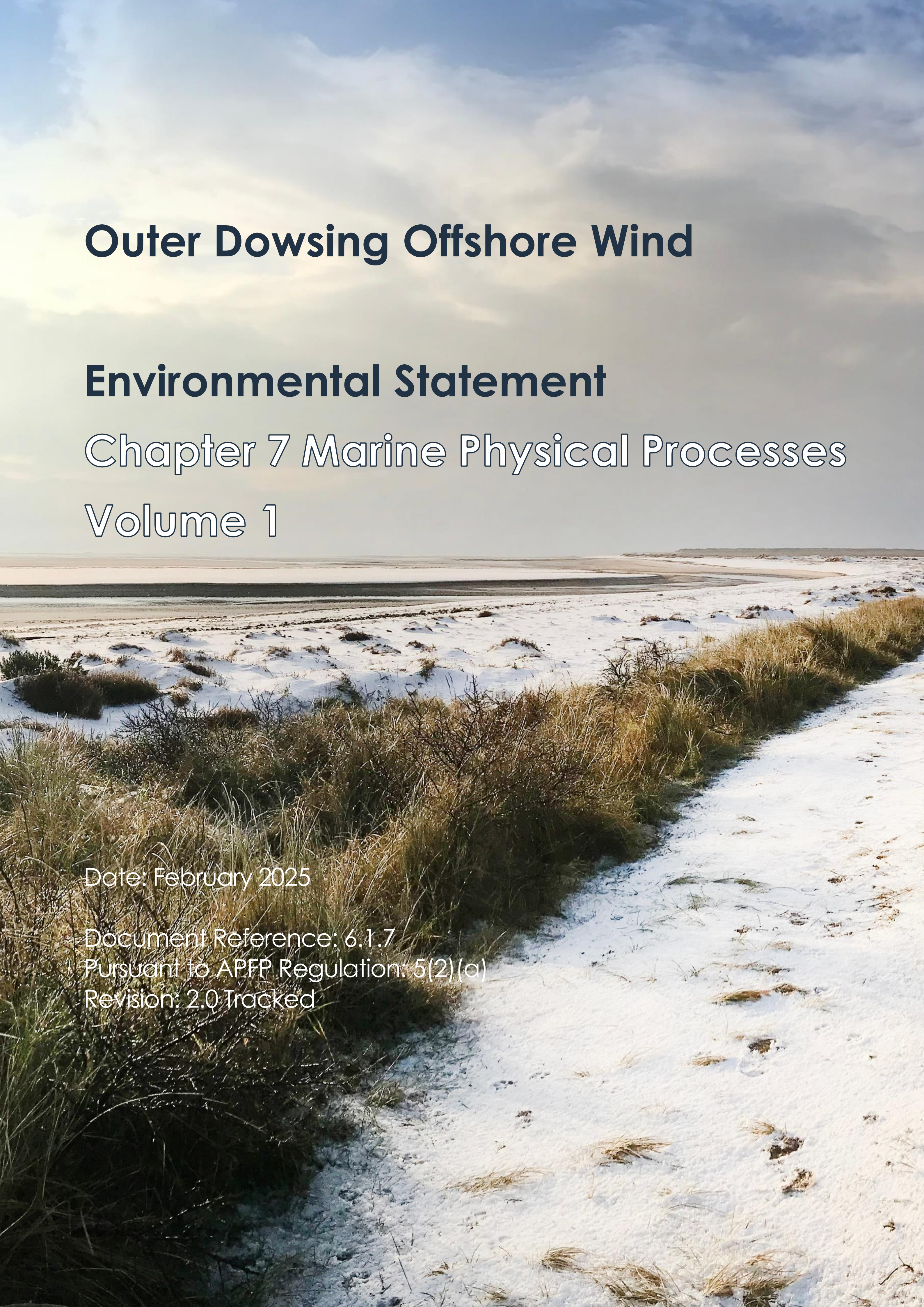

Outer Dowsing Offshore Wind

Environmental Statement

Chapter 7 Marine Physical Processes

Volume 1

Date: February 2025

Document Reference: 6.1.7
Pursuant to APFP Regulation: 5(2)(a)
Revision: 2.0 Tracked

Company:	**Outer Dowsing Offshore Wind**	Asset:	**Whole Asset**
Project:	**Whole Wind Farm**	Sub Project/Package:	Whole Asset
Document Title or Description:	Chapter 7 Marine Physical Processes		
Internal Document Number:	PP1-ODOW-DEV-CS-REP-0115_02	3rd Party Doc No (If applicable):	N/A

Rev No.	**Date**	**Status / Reason for Issue**	**Author**	**Checked by**	**Reviewed by**	**Approved by**
1.0	March 2024	Final	GoBe	GoBe	Shepherd & Wedderburn	Outer Dowsing
2.0	February 2025	Examination ES Update: updates to reflect, where relevant: clarifications to date in Examination; correcting errata; additional commitments made through Examination; and changes to status of or addition of cumulative projects	GoBe	GoBe	Shepherd & Wedderburn	Outer Dowsing

Change Log

- Examination Update: updates to reflect, where relevant: clarifications to date in Examination; correcting errata; additional commitments made through Examination; and changes to status of or addition of cumulative projects.

Table of Contents

Table of Tables

Table of Plates

Table of Figures

Acronyms & Terminology

Abbreviations / Acronyms

Abbreviation / Acronym	Description
AfL	Agreement for Lease
ANS	Artificial Nesting Structure
BEIS	Department for Business, Energy & Industrial Strategy (now the Department for Energy Security and Net Zero (DESNZ))
BERR	Department for Business, Enterprise and Regulatory Reform
BGS	British Geological Survey
BMAPA	British Marine Aggregate Producers Association
BOEM	Bureau of Ocean Energy Management
BSI	British Standards Institution
CBRA	Cable Burial Risk Assessment
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CIRIA	Construction Industry Research and Information Association
CoCP	Code of Construction Practice
COWRIE	Collaborative Offshore Wind Energy Research into the Environment
CPA	Coast Protection Act
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
ECC	Export Cable Corridor
EEA	European Economic Area
EIA	Environmental Impact Assessment
EMF	Electromagnetic fields
EMP	East Marine Plan
EPP	Evidence Plan Process
ES	Environmental Statement
ETG	Expert Topic 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

Abbreviation / Acronym	Description
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide
LiDAR	Light Detection and Ranging
MAREA	Marine Aggregate Regional Environmental Assessment
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)
ORBA	Offshore Restricted Build Area
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
SPCPMP	Scour Protection and Cable Protection Management Plan
SPM	Suspended Particulate Matter
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
Agreement for Lease (AfL0 array area	The area of the seabed awarded to GT R4 Ltd. through an Agreement for Lease (AfL) for the development of an offshore windfarm, as part of The Crown Estate's Offshore Wind Leasing Round 4.
Array area	The area offshore 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, including the ORBA.
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 additively with the effects of other developments, 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).
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 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 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	The area between Mean High Water Springs (MHWS) and Mean Low Water Springs (MLWS).
Landfall	The location at the land-sea interface where the offshore export cables and fibre optic cables will come ashore.
Maximum Design Scenario	The project design parameters, or a combination of project design parameters that are likely to result in the greatest potential for change in relation to each impact assessed.

Term	Definition
Mitigation	Mitigation measures 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 Order Limits within which the export cable running from the array to landfall will be situated.
Offshore Substation (OSS)	A structure attached to the seabed by means of a foundation, with one or more decks and a helicopter platform (including bird deterrents), containing— (a) electrical equipment required to switch, transform, convert electricity generated at the wind turbine generators to a higher voltage and provide reactive power compensation; and (b) housing accommodation, storage, workshop auxiliary equipment, radar and facilities for operating, maintaining and controlling the substation or wind turbine generators.
Offshore Restricted Build Area (ORBA)	The area within the array area, where no wind turbine generator, offshore transformer substation or offshore accommodation platform shall be erected.
Offshore Reactive Compensation Station (ORCP)	A structure attached to the seabed by means of a foundation, with one or more decks ~~and a helicopter platform~~ (including bird deterrents) housing electrical reactors and switchgear for the purpose of the efficient transfer of power in the course of HVAC transmission by providing reactive compensation.
Order Limits	The area subject to the application for development consent, the limits shown on the works plans within which the Project may be carried out.
Preliminary Environmental Information Report (PEIR)	The PEIR was written in the style of a draft Environmental Statement (ES) and provided information to support and inform the statutory consultation process during the pre-application phase.
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.
Statement of Common Ground (SoCG)	A statement of common ground is a written statement produced jointly between The Applicant and another Interested Party setting out the areas of agreement and /or disagreement between parties.
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.~~

Term	Definition
	~~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.~~ GTR4 Limited (a joint venture between Corio Generation (and its affiliates), TotalEnergies and Gulf Energy Development), trading as Outer Dowsing Offshore Wind.
The Planning Inspectorate	The agency responsible for operating the planning process for Nationally Significant Infrastructure Projects (NSIPs).
The Project	Outer Dowsing Offshore Wind, an offshore wind generating station together with associated 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)	A structure comprising a tower, rotor with three blades connected at the hub, nacelle and ancillary electrical and other equipment which may include J-tube(s), transition piece, access and rest platforms, access ladders, boat access systems, corrosion protection systems, fenders and maintenance equipment, helicopter landing facilities and other associated equipment, fixed to a foundation.

Reference Documentation

Document Number	Title	Most Recent Examination Reference
6.1.3	Chapter 3: Project Description	V2 to be submitted at Deadline 5
6.1.4	Chapter 4: Site Selection and Consideration of Alternatives	V2 to be submitted at Deadline 5
6.1.6	Chapter 5: Technical Consultation	V2 to be submitted at Deadline 5
6.1.8	Chapter 8: Marine Water and Sediment Quality	V3 to be submitted at Deadline 5
6.1.9	Chapter 9: Benthic Subtidal and Intertidal Ecology	V2 to be submitted at Deadline 5
6.1.10	Chapter 10: Fish and Shellfish Ecology	V2 to be submitted at Deadline 5
6.1.11	Chapter 11: Marine Mammals	V2 to be submitted at Deadline 5
6.1.12	Chapter 12: Offshore and Intertidal Ornithology	V3 to be submitted at Deadline 5
6.3.5.2	Appendix 2: Cumulative Effects Assessment Approach	APP-147

6.3.7.1	Appendix 7.1: Marine Physical Processes Technical Baseline	AS-003
6.3.7.2	Appendix 7.2: Marine Physical Processes Numerical Modelling Report	APP-151
5.1	Consultation Report	AS1-034

7 Marine Physical Processes

7.1 Introduction

1. This chapter of the Environmental Statement (ES) presents the results of the Environmental Impact Assessment (EIA) process for the potential impacts of Outer Dowsing Offshore Wind ('the Project') on Marine Physical Processes. Specifically, this chapter considers the potential impacts of the Project seaward of Mean High Water Springs (MHWS) during the construction, operation and maintenance, and decommissioning phases, in addition to specific receptors above MHWS that are considered Marine Physical Processes receptors for the purposes of this chapter.
2. GT R4 Limited (trading as Outer Dowsing Offshore Wind) hereafter referred to as the 'Applicant', is proposing to develop the Project. The Project array area 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, Offshore Reactive Compensation Platforms (ORCPs), onshore cables, connection to the electricity transmission network, ancillary and associated development, up to two Artificial Nesting Structures (ANS) and the creation and re-creation of a biogenic reef (if these compensation measures are deemed to be required by the Secretary of State) (see Volume 1, Chapter 3: Project Description (document reference 6.1.3) for full details).
3. For the purposes of this ES, Marine Physical 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.
4. This chapter should be read in conjunction with the following chapters and appendices:
   - Volume 1;
     - Chapter 3: Project Description (document reference 6.1.3);
     - Chapter 8: Marine Water and Sediment Quality (document reference 6.1.8);
     - Chapter 9: Benthic Subtidal and Intertidal Ecology (document reference 6.1.9);
     - Chapter 10: Fish and Shellfish Ecology (document reference 6.1.10);
     - Chapter 11: Marine Mammals (document reference 6.1.11); and
     - Chapter 12: Offshore and Intertidal Ornithology (document reference 6.1.12);
   - Volume 3;
     - Appendix 7.1: Marine Physical Processes Technical Baseline (document reference 6.3.7.1); and
     - Appendix 7.2: Marine Physical Processes Modelling Report (document reference 6.3.7.2).

7.2 Statutory and Policy Context

5. The assessment of potential impacts on Marine Physical 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.

6. In undertaking the assessment, the following policy and legislation has been considered:
   - The Conservation of Habitats and Species Regulations 2017;
   - The Conservation of Offshore Marine 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]; and
   - The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017.

7. 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 Security and Net Zero (DESNZ, 2023a);
   - The NPS for Renewable Energy Infrastructure (NPS EN-3; DESNZ, 2023b);
   - The NPS for Electricity Networks Infrastructure (NPS EN-5; DESNZ, 2023c); and
   - The UK Marine Policy Statement (MPS; HM Government, 2011).

8. Other policies of relevance to Marine Physical Processes are the:
   - East Inshore and East Offshore Marine Plans (Marine Management Organisation (MMO), 2014);
   - National Flood and Coastal Erosion Risk Management Strategy for England (Environment Agency, 2020); and
   - Marine Strategy Framework Directive (MSFD) (EU, 2008)[2].

9. Legislation relevant to Marine Physical Processes and details on how they have been addressed in this ES 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 UK national site network.

[2] The MSFD was transposed into UK law under the Marine Strategy Regulations 2010, which are the primary legislative mechanism for the implementation of the provisions of the MSFD as the MSFD no longer has direct effect in the UK.

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

Legislation/policy	Key provisions	Section where comment addressed
The 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 of which are designated on the basis of geological and geomorphological features contained within them. The locations of these sites are shown in Volume 2, Figure 7.9 (document reference 6.2.7.9) with an assessment of potential impacts of the Project in Section 7.12 of this chapter.
The Conservation of Offshore Marine Habitats and Species Regulations 2017	Maintain or, where appropriate, restore offshore 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 offshore nature conservation sites, some of which are designated on the basis of geological and geomorphological features contained within them. The locations of these sites are shown in Volume 2, Figure 7.9 (document reference 6.2.7.9) with an assessment of potential impacts of the Project in Section 7.12 of this 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. While the Habitats Directive will no longer have direct effect in the UK (after 31 December 2023 through the Retained EU Law (Revocation and Reform) Act 2023), its provisions are implemented in UK domestic law by way of the Conservation of Habitats and Species Regulations 2017 and the Conservation of Offshore Marine Habitats and Species Regulations 2017 (together the Habitats Regulations). Any references to the Habitats Directive in the chapter is to provide	The study area overlaps with a number of nationally and internationally designated nature conservation sites, some of which are designated on the basis of geological and geomorphological features contained within them. The locations of these sites are shown in Volume 2, Figure 7.9 (document reference 6.2.7.9) with an assessment of potential impacts of the Project in Section 7.12 of this chapter.

Legislation/policy	Key provisions	Section where comment addressed
	context to the Habitats Regulations (which are now the primary legislative mechanism, along with relevant guidance, for implementing the provisions of the Directive).	
National Policy Statements (DESNZ, 2023)		
NPS EN-1 (DESNZ, 2023a)	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 document reference 6.3.7.1 and are considered alongside predicted changes described in the assessment (Section 7.12).
NPS EN-1 (DESNZ, 2023a)	EN-1, Paragraph 5.6.10: 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 Physical Processes using the evidence base, project specific baseline characterisation and project specific numerical modelling is provided in Section 7.12 of this chapter.
NPS EN-1 (DESNZ, 2023a)	EN-1, Paragraph 5.6.11: 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 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	A description of the baseline (existing) Marine Physical Processes is provided in Section 7.4 of this chapter as well as within document reference 6.3.7.1. The impact of the Project on coastal processes and geomorphology is considered in Section 7.12 of this chapter. The implications of the Project on strategies for managing the coast are considered in Paragraph 139 *et seq*. The effects of the Project on marine ecology, biodiversity and protected sites are considered elsewhere in the ES within the following chapters:

Legislation/policy	Key provisions	Section where comment addressed
	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.	▪ Document reference 6.1.9; ▪ Document reference 6.1.10; ▪ Document reference 6.1.11; ▪ Document reference 6.1.12; 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 (document reference 6.1.18).
NPS EN-1 (DESNZ, 2023a)	EN-1, Paragraph 5.6.13: 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 Volume 2, Figure 7.9 (document reference 6.2.7.9) with potential impacts considered in Section 7.12 of this chapter. Potential impacts of the Project upon Marine Physical Processes are considered in terms of indirect effects (including pathways) on other receptors elsewhere in the ES, in particular in document reference 6.1.9 and in Document Reference 7.1.
NPS EN-1 (DESNZ, 2023a)	EN-1, Paragraph 5.6.17: The Secretary of State should not normally consent new development in areas of dynamic 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	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 139 *et seq*. A full description of coastal processes

Legislation/policy	Key provisions	Section where comment addressed
	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.	understanding at the landfall is set out in document reference 6.3.7.1.
NPS EN-3 (DESNZ, 2023b)	EN-3, Paragraph 2.8.111: 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 Physical Processes (including all of those listed in Paragraph 2.8.111 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 chapter.
NPS EN-3 (DESNZ, 2023b)	EN-3, Paragraph 2.8.112 and 2.8.113: Applicant assessments 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 scouring that may result from the proposed development and how that might impact sensitive species and habitats.	An assessment of the potential impacts of the Project on Marine Physical Processes is provided in Section 7.12 of this chapter.
NPS EN-3 (DESNZ, 2023b)	EN-3, Paragraph 2.8.114: Applicants should undertake geotechnical investigations as part of the assessment, enabling	Geotechnical data has been included within document reference 6.3.7.1 as part of the characterisation of the baseline environment.

Legislation/policy	Key provisions	Section where comment addressed
	the design of appropriate construction techniques to minimise any adverse effects	Geotechnical data has been used alongside the project specific geophysical survey to inform the assessment and project design of the Project.
NPS EN-3 (DESNZ, 2023b)	EN-3, Paragraph 2.8.119: 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; ▪ Potential risk from invasive and non-native species; ▪ 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 Physical Processes is provided in Section 7.12 of this 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 139 *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 (DESNZ, 2023b)	EN-3, Paragraph 2.8.126: Applicant assessment of the effects on the subtidal environment should include:	An assessment of the potential impacts of the Project on Marine Physical Processes is provided in Section 7.12 of this chapter.

Legislation/policy	Key provisions	Section where comment addressed
	▪ 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; ▪ Potential impacts upon natural ecosystem functioning; ▪ Protected sites; and ▪ Potential for invasive/non-native species introduction.	Potential impacts of the Project on Marine Physical Processes are considered in terms of indirect effects (including pathways) on other receptors elsewhere in the ES, in particular in document reference 6.1.9 and in Document Reference 7.1.
NPS EN-3 (DESNZ, 2023b)	EN-3, Paragraph 2.8.308: Where indirect effects are predicted, the Secretary of State should refer to relevant sections of this NPS and EN-1.	Potential impacts of the Project on Marine Physical Processes are considered in terms of indirect effects (including pathways) on other receptors elsewhere in the ES, in particular in document reference 6.1.9 and in Document Reference 7.1.
NPS EN-3 (DESNZ, 2023b)	EN-3, Paragraph 2.8.309: The Secretary of State must be satisfied that the design of the windfarm, offshore transmission and the methods of construction, including use of	The Project has proposed designs and installation methods that seek to minimise significant adverse effects on the physical environment where

Legislation/policy	Key provisions	Section where comment addressed
	materials, are such as to reasonably minimise the potential for impact on the physical environment.	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 (DESNZ, 2023b)	EN-3, Paragraph 2.8.224 and 2.8.225: 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 is set out in Table 7.4. Consultation is ongoing with statutory consultees and other interested parties.
NPS EN-5 (DESNZ, 2023c)	EN-5, Paragraph 2.3.2: As climate change is likely to increase risks to the resilience of some of this infrastructure, from flooding for example, or in situations where it is located near the coast or an estuary or is underground, 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:	The implications of the Project on strategies for managing the coast are considered in Paragraph 139 *et seq*. A full description of Marine Physical Processes understanding at the landfall is set out document reference 6.3.7.1.

Legislation/policy	Key provisions	Section where comment addressed
	• coastal erosion – for the landfall of offshore transmission cables and their associated 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. Marine plan authorities should not consider development which may affect areas at high risk and probability of coastal change unless the impacts upon it can be managed. Marine plan authorities should seek to minimise and mitigate any geomorphological changes that an activity or development will have on coastal processes, including sediment movement.	Potential changes in climate are described in document reference 6.3.7.1 and are considered alongside predicted changes identified in the assessment for each stage of the development (Section 7.12). 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 139 *et seq*.
MPS (HM Government, 2011)	Paragraph 2.6.8.3: Indirect changes to the coastline and seabed might also arise as a result in response to some of these direct changes. This could lead to localised or more widespread coastal erosion or accretion and changes to offshore features such as submerged banks and ridges. 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 162 *et seq*. The potential for effects (change/loss) on habitats is considered in document reference 6.1.9.
Marine Plans		

Legislation/policy	Key provisions	Section where comment addressed
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. Where detrimental impacts on climate change adaptation measures are identified, evidence should be provided as to how the proposal will reduce such impacts.	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 document reference 6.3.7.1. A description of the Marine Physical Processes understanding at the landfall is set out document reference 6.3.7.1. An assessment of the potential impacts of the Project on coastal processes and geomorphology is provided in Paragraph 139 *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. Details will be confirmed as part of the Cable Specification and Installation Plan (CSIP), which will follow the principles of the Outline CSIP (document reference 8.5). Indicative design options for cable burial and protection are set out in Volume 1, Chapter 3 (document reference 6.1.3).
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 chapter.

Legislation/policy	Key provisions	Section where comment addressed
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 Volume 2, Figure 7.9 (document reference 6.2.7.9) with an assessment of potential impacts of the Project in Section 7.12 of this 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 document reference 6.1.9.
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 chapter.

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

- Environmental Impact Assessment for offshore renewable energy projects (British Standards Institution (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 (Centre for Environment, Fisheries and Aquaculture Science (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 (Department for Business, Enterprise and Regulatory Reform (BERR), 2008);
- Offshore wind cabling: ten years' experience and recommendations (Natural England, 2018);
- Nature conservation considerations and environmental best practice for subsea cables for English Inshore and UK offshore waters (Natural England and Joint Nature Conservation Committee (JNCC), 2022);
- 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 Food and Environment Protection Act (FEPA) and Coast Protection Act (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

11. Consultation is a key part of the Development Consent Order (DCO) application process. Consultation regarding Marine Physical Processes has been conducted through the Evidence Plan Process (EPP) Expert Technical Group (ETG) meetings, the EIA scoping process (Outer Dowsing Offshore Wind, 2022) and the Preliminary Environmental Information Report (PEIR) process (Outer Dowsing Offshore Wind, 2023). An overview of the Project's Technical Consultation (document reference 6.1.6) and wider consultation is presented in the Consultation Report (document reference 5.1).
12. A summary of the key issues raised during consultation to date, specific to Marine Physical Processes, is detailed in Table 7.2, alongside information on how these issues have been considered in the production of this ES.
13. As identified in the Project Description (document reference 6.1.3) and the Site Selection and Consideration of Alternatives chapter (document reference 6.1.4), the Project design envelope has been refined for DCO submission. This process has been reliant on stakeholder consultation feedback. Design amendments to cable routing and landfall are of relevance to this chapter.

Table 7.2 Consultation responses relevant to Marine Physical 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. This data source is not available at the time of writing and has therefore not been integrated into the assessment. Consideration of historic and contemporary rates of coastal change is provided within Section 7.4 of this ES chapter and more fully within document reference 6.3.7.1, including analysis of Light Detecting and Radar (LiDAR) data from between 2016 and 2020.
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.	An assessment of potential impacts associated with seabed scouring is provided in Paragraph 182 *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 Environment Agency will 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 ES 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 chapter and more fully within document reference 6.3.7.1.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
Scoping Opinion (the Planning Inspectorate, 9th August 2022)	The Planning Inspectorate notes that scour protection would be installed, thus reducing the risk of scour; however, the Planning Inspectorate has considered the responses of the EA, the Marine Management Organisation (MMO) and Natural England 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 182 *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 Planning 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 consequential impacts on sediment transport, is provided in Section 7.13 of this chapter.

