume SSC having a relatively lower concentration than on a comparable neap tide.

7.12.10 The plume's limited width/footprint is such that specific locations will only be affected by an increased SSC for the limited duration it takes for the plume to be advected past by the tide. Discrete areas of larger depths of deposited sediments are considered to be over-predicted in the numerical model given the 200m spatial resolution within the array.

7.12.11 If multiple activities causing sediment disturbance (such as dredging, drilling or cable installation) are undertaken simultaneously at two or more locations that are aligned in relation to the ambient tidal streams, the areas affected (either by change in SSC or sediment deposition) may potentially overlap. The change in SSC in areas of overlap will be additive if the downstream activity occurs within the area of effect from upstream (i.e. sediment is disturbed within the sediment plume from the upstream location). The change in SSC will not be additive (i.e. the effects will be as described for single occurrences only) if the areas of effect only meet or overlap downstream following advection or dispersion of the effects. Effects on sediment deposition will be additive if and where the footprints of the deposits overlap.

Mass Flow Excavation

7.12.12 The main cable installation methodologies available are described in Volume 1, Chapter 3. As outlined in Table 7.3, the use of MFE is considered to represent the realistic worst case scenario in terms of displacing sediment into the water column. It has been conservatively assumed that the MFE option will hydraulically force 100% (spill factor) of the trenched sediment into suspension to a height of around 2m above the seabed, with the fastest trenching rate of 300m/hr representing the highest sediment release rate. Full details of the assumptions and parameters used in the modelling scenario are provided in Volume 2, Appendix 7.2. The values below have been determined based on the observed advection of the plume features in the sediment plume model results, and are in turn based on a realistic, indicative turbine layout.

7.12.13 For this release scenario, for the installation of inter-array cables over a period of around seven hours (based on the distance between two indicative WTGs at the fastest trenching rate) with a continuous release of fine sediments, it is shown that:

- The sediment releases associated with these activities result in a long, relatively thin plume extending downstream from the point of active disturbance, particularly during high current speeds as shown in Figure 7.11. Where the source is moving, the path of active disturbance in the simulation period is visible in the results images as a line of higher maximum instantaneous SSC;
- During high current speed conditions (Figure 7.11), the disturbed sediment is carried away from the working area at a faster rate, dispersing the sediment mass over a larger area and water volume, and so the resulting SSC in the plume is relatively lower than during low current speed conditions (Figure 7.12);
- SSC resulting from the disturbance of all sediment types located at any one location can be expected to be very high at, and in the immediate locality of, the MFE activities. Immediately adjacent to, and within several metres of the activity, SSC can be expected to be millions of mg/l or more (CIRIA, 2000). Of note is that the effect is very localised and of very short (temporary) duration;
- The sediment suspended in the plume will be continually deposited, re-suspended and dispersed in response to the magnitude of the tidal regime. The SSC is expected to reduce to hundreds of mg/l within tens to low hundreds of metres. These detailed near-field processes are only relatively coarsely resolved in the model (at a resolution of 200m);
- During the first half of the tidal cycle (~six hours), the plume width will increase through dispersion to between 500 and 2000m, all sediments sand-sized and larger will have re-settled to the seabed. The plume may extend up to 12km from the MFE activity location, although SSC will reduce to below 50mg/l within approximately 1km to 2km (see Figure 7.11); and
- After 15 hours, the SSC will have reduced to below 50mg/l, with fine sediments widely dispersed to nominal concentrations. After 20 hours (~one full tidal cycle after the cessation of MFE activities), SSC will have reduced to below 5mg/l, with no measurable SSC during peak high current speed conditions (as in Figure 7.11).

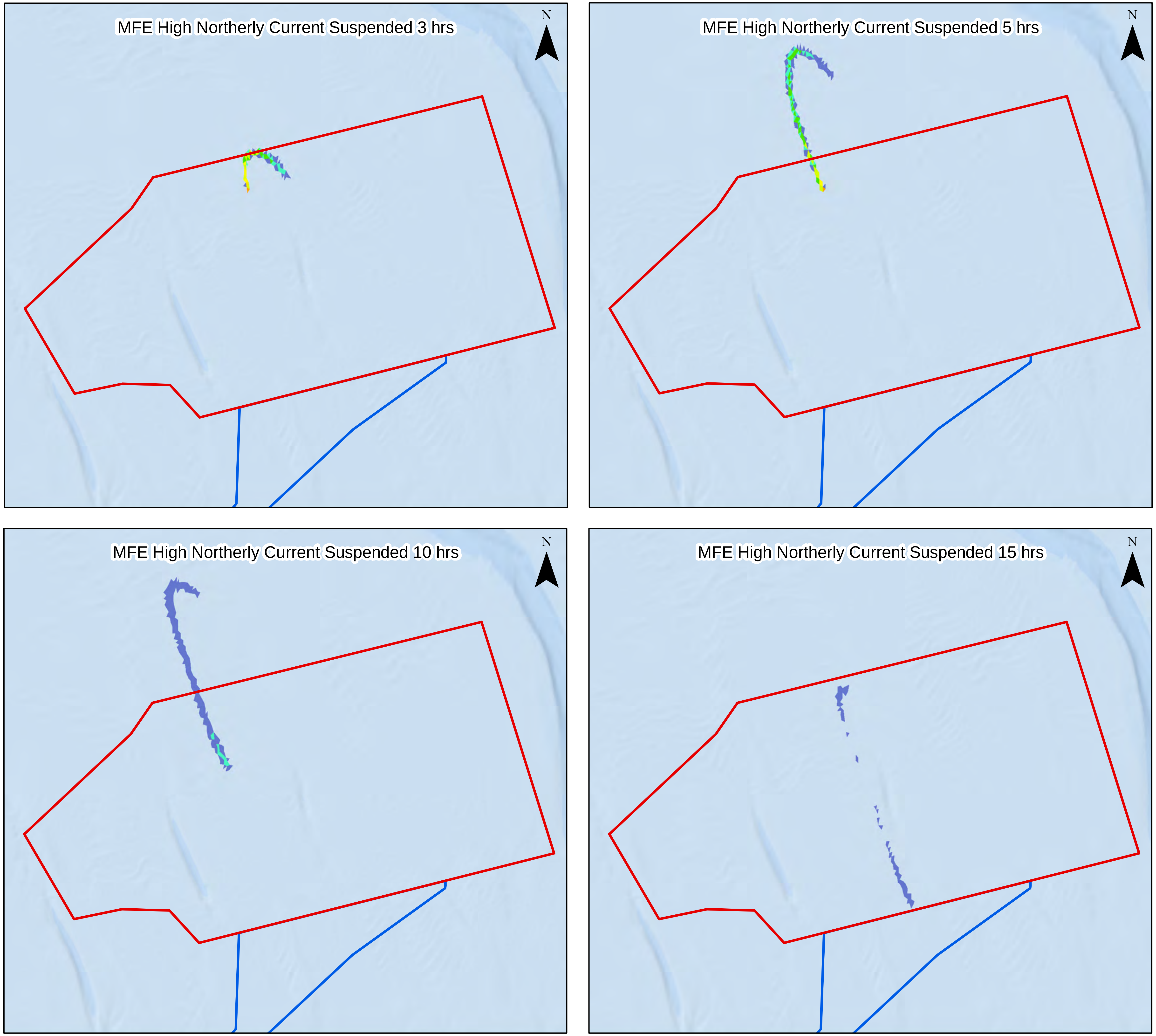
7.12.14 The deposition resulting from the seabed disturbance by the MFE project activities within the array area is shown in Figure 7.13, for both flood and ebb tides under high and low current scenarios. The numerical modelling indicates that:

- The coarser (sand/gravel) sediment will settle to the seabed relatively quickly (of the order of seconds to less than two minutes) following its release into the water column (further detail regarding the settling characteristics within the array are provided in Volume 2, Appendix 7.2);
- Sediment deposition of up to 50mm is expected in the vicinity of the active disturbance, visible in the results as a line of higher maximum deposition up to approximately 400m wide and 2km long. Deposition of finer sediment fractions is expected from the advected plume settling out of suspension, with thicknesses between 5 and 20mm deposited up to 600m away from the active disturbance area. Deposition thicknesses of between 1mm and 5mm are predicted to occur downstream of the disturbance, representing the advection of finer sediment fractions, particularly during spring tidal conditions. These thicknesses extend generally between 0.5km to 1km from the MFE activities, although they may occur up to 3km (as shown in Figure 7.13);
- Sediment accumulation of less than 1mm will not be measurable in practice and would not result in a change of sediment type. Of note is that the model does not include re-suspension. In reality, any fine sediments which are deposited will be re-suspended and dispersed further during subsequent tides; and
- The greatest deposition thicknesses are predicted to occur immediately adjacent to the project activities and given that deposition occurs on the seabed next to which the disturbance occurs will not result in a change in the seabed sediment characteristics.

7.12.15 The use of MFE is also considered to represent the realistic worst case scenario for the installation of the export cable. Numerical modelling results for MFE activities in the ECC are presented in Figure 7.14 and Figure 7.15 and it is shown that:

- The behaviour of sediment releases is comparable to those for MFE activities in the array area, with a long, relatively thin plume extending downstream from the point of active disturbance. As outlined in Paragraph 7.12.13, SSC within several meters of the activity will be highly elevated, although this effect is localised and temporary; and
- Within the first five hours, the plume width will increase through dispersion to approximately between 500m and 1500m, extending during this period only up to 20km from the MFE activity location. SSC reduces to below 150mg/l within 1.5km (see Figure 7.14). SSC will reduce to below 10mg/l after 15 hours, and below 5mg/l after 20 hours.

7.12.16 The deposition resulting from the seabed disturbance by the MFE project activities along the Offshore ECC is shown in Figure 7.15, for both flood and ebb tides under high and low current scenarios. Sediment deposition of up to 150mm may occur within several hundred meters of the active disturbance, reducing to below 20mm approximately 1km away. During spring tidal conditions deposition may occur up to 4km away from the active disturbance, although this is less than 5mm.

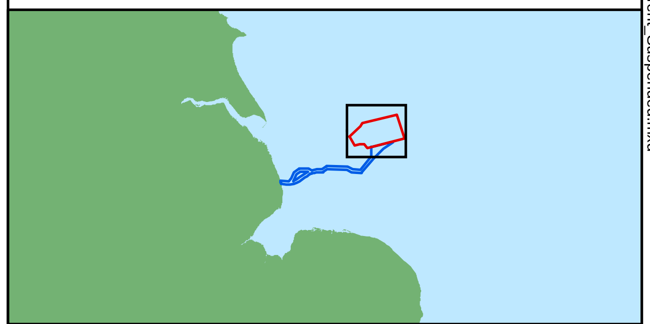


Legend

- Array Area
- Offshore Export Cable Corridor

Suspended sediment concentrations (mg/l)

- 1 - 4.99
- 5 - 9.99
- 10 - 19.99
- 20 - 49.99
- 50 - 99.99
- 100 - 149.99
- 150 - 249.99
- 250 - 499.99
- 500 - 999.99
- <1000



Coordinate System: WGS 1984 UTM Zone 31N

0 5 10 km

Scale: 1:250,000

Preliminary Environmental Information Report

Suspended sediment concentrations 3, 5, 10 and 15 hours after the start of Mass Flow Excavator activities within the Project array area during a high spring ebb tide

Figure 7.11

OUTER DOWSING OFFSHORE WIND

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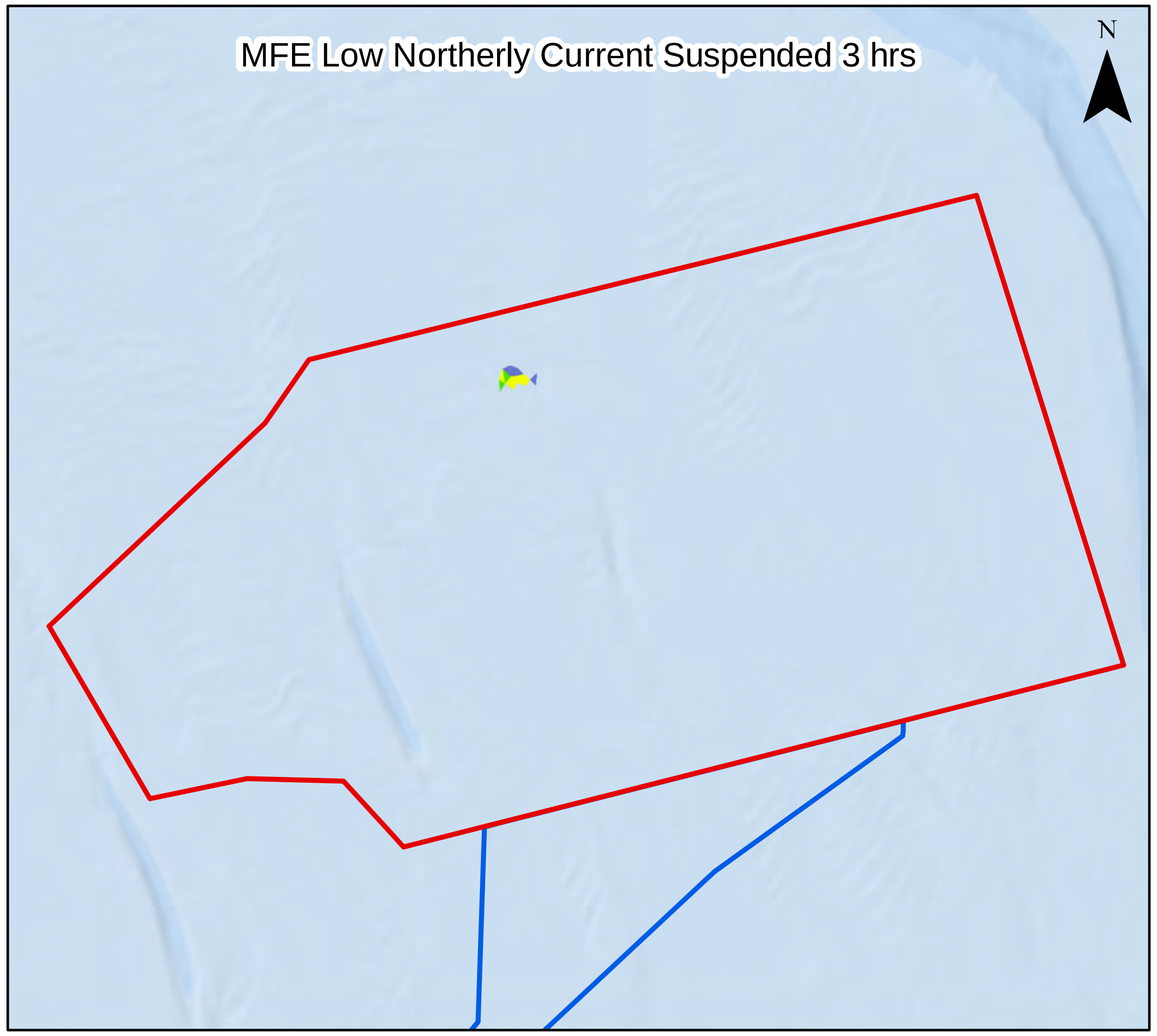
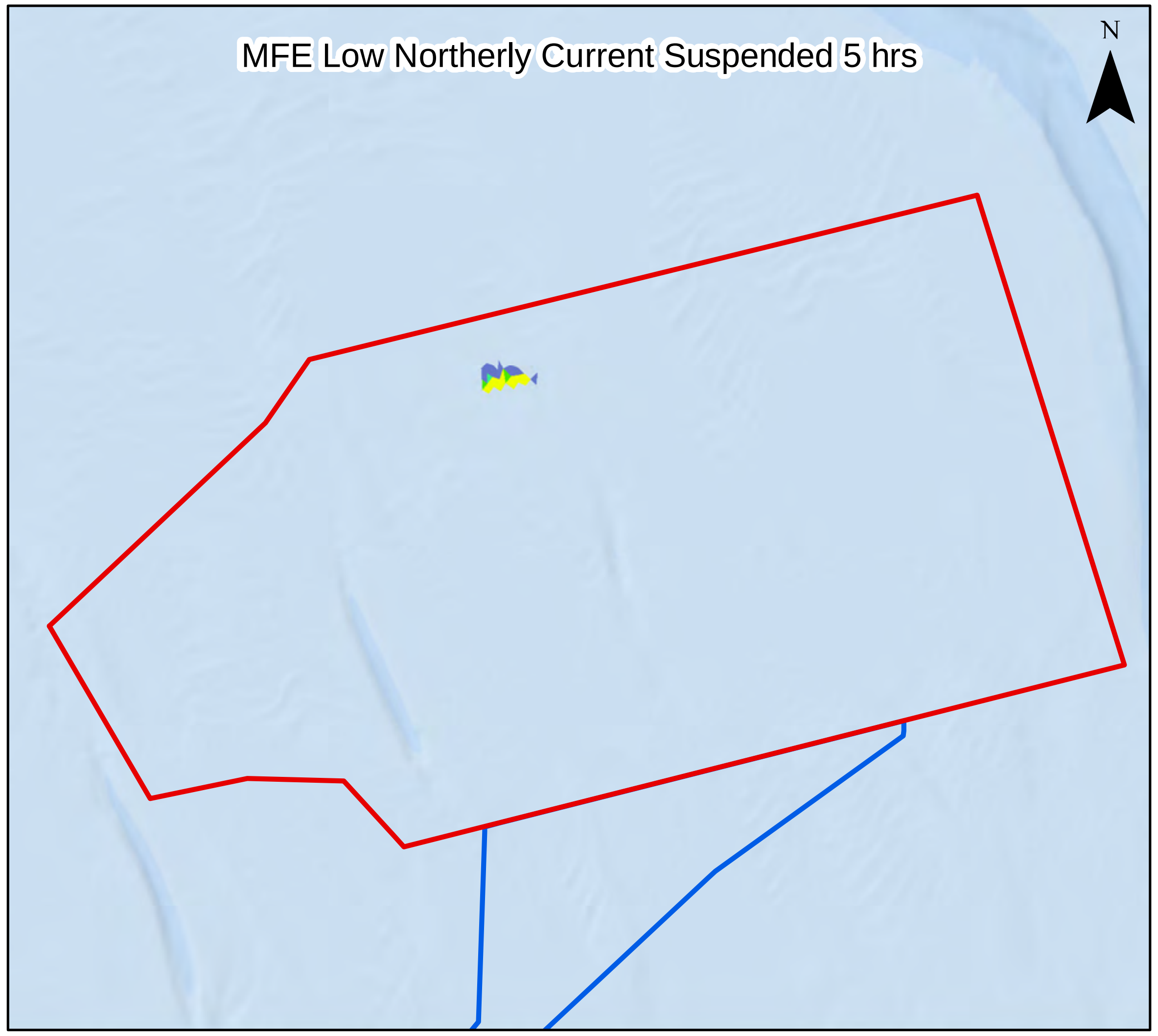
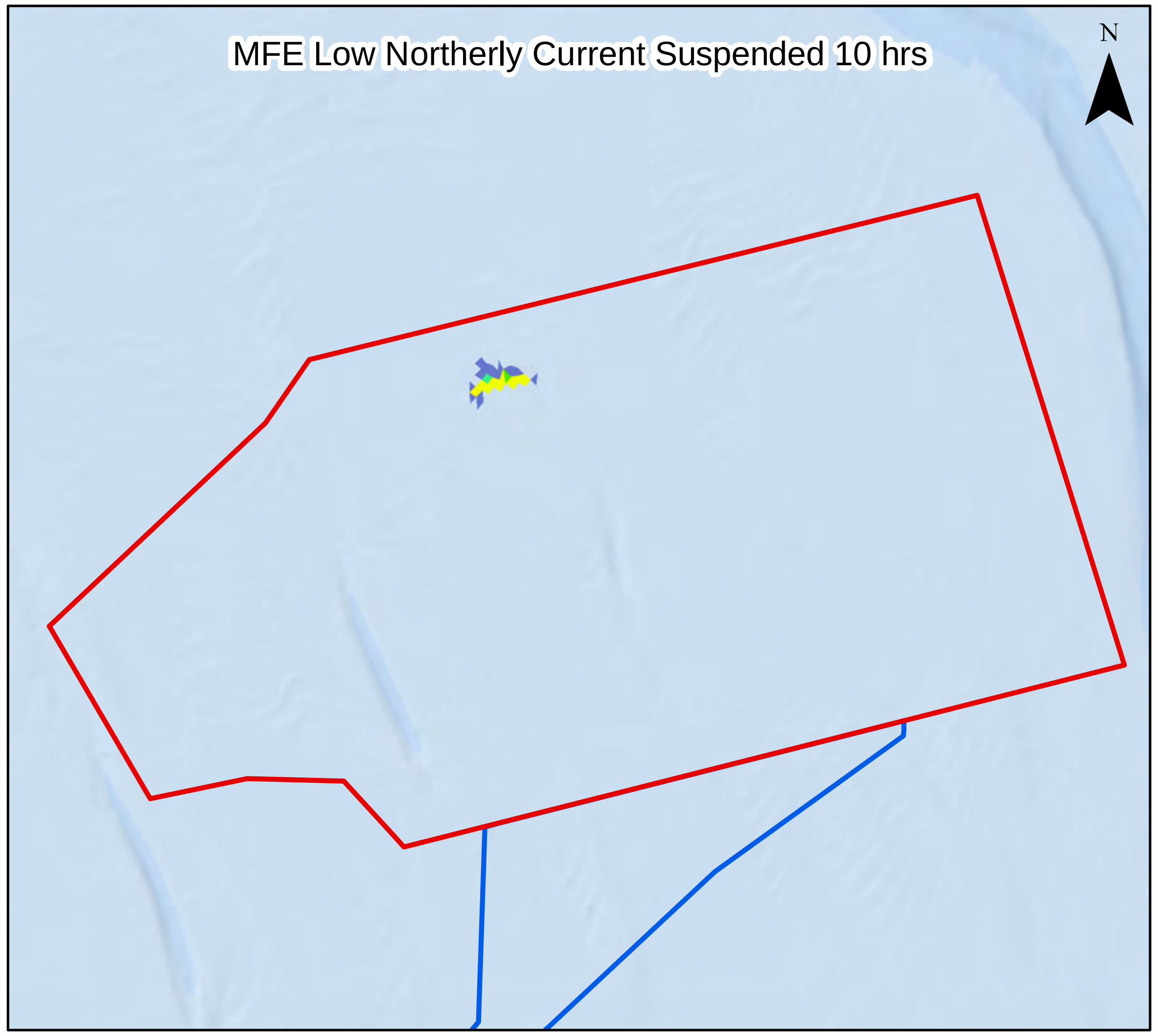
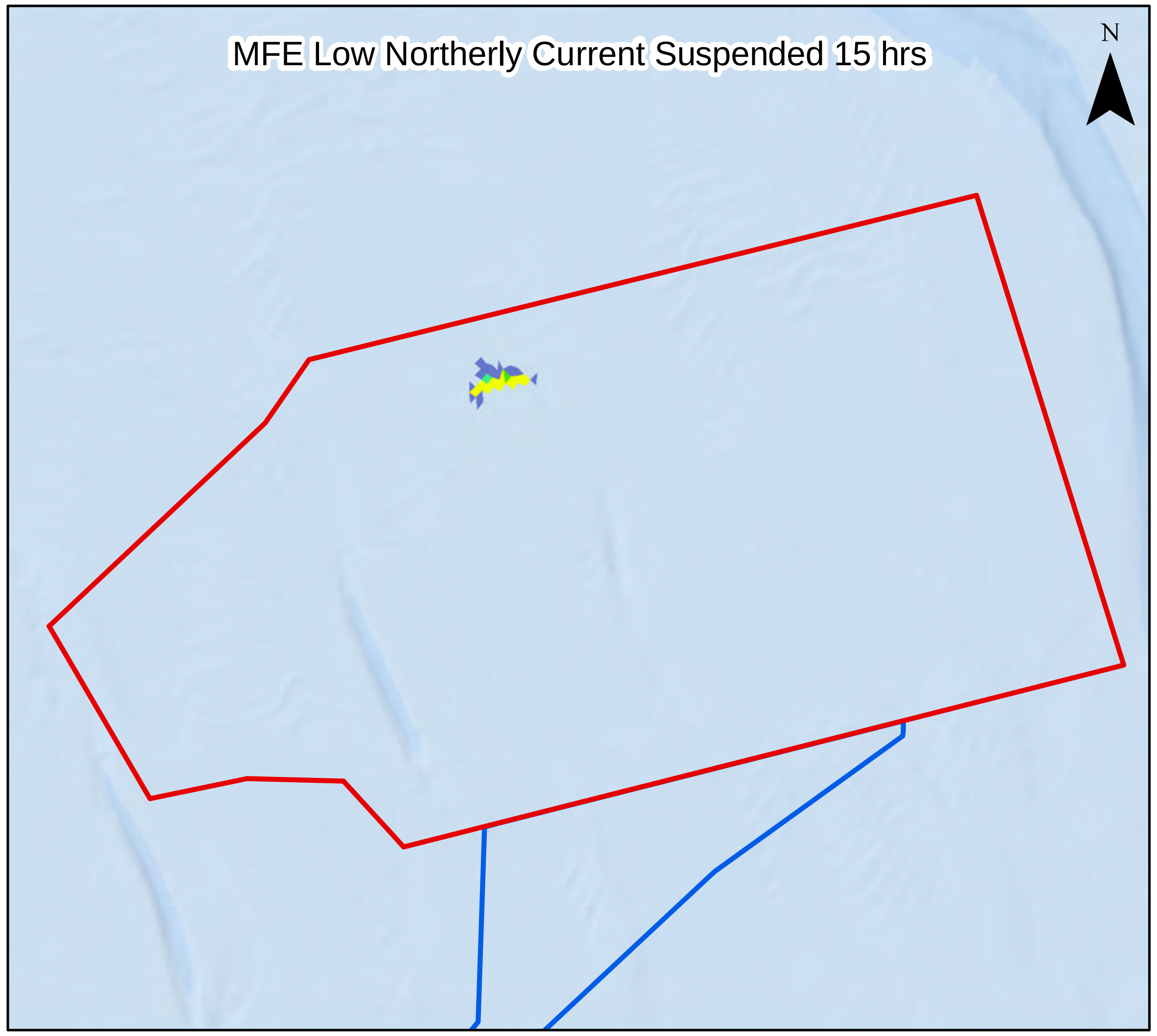