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 Planning Inspectorate cannot agree to scope these effects out. The ES should include an assessment of such cumulative effects, where likely significant effects could arise.	
Scoping Opinion (the Planning 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 Planning 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 Planning 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 Chapter 7.1 include a ‘study area’ boundary around the	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 Volume 2, Figure 7.1 (document reference 6.2.7.1), as well as more fully within document reference 6.3.7.1.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	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 Planning 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 (which at the point of the Scoping Opinion was a candidate Highly Protected Marine Area (HPMA)) has not been as an HPMA (Defra, 2023) and has therefore been excluded from further assessment.
Scoping Opinion (the Planning 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. Mitigation with direct relevance to Marine Physical Processes is outlined in Table 7.4 and has been included within the Impact Assessment.
Scoping Opinion (the Planning 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 Volume 2, Figure 7.10 (document reference 6.2.7.10) to Volume 2, Figure 7.23 (document reference 6.2.7.23). Further details are provided in document reference 6.3.7.2: Marine Physical Processes Modelling Report (document reference 6.3.7.2).
Scoping Opinion (the Planning 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 stakeholders represented on the Marine Ecology and	The approach to numerical modelling has been presented within the Marine Ecology and Coastal Processes ETG with relevant stakeholders, following submission of the PEIR. Details of the numerical modelling assumptions including the parameters, data sources and calibration/validation details are provided in document reference 6.3.7.2.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	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.	
Scoping Opinion (the Planning 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 32 *et seq.* of this chapter as well as more fully within document reference 6.3.7.1. Potential effects during construction on coastal morphology and processes are provided in Paragraph 139 *et seq*.
Scoping Opinion (the Planning 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 document reference 6.3.7.1. Potential effects of cable protection measures have been assessed in Paragraph 119 *et seq.* and Paragraph 152 *et seq.*
Scoping Opinion (the Planning 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) ESs. The scoping out of this impact has been presented at all relevant ETGs, with no further comment from stakeholders. Cofferdams are not being considered within the Project's design..
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-	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
	based studies which will provide information on 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. Geotechnical and geophysical data has been included within document reference 6.3.7.1 as part of the characterisation of the baseline environment.
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 182 *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 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 provided within Volume 1, Chapter 3. A summary of project design parameters of relevance to Marine Physical Processes is provided in Table 7.3 of this 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 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 be provided. This should include any assumptions, the	Details of the numerical modelling assumptions including the parameters, data sources and calibration/validation details is provided in document reference 6.3.7.2.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	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 Flamborough and Filey Coast (FFC) SPA seabirds.	An assessment of the potential impacts of the Project on offshore ornithology receptors is provided in document reference 6.1.12, making use of information provided within this 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 Volume 2, Figure 7.5 (document reference 6.2.7.5) within this chapter, with a comprehensive regional overview provided in document reference 6.3.7.1.
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 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 chapter and more fully within document reference 6.3.7.1. Potential impacts on coastal behaviour at the landfall site has been assessed in Paragraph 139 *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 effect on cable burial and the likely levels of introduced	Seabed mobility and its effect on cable burial has been considered as part of the baseline environmental description in document reference 6.3.7.1. Potential

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	rock or hard substrate that will be required for cable and turbine base scour protection.	effects of cable protection measures have been assessed in Paragraph 119 *et seq.* and Paragraph 152 *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 document reference 6.3.7.1 and has been used to inform the baseline within Section 7.4 of this 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 (which at the point of the Scoping Opinion was a candidate HMPA) has not been designated an HPMA (Defra, 2023) and has therefore been excluded from further assessment.
Scoping Opinion (Natural England, 9th August 2022)	Natural England advise that other mitigation measures should also be considered.	Mitigation with direct relevance to Marine Physical Processes is outlined in Table 7.4 and has been included within the Impact Assessment. Information pertaining to

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
		the mitigation approach is provided in Volume 1, Chapter 3.
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 chapter as well as within document reference 6.3.7.2.
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) ESs. The scoping out of this impact has been presented at all relevant ETGs, with no further comment from stakeholders, including Natural England.
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 139 *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 Paragraph 162 *et seq.* of this chapter.
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	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

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	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).	approximately 24km, that this feature can be scoped out of the Marine Physical Processes assessment. Potential impacts on coastal behaviour at the landfall site, including below MHWS and certain features above MHWS (specifically dune features behind the landfall beach), have been assessed in Paragraph 139 *et seq*. These receptors have also been included within Impact 8, specifically in Paragraph 178. 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 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 document reference 6.1.9 have been used for reference within this 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 consideration of the impact from deployment of scour protection can be assessed.	An assessment of potential impacts associated with seabed scouring, including impacts associated with secondary scour, is provided in Paragraph 182 *et seq.*, with relevant mitigation measures outlined in Table 7.4.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
Scoping Opinion (Natural England, 9th August 2022)	We advise that cumulative modifications to the wave and tidal regime (and associated potential impacts to the sediment transport regime) 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 chapter. The location of other offshore windfarm developments in the vicinity of the Project are shown in Volume 2, Figure 7.27 (document reference 6.2.7.27). 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 chapter are presented in document reference 6.3.7.1. Consideration of historic and contemporary rates of coastal change is provided within Section 7.4 of this chapter and more fully within document reference 6.3.7.1.
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.
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	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
	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.	consequential impacts on sediment transport, is provided in Section 7.13 of this chapter. The location of other offshore windfarm developments in the vicinity of the Project are shown in Volume 2, Figure 7.27 (document reference 6.2.7.27). 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 Volume 2, Figure 7.1 (document reference 6.2.7.1), as well as more fully within document reference 6.3.7.1.
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 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 development alone, and in combination with other nearby developments.	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 7.13 of this chapter.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
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 7.12 of this chapter. This has been used to inform the assessment provided in Section 7.13, 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.	NCERM2 was released in January 2024, and has been considered within the assessment. Consideration of historic and contemporary rates of coastal change is provided within Section 7.4 of this ES chapter and more fully within document reference 6.3.7.1, including analysis of LiDAR data from between 2016 and 2020.
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 182 *et seq.,* with relevant mitigation measures outlined in Table 7.4.
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, including below MHWS and certain features above MHWS (specifically dune features behind the landfall beach), have been assessed in Paragraph 139 *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 construction or operation of the development.	Potential impacts on coastal behaviour at the landfall site, including below MHWS and certain features above MHWS, (specifically dune features behind the landfall beach), have been assessed in Paragraph 139 *et seq*.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	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 Volume 2, Chapter 7, and referenced throughout this 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 66 *et seq*. of this 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 chapter and more fully within document reference 6.3.7.1.
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.	Potential impacts on coastal behaviour at the landfall site, including below MHWS and certain features above MHWS, (specifically dune features behind the landfall beach), have been assessed in Paragraph 139 *et seq*.
Section 42 Consultation Response (Environment Agency, 20th July 2023)	The Environment Agency notes that the use of bentonite is referred to within this Chapter. We have previously been involved with incidents of 'blow out' of bentonite slurry for similar projects when coming ashore; in one case the sands did not provide a stable enough seal to prevent break-out and resulted in	The Project will ensure that learnings from previous projects will be taken on-board to minimise the risk of a breakout, and the Project has already undertaken onshore geotechnical investigations which have confirmed the suitability of the landfall for Horizontal Directional Drilling (HDD) installation methods. Notwithstanding this, the

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	drilling mud having to be incorporated on the beach to dry naturally. East Lindsey District Council raised safety concerns because the safety data sheet indicated a chronic carcinogen risk from breathing in dust, and after drying there would be a risk of wind-blown dust generation. It may be prudent to discuss this issue with the Council. We note from Chapter 7 that there is an expectation of bentonite release, and allowance is made for two failures. You have also quantified the expected release rate and duration and that these will result in increased sediment load, but the bentonite will behave in much the same way as seawater. It is a non-toxic mud and no impacts are predicted for release within the marine environment (indiscernible from background concentrations). At the landfall point, the SSSIs have been avoided to mitigate the risk of impact. However, contingencies must be in place to deal with any 'blow out' during installation of the duct/cable, which may restrict access/delay other works in the area. As discussed in our recent meeting all work in this area will need to be programmed around the Environment Agency's beach nourishment works and we will look to capture this in a legal agreement.	procedures and methods to manage bentonite breakouts are detailed in the Outline Project Environmental Management Plan (document reference 8.4). The Applicant notes the requirement for a legal agreement regarding the timing of landfall works and will work with the Environment Agency to achieve this.
Section 42 Consultation Response (Natural England, 20th July 2023)	Based on Natural England's experience of sustainable development impacts within the Inner Dowsing Race Bank North Ridge SAC and wider southern North Sea,	The Applicant acknowledges the concerns raised by Natural England and can confirm that revised Marine Physical Processes modelling has been undertaken for the

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	Natural England wishes to highlight the importance of marine physical processes in maintaining balanced coastal and marine ecosystems. Therefore, Natural England advise that changes in marine physical processes are highly likely to have critical cross-cutting impacts across all thematic areas, with potential changes in marine physical processes impacting on benthic SAC interest features and supporting habitats and prey availability for mobile MPA interest features. Natural England advise that the Applicant provide robust project and site-specific modelling validated where possible from empirical evidence from adjacent windfarms and cables.	Project, supported by empirical evidence from nearby infrastructure, where available. The results of the project specific modelling have been used to inform the assessment conclusions for Marine Physical Processes as well as other topic assessments, as appropriate. Potential impacts of the Project on Marine Physical Processes are considered in terms of indirect effects (including pathways) on other receptors, including designated sites and habitats, elsewhere in the ES, in particular within document reference 6.1.9 and Document Reference 7.1. Potential inter-relationships relevant to the assessment of Marine Physical Processes are presented in Table 7.14.
Section 42 Consultation Response (Natural England, 20th July 2023)	Natural England notes that further evidence and clarification is required before Natural England can provide further advice on the significance of predicted impacts and proposed mitigation measures to address them. Natural England advises that the ES is updated to include relevant data and address ambiguity.	Evidence and data provided within this chapter, as well as document reference 6.3.7.1, have been reviewed and updated where necessary.
Section 42 Consultation Response (Natural England, 20th July 2023)	A number of pressures are already being exerted on IDRBNR SAC, including Race Bank OWF. Natural England consider that the extent, distribution, structure and function attributes of the Annex I sandbank feature have already been affected by the installation of Race Bank OWF. Natural England are, therefore, concerned that construction and operational impacts due to ODOW may further hinder	The Project notes Natural England's concerns and can confirm that refinement to the Project Design has taken place in accordance with the mitigation hierarchy. The mitigation options considered by the Project, and any reasoning regarding the implementation of the measure are discussed in Volume 1, Chapter 9: Benthic Subtidal and Intertidal Ecology (document reference 6.1.9).

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	site integrity and further compromise the ability of the site to meet its conservation objectives. The mitigation hierarchy should be applied and in the first instance every effort should be made to avoid an adverse effect on site integrity altogether; but if this is not possible impact reduction measures should be applied.	Annex I Sandbank features within the IDRBNR SAC have been considered as a receptor within the assessment provided in Section 7.12 of this chapter, and a full assessment of potential impacts to the IDRBNR SAC is provided in Document Reference 7.1.
Section 42 Consultation Response (Natural England, 20th July 2023)	There is a significant maximum design scenario (MDS) for the amount of sandwave clearance/levelling required for the project including within IDRBNR SAC. Natural England encourage the Project to refine the MDS as much as possible using project-specific geophysical/ground condition data, to reduce impacts. Where sandwave levelling is considered necessary, consideration should be given to the benefit of sandwave clearance in reducing the need for external cable protection versus potential impacts of the sandwave clearance on the conservation objectives of the MPA and/or form and function of sandbank-sandwave systems.	All project details presented in Chapter 3 (document reference 6.1.3) and Table 7.3 have been reviewed and updated where required. This includes the MDS for sandwave clearance/levelling, with details provided of the volumes assessed within the IDRBNR SAC. Due consideration has been given to the relative benefits of sandwave clearance during refinements to the Project Design. An assessment of the potential impacts of sandwave levelling is provided in Paragraph 105 *et seq.* Further evidence will be provided as part of a separate Project-specific Sandwave Levelling Assessment that will be submitted into the Examination.
Section 42 Consultation Response (Natural England, 20th July 2023)	Potential cable protection measures in shallow/nearshore areas could modify waves and flows and in turn interrupt sediment transport pathways. Natural England advise that cable protection should be avoided in shallow nearshore areas which would cause disruption to longshore sediment transport.	An assessment of potential impacts of cable protection measures on coastal receptors, including sediment transport pathways, is provided in Paragraph 152 *et seq.* Details will be confirmed as part of the Cable Specification and Installation Plan (CSIP), which will follow the principles of the Outline CSIP (document reference 8.5). Details of embedded mitigation measures are provided in Table 7.4.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
Section 42 Consultation Response (Natural England, 20th July 2023)	The downplaying of impact magnitude has led to the downgrading of effect significance which, in turn, means that effects are considered not significant in EIA terms. Natural England advise that it is important to make a clear distinction between evidence-based and value-based judgements so as to establish the level of subjective evaluation that has been used.	The assessments made in this chapter have been supported by empirical evidence from nearby infrastructure, project specific numerical modelling, as well as scientific literature from other offshore industries. Supporting evidence and data has been provided as appropriate throughout the assessment within Section 7.12 of this chapter.
Section 42 Consultation Response (Natural England, 20th July 2023)	Impacts to offshore sandbank systems within and near the array have not been considered. The Project needs to fully consider potential impacts to ecologically and morphologically important offshore sandbank systems within and near the array area. All phases of the project development should be considered, including impacts on sandbank extent, structure and function and sandwave recovery as this could have wider impacts to marine physical processes and ecosystems reliant upon them.	Offshore sandbanks have been considered as receptors within this chapter as appropriate, specifically within Paragraph 136 and Paragraph 178. Impacts on the ecology of sandbank systems is considered within document 6.1.9.
Section 42 Consultation Response (Natural England, 20th July 2023)	Rationale behind Worst Case Scenario (WCS) is not always clear. MDS foundation structure dimensions have not been provided. The rationale for spoil/drill volume for foundation installation is not clear.	All project details presented in Volume 1, Chapter 3 and Table 7.3 have been reviewed and updated where required, with further details provided regarding the rationale.
Section 42 Consultation Response (Natural England, 20th July 2023)	Natural England note for several aspects of the baseline, data sources are considered old and more up to date data should be used, for example, the specifical geophysical and benthic surveys. ▪ Holocene sediment layer thickness across the export cable corridor (ECC) has been obtained from Dove *et al.* (2017) and Tappin *et al.* (2011).	Further data has been provided as part of this chapter and document reference 6.3.7.1. This includes data from the Project-specific geophysical surveys, including along the Offshore ECC. Updated characterisation of the coastal frontage, including an assessment of change between 2016 and 2020, has now been provided.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	▪ Beach recharge material analysis results have been based on Blott and Pye (2004). ▪ The bedload transport pathways are assessed using Kenyon and Cooper (2005). ▪ Coastal erosion rate (HADA, 2012a and TKOWFL, 2015). ▪ Characterisation of the coastal frontage (HADA, 2012a). ▪ Three years of beach profile provided (EA, 2011, 2013a). Natural England recommend that up to date project/designated site/location specific data should be included in the ES.	The Applicant has undertaken to search for more recent reports, however, notes that several of the listed sources are the most up to date available in the public domain for specific aspects, or are otherwise considered to give an appropriate characterisation given the nature of the processes in question (e.g. Kenyon and Cooper, 2005). The Applicant further notes that these publicly available datasets are complemented by the site-specific surveys.
Section 42 Consultation Response (Natural England, 20th July 2023)	Natural England request that the Appendix E (Particle Size Distribution), PSA documents embedded in Appendix 9.2 (Benthic Ecology) Technical Report (ECC), are provided.	Appendix E (PSA Documents) have been provided as part of the Benthic Ecology Technical Report for the Array and ECC (Volume 3, Appendix 9.1 and 9.2 respectively (document reference 6.3.9.1 and 6.3.9.2))
Section 42 Consultation Response (Natural England, 20th July 2023)	Natural England note that metocean measurements are being collected within the array area, including the use of a floating lidar system and Seaguard Seabed Frame. Please clarify if that latter will also include turbidity/SSC measurements.	The Applicant can confirm that Project-specific turbidity measurements were collected as part of the Project campaign. A summary of this turbidity data is provided in document reference 6.3.7.1.
Section 42 Consultation Response (Natural England, 20th July 2023)	The numerical hydrodynamic and wave modelling show good levels of fit, with the exception of the inshore Race Bank model data which overpredicts current speeds. Are there any other data that could be used to validate the inshore data? We also note that only one wave direction (NE) has been modelled. This	The Project notes that, based on the categories used in Pye *et al.* (2017), the calibration and validation of the numerical model provides an 'excellent fit'. Updated numerical modelling has been undertaken, including the northern and north-eastern wave directions

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	correlates with prevailing wave conditions along the western part of the ECC and closer to the shore. How will the modelling take account of different prevailing wave directions across the study area?	as identified as those of relevance to the identified Marine Physical Processes receptors.
Section 42 Consultation Response (Natural England, 20th July 2023)	Natural England note that Project's site-specific measurements of current and water level used to calibrate and validate the hydrodynamic model, cover the period 17 April 2022 to 04 August 2022. Natural England note that Section 7.3.4 (Chapter 7) refers to the Seawatch Wind Lidar Buoy (SWLB) but not the Seaguard Seabed Frame (Table 4.1, Appendix 7.2). We also note that in Section 7.3.4, it states that monthly datasets are available from April 2022-November 2022, and further data will be submitted as part of the ES.	The Applicant can confirm that site-specific measurements have been collected in order to calibrate the numerical modelling and provide a baseline characterisation of the site. Metocean measurements have continued to be collected past the commencement of modelling, and a summary of these datasets is provided as part of the baseline characterisation in document reference 6.3.7.1.
Section 42 Consultation Response (Natural England, 20th July 2023)	Tidal ellipse excursions across the study area have not been provided.	Tidal ellipses are provided in Volume 2, Figure 7.4 (document reference 6.2.7.4).
Section 42 Consultation Response (Natural England, 20th July 2023)	The Cable Burial Risk Assessment (CBRA) refers to 'Outer Dowsing Offshore Windfarm Seabed Mobility Study' (East Point Geo., 2023). This may be useful for understanding seabed mobility across the ECC that overlaps Annex I sandbanks. Annexes A and B are referenced in Appendix 7.2: Marine Physical Processes Modelling Report, but have not been included. These relate to determination of Marine Processes Realistic WCS and assessment of spoil mounds.	Relevant output from the 'Outer Dowsing Offshore Windfarm Seabed Mobility Study' (East Point Geo., 2023) has been provided within document reference 6.3.7.1 as part of the characterisation of the baseline environment. Annexes A and B have been provided as part of document reference 6.3.7.2.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
Section 42 Consultation Response (Natural England, 20th July 2023)	Natural England advise that there are a number of other marine process receptors which should be considered. These include offshore sandbanks not located within a designated site, The Wash, North Norfolk Coast (including relevant nationally or internationally important sites) and the sand dunes backing Wolla Bank Beach. The Wash and North Norfolk Coast could be affected by modifications to sandbank systems offshore due to the project alone and in combination with other projects/plans. Furthermore, the dunes backing the beach at landfall (Wolla Bank) are key morphological features that play a significant role in natural coastal defence at the shoreline and have important environmental and often geoscience value. Natural England advise the following receptors should be included for consideration in the EIA: ▪ Offshore sandbanks ▪ The Wash (and associated designated sites) ▪ North Norfolk Coast (and associated designated sites) ▪ Wolla Bank Beach dunes	Consideration of the relevant receptors is provided within this chapter. Offshore sandbanks not located within a designated site, and the Wolla Bank beach dunes have been included as receptors within the relevant impact pathways. The Marine Physical Processes study area is based on the Zone of Influence (ZoI), derived from the numerical modelling of sediment plumes and tidal flows. Based on this approach, the Applicant does not consider that an inclusion of The Wash and the North Norfolk Coast as receptors is appropriate and in-keeping with best practice, given their location outwith the ZoI.
Section 42 Consultation Response (Natural England, 20th July 2023)	The significance of effect for multiple impacts have been combined. For example, Construction Impact 2: Potential impacts to seabed morphology. This assessment considers separately the potential for impacts associated with five different activities. However, the magnitude of impacts, sensitivity of	This approach has been taken in order to reduce the need for repetition within the assessment, as the same evidence and argument have been considered appropriate for multiple activities.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	receptors, and significance of effect have been combined for all impacts. Furthermore, the magnitude of each impact assessed will differ, as will the receptors and, in turn, the significance of effect will vary too. Natural England advise that each impact should be assessed separately and its effect significance determined separately.	While the Project acknowledges that impact magnitude, receptor sensitivity, and effect significance will differ for different activities, the worst case scenario for effect significance has been considered for all receptors.
Section 42 Consultation Response (Natural England, 20th July 2023)	Remedial and maintenance activities relevant to operations that cause additional impacts to the marine physical environment during the operational lifetime of the project can include: ▪ Cable repair and replacement ▪ Cable remedial burial ▪ Maintenance of external cable protection ▪ New external cable protection These impacts should be considered and assessed in the EIA. Where MPAs are likely to be affected, the WCS for each MPA needs to be established (extent of impact, frequency, maximum number of events etc). Similarly, affected features, pressures and sensitivity should be identified and the WCS of impact assessed.	Remedial and maintenance activities during the operational lifetime of the Project are short-lived in both duration and extent when compared to construction activities, and as such are not considered to represent the worst-case scenario (as outlined in Table 7.3). Therefore, in line with best practice, they have not been assessed as a separate impact within this chapter, but instead are considered to be fully encapsulated within the conclusions of impact magnitude, receptor sensitivity, and significance of effect as presented within the assessment of construction activities.
Section 42 Consultation Response (Natural England, 20th July 2023)	Impacts on coastal processes and geomorphology above MHWS have been scoped out. However, the beach at Wolla Bank is backed by sand dunes and the beach subject to erosion. Natural England advise that this impact should remain scoped into the EIA until it can be demonstrated that morphological change along	Potential impacts on coastal behaviour at the landfall site, including below MHWS and certain features above MHWS (specifically dune features behind the landfall beach), have been assessed in Paragraph 139 *et seq*. This assessment is based on analysis of coastal change between 2016 and 2020, as provided within document reference 6.3.7.1.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	the coastal frontage is unlikely. This should be based on analysis of recent data on dune frontage and beach profile change.	
Section 42 Consultation Response (Natural England, 20th July 2023)	For foundation installation, it states that site preparation for monopiles and piled jacket foundation types, is usually minimal. Seabed preparation may include levelling, dredging, removing surface and subsurface debris, boulder clearance etc. How would minimal be described or evaluated here. Please clarify and provide a WCS for boulder clearance for foundation installation. Please also consider whether impacts arising from UXO clearance/detonation should be considered. If so then please support judgements with empirical data gathered from other OWF developments.	The MDS for seabed preparation prior to foundation installation has been updated where necessary and is provided within Table 7.3. As it is not currently intended to licence UXO clearance in the DCO, an assessment of the potential impacts has not been provided in this chapter. The Applicant will apply to the MMO separately in due course for a marine licence for any necessary UXO investigation and clearance works, who will be able to impose necessary conditions at that time.
Section 42 Consultation Response (Natural England, 20th July 2023)	Boulders greater than 0.3m in any dimension, which are located within the footprint of any infrastructure, may necessitate removal. Where would the boulders be removed to? Will boulders be relocated close to their source location?	Details of proposed boulder clearance are included as part of the CSIP, which will follow the principles of the Outline CSIP (document reference 8.5). The Applicant can confirm that boulders will be relocated in close proximity to their original location.
Section 42 Consultation Response (Natural England, 20th July 2023)	The WCS for boulder clearance is currently 100%, owing to the lack of high resolution geotechnical/geophysical information. It is stated that geophysical surveys will be undertaken within the Project array and offshore export cable corridor (OECC) and used to inform boulder clearance requirements. Will these data be included in the ES?	Details of proposed boulder clearance are included as part of the CSIP, which will follow the principles of the Outline CSIP (document reference 8.5).

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	Natural England recommend the Applicant refine the MDS for boulder clearance when high resolution geophysical/geotechnical data are available and identify any area of MPA affected. Include in ES, if available. Following refinement of the boulder clearance MDS, areas of MPA affected should be identified, including extent and location. Affected features, pressures and sensitivity should also be identified as a result of changes to physical processes.	
Section 42 Consultation Response (Natural England, 20th July 2023)	The rationale for MDS sandwave clearance is unclear. The anticipated depth of sandwave crest lowering / levelling has also not been included. Table 3.24 includes sandwave clearance for export cables within array area and also along the OECC. Please clarify within a project specific sandwave levelling assessment, for example that undertaken for Norfolk Boreas.	All project details presented in Volume 1, Chapter 3: Project Description (document reference 6.1.3) and Table 7.3 have been reviewed and updated where required. This includes the MDS for sandwave clearance/levelling, with details provided of the volumes assessed within the IDRBNR SAC. An assessment of the potential impacts of sandwave levelling is provided in Paragraph 105 *et seq.* Further evidence will be provided as part of a separate Project-specific Sandwave Levelling Assessment that will be submitted into the Examination.
Section 42 Consultation Response (Natural England, 20th July 2023)	Beach access may be required for emergency access and some improvement works to the access points may also be necessary. It is not yet known if this feature will be located below MHWS or the duration that it will be in place. A more detailed plan of landfall construction methodology will be defined and any refinement to the Project Description assessed in the ES. Any potential impacts on coastal processes and morphology should be identified and assessed in the ES.	Potential impacts on coastal behaviour at the landfall site, including below MHWS and certain features above MHWS, (specifically dune features behind the landfall beach), have been assessed in Paragraph 139 *et seq*. Beach access will be via existing routes or via the sea, as outlined in document reference 6.1.3.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
Section 42 Consultation Response (Natural England, 20th July 2023)	Preferred shoreline management strategy over the next 100 years is to implement a combination of rock structures and beach nourishment. This will be a phased approach with beach nourishment continuing until 2024 in its current form, and then structures are to be implemented between 2025-2030. The Applicant need to consider buried asset integrity and the feasibility of HDD/trenchless techniques in the presence of hard structures at the coast.	Information is not currently available on the location or form of the hard structures proposed along this area of coastline. The Applicant will liaise with the Environment Agency where appropriate throughout the continued project refinement post-application and prior to construction. The Project has already committed to a subtidal HDD exit pit, which will inherently reduce the likelihood for any interaction with hard structures established at the landfall for shoreline management purposes.
Section 42 Consultation Response (Natural England, 20th July 2023)	For Impact 3, it is not stated whether there may be a requirement for temporary cofferdams at the HDD exit pits. However, if used, they may lead to local blockage effects in the landfall area, interrupting local flows and waves which may lead to scouring around their base, subject to the erodibility of the seabed. If cofferdams are closely spaced, this may also lead to interaction of wakes and group scour development. If cofferdams are to be used, the Applicant should consider potential impacts to local flows, waves and sediment transport processes, and potentially for scouring around bases. If necessary, the Applicant should include cofferdams in the MDS assessment for Impact 3.	Cofferdams are currently not being considered as part of the Project works, as indicated in document reference 6.1.3.
Section 42 Consultation Response (Natural England, 20th July 2023)	Natural England note that permanent rock protection will not be installed in the intertidal, and any rock protection in the subtidal will not exceed LAT. However, rock protection in the shallow nearshore	An assessment of potential impacts of cable protection measures on coastal receptors, including sediment transport pathways, is provided in Paragraph 152 *et seq.* Details will be confirmed as part of the CSIP, which will

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	zone, could modify the nearshore hydrodynamic regime and affect the sediment transport regime. Natural England advise that rock protection should be avoided in shallow nearshore water where it could interrupt sediment transport paths.	follow the principles of the outline CSIP (document reference 8.5). Details of embedded mitigation measures are provided in Table 7.4. The Project has committed to the HDD exit pit being located in the subtidal zone, approximately 500m seaward from MLWS, therefore inherently reducing the need for cable protection in the shallow nearshore.
Section 42 Consultation Response (Natural England, 20th July 2023)	Approx 4 million cubic metres of sediment are likely to be removed through seabed levelling within the array area, which is characterised by a number of ecologically and morphologically important sandbank-channel systems. We are concerned that substantial sediment removal through sandwave levelling / lowering could affect the form and function of the sandbank systems. We need to better understand sandwave (and sandbank) morphology, migration rates and patterns of change. Natural England advise considering micro-siting and/or avoiding siting GBS foundations on important sandbanks/sandwave systems to minimise impacts. Undertake sandwave migration analysis to establish recoverability of sandwaves within the array.	All project details presented in document reference 6.1.3 and Table 7.3 have been reviewed and updated where required. This includes the MDS for sandwave clearance/levelling, with details provided of the volumes assessed within the IDRBNR SAC. An assessment of the potential impacts of sandwave levelling is provided in Paragraph 105 *et seq.* Further evidence will be provided as part of a separate Project-specific Sandwave Levelling Assessment that will be submitted into the Examination.
Section 42 Consultation Response (Natural England, 20th July 2023)	Based on post-construction monitoring results from Lincs, Lynn and Inner Dowsing OWFs, we are concerned that drill arising mounds could not only persist longer than anticipated, but also spread out laterally, reduce in height slowly, and alter the	Post-construction monitoring results from the Lynn and Inner Dowsing OWFs have been considered within the assessment in Paragraph 129. These results indicate that after four months, mounds had been reduced from 3m from 1.2m due to natural processes, although some

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	sediment distribution and benthic communities across the array area. Natural England would advise monitoring to determine the nature of the mounds, rate of change, and requirements for potential mitigation actions. Potential impacts on the hydrodynamic and wave regimes should also be considered where mounds may be located in shallow water.	remained discernible (approximately 1.0m above the seabed) for more than four years after disposal. Drill arising mounds will form discrete, highly localised features, with a change in potential topography comparable to the presence of scour protection in size. They are not considered to exceed any potential impacts to the hydrodynamic and wave regimes caused by MDS as defined in Table 7.3 and therefore have not been assessed. On the basis of the highly localised nature of these mounds, monitoring has not been considered necessary.
Section 42 Consultation Response (Natural England, 20th July 2023)	Regarding Impact 1, conservation advice for Inner Dowsing, Race Bank and North Ridge SAC (IDRBNR SAC) identifies features/subfeatures that are sensitive to heavy deposition. Moreover, the offshore sandbanks located within the ODOW array provide important nursery and spawning grounds for commercially important fish species such as herring, which could be affected (at the larval stage) by smothering due to heavy sediment deposition. The array sandbanks are, therefore, supporting habitats which could be affected by construction-related changes to bed level. Therefore, we do not agree that the magnitude of impact is low, or that all marine process receptors are insensitive to this impact.	Offshore sandbanks are considered within this chapter with respect to their form and function and their influence on the physical environment, with consideration of habitat suitability, including designated features/subfeatures, provided in document reference 6.1.9 and document reference 6.1.10. Potential inter-relationships relevant to the assessment of Marine Physical Processes are presented in Table 7.14. Consideration of spawning habitat suitability for commercially important fish species provided in document reference 6.1.10. The reasoning for the definition of the magnitude and sensitivity of the sandbanks for the purposes of the assessment below is outlined in Section 7.12, focusing on the physical attribute of the features. Furthermore, it is noted that the array area does not overlap with the Inner Dowsing, Race Bank and North Ridge SAC.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	Natural England advise that the magnitude of impact is not low and not all marine processes receptors are insensitive to bed level changes.	
Section 42 Consultation Response (Natural England, 20th July 2023)	The supporting evidence for sandwave recovery at ODOW has been based on evidence collected at Race Bank OWF. We would not advise using this evidence as an analogue for ODOW sandwave recovery at IDRBNR SAC. We expressed our uncertainty (NE Relevant Representations to Norfolk Boreas, 2019) as to whether or not full recovery of Annex I sandbanks was achievable from Race Bank OWF sandwave sweeping. We continue to have reasonable scientific doubt and our advice remains unchanged. Natural England advise the Project to adopt a project-specific approach to establishing likelihood of sandwave recovery following sandwave levelling/clearance rather than using Race Bank OWF as an analogue. We also advise that the process of method selection and final route refinement within the cable corridor is undertaken using the avoid, reduce, mitigate hierarchy. Where sandwave levelling is considered necessary to provide protection to the cable or enable burial machines to operate, consideration should be given to the relative merit of using sandwave clearance/lowering to reduce the need for external cable protection versus the potential impacts of sandwave clearance on the conservation objectives of the MPA.	Project details, including the MDS for sandwave clearance/levelling, have been reviewed and updated where required. Details are presented in document reference 6.1.3 and Table 7.3, including the volumes assessed within the IDRBNR SAC. An assessment of the potential impacts of sandwave levelling is provided in Paragraph 105 *et seq.* This is based on evidence collected at Race Bank OWF in addition to monitoring data from other sites in order to assess the potential for recovery. Due consideration has been given to the relative benefits of sandwave clearance during refinements to the Project Design.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
Section 42 Consultation Response (Natural England, 20th July 2023)	Anticipated maximum volume sandwave clearance within the array is 13,672,800m^2 and 7,413,120m^2 within the ECC. These are significant amounts. We understand that the exact locations requiring sandwave clearance are presently not known. Therefore, project-specific acoustic/ground condition data should be used to establish a realistic WCS for sandwave clearance/lowering. Project-specific geophysical data should be used to refine the MDS for sandwave clearance and thus reduce the impact to sandbank/sandwave systems. The area of MPAs/features affected (extent and location) should be provided, along with a map to show locations requiring sandwave clearance. This should be provided in a sandwave levelling assessment as per Norfolk Boreas OWF's.	All project details presented in document reference 6.1.3 and Table 7.3 have been reviewed and updated where required. This includes the MDS for sandwave clearance/levelling, with details provided of the volumes assessed within the IDRBNR SAC. Due consideration has been given to the relative benefits of sandwave clearance during refinements to the Project Design. An assessment of the potential impacts of sandwave levelling is provided in Paragraph 105 *et seq.* Further evidence will be provided as part of a separate Sandwave Levelling Assessment that will be submitted into the Examination.
Section 42 Consultation Response (Natural England, 20th July 2023)	Spoil deposition in the shallow nearshore environment could affect sediment transport processes. Natural England advise that the Applicant need to consider and assess the potential hydrodynamics, wave and sediment transport impacts of spoil deposition in the shallow nearshore zone.	Spoil deposition as a result of bentonite release is assessed within Paragraph 99, with deposition considered to be small-scale and highly localised. These spoil mounds are likely to be rapidly redistributed by wave action and impacts on the hydrodynamic and wave regime are therefore not considered a project consequence. Potential impacts on coastal behaviour, including Project activities within the shallow nearshore zone, have been assessed in in Paragraph 139 *et seq*.
Section 42 Consultation Response (Natural England, 20th July 2023)	Up to 25% laid cables are estimated to require cable protection, including 20 sites with cable crossings and comprises a total area of 1,899,000m^2 for the inter-	All project details presented in document reference 6.1.3 and Table 7.3 have been reviewed and updated where required. This includes the MDS for cable protection and

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	array cables and 2,059,200m^2 for the export cable. This is a considerable cable protection allowance. Natural England advise that cable protection should be avoided in MPAs, sensitive habitats, and the shallow nearshore zone. The CBRA should allow refinement of mobile seabed areas as well as ground conditions where full burial may be problematic. A cable crossing map should be provided in the ES. Specific locations requiring cable protection (informed by acoustic data) should also be provided. In addition, the following should be provided: ▪ Total volumes of cable protection, ▪ Total area of impact, habitats impacts, ▪ Presence of sensitive habitats, ▪ Methods likely to be used. ▪ Consideration of the impact of cable protection throughout its lifetime and across more than one cable at the same location.	cable crossings, with details provided of the volumes assessed within the IDRBNR SAC. The potential impacts of cable protection are assessed in Paragraph 119 *et seq.* and Paragraph 152 *et seq.* Potential impacts on sensitive habitats are considered within document reference 6.1.9 and Document Reference 7.1.
Section 42 Consultation Response (Natural England, 20th July 2023)	Where cable protection and/or cable crossing locations are anticipated in the nearshore zone and/or shallow water depths they may have the potential to interfere with wave energy transformation. Therefore, these areas should be identified and potential modification to wave propagation and interruption to sediment pathways assessed.	An assessment of potential impacts of cable protection measures on coastal receptors, including sediment transport pathways, is provided in Paragraph 152 *et seq.* Details will be confirmed as part of the CSIP, which will follow the principles of the Outline CSIP (document reference 8.5). Details of embedded mitigation measures are provided in Table 7.4.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	The Applicant should highlight anticipated areas of cable protection/crossings within the nearshore and/or shallow water depths. The Applicant should assess potential impacts to wave energy transformation and sediment pathways.	
Section 42 Consultation Response (Natural England, 20th July 2023)	Impacts to seabed morphology due to construction activities have been assessed for IDRBNR SAC and undesignated areas of seabed. Natural England consider the IDRBNR SAC to have high ecological importance, but also to be vulnerable to morphological change. The SNCBs consider site integrity to have been hindered by impacts due to Race Bank OWF infrastructure. This has also compromised the ability of the site to meet its conservation objectives. The SAC sandbank features currently have a restore target for their extent and distribution and maintain target for topography and volume attributes. Consequently, we are unable to agree that SAC sensitivity is medium. We would also advise that the magnitude of impact is greater than low, for the reasons already discussed. We also note that undesignated areas of seabed have been assessed as having negligible sensitivity to morphological change due to construction activities. We advise that the sandbank systems across and adjacent to the array are important ecologically, morphologically and hydrodynamically. Insufficient information has been provided upon which to assess impacts to these features for construction-related changes. Nevertheless, we advise that their sensitivity	Annex I Sandbank features within the IDRBNR SAC have been considered as a receptor within the assessment provided in Section 7.12 of this chapter, and a full assessment of potential impacts to the IDRBNR SAC is provided in Document Reference 7.1. The conservation advice package published in May 2023 has been taken into account within the assessment laid out in Section 7.12, specifically within Paragraph 120 Further evidence has been provided within Paragraph 105 *et seq.* to support the assessment.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	should be greater than negligible and magnitude greater than low. Natural England advise that magnitude of impact may be greater than low, the sensitivity of IDRBNR SAC is likely to be greater than medium, and undesignated sandbanks should be greater than negligible. Further evidence should be provided to support the conclusion that effect significance on these receptors will be minor adverse for EIA impacts to Marine Processes. Please also see Benthic advice on features of the IDRBNR SAC.	
Section 42 Consultation Response (Natural England, 20th July 2023)	It is stated that the presence of annual beach nourishment means that the choice of location for onshore HDD works and jointing bay is unaffected by the possibility of coastal retreat, for as long as the 'hold the line' strategy is in place. However, we advise that future approaches to flood and coastal erosion risk management at landfall cannot be assured. Rather, it is the Applicant's responsibility to ensure that there is sufficient coverage of their buried assets in the intertidal through the lifetime of the project (and decommissioning). Natural England advise close liaison with the Environment Agency.	Consideration of long-term coverage of assets at landfall is dependent on an understanding of the future approaches to coastal protection. The Applicant will continue to engage with the Environment Agency throughout the post-application and pre-construction phases of the Project.
Section 42 Consultation Response (Natural England, 20th July 2023)	Natural England welcome the proposed use of trenchless installation techniques by the Project. However, we advise that this is an eroding coastline which has experiences high rates of erosion; the beach	Potential impacts on coastal behaviour at the landfall site, including below MHWS and certain features above MHWS (specifically dune features behind the landfall beach), have been assessed in Paragraph 139 *et seq*. This assessment is

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	mid-section shows an erosional trend and annual beach recharge is currently undertaken. The beach and dunes that back the beach provide important protection to the low-lying hinterland of East Lincolnshire. Therefore, we would advise that the sensitivity of the coastline at landfall is greater than low. We also advise that the placement cable protection within the shallow nearshore could interrupt nearshore sediment pathways that supply sediment to receptors south and along the adjacent coastline at landfall. Therefore, we advise that the magnitude of impact is greater than low, and effect significance is greater than minor adverse. Natural England advise against the use of cable protection inshore of the depth of closure. We also advise that the coastline at landfall has greater than low sensitivity and effect significant is greater than minor adverse.	based on analysis of coastal change between 2016 and 2020, as provided within document reference 6.3.7.1. An assessment of potential impacts of cable protection measures on coastal receptors, including sediment transport pathways, is provided in Paragraph 152 *et seq.* Details will be confirmed as part of the CSIP, which will follow the principles of the Outline CSIP (document reference 8.5). Details of embedded mitigation measures are provided in Table 7.4, with no permanent rock protection to be employed within the intertidal zone. The Project has committed to the HDD exit pit being located in the subtidal zone, approximately 500m seaward from MLWS, therefore inherently reducing the need for cable protection in the shallow nearshore.
Section 42 Consultation Response (Natural England, 20th July 2023)	Impacts on the wave and tidal regime due to the two ORCPs have not been assessed. Given their proximity to Inner Dowsing sandbank, IDRBNR SAC, we advise that they should be considered in this impact assessment. The Applicant should consider and assess the potential impact of the two ORCPs on the wave-climate regime. Include these two structures in the wave blockage modelling.	The ORCPs and ANSs have been included within updated Marine Physical Processes numerical modelling, with potential impacts to the wave and tidal regime, including within the IDRBNR SAC, discussed in Paragraph 162 *et seq.*

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
Section 42 Consultation Response (Natural England, 20th July 2023)	Receptors considered in the assessment of modifications to the wave and tidal regime include IDRBNR SAC and areas of undesignated seabed. This latter term is not useful. It would be more useful to identify the sandbank-sandwave systems within and near the array, as receptors. The Applicant should include offshore sandbank-sandwave systems as receptors.	Offshore sandbanks not located within a designated site has been included as a receptor for this impact, with an assessment provided in Paragraph 174 *et seq.*
Section 42 Consultation Response (Natural England, 20th July 2023)	Numerical modelling results show maximum reductions in current speed of 0.05-0.1m/s within 200m of a small number of foundations and 0.02-0.05m/s forming wakes up to 1km downstream of the majority of foundations. Changes in wave height of 0.1-1.0m were found to occur within 1km of foundations. A concomitant change in wave direction of 90-180 degrees south of the array, and -90 to -2 degrees to the west. These results present potentially significant changes to the waves, hydrodynamics and sediment transport within and around the array. We wish to understand how these reductions in wave energy and tidal flow might affect the sandbank systems within the array. Natural England advise that further consideration should be given to the impact of reduced wave energy and direction, and tidal flow on sandbanks within the array. This will help inform understanding of potential changes to physical and biological conditions such as	A full assessment of the impact of reduced wave energy and direction and tidal flow is provided in Paragraph 162 *et seq.*, including consideration of potential effects on sandbanks within the array. This is supported by sediment mobility analysis using results from numerical modelling, the results of which are provided in Annex A., and considered within the assessment throughout Section 7.12 of this chapter.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	grain size distribution and exposure levels across important sandbank habitats.	
Section 42 Consultation Response (Natural England, 20th July 2023)	Small percentage significant wave height reductions (-2.7%) due to the presence of the array may reach IDRBNR SAC. It is considered unlikely that this will lead to any meaningful change to sandbank crest height. Whilst it is recognised that tidal currents maintain the sandbank system, waves also play a key role in shaping them. We wish to understand potential cumulative wave regime impacts of ODOW and other nearby OWFs on the SAC over the lifetime of the project. It is also stated that IDRBNR SAC has a high capacity to accommodate change to the wave regime. However, how would the SAC respond to this change over the lifetime of the project? With regards to the 'areas of undesignated seabed around and within the array,' we would like to see further consideration of potential changes to the sandwave-sandbank systems within and near the array due to modification of the tidal and wave regimes over the lifetime of the project. Therefore, we advise that their sensitivity is likely to be greater than negligible. Consequently, for both receptors assessed, we advise that the significance of effect is greater than minor adverse. Natural England advise it would be useful to consider the potential cumulative impact on IDRBNR SAC due to	Assessment of the impact of reduced wave energy and direction and tidal flow is provided in Paragraph 162 *et seq.*, with potential cumulative modifications to the wave and tidal regime considered within Paragraph 236 *et seq.* Numerical modelling indicates that changes to wave height, although they may reach up to 35m from the array area, dissipate with distance southwest of the Project infrastructure and are therefore unlikely to contribute meaningfully to any array-scale wave blockage caused by other OWF infrastructure. Assessment of potential changes to the wave regime within the IDRBNR SAC is supported by sediment mobility analysis using results from numerical modelling, the results of which are provided in Annex A A full assessment of potential impacts to the IDRBNR SAC is provided in Document Reference 7.1. A full assessment of the impact of reduced wave energy and direction and tidal flow is provided in Paragraph 162 *et seq.*, including consideration of potential effects on sandbanks within the array.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	the presence of ODOW and other nearby OWFs. We would also advise further additional assessment is needed regarding the capacity of the SAC to accommodate change to the wave regime over the lifetime of the project. We also advise assessment of the likely morphological response of the sandbank systems within he near the array, to change in the wave and tidal regimes over the lifetime of the project.	
Section 42 Consultation Response (Natural England, 20th July 2023)	Triton Knoll OWF landfall may be in close proximity to the ODOW landfall. The potential for overlapping works between Triton Knoll OWF and ODOW at landfall should be considered.	An assessment of the potential for cumulative effects with other projects, including Triton Knoll OWF, is provided in Section 7.13 of this chapter. It is noted that current project programmes indicate that Triton Knoll OWF is now constructed and only operational and maintenance and decommissioning activities have the potential to temporally overlap with Project activities. Furthermore, the landfall for Triton Knoll OWF is geographically distinct from that of the Project, and overlapping works are therefore unlikely to interact with one another.
Section 42 Consultation Response (Natural England, 20th July 2023)	Currently there is limited information to adequately inform the EIA for cumulative effect assessments (increases in SSC and seabed level changes and impacts to seabed morphology). If/when further information becomes available, it should be included in an updated cumulative impact assessment in the ES.	Information to support the cumulative effects assessment provided in Section 7.13 has been reviewed and updated, where necessary.
Section 42 Consultation Response (Natural England, 20th July 2023)	Natural England note that cumulative impacts to the wave regime due to project and Triton Knoll OWF have been considered. However, DEPN / DOW are located south of the ODOW array and have the potential to create cumulative blockage effects.	An assessment of the potential for cumulative effects with other projects is provided in Section 7.13 of this chapter.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	Natural England advise that cumulative impacts due to the project and DEPN/DOW should be considered in the EIA.	
Section 42 Consultation Response (Natural England, 20th July 2023)	The Applicant should consider phase of proposed development i.e. construction, operation, decommissioning. Definition of impact magnitude should consider temporal scale (i.e. length/duration) and project development phase. The Applicant should consider timescale and phase of development when deriving magnitude of impact.	Project phase and temporal scale have been integrated into the derivation of impact magnitude, as outlined in Table 7.6.
Section 42 Consultation Response (Natural England, 20th July 2023)	MDS for sandwave clearance is up to 60% of the array/interlink cable route and 30% of the export cable route. This MDS should be refined using project-specific geophysical/geotechnical data. Natural England advise that the MDS for sandwave clearance should be refined using project-specific geophysical/geotechnical data and included in a sandwave levelling assessment. Further, the total area of impact (both direct and indirect) and location of any affected MPA and Annex I sandbanks affected should be assessed. Affected features, pressures and sensitivities should be identified.	All project details presented in document reference 6.1.3 and Table 7.3 have been reviewed and updated where required. This includes the MDS for sandwave clearance/levelling, with details provided of the volumes assessed within the IDRBNR SAC. An assessment of the potential impacts of sandwave levelling is provided in Paragraph 105 *et seq.* Further evidence will be provided as part of a separate Project-specific Sandwave Levelling Assessment that will be submitted into the Examination.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
Section 42 Consultation Response (Natural England, 20th July 2023)	Appendix 3.1 Cable Burial Risk Assessment (CBRA) relates to a relatively limited section of the cable corridor crossing the Annex I Sandbanks and clustered within the SAC. The Reference Seabed Level (RSBL) at Sandbank 1 (Inner Dowsing) is expected to be 5-6m below current seabed elevation and at Sandbank 2 (North Ridge/Outer Dowsing), is expected to be 2-3m below current seabed elevation. Yet, in Table 7.3, sandwave clearance dredged corridor is 30m per cable circuit and the dredged depth is 2m. Is this 2m below RSBL?	All project details presented in document reference 6.1.3 and Table 7.3 have been reviewed and updated where required. This includes the MDS for sandwave clearance/levelling, with details provided of the volumes assessed within the IDRBNR SAC. Details of the RSBL has been provided within the CSIP, which will follow the principles of the Outline CSIP (document reference 8.5).
Section 42 Consultation Response (MMO, 21st July 2023)	Appropriate data sources have been identified for marine physical processes as discussed in Section 7.4.3 and Table 7.1 in Appendix 7.1. These are a mixture of desk-based studies as well as project specific studies, including geophysical and Metocean measurements. There are also other Offshore WindFarm (OWF) projects with data the applicant can use, the MMO expresses caution with relying heavily on older OWF projects (such as Race Bank OWF) where datasets are as old as 2009. Whilst older datasets can be considered please take caution in relying on that too heavily.	The Applicant notes the MMO's caution on using evidence from existing, older, OWF studies. Where appropriate and available, this evidence has been supported by more recent, project-specific surveys and numerical modelling exercises, as outlined in Section 7.4.2.
Section 42 Consultation Response (MMO, 21st July 2023)	The MMO agrees with scoping out the hydrodynamic impacts from installation vessels such as jack-rigs and cable laying vessels during construction phase.	The Applicant welcomes the MMO response that hydrodynamic impacts from installation vessels such as the jack-up rigs and cable laying vessels during construction phase, can be scoped out.
Section 42 Consultation Response (MMO, 21st July 2023)	The MMO notes that impacts on coastal processes and geomorphology above the MHWS on construction has	Potential impacts on coastal behaviour at the landfall site, including below MHWS and certain features above MHWS (specifically dune features behind the landfall beach), have