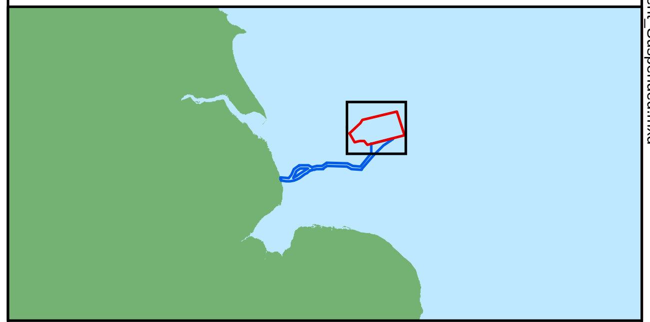


Legend

- Array Area
- Offshore Export Cable Corridor

Deposited Sediment (mm)

- 1 - 4.99
- 5 - 9.99
- 10 - 19.99
- 20 - 49.99
- 50 - 99.99
- 100 - 149.99
- 150 - 249.99
- 250 - 499.99
- >500



Coordinate System: WGS 1984 UTM Zone 31N

0 5 10 km

Scale: 1:250,000

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Suspended sediment concentrations 3, 5, 10 and 15 hours after the start of Mass Flow Excavator activities within the Project array area during a low neap ebb tide

Figure 7.12

OUTER DOWSING OFFSHORE WIND

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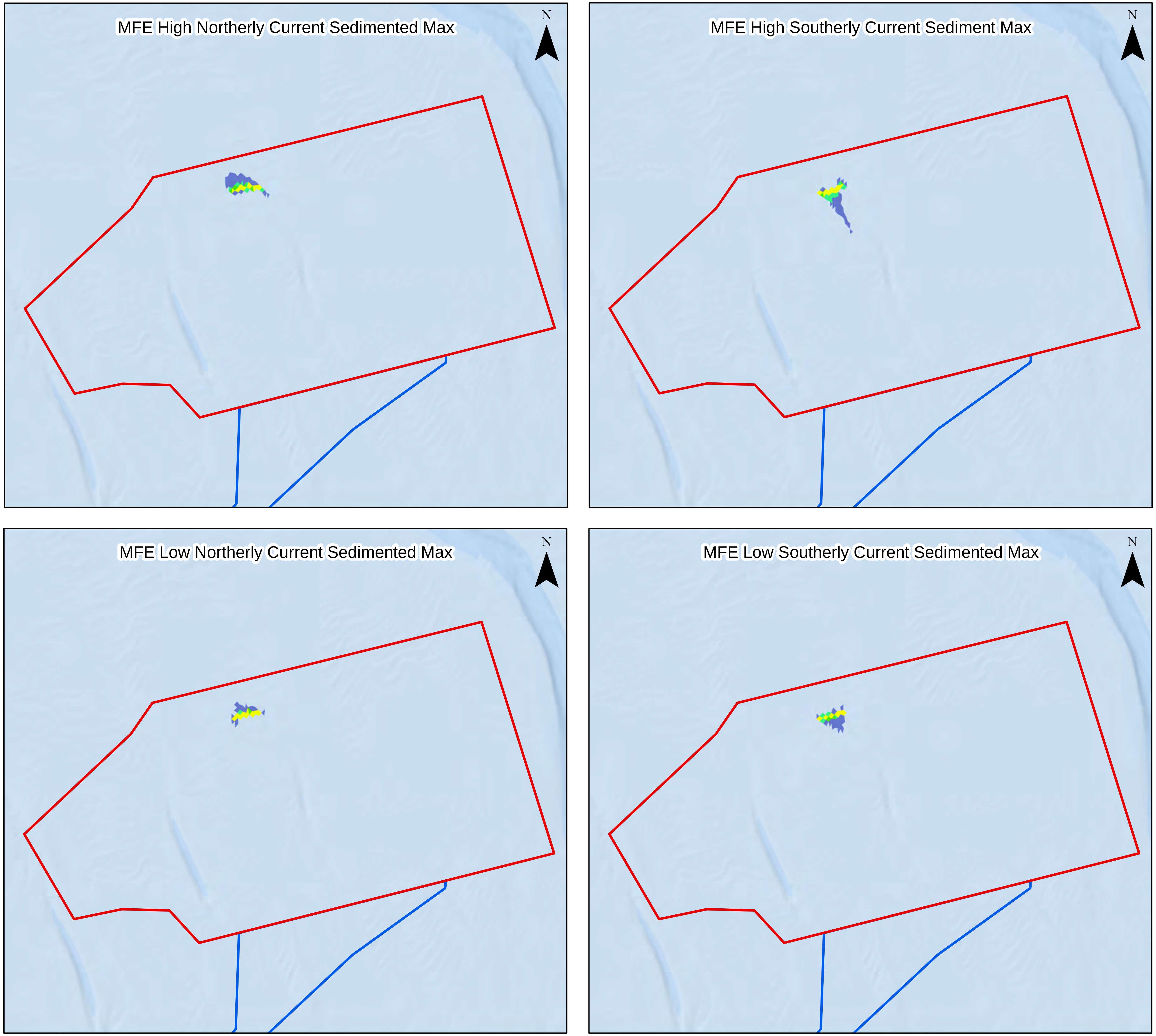
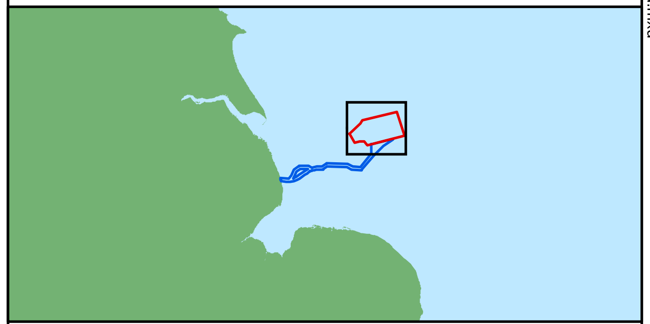


Legend

- Array Area
- Offshore Export Cable Corridor

Deposited Sediment (mm)

- 1 - 4.99
- 5 - 9.99
- 10 - 19.99
- 20 - 49.99
- 50 - 99.99
- 100 - 149.99
- 150 - 249.99
- 250 - 499.99
- >500



Coordinate System: WGS 1984 UTM Zone 31N

0 5 10 km

Scale: 1:250,000

Preliminary Environmental Information Report

Maximum sediment deposition 20 hours after the start of Mass Flow Excavator activities within the Project array area, for a range of tidal conditions

Figure 7.13

OUTER DOWSING OFFSHORE WIND

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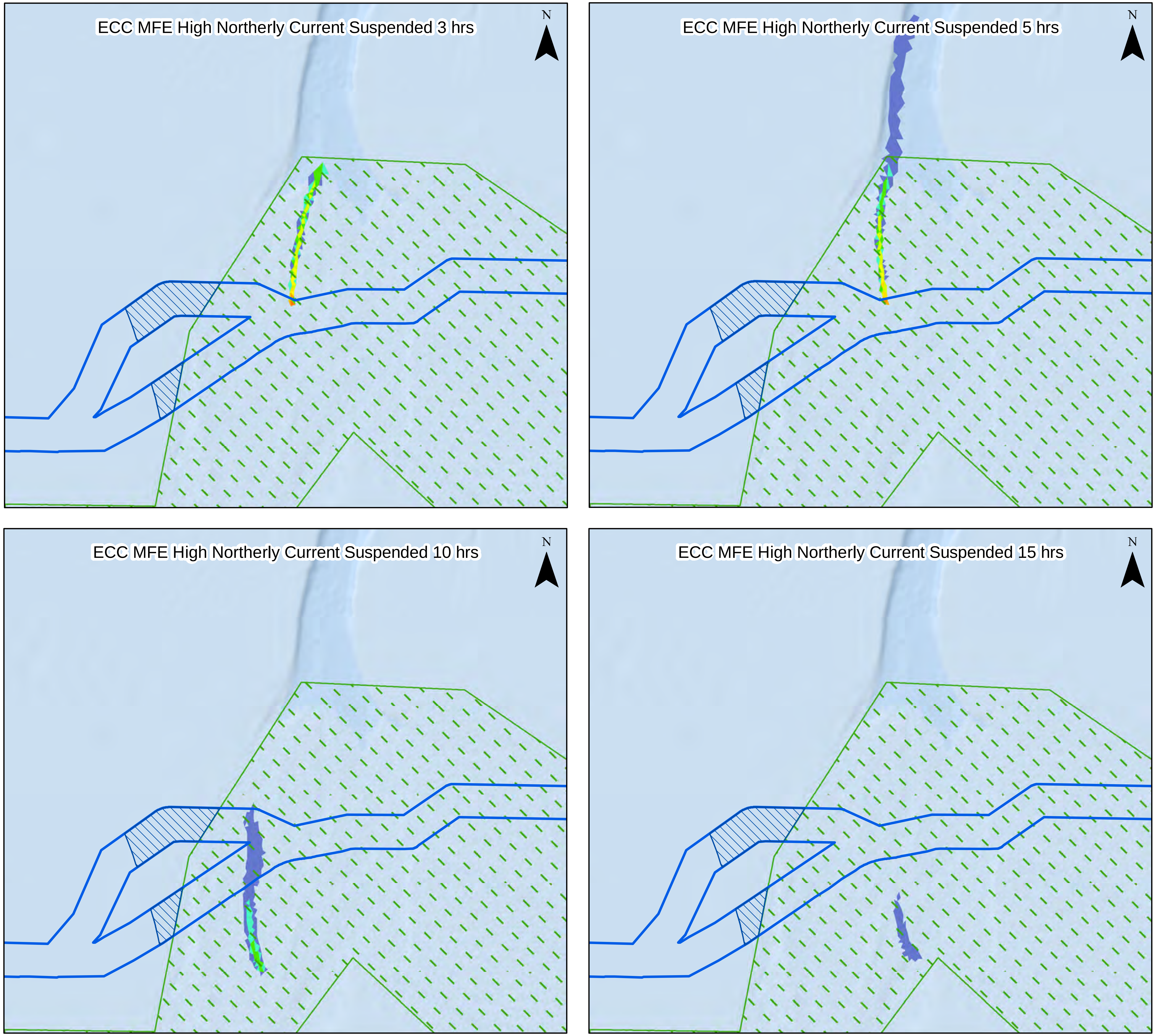
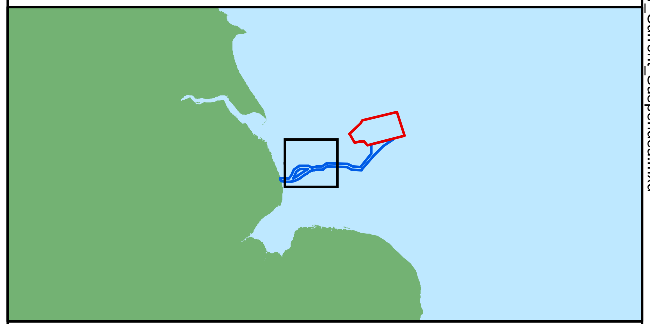


Legend

- Array Area
- Offshore Export Cable Corridor
- ORCP Search Area
- Special Areas of Conservation

Suspended sediment concentrations (mg/l)

- 1 - 4.99
- 5 - 9.99
- 10 - 19.99
- 20 - 49.99
- 50 - 99.99
- 100 - 149.99
- 150 - 249.99
- 250 - 499.99
- 500 - 999.99
- <1000



Coordinate System: WGS 1984 UTM Zone 31N

0 5 10 km

Scale: 1:225,000

Preliminary Environmental Information Report

Suspended sediment concentrations 3, 5, 10 and 15 hours after the start of Mass Flow Excavator activities along the offshore ECC during a high spring ebb tide

Figure 7.14

OUTER DOWSING OFFSHORE WIND

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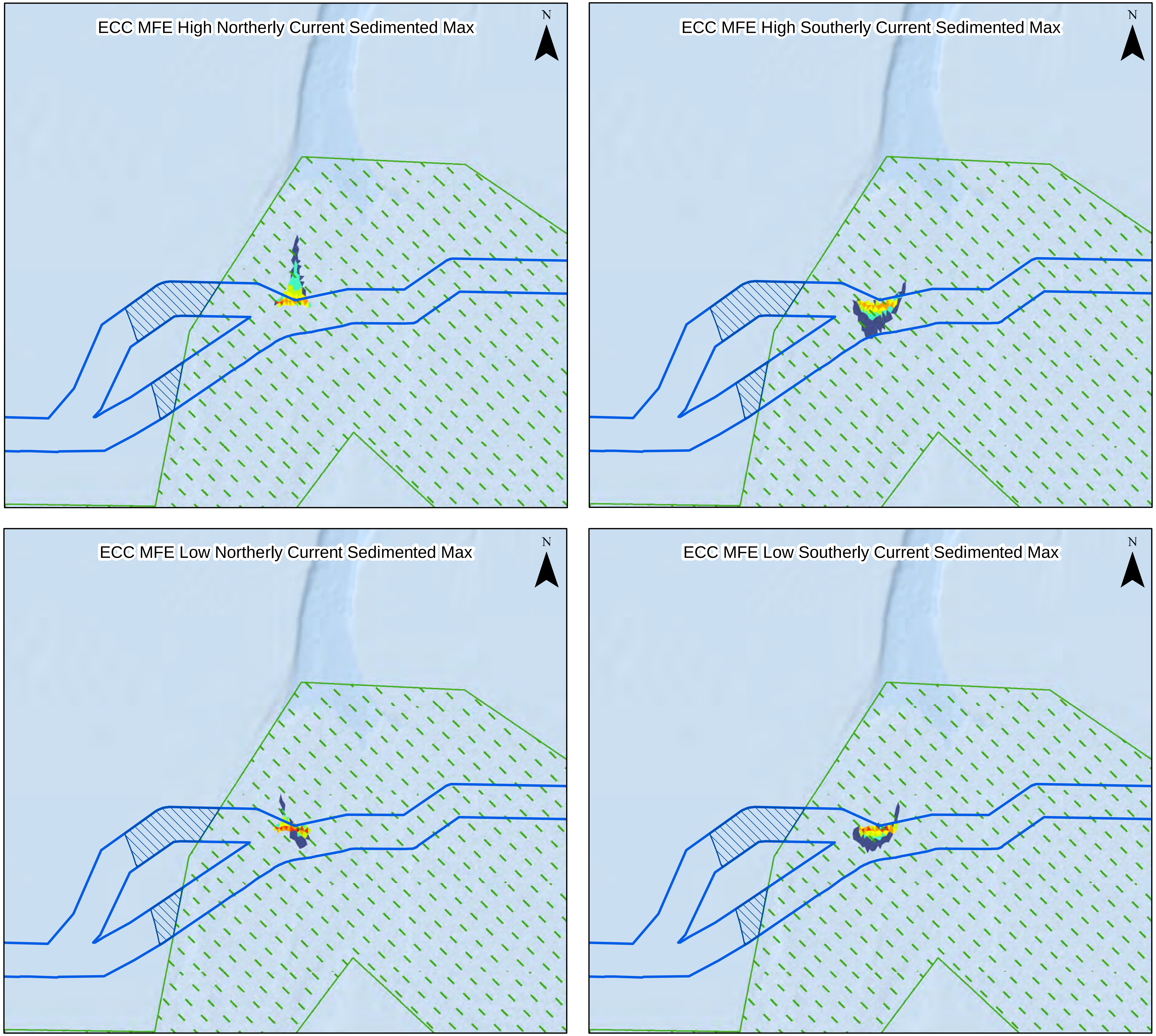
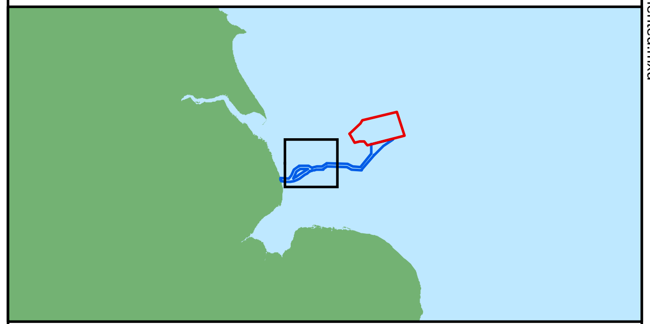


Legend

- Array Area
- Offshore Export Cable Corridor
- ORCP Search Area
- Special Areas of Conservation

Deposited Sediment (mm)

- 1 - 4.99
- 5 - 9.99
- 10 - 19.99
- 20 - 49.99
- 50 - 99.99
- 100 - 149.99
- >150



Coordinate System: WGS 1984 UTM Zone 31N

0 5 10 km

Scale: 1:225,000

Preliminary Environmental Information Report

Maximum sediment deposition 20 hours after the start of Mass Flow Excavator activities along the offshore ECC, for a range of tidal conditions

Figure 7.15

OUTER DOWSING OFFSHORE WIND

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Seabed Levelling and Sandwave Clearance

7.12.17 Seabed preparation may be required prior to the installation of the Project infrastructure. This is likely to include seabed levelling, which will be required around specific foundation types that need to be placed onto a flat seabed, such as Gravity Base Structures (GBS), as well as for areas of scour protection where required. In addition, sandwave clearance (the removal of sections of mobile bedforms) may be necessary for cable installation activities in order to ensure effective cable burial below the level of the stable bed. The MDS for these activities are outlined in Table 7.3 (and characterised fully in Volume 1, Chapter 3), with the full details of the assumptions made in each model scenario provided in Volume 2, Appendix 7.2.