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	been scoped out. The MMO does not agree that this should be scoped out. Section 7.7 sets out what is to be scoped in and Impact 3 of construction is modifications to littoral transport and coastal behaviour (erosion), including at landfall. Landfall has been defined as the location at the land-sea interface where the offshore export cable will come ashore. The MMO would expect that coastal processes and geomorphology above MHWS would be discussed within this Impact 3 as the Impact Assessment (Section 7.12 in Volume 1, Chapter 7: Marine Physical Processes. Rev V1.0. June 2023) mentions temporary beach access (which is not known to be below MHWS or not) which could impact beach geomorphology. Also, within that section (7.12.76) it is noted that cable protection could act in a similar way to submerged breakwaters which could impact beach morphology, and littoral sediment transport which in the nearshore is driven by the wave regime. These impacts do not stop at the MHWS but will impact coastal processes above this line. Therefore, Impact 3 should consider impacts above the MHWS. The MMO requests that ODOW clarify if ‘landfall’ in this instance does include above MHWS. If it does not, then this should be included.	been assessed in Paragraph 139 *et seq*. These receptors have also been included within Impact 8, specifically in Paragraph 178.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	The MMO recommends that impacts above MHWS are also included in Impact 4 (Modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime and morphological features) and Impact 8 (Modifications to littoral transport, coastal behaviour (erosion) including at landfall) and should be scoped into the Operations and Maintenance and Decommissioning. This is to include the beach evolution over the lifespan of the project and to consider impacts of sea level rise on the beach profile, which could change the MHWS line.	
Section 42 Consultation Response (MMO, 21st July 2023)	Table 7.4 highlights the mitigation proposed. Please note the use of scour protection is proposed in areas where scour would be predicted to occur, therefore potential impacts from sediment that would be mobilised due to erosion occurring during scour development is not fully assessed. The impacts of using scour protection (relating to a greater footprint of hard substrate being introduced, which may lead to habitat change/loss) should be compared to the impacts of simply designing foundations which can accommodate scour development. The resulting effects of scour (lowering of the seabed, winnowing/coarsening of sediment, plus release of sediment into the wider environment after installation) may have a lesser impact than compared to the introduction of hard substrate into the environment (particularly given that rock scour and/or cable protection is difficult to decommission).	The impacts of introducing scour protection and/or the formation of scour pits on benthic habitats has been assessed within document reference 6.1.9. An assessment of potential impacts associated with seabed scouring, including impacts associated with secondary scour, is provided in Paragraph 182 *et seq.*, with relevant mitigation measures outlined in Table 7.4.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	Secondary scour can occur around the edges of scour protection and the potential for this to increase the footprint of the project effects should be assessed. It is noted that 'there is limited numerical basis for the prediction of this secondary scour'. The MMO recommends that further evidence is collected from field data/monitoring evidence from other windfarms if available, acknowledging that empirical assessment methodologies are less established for edge/secondary scour than they are for primary scour where no scour protection is applied.	
ETG held 7th August 2023	Cefas noted that due to the form and function of sandbanks it is difficult to demonstrate that there has been no impact, and that natural dynamics will not be impacted. They recommended that the Applicant investigate sediment mobility, including estimated rates before and after construction, in order to identify if the impact is within the natural variability of the sandbank.	Sediment mobility both before and after the installation of Project infrastructure has been investigated using results from numerical modelling. The results of this analysis are provided in Annex A, and considered within the assessment throughout Section 7.12 of this chapter.
ETG held 7th August 2023	Cefas noted that the interface between scour protection and the substrate will need to be assessed as part of the ES.	Consideration of secondary scour around scour protection is provided in Paragraph 188 *et seq.*
ETG held 14th September 2023	Natural England advised that the coastal dunes at the landfall area form part of the coastal defences. As part of the future management strategy, over 2000 rock structures are being proposed along the coastline and it is advised that the Project should consult with the Environment Agency about potential effects.	Potential impacts on coastal behaviour at the landfall site, including below MHWS and certain features above MHWS (specifically dune features behind the landfall beach), have been assessed in Paragraph 139 *et seq*. Information is not currently available on the location or form of the hard structures proposed along this area of coastline. The

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
		Applicant will liaise with the Environment Agency where appropriate throughout the continued project refinement post-application and prior to construction. The Project has already committed to a subtidal HDD exit pit, which will inherently reduce the likelihood for any interaction with hard structures established at the landfall for shoreline management purposes.
ETG held 14th September 2023	The Environment Agency raised that regarding dunes and features above MHWS, they would like to see detail of impacts to these features, including any potential impact on flood risk.	Potential impacts on coastal behaviour at the landfall site, including below MHWS and certain features above MHWS (specifically dune features behind the landfall beach), have been assessed in Paragraph 139 *et seq*. These receptors have also been included within Impact 8, specifically in Paragraph 178.
ETG held 14th September 2023	Natural England advise that cable burial should be attempted in the nearshore zone in order to avoid potential impacts. Specific detail of the locations and volumes of proposed rock protection should be provided, particularly within the nearshore zone, in order to assess potential effects.	An assessment of potential impacts of cable protection measures on coastal receptors, including sediment transport pathways, is provided in Paragraph 152 *et seq.* Details will be confirmed as part of the CSIP, which will follow the principles of the Outline CSIP (document reference 8.5). Details of embedded mitigation measures are provided in Table 7.4.
ETG held 14th September 2023	Natural England advised that evidence of the impact of Race Bank OWF during the installation phase on the Annex I sandbank is set out in the conservation advice package published in May 2023.	The conservation advice package published in May 2023 has been taken into account within the assessment laid out in Section 7.12, specifically within Paragraph 131
Post-meeting note received 20th October 2023	Natural England recommend that high-resolution bathymetry surveys should be used pre- and post-installation to ensure total seabed coverage of the areas where is it proposed to dredge or partially dredge sandwaves, including a buffer area. This should	The Applicant welcomes the provision of further evidence relating to sandwave recovery. The Applicant does, however, note that the suggested Larsen *et al.* (2019) publication is based on data collected at the Race Bank OWF, which Natural England have previously stated that

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	be carried out to an appropriate standard. This would enable a full site comparison of seabed topography, gradient and seabed mobility and features. In addition, it would be useful to carry out sandwave migration analysis for specific sites. It is important to try to monitor changes in sandwave shape and height (including neighbouring sandwaves) and sandwave migration speed and direction, before and after sandwave levelling/lowering. Cefas may have further information or advice to add to this. Natural England also direct the Applicant to a study conducted on the Dudgeon OWF on sandwave recovery: ▪ Larsen. S.M, Roulund. A, and McIntyre. D.L (2019). Regeneration of partially dredged sandwaves. Coastal Sediments 2019, pp. 3026-3039 ▪ MMT. 2018. Dudgeon OWF – ST18692. Sand wave migration analysis North Sea, September-October 2018. Report to Equinor, November 2018.	they "would not advise using … as an analogue for ODOW sandwave recovery at IDRBNR SAC". An assessment of the potential impacts of sandwave levelling is provided in Paragraph 105 *et seq.* Further evidence will be provided as part of a separate Project-specific Sandwave Levelling Assessment that will be submitted into the Examination. The MMT (2018) is not currently publicly available online.
Autumn Section 42 Consultation Response (MMO, 22nd November 2023)	The MMO notes that impacts on the Marine Processes assessments are summarised in Table 3.3 of the Environmental Update Report. Table 3.3 indicates that updated hydrodynamic modelling will be presented, despite the suggestion that no new or materially different impacts will arise as	The Applicant welcomes the comments from the MMO. Updates to the modelling were discussed at the ETG held on the 8th November 2023, with no comments from stakeholders.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	a result of the changes. MMO concurs with the applicant's approach, albeit recognising that the Environmental Update Report does not specify in detail what updates will in fact be made to the modelling, and therefore that these changes will need to be reviewed as and when completed. MMO would welcome this as part of the evidence plan process.	
Post-meeting note received 12th December 2023	As per advice provided at the September ETG, Natural England advise that ODOW need to consider their own site and to try to establish a baseline now against which future morphological change can be gauged. The inherent difficulty in monitoring sandwave recovery is in trying to differentiate between change due to natural processes operating on the site and those influenced by the construction and presence of the OWF. As per our advice to the SEP/DEP project, to do this there is a requirement to utilise bathymetry data sets from different time periods to better inform quantification of trends. Analysis of datasets over different time periods is needed to establish whether bedform changes and migration rates are due to natural or anthropogenic drivers. The first step would be to characterise the contemporary seabed morphology and look at any historical data to establish trends and rates of bedform change. To help ODOW, Natural England recommend the methods used in the Larsen paper. There is a possibility that data presented in Larsen paper and	The Applicant welcomes the provision of further advice on sandwave recovery. An assessment of the potential impacts of sandwave levelling is provided in Paragraph 105 *et seq.* Further evidence will be provided as part of a separate Project-specific Sandwave Levelling Assessment that will be submitted into the Examination.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	other data acquired from race bank and the surrounding area may be useful in providing the historical context as mentioned above. Historical data, should be used to support specific site data only in the context of informing trends for the development site either in the condition which it currently exists or to support predictions of foreseeable future trends within the red line boundary.	
Post-meeting note received 12th December 2023	Natural England are unable to provide this evidence report [MMT. 2018. Dudgeon OWF – ST18692. Sand wave migration analysis North Sea, September-October 2018. Report to Equinor, November 2018.] as it belongs to Equinor and was used to provide supportive evidence to the marine processes technical note submitted during examination. We suggest contacting Equinor directly. The advice that we gave Equinor on sandwave characterisation and recovery during examination for their Sheringham and Dudgeon Extension Project remains applicable to this project and is available via the PINS website.	An assessment of the potential impacts of sandwave levelling is provided in Paragraph 105 *et seq.* Further evidence will be provided as part of a separate Project-specific Sandwave Levelling Assessment that will be submitted into the Examination. Advice provided by Natural England to other comparable OWF projects, including the Sheringham and Dudgeon Extension Projects, have been considered within the assessment, where appropriate.
Post-meeting note received 12th December 2023	Questions as posed to the Environment Agency by the Applicant within the ETG held on the 8th November 2023 are responded to as follows: 1) ODOW question: Is the current shoreline management plan (SMP) which includes beach nourishment on its own, still planned to continue until 2024?	The Applicant welcomes the provision of further information on planned shoreline management. The Applicant will liaise with the Environment Agency where appropriate throughout the continued project refinement post-application and prior to construction. The Project has already committed to a subtidal HDD exit pit, which will inherently reduce the likelihood for any interaction with

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	▪ 1) EA response: It is not the SMP that proposes the use of beach nourishment. It is the Saltfleet to Gibraltar Point Strategy (which is the strategy to deliver the aspirations of the SMP) that includes beach nourishment, and this is planned to continue in 2024. 2a) ODOW question: For any future years of beach nourishment, are volumes of introduced sediment expected to be of the same order of magnitude as 2022/ 2023 and is this volume expected to be placed at the same locations? ▪ 2a) EA response: Not necessarily. Each year the beach profile is surveyed to determine which areas require nourishment and to what extent. This will vary from year to year and location to location depending on the amount of sand losses/erosion that has taken place. Nourishment will be directed to areas that have fallen below the required standard of protection. 2b) ODOW Question: Could you please clarify these volumes and locations? ▪ 2b) EA response: No, as mentioned above this will vary from year to year. 3) ODOW Question: Will the programming of nourishment during the year remain the same for any future years, and could this please be clarified? ▪ 3) EA response: Please see below in answer to this and the next two questions.	hard structures established at the landfall for shoreline management purposes.

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	4) ODOW Question: Does the intent remain to undertake nourishment alongside the installation of rock structures from 2025 until 2050? 5) ODOW Question: With respect to the proposed rock structures, are any/ all of the following details available to ODOW: ▪ Form of structures, including width, height, slope ▪ Location of structures, both longshore and cross-shore ▪ Programme of planned installation, duration of works per year and timing ▪ 5) EA response: We are currently reviewing the options to deliver the Saltfleet to Gibraltar Point Flood Risk Management Strategy which sets out a plan to change the management regime, in combination with continued beach nourishment, to form a sustainable flood risk management approach for the next 100 years. As part of this work, we have carried out an assessment of our concrete flood defences which has shown they will need increased maintenance and some repairs in the next 20 years due to their age. Options may now need to look different to the initial preferred strategy option of introducing control structures such as rock groynes, and could	

Date and consultation phase	Consultation and key issues raised	Section where comment addressed
	require additional funding, meaning they will need to be developed in partnership. Until a long-term solution is developed, we aim to continue our yearly Beach Management programme and are working on an enhanced monitoring and maintenance programme to make sure the beach height is maintained, and necessary repairs are undertaken. Flood Risk Management activities are permissive and this reflects our aim to continue to deliver the standard of protection against tidal inundation, although any works are subject to bidding for available funding prioritising the greatest benefit to reducing flood risk to people and property.	

7.4 Baseline Environment

7.4.1 Study Area

14. The Marine Physical Processes study area is shown in Volume 2, Figure 7.1 (document reference 6.2.7.1). A ZoI has been used to identify those Marine Physical Processes receptors which have the potential to be affected by the Project infrastructure and associated activities. The ZoI (Volume 2, Figure 7.1 (document reference 6.2.7.1)) has been defined using the outputs from the Project-specific numerical modelling (document reference 6.3.7.2) 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).
15. 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 than those along the ECC. This ellipse similarly encapsulates the maximum extent of measurable sediment plumes predicted by the modelling (see document reference 6.3.7.2).

7.4.2 Data Sources

16. Baseline understanding of Marine Physical 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 7.1of document reference 6.3.7.1 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 physical processes 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 (document reference 6.3.7.2).
17. 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 document reference 6.3.7.2);
    - 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).

7.4.3 Existing Environment

18. The existing environment across the study area is described in detail within document reference 6.3.7.1, and a summary provided in the following sections of this 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 Volume 2, Figure 7.27 (document reference 6.2.7.27)), as well as data collected as part of regional coastal and seabed monitoring programmes. Full details are provided in Table 7.1 of document reference 6.3.7.1.

7.4.3.1 Metocean

Offshore Array

19. The array area is exposed predominantly to waves originating from the north and north-northwest (Volume 2, Figure 7.2 (document reference 6.2.7.2)). 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 (Volume 2, Figure 7.2 (document reference 6.2.7.2); MetOceanWorks, 2021a).
20. Tidal range (Volume 2, Figure 7.3 (document reference 6.2.7.3)) 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).
21. 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 Volume 2, Figure 7.4 (document reference 6.2.7.4)). Annual mean surface and near-bed (1m above bed) current speeds in the centre of the array area are modelled at 0.53m/s and 0.34m/s, respectively (MetOceanWorks, 2021a; 2021c). Data recorded within the array area between 2022 and 2023 recorded mean depth-average tidal current speeds of 0.83m/s and 0.41m/s for springs and neaps, respectively. These are higher than the annual modelled mean values, potentially as a result of variations in current speed within the water column, whereas the modelled values have been identified from the surface and near-bed.

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

Offshore Export Cable Corridor

22. 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 (Volume 2, Figure 7.2 (document reference 6.2.7.2)). Closer to the shore, waves occur most frequently from the north-northeast and northeast, as shown on Volume 2, Figure 7.2 (document reference 6.2.7.2), with an annual mean wave height of 0.8m and the most common peak wave period between 4 and 6 seconds.
23. 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 Volume 2, Figure 7.1 (document reference 6.2.7.1)), 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 (Volume 2, Figure 7.4 (document reference 6.2.7.4)).
24. 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, Volume 2, Figure 7.(document reference 6.2.7.4). 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).

Coast

25. Waves predominantly arrive on the Lincolnshire coast from the northeast (Volume 2, Figure 7.2 (document reference 6.2.7.2)), 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).
26. 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; Triton Knoll Offshore Windfarm Ltd (TKOWFL), 2015).

7.4.3.2 Seabed

Offshore Array

27. The western half of the array area is underlain by Cretaceous Chalk, with mudstones, limestones and sandstones present in the east (Volume 2, Figure 7.5 (document reference 6.2.7.5); 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).

28. Water depths across the array area range from 5 to 47m, with over 90% between 15 and 25m (Lowest Astronomical Tide (LAT)) (Volume 2, Figure 7.6 (document reference 6.2.7.6)). Surficial seabed sediments within the array area are characterised generally by a mix of sand and gravel (as shown Volume 2, Figure 7.7 (document reference 6.2.7.7) and characterised in detail in document reference 6.3.7.1), 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

29. 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 Volume 2, Figure 7.5 (document reference 6.2.7.5) (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).
30. Water depths in the ECC range generally between 10 to 30m (LAT) (see Volume 2, Figure 7.1 (document reference 6.2.7.1)). From approximately 12km offshore, water depths typically shallow uniformly from circa 14m towards the coast (Volume 2, Figure 7.6 (document reference 6.2.7.6); EMODnet, 2022).
31. Surficial sediments in the Offshore ECC area are characterised mainly by sandy gravel, with some mud component to the south of Inner Silver Pit (Volume 2, Figure 7.7 (document reference 6.2.7.7); 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 Volume 2, Figure 7.7 (document reference 6.2.7.7). Closer to the coast, the proportion of sand generally decreases, with a corresponding increase in gravel and fines content.

Coast

32. 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).
33. The present form of the Lincolnshire beaches has been directly influenced by the 'Lincshore' annual beach nourishment scheme, outlined further in Paragraph 41 ~~140~~. 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).

7.4.3.3 Morphology

Offshore Array

34. 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 Volume 2, Figure 7.8 (document reference 6.2.7.8) (Kenyon and Cooper, 2005). This is supported by analysis of bedform migration, identifying transport to the north-northwest in the western half of the array area, although features in the east of the array area were observed to migrate towards the southeast (East Point Geo Ltd., 2023).
35. 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 Volume 2, Figure 7.1 (document reference 6.2.7.1)). 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

36. Bedload sediment transport in the most offshore part of the ECC is directed towards the northwest, as in the Project array area (shown on Volume 2, Figure 7.8 (document reference 6.2.7.8)). 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.
37. The Race Bank – North Ridge – Dudgeon Shoal and Inner Dowsing sandbank system is 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), although geomorphological analysis indicates the anticlockwise migration of bedforms on the North Ridge sandbank (East Point Geo Ltd., 2023). 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).
38. Inner Silver Pit, located landward of the array area and on the northern boundary of the Offshore ECC (Volume 2, Figure 7.1 (document reference 6.2.7.1)), 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 (Volume 2, Figure 7.5 (document reference 6.2.7.5)).

Coast

39. 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 (Volume 2, Figure 7.2 (document reference 6.2.7.2); Volume 2, Figure 7.8 (document reference 6.2.7.8); 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.

~~40.~~ This coastal section has experience long-term erosion, with an estimated erosion rate of approximately 1.3m/year (Humber Aggregate Dredging Association (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). Data from the National Coastal Erosional Risk Mapping 2018 – 2021 (NCERM2) dataset indicates that the main risk on this part of the coast is from flooding, and no erosion risk information is provided (Environment Agency, 2024).~~predicts no future erosion over the frontages located at landfall over the next 100 years (Environment Agency, 2024).~~

40.

41. 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 (Environment Agency, 2011; 2013a). Erosion is particularly focused in the mid-beach as shown in Plate 7.1, with analysis of Light Detection and Ranging (LiDAR) data identifying elevation changes of around 1m to 2m between 2016 and 2020 (APEM, 2023). The dunes backing Wolla Bank have been interpreted as being stable over approximately the last decade, based on LiDAR data analysis and aerial imagery comparison showing vegetation cover.

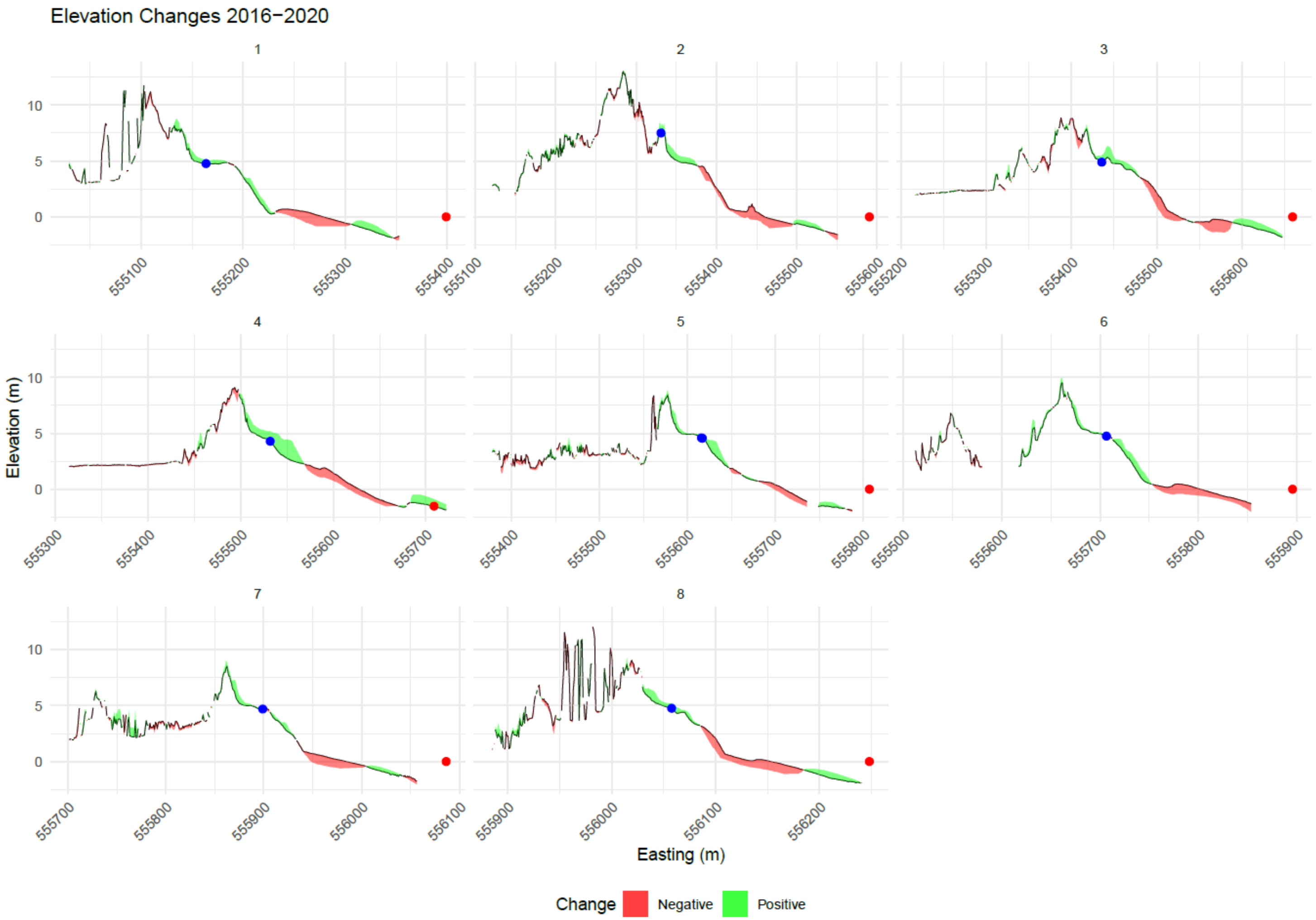

Plate 7.1 Change in beach profile between 2016 and 2020, based on LiDAR data across the dune and beach frontage. The location of transects are shown in Volume 3, Appendix 7.1, Figure 7.19 (document reference 6.3.7.1). MHWS and MLWS are indicated by the blue and red dots, respectively.

7.4.3.4 Suspended Sediment Concentrations

42. 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 summer concentrations of circa 2.4mg/l and 9.2mg/l, respectively, between April and August 2022 within the array area, and winter concentrations of 2.3mg/l and 8.9mg/l, respectively, between November 2022 and May 2023 (Fugro, 2022).
43. 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.

7.4.4 Compensation Areas

44. Areas for the delivery of potential compensation measures associated with the Project have been provided in Volume 2, Figure 7.1 (document reference 6.2.7.1), with the baseline conditions in these areas provided in document reference 6.3.7.1. These compensation options have been assessed within this chapter.

7.5 Future Baseline

45. 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 chapter, the Representative Concentration Pathway (RCP) 8.5 (high emissions) scenario (Palmer *et al.*, 2018) has been presented.
46. The UK Climate Projections 2018 (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).
47. 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).

48. 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

49. 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 Volume 2, Figure 7.9 (document reference 6.2.7.9). This includes the following designated sites which are located outside the Marine Physical 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.

50. A list of designated sites within the Marine Physical 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.
  - One coastal (Sites of Special Scientific Interest (SSSI)) site is also present:
- Chapel Point – Wolla Bank SSSI: national importance in the Geological Conservation Review.

51. Notably, a standalone Habitats Regulation Assessment (HRA) Report to Inform Appropriate Assessment (RIAA) (Report 7.1) and a Marine Conservation Zone (MCZ) Assessment (Volume 3, Appendix 9.4 (document reference 6.3.9.4)) has been produced detailing all matters associated with statutory designations.

7.7 Basis of Assessment

7.7.1 Scope of the Assessment

7.7.1.1 Impacts Scoped In for Assessment

52. 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, and also including coastal processes and geomorphology above MHWS.
- Operation and maintenance:
  - Impact 4: Modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime and morphological features, including coastal processes and geomorphology above MHWS;~~ and~~
  - Impact 5: Seabed scouring; and~~.~~
  - Impact 6: Potential impacts during operational and maintenance activities, including increases in SSC and potential changes to seabed levels and seabed morphology.
- Decommissioning:
  - Impact 7~~6~~: Increases in SSC and consequential changes to seabed levels;
  - Impact 8~~7~~: Potential impacts to seabed morphology (sandbanks, sandwave areas and notable bathymetric depressions); and
  - Impact 9~~8~~: Modifications to littoral transport, coastal behaviour (erosion) including at landfall, and also including coastal processes and geomorphology above MHWS.
- Cumulative:
  - Impact 10~~9~~: Cumulative increases in SSC and consequential changes to seabed levels;
  - Impact 11~~0~~: Cumulative impacts to seabed morphology (sandbanks, sandwave areas and notable bathymetric depressions); and
  - Impact 12~~1~~: Cumulative modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime.

7.7.1.2 Impacts Scoped Out of Assessment

53. Although identified in the Scoping Opinion (The Planning Inspectorate, 2022) as a potential impact, based on the receiving environment, expected parameters of the Project (document reference 6.1.3) and expected scale of impact/potential for a pathway for effect on the environment, the following impacts have not been taken forward for assessment, as discussed through the relevant ETGs (Table 7.2), with no further comment from stakeholders:

- Construction:
    - Hydrodynamic impacts from installation vessels such as jack-up rigs, cable laying vessels etc.

7.8 Realistic Worst Case Scenario

54. This section describes the Maximum Design Scenario (MDS) parameters for Marine Physical 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 document reference 6.1.3) and includes embedded mitigation measures.

Table 7.3 Maximum design scenario for Marine Physical 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** ▪ 100 Wind Turbine Generator (WTG) foundations, 50% of which Gravity Base Structures (GBS) and 50% jackets with suction buckets, with a total spoil volume of 2,037,500m^3; ▪ 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 = 2,280,000m^3 (WTG and offshore platform foundations). **Greatest volume of sediment disturbed and released for dredging for seabed preparation prior to foundation installation remote from the array area** ▪ 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); and	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 document reference 6.3.7.2. The creation of biogenic reef is not expected to result in any increases in SSC. **Dredging for seabed preparation prior to foundation installation** Seabed preparation works would be required prior to installation of certain

Potential effect	Maximum design scenario assessed	Justification
	▪ Two Artificial Nesting Structures (ANS), with a total spoil volume of 72,600m^3 (36,300m^3 per foundation). **Greatest volume of sediment disturbed and released by drilling as part of foundation installation at a single foundation location** ▪ Jacket foundation offshore platform with pin-piles, embedment depth = 110m, drill volume per location (Area 1) = 74,644m^3 (including overburden). See document reference 6.3.7.2 for further details. **Greatest volume of sediment disturbed and released by drilling as part of the foundation installation over the entire array area** ▪ Total estimated drilling volume for 100 monopile foundations: = 780,000m^3; ▪ Total estimated drilling volume for five offshore platform foundations = 137,000m^3; and ▪ Total estimated drilling volume for WTGs and offshore platforms = 780,000m^3 + 127,000m^3 = 917,000m^3. **Greatest volume of sediment disturbed and released by drilling as part of foundation installation remote from the array area**	foundation types, particularly GBS. The use of a jumbo Trailer Suction Hopper Dredger (TSHD) is considered to be the realistic worst case option. As outlined in document reference 6.1.3 and document reference 6.3.7.2, four different types of WTG foundations are being considered for consenting purposes. Of these, sediment volumes disturbed through seabed levelling are greatest for GBS foundations. Given that GBS foundations are being considered for a maximum of 50% of the WTGs, the MDS is represented by 50% of WTG foundations as GBS, and 50% as jackets with suction buckets, which results in the second largest volume of sediment disturbed. The MDS for offshore platforms, ORCPs and ANS for sediment volumes disturbed through seabed levelling is represented by GBS foundations. Details are provided in document reference 6.3.7.2. **Drilling as part of foundation installation** For foundation options that require installation of piles (i.e. monopiles and jackets with pin-piles), there is a potential requirement for drilling when pile driving is not possible. Although the volumes of

Potential effect	Maximum design scenario assessed	Justification
	▪ Average drill spoil volume for a jacket ORCP foundation with pin-piles = 27,400m^3; ▪ Total estimated drilling volume for two ORCP foundations = 54,800m^3; ▪ Average drill spoil volume for jacket ANS with pin-piles = 7,800m^3; ▪ Total estimated drilling volume for two ANS foundations = 15,600m^3. **Installation of inter-array cables** ▪ Total length: 377.42km; ▪ Circular cross section trench shape; seabed width = 15m, depth = 2.5m; ▪ Assume 100% of material is forced into suspension to a height of, approximately, 2.5m above the seabed; ▪ Total volume of disturbance = 6,038,720m^3; ▪ Installation method: MFE; and ▪ Assumed installation rate of up to 215m/hr. **Installation of interlink cables** ▪ Total length: 123.75km; ▪ Circular cross section trench shape; seabed width = 15m, depth = 2.5m; ▪ Assume 100% of material is forced into suspension to a height of, approximately, 2.5m above the seabed; ▪ Total volume of disturbance = 1,980,000m^3; ▪ Installation method: MFE; and	material released via drilling are less than for seabed preparation via dredging, drilling has the potential to release larger volumes of relatively finer sediment. Two maximum adverse scenarios have been identified, corresponding to the greatest volume of sediment disturbance locally (from a single foundation) and across the entire array (from all foundations). There is variable likelihood of the need for foundation drilling (as well as other factors such as foundation embedment depths and required drilling rate) as a result of variable seabed geology across the array area. This has been taken into account in the calculation of the MDS, with full details provided in document reference 6.3.7.2. The greatest volume of drill arisings from a single foundation location is associated with jacket foundations with pin-piles for an offshore platform. The greatest volume of drill arisings for the entire array area is associated with a layout comprising of 100 jacket foundations with pin-piles. **Cable Installation**

Potential effect	Maximum design scenario assessed	Justification
	▪ Assumed installation rate of up to 215m/hr. **Installation of export cables** ▪ Total length of (4) export cables = 440km, each up to 110km in length from array area to landfall; ▪ Circular cross section trench shape; seabed width = 15m, depth = 2.5m; ▪ Assume 100% of material is forced into suspension to a height of approximately 2.5m above the seabed; ▪ Total volume of disturbance = 7,040,000m^3; ▪ Installation method: MFE; and ▪ Assumed installation rate of up to 215m/hr. **Sandwave clearance via dredging (cables within the array area)** ▪ Total length of cables within the array area = 377.42km (inter-array) + 123.75km (interlink) + 110km (export cables within the array area) = 611.17km; ▪ With 32.5% of the inter-array and interlink cables requiring sandwave clearance (to a width of 33m and an average depth of 2.5m), and 20% of the export cables within the array area (to a width of 33m and an average depth of 2.25m);	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, which develops the largest trench cross-section with the greatest potential to displace fine sediments into the water column to the same height as the depth of the trench. The fastest trenching rate of 300m/hr represents the highest release rate of sediments operating in locations with the largest contribution of fine sediments. **Horizontal Directional Drilling (HDD) Operations** The trenchless technique that will be adopted at the landfall is HDD. 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 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

	▪ Total sandwave clearance volume within the array area (for 100 WTGs) = 11,615,616m^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 = 440km, each up to 110km in length;
	    ▪ Export cable length outside the SAC = 4 x 54.8km = 219.2km, 20% of which requiring sandwave clearance, to a width of 33m and average depth of 2.25. Total clearance volume = 2,454,861m^3;
	    ▪ Export cable length within the Sandbank 1 Area = 4 x 2km = 8km, 100% of which requiring sandwave clearance, to a width of 51m and average depth of 4m. Total clearance volume = 960,000m^3;
	    ▪ Export cable length within the Sandbank 2 Area = 4 x 2km = 8km, 100% of which requiring sandwave clearance, to a width of 33m and average depth of 2.5m. Total clearance volume = 512,000m^3;
		Sandwave Clearance
		For the assessment of sandwave clearance requirements for the export cables, the ECC has been split into constituent parts, allowing for a more comprehensive assessment. These comprise:
		▪ Export cables within the array area;
		▪ Export cables within the ECC but outside of the IDRBNR SAC;
		▪ Export cables within the ECC within the Sandbank 1 Area (as defined in Volume 2, Figure 7.6 (document reference 6.2.7.6));
		▪ Export cables within the ECC within the Sandbank 2 Area (as defined in Volume 2, Figure 7.6 (document reference 6.2.7.6)); and
		▪ Export cables within the ECC within the IDRBNR SAC (excluding Sandbank Areas 1 and 2).

Potential effect	Maximum design scenario assessed	Justification
	▪ Export cable length within the SAC (excluding Sandbank Areas 1 and 2) = 4 x 23.7km = 94.8km, 13% of which requiring sandwave clearance, to a width of 30m and average depth of 2m. Total clearance volume = 591,652m^3; ▪ Total sandwave clearance volume outside of the array area = 4,518,513m^3; and ▪ Material disposed of within the Project array area and Offshore ECC, in area of similar sediment characteristics. **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 morphology (sandbanks, sandwave areas and notable bathymetric depressions)	See **Impact 1.**	During the construction phase, the primary means by which sandbanks and sandwaves could be impacted is through the interruption of sediment transport patterns via sandwave clearance and other seabed preparation activities. Details of the relevant activities, as well as the justification for the MDS identified for seabed preparation, are provided in **Impact 1.**

Potential effect	Maximum design scenario assessed	Justification
Impact 3: Modifications to littoral transport and coastal behaviour (erosion), including at landfall, as well as coastal processes and geomorphology above MHWS	**Horizontal Directional Drilling (HDD)** ▪ Exit pit 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; ▪ Maximum of three exit pits open at one time; 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, including coastal processes and geomorphology above MHWS	**Foundations** ▪ 100 WTG foundations, 50% of which slab-based GBS (base height up to 13m) and 50% jackets with suction buckets; ▪ Up to five offshore platforms within the array area, ~~two ORCPs within the ECC,~~ and two ANSs, all with GBS foundations (base height up to 12m); and ▪ Up to two ORCPs within the ECC with jacket suction bucket foundations. **Cable protection** ▪ Standard options include rock placement, concrete mattresses, flow dissipation devices, protective aprons, bagged protection, etc.;	An individual foundation will locally interfere with passing waves and currents with a group of foundation structures having the potential to develop an array-scale blockage effect, taking into account the number, arrangement, and spacing of foundations. For the 50 WTG scenario, slab-based GBS foundations are identified as having the highest individual blockage factor due to the size of the foundations, however since the number of GBS foundations is limited to 50% of the array, the next highest blockage case has been identified as jackets with suction buckets. The greatest total in-water column blockage to currents, waves and sediment

Potential effect	Maximum design scenario assessed	Justification

	▪ Rock berm protection with crest height = 1.5m, crest width = 2m, side slopes = 1:3 gradient and width at seabed = 12m (including a provision for 1m buffer either side);
	▪ Total length of cables which may potentially require seabed protection anticipated to be up to:
	  ▪ 22.75% of inter-array cable length, for a total area of 814,496m^2;
	  ▪ 18.75% of interlink cable length, for a total area of 278,438m^2;
	  ▪ 25% of export cable length within the array area, for a total area of 330,000m^2;
	  ▪ 25% of export cable length outside the SAC, for a total area of 657,552m^2;
	  ▪ 5% of export cable length within Sandbank Area 1, for a total area of 2,880m$^{2;}$
	  ▪ 5% of export cable length within Sandbank Area 2, for a total area of 2,880m^2;
	  ▪ 20% of export cable length within the SAC (excluding Sandbank Areas 1 and
		transport processes is therefore presented by an array comprising of 100 WTGs, 50% with slab-based GBS foundations and 50% with jacket foundations with suction buckets. This is in addition to five offshore platforms, two ORCPs, and two ANSs, all with GBS foundations. Further details and justification are provided in document reference 6.3.7.2.
		The creation of biogenic reef will not result in any modifications to wave and tidal regimes.

Potential effect	Maximum design scenario assessed	Justification
	2), for a total area of 227,558m^2; ▪ Overall rock protection area of 1,422,934m^2 within the array area and 890,870m^2 outside of the array area; ▪ If cable protection is required in the nearshore (defined as the inner depth of closure out to 7.1m (LAT) water depth), concrete mattresses will be utilised; ▪ In addition to cable crossing, berms 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); ▪ Rock protection for cable crossings = 240,000m^2 for the inter-array cables (30 crossings) + 128,000m^2 for the interlink cables (16 crossings) + 304,000m^2 for the export cables (38 crossings) = 672,000m^2.	
Impact 5: Seabed scouring.	▪ 100 WTG foundations, with monopiles; and ▪ 100 WTG foundations, with jackets.	Each foundation type may produce different scour patterns, therefore both monopiles and jacket foundations have been considered.
Impact 6: Potential impacts during operational and maintenance activities, including increases in SSC and potential changes to seabed levels and seabed morphology.	**Inter-array cables** ▪ Cable remedial burial events = 26; ▪ Maximum footprint of temporary seabed disturbance per remedial burial event = 210,000m^2; ▪ Maximum footprint of seabed disturbance per cable repair event = 15,000m^2;	Maximum disturbance of seabed from O&M activities during the lifetime of the Project.

Potential effect	Maximum design scenario assessed	Justification
	▪ Footprint of seabed disturbance via jacking-up activities per cable repair event = 1,500m². **Interlink cables** ▪ Cable remedial burial events = 9; ▪ Maximum footprint of temporary seabed disturbance per remedial burial event = 200,000m²; ▪ Maximum footprint of seabed disturbance per cable repair event = 15,000m²; ▪ Footprint of seabed disturbance via jacking-up activities per cable repair event = 1,500m². **Offshore export cables** ▪ Cable remedial burial events = 31; ▪ Maximum footprint of temporary seabed disturbance per remedial burial event = 155,000m²; ▪ Maximum footprint of seabed disturbance per cable repair event = 15,000m²; ▪ Footprint of seabed disturbance via jacking-up activities per cable repair event = 1,500m².	
Decommissioning		
Impact 76: Increases in SSC and consequential changes to seabed levels.	▪ Array comprising the largest number of foundations (100 WTG foundations, 50% of which GBS and 50% jackets with suction	When removing foundations, the greatest disturbance will be associated with the

Potential effect	Maximum design scenario assessed	Justification
	buckets, five offshore platforms within the array area, two ORCPs, and two ANSs); ▪ 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.	layout containing the greatest number of structures.
Impact 8~~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

55. 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 Physical 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 Physical Processes issues associated with the array, ECC and landfall are described separately.

Table 7.4 Embedded mitigation relating to Marine Physical 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, ORCP area, ANS and benthic compensation areas and Offshore ECC route selected to ensure the impacts on sensitive environmental receptors are minimised.
Construction	
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 has been prepared in support of the Application (document reference 8.5), which will be finalised post-consent.
Offshore cables	Cable installation will follow the burial hierarchy, with at least two attempts made to bury cables before cable protection is used.
Offshore cables	Cable protection installed on sandbanks within the Inner Dowsing, Race Bank and North Ridge SAC will be removable.
Offshore cables	If cable protection is required in the nearshore (defined as the inner depth of closure[4] out to 7.1m (LAT) water depth), concrete mattresses will be utilised, a description of concrete mattresses is set out in Section 6.11.5.2 of ES Chapter 3 Project Description.
Landfall	The installation of the offshore export cables at landfall will be undertaken by HDD. The exit pits will be at least 500m offshore of the Mean Low Water Springs (MLWS) mark.
Landfall	No cable protection will be used inshore of the HDD exit pits.
Foundations and offshore cable	Dredged material will be deposited within an area of similar sedimentary characteristics, in close proximity to the dredge location in order to retain sediment within the sediment transport system, and upstream. No disposal will take place outside agreed disposal sites. These commitments are secured within the Outline Cable Specification and

[4] The inner depth of closure marks the seaward limit of the upper shoreface and has been calculated as approximately 7.1m (LAT), with details provided in Paragraph 104, Appendix 7.1 Physical Processes Technical Baseline (document reference 6.3.7.1).

Parameter	Mitigation measures embedded into the project design
	Installation Plan (CSIP) (document 8.7) (to be submitted in Deadline 4A).
Foundations and offshore cable	Any material dredged from within the Inner Dowsing, North Ridge and Race Bank SAC will be deposited within and upstream of sandbanks in the Inner Dowsing, North Ridge and Race Bank SAC (as secured within the Outline Cable CSIP (document 8.7) (to be submitted in Deadline 4A).
Foundations and offshore cable	No jack-up vessels are to be used within the Inner Dowsing, Race Bank and North Ridge SAC.
Operation and Maintenance	
Project Design	The installation of scour protection where required for engineering purposes. Scour protection may take the form of rock/gravel placement, concrete mattresses, flow energy dissipation devices, protective aprons or coverings, ecological based solutions and bagged solutions.
Scour Protection	Development of a Scour Protection and Cable Protection Management Plan (SPCPMP) and Cable Specification and Installation Plan (CSIP) which will consider the need for scour protection.
Scour protection	Ecological based solutions for scour protection will be prioritised, where practicable.
Decommissioning	
Decommissioning Programme	Development of, and adherence to, a Decommissioning Programme (DP).

7.10 Assessment Methodology

56. The assessment methodology for Marine Physical 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.

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

58. For the most part Marine Physical Processes are not in themselves receptors but are instead ‘pathways’. However, changes to Marine Physical Processes have the potential to indirectly impact other environmental receptors (Lambkin *et al.*, 2009). The receptors which may be impacted by changes to Marine Physical Processes are most notably marine water and sediment quality (document reference 6.1.8), benthic ecology (document reference 6.1.9) and fish and shellfish ecology (document reference 6.1.10). An example of this 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 document reference 6.1.9. 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, including coastal processes and geomorphology above MHWS.	Pathway/receptor
Operation and Maintenance	
Impact 4: Modifications to the wave and tidal regime and associated potential impacts to morphological features, including coastal processes and geomorphology above MHWS.	Pathway/receptor
Impact 5: Seabed scouring.	Pathway/receptor
Impact 6: Potential impacts during operational and maintenance activities, including increases in SSC and potential changes to seabed levels and seabed morphology.	Pathway/receptor
Decommissioning	
Impact 7~~6~~: Increases in SSC and consequential changes to seabed levels.	Pathway
Impact 8~~7~~: Potential impacts to seabed morphology (sandbanks, sandwaves and notable bathymetric depressions).	Pathway/receptor
Impact 9~~8~~: Modifications to littoral transport and coastal behaviour (erosion), including at landfall, as well as coastal processes and geomorphology above MHWS.	Pathway/receptor

59. Whilst Marine Physical Processes can largely be considered as pathways, there are a small number of features which have been identified as potentially sensitive Marine Physical Processes receptors. These features, as presented in Volume 2, Figure 7.9 (document reference 6.2.7.9) are:

- The shoreline, including the Chapel Point – Wolla Bank SSSI and the dunes backing the beach;

- Nearby designated offshore sandbanks (including North Norfolk Sandbanks and Saturn Reef SAC and Inner Dowsing, Race Bank and North Ridge SAC) and undesignated sandbank systems; and
- Seabed areas contained within nationally or internationally important sites.

60. 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 Planning Inspectorate, 2022);
    - Outcomes from the consultation process completed to date; and
    - Reference to best practice guidance.
61. 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.
62. 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 ES chapter to assign values of sensitivity to the receptors and determine the magnitude of potential impacts.
63. 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-field and large parts of the far-field to key characteristics or features of the particular environmental aspect’s character or distinctiveness. Impact is of long-term duration (i.e. total life of the Project.
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. Impact is of medium-term duration (i.e. operational period).
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. Impact is of short- to medium-term duration (i.e. construction period).
Negligible	Changes which are not discernible from background conditions. Impact is of short-term duration (i.e. duration of individual construction works).

64. The sensitivity/importance of the receptor is defined in Table 7.7. The sensitivities (or importance) of Marine Physical Processes 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.
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.

65. The significance of the effect on Marine Physical 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

66. 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.
67. 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 (Volume 2, Figure 7.7 (document reference 6.2.7.7)). 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.
68. 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.
69. 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.
70. The availability of robust data, as outlined in paragraph 16 and summarised in Table 7.1 of document reference 6.3.7.1, relevant for the characterisation and assessment of Marine Physical 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

7.12.1 Construction

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

71. 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)operations.
72. 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.
73. The release events that have been simulated within the numerical model, as described in document reference 6.3.7.2, 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).
74. 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 document reference 6.3.7.2. The findings are presented below.

Conceptual Understanding of Change

75. 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.

76. The maximum distance, and as such the overall spatial extent that any resultant plume might be reasonably experienced over, 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.
77. 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.
78. 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.
79. 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.
80. 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.
81. 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

82. The main cable installation methodologies available are described in document reference 6.1.3. 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 2.5m 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 document reference 6.3.7.2. 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.
83. 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 Volume 2, Figure 7.10 (document reference 6.2.7.10). 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 (Volume 2, Figure 7.10 (document reference 6.2.7.10)), 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 (Volume 2, Figure 7.11 (document reference 6.2.7.11));
    - 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 (Construction Industry Research and Information Association (CIRIA), 2000). Notably, 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 2,000m, all sediments sand-sized and larger will have re-settled to the seabed. The plume may extend up to 13km from the MFE activity location, although SSC will generally reduce to below 50mg/l within approximately 5km (see Volume 2, Figure 7.10 (document reference 6.2.7.10)); and

- After 15 hours, the SSC will have reduced to generally below 50mg/l, with localised areas (less than approximately 500m^2) up to 100mg/l, and fine sediments widely dispersed to nominal concentrations (as in Volume 2, Figure 7.10 (document reference 6.2.7.10)). After 20 hours (~one full tidal cycle after the cessation of MFE activities), SSC will have reduced to generally below 20mg/l, with localised areas up to 50mg/l. Elevated SSC is expected to continue to disperse, so that no measurable SSC is expected to be present after several tidal cycles.

84. The deposition resulting from the seabed disturbance by the MFE project activities within the array area is shown in Volume 2, Figure 7.12 (document reference 6.2.7.12), 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 document reference 6.3.7.2);
- Sediment deposition of up to 100mm is expected in the vicinity of the active disturbance, visible in the results as a line of higher maximum deposition up to approximately 500m wide and 2km long. Deposition of finer sediment fractions is expected from the advected plume settling out of suspension, with thicknesses between 5mm and 20mm deposited up to 3km 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 may occur up to 4km from the MFE activities (as shown in Volume 2, Figure 7.12 (document reference 6.2.7.12));
- 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.

85. 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 Volume 2, Figure 7.13 (document reference 6.2.7.13) and Volume 2, Figure 7.14 (document reference 6.2.7.14) 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 83, 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 1,500m, extending during this period up to 20km from the MFE activity location. SSC reduces to below 150mg/l within 1.5km (see Volume 2, Figure 7.13 (document reference 6.2.7.13)). SSC will reduce to below 50mg/l after 15 hours, and below 5mg/l after 20 hours. Elevated SSC is expected to continue to disperse, so that no measurable SSC is expected to be present after several tidal cycles.

86. The deposition resulting from the seabed disturbance by the MFE project activities along the Offshore ECC is shown in Volume 2, Figure 7.14 (document reference 6.2.7.14), 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 certain tidal conditions deposition may occur up to 4km away from the active disturbance, although this is less than 5mm.

Seabed Levelling and Sandwave Clearance

87. 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 document reference 6.1.3), with the full details of the assumptions made in each model scenario provided in document reference 6.3.7.2.

88. The largest sediment volume likely to be removed for seabed levelling within the array area is around 2,280,000m^3, to be excavated using a TSHD with an assumed hopper volume of 22,000m^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).

89. 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 115*et seq.* and detailed in document reference 6.3.7.2. 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.

90. Numerical modelling results for seabed levelling activities in the array area are provided in Volume 2, Figure 7.15 (document reference 6.2.7.15) and Volume 2, Figure 7.16 (document reference 6.2.7.16) and can be summarised as follows:

- In the first four hours, SSC up to 5,000mg/l is present within several hundred metres of the activity, reducing to below 2,500mg/l within approximately 1km. The plume of elevated SSC may be advected by the tide up to 12km away during spring tides, with concentrations up to 1,000mg/l;
- After five hours, a narrow, roughly continuous plume up to 1.5km wide and 7km long has been advected away from original point of activity by between 5km and 10km, with SSC ranging between, approximately, 20mg/l and 500mg/l, although concentrations may locally reach up to 1,000mg/l (Volume 2, Figure 7.15 (document reference 6.2.7.15));
- The plume continues to be dispersed and advected along the axis of tidal flow, reducing to below 100mg/l after 15 hours and below 20mg/l after 20 hours. Elevated SSC is expected to continue to disperse, so that no measurable SSC is expected to be present after several tidal cycles. 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 116 and document reference 6.3.7.2. Deposition from the passive phase of the plume is shown on Volume 2, Figure 7.16 (document reference 6.2.7.16), 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 50mm. The majority of deposition occurring more than 1km away is between 1mm and 20mm. Localised areas of deposition may occur up to 8km away, although this is less than 20mm. More than 8km away, no measurable deposition can be identified.