7.12.18 The largest sediment volume likely to be removed for seabed levelling within the array area is around 3,670,000m^3, to be excavated using a TSHD with an assumed hopper volume of 15,000m^3. Whilst the hopper is being filled, overspill is likely to develop a near-surface sediment plume composed primarily of fine sediments. Once each hopper is filled, dredged material (spoil) will be returned to the seabed in the middle of the four adjacent foundations as a relatively sudden release from under the vessel (i.e. at the water surface).

7.12.19 Once the dredger moves to discharge a full hopper load, the majority of the finer sediments are expected to have already been lost to overspill, although this will vary based on the sediment type and filling rate. During spoil disposal, sediments will be discharged as a highly turbid dynamic plume, with the coarser sediment fraction falling quickly to the seabed (on timescales of minutes to tens of minutes) with limited opportunity to be advected away by tidal currents, leading to a correspondingly greater localised depth of accumulation on the seabed. An assessment of spoil mounds formed by the dynamic phase of the plume is presented in Paragraph 7.12.45 *et seq*., and detailed in Volume 2, Appendix 7.2. Finer sediments in the spoil will remain in suspension for longer (up to around a day), forming a passive plume which will then be advected by tidal currents.

7.12.20 Numerical modelling results for seabed levelling activities in the array area are provided in Figure 7.16 and Figure 7.17 and can be summarised as follows:

- In the first four hours, SSC up to 5000mg/l is present within several hundred metres of the activity, reducing to below 1000mg/l within approximately 1km. The plume of elevated SSC may be advected by the tide up to 5km away during spring tides, with concentrations up to 500mg/l;
- After five hours, a narrow, roughly continuous plume up to 1.5km wide and 5km long has been advected away from original point of activity by between 500m and 3km, with SSC ranging between, approximately, 50mg/l and 250mg/l, although concentrations may locally reach up to 5,000mg/l (Figure 7.16);
- The plume continues to be dispersed and advected along the axis of tidal flow, reducing to below 50mg/l after 15 hours and below 20mg/l after 20 hours. Although there is the potential for elevated SSC to be advected up to 18km away from the release point, concentrations are low; and

- Sediment deposition is high in the vicinity of the active disturbance, with accumulation depths and areas of deposition provided in the assessment of spoil mounds in Paragraph 7.12.46 and Volume 2, Appendix 7.2. Deposition from the passive phase of the plume is shown on Figure 7.17, with sediment thicknesses of between 10mm and 100mm deposited within several hundred metres of the active disturbance. Beyond this sediment deposition reduces to less than 20mm. The majority of deposition occurring more than 1km away is between 1mm and 10mm. More than 5km away, no measurable deposition can be identified.

7.12.21 The largest total volume of sandwave clearance within the array area is estimated to be 13,672,800m^3, representing around 60% of cables. The disposal of the dredged sediment back to the seabed will take place at a nearby location within the PEIR boundary and in a similar sedimentary environment. Numerical modelling results for sandwave clearance activities in the array area are provided in Figure 7.18 and Figure 7.19 and can be summarised as follows:

- Due to the variation in sediment release over time (relating to the different dredging phases) elevated SSC forms separate plumes as shown in Figure 7.18, which are advected along the axis of tidal flow and disperse in succession during spring tidal conditions. During neap tidal conditions, these plumes are more likely to combine, resulting in higher SSC over a smaller distance;
- Within the first five hours, SSC between approximately 20mg/l and 1000mg/l is present within approximately 1km of the activity, although concentrations may reach 2500mg/l. This reduces to between approximately 5mg/l to 150 mg/l up to approximately 3km away, with concentrations between 1mg/l and 10mg/l advected up to 10km away during spring tides. After 20 hours, SSC at all points will be less than 50mg/l, with the majority between 1mg/l and 20mg/l. Increased SSC may be advected up to 20km away, although these concentrations are generally low; and
- Sediment deposition is high in the vicinity of the active disturbance, with accumulation depths and areas of deposition provided in the assessment of spoil mounds in Paragraph 7.12.46. Deposition from the passive phase of the plume is shown on Figure 7.19, with sediment thicknesses of between 20mm and 250mm deposited within several hundred metres of the active disturbance. Beyond this sediment deposition reduces to less than 50mm, and measurable deposition may reach up to 3km away. The majority of deposition more than 1km away from the disturbance site is between 1mm and 10mm, although in some locations may reach 50mm. More than 3km away, no measurable deposition can be identified.

7.12.22 The largest volume of sandwave clearance for up to four export cables is 7,413,120m^3, representing around 30% of the total length. The disposal of the dredged sediment back to the seabed will take place at a nearby location within the PEIR boundary. Numerical modelling results for sandwave clearance activities along the Offshore ECC are provided in Figure 7.20 to Figure 7.22 and can be summarised as follows:

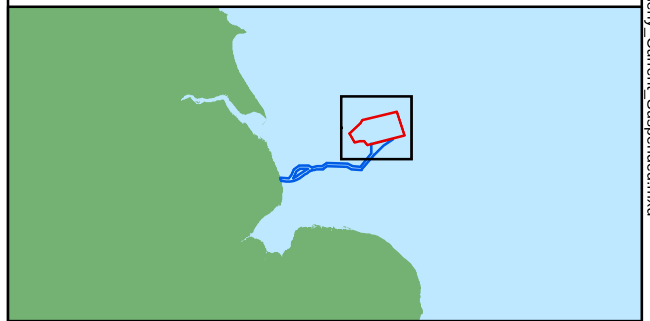
- Within the first five hours, SSC between approximately 150mg/l and 500mg/l is present within approximately 3km of the activity, although concentrations may reach 2,500mg/l (Figure 7.20 and Figure 7.21). This reduces to between approximately 10mg/l to 100 mg/l up to approximately 5km away, and advected up to 10km away during spring tides. Sediment plumes continue to disperse along the tidal axis, with SSC less than 5mg/l at all points after 20 hour; and
- Sediment deposition is high in the vicinity of the active disturbance, with accumulation depths and areas of deposition provided in the assessment of spoil mounds in Paragraph 7.12.46. Deposition from the passive phase of the plume is shown on Figure 7.22, with sediment thicknesses of between 20mm and 150mm deposited within approximately 500m of the active disturbance. Beyond this sediment deposition reduces to less than 50mm, and measurable deposition may reach up to 3km away. The majority of deposition more than 1km away from the disturbance site is between 1mm and 10mm, although some may reach up to 50mm. More than 3km away, no measurable deposition can be identified.

Legend

- Array Area
- Offshore Export Cable Corridor
- Special Areas of Conservation

Suspended Sediment Concentrations (mg/l)

- 1 - 4.99
- 5 - 9.99
- 10 - 19.99
- 20 - 49.99
- 50 - 99.99
- 100 - 149.99
- 150 - 249.99
- 250 - 499.99
- 500 - 999.99
- 1000 - 2499.99
- 2500 - 4999.99
- >5000



Coordinate System: WGS 1984 UTM Zone 31N

0 5 10 km

Scale: 1:300,000

Preliminary Environmental Information Report

Suspended sediment concentrations 3, 5, 10 and 15 hours after the start of Seabed Levelling activities within the Project array area during a high spring flood tide

Figure 7.16

OUTER DOWSING OFFSHORE WIND

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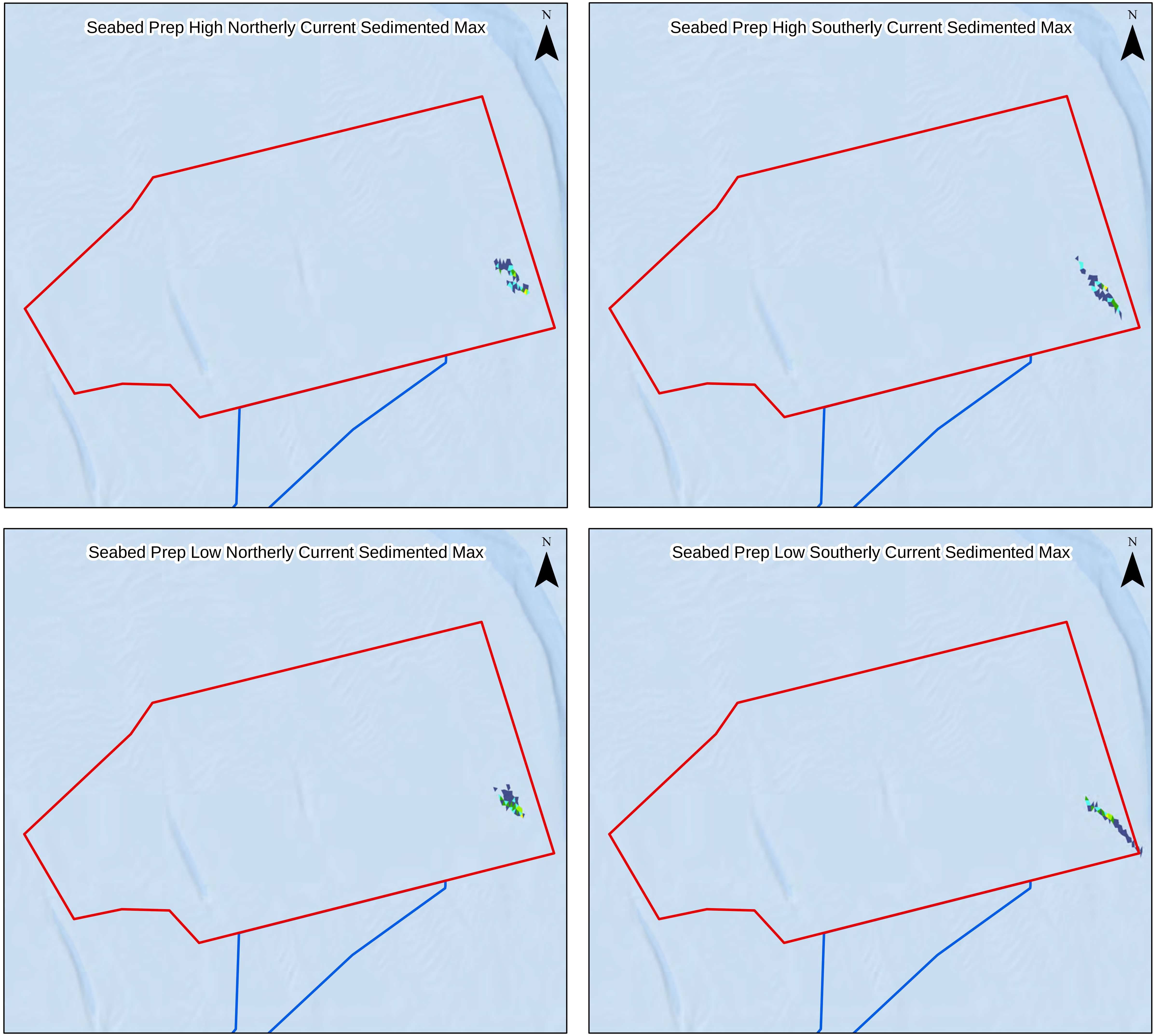
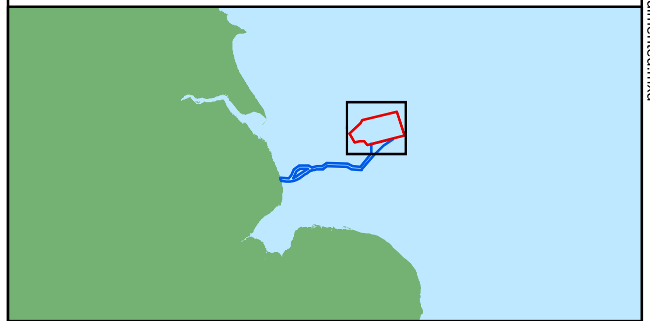


Legend

- Array Area
- Offshore Export Cable Corridor

Deposited sediment (mm)

- 1 - 4.99
- 5 - 9.99
- 10 - 19.99
- 20 - 49.99
- 50 - 99.99
- 100 - 149.99
- 150 - 249.99
- 250 - 499.99
- 500 - 749.99
- 750 - 999.99
- >1000



Coordinate System: WGS 1984 UTM Zone 31N

0 5 10 km

Scale: 1:250,000

Preliminary Environmental Information Report

Maximum sediment deposition 20 hours after the start of Seabed Levelling activities within the Project array area, for a range of tidal conditions

Figure 7.17

OUTER DOWSING OFFSHORE WIND

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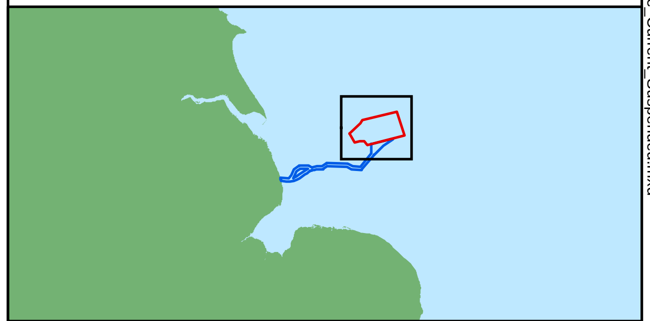
Legend

- Array Area
- Offshore Export Cable Corridor
- Special Areas of Conservation

Suspended sediment concentrations (mg/l)

- 1 - 4.99
- 5 - 9.99
- 10 - 19.99
- 20 - 49.99
- 50 - 99.99
- 100 - 149.99
- 150 - 249.99
- 250 - 499.99
- 500 - 999.99
- 1000 - 2449.99
- 2450 - 4999.99
- 5000 - 7499.99
- 7500 - 9999.99
- >10000



Coordinate System: WGS 1984 UTM Zone 31N

0 5 10 km

Scale: 1:300,000

Preliminary Environmental Information Report

Suspended sediment concentrations 3, 5, 10 and 15 hours after the start of Sandwave Clearance activities within the Project array area during a high spring ebb tide

Figure 7.18

OUTER DOWSING OFFSHORE WIND

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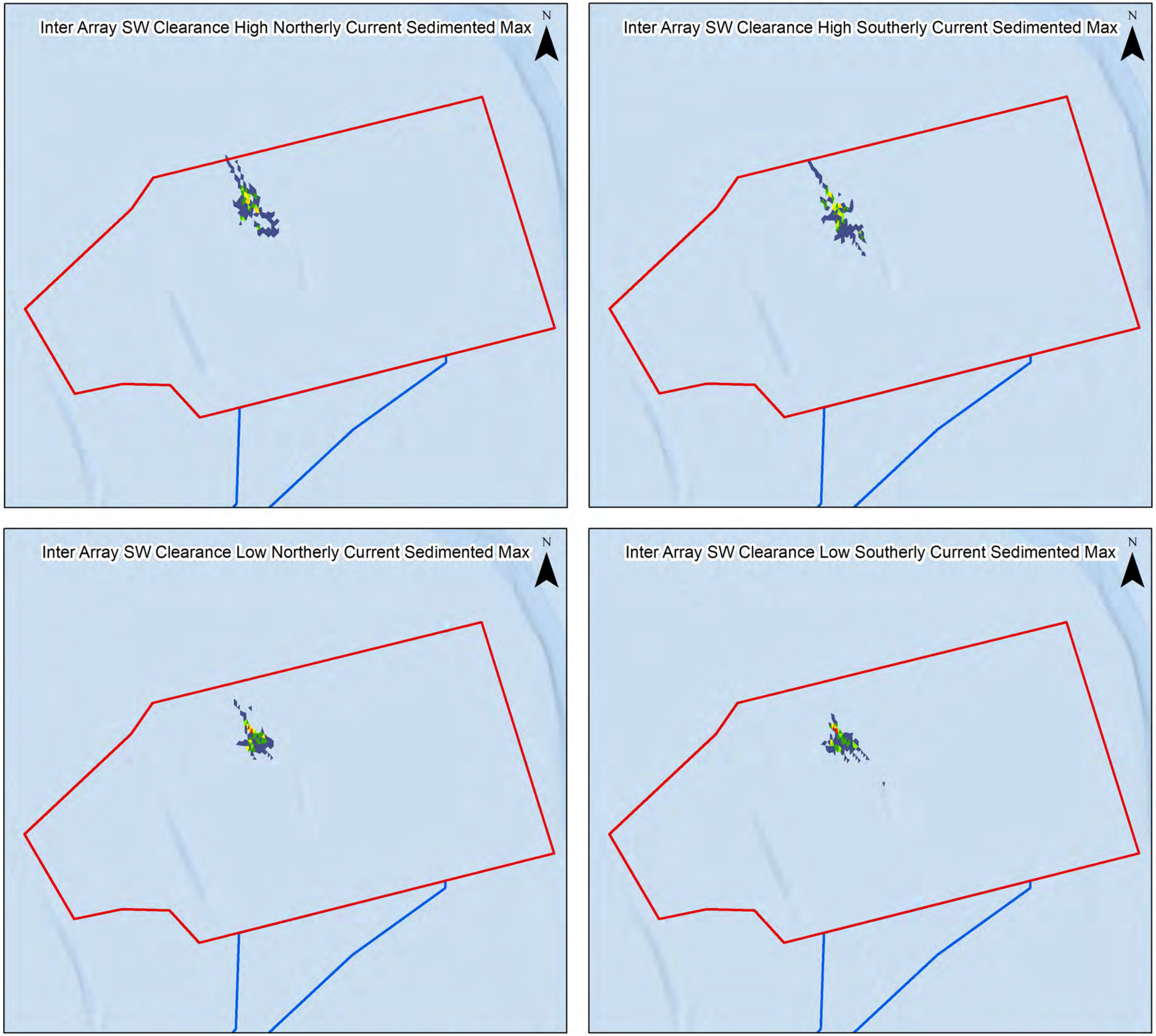

Legend

- Array Area
- Offshore Export Cable Corridor

Deposited sediment (mm)

- 1 - 4.99
- 5 - 9.99
- 10 - 19.99
- 20 - 49.99
- 50 - 99.99
- 100 - 149.99
- 150 - 249.99
- >250

Coordinate System: WGS 1984 UTM Zone 31N

0 5 10 km

Scale: 1:250,000

Preliminary Environmental Information Report

Maximum sediment deposition 20 hours after the start of Sandwave Clearance activities within the Project array area, for a range of tidal conditions

Figure 7.19

OUTER DOWSING OFFSHORE WIND

Date: 19/04/2023
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Revision: 0.1