91. The largest total volume of sandwave clearance within the array area is estimated to be 11,615,616m^3, representing 32.5% of inter-array and interlink cables, and 20% of the export cables within the array area. The disposal of the dredged sediment back to the seabed will take place at a nearby location within the Order Limits and in a similar sedimentary environment. Numerical modelling results for sandwave clearance activities in the array area are provided in Volume 2, Figure 7.17 (document reference 6.2.7.17) and Volume 2, Figure 7.18 (document reference 6.2.7.18) 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 Volume 2, Figure 7.17 (document reference 6.2.7.17), 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 1,000mg/l is present within several kilometres of the activity, although concentrations may reach 2,500mg/l. This reduces to between approximately 5mg/l to 500 mg/l up to approximately 7km away, with concentrations between 1mg/l and 20mg/l advected up to 15km away during spring tides. After 10 hours, concentrations of up to 250mg/l may be advected up to 15km away, with localised areas of up to 7,500mg/l present after 15 hours. After 20 hours, SSC at all points will be less than 250mg/l, with the majority between 1mg/l and 50mg/l. Elevated SSC is expected to continue to disperse, so that no measurable SSC is expected to be present after several tidal cycles; 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 116. Deposition from the passive phase of the plume is shown on Volume 2, Figure 7.18 (document reference 6.2.7.18), 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 100mm, and measurable deposition may reach up to 5km away. The majority of deposition more than 2.5km away from the disturbance site is between 1mm and 20mm, although in some locations may reach 50mm. More than 5km away, very little deposition can be identified, and is all less than 5mm.

92. The largest volume of sandwave clearance for up to four export cables (outside of the array area) is 4,518,513m^3. As outlined in Table 7.3, this represents 20% of export cables outside of the Inner Dowsing, Race Bank and North Ridge SAC, 100% of export cables within Sandbank Area 1 and 2 (as defined in Volume 2, Figure 7.6 (document reference 6.2.7.6)), and 13% of export cables within the SAC, but outside these defined sandbank areas. The disposal of the dredged sediment back to the seabed will take place at a nearby location within the Order Limits. Numerical modelling results for sandwave clearance activities along the Offshore ECC are provided in Volume 2, Figure 7.19 (document reference 6.2.7.19) to Volume 2, Figure 7.21 (document reference 6.2.7.21) 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 (Volume 2, Figure 7.19 (document reference 6.2.7.19) and Volume 2, Figure 7.20 (document reference 6.2.7.20)). Sediment plumes continue to disperse along the tidal axis, although concentrations remain similar within 3km of the activity up to 15 hours from the start of operations. This reduces to between approximately 20mg/l to 150 mg/l up to approximately 5km away, and is advected up to 15km away during spring tides. Sediment plumes continue to disperse along the tidal axis, with SSC less than 150mg/l at all points after 20 hours. Elevated SSC is expected to continue to disperse, so that no measurable SSC is expected to be present after several tidal cycles; 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 116. Deposition from the passive phase of the plume is shown on Volume 2, Figure 7.21 (document reference 6.2.7.21), with sediment thicknesses primarily between 20mm and 150mm deposited within approximately 500m of the active disturbance, with localised areas (less than 100m) reaching up to 250mm. Beyond this sediment deposition reduces to less than 50mm, and measurable deposition may reach up to 4km away. The majority of deposition more than 1km away from the disturbance site is between 1mm and 20mm, although some may reach up to 50mm. More than 4km away, no measurable deposition can be identified.

Foundation Drilling

93. 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 document reference 6.3.7.2.
94. 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).
95. Numerical modelling has simulated drilling at two adjacent foundation locations along the tidal axis in the array area, with both locations being drilled simultaneously and lasting for 24.5 hours. The initial release of overburden is simulated to last for around 3.5 hours, with the remainder of the drilling period simulating release of material from the rock layer. The results can be summarised as follows:
    - SSC resulting from foundation drilling is minimal, never exceeding 10mg/l. SSC may be advected up to 20km away in low concentrations of less than 7.5mg/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 Volume 2, Figure 7.22 (document reference 6.2.7.22). Deposition of up to 30mm is predicted within several hundred metres of the foundation, reducing rapidly to below 10mm. The maximum extent of deposition is predicted to be less than 2km, with only thicknesses below 2mm identified at these distances. This effect is small-scale and highly localised, as well as occurring intermittently.
96. 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.

97. 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 129.

98. 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

99. The subsea export cable ducts will be installed underneath the beach using HDD as identified in 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. Management measures to minimise the likelihood of unplanned release of drilling fluid is outlined in the Code of Construction Practice (CoCP).

100. 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 HDD exit pit. 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 Volume 2, Figure 7.23 (document reference 6.2.7.23). Deposition of up to 10mm is predicted within several hundreds of metres of the exit pit, 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.

Magnitude of Impact

101. 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. Elevated SSC may remain past 20 hours from the start of activities, although this is expected to continue to disperse and become indistinguishable from background levels (outlined in Paragraph 42 *et seq.*) within several tidal cycles, 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 115 *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 2km (for foundation drilling) and 500m (for bentonite release). The effect of these activities is therefore considered to be restricted to the near-field, temporary, and indiscernible from background conditions.

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

Sensitivity of the Receptor

103. All the identified Marine Physical Processes receptors (as outlined in paragraph 59) 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 ES, in particular:

- Volume 1, Chapter 8: Marine Water and Sediment Quality (document reference 6.1.8);
- Volume 1, Chapter 9: Benthic Subtidal and Intertidal Ecology (document reference 6.1.9);
- Volume 1, Chapter 10: Fish and Shellfish Ecology (document reference 6.1.10);
- Volume 1, Chapter 11: Marine Mammals (document reference 6.1.11); and
- Volume 1, Chapter 14: Commercial Fisheries (document reference 6.1.14).

Significance of Effects

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

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

105. 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

106. 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.

107. Areas of sandwaves are present in several locations across both the array area and Offshore ECC, as indicated on Volume 2, Figure 7.6 (document reference 6.2.7.6) and characterised within document reference 6.3.7.1. This includes up to 100km within the Inner Dowsing, Race Bank and North Ridge SAC (as outlined in Table 7.3), including two main sandbank areas.

108. 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 (RPS, 2018). This includes monitoring data from the Race Bank OWF (DONG Energy, 2017), located approximately 30km southwest of the Project array area as shown on Volume 2, Figure 7.27 (document reference 6.2.7.27). 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.

109. 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.

110. 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 (RPS, 2018). 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. This is corroborated by evidence of sandwave regeneration after dredging by Larsen *et al.* (2019), with sandwave height at Race Bank OWF observed to have regenerated to approximately 65% after 300 days and a prediction of full recovery (98%) after three years.

111. 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 11,615,616m^3 within the array area and approximately 4,518,513m^3 within the Offshore ECC. This includes up to 2,063,652m^3 within the Inner Dowsing, Race Bank and North Ridge SAC.

112. 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 Order Limits 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.

113. The tidal current regime, with spring tidal current speeds between approximately 1.0m/s to 1.4m/s, is sufficiently strong to cause the regular mobility of sand and finer sediments, as outlined in detail in document reference 6.2.7.1. 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.

114. 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 between 30m to 33m (with the exception of Sandbank Area 1, where trench widths have been assessed as 51m). 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.

115. 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 88. 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.

116. 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 as outlined in document reference 6.3.7.2, with the results summarised below:

- For seabed levelling around foundation locations, the results indicate an area of deposition of up to 440,000m^2 for each spoil mound with a maximum height of 1.25m. However, the area of deposition over 1m in height is restricted to 2,000m^2, with deposition heights below 0.5m over 336,000m^2;
- For sandwave clearance of inter-array cable routes within the array area, the results indicate an area of deposition of up to 397,000m^2 for each spoil mound with a maximum height of 1.55m. However, the area of deposition over 1m in height is restricted to 5,000m^2, with deposition heights below 0.5m over 302,000m^2; and

- For sandwave clearance along the ECC, the results indicate an area of deposition of up to 166,000m^2 for each spoil mound with a maximum height of 3.35m. However, the area of deposition over 1m in height is restricted to 13,000m^2, with deposition heights below 0.5m over 95,000m^2. This spoil mound is higher than that formed from sandwave clearance in the array area, notably because the local water depth closer to shore is shallower (and consequently sediment has less time in which to be advected horizontally), and the relative contribution from coarser sediments is larger.

117. 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

118. 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 trench with a circular cross section, with a width of 15m and a depth of 2.5m. The trenched sediment volume is forced into suspension to a height of around 2.5m above the seabed and then will subsequently settle within several meters of the trench, as outlined previously in Paragraph 82. 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 to ensure effective cable burial depths. As outlined in Paragraph 106 *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

119. 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 1.5m and a width at seabed of 12m, comprising a total area of 1,422,934m^2 within the array area and 890,870m^2 for the export cable outside of the array area. This is in addition to cable crossings, where rock berms with a maximum height of 2m and a width at seabed of 16m will be installed, comprising a total area of 672,000m^2.

120. The implementation of rock berms (as worst case) will result in a change in the seabed profile of up to 1.5m 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 182. 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 Volume 2, Figure 7.5 (document reference 6.2.7.5)).

121. In areas of sand, active sediment transport processes are indicated by the presence of mobile bedforms such as sandwaves and megaripples, as shown in Volume 2, Figure 7.6 (document reference 6.2.7.6). 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 125mm, up to a maximum of 250mm. 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.

122. In areas where chalk is close to the seabed surface, as indicated on Volume 2, Figure 7.5 (document reference 6.2.7.5), 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.

123. Conservation advice provided by Natural England on the Inner Dowsing, Race Bank and North Ridge SAC (Natural England, 2023) has identified the placement of cable protection (with no guarantee that the protection will be removed) as part of the Race Bank OWF infrastructure as likely to result in lasting change and/or loss of the Annex I sandbank feature. In light of this advice, the Applicant has committed to only removable cable protection being used where required over the sandbanks within the SAC (as outlined in Table 7.4), such as rock bags and concrete mattresses, which are able to be removed with only short-term disturbance to the seabed as outlined in Peritus International Ltd. (2022).

Installation Vessel Footprints

124. 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. As outlined in Table 7.4, no jack-up vessels are to be used within the Inner Dowsing, Race Bank and North Ridge SAC.

125. 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 document reference 6.3.7.1. The Dudgeon and Sheringham Shoal Extension projects are located in similar geological environments to that of the Project, with Holocene sands overlying Pleistocene deposits including the Bolders Bank and Swarte Bank Formations, which in turn overlay Cretaceous Chalk.

126. 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.

127. 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

128. As outlined in Paragraph 93, 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 600m from the foundation and maximum thicknesses of 75mm within 100m.

129. 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 they remained discernible (approximately 1.0m above the seabed) for more than four years after disposal (Bureau of Ocean Energy Management (BOEM), 2017). This figure is only presented as a guide as oceanographic conditions may be slightly different at the Project location (CREL, 2008). Although located in broadly similar sedimentary environments and characterised by peak spring current speeds of 0.9m/s to 1.1m/s (ABPmer *et al.*, 2010), the Lynn and Inner Dowsing OWFs are located closer to shore, and therefore drill spoil mounds will be located in shallower water depths and subject to variable wave climate when compared to the Project array area.

130. Drill arisings will comprise of some softer material (overburden) and harder underlying rock, including chalk in the western half of the array area, the relative amounts of which will vary between foundation locations. The bedrock geology at the Lynn and Inner Dowsing OWF comprises Cretaceous chalk, overlain by stiff gravelly clay with a veneer of overlying Holocene sandy gravel between approximately 0.2m to 0.5m. This is similar to conditions found in the western half of the array area, making these OWF an appropriate analogue for processes occurring at the Project location.

Magnitude of Impact

131. The conservation advice provided by Natural England on the Inner Dowsing, Race Bank and North Ridge SAC (Natural England, 2023) has identified impacts from Race Bank OWF infrastructure as likely to result in lasting change and/or loss of the Annex I sandbank feature, based primarily on the placement of cable protection with no guarantee that the protection will be removed. Where it is required that cable protection be used, the Applicant will respond to this advice by committing to the use of removable protection over the sandbanks within the SAC, such as rock bags and concrete mattresses. These measures are able to be removed with only short-term disturbance to the seabed as outlined in Peritus International Ltd. (2022). Although present for the operational period of the Project, the use of less intrusive methods of cable protection are considered to result in barely discernible changes to the form of the sandbanks, with effects restricted to the near-field areas. The magnitude of impact has therefore been assessed as low for cable protection.

132. 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 (outside of cable protection) 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 not permanent, and generally restricted to the near-field. The magnitude has therefore been assessed as low.

Sensitivity of the Receptor

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

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

134. 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.

135. This judgement is based on the evidence provided within Paragraph 108 to Paragraph 114, which provides evidence of sandwave recovery from the Race Bank OWF, located within the SAC. This is further supported by evidence from Larsen *et al.* (2019), which compares multiple high-resolution bathymetry datasets to investigate the response of sandwaves within the Race Bank OWF to the dredging of two 16m bottom width trenches. For both areas surveyed, the sandwave height is observed to have regenerated to approximately 65% after 300 days, with a prediction of full recovery (98%) after three years. Based on these sources, natural sedimentary processes are expected to continue after operations have taken place, leading to continued development of sandwave features and the recovery towards a new equilibrium state.

136. There are a number of Annex I sandbanks within the ZoI, outwith the Inner Dowsing, Race Bank and North Ridge SAC. These features are shown in Volume 2, Figure 7.8 (document reference 6.2.7.8), with characterisation, including sediment mobility estimates, provided in document reference 6.3.7.1. These features have been assessed as having a moderate capacity to accommodate the proposed form of change, based on the evidence provided above. The sensitivity of this receptors has therefore been assessed as medium.

137. 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

138. The assessment has concluded that the magnitude of impact on the seabed morphology 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.

7.12.1.3 Impact 3: Modifications to Littoral Transport and Coastal Behaviour (Erosion), Including at Landfall, including Coastal Processes and Geomorphology above MHWS

139. The offshore export cables will make landfall at Wolla Bank, just south of Anderby Creek, Lincolnshire (see Volume 2, Figure 7.1 (document reference 6.2.7.1)). 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 document reference 6.3.7.1. The assessment below separately considers the potential for impacts associated with:

- Horizontal Directional Drilling (HDD);

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

140. In line with stakeholder consultation, as outlined in Table 7.2, receptors above MHWS are considered within this impact where appropriate. This is in recognition of the interrelated nature of the beach and dune systems along the coastline, as well as their potential interactions with the hydrodynamic and sediment transport regime.

Conceptual Understanding of Change

141. 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).

142. This pattern has also been identified using LiDAR data from the National Network of Regional Coastal Monitoring Programmes (NNRCMP), compared between 2016 and 2020 as presented in Plate 7.1 and document reference 6.3.7.1 (APEM, 2023). Elevation differences generally of the order of 0.5m to 1m can be identified along the beach frontage, with sediment accretion occurring in the upper beach, in some areas up to 2m. Differences in elevation around the low water mark generally indicate accretion, although some transects demonstrate an alternating accretionary and erosional pattern on the lower beach. This may be attributed to ridge and runnel patterns, which can be further identified on aerial imagery as presented in document reference 6.3.7.1.

143. Elevation change identified from the LiDAR data also indicates that the sand dunes behind Wolla Bank beach have generally experienced only minor changes between 2016 and 2020, with variations of less than 1m suggesting individual dune mobility rather than variation of the dunefield as a whole (APEM, 2023). These dunes are referred to as vegetated within the HADA Marine Aggregate Regional Environmental Assessment (MAREA) published in 2012, a description supported by aerial imagery from both 2013 and 2023 (provided in document reference 6.3.7.1). This provides further evidence of the stability of the dune system over approximately the last decade.

144. 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.

145. 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 1. 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.

Horizontal Directional Drilling (HDD)

146. As outlined in Table 7.3, HDD has been identified as the MDS for trenchless installation. 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).

147. 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, including coastal erosional processes. The design of the HDD operation will take this into account.

148. The presence of annual beach nourishment (as outlined in Paragraph 1 and Paragraph 145) 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

149. HDD will be used to install the export cables at the landfall, with a maximum of six HDD exit pits, which allows for up to two failures. The HDD exit pits will be excavated as required for each export cable installation, which has been assessed as being located within the Project subtidal area (subtidal exit pit) 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.

150. 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.

151. 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

152. 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). 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 120. Cable protection measures could also cause a morphological response through modification of the local nearshore wave regime and associated patterns of sediment transport.

153. The HDD exit pit will be within the subtidal zone, at least approximately 500m seaward from MLWS, with no cable protection required shoreward of this mark. ~~Within the subtidal zone (seaward of the HDD exit pit), 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). As outlined in Table 7.4, if cable protection is required in the nearshore (defined as shoreward of the inner depth of closure of 7.1m (LAT)), concrete mattresses will be utilised, with a description set out in Section 6.11.5.2 of ES Chapter 3 Project Description. Concrete mattresses are a low-profile form of cable protection and therefore will not impede littoral transport. ~~Rock berms, where required, will 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, with full details provided within the CSIP.~~

154. 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

155. The use of HDD 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.

156. 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 measures will be necessary within the intertidal zone, ~~-~~and no cable protection is to be employed seaward of the HDD exit pits. As outlined in Table 7.4, if cable protection is required in the nearshore (defined as shoreward of the inner depth of closure of 7.1m (LAT)), concrete mattresses will be utilised, with a description set out in Section 6.11.5.2 of ES Chapter 3 Project Description. Concrete mattresses are a low-profile form of cable protection and potential impacts will be restricted to the near-field, with limited potential to impact coastal behaviour more widely.~~Although water depths at this distance are such that the installation of 1.5m high rock berms, even if they are not exposed at low water, would result in a permanent change with the potential to impact coastal behaviour in both the near- and far-field, cable protection measures will be designed to fit the requirements of the area concerned. 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 are provided within the CSIP.~~ On this basis, the magnitude of change to littoral transport and coastal behaviour is assessed to be medium.

Sensitivity of the Receptor

157. 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;
- The Wolla Bank Beach dunes; and

- Chapel Point to Wolla Bank SSSI.

158. 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.

159. Wolla Bank Beach is backed by a series of vegetated sand dunes, classified as 'foredunes' and primarily composed of medium sand. Sand dune systems are an important natural coastal flood defence, with moderate to high economic value given the protection afforded to areas inland. The mobility and stability of dune systems is related to the sediment budget of the upper beach, and therefore impacts to sediment processes in the nearshore zone have the potential to influence this receptor. However, Wolla Bank Beach is a dynamic environment subject to both coastal erosion and annual nourishment (as outlined in Paragraph 1 and Paragraph 145) during which time the dune systems have remained stable (as indicated in document reference 6.3.7.1 and outlined in Paragraph 143). This evidence suggests that the dune system has a high capacity to accommodate proposed changes, and this receptor has therefore been assessed as of low sensitivity.

160. 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, and therefore is identified as having high sensitivity. As outlined in Table 7.4, the HDD exit pit will be micro-sited to avoid direct interaction with the SSSI such that that there is no pathway of effect on this receptor.

Significance of Effects

161. The assessment has concluded that the magnitude of impact on littoral transport and coastal behaviour from the use of HDD, the construction of HDD exit pits, and the use of cable protection measures is medium. Whilst the Chapel Point to Wolla Bank SSSI is considered to be of high sensitivity, there is no pathway of effect between cable protection measures or HDD operations and this receptor. The other receptors identified are considered to be of low sensitivity. 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.

7.12.2 Operations and Maintenance

7.12.2.1 Impact 4: Modifications to the Wave and Tidal Regime and Associated Potential Impacts to Morphological Features, including Coastal Processes and Geomorphology above MHWS

162. 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 100 WTG foundations, 50% of which are slab-based GBS foundations (with a base extending 13m above the seabed) and 50% of which are jackets with suction bucket foundations. This is in addition to up to five slab-based GBS offshore platform foundations, in addition to slab-based foundations for two ORCPs, located within the Offshore ECC, and two ANSs (as shown on Volume 2, Figure 7.1 (document reference 6.2.7.1)). It should be noted that this modelling represents a conservative scenario for the ORCPs, for which the GBS option has been removed as of Examination Deadline 4a.

Conceptual Understanding of Change

163. 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).

164. Numerical modelling has been undertaken to quantify change in hydrodynamic flows and water levels, with details of the model scenarios and method presented in document reference 6.3.7.2. Changes in depth average current speed from baseline conditions are predicted to be small in absolute and relative terms, with predicted changes ~~of primarily~~typically of the order of <±0.1m/s. Volume 2, Figure 7.24 (document reference 6.2.7.24) shows the change in current speeds for a high northerly current speed scenario (high spring ebb tide). Reductions in speed of between 0.05m/s and 0.1m/s are predicted within ~~400m~~, approximately, 500m to 1km of a small minority of foundations, with reductions between 0.02m/s and 0.05m/s forming wakes up to 1.5km downstream of the majority of foundations in the west of the array. In several locations these wakes are suggested to overlap, ~~however this is largely mitigated by the separation distance.~~particularly to the western edge of the array. In other parts of the array area, any overlapping of current speed changes is largely mitigated by the separation distances of the foundations.

165. Localised reductions in current speed greater than of >0.1m/s are predicted up to 500m downstream of the northern ORCPs, with reductions between 0.02m/s and 0.05m/s forming a wake up to 3km from the foundationextending up to 4km from the structures. The presence of the northerly ANS foundation is predicted to result in current speed reductions between 0.02m/s and 0.05m/s up to 2km downstream of the foundation, as indicated in Volume 2, Figure 7.24 (document reference 6.2.7.24).

166. The presence of the foundations in the sea also has the potential to modify the 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; and
- Diffraction of wave energy around the structure.

167. 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.

168. The wave modelling considered waves originating from the north and northeast for three event magnitudes: p50 (median) conditions, 1 in 1-year extreme waves, and 1 in 100-year extreme waves. These wave directions represent the prevailing conditions across the study area, as identified in paragraph 22. The resulting difference to the baseline wave regime is shown in Volume 2, Figure 7.25 (document reference 6.2.7.25) and Volume 2, Figure 7.26 (document reference 6.2.7.26).

169. For waves originating from the north, 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 (Volume 2, Figure 7.25 (document reference 6.2.7.25)). This causes a wave shadow effect to be created by each foundation, which interact to form an array-scale blockage. The results indicate that, for p50 (or median baseline) conditions, a slight reduction in wave conditions, of up to 0.05m in significant wave height (Hm0) is present up to approximately 360km away from the array area. Changes to significant wave heights of up to -0.1m are shown up to approximately 154km away from the array area (towards the south), with reductions between 0.1251m and 10.25m found usually within 1kmseveral kilometres of individual foundations, and up to 45km from individual foundations in the south of the array area. These reductions are over 50km away from the nearest coastline.

170. For waves originating from the northeast, the results (presented in Volume 2, Figure 7.26 (document reference 6.2.7.26)) show that during p50 (or median baseline) conditions, there is a slight reduction in wave conditions, up to 0.05m in in significant wave height (Hm0) up to approximately 35km away from the array area. Changes to significant wave heights of up to -0.1m are shown up to approximately 18km away from the array area, with reductions between 0.125m and ~~1~~0.25m found usually within ~~1km~~ several kilometres of individual foundations, and up to ~~4~~5km from individual foundations in the southwest of the array area. This is accompanied by a change in peak wave period of up to -0.1s extending southwest of the array area towards the coast. However, although this change is over a wide spatial extent, it represents only a small change compared to baseline conditions, with peak wave periods generally between 4 and 8 seconds as outlined in document reference 6.3.7.1. A change in peak wave period of -0.1s therefore represents a change of, at most, 2.5% of the baseline.

171. In significant wave height for both northerly and northeasterly waves, ~~there is a full dissipation of wave energy well away from the coastline~~changes in significant wave height are not detectable close to the coastline. Similarly for 1 in 100-year extreme events measurable change to significant wave height is dissipated well away from the coast, as shown in Volume 2, Figure 7.25 (document reference 6.2.7.25) and Volume 2, Figure 7.26 (document reference 6.2.7.26). This is the case for the ORCP foundations as well as those within the array area, although these foundations are located closer to the shore, measurable~~s~~ changes to the wave height nevertheless dissipate over 5km from the coast.