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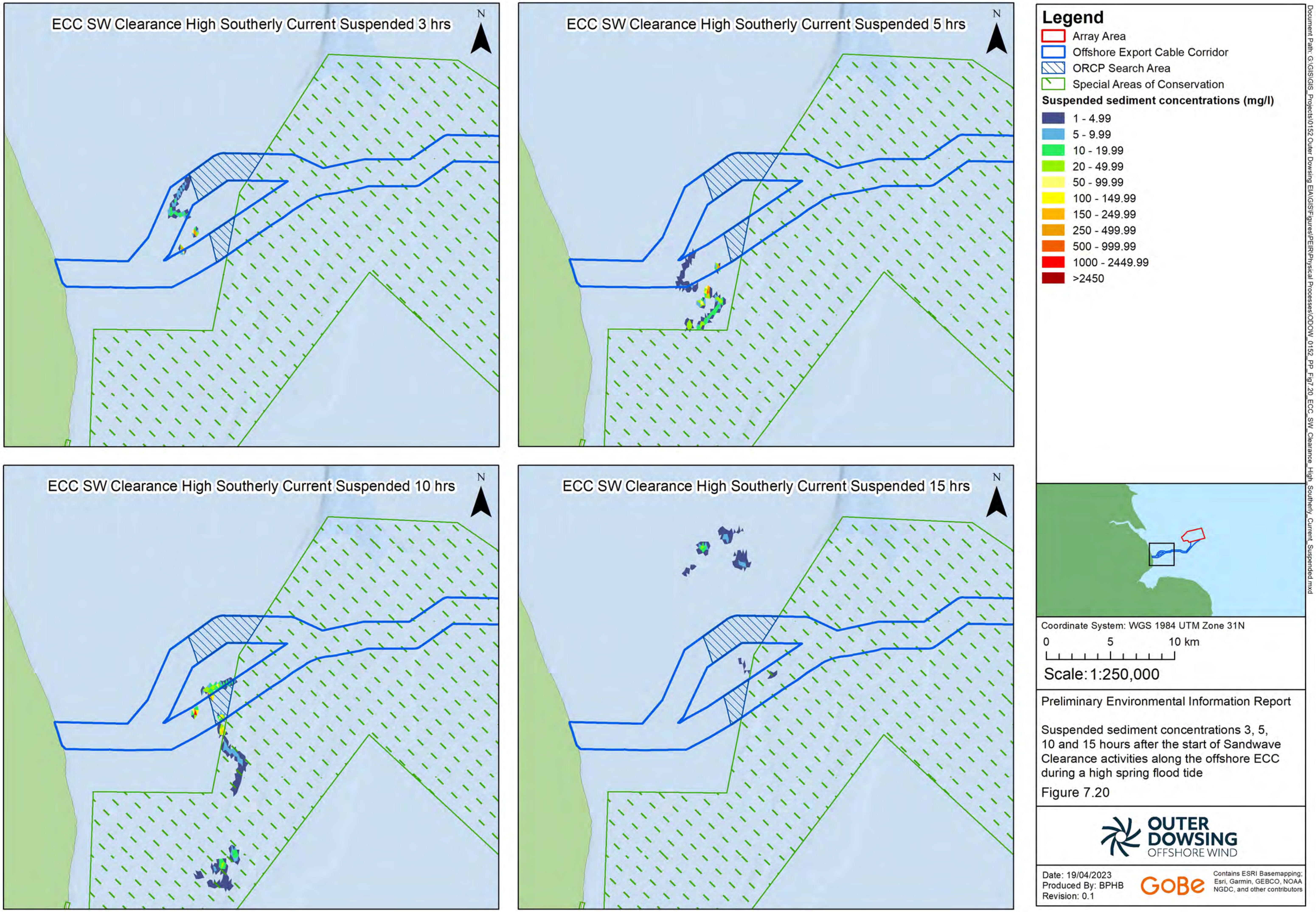

Preliminary Environmental Information Report

Suspended sediment concentrations 3, 5, 10 and 15 hours after the start of Sandwave Clearance activities along the offshore ECC during a high spring flood tide

Figure 7.20

OUTER DOWSING OFFSHORE WIND

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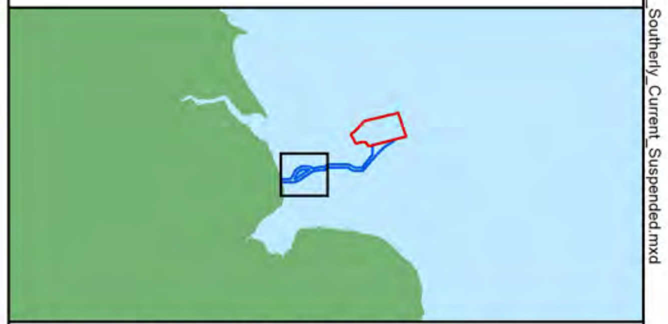
Legend

- Array Area
- Offshore Export Cable Corridor
- ORCP Search Area
- Special Areas of Conservation

Suspended sediment concentrations (mg/l)

- 1 - 4.99
- 5 - 9.99
- 10 - 19.99
- 20 - 49.99
- 50 - 99.99
- 100 - 149.99
- 150 - 249.99
- 250 - 499.99
- 500 - 999.99
- 1000 - 2449.99
- >2450



Coordinate System: WGS 1984 UTM Zone 31N

0 5 10 km

Scale: 1:200,000

Preliminary Environmental Information Report

Suspended sediment concentrations 3, 5, 10 and 15 hours after the start of Sandwave Clearance activities along the offshore ECC during a low neap flood tide

Figure 7.21

OUTER DOWSING OFFSHORE WIND

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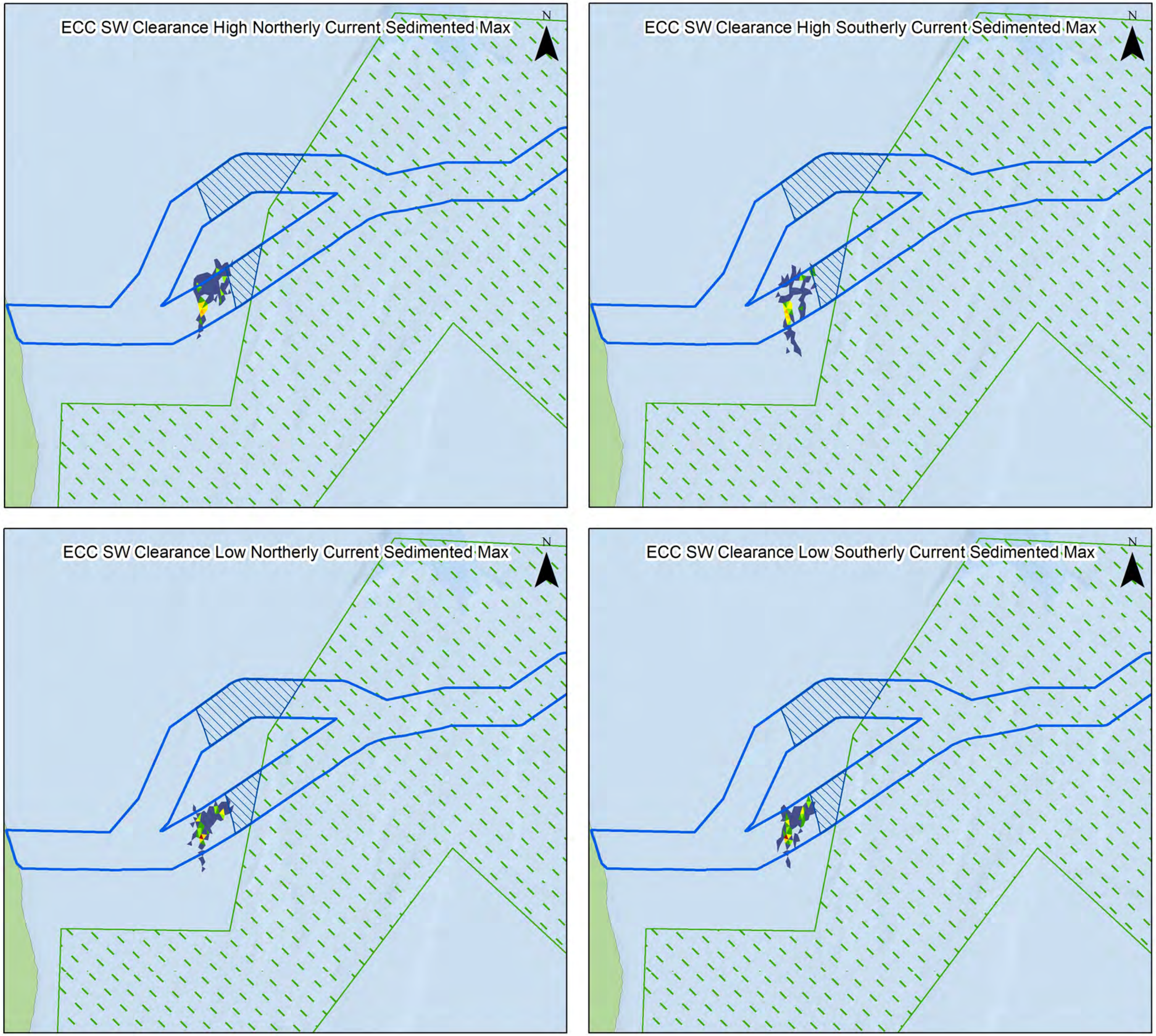

Legend

- Array Area
- Offshore Export Cable Corridor
- ORCP Search Area
- Special Areas of Conservation

Deposited sediment (mm)

- 1 - 4.99
- 5 - 9.99
- 10 - 19.99
- 20 - 49.99
- 50 - 99.99
- 100 - 149.99
- 150 - 249.99
- >250

Coordinate System: WGS 1984 UTM Zone 31N

0 5 10 km

Scale: 1:200,000

Preliminary Environmental Information Report

Maximum sediment deposition 20 hours after the start of Sandwave Clearance activities along the offshore ECC, for a range of tidal conditions

Figure 7.22

OUTER DOWSING OFFSHORE WIND

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Foundation Drilling

7.12.23 Monopile foundations and pin-piles will be installed into the seabed using standard piling techniques. In some locations, the particular geology may present some obstacle to piling, in which case, some or all of the seabed material might be drilled within the pile footprint to assist in the piling process. Around 50% of locations within the array area have been estimated to require drilling, the majority of which are located to the east of the array area. This has been assessed based on available geophysical information, further details of which are provided in Volume 2, Appendix 7.2.

7.12.24 The impact of drilling operations mainly relates to the release of drilling spoil at or above the water surface which will put sediment into suspension and the subsequent redeposition of that material to the seabed. The nature of the disturbance will be determined by the rate and total volume of material to be drilled, the seabed and sub-bottom material type, and the drilling method (affecting the texture and grain size distribution of the drill spoil).

7.12.25 Numerical modelling has simulated drilling at one location in the array area, lasting for approximately 55 hours. The realistic worst case scenario assumes that 50% of the drill cuttings are fine sediments which would be subject to wider dispersion as a sediment plume. The results can be summarised as follows:

- SSC resulting from foundation drilling is minimal, never exceeding 7.5mg/l and reducing to less than 2.5mg/l within hundreds of metres. SSC may be advected up to 2.5km away in low concentrations of less than 2.5mg/l. These concentrations are expected to occur for the full extent of the drilling works, approximately 55 hours, before dispersing. Considering the average near-bed turbidity measurements this change is likely to be indiscernible from background conditions; and
- Sediment deposition is shown in Figure 7.23. Deposition of up to 30mm is predicted within 100m of the foundation, reducing rapidly to below 5mm. The maximum extent of deposition is predicted to be less than 500m, with only thicknesses below 2mm identified at these distances. This effect is small-scale and highly localised, as well as occurring intermittently.

7.12.26 The evidence-base does not presently include many measurements of SSC resulting from drilling operations for monopile or pin-pile installation. This is due to the relatively small number of occasions that such works have been necessary. Evidence from the field is provided by the during- and post-construction monitoring of monopile installation using drill-drive methods into chalk at the Lynn and Inner Dowsing OWF (Centrica Renewable Energy Limited (CREL), 2008), located approximately 50km southwest of the Project. The monitoring was carried out due to the possibility of sub-surface chalk arisings leading to high levels of SSC of an atypical sediment type. The results of sediment trap monitoring were that chalk was not observed to collect in significant quantities. However, direct measurements of SSC were not possible during the drilling operations.

7.12.27 Observation of spoil mounds at the site indicated a relatively high, but localised pile of chalk and flint deposits, consisting primarily of pebble and cobble-sized clasts. The volume of the deposit was similar to the volume of the drilled hole, indicating that the majority of the total drill arisings volume had been deposited locally. Due to the generally large clast size of the drill arisings, they would be unlikely to disperse over a large area (CREL, 2008; ABPmer *et al.*, 2010). Further detail of spoil mounds identified at the Lynn and Inner Dowsing OWF is provided in Paragraph 7.12.57.

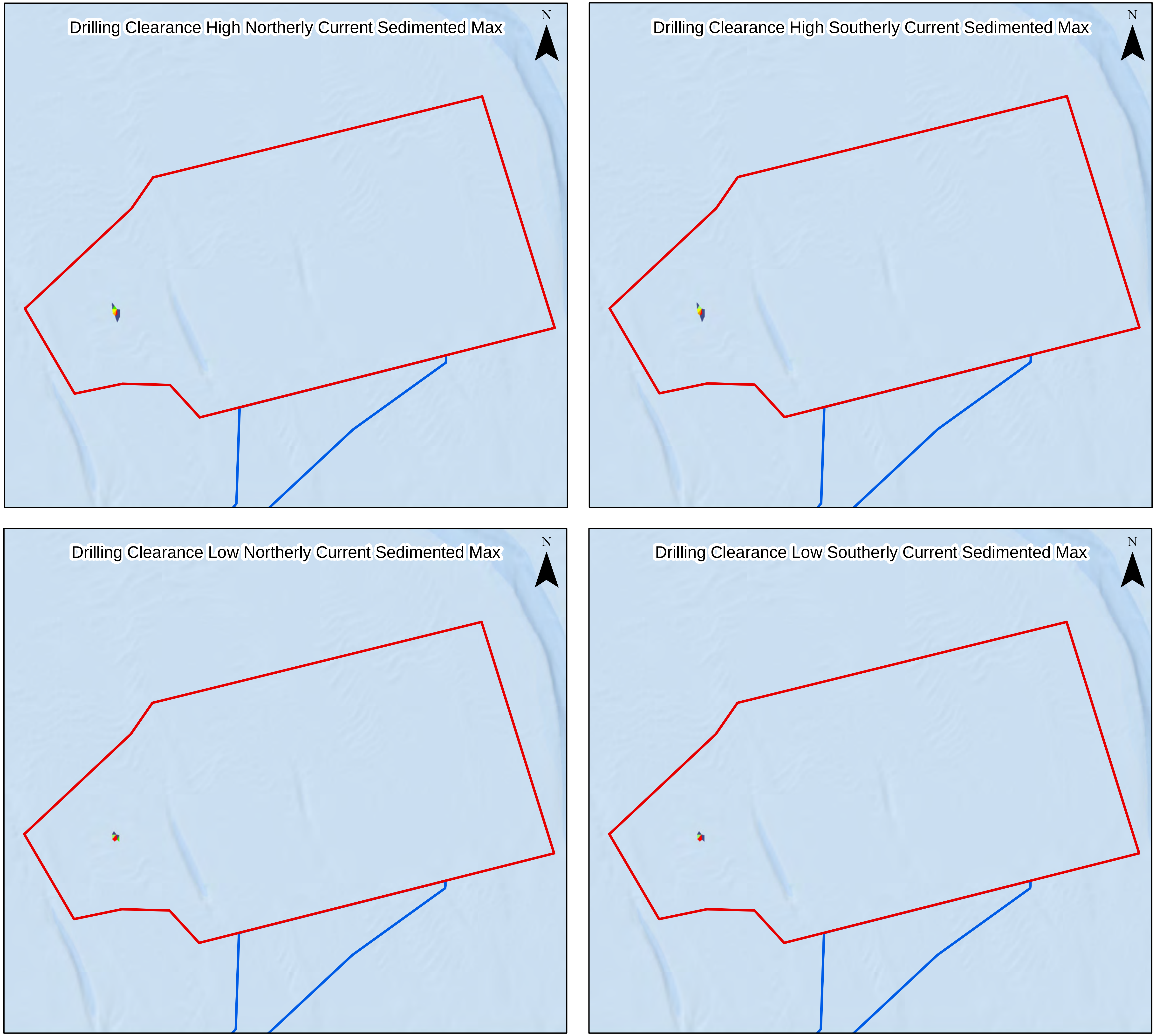
7.12.28 The requirement to drill into chalk depends on pile depth reaching this horizon as well as the hardness of the substrate. Notably, the Sheringham Shoal OWF, located approximately 35km to the south of the Project in an area of the same Cretaceous Chalk, was able to drive all piles into the seabed without the need of drilling (Carotenuto *et al.*, 2018). Further information on the requirements for drilling will be provided once geotechnical surveys are complete.

HDD Operations

7.12.29 The subsea export cable ducts will be installed underneath the beach using trenchless installation techniques, with HDD techniques identified as the MDS (as outlined in Table 7.3). The drilling activity utilises a viscous drilling fluid which consists of a mixture of water and bentonite, a non-toxic, naturally-occurring clay mineral. The release of drilling fluid and drill cuttings from HDD operations will result in a plume of elevated SSC. The drilling fluid has an overall density and viscosity similar to seawater and so is expected to behave in a similar manner.

7.12.30 The results of bentonite release modelling demonstrate that:

- Elevated SSC will be of localised extent and temporary duration, with maximum concentrations of 7.5mg/l occurring within several hundreds of metres of the punch-out. SSC is advected along the coast along the tidal axis to distances of up to 2km, although concentrations at this distance are limited to below 2.5mg/l. All measurable SSC will have dispersed after 15 hours. Considering generally higher background SSC conditions along the coast, these changes are likely to be indiscernible from background conditions; and
- Sediment deposition is shown in Figure 7.24. Deposition of up to 10mm is predicted within several hundreds of metres of the punch-out, reducing rapidly to below 5mm. The maximum extent of deposition is predicted to be approximately 500m from release, with only thicknesses below 2mm identified at these distances. This deposition is small-scale and highly localised and is likely to be rapidly redistributed by wave action.

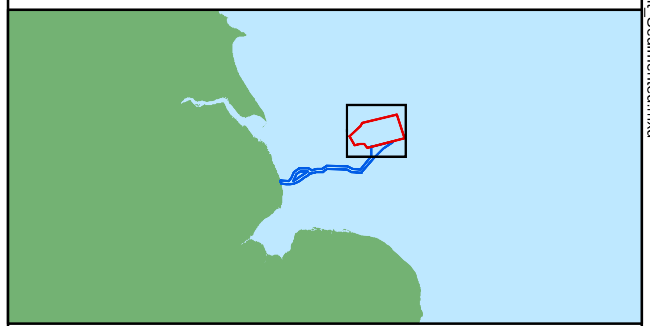


Legend

- Array Area
- Offshore Export Cable Corridor

Deposited sediment (mm)

- 1 - 1.99
- 2 - 2.99
- 3 - 4.99
- 5 - 7.49
- 7.5 - 9.99
- 10 - 14.99
- 15 - 19.99
- 20 - 29.99
- >30



Coordinate System: WGS 1984 UTM Zone 31N

0 5 10 km

Scale: 1:250,000

Preliminary Environmental Information Report

Maximum sediment deposition 20 hours after the start of foundation drilling activities within the Project array area, for a range of tidal conditions

Figure 7.23

OUTER DOWSING OFFSHORE WIND

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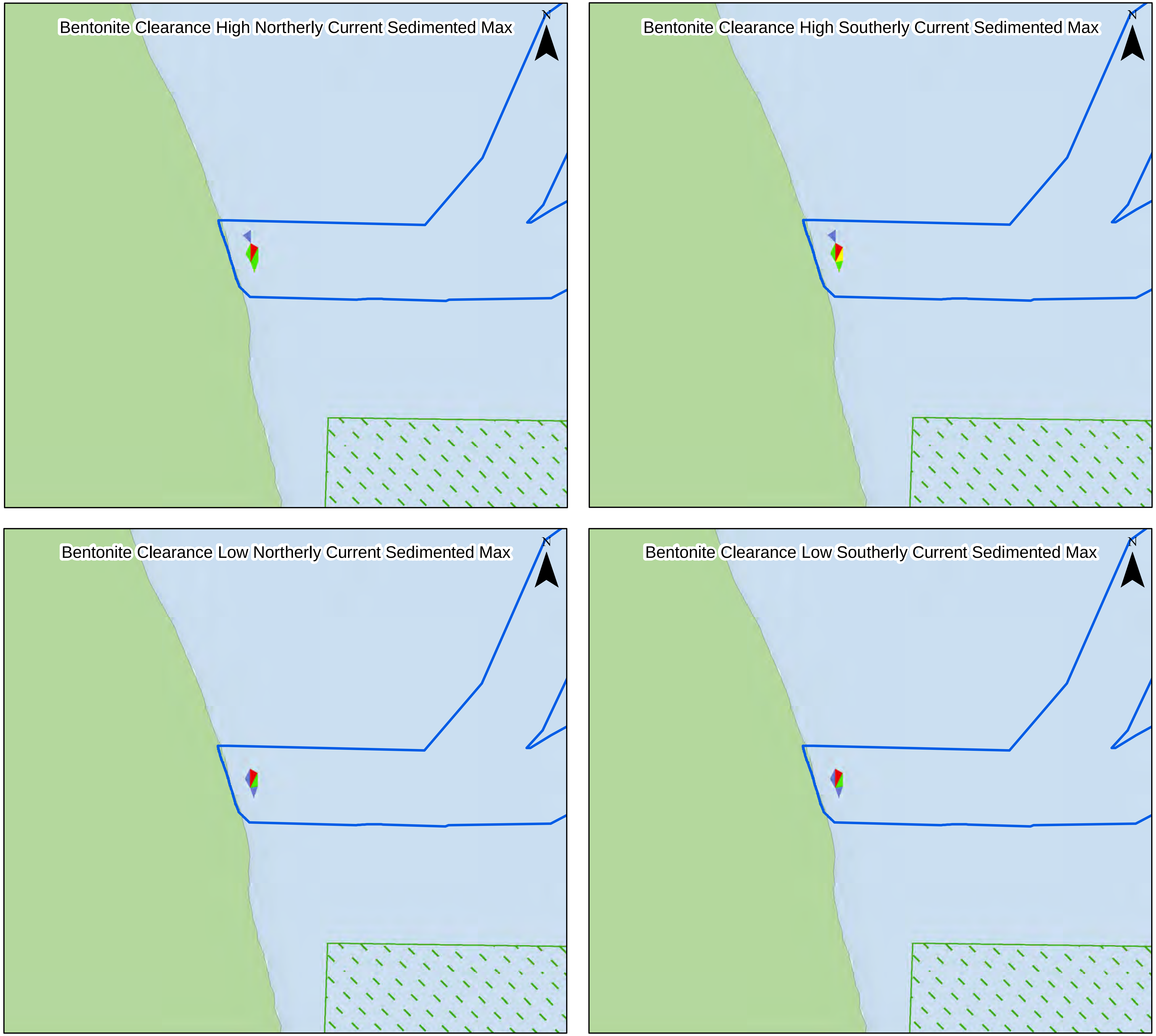
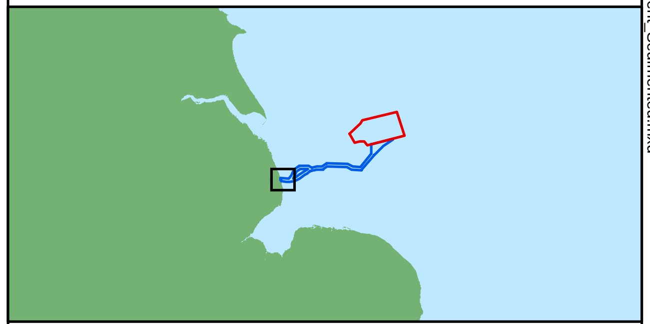


Legend

- Array Area
- Offshore Export Cable Corridor
- Special Areas of Conservation

Deposited sediment (mm)

- 1 - 1.99
- 2 - 2.99
- 3 - 3.99
- 4 - 4.99
- 5 - 9.99
- >10



Coordinate System: WGS 1984 UTM Zone 31N

0 2.5 5 km

Scale: 1:100,000

Preliminary Environmental Information Report

Maximum sediment deposition 20 hours after the start of HDD punch-out activities (and associated bentonite release), for a range of tidal conditions

Figure 7.24

OUTER DOWSING OFFSHORE WIND

Date: 19/04/2023
Produced By: BPHB
Revision: 0.1

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Magnitude of Impact

7.12.31 The numerical modelling results outlined above can be broadly summarised as follows:

- MFE, seabed levelling and sandwave clearance activities may produce sediment plumes with SSC up to thousands of mg/l, however these concentrations will be spatially restricted and short-lived. Elevated SSC may be advected by tidal currents up to 20km away, although these concentrations will be low. In the vast majority of cases, elevated SSC will be indistinguishable from background levels (outlined in Paragraph 7.4.29 *et seq.*) after 20 hours from the start of activities, and can therefore be considered temporary and localised;
- Associated deposition from sediment plumes is generally in the order of tens to low hundreds of mm within several hundreds of metres from the point of disturbance, reducing to low tens of mm beyond this. Sediment deposition is generally not measurable beyond 3km to 5km away from the associated activities and is therefore generally small-scale and restricted to the near-field. This deposition is likely to become integrated into the local sediment transport regime and will be redistributed by tidal currents. The formation of spoil mounds from dredge disposal is considered separately within Impact 2 in Paragraph 7.12.45 *et seq*; and
- Foundation drilling and bentonite release during HDD operations will produce low levels of SSC and is likely to be indiscernible from background conditions. This will correspond to low sediment deposition of tens of mm within several hundred metres of the activity and a maximum deposition extent of 500m. The effect of these activities is therefore considered to be restricted to the near-field, temporary, and indiscernible from background conditions.

7.12.32 Overall, the magnitude of change from increases in SSC is noticeable but temporary, with the majority of effects limited to the near-field. The magnitude of impact has therefore been assessed as low.

Sensitivity of the Receptor

7.12.33 All the identified Marine Processes receptors will be insensitive to localised changes in SSC and bed levels associated with the sediment disturbance activities described in this section. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere in the PEIR, in particular:

- Volume 1, Chapter 8: Marine Water Quality;
- Volume 1, Chapter 9: Benthic and Intertidal Ecology;
- Volume 1, Chapter 10: Fish and Shellfish Ecology;
- Volume 1, Chapter 11: Marine Mammals; and
- Volume 1, Chapter 14: Commercial Fisheries.

Significance of Effects

7.12.34 There are no Marine Processes receptors sensitive to the impact pathway and assessment of residual effects is not applicable.

Impact 2: Potential Impacts to Seabed Morphology (Sandbanks, Sandwave Areas and Notable Bathymetric Depressions)

7.12.35 Seabed morphology may be impacted directly or indirectly during the construction activities of the Project. The assessment below separately considers the potential for impacts associated with:

- Seabed preparation (seabed levelling and sandwave clearance) including spoil disposal via a TSHD;
- Pre-lay cable trenching using an MFE tool at the seabed;
- Use of cable protection measures;
- Indentations to the seabed from installation vessels; and
- Foundation installation using drilling techniques.

Conceptual Understanding of Change

Seabed Levelling and Sandwave Clearance

7.12.36 In order to ensure effective cable burial below the level of the stable bed, it may be necessary in place to remove sections of mobile bedforms (i.e. sandwave clearance) through the use of a TSHD. Seabed levelling is also required around specific foundation types that need to be placed onto a flat seabed, for example GBS, and for areas of scour protection where required. In addition to short-term elevations in SSC, these activities will necessarily result in localised changes to seabed topography through both the levelling and clearance activities themselves, as well as the deposition of dredge spoil. This could impact identified physical process receptors either directly (if the activity is located on the receptor) or indirectly, through a change in sediment supply to downdrift locations. This section assesses the potential for seabed recovery and for longer term changes to sediment transport, based on the MDS set out in Table 7.3.

7.12.37 Areas of sandwaves are present in several locations across both the array area and Offshore ECC, as indicated on Figure 7.6 and characterised within Volume 2, Appendix 7.1.

7.12.38 A detailed analysis and discussion of sandwave clearance and recovery was produced as part of the Habitats Regulation Appraisal (HRA) for the Hornsea Project Three OWF (ABPmer, 2018a). This includes monitoring data from the Race Bank OWF (DONG Energy, 2017), located approximately 30km southwest of the Project array area as shown on Figure 7.27 This includes pre-levelling, levelling, and post-levelling bathymetry data for 19 locations (over 12 monitoring sites), providing observations of post-levelling sandwave response and recovery (approximately one to five months following levelling) across a range of similar but subtly different sandwave bedforms and sedimentary environments.

7.12.39 This assessment draws on evidence and conclusions presented in the above references with regards to the observed underlying mechanisms for sandwave recovery, whilst acknowledging and accounting for differences in the environmental setting that might affect the recovery rate. The Race Bank OWF is located in an area of generally similar oceanographic and sedimentary conditions to the Project, with comparable water depths, predominantly sandy sediments and peak current speeds of between 1.0m/s to 1.2m/s (Centrica, 2009). Evidence from this location can therefore be used with relative confidence as an analogue for processes occurring at the Project location.

7.12.40 The Race Bank monitoring data (DONG Energy, 2017) indicates that locally levelled sandwaves continue to evolve in a manner that is consistent with recovery towards a new natural equilibrium state in the months to years post-levelling. There was evidence of partial to complete sandwave recovery at ten of the twelve monitoring sites within five months of levelling, consistent with the site being an active and dynamic sedimentary environment that is conducive to the development, maintenance and migration of sandwave bedforms (ABPmer, 2018a). Local perturbations to existing sandwaves that do not change the fundamental conditions of the setting (i.e. the tidal and wave regime and the volume of mobile sediment present) will not prevent continued evolution of the features through the same naturally occurring processes and the features will therefore recover towards a new equilibrium state over time.

7.12.41 The volume of material to be displaced from individual sandwaves will vary according to the local dimensions of the sandwave (height, length and shape) and the level to which the sandwave must be reduced (also accounting for stable sediment slope angles and the capabilities and requirements of the cable burial tool being used). Based on the available geophysical data (Enviros, 2022), it is anticipated that the bedforms requiring localised levelling (or crest lowering) are likely to be up to 8m in height. The total volume that could be affected by sandwave clearance is presently estimated to up to approximately 13,672,800m^3 within the array area and approximately 7,413,120m^3 within the Offshore ECC. Exact locations requiring sandwave clearance are presently unknown.

7.12.42 The sediments comprising the sandwave features will be predominantly sand, although a small proportion of fines and gravel may also be present. Individual sandwaves will require multiple dredging cycles to achieve the required width of corridor. All dredge spoil will remain within the PEIR boundary and the preference is for it to be returned to the seabed in the vicinity of the dredged area in areas with a similar sediment type (e.g. sandwave dredging spoil disposed of on an adjacent area of sandwaves). In particular, any seabed preparation within designated SACs will be retained within the same area.

7.12.43 The tidal current regime, with spring tidal current speeds between approximately 1.0m/s to 1.4m/s, is sufficiently strong to cause the mobility of sand, although this is generally restricted to peak spring tides (see Volume 2, Appendix 7.1). The tidal current regime will not be measurably impacted as a result of the localised levelling and although the volume of sediment available in each local system will be locally redistributed by the levelling, it will not change in an overall net sense. As the controlling factors will also not change, the levelled areas and sandwave features will have the potential to recover in time to a new, dynamically evolving natural state.

7.12.44 The levelled areas are not considered likely to create a barrier to sediment movement and displaced material will not be removed from the sedimentary system. Evidence drawn from aggregate dredging activities indicates that if any changes occur to the flow conditions or wave regime, these are localised in close proximity to the dredge pocket (with widths and lengths of several kilometres). The proposed works will be at a much smaller scale and footprint, with trench widths expected to be in the order of 30m. This means there is likely to be little to no influence on the flow or wave regime, which in turn means no change to the regional scale sediment transport processes across the array area and Offshore ECC.

7.12.45 Seabed levelling and sandwave clearance activities will also result in the formation of spoil disposal mounds. Once the dredger moves to discharge a full hopper load close by, the majority of the finer sediment fractions are expected to have already been lost as overspill, as discussed within Paragraph 7.12.18. The remaining sediments within the hopper should be predominantly composed of coarser sediment (sands and gravels) meaning that the majority of the spoil will fall quickly to the seabed with limited opportunity to disperse, leading to the formation of spoil mounds. Coarser sediments are less likely to be transported away by ambient flows, so these mounds remain as a semi-permanent feature, subject to a slow rate of winnowing.

7.12.46 The deposition depth and area covered will be determined by the volume of the hopper load, the course of the vessel in the period of opening hopper doors, the tidal flows at the time and the relative composition of the sediment being disposed of. Individual discharges of spoil disposal have been modelled for three separate activities, with the results outlined below:

- For seabed levelling around foundation locations, the results indicate an area of deposition of up to 163,000m^2 for each spoil mound with a maximum height of 1.25m. However, the area of deposition over 1m in height is restricted to 5,000m^2, with deposition heights below 0.5m over 143,000m^2;
- For sandwave clearance of inter-array cable routes within the array area, the results indicate an area of deposition of up to 164,000m^2 for each spoil mound with a maximum height of 1.16m. However, the area of deposition over 1m in height is restricted to 4,000m^2, with deposition heights below 0.3m over 143,000m^2; and
- For sandwave clearance along the ECC, the results indicate an area of deposition of up to 162,000m^2 for each spoil mound with a maximum height of 1.74m. However, the area of deposition over 1m in height is restricted to 5,000m^2, with deposition heights below 0.5m over 141,000m^2.

7.12.47 In those areas where disposal mounds are comprised largely of sandy material similar to the surrounding seabed, as in areas of sandwaves, given the prevailing hydrodynamic conditions it can reasonably be expected that the sand will be re-mobilised and re-incorporated into the active sediment regime over time. This process will winnow down the spoil mounds, however, in the array area sediment mobility is typically limited to the peak flows of spring tides, which may lead to a slower winnowing process. For spoil deposition in the shallower nearshore environment, where flows are typically stronger and waves begin to interact with the seabed, the mobility of sediments can be expected to be higher and the spoil is likely to disperse at a faster rate.

Mass Flow Excavation

7.12.48 The use of MFE for pre-lay cable trenching has been identified as the worst case scenario for cable installation, resulting in direct impacts to seabed morphology. As outlined in Table 7.3, this process would be used to excavate a V-shaped trench (with slopes of 1:2.5) with a width of 18m and a depth of 3m. The trenched sediment volume is forced into suspension to a height of around 2m above the seabed and then will subsequently settle within several meters of the trench, as outlined previously in Paragraph 7.12.12. Displaced material will therefore not be removed from the sedimentary system, and these small-scale changes in bed levels are likely to be quickly redistributed by hydrodynamic processes. Cable installation may require sandwave clearance to take place beforehand in order to ensure effective cable burial depths. As outlined in Paragraph 7.12.36 *et seq*., these features are expected to recover towards a new equilibrium state over time through the naturally-occurring hydrodynamic conditions of the site.

Cable Protection Measures

7.12.49 As far as practicable, all offshore cables will be buried. However, where it is not possible to bury cables to an adequate depth it may be necessary to install cable protection to prevent scour and minimise the risk of cable exposure. The MDS option for cable protection is outlined in Table 7.3 and consists of rock berms with a maximum height of 2m and a width at seabed of 16m. Up to 25% of laid cables are estimated to require cable protection to help maintain the target burial depth, this includes up to 20sites with cable crossings and comprises a total area of 1,899,000m^2 for the inter-array cables and 2,059,200m^2 for the export cable.

7.12.50 The implementation of rock berms (as worst case) will result in a change in the seabed profile of up to 2m in addition to a change in substrate type, with potential effects which may last over the operational period. These could result in increased drag forces resulting in localised scour, which is discussed further in Paragraph 7.12.98. The presence of cable protection measures may also have the potential to cause a direct (albeit highly localised) blockage of bedload sediment transport processes. Based on the seabed environment outlined in Section 7.4, two worst case scenarios have been identified:

- Installation of rock berms in areas of mobile, sandy sediments; and
- Installation of rock berms in areas of chalk bedrock with a thin veneer of overlying sand (as indicated on Figure 7.5).

7.12.51 In areas of sand, active sediment transport processes are indicated by the presence of mobile bedforms such as sandwaves and megaripples, as shown in Figure 7.6. In these areas, the installation of rock berms will result in a change to sediment substrate, with the mean rock size used in the cable protection being in the range of 90mm to 125mm. However, following installation and under favourable hydrodynamic conditions, an initial period of sediment accumulation would be expected to occur, creating a smooth slope against the cable protection. Once any void spaces have been infilled, saltation is expected to be largely unaffected by the presence of the cable protection such that existing transport process (including bedform migration) will remain unaffected.

7.12.52 In areas where chalk is close to the seabed surface, as indicated on Figure 7.5, low deposition rates and the lack of bedforms suggest low sediment transport rates. Any installation of cable protection is therefore unlikely to inhibit sediment transport processes, although its presence will result in a change to sediment substrate.

Installation Vessel Footprints

7.12.53 There is potential for certain vessels used during the installation of the Project to directly impact the seabed. This applies for vessels that utilise jack-up legs or several anchors to hold station and to provide stability for a working platform. Where legs or anchors (and associated chains) have been inserted into the seabed and then subsequently 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 in WTG foundation installation, since the depressions would be larger than anchor scars.

7.12.54 A single jack-up barge could have a footprint of approximately 170m^2 per leg, with a total of up to six legs per vessel. Each leg has the potential to penetrate 5m to 15m into the seabed (as defined within the Dudgeon and Sheringham Shoal Extension project), although precise depths of penetration are highly dependent on the nature of the surficial sediments and underlying geology, which have been summarised in Section 7.4 and characterised in detail in Volume 2, Appendix 7.1.

7.12.55 As the jack-up leg is inserted, the seabed sediments would primarily be compressed vertically downwards and displaced laterally. This may cause the seabed around the inserted leg to be raised in a series of concentric pressure ridges. As the leg is retracted, some of the sediment would return to the hole via mass slumping under gravity until a stable slope angle is achieved. On longer timescales, the hole is likely to become shallower and less distinct due to infilling from mobile seabed sediments, although the seabed response is dependent on the actual dimensions of the leg and the local geotechnical properties of the soils.

7.12.56 Depressions in clay-type soils are likely to persist for longer periods than mobile sands, in the order of months to years, as evidenced by post-construction scour monitoring undertaken at several Round 1 and Round 2 windfarm sites (TKOWFL, 2015). Indentations with depths between 0.5 and 2.0m were identified at the Kentish Flats OWF, which is characterised by variable thicknesses of coarse sand underlain by soft to firm clays. After approximately three years, these depressions had infilled by an average of 0.6m (ABPmer *et al.*, 2010).

Foundation Drilling

7.12.57 As outlined in Paragraph 7.12.23, foundation drilling, should it be required, will result in the deposition of drill arisings on the seabed, resulting in the formation of localised spoil mounds. Based on the numerical modelling results these are likely to be minimal, with a maximum extent of less than 500m from the foundation and maximum thicknesses of 30mm within 100m.

7.12.58 Monitoring of drill arisings mounds on the Lynn and Inner Dowsing OWF found that after four months, mounds had been reduced from 3m to 1.2m due to natural processes, however this figure is only presented as a guide as sedimentary and oceanographic conditions may be slightly different at the Project location (CREL, 2008).

Magnitude of Impact

7.12.59 Overall, the patterns of processes governing the overall evolution of the systems (the flow regime, water depths and sediment availability) are at a much larger scale than the proposed local works. As a result, proposed modifications to seabed morphology are not considered likely to influence the overall form and function of the system and eventual recovery via natural processes is therefore expected. The magnitude of impact is therefore considered to be noticeable but permanent, and generally restricted to the near-field. The magnitude has therefore been assessed as low.

Sensitivity of the Receptor

7.12.60 The following receptors have been considered in the assessment of potential changes to seabed morphology:

- Inner Dowsing, Race Bank and North Ridge SAC; and
- Areas of undesignated seabed.

7.12.61 Features of the Inner Dowsing, Race Bank and North Ridge SAC are likely to be impacted by modifications to seabed morphology as a result of construction activities within the Offshore ECC. This receptor is designated, however has been assessed as having a moderate capacity to accommodate the proposed form of change. The sensitivity of this receptor has therefore been assessed as medium.

7.12.62 Areas of undesignated seabed are expected to be subject to changes in seabed morphology as described above. However, due to the fact that it is undesignated, this receptor has been assessed as negligible.

Significance of Effects

7.12.63 The assessment has concluded that the magnitude of impact on the wave and tidal regime is low (at worst). All receptors identified are considered to be of medium sensitivity (at worst). Based on the matrix provided in Table 7.8, the effect will be of **minor adverse** significance, which is not significant in EIA terms.

Impact 3: Modifications to Littoral Transport and Coastal Behaviour (Erosion), Including at Landfall

7.12.64 The offshore export cables will make landfall at Wolla Bank, just south of Anderby Creek, Lincolnshire (see Figure 7.1). Full details of the MDS are provided in Table 7.3, while a full description of coastal characteristics, including observed historic change and existing/future management policies, are provided in Volume 2, Appendix 7.1. The assessment below separately considers the potential for impacts associated with:

- Trenchless installation techniques;
- Construction of HDD exit pits; and
- Use of cable protection measures in the nearshore zone.

7.12.65 In addition, the construction phase also includes a temporary beach access track, although this will not be used during cable installation. At this time, it is not known whether this feature will be located below MHWS. A more detailed plan of the landfall construction methodology will be defined once further site-specific surveys and feasibility studies have been conducted, with any refinement to the Project Description (PD) to be assessed at ES.

Conceptual Understanding of Change

7.12.66 The beach frontage at Wolla Bank consists of a sandy beach backed by vegetated sand dunes, with a geology comprising of marine sand deposits underlain by Burnham Chalk bedrock (BGS, 2022). Sediment transport is directed towards the south, driven primarily by waves arriving from the northeast. There is a distinctive ridge and runnel pattern on the beach, thought to influence vertical change in beach elevation over time, with an erosional trend in the mid-beach region (Environment Agency, 2011; 2013a). Another feature in the nearshore area is the presence of a concrete outfall extending into the intertidal zone. A greater width of sediment accumulation on the northern side of the outfall is consistent with the conceptual understanding of net sediment transport to the south in this area.