Magnitude of Impact

172. 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 5~~4~~00m to 1km 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. Current speed reductions are higher downstream of the ORCPs, exceeding 0.1m/s within approximately 500m of the foundation. However, although this change is noticeable, it is restricted in both spatial and temporal extent, with localised variation throughout the tidal cycle. This conclusion is further supported by the results of sediment mobility analysis carried out at the points identified on Volume 2, Figure 7.8 (document reference 6.2.7.8) and outlined in document reference 6.3.7.1. The results, presented in Annex A, indicate that estimated changes in sediment mobility after the installation of Project infrastructure do not exceed 1% (of total time that sediment is mobile) for any sediment size class. On this basis, the magnitude of impact to the tidal regime is assessed to be low.

173. 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 Volume 2, Figure 7.25 (document reference 6.2.7.25), any change to the wave height 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. Although changes to peak wave period may reach the coast under some conditions, this represents only a minor change (less than 2.5%) to baseline conditions. 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 seabed or coastal morphology. The magnitude of impact to the wave regime is therefore assessed to be negligible.

Sensitivity of the Receptor

174. 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;
- Offshore sandbanks;
- Coastal receptors, including morphodynamic features above MHWS; and
- Areas of undesignated seabed.

175. Small reductions in significant wave height, of the order of 2.7~~6~~% and 1.3% (for waves arriving from the northeast and north, respectively) caused by array-scale blockage may reach the Inner Dowsing, Race Bank and North Ridge SAC, as indicated by Volume 2, Figure 7.25 (document reference 6.2.7.25). However, the Race Bank – North Ridge – Dudgeon Shoal sandbank system, located within the area affected by wave blockage (Volume 2, Figure 7.25 (document reference 6.2.7.25)) 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), although geomorphological analysis indicates anticlockwise migration of bedforms on the North Ridge sandbank (East Point Geo Ltd., 2023). 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).

176. 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 (reaching a maximum of -4.25% for waves from the north, and -6.25% for waves from the northeast)~~-~~, there is unlikely to be any meaningful change to the banks' crest height. Although the ORCPs are in close proximity to the Inner Dowsing, Race Bank and North Ridge SAC, they are located to the west of the Inner Dowsing sandbank (as shown in Volume 2, Figure 7.8 (document reference 6.2.7.8)). At this location waves predominantly occur from the north-northeast and northeast (Environment Agency, 2021), meaning that any blockage impacts from the ORCPs will not propagate towards the east, and therefore there is limited pathway of effect on the Inner Dowsing sandbank or the wider SAC. 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.

~~176.~~177. With regard to changes in tidal regime, predicted modifications to tidal current speed from the presence of the array area will not reach the Inner Dowsing, Race Bank and North Ridge SAC, as shown in Volume 2, Figure 7.24 (document reference 6.2.7.24). The ORCPs are located in close proximity to the Inner Dowsing sandbank, as shown in Volume 2, Figure 7.8 (document reference 6.2.7.8), however, tidal flows here are generally oriented north to south, meaning that potential hydrodynamic blockage impacts resulting from the ORCPs are unlikely to propagate towards the east. This conclusion is supported by the sediment mobility results presented in Annex A (with the locations of extraction points shown in Volume 2, Figure 7.8 (document reference 6.2.7.8)). The installation of Project infrastructure is predicted to result in an increase of 1% (of total time that sediment is mobile) for very fine sand during neap tides at Point 4, with no changes in sediment mobility estimated at Point 3. The scale of this change is considered to be well within the natural variability of the site, and given that it only affects fine-grained sediment, is unlikely to represent a controlling influence on sandbank form. The Inner Dowsing, Race Bank and North Ridge SAC is therefore considered to have a high capacity to accommodate predicted potential change to the tidal regime from the ORCP. In combination with its designated status, the sensitivity of this receptor has been assessed as medium. It should furthermore be noted that this modelling represents a conservative scenario for the ORCPs, for which the GBS option has now been removed.

~~177.~~178. Coastal receptors, including receptors above MHWS are described in Paragraph 139 *et seq.* and assessed in Paragraph 157 *et seq.* These features, including the beach-dune system along the coast, are under the influence of waves and tides, and therefore may be impacted by changes to the wave and tidal regime. However, as outlined above, numerical modelling indicates that wave and tidal blockage effects are limited to the near-field, and do not reach the coast. There is therefore no pathway of effect on coastal receptors.

~~178.~~179. Offshore sandbanks within the ZoI are described in Paragraph 136 and shown in Volume 2, Figure 7.8 (document reference 6.2.7.8). Those features located within and around the array area are likely to be impacted by changes to the wave and tidal regime, particularly those features located to the south and southeast of the array area. These features are generally more linear than the Race Bank – North Ridge – Dudgeon Shoal sandbank system, and may be described as open shelf linear sandbanks (Kenyon and Cooper, 2005). Wave processes are understood to be important in enhancing sediment transport across the crest and limiting the vertical growth of banks of this type (Dyer and Huntley, 1999). Given the small percentages of wave reduction predicted to result from the presence of the foundations, there is unlikely to be a meaningful change to the banks' crest height, and these features are therefore considered to have a high capacity to accommodate change to the wave regime. The sensitivity of this receptor has therefore been assessed as low.

~~179.~~180. Areas of undesignated seabed around and within the array area will not be affected by changes to the wave regime, as sediment transport in this area is dominated by the action of tidal currents. However, as outlined in Paragraph 172, hydrodynamic blockage effects may lead to localised changes to sediment mobility. Since this area of seabed is undesignated and effects would be localised, the sensitivity of this receptor has been assessed as negligible.

Significance of Effects

~~180.~~181. The assessment has concluded that the magnitude of impact is low (on the wave regime) to negligible (on the tidal regime). Receptor sensitivity is considered to be negligible for areas of undesignated seabed, low for undesignated offshore sandbanks, and medium for the Inner Dowsing, Race Bank and North Ridge SAC, with no pathway of effect on coastal receptors. 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.

7.12.2.2 Impact 5: Seabed Scouring

~~181.~~182. 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.

~~182.~~183. 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).

~~183.~~184. 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.

~~184.~~185. 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

~~185.~~186. Scour assessment for EIA purposes is considered here for monopiles and jackets, with the MDS outlined in Table 7.3. Scouring around GBS or suction caissons is currently not well understood as there is limited information available from the field. 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.

~~186.~~187. 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. Scour holes are assumed to develop down to either the thickness of the Holocene sand layer, or 18m, with the radius of an approximately conical scour hole as a function of 1:2 of the depth of scour. Estimated scour volumes are presented for an array of 100 monopile foundations in Table 7.9, with the total volume of scour across all WTG foundations calculated as 77,252m^3, and for an array of 100 jacket WTG foundations in Table 7.10, with the total volume of scour across all WTG foundations calculated as 163,536m^3.

Table 7.9 Estimated scour for an array consisting of 100 WTGs with monopile foundations

Scour depth (m)	Pile diameter (m)	Scour radius[5] (m)	Volume[6] (m^3)	% of locations[7]	Number of locations	Total volume (m^3)
3	12.5	12.25	466.5	35%	35	16,328
5	12.5	16.25	1,505	25%	25	37,634
8	12.5	22.25	4,658	5%	5	23,290

Table 7.10 Estimated scour for an array consisting of 100 WTGs with jacket foundations

Scour depth (m)	Pile diameter (m)	Scour radius (m)	Volume (m^3)	% of locations[8]	Number of locations	Total volume (m^3)
3	5	8.5	255	35%	35	35,626
5	5	12.5	916	25%	25	91,630
6.5	5	15.5	1,814	5%	5	36,280

~~187.~~188. Scour caused around foundations will, however, be limited by the installation of scour protection where required as outlined in document reference 6.1.3. For an array consisting of 100 WTGs this will consist of 4,300m^2 per foundation for monopiles, with 1,000m^2 per foundation for jackets with pin-piles. 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.

~~188.~~189. Post-construction monitoring data from the Hornsea One OWF, located approximately 20km to the northeast of the Project, identified minor bathymetric changes around foundations with scour protection in the Year 2 surveys. These changes are of the order of 20cm to 40cm, and may indicate secondary scour processes, although at some sites this cannot be distinguished from natural sediment mobility processes (Ørsted, 2021).

~~189.~~190. 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.

[5] Including pile radius.
[6] Calculated as the volume of a truncated cone minus the pile cylinder.
[7] At approximately 35% of locations, no notably near-surface Holocene sand has been identified in the survey data, therefore no scour is expected to develop.
[8] At approximately 35% of locations, no notably near-surface Holocene sand has been identified in the survey data, therefore no scour is expected to develop

Magnitude of Impact

~~190.~~191. 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

~~191.~~192. The following receptors have been considered in the assessment of potential changes from seabed scour:

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

~~192.~~193. 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.

~~193.~~194. Offshore sandbanks are present within and around the array area, as indicated on Volume 2, Figure 7.8 (document reference 6.2.7.8). These features are expected to be impacted by secondary seabed scouring as described above. These receptors are designated as Annex I features, however have been assessed as having a moderate capacity to accommodate the proposed form of change. This is based on the results of sediment mobility analysis carried out at the points identified on Volume 2, Figure 7.8 (document reference 6.2.7.8) and outlined in document reference 6.3.7.1. The results, presented in Annex A indicate that estimated changes in sediment mobility after the installation of Project infrastructure do not exceed 1% (of total time that sediment is mobile) for any sediment size class.

~~194.~~195. 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 of negligible sensitivity.

Significance of Effects

196. 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.

7.12.2.3 Impact 6: Potential Impacts during Operational and Maintenance Activities, including Increases in SSC and Potential Changes to Seabed Levels and Seabed Morphology

197. During the O&M phase of the Project there will be no planned maintenance or replacement of the subsea cables, however repairs may be required should the cable fail or be damaged. Cable replacement works may require de-burial and re-burial of a cable or cable sections and along with cable preventative maintenance, including re-burial, will result in seabed disturbance. This seabed disturbance will give rise to increased SSC and consequential sediment deposition, as well as potential impacts to seabed morphology.

198. The MDS for operational and maintenance activities is provided in Table 7.3, with further details provided in the Outline Offshore Operation and Maintenance Plan (APP-275).

199. In terms of suspended sediment plumes and associated deposition, the sediment volumes arising from cable repair and reburial are considerably smaller than those assessed during the construction phase. The magnitude of the impacts has been assessed as low, with no Marine Physical Processes receptors sensitive to the impact pathway and assessment of residual effects not applicable.

200. Similarly, potential impacts to seabed morphology will be less than those which occur during construction. Activities which disturb the seabed during the operational phase have the potential to slow the ability of features to recover (Natural England and JNCC, 2022), however, as outlined in Paragraph 132, the patterns of processes governing the overall evolution of the systems are at a much larger scale than the proposed local works. As a result, proposed modifications to seabed morphology from O&M activities are not considered likely to influence the overall form and function of the system and eventual recovery via natural processes is therefore expected. This is further supported by evidence submitted as part of the Sandwave Levelling Study (REP3-047), which demonstrates that the Project area is characterised by a dynamic sediment environment that is conducive to the development and maintenance of mobile bedforms. Whilst cable repair works, if required, may result in some interruption to the recovery of features, this will be over a localised area and infrequent, with feature recovery expected to commence following the completion of the works.

201. Impacts arising from maintenance activities are therefore considered to be similar to, 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.

~~195.~~

7.12.3 Decommissioning

~~196.~~202. 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.

~~197.~~203. 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.

~~198.~~204. 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.

7.12.3.1 Impact 7~~6~~: Increases in SSC and Consequential Changes to Seabed Levels

~~199.~~205. 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 Physical 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 ES, in particular:

- Document reference 6.1.8;
- Document reference 6.1.9;
- Document reference 6.1.10;
- Document reference 6.1.11; and
- Document reference 6.1.14.

7.12.3.2 Impact 8~~7~~: Potential Impacts to Seabed Morphology (Sandbanks, Sandwaves and Notable Bathymetric Depressions)

~~200.~~206. Impacts arising from decommissioning activities are considered to be similar to, 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.

7.12.3.3 Impact 9~~8~~: Modifications to Littoral Transport, Coastal Behaviour (Erosion) Including at Landfall, including Coastal Processes and Geomorphology above MHWS

~~201.~~207. Impacts arising from decommissioning activities are considered to be similar to, or less than, those which occur during construction. The magnitude of impact upon littoral transport and coastal behaviour from the construction of the project infrastructure at landfall is medium at worst. All 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

~~202.~~208. This cumulative impact assessment for Marine Physical Processes has been undertaken in accordance with the methodology provided in Volume 3, Appendix 5.2 Cumulative Effect Assessment Approach (document reference 6.3.5.2).

~~203.~~209. The projects and plans selected as relevant to the assessment of impacts to Marine Physical 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 document reference 6.3.5.2, and outlined here in Table 7.11.

Table 7.11 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.

~~204.~~210. For the purposes of assessing the impacts of the Project on Marine Physical Processes in the region, the cumulative effect assessment technical note submitted through the EIA Evidence Plan and forming Volume 2, Appendix 5.2 of this ES screened in a number of projects and plans as presented in Table 7.12 and Volume 2, Figure 7.27 (document reference 6.2.7.27). The cumulative MDS for the Project is outlined in Table 7.13.

Table 7.12 Projects considered within the Marine Physical Processes cumulative effect assessment

Development type	Project	Status	Data confidence assessment/phase	Tier
Offshore Energy	Sheringham Shoal Extension	~~Under Examination~~Consented/ Under Construction	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 WindFarm 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	Complete/In Operation	High – Third party project details published in the public domain and confirmed as being ‘accurate’ by The Crown Estate	1
	Eastern Green Link 3 (EGL 3) and Eastern Green Link 4 (EGL 4)	Scoping report submitted	Medium – Third party project details published in the public domain but not confirmed as being ‘accurate’	2
Pipelines	Gas Shearwater to Bacton Seal Line	Active/In Operation	High – Third party project details published in the public domain and	1

Development type	Project	Status	Data confidence assessment/phase	Tier
	Malory to Galahad Tee Gas Export		confirmed as being 'accurate' by The Crown Estate	
	Gas Barque PB to Clipper PT			
	Excalibur to Lancelot Tee Gas Export			
	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			

Development type	Project	Status	Data confidence assessment/phase	Tier
	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)			
	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)			

Development type	Project	Status	Data confidence assessment/phase	Tier
	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~~application submitted to the MMO 25th April 2024, not yet determined)		1~~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			
Carbon Capture Storage Licences	Carbon Storage Licence CS017	Licence Area	Medium – Third party project details published in the public domain but not confirmed as being 'accurate'	3
	Carbon Storage Licence CS018			
	Carbon Storage Licence CS028			

Table 7.13 Cumulative MDS

Impact	Scenario	Justification
Cumulative increases in SSC and consequential changes to seabed levels	Tier 1: ▪ Offshore WindFarm 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); and ▪ EGL 3 and EGL 4 (Construction). Tier 3: ▪ Aggregate Tender Area 2103 (Operation); and ▪ Carbon Storage Licences CS017, CS018, and CS028.	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 littoral transport and coastal behaviour (erosion), including at landfall, including coastal processes and geomorphology above MHWS	Tier 2: ▪ EGL 3 and EGL 4 (Construction)	If EGL3 and EGL4 landfall activities overlap temporally with the construction of the Project, there is the potential for cumulative modifications to littoral transport and coastal behaviour.

Impact	Scenario	Justification
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.

7.13.1 Impact 109: Cumulative Increases in SSC and Consequential Changes to Seabed Levels

205.211. 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.

206.212. 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.

207.213. Carbon Capture, Usage and Storage (CCUS) licences were awarded in September 2023, with several within the vicinity of the Project as shown in Volume 2, Figure 7.27 (document reference 6.2.7.27). In addition to these licences, CCUS activities also require a storage agreement for lease granted by TCE, enabling applicants to proceed with a Permit application and a lease if successful. . At the time of writing, no permits for CS017, CS018, and CS028 have been granted, by North Sea Transition Authority. At the time of writing, it is understood that none have been awarded for the areas licensed in September 2023, including those listed in Table 7.12 and Table 7.13. As such, no information is currently publicly available on the scope or timing of potential works associated with CCUS activities, and there is therefore insufficient data on which to undertake a quantitative or semi-quantitative assessment. As such, no assessment has been made of potential cumulative effects with carbon storage licences CS017, CS018, and CS028.

214. Aggregate Area 515/2 ('Outer Dowsing') is located approximately 1.1km from the Project array area, and is adjacent to the Offshore ECC, as shown in Volume 2, Figure 7.27 (document reference 6.2.7.27). 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 Volume 2, Figure 7.27 (document reference 6.2.7.27). A Marine Licence application (MLA/2024/00227) was submitted in April 2024 for Exploration and Option Area 1805. The application is currently on hold at the time of writing and is yet to be determined.

215. ~~, and an application is expected shortly for a production licence.~~ Area 2103, also overlapping the Offshore ECC (see Volume 2, Figure 7.27 (document reference 6.2.7.27)) has been selected by The Crown Estate (TCE) within the 2021/22 marine aggregates tender round, and the award of seabed rights is subject to the outcome of a plan-level HRA. Due to uncertainty associated with the timing, possible extent, or ~~license~~ licence 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.

~~208.~~216. Works associated with Eastern Green Link 3 (EGL 3) and Eastern Green Link 4 (EGL 4) may result in sediment plumes with the potential to overlap with those of the Project. These projects are HVDC subsea cables planned to make landfall in Lincolnshire for which a Scoping Report was published in July 2024. The indicative location (as shown in Volume 2, Figure 7.27 (document reference 6.2.7.27)) is located within the ZoI associated with the Project ECC, located 1.4km from the ECC at their closest point.

~~209.~~217. On the basis of sediment plume modelling presented in Paragraph 71 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 or construction works associated with EGL 3 and ELG 4, 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).

7.13.1.1 Conceptual Understanding of Change

~~210.~~218. 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).

~~211.~~219. 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.

~~212.~~220. The target material in terms of aggregate extraction is sands and gravels (HADA, 2012a). 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 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.

~~213.~~221. 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 and construction activities from EGL 3 and EGL 4, any overlap is expected to be short-lived and affect only a small area.

7.13.1.2 Magnitude of Impact

~~214.~~222. As outlined in Paragraph 101, levels of sediment dispersion are high, with all sediment plumes expected to be indistinguishable from background levels after several tidal cycles. Given the short-lived nature of the sediment plumes, alongside the location of other infrastructure (Volume 2, Figure 7.27 (document reference 6.2.7.27)), 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.

7.13.1.3 Sensitivity of the Receptor

~~215.~~223. All the identified Marine Physical Processes receptors (as outlined in paragraph 59) 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 ES, in particular:

- Volume 1, Chapter 8: Marine Water and Sediment Quality (document reference 6.1.8);
- Volume 1, Chapter 9: Benthic Subtidal and Intertidal Ecology (document reference 6.1.9);
- Volume 1, Chapter 10: Fish and Shellfish Ecology (document reference 6.1.10);

- Volume 1, Chapter 11: Marine Mammals (document reference 6.1.11); and
- Volume 1, Chapter 14: Commercial Fisheries (document reference 6.1.14).

7.13.1.4 Significance of Effects

~~216.~~224. There are no Marine Physical Processes receptors sensitive to the impact pathway and assessment of residual effects is not applicable.

7.13.2 Impact 1~~0~~1: Cumulative Impacts to Seabed Morphology (Sandbanks, Sandwave Areas and Notable Bathymetric Depressions)

~~217.~~225. 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 Order Limits. 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.

~~218.~~226. ~~Two aggregate areas have been identified to have a significant overlap with the Order Limits, a~~As previously outlined in Paragraph 214 *et seq.* The Exploration and Option Area 1805 (‘Inner Dowsing’) ~~overlaps~~is adjacent to ~~with~~ the Offshore ECC, as shown in Volume 2, Figure 7.27 (document reference 6.2.7.27), and ~~is currently in~~submitted an application for a marine licence in April 2024. ~~, and t~~The Aggregate Tender Area 2103 is part of the 2021/22 marine aggregates tender round, and overlaps with the Offshore ECC as shown in Volume 2, Figure 7.27 (document reference 6.2.7.27), 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.

7.13.2.1 Conceptual Understanding of Change

~~219.~~227. 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).

~~220.~~228. As with Project construction activities, as outlined in Paragraph 105 *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.

7.13.2.2 Magnitude of Impact

~~221.~~229. As outlined above, there is the potential for long-term change in the near-field, where the Order Limits 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.

7.13.2.3 Sensitivity of the Receptor

~~222.~~230. The following receptors have been considered in the assessment of potential changes to seabed morphology:

- Areas of undesignated seabed.

~~223.~~231. 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, the sensitivity of this receptor has been assessed as negligible.

7.13.2.4 Significance of Effects

~~224.~~232. 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.

7.13.3 Impact 12~~1~~: Cumulative Modification to Littoral Transport and Coastal Behaviour (Erosion), including at Landfall, including Coastal Processes and Geomorphology above MHWS

233. Project activities at landfall may potentially interact with those of other projects and activities, in particular EGL 3 and EGL 4~~,~~ for which two HVDC subsea cables are planned to make landfall in Lincolnshire and for which a Scoping Report was published in July 2024. Two potential landfall options have been identified, Theddlethorpe or Anderby Creek. The proposed landfall option at Anderby Creek is located approximately 1.1km north of the Project landfall, with construction proposed between 2028 and 2032, and therefore potentially overlapping with the Project (with construction proposed between 2026 to 2031).

234. Works at landfall for EGL 3 and EGL 4 may take the form of trenchless installation techniques (such as HDD) or open cut trenching, which may require the temporary use of a cofferdam. The use of a cofferdam may result in potential wave and hydrodynamic blockage effects, with subsequent effects on littoral transport and coastal behaviour. This has the potential to interact with Project landfall and nearshore works as assessed in Section 7.12.1.3, including the use of HDD, the construction of HDD exit pits, and the use of cable protection measures. If a cofferdam were used, it is likely that safety and logistical considerations (for example the use of safety zones) will preclude these operations from taking place concurrently. Therefore, no significant effects in EIA terms are predicted.

235. Due to considerable uncertainty associated with the potential landfall option, possible installation techniques used, likelihood of a cofferdam being required, timing of construction or consent outcome of EGL 3 and EGL 4, the potential interactions at landfall are not able to be assessed further in any reasonable or meaningful way.

~~7.13.3~~7.13.4 Impact 13: Cumulative Modifications to the Wave and Tidal Regime and Associated Potential Impacts to the Sediment Transport Regime

~~225.~~236. 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 162 *et seq.*, it is expected that only projects within 35km 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 Volume 2, Figure 7.26 (document reference 6.2.7.26). Projects that have the potential to create cumulative blockage effects therefore include Triton Knoll and Dudgeon Extension.

~~7.13.3.1~~7.13.4.1 Conceptual Understanding of Change

~~226.~~237. Numerical hydrodynamic modelling, as presented in Paragraph 163, 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.

~~227.~~238. Triton Knoll OWF is located 7.7km away from the Project array area, as shown in Volume 2, Figure 7.27 (document reference 6.2.7.27). 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.

~~228.~~239. Similarly, the Dudgeon OWF and associated Dudgeon Extension Project are located 19.9km and 13.5km from the Project array area, respectively (as shown in Volume 2, Figure 7.27 (document reference 6.2.7.27)). 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, potentially interacting with blockage effects caused by the infrastructure of these projects. However, as before, impacts dissipate with distance south of the Project infrastructure and therefore are unlikely to meaningfully contribute to array-scale wave blockage associated with Dudgeon and Dudgeon Extension 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.

~~7.13.3.2~~7.13.4.2 Magnitude of Impact

~~229.~~240. 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.

~~7.13.3.3~~7.13.4.3 Sensitivity of the Receptor

~~230.~~241. 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;
- Offshore sandbanks; and
- Areas of undesignated seabed.

~~231.~~242. As outlined previously in Paragraph 174 *et seq.*, these receptors have been identified as negligible.

~~7.13.3.4~~7.13.4.4 Significance of Effects

~~232.~~243. 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

~~233.~~244. 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).

~~234.~~245. The potential inter-relationships which are relevant to this Marine Physical Processes assessment are presented in Table 7.14.

Table 7.14 Marine Physical Processes Inter-Relationships

Potential effect	Related chapter	Consideration within ES	Rationale
Construction			
Increases in SSC resulting in elevated turbidity and consequential changes to seabed levels	▪ Document reference 6.1.8; ▪ Document reference 6.1.9; ▪ Document reference 6.1.10; ▪ Document reference 6.1.11; and ▪ Document reference 6.1.14.	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)	▪ Document reference 6.1.9; ▪ Document reference 6.1.10; and ▪ Document reference 6.1.14.	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	▪ Document reference 6.1.9; ▪ Document reference 6.1.10; and ▪ Document reference 6.1.14.	Section 7.12 (Impact 4)	Benthic communities and fish species could be adversely affected by disturbance to seabed habitats.
Seabed scouring	▪ Document reference 6.1.9; ▪ Document reference 6.1.10; and ▪ Document reference 6.1.14.	Section 7.12 (Impact 5)	Benthic communities and fish species could be adversely affected by disturbance to seabed habitats.
Potential impacts during operational and maintenance activities, including increases in SSC and potential changes to seabed levels and seabed morphology	▪ Document reference 6.1.8; ▪ Document reference 6.1.9; ▪ Document reference 6.1.10; ▪ Document reference 6.1.11; and ▪ Document reference 6.1.14.	Section 7.12 (Impact 6)	Benthic communities and fish species could be adversely affected by increased suspended sediment concentrations and disturbance to seabed habitats.