7.12.67 Historical coastal erosion rates on the Lincolnshire coastline are significant and an annual beach replenishment programme, managed by the Environment Agency, is undertaken on a regular basis, as outlined in Paragraph 7.4.27. The proposed strategy over the next 100 years is to implement a combination of rock structures and beach nourishment, which will take the form of a phased process with beach nourishment continuing in its current form until 2024, with structures to be implemented between 2025 and 2050 (Environment Agency, 2019). Details of this strategy are not currently available and therefore a full and detailed assessment of long-term future change is not possible. If available before the anticipated start date of construction, these plans will be considered within the cable burial studies undertaken to inform engineering requirements.

Trenchless Installation Techniques

7.12.68 HDD is the established solution for trenchless installation, however it should be noted that other technologies are available, such as micro-boring. As outlined in Table 7.3, HDD has been identified as the MDS for trenchless installation, with all impacts being no greater for other trenchless techniques. HDD involves drilling a long borehole underground using a drilling rig located within the landfall compound. This technique avoids interaction with surface features and is used to install ducts through which cables can be pulled. HDDs can vary in length depending on the ground conditions, with the maximum length proposed for the Project being 2.0km (see Table 7.3).

7.12.69 Trenchless techniques such as HDD will cause minimal direct disturbance to the existing coastline because it will not interact directly with, or leave any infrastructure exposed in, the active parts of the beach (between the entry and exit points of the drill) and so will not impact upon littoral processes in these areas. Provided that the cable remains buried beyond the exit of the HDD, there is no possibility for it to interact with, or have any effect on nearshore beach processes or morphology. The design of the HDD operation will take this into account.

7.12.70 The presence of annual beach nourishment (as outlined in Paragraph 7.4.27 and Paragraph 7.12.67) means that the choice of location for the onshore HDD works and jointing bay is unaffected by the possibility of coastal retreat due to either natural erosion or sea level rise due to climate change, for as long as the 'hold the line' strategy is in place. Nourishment will take place at the landfall site until at least 2024, with a combination of nourishment and rock structures to be implemented after this, up until 2050.

Construction of HDD Exit Pits

7.12.71 If HDD is used to install the export cables at the landfall, up to six HDD exit pits, allowing for two failures, may be excavated at the punch-out location, which has been assessed as being located within the Project subtidal area (subtidal punch-out)in line with embedded mitigation measures as provided in Table 7.4. These will be up to 5m deep with an area of 1,000m^2, with a total volume of 30,000m^3 of excavated material (5,000m^3 per pit). The excavated material may be temporary stored before being dredged again and used as backfill when the pits are closed. As detailed previously, a more detailed plan of the landfall construction methodology will be defined once further site specific surveys and feasibility studies have been conducted, with any refinement to the Project design envelope to be assessed at ES.

7.12.72 The storage of this excavated material may form temporary spoil mounds, which, depending on their position in the subtidal (and hence the water depth in which they are situated), may have the potential to modify the nearshore wave regime through the differently distributed transmission of wave energy across the beach. This could theoretically result in a morphological response although this would be highly localised to the area around mounds. Due to a combination of the natural erosional trend and annual beach nourishment, any morphological response resulting from temporary spoil mounds is likely to be short-lived.

7.12.73 Once the duct has been installed, the pit may be secured through the use of rock or grout bags to prevent collapse and manage natural infill. The period between duct installation and cable installation may be up to 12 months. Although the pits may be present for this long, the potential for these temporary features to modify the wave regime will be limited as they will be temporarily infilled. Accordingly, water depths within their footprint will remain similar to baseline levels.

Cable Protection Measures

7.12.74 The requirement for cable protection at the landfall is not presently known but will be confirmed as part of the Cable Specification and Installation Plan (CSIP), an outline of which will be produced for PEIR. The presence of cable protection measures has the potential to cause a direct (albeit highly localised) blockage of littoral sediment transport, similar to that described in Paragraph 7.12.50. Cable protection measures could also cause a morphological response through modification of the local nearshore wave regime and associated patterns of sediment transport.

7.12.75 As outlined in Table 7.3, no cable protection is to be employed within 350m seaward of MLWS. At a distance of greater than 350m from the MLWS mark, rock berms could potentially be used to protect the export cables, although cable burial is the preferred method of cable protection where practicable (as outlined in Table 7.4). Water depths at this distance offshore range generally between 1.5m to 2.0m (LAT), with depths below 3.0m up to approximately 1.5km offshore (EMODnet, 2020). Rock berms constructed to the MDS parameters installed in the nearshore zone would therefore become uncovered at low water and inhibit littoral transport. It is noted that rock berms, where required, would be designed to meet cable protection requirements for the specific section of cable and therefore in shallow waters are likely to not require the MDS parameters. The form of cable protection within the nearshore zone will be selected in order to ensure littoral transport is not impeded.

7.12.76 In terms of the potential for cable protection measures to modify the wave regime, the dominant wave direction at the Lincolnshire coast is from the northeast. Cable protection measures would be oriented approximately perpendicular to the shore and would therefore present interference to the passage of incoming waves. Cable protection in shallow areas could therefore theoretically act in a similar manner to a submerged offshore breakwater, affecting wave transformation processes closer to the shore and potentially leading to wave focusing and subsequently enhanced coastal erosion. This could result in changes to the beach morphology as well as further alterations to littoral sediment transport, which in the nearshore zone is driven primarily by the wave regime.

Magnitude of Impact

7.12.77 The use of trenchless installation techniques means that any modification of littoral transport processes from landfall installation is likely to be temporary and restricted to the near-field. While the HDD activity itself is not expected to have any impact on the coastal morphology, the excavation of HDD exit pits and the deposition of temporary spoil mounds could result in short-term and localised morphology change. These changes would not be expected to persist once HDD exit pits are backfilled following cable installation, and their magnitude of change has therefore been assessed as low.

7.12.78 The use of cable protection measures in the nearshore zone has the potential to both locally trap sediment, potentially impacting downdrift locations, and modify the transmission of waves, thereby influencing patterns of littoral sediment transport and beach morphology. No cable protection is to be employed within 350m seaward of MLWS, although water depths at this distance are such that the installation of 2m high rock berms would result in a permanent change with the potential to impact coastal behaviour in both the near- and far-field. Once more detailed nearshore surveys have been carried out, the form of cable protection within the nearshore zone will be selected in order to ensure impacts to sediment transport and beach morphology are minimised, details of which will be provided at ES. On this basis, the magnitude of change to littoral transport and coastal behaviour is assessed to be low.

Sensitivity of the Receptor

7.12.79 The following receptors have been considered in the assessment of changes to littoral transport and coastal behaviour, including erosion, resulting from installation of the export cable at the landfall:

- The coast at the Project landfall; and
- Chapel Point to Wolla Bank SSSI.

7.12.80 Using the criteria presented in Table 7.7, the coastline at the Project landfall is considered to be of low sensitivity. The beach in this location is a dynamic environment subject to both natural and anthropogenic change under baseline conditions, in the form of coastal erosion and annual beach nourishment, respectively. Accordingly, it is assessed to have high capacity to accommodate the proposed changes.

7.12.81 The Chapel Point to Wolla Bank SSSI is designated for its intertidal sediments, which are of national importance for the interpretation of Holocene stratigraphy and environmental reconstruction (Natural England, 2014). This receptor has low capacity to accommodate the proposed form of change, particularly direct impacts from HDD operations. As outlined in Table 7.4, the HDD punch-out will be micro-sited to avoid direct interaction with the SSSI, therefore reducing the sensitivity to low.

Significance of Effects

7.12.82 The assessment has concluded that the magnitude of impact on littoral transport and coastal behaviour from the use of trenchless installation techniques, the construction of HDD exit pits, and the use of cable protection measures is low. Whilst both the receptors identified are considered to be of low sensitivity, there is no pathway of effect between cable protection measures and the Chapel Point to Wolla Bank SSSI. Based on the matrix provided in Table 7.8, the effect on the coast at the Project landfall will be of **minor adverse** significance, which is not significant in EIA terms.

Operations and Maintenance

Impact 4: Modifications to the Wave and Tidal Regime and Associated Potential Impacts to Morphological Features

7.12.83 The installation of WTG and offshore platform foundations have the potential to result in a localised blockage of waves and tides, which could lead to changes to seabed and coastal morphology. This blockage will commence when offshore construction begins, increasing incrementally up to the MDS, which is outlined in Table 7.3 and corresponds to an array comprising 93 GBS slab-based WTG foundations which has a base which extends 13m above the seabed, in addition to up to five slab-based GBS offshore platform foundations. ORCPs, although located closer to the coast, have not been assessed further, as though they will be located closer to the coast (see Figure 7.1), the potential impact from up to two structures within the water column will be significantly less than that from the array area.

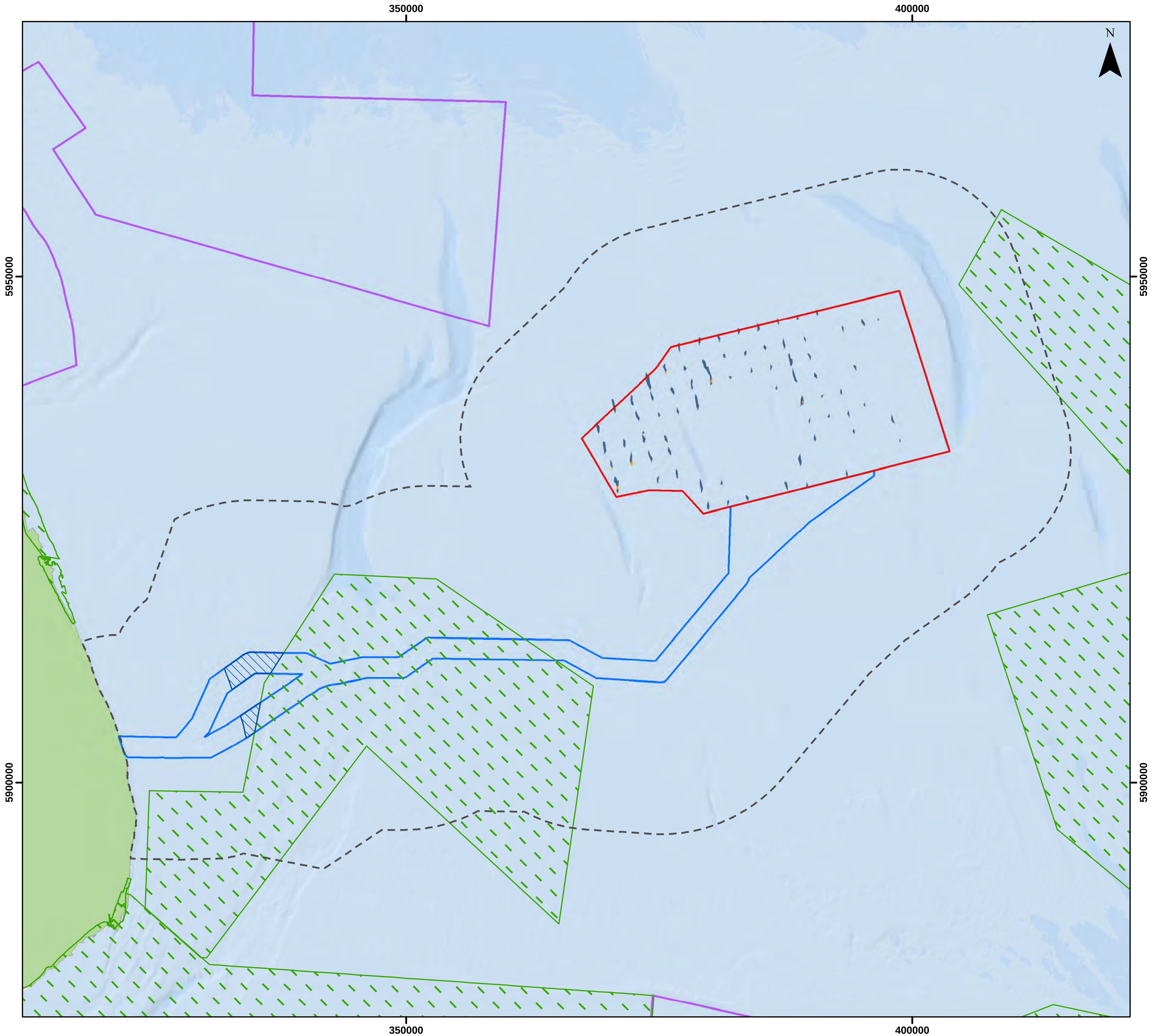
Conceptual Understanding of Change

7.12.84 The interaction between the tidal regime and the foundations of the windfarm infrastructure will result in a general reduction in current speed and an increase in levels of turbulence in a narrow, localised wake due to frictional drag effects. Incident flows will be decelerated immediately upstream and downstream of each foundation, with separation around the structure resulting in localised acceleration and the creation of vortices. Within the extent of the array areas, the effect on tidal currents will be evident as a series of narrow and discrete wake features extending downstream along the tidal axis from each foundation. For smaller structures such as the windfarm foundations, the wake signature is expected to naturally dissipate within a distance in the order of ten to twenty obstacle diameters downstream (Li *et al.*, 2014; Cazaneve *et al.*, 2016; Rogan *et al*., 2016).

7.12.85 Numerical modelling has been undertaken to quantify change in hydrodynamic flows and water levels, with details of the model scenarios and method presented in Volume 2, Appendix 7.2. Changes in depth average current speed and direction are predicted to be small in absolute and relative terms, with <±0.1m/s change in current speed, <±2 degrees change in current direction, and no visible change in surface elevation. Figure 7.25 below shows the change in current speeds for a high northerly current speed scenario. Reductions in speed of between 0.05m/s and 0.1m/s are predicted within 200m of a small minority of foundations, with reductions between 0.02m/s and 0.05m/s forming wakes up to 1km downstream of the majority of foundations. In several locations these wakes are suggested to overlap, however this is largely mitigated by the separation distance.

7.12.86 The presence of the foundations in the sea also has the potential to modify the wave and wind wave regime passing through an OWF. The primary effects on waves (as identified by Christensen *et al*., 2013) are caused by:

- Drag forces against passing waves in contact with the foundation;
- Reflection (and scattering) of wave energy off the face of the foundation;
- Diffraction of wave energy around the structure; and
- Modified wind field within and leeward of the OWF as a consequence of WTG blades, reducing local wind-wave development across the leeward fetch.



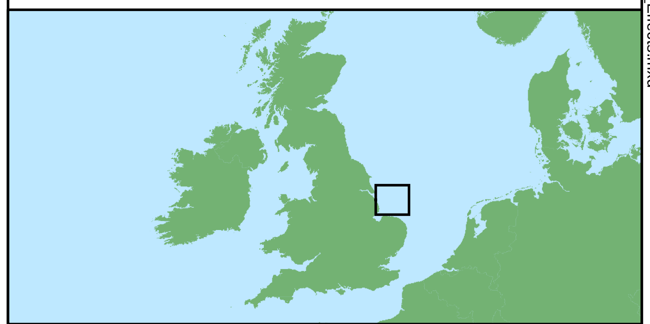
Legend

- Array Area
- Offshore Export Cable Corridor
- ORCP Search Area
- Physical Processes Zone of Influence
- Special Areas of Conservation
- Marine Conservation Zones

High Northerly Current Current Speed

Current Speed (m/s)

- < -0.1
- -0.05 - -0.1
- -0.02 - -0.05



Coordinate System: WGS 1984 UTM Zone 31N

0 10 20 km

Scale: 1:350,000

Preliminary Environmental Information Report

Hydrodynamic blockage effects during a high spring ebb tide

Figure 7.25

OUTER DOWSING OFFSHORE WIND

Date: 19/04/2023
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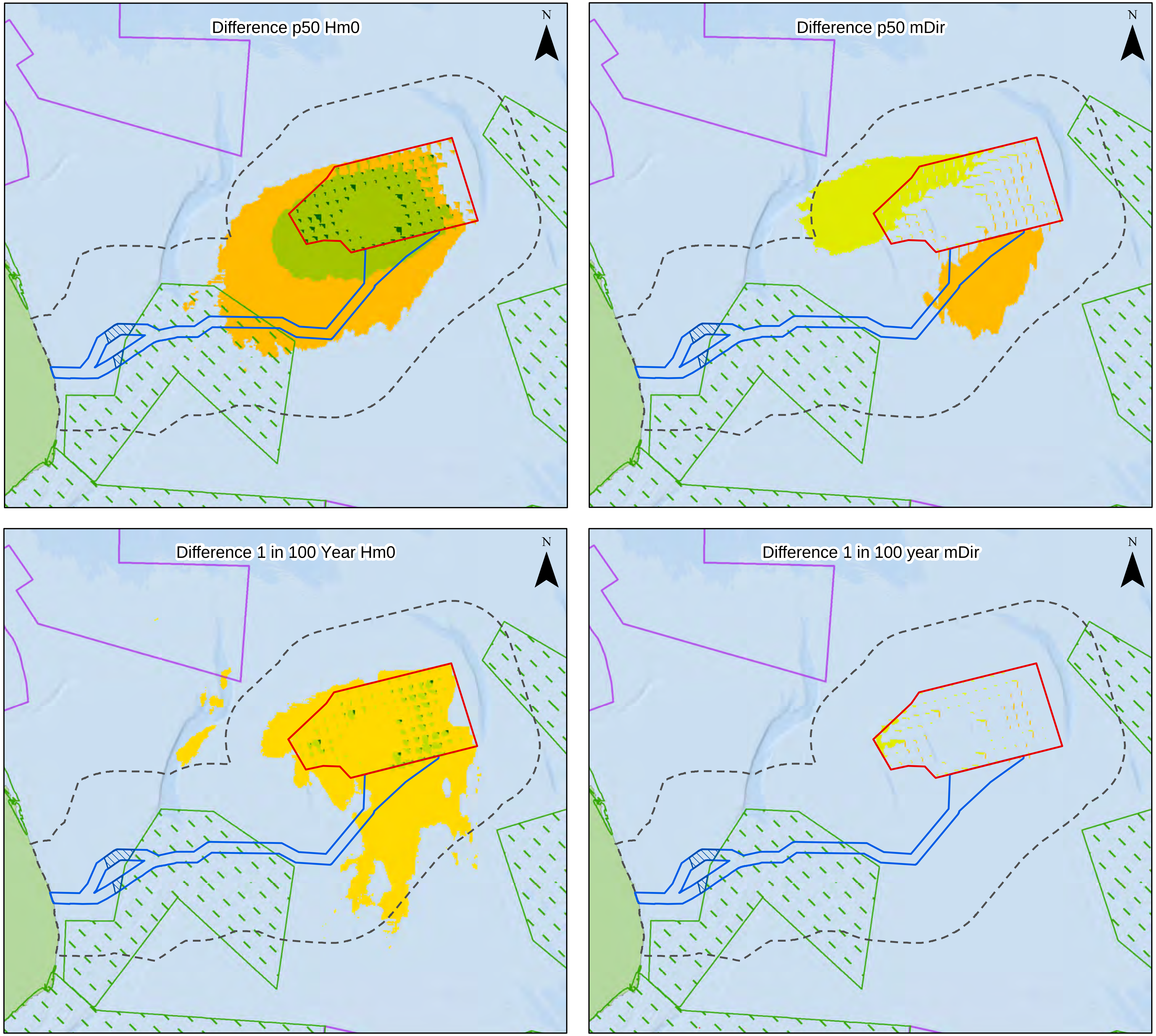


Legend

- Array Area
- Offshore Export Cable Corridor
- ORCP Search Area
- Special Areas of Conservation
- Marine Conservation Zones

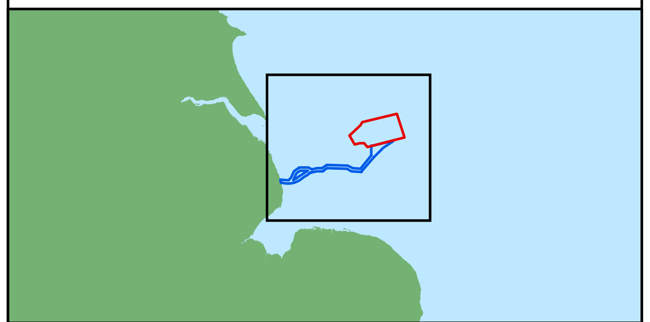
Difference p50 Hm0 (m)

- -1 - -0.1
- -0.1 - -0.05
- -0.05 - -0.025
- -0.025 - 0.025

Difference 1 in 100 Year Hm0 (m)

- < -1
- -1 - -0.75
- -0.75 - -0.4
- -0.4 - -0.025
- -0.025 - 0.025
- > 0.025

Difference p50 mDir (degrees)	**Difference 1 in 100 Year mDir (degrees)**
-358 - -270	-358 - -270
-270 - -180	-270 - -180
-180 - -90	-180 - -90
-90 - -2	-90 - -2
-2 - 2	-2 - 2
2 - 90	2 - 90
90 - 180	90 - 180
180 - 270	180 - 270
270 - 358	270 - 358



Coordinate System: WGS 1984 UTM Zone 31N

0 10 20 km

Scale: 1:700,000

Preliminary Environmental Information Report

Wave blockage effects (on significant wave height and direction) during median and extreme conditions

Figure 7.26

OUTER DOWSING OFFSHORE WIND

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7.12.87 The interaction between waves and the foundations of the windfarm infrastructure may result in a reduction in wave energy locally around foundations. Where the wave climate is important to local processes and is persistently modified, these changes may potentially alter the frequency of pattern of sediment transport and therefore seabed morphology in affected offshore areas, and/or the rate and direction of littoral transport and therefore coastal morphology on affected coastlines.

7.12.88 The wave modelling considered waves originating from the northeast for two events: p50 (median) conditions and 1 in 100-year extreme waves. The resulting difference to the baseline wave regime is shown in Figure 7.26.

7.12.89 The results show that during median baseline conditions, each foundation would present an obstacle to the passage of waves locally, causing a small modification to the height and direction as they pass (Figure 7.26). This causes a wave shadow effect to be created by each foundation, which interact to form an array-scale blockage The results indicate, for p50 conditions, a slight reduction in wave conditions, up to 0.05m in significant wave height (H_{m0}) up to approximately 20km away from the array area. Changes to significant wave heights of up to -0.1m are shown up to approximately 8km away from the array area, with reductions between 0.1m and 1m found only within 1km of individual foundations.

7.12.90 This is accompanied by a change in wave direction of 90 to 180 degrees to the south of the array area, and -90 to -2 degrees to the west. In both significant wave height and direction, there is a full dissipation of wave energy well away from the coastline. Similarly for 1 in 100-year extreme events, measurable change to significant wave height and direction is dissipated well away from the coast, as shown in Figure 7.26.

Magnitude of Impact

7.12.91 Changes in the tidal regime may indirectly impact seabed morphology in a number of ways. In particular, there is a close relationship between flow speed and bedform type (Belderson *et al.*, 1982) and therefore any changes to flows have the potential to alter seabed morphology over the lifetime of the Project. In the immediate near-field, within approximately 200m of individual turbines, there may be localised reductions in current speed of up to 0.1m/s during high current conditions, leading to localised reductions in seabed mobility. However, although this change is noticeable, it is restricted in both spatial and temporal extent, with localised variation throughout the tidal cycle. On this basis, the magnitude of impact to the tidal regime is assessed to be low.

7.12.92 Similarly, any changes in the wave regime may contribute to changes in seabed morphology due to alteration of sediment transport patterns. Within the study area, sediment transport is dominated by the action of tidal currents, with wave-driven sediment transport only becoming important to shallow coastal waters, distant to the array area. As shown in Figure 7.26, any change to the wave climate dissipates far from the coast, and therefore there is no pathway of effect on the nearshore wave climate. This also limits any potential for impact on coastal erosion or processes. Impacts on the wave regime will therefore be noticeable and permanent within the near-field, but this will not result in any discernible change to morphology. The magnitude of impact to the wave regime is therefore assessed to be negligible.

Sensitivity of the Receptor

7.12.93 The following receptors have been considered in the assessment of modifications to the wave and tidal regime and associated potential impacts on morphology:

- Inner Dowsing, Race Bank and North Ridge SAC; and
- Areas of undesignated seabed.

7.12.94 Small reductions in significant wave height, of the order of 2.7% caused by array-scale blockage may reach the Inner Dowsing, Race Bank and North Ridge SAC, as indicated by Figure 7.26. However, the Race Bank – North Ridge – Dudgeon Shoal sandbank system, located within the area affected by wave blockage (Figure 7.26) is understood to be maintained by tidal currents (TKOWFL, 2011). The banks have been classified by Kenyon and Cooper (2005) as open shelf sinuous sandbanks, divided into mutually evasive ebb dominant or flood dominant channels, resulting in clockwise sediment transport (HR Wallingford *et al.*, 2002). Their formation is considered likely to be analogous to the Great Yarmouth Banks, which are consistent with the dynamics of a flood-ebb tidal meander channel (Cooper *et al.*, 2008; Tappin *et al.*, 2011).

7.12.95 The vertical growth of sandbanks of this type is thought to be limited by wave activity which act to plane off the crests (Cooper *et al.*, 2008), however given the small percentages of wave reduction predicted to result from the presence of the array (-2.4% to -3.3%), there is unlikely to be any meaningful change to the banks' crest height. Given the importance of tidal currents in maintaining the form of the sandbanks, the Inner Dowsing, Race Bank and North Ridge SAC therefore has a high capacity to accommodate change to the wave regime. In combination with its designated status, the sensitivity of this receptor has been assessed as medium.

7.12.96 Areas of undesignated seabed around and within the array area will not be affected by changes to the wave regime, due to the fact that sediment transport in this area is dominated by the action of tidal currents. However, as outlined in Paragraph 7.12.91, hydrodynamic blockage effects may lead to localised changes to sediment mobility. Due to the fact that it is undesignated, this receptor has been assessed as negligible.

Significance of Effects

7.12.97 The assessment has concluded that the magnitude of impact is low (on the wave regime) negligible (on the tidal regime). Receptor sensitivity is considered to be negligible for areas of undesignated seabed, and medium for the Inner Dowsing, Race Bank and North Ridge SAC. Based on the matrix provided in Table 7.8, the effect will be of **minor adverse** significance (at worst), which is not significant in EIA terms.

Impact 5: Seabed Scouring

7.12.98 The term scour refers here to the development of pits, troughs or other depressions in the seabed sediments around the base of foundations and in response to the placement of cables. Scour is the result of net sediment removal over time due to the complex three-dimensional interaction between the foundation and ambient flows (currents and/or waves). Such interactions result in locally accelerated mean flow and locally elevated turbulence levels that also locally enhance sediment transport potential. The resulting dimensions of the scour features and their rate of development are, generally, dependent upon the characteristics of the:

- Obstacle (dimensions, shape and orientation);
- Ambient conditions such as the tidal flow and waves; and
- Seabed sediment properties.

7.12.99 As scour is a dynamic process, its greatest extent (depth and footprint) will develop during high energy periods and will therefore be short-lived. Equilibrium principles are such that, once the energy reduces, the scour holes will begin to refill (DECC, 2008).

7.12.100 Based on the existing literature and evidence base, an equilibrium depth and pattern of scour can be empirically approximated for given combinations of these parameters. Natural variability in the above parameters means that the predicted equilibrium scour condition may also vary over time on, for example, spring-neap, seasonal or annual timescales. The time required for the equilibrium scour condition to initially develop is also dependant on these parameters and may vary from hours to years.

7.12.101 Following the development of scour pits, the seabed areas may become modified from its natural state in several ways, including:

- A different (coarser) surface sediment grain size distribution may develop due to winnowing of finer material by the more energetic flow within the scour pit;
- A different surface character will be present if scour protection (e.g. rock protection) is used;
- Seabed slopes may be locally steeper in the scour pit; and
- Flow speed and turbulence may be locally elevated.

Conceptual Understanding of Change

7.12.102 Scour assessment for EIA purposes is considered here for monopiles, with the MDS outlined in Table 7.3. The scale of local scouring is mainly related to the scale and shape of the structure as well as sediment properties, such as the angle of repose. Scour holes will continue to deepen and widen until equilibrium scour depth is reached, which eventually accommodates and dissipates the increased flow velocities and near-bed vortices. Scour depths are expected to be limited by the presence of stiff glacial tills across much of the array area, which is likely to resist or inhibit scour. Evidence from the Kentish Flats OWF, as outlined in ABPmer (2010), indicates that the stiff clays underlying sands at this site have limited the depth to which scour forms. It is assumed that the vertical resistance to scour, by the underlying soils, does not constrain the potential horizontal scour radius.

7.12.103 For monopiles with a maximum diameter of 14m (the maximum diameter of monopiles for offshore platform foundations), the maximum depth of scour is predicted to be of the order of 18m. However, this is based on the assumption of an unlimited depth of sandy soil, and the depth of scour at this location is likely to be lower due to the underlying geology, as outlined above. Scouring around GBS structures is currently not well understood, with limited information available from the field. Scour caused around foundations will, however, be limited by the installation of scour protection where required as outlined in Table 7.3. There may be the opportunity for some secondary scour around this protection, although there is limited numerical basis for the prediction of this secondary scour.

7.12.104 There is also the expectation that cable protection measures may result in scour development. Given the projected dimensions of any protection, including its extent along the cable route (as outlined in Table 7.3), it is anticipated that any such morphological response will be on a smaller scale than expected around the foundations.

Magnitude of Impact

7.12.105 Due to the installation of scour protection where required for engineering purposes, in addition to the underlying geology of the area, scour is likely to be limited to secondary scour around protection, to a depth limited to that of the underlying stiff till. It is assumed that where scour protection is not required for engineering purposes, the resulting scour will be small-scale and localised. This change, while permanent, is therefore likely to be restricted in scale and limited to the near-field, and has therefore been assessed as of low magnitude.

Sensitivity of the Receptor

7.12.106 The following receptors have been considered in the assessment of potential changes from seabed scour:

- Inner Dowsing, Race Bank and North Ridge SAC; and
- Areas of undesignated seabed.

7.12.107 Features of the Inner Dowsing, Race Bank and North Ridge SAC are likely to be impacted by seabed scouring as a result of the installation of cable protection and scour protection within the Offshore ECC. This receptor is designated, however has been assessed as having a moderate capacity to accommodate the proposed form of change due to the underlying geology of the area limiting the depth of scour. The sensitive of this receptor has therefore been assessed as medium.

7.12.108 Areas of undesignated seabed are expected to be subject to seabed scouring as described above. However, due to the fact that it is undesignated, this receptor has been assessed as negligible.

Significance of Effects

7.12.109 The assessment has concluded that the magnitude of impact of seabed scouring is low (at worst). All receptors identified are considered to be of medium sensitivity (at worst). Based on the matrix provided in Table 7.8, the effect will be of **minor adverse** significance, which is not significant in EIA terms.

Decommissioning

7.12.110 The nature and scale of impacts arising from decommissioning are expected to be of similar or reduced magnitude to those generated during the construction phase. Certain activities, such as piling, will not be required.

7.12.111 As presented in Table 7.4, the Project infrastructure will be decommissioned in accordance with the decommissioning plan in addition to the best environmental practice at the time. Of note is that this may indicate that infrastructure such as cables should be retained *in situ*. For the purposes of undertaking this MDS assessment, it is assumed that the decommissioning phase of works is a reverse of the construction process, should there be a requirement to remove the seabed infrastructure.

7.12.112 To date, no large offshore windfarm has been decommissioned in UK waters. It is anticipated that any future programme of decommissioning will be developed in close consultation with the relevant statutory marine and nature conservation bodies and in line with the Decommissioning Plan. This will enable the guidance and best practice at the time to be applied to minimise any potential impacts.

Impact 6: Increases in SSC and Consequential Changes to Seabed Levels

7.12.113 Impacts arising from decommissioning activities are considered to be similar, or less, than those which occur during construction. The magnitude of the impacts has been assessed as low, with no Marine Processes receptors sensitive to the impact pathway and assessment of residual effects not applicable. The potential for changes to impact other EIA receptor groups are considered elsewhere in the PEIR, in particular:

- Volume 1, Chapter 8: Marine Water Quality;
- Volume 1, Chapter 9: Benthic and Intertidal Ecology;
- Volume 1, Chapter 10: Fish and Shellfish Ecology;
- Volume 1, Chapter 11: Marine Mammals; and
- Volume 1, Chapter 14: Commercial Fisheries.

Impact 7: Potential Impacts to Seabed Morphology (Sandbanks, Sandwaves and Notable Bathymetric Depressions)

7.12.114 Impacts arising from decommissioning activities are considered to be similar, or less, than those which occur during construction. The magnitude of the impacts has been assessed as low (at worst), with the maximum sensitivity of the receptors being medium. Based on the matrix provided in Table 7.8, the effect will be of **minor adverse** significance, which is not significant in EIA terms.

Impact 8: Modifications to Littoral Transport, Coastal Behaviour (Erosion) Including at Landfall.

7.12.115 Impacts arising from decommissioning activities are considered to be similar, or less, than those which occur during construction. The magnitude of impact upon littoral transport and coastal behaviour from the decommissioning of the project infrastructure at landfall is low. Both the receptors identified are considered to be of low sensitivity and there is no pathway of effect between the cable protection measures to be removed and the Chapel Point to Wolla Bank SSSI. Based on the matrix provided in Table 7.8, the effect on the coast at the Project landfall will be of **minor adverse** significance, which is not significant in EIA terms.

7.13 Cumulative Impact Assessment

7.13.1 This cumulative impact assessment for Marine Processes has been undertaken in accordance with the methodology provided in Volume 2, Appendix 5.1: Offshore Cumulative Impact Assessment.

7.13.2 The projects and plans selected as relevant to the assessment of impacts to Marine Processes are based upon an initial screening exercise undertaken on a long list. Each project, plan or activity has been considered and scoped in or out on the basis of effect-receptor pathway, data confidence and the temporal and spatial scales involved. All relevant longlist plans and projects were allocated into tiers reflecting varying levels of certainty. These are defined in Volume 2, Annex 5.1: Offshore Cumulative Impact Assessment and outlined here in Table 7.9.

Table 7.9: Description of Tiers of other developments considered for cumulative effect assessment.

Tiers	Development Stage
Tier 1	Projects under construction.
	Permitted applications, whether under the Planning Act 2008 or other regimes, but not yet implemented.
	Submitted applications, whether under the Planning Act 2008 or other regimes, but not yet determined.
Tier 2	Projects on the Planning Inspectorate's Programme of Projects where a Scoping Report has been submitted.
	Projects under the Planning Act 2008 where a PEIR has been submitted for consultation.
Tier 3	Projects on the Planning Inspectorate's Programme of Projects where a Scoping Report has not been submitted.
	Identified in the relevant Development Plan (and emerging Development Plans with appropriate weight being given as they move closer to adoption) recognising that much information on any relevant proposals will be limited.
	Identified in other plans and programmes (as appropriate) which set the framework for future development consents/ approvals, where such development is reasonably likely to come forward.

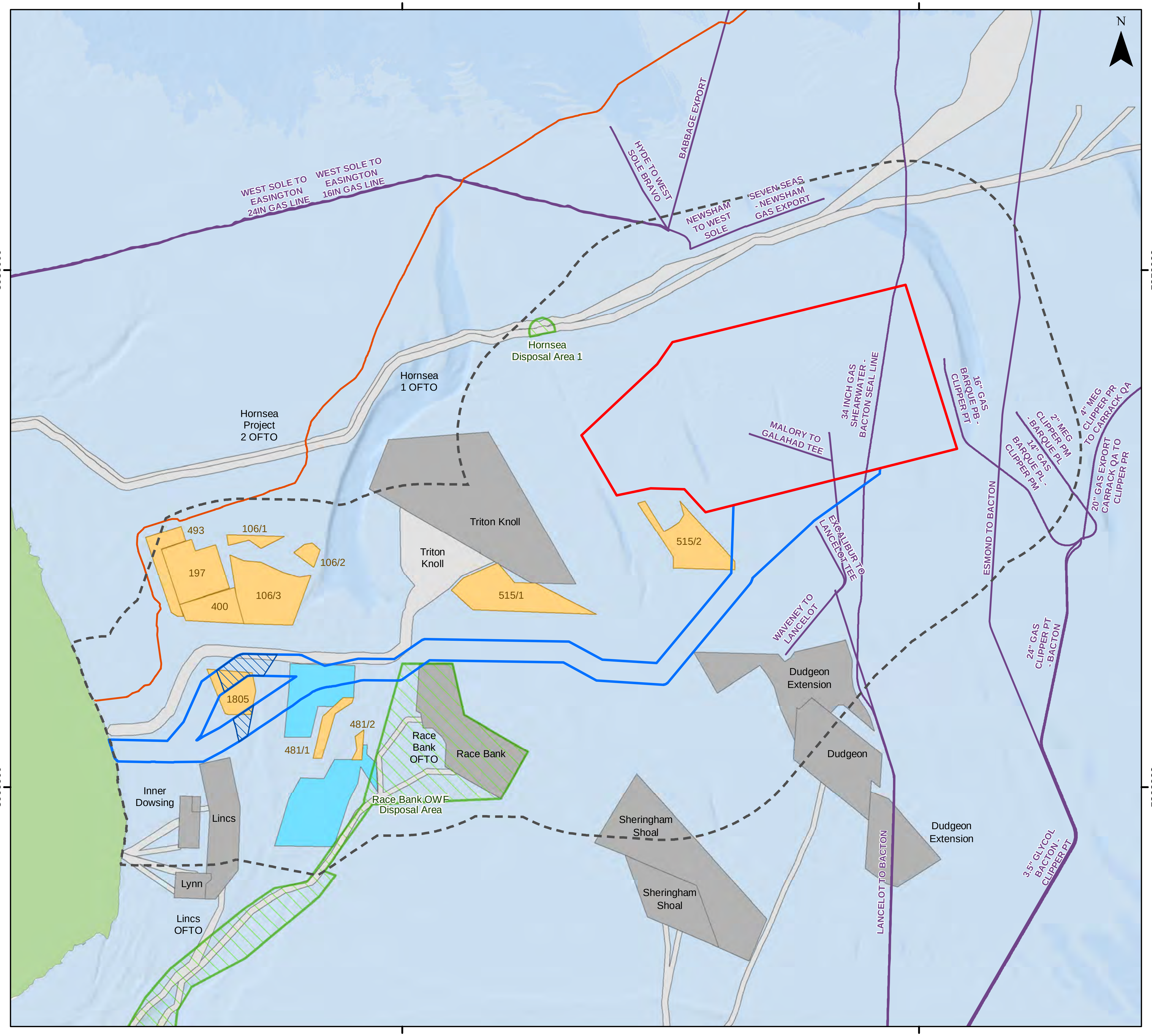
7.13.3 For the purposes of assessing the impacts of the Project on Marine Processes in the region, the cumulative effect assessment technical note submitted through the EIA Evidence Plan and forming Volume 2, Appendix 5.1 of this PEIR screened in a number of projects and plans as presented in Table 7.10 and Figure 7.27. The cumulative MDS for the Project is outlined in Table 7.11.

Table 7.10: Projects considered within the Marine Processes cumulative effect assessment

Development type	Project	Status	Data confidence assessment/phase	Tier
Offshore Energy	Sheringham Shoal Extension	Under Examination	High – Third party project details published in the public domain and confirmed as being 'accurate' by the Crown Estate	1
	Dudgeon Extension			
	Dudgeon	Active/In Operation		
	Lincs			
	Race Bank			
	Lynn			
	Inner Dowsing			
	Triton Knoll			
Offshore Wind Farm Export Cable	Race Bank OFTO	Active/In Operation	High – Third party project details published in the public domain and confirmed as being 'accurate' by the Crown Estate	1
	Lincs OFTO			
	Lynn			
	Lincs			
	Inner Dowsing			
	Triton Knoll			
	Hornsea 1 OFTO			
	Hornsea Project 2 OFTO			
Subsea Cables	Viking Link Interconnector	Under Construction	Medium – Third party project details published in the public domain but not confirmed as being 'accurate'	1
Pipelines	Gas Shearwater to Bacton Seal Line	Active/In Operation	High – Third party project details published in the public domain and confirmed as being 'accurate' by the Crown Estate	1
	Malory to Galahad Tee Gas Export			
	Gas Barque PB to Clipper PT			
	Excalibur to Lancelot Tee Gas Export			

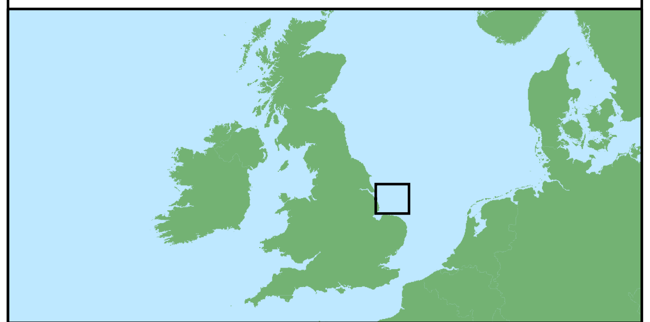
Development type	Project	Status	Data confidence assessment/phase	Tier
	Esmond to Bacton Gas Export Line			
	Gas Barque PL to Clipper PM			
	Meg Clipper PM to Barque PL			
	Newsham to West Sole Gas Line			
	West Sole to Easington Gas Line			
	Seven Seas to Newsham Gas Export			
	Lancelot to Bacton Gas Export			
	Hyde to West Sole Bravo Gas Line			
	Babbage export top West Sole			
	Waveney to Lancelot Gas Line			
	Meg Clipper PR to Carrack QA			
	Gas Export Carrack QA to Clipper PR			
	Gas Clipper PT to Bacton			
	Glycol Bacton to Clipper PT			
Aggregates	Outer Dowsing Westminster Gravels (515/2)	Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by the Crown Estate	1
	Outer Dowsing Westminster Gravels (515/1)			
	Humber Estuary Hanson Aggregates Marine Ltd (106/2)			

Development type	Project	Status	Data confidence assessment/phase	Tier
	Humber Estuary Hanson Aggregates Marine Ltd (106/3)			
	Humber Estuary Hanson Aggregates Marine Ltd (106/1)			
	Humber Estuary Hanson Aggregates Marine Ltd (400)			
	Off Saltfleet Tarmac Marine Ltd (197)			
	Humber Overfalls Tarmac Marine Ltd (493)			
	Inner Dowsing Tarmac Marine Ltd (481/1)			
	Inner Dowsing Tarmac Marine Ltd (481/2)			
	Inner Dowsing Hanson Aggregates Marine Ltd (1805)	Operational (Exploration and Option Area, application for Extraction expected shortly)		2
	Aggregate Tender Area (2103)	Tender Area (2021/2022)	Low – no information available	3
Sea Disposal Sites	Hornsea Disposal Area 1	Open	High – Third party project details published in the public domain and confirmed as being 'accurate' by the Crown Estate	1
	Race Bank OWF			



Legend

- Array Area
- Offshore Export Cable Corridor
- ORCP Search Area
- Physical Processes Zone of Influence
- Offshore Wind Farm Sites
- Offshore Wind Farm Cable Agreements
- Aggregate Area
- Provisional Aggregates Area (2103)
- Open Disposal Area
- Viking Link Interconnector
- Telecom Cables
- Subsea Pipeline



Coordinate System: WGS 1984 UTM Zone 31N

0 10 20 km

Scale: 1:350,000

Preliminary Environmental Information Report

Location of Cumulative Projects relative to the Physical Processes Study Area

Figure 7.27

OUTER DOWSING OFFSHORE WIND

Date: 19/04/2023
Produced By: BPHB
Revision: 0.1

GoBe

Contains ESRI Basemapping; Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

Document Path: G:\GIS\GIS_Projects\0152 Outer Dowsing EIA\GIS\Figures\PEIR\Physical Processes\ODOW_0152_PP_Fig7.27_Cumulative_Projects.mxd

7.13.4 The cumulative MDS for the Project is presented in Table 7.11.

Table 7.11: Cumulative MDS

Impact	Scenario	Justification
Cumulative increases in SSC and consequential changes to seabed levels	Tier 1: ▪ Offshore Wind Farm Export Cables (O&M activities); ▪ Subsea Cables (O&M activities); ▪ Pipelines (O&M activities); ▪ Aggregate Production Areas (Operation); ▪ Marine Disposal Sites (Operation); and ▪ Oil and Gas (O&M activities). Tier 2: ▪ Aggregate Area 1805 (Inner Dowsing Hanson Aggregates Marine Ltd) (Operation). Tier 3: ▪ Aggregate Tender Area 2103 (Operation).	If these intermittent activities overlap temporally with either the construction or O&M of the Project, there is potential for cumulative SSC and sediment deposition to occur within the modelled plume footprints.
Cumulative impacts to seabed morphology (sandbanks, sandwave areas and notable bathymetric depressions)	Tier 2: ▪ Aggregate Area 1805 (Inner Dowsing Hanson Aggregates Marine Ltd) (Operation). Tier 3: ▪ Aggregate Tender Area 2103 (Operation).	Activities that directly interact with the seabed could overlap spatially or temporally, resulting in greater magnitude of change to seabed morphology or inhibiting the ability of the system to recover.
Cumulative modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime	Tier 1: ▪ Offshore Energy (Operation).	Maximum potential for cumulative changes to hydrodynamics, waves and sediment transport.

Impact 9: Cumulative Increases in SSC and Consequential Changes to Seabed Levels

7.13.5 Due to uncertainty associated with the exact timing of other projects and activities, there is insufficient data on which to undertake a quantitative or semi-quantitative assessment. As such, the discussion presented here is qualitative. It is considered highly unlikely that each of the identified projects would be undertaking major maintenance works, in particular asset reburial or repairs, as these are infrequent occurrences during the lifetime of developments.

7.13.6 Sediment plumes from operational and maintenance activities are generally short-lived, with major maintenance works infrequent. Any impacts from operational offshore windfarm export cables, pipelines, and oil and gas activities are therefore likely to be short-lived and of localised extent, with limited opportunity to overlap with Project-related activities. The Viking Link Interconnector is currently in construction and is expected to be in service by the end of 2023, therefore maintenance-related impacts are similarly considered to be primarily short-lived and localised. Accordingly, the potential for cumulative interaction with these sites is limited and therefore has not been assessed further.

7.13.7 Aggregate Area 515/2 ('Outer Dowsing') is located approximately 1.1km from the Project array area, and 0km from the Offshore ECC, as shown in Figure 7.27. In addition, Area 481/1 ('Inner Dowsing') is located 1.3km south of the Offshore ECC, and Areas 5.15/1, 106/3, and 400 are located between 2.5km and 3km north of the Offshore ECC. In addition, the Exploration and Option Area 1805 ('Inner Dowsing') overlaps with the Offshore ECC, as shown in Figure 7.27, and an application is expected shortly for a production licence. Area 2103, also overlapping the Offshore ECC (see Figure 7.27) has been selected by TCE within the 2021/22 marine aggregates tender round, and is subject to the outcome of a plan-level HRA. Due to uncertainty associated with the timing, possible extent, or license outcome of Tender Area 2103, this area has not been assessed further. Area 2103 may be incorporated into future assessments as more information becomes available.

7.13.8 On the basis of sediment plume modelling presented in Paragraph 7.12.1, it can reasonably be assumed that sediment plumes may be advected this distance from the Project infrastructure. This means that in theory, should Project construction related activities be occurring at the same time as aggregate extraction, there could be the potential for cumulative changes in SSC and bed levels. According to figures provided by British Marine Aggregate Producers Association (BMAPA) for the last five years, dredging intensity within these Areas located within the Humber Region primarily ranges from low (<15 minutes) to medium (15 minutes to 75 minutes), with only a small proportion dredged at a high intensity (>75 minutes).

Conceptual Understanding of Change

7.13.9 The interaction between sediment plumes generated by Project construction activities and those from nearby aggregate dredging could theoretically occur in two ways:

- Where plumes generated from the two different activities meet and coalesce to form one larger plume; or
- Where aggregate extraction occurs within the plume generated by Project construction activities (or vice versa).

7.13.10 For two or more separately formed plumes that meet and coalesce, the physical laws of dispersion theory mean concentrations within the plumes are not additive but instead a larger plume is created with regions of potentially differing concentration representative of the separate respective plumes. In contrast, in the case of plumes formed by a dredging vessel operating within the plume created by foundation installation or bed preparation activities (or vice versa), the two plumes would be additive, creating a plume with higher SSC.

7.13.11 The target material in terms of aggregate extraction is sands and gravels (HADAa, 2012). Characteristically, the aggregate deposits in this region contain 1% to 3% fines (silt and clay) *in situ.* and consequently dredging overspill is predicted to be relatively low. The predicted footprint of fine sediment plumes arising from aggregate dredging in this region has previously been considered for the Humber Regional Environmental Assessment (MAREA) using plume dispersion modelling. The spatial extent of the zones around the aggregate areas experiencing elevated levels of SSC in excess of 20mg/l above background levels remains localised (i.e. within 1km to 2km) to the marine aggregate areas.

7.13.12 On the basis of the numerical modelling of construction related activities within the Project array area, it is found that MFE, seabed levelling and sandwave clearance activities gives rise to the greatest extent of suspended sediment plumes. Although SSC may be highly elevated within several hundreds of metres of activities, this is expected to reduce rapidly with distance, with SSC in the low hundreds of mg/l at distance beyond approximately 2km. In almost all cases, sediment plumes are indistinguishable from background levels after 20 hours. On this basis, although there is potential for sediment plumes from Project activities to interact with those from aggregate dredging, any overlap is expected to be short-lived and affect only a small area.

Magnitude of Impact

7.13.13 As outlined in Paragraph 7.12.31, levels of sediment dispersion are high, with almost all sediment plumes being indistinguishable from background levels after 20 hours. Given the short-lived nature of the sediment plumes, alongside the location of other infrastructure (Figure 7.27), there is not anticipated to be a notable overlap with concentrated sediment plumes created from other industry activities. Any overlap expected with aggregate dredging activities is likely to be temporary and restricted to the near-field, with the magnitude of this change being assessed as low.

Sensitivity of the Receptor

7.13.14 All the identified Marine Processes receptors will be insensitive to localised changes in SSC and bed levels associated with the sediment disturbance activities described in this section. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere in the PEIR, in particular:

- Volume 1, Chapter 8: Marine Water Quality;
- Volume 1, Chapter 9: Benthic and Intertidal Ecology;
- Volume 1, Chapter 10: Fish and Shellfish Ecology;
- Volume 1, Chapter 11: Marine Mammals; and

- Volume 1, Chapter 12: Offshore and Intertidal Ecology.

Significance of Effects

There are no Marine Processes receptors sensitive to the impact pathway and assessment of residual effects is not applicable.

Impact 10: Cumulative Impacts to Seabed Morphology (Sandbanks, Sandwave Areas and Notable Bathymetric Depressions)

7.13.15 Project activities that directly interact with the seabed may potentially overlap with those of other industries, leading to higher magnitude or more continuous change to seabed morphology. This is primarily expected to occur within the PEIR Boundary. As outlined previously, it is considered highly unlikely that offshore energy or O&G projects and infrastructure would be undertaking major maintenance works, in particular asset reburial or repairs, as these are infrequent occurrences during the lifetime of developments.

7.13.16 Two aggregate areas have been identified to have a significant overlap with the PEIR Boundary, as previously outlined in Paragraph 7.13.7 *et seq.* The Exploration and Option Area 1805 ('Inner Dowsing') overlaps with the Offshore ECC, as shown in Figure 7.27, and is currently in application for a production licence, and the Aggregate Tender Area 2103 is part of the 2021/22 marine aggregates tender round, with potential to be awarded an Exploration and Option Agreement subject to the results of a plan-level HRA. Due to uncertainty associated with the timing, possible extent, or license outcome of Tender Area 2103, this area has not been assessed further. Area 2103 may be incorporated into future assessments as more information becomes available.

Conceptual Understanding of Change

7.13.17 The primary direct impact of aggregate dredging on the physical seabed environment is the removal of surface layers of sediment, resulting in change to topography, sediment particle size, and water depth. Aggregate extraction in the UK is carried out by TSHD, which creates shallow furrows around 0.5m deep and 2m to 3m wide, that may extend for several kilometres in length (Tillin, 2011). However, over time, repeated passage of the draghead across the same area can lower the seabed by several metres, if the deposits are thick enough (HADA, 2012b).

7.13.18 As with Project construction activities, as outlined in Paragraph 7.12.35 *et seq.*, physical recovery of the seabed is generally expected to occur in areas that have been dredged through natural hydrodynamic processes (HADA, 2012b). However, in combination with certain Project activities, particularly sandwave clearance which will result in topographic and bathymetric change, the magnitude of this change will be greater, with recovery expected to take longer. In addition, seabed recovery and bedform migration may be inhibited further if dredging activities occur in the months or years after sandwave clearance.

Magnitude of Impact

7.13.19 As outlined above, there is the potential for long-term change in the near-field, where the PEIR Boundary overlaps with potential future aggregate extraction. This change will be noticeable and temporary, but with the potential to last over the period of aggregate extraction. On this basis, the magnitude of change has been assessed as medium.

Sensitivity of the Receptor

7.13.20 The following receptors have been considered in the assessment of potential changes to seabed morphology:

- Areas of undesignated seabed.

7.13.21 Areas of undesignated seabed are expected to be subject to changes in seabed morphology as described above. However, due to the fact that it is undesignated, this receptor has been assessed as negligible.

Significance of Effects

7.13.22 The assessment has concluded that the magnitude of impact seabed morphology is medium. The receptor identified is considered to be of negligible sensitivity (at worst). Based on the matrix provided in Table 7.8, the effect will be of **minor adverse** significance, which is not significant in EIA terms.

Impact 11: Cumulative Modifications to the Wave and Tidal Regime and Associated Potential Impacts to the Sediment Transport Regime

7.13.23 Blockage effects from the installation of Project infrastructure have the potential to combine with those from other projects within the region. On the basis of hydrodynamic and wave blockage modelling presented in Paragraph 7.12.83, it is expected that only projects within 20km of the array area have the potential to create overlapping blockage effects. This is based on the maximum array-scale wave blockage created by the array area over baseline conditions, as shown in Figure 7.26. Projects that have the potential to create cumulative blockage effects therefore include Triton Knoll and Dudgeon Extension.

Conceptual Understanding of Change

7.13.24 Numerical hydrodynamic modelling, as presented in Paragraph 7.12.85, indicates that change to tidal flows and water levels is restricted to within 1km of the array area. Any interaction with other project infrastructure is therefore not considered likely and hence hydrodynamic blockage effects have not been considered further.

7.13.25 Triton Knoll OWF is located 7.7km away from the Project array area, as shown in Figure 7.27. At this distance there is expected to be an array-scale wave shadow effect of between 0.025m to 0.1m in significant wave height. This will potentially interact with blockage effects caused by Triton Knoll infrastructure. However, these impacts dissipate with distance southwest of the Project infrastructure and are therefore unlikely to contribute meaningfully to any array-scale wave blockage caused by Triton Knoll infrastructure. In addition, localised change in the wave regime at this location is unlikely to result in any changes to seabed morphology as sediment transport in this area is driven by the action of tidal currents. Cumulative impacts to the wave regime will therefore be noticeable and permanent but restricted spatially.

Magnitude of Impact

7.13.26 Due to distance from other projects, as well as the tidally driven nature of sediment transport in the area, the magnitude of cumulative blockage effects is expected to be noticeable and permanent, but restricted to the near-field, and unlikely to result in any discernible change to morphology. It has therefore been assessed to be negligible in magnitude.

Sensitivity of the Receptor

7.13.27 The following receptors have been considered in the assessment of modifications to the wave and tidal regime and associated potential impacts on morphology:

- Inner Dowsing, Race Bank and North Ridge SAC; and
- Areas of undesignated seabed.

7.13.28 As outlined previously in Paragraph 7.12.94 *et seq.*, these receptors have been identified as negligible.

Significance of Effects

7.13.29 The assessment has concluded that the magnitude of impact on the wave and tidal regime is negligible. All receptors identified are considered to be of negligible sensitivity. Based on the matrix provided in Table 7.8, the effect will be of **negligible** significance, which is not significant in EIA terms.

7.14 Inter-Relationships

7.14.1 Inter-relationships are those impacts and associated effects of different aspects of the proposed Project upon the same receptor. These can be identified as:

- Receptor-led effects: Assessment of the scope for all effects to interact, spatially and temporally, to create inter-related effects on a receptor. As an example, all effects on benthic ecology such as direct habitat loss or disturbance, sediment plumes, scour, etc., may interact to produce a different, or greater effect on this receptor than when the effects are considered in isolation. Receptor-led effects may be short-term, temporary or transient but may also incorporate longer term effects; and
- Project lifetime effects: Assessment of the scope for effects that occur throughout more than one phase of the Project (construction, operation and maintenance and decommissioning); to interact to potentially create a more significant effect on a receptor than if just assessed in isolation in these three key project stages (for example subsea noise effects from piling, operational WTGs, vessels and decommissioning).

7.14.2 The potential inter-relationships which are relevant to this Marine Processes assessment are presented in Table 7.12.

Table 7.12: Marine Processes Inter-Relationships

Potential effect	Related chapter	Consideration within PEIR	Rationale
Construction			
Increases in SSC resulting in elevated turbidity and consequential changes to seabed levels	▪ Volume 1, Chapter 8: Marine Water Quality; ▪ Volume 1, Chapter 9: Benthic Subtidal and Intertidal Ecology; ▪ Volume 1, Chapter 10: Fish and Shellfish Ecology; ▪ Volume 1, Chapter 11: Marine Mammals; and ▪ Volume 1, Chapter 14: Commercial Fisheries.	Section 7.12 (Impact 1)	Benthic communities and fish species could be adversely affected by increased suspended sediment concentrations.
Potential impacts to seabed morphology (sandbanks, sandwave areas and notable bathymetric depressions)	▪ Volume 1, Chapter 9: Benthic Subtidal and Intertidal Ecology; ▪ Volume 1, Chapter 10: Fish and Shellfish Ecology; and ▪ Volume 1, Chapter 14: Commercial Fisheries.	Section 7.12 (Impact 2)	Benthic communities and fish species could be adversely affected by disturbance to seabed habitats.
Operation and Maintenance			
Modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime and morphological features	▪ Volume 1, Chapter 9: Benthic Subtidal and Intertidal Ecology; ▪ Volume 1, Chapter 10: Fish and Shellfish Ecology; and ▪ Volume 1, Chapter 14: Commercial Fisheries.	Section 7.12 (Impact 4)	Benthic communities and fish species could be adversely affected by disturbance to seabed habitats.
Seabed scouring	▪ Volume 1, Chapter 9: Benthic Subtidal and Intertidal Ecology; ▪ Volume 1, Chapter 10: Fish and Shellfish Ecology; and ▪ Volume 1, Chapter 14: Commercial Fisheries.	Section 7.12 (Impact 5)	Benthic communities and fish species could be adversely affected by disturbance to seabed habitats.
Decommissioning			

Potential effect	Related chapter	Consideration within PEIR	Rationale
Increases in SSC and consequential changes to seabed levels	▪ Volume 1, Chapter 8: Marine Water Quality; ▪ Volume 1, Chapter 9: Benthic Subtidal and Intertidal Ecology; ▪ Volume 1, Chapter 10: Fish and Shellfish Ecology; ▪ Volume 1, Chapter 11: Marine Mammals; and ▪ Volume 1, Chapter 14: Commercial Fisheries.	Section 7.12 (Impact 6)	Benthic communities and fish species could be adversely affected by increased suspended sediment concentrations.
Potential impacts to seabed morphology (sandbanks, sandwaves and notable bathymetric depressions)	▪ Volume 1, Chapter 9: Benthic Subtidal and Intertidal Ecology; ▪ Volume 1, Chapter 10: Fish and Shellfish Ecology; and ▪ Volume 1, Chapter 14: Commercial Fisheries.	Section 7.12 (Impact 7)	Benthic communities and fish species could be adversely affected by disturbance to seabed habitats.

7.15 Transboundary effects

7.15.1 No transboundary effects are predicted to result from the construction, operation and maintenance nor decommissioning phases of the proposed Project with respect to marine processes receptors.

7.15.2 Therefore, no significant transboundary effects are predicted for marine processes and as such an assessment of transboundary effects are not considered necessary in this PEIR chapter.

7.16 Conclusions

7.16.1 This PEIR chapter has investigated the potential effects on Marine Processes receptors arising from the Project. The range of potential impacts and associated effects has been informed by the Scoping Opinion and consultation responses (including those submitted during the EPP) from stakeholders, alongside reference to existing legislation and guidance.

Table 7.13: Summary of Potential Impacts on Marine Processes

Description of effect	Effect	Additional mitigation measures	Residual impact
Construction			
Effect 1: Increases in SSC resulting in elevated turbidity and consequential changes to seabed levels	(Pathway)	Not Applicable – no additional mitigation identified	(Pathway)
Effect 2: Potential impacts to seabed morphology (sandbanks, sandwave areas and notable bathymetric depressions)	Minor significance of effect (at worst)	Not Applicable – no additional mitigation identified	No significant adverse residual effects.
Effect 3: Modifications to littoral transport and coastal behaviour (erosion), including at landfall	Minor significance of effect (at worst)	Not Applicable – no additional mitigation identified	No significant adverse residual effects.
Operation and Maintenance			
Effect 4: Modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime and morphological features	Minor significance of effect (at worst)	Not Applicable – no additional mitigation identified	No significant adverse residual effects.
Effect 5: Seabed scouring	Minor significance of effect (at worst)	Not Applicable – no additional mitigation identified	No significant adverse residual effects.
Decommissioning			
Effect 6: Increases in SSC and consequential changes to seabed levels	(Pathway)	Not Applicable – no additional mitigation identified	(Pathway)

Description of effect	Effect	Additional mitigation measures	Residual impact
Effect 7: Potential impacts to seabed morphology (sandbanks, sandwaves and notable bathymetric depressions)	Minor significance of effect (at worst)	Not Applicable – no additional mitigation identified	No significant adverse residual effects.
Cumulative			
Effect 8: Cumulative increases in SSC and consequential changes to seabed levels	(Pathway)	Not Applicable – no additional mitigation identified	(Pathway)
Effect 9: Cumulative impacts to seabed morphology (sandbanks, sandwave areas and notable bathymetric depressions)	Minor significance of effect (at worst)	Not Applicable – no additional mitigation identified	No significant adverse residual effects.
Effect 10: Cumulative modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime	Negligible significance of effect (at worst)	Not Applicable – no additional mitigation identified	No significant adverse residual effects.

7.17 References

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