Potential effect	Related chapter	Consideration within ES	Rationale
Decommissioning			
Increases in SSC and consequential changes to seabed levels	▪ Document reference 6.1.8; ▪ Document reference 6.1.9; ▪ Document reference 6.1.10; ▪ Document reference 6.1.11; and ▪ Document reference 6.1.14.	Section 7.12 (Impact 7~~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)	▪ Document reference 6.1.9; ▪ Document reference 6.1.10; and ▪ Document reference 6.1.14.	Section 7.12 (Impact 8~~7~~)	Benthic communities and fish species could be adversely affected by disturbance to seabed habitats.

7.15 Transboundary Effects

~~235.~~246. No transboundary effects are predicted to result from the construction, operation and maintenance nor decommissioning phases of the proposed Project with respect to Marine Physical processes receptors.

~~236.~~247. Therefore, no significant transboundary effects are predicted for Marine Physical Processes and as such an assessment of transboundary effects are not considered necessary in this chapter.

7.16 Conclusions

~~237.~~248. This chapter has investigated the potential effects on Marine Physical 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 7.15 Summary of Potential Impacts on Marine Physical 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, including coastal processes and geomorphology above MHWS	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.
Effect 6: Potential impacts during operational and maintenance activities	Minor significance of effect (at worst)	Not Applicable – no additional mitigation identified	No significant adverse residual effects.

Description of effect	Effect	Additional mitigation measures	Residual impact
Decommissioning			
Effect 7~~6~~: Increases in SSC and consequential changes to seabed levels	(Pathway)	Not Applicable – no additional mitigation identified	(Pathway)
Effect 8~~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.
Effect 9: Modifications to littoral transport, coastal behaviour (erosion) including at landfall, including coastal processes and geomorphology above MHWS	Minor significance of effect (at worst)	Not Applicable – no additional mitigation identified	No significant adverse residual effects.
Cumulative			
Effect 10~~8~~: Cumulative increases in SSC and consequential changes to seabed levels	(Pathway)	Not Applicable – no additional mitigation identified	(Pathway)
Effect 11~~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 12: Cumulative modification to littoral transport and coastal behaviour (erosion), including at landfall, including coastal processes and geomorphology above MHWS	Minor significance of effect (at worst)	Not Applicable – no additional mitigation identified	No significant adverse residual effects.
Effect 13~~0~~: 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

ABPmer (2018). SEASTATES Metocean Data and Statistics Interactive Map. Available online at: www.seastates.net [Accessed: February 2024].

ABPmer and METOC (2002), 'Potential effects of offshore wind developments on coastal processes'.

ABPmer, Cefas and HR Wallingford (2007), 'Review of Round 1 Sediment process monitoring data – lessons learnt (Sed01)'.

ABPmer, HR Wallingford and Cefas (2010), 'Further review of sediment monitoring data (Collaborative Offshore Wind Energy Research into the Environment (COWRIE) ScourSed-09)'.

ABPmer, Met Office and POL (2008). 'Atlas of UK Marine Renewable Energy Resources: Atlas Pages. A Strategic Environmental Assessment Report, March 2008'. BP Marine Environmental Research Ltd. Produced for BERR. Report and associated GIS layers available at: http://www.renewables-atlas.info/ [Accessed: February 2024].

APBmer, Met Office and SeaRoc UK Ltd. (2008), 'Guidelines in the use of metocean data through the lifecycle of a marine renewables development'.

Balson, P. S. (1999), 'The Holocene Coastal Evolution of Eastern England: Evidence from the southern North Sea'. Proceedings of Coastal Sediments, 99,1284-1293.

BERR (2008), 'Review of Cabling Techniques and Environmental Effects Applicable to the Offshore Windfarm Industry'. Department for Business Enterprise and Regulatory Reform in association with Defra.

Blott, S.J. and Pye, K. (2004), 'Morphological and sedimentological changes on an artificially nourished beach, Lincolnshire, UK'. Journal of Coastal Research, 20(1), 214-233.

Bonaduce, A., Staneva, J., Behrens, A., Bidlot, J-R., and Wilcke, R.A.I, (2019), 'Wave Climate Change in the North Sea and Baltic Sea'. Journal of Marine Science and Engineering, 2019(7), DOI:10.3390/jmse7060166.

Briggs, K., Thomson, K., and Gaffney, V., (2007), 'A geomorphological investigation of submerged depositional features within the Outer Silver Pit, Southern North Sea', in Gaffney, V.L., Thomson, K. and Fitch, S. (eds.), Mapping Doggerland: the Mesolithic landscapes of the southern North Sea. Archaeopress (Oxford).

Brooks, A.J., Whitehead, P., Lambkin, D. (2018), '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'. For Natural Resources Wales (NRW).

BSI (2015), 'Environmental impact assessment for offshore renewables energy projects'.

Bureau of Ocean Energy Management (BOEM) (2017), 'Improving Efficiencies of National Environmental Policy Act Documentation for Offshore Wind Facilities – Case Studies Report', OCS Study, BOEM 2017-16.

Carotenuto, P., Meyer, V.M., Strøm, P.J., Cabarkapa, Z., St John, H. and Jardine, R. (2018), 'Installation and axial capacity of the Sheringham Shoal offshore windfarm monopiles – a case history', Engineering in Chalk: Proceedings of the Chalk 2018 Conference, 117-122. ICE Publishing.

Cathie (2021), 'Desktop Study and Preliminary Ground Model'. UK Round 4 Offshore Windfarm – Outer Dowsing. Report for Total E&P.

Cefas (2004), 'Offshore Windfarms: Guidance note for Environmental Impact Assessment in Respect of FEPA and CPA requirements'.

Cefas (2011), 'Guidelines for Data Acquisition to Support Marine Environmental Assessment of Offshore Renewable Energy Projects'.

Cefas (2016), 'Sediment Climatologies around the UK'. Report for the UK Department for Business, Energy & Industrial Strategy (BEIS) Offshore Energy Strategic Environmental Assessment (OESEA) programme.

Centrica (2007), 'Lincs Offshore Windfarm Environmental Statement. Chapter 5: Description of the Existing Environment'.

Centrica (RBW) Ltd (2008), 'Race Bank Environmental Statement. Chapter 5: Physical Environment'.

CIRIA. (2000). 'Scoping the assessment of sediment plumes arising from dredging'. Report CIRIA C547.

Cooper, W.S., Townend, I.H. and Balson, P.S. (2008), 'A synthesis of current knowledge on the genesis of the Great Yarmouth and Norfolk Bank Systems', The Crown Estate, London.

Defra (2022), 'Inner Silver Pit South: Consultation factsheet for candidate Highly Protected Marine Area (HPMA)'. https://consult.defra.gov.uk/hpma/consultation-on-highly-protected-marine-areas/supporting_documents/Annex%20E%20Inner%20Silver%20Pit%20South%20candidate%20HPMA%20factsheet.pdf [Accessed: February 2024].

Defra (2023), 'Highly Protected Marine Areas (HPMAs)'. https://www.gov.uk/government/publications/highly-protected-marine-areas/highly-protected-marine-areas-hpmas [Accessed: February 2024].

DESNZ (2023a), 'Overarching National Policy Statement for Energy (EN-1)'. https://assets.publishing.service.gov.uk/media/64252f3b60a35e00120cb158/NPS_EN-1.pdf [Accessed: February 2024].

DESNZ (2023b), 'National Policy Statement for Renewable Energy Infrastructure (EN-3)'. https://assets.publishing.service.gov.uk/media/64252f5f2fa848000cec0f52/NPS_EN-3.pdf [Accessed: February 2024].

DESNZ (2023c), 'National Policy Statement for Electricity Networks Infrastructure (EN-5)'. https://assets.publishing.service.gov.uk/media/64252f852fa848000cec0f53/NPS_EN-5.pdf [Accessed: February 2024].

Dove, D., Evans, D.J., Lee, J.R., Roberts, D.H., Tappin, D.R., Mellett, C.L., Long, D. and Callard, S.L. (2017), 'Phased occupation and retreat of the last British–Irish Ice Sheet in the southern North Sea;

geomorphic and seismostratigraphic evidence of a dynamic ice lobe', Quaternary Science Reviews, 163: 114-134.

Dyer, K.R. and Huntley, D.A. (1999), 'The origin, classification and modelling of sand banks and ridges', Continental shelf research, 19(10), pp.1285-1330.

East Point Geo Ltd. (2023), 'Outer Dowsing Offshore Wind – Seabed Mobility Study'. CONFIDENTIAL.

EDF ENERGY, SZC and CGN (2020), 'The Sizewell C Project. Volume 2 Main Development Site, Chapter 20 Coastal Geomorphology and Hydrodynamics'. Revision 1.0. The Planning Inspectorate Reference Number: EN010012.

EMODnet. (2020), 'European Marine Observation and Data Network (EMODnet) Bathymetry data'. https://portal.emodnet-bathymetry.eu [Accessed: February 2024].

Environment Agency (2020), 'National Flood and Coastal Erosion Risk Management Strategy for England'. https://www.gov.uk/government/publications/national-flood-and-coastal-erosion-risk-management-strategy-for-england--2 [Accessed: February 2024].

Environment Agency (2011), 'Coastal Morphology Report: Lincolnshire (Mablethorpe to Skegness)'.

Environment Agency (2013a), 'Coastal Morphology Technical Note Lincshore'.

Environment Agency (2013b), 'Sea State Report: Chapel Point wave buoy, 2012-2013'.

Environment Agency (2013b), 'Sea State Report: Chapel Point wave buoy, 2012-2013'.

~~Environment Agency (2014), 'National Coastal Erosion Risk Mapping (NCERM) – National (2018 – 2021)'. https://www.data.gov.uk/dataset/7564fcf7-2dd2-4878-bfb9-11c5cf971cf9/national-coastal-erosion-risk-mapping-ncerm-national-2018-2021 [Accessed: February 2024].~~Environment Agency (2024),' National assessment of flood and coastal erosion risk in England 2024'. https://www.gov.uk/government/publications/national-assessment-of-flood-and-coastal-erosion-risk-in-england-2024 [Accessed: February 2025].

Environment Agency (2019a), 'Saltfleet to Gibraltar Point Strategy'.

Environment Agency (2019b), 'Saltfleet to Gibraltar Point Strategy. Strategic Environmental Assessment: Environmental Report'.

Environment Agency (2021a), 'Chapel Point Annual Wave Report 2021'.

Enviros (2022), 'Outer Dowsing Offshore WindFarm Geophysical UHRS and Light Geotechnical Survey, East Anglia, Offshore UK'.

EU (2008), 'The Marine Strategy Framework Directive'. https://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm [Accessed: February 2024].

Fugro (2022), 'Turbidity data collected from Floating LiDAR'.

Fugro-Emu (2014), 'Review of environmental data associated with post-consent monitoring of licence conditions of offshore windfarms'. MMO Project No: 1031.

GEOxyz. (2022a), 'Benthic Ecology OWF Area Results Report (Vol. 1) UK4855H-824-RR-01'.

GEOxyz. (2022b), 'Benthic Ecology ECC Area Results Report (Vol. 2) UK4855H-824-RR-02'.

HM Government (2011), 'UK Marine Policy Statement'. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69322/pb3654-marine-policy-statement-110316.pdf [Accessed: February 2024].

Holmes, R., and Wild, J.B.I (2003), 'DTI Strategic Environmental Assessment Area 2 (SEA2) geological processes (interpretation of multibeam, sidescan sonar, chirp and grain size data acquired in 2001 from the seafloor of the Norfolk Banks and Dogger Bank, southern North Sea)'. BGS Internal Report CR/03/188.

HR Wallingford *et al.* (2007), 'Dynamics of scour pits and scour protection – Synthesis report and recommendations (Sed02)'.

HR Wallingford, Posford Haskoning, CEFAS and Dr Brian D'Olier (2002), 'Southern North Sea Sediment Transport Study (SNSSTS) Phase 2: Sediment Transport Report'. Report No. EX4526, August 2002.

Humber Aggregate Dredging Association (HADA) (2012a), 'Marine Aggregate Regional Environmental Assessment of the Humber and Outer Wash Region Volume I: Chapters 1 - 6'. http://marine-aggregate-rea.info/sites/www.marine-aggregate-rea.info/files/private/volume-i-marea-final-hada-report-10-may-2012.pdf [Accessed: February 2024].

Humber Aggregate Dredging Association (HADA) (2012b), 'Marine Aggregate Regional Environmental Assessment of the Humber and Outer Wash Region Volume II: Chapters 7 – 12'. http://marine-aggregate-rea.info/sites/www.marine-aggregate-rea.info/files/private/volume-ii-marea-final-hada-report-10-may-2012.pdf [Accessed: February 2024].

JNCC (2010). 'Special Area of Conservation (SAC): Inner Dowsing, Race Bank and North Ridge. SAC Selection Assessment Version 5.0'. http://publications.naturalengland.org.uk/publication/3288484?category=3229185 [Accessed: February 2024].

JNCC and Natural England (2011), 'General advice on assessing potential impacts and mitigation for human activities on Marine Conservation Zone (MCZ) features, using existing regulation and legislation'.

Kenyon, N. and Cooper, B. (2005), 'Sand banks, sand transport and offshore windfarms: Technical Report', DTI SEA 6 Technical Report.

Lambkin, D., Harris, J., Cooper, W., Coates, T. (2009), 'Coastal Process Modelling for Offshore Windfarm Environmental Impact Assessment: Best Practice Guide'. Technical Report, COWRIE.

Lowe, J., Howard, T., Pardaens, A., Tinker, J., Holt, J., Wakelin, S., Milne, G., Leake, J., Wolf, J., Horsburgh, K., Reeder, T., Jenkins, G., Ridley, J., Dye, S., Bradley, S. (2009), 'UK Climate Projections Science Report: Marine and coastal projections'. Met Office Hadley Centre: Exeter.

MetOceanWorks (2021a), 'Outer Dowsing Offshore WindFarm: Metocean Design Criteria. Location: CENTRAL'. Commercial in Confidence.

MetOceanWorks (2021b), 'Outer Dowsing Offshore WindFarm: Metocean Design Criteria. Location: EAST'. Commercial in Confidence.

MetOceanWorks (2021c), 'Metocean Data Overview: Outer Dowsing Offshore Wind Farm'. Commercial in Confidence.

MetOceanWorks (2021d), 'Outer Dowsing Offshore WindFarm: Metocean Design Criteria. Location: WEST'. Commercial in Confidence.

MMO (2014), 'East Inshore and East Offshore Marine Plans'. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/312496/east-plan.pdf [Accessed: February 2024].

Natural England (2018), 'Offshore wind cabling: ten years experience and recommendations'.

Natural England (2022), 'Best Practice Advice for Evidence and Data Standards for offshore renewables projects'.

Natural England and JNCC (2022), 'Nature conservation considerations and environmental best practice for subsea cables for English Inshore and UK offshore waters'.

Ørsted (2021), 'Hornsea 1 Offshore Windfarm (HOW01) Post Construction Year 2 and Asset Integrity Surveys 2021, Interpretative Report, Survey 1e'.

Palmer., M, Howard., T, Tinker., J, Lowe., J, Bricheno., L, Calvert., D, Edwards., T, Gregory., J, Harris., G, Krijnen., J, Pickering., M, Roberts., C and Wolf., J. (2018), 'UKCP18 Marine report'. November 2018.

Peritus International Ltd (2022), 'Scour and Cable Protection Decommissioning Study', NECR403, Natural England.

Proctor, R., Holt, J.T. and Balson, P.S. (2001), 'Sediment deposition in offshore deeps of the Western North Sea: questions for models'. Estuarine, Coastal and Shelf Science, 53(4), 553-567.

Pye, K., Blott, S. and Brown, J. (2017), 'Advice to Inform Development of Guidance on Marine, Coastal and Estuarine Physical Processes Numerical Modelling Assessments', NRW Report No: 208, 139 pp, Natural Resources Wales, Cardiff.

Rogan, C., Miles, J., Simmonds, D., Iglesias. G. (2016), 'The Turbulent Wake of a Monopile Foundation', Renewable Energy 93: 180-187.

RPS (2018), 'Hornsea Project Three Offshore Wind Farm: Appendix 11 to Deadline I Submission – Sandwave Clearance Clarification Note'.

Spencer, T., Brooks, S.M., Evans, B.R., Tempest, J.A. and Möller, I. (2015), 'Southern North Sea storm surge event of 5 December 2013: Water levels, waves and coastal impacts', Earth-Science Reviews, 146: 120-145.

Sündermann, J. and Pohlmann, T. (2011), 'A brief analysis of North Sea physics'. Oceanologia, 53(3), 663-689.

Tappin, D. R., Pearce, B., Fitch, S., Dove, D., Gearey, B., Hill, J. M., Chambers, C., Bates, R., Pinnion, J., Diaz Doce, D., Green, M., Gallyot, J., Georgiou, L., Brutto, D., Marzialetti, S., Hopla, E., Ramsay, E., and Fielding, H. (2011), 'The Humber Regional Environmental Characterisation', British Geological Survey Open Report OR/10/54.

Tillin, H.M., Houghton, A.J., Saunders, J.E. Drabble, R. and Hull, S.C. (2011), 'Direct and indirect impacts of aggregate dredging', Science Monograph Series No. 1, MEPF 10/P144.

Triton Knoll OWF Limited (2011), 'Triton Knoll Offshore WindFarm Physical Processes Technical Documentation'.

Triton Knoll OWF Limited (2012), 'Triton Knoll Offshore WindFarm Environmental Statement: Physical Processes'.

Triton Knoll OWF Limited (2014), 'Triton Knoll Electrical System Preliminary Environmental Information: Marine Physical Environment Baseline'.

Triton Knoll OWF Limited (2015), 'Triton Knoll Electrical System Environmental Statement: Marine Physical Environment'.

OUTER DOWSING OFFSHORE WIND

7.18 Annex A

~~238.~~249. Modelled current time-series data from the Project numerical outputs (the details of which are provided in document reference 6.3.7.2) have been used to estimate the potential sediment mobility of sediments across the study area before and after the installation of the Project infrastructure, with results shown in Table 7.16. Potential sediment mobility across a spring and neap tidal cycle are presented at 27 points, the locations of which are shown in Volume 2, Figure 7.8 (document reference 6.2.7.8). Highlighted cells identify differences in the sediment mobility with Project infrastructure within the model.

Table 7.16 Estimated potential sediment mobility across the study area from modelled tidal currents

Point	Size Class	Grain Size (upper boundary) (mm)	Approximate Water Depth (m)	Threshold of Bed Shear Stress (N/m^2)	Corresponding Critical Depth-averaged Current Speeds (m/s)	Baseline Sediment Mobility[6] (Spring)	Baseline Sediment Mobility (Neap)	Scheme Sediment Mobility (Spring)	Scheme Sediment Mobility (Neap)
1	Granule Gravel	4	25	3.007	1.32	6%	0%	6%	0%
	Very Coarse Sand	2	25	1.166	0.908	32%	2%	32%	2%
	Coarse Sand	1	25	0.481	0.643	56%	13%	56%	13%
	Medium Sand	0.5	25	0.262	0.524	65%	30%	64%	30%
	Fine Sand	0.25	25	0.189	0.492	66%	35%	66%	35%
	Very Fine Sand	0.125	25	0.153	0.489	66%	36%	66%	36%
	Coarse Silt	0.0625	25	0.120	0.477	67%	38%	67%	38%
2	Granule Gravel	4	5	3.007	1.049	9%	0%	9%	0%
	Very Coarse Sand	2	5	1.166	0.721	42%	6%	42%	6%
	Coarse Sand	1	5	0.481	0.511	66%	33%	66%	33%
	Medium Sand	0.5	5	0.262	0.416	74%	50%	74%	50%
	Fine Sand	0.25	5	0.189	0.391	76%	54%	76%	54%

	Very Fine Sand	0.125	5	0.153	0.388	76%	54%	76%	55%
	Coarse Silt	0.0625	5	0.120	0.379	77%	56%	77%	56%
3	Granule Gravel	4	15	3.007	1.227	12%	0%	12%	0%
	Very Coarse Sand	2	15	1.166	0.844	51%	7%	51%	7%
	Coarse Sand	1	15	0.481	0.598	69%	33%	69%	33%
	Medium Sand	0.5	15	0.262	0.487	76%	49%	76%	49%
	Fine Sand	0.25	15	0.189	0.458	78%	53%	78%	53%
	Very Fine Sand	0.125	15	0.153	0.454	78%	54%	78%	54%
	Coarse Silt	0.0625	15	0.120	0.444	79%	55%	79%	55%
4	Granule Gravel	4	5	3.007	1.049	4%	0%	4%	0%
	Very Coarse Sand	2	5	1.166	0.721	36%	3%	36%	3%
	Coarse Sand	1	5	0.481	0.511	64%	18%	64%	18%
	Medium Sand	0.5	5	0.262	0.416	74%	38%	74%	38%
	Fine Sand	0.25	5	0.189	0.391	78%	44%	78%	44%
	Very Fine Sand	0.125	5	0.153	0.388	78%	44%	78%	45%
	Coarse Silt	0.0625	5	0.120	0.379	78%	47%	78%	47%
5	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%
	Very Coarse Sand	2	15	1.166	0.844	32%	1%	32%	1%
	Coarse Sand	1	15	0.481	0.598	82%	25%	82%	25%
	Medium Sand	0.5	15	0.262	0.487	95%	50%	95%	50%
	Fine Sand	0.25	15	0.189	0.458	97%	57%	97%	57%
	Very Fine Sand	0.125	15	0.153	0.454	97%	58%	97%	58%
	Coarse Silt	0.0625	15	0.120	0.444	98%	60%	98%	60%
6	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%
	Very Coarse Sand	2	15	1.166	0.844	37%	4%	37%	4%
	Coarse Sand	1	15	0.481	0.598	68%	36%	68%	36%
	Medium Sand	0.5	15	0.262	0.487	82%	52%	82%	52%
	Fine Sand	0.25	15	0.189	0.458	85%	57%	85%	57%

	Very Fine Sand	0.125	15	0.153	0.454	85%	57%	85%	57%
	Coarse Silt	0.0625	15	0.120	0.444	86%	58%	86%	58%
7	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%
	Very Coarse Sand	2	15	1.166	0.844	39%	1%	39%	1%
	Coarse Sand	1	15	0.481	0.598	84%	23%	84%	23%
	Medium Sand	0.5	15	0.262	0.487	97%	45%	97%	45%
	Fine Sand	0.25	15	0.189	0.458	98%	53%	99%	53%
	Very Fine Sand	0.125	15	0.153	0.454	99%	54%	99%	54%
	Coarse Silt	0.0625	15	0.120	0.444	99%	57%	99%	58%
8	Granule Gravel	4	5	3.007	1.049	0%	0%	0%	0%
	Very Coarse Sand	2	5	1.166	0.721	55%	7%	55%	7%
	Coarse Sand	1	5	0.481	0.511	86%	40%	86%	40%
	Medium Sand	0.5	5	0.262	0.416	96%	59%	96%	59%
	Fine Sand	0.25	5	0.189	0.391	97%	63%	97%	63%
	Very Fine Sand	0.125	5	0.153	0.388	98%	64%	98%	64%
	Coarse Silt	0.0625	5	0.120	0.379	98%	66%	98%	66%
9	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%
	Very Coarse Sand	2	15	1.166	0.844	23%	0%	23%	0%
	Coarse Sand	1	15	0.481	0.598	81%	19%	81%	19%
	Medium Sand	0.5	15	0.262	0.487	96%	44%	96%	44%
	Fine Sand	0.25	15	0.189	0.458	98%	51%	98%	51%
	Very Fine Sand	0.125	15	0.153	0.454	98%	52%	98%	52%
	Coarse Silt	0.0625	15	0.120	0.444	99%	54%	99%	54%
10	Granule Gravel	4	25	3.007	1.32	0%	0%	0%	0%
	Very Coarse Sand	2	25	1.166	0.908	7%	0%	7%	0%
	Coarse Sand	1	25	0.481	0.643	56%	12%	56%	12%
	Medium Sand	0.5	25	0.262	0.524	69%	29%	69%	29%
	Fine Sand	0.25	25	0.189	0.492	73%	36%	73%	36%

	Very Fine Sand	0.125	25	0.153	0.489	74%	37%	74%	37%
	Coarse Silt	0.0625	25	0.120	0.477	76%	39%	76%	39%
11	Granule Gravel	4	5	3.007	1.049	0%	0%	0%	0%
	Very Coarse Sand	2	5	1.166	0.721	29%	1%	29%	1%
	Coarse Sand	1	5	0.481	0.511	74%	30%	74%	30%
	Medium Sand	0.5	5	0.262	0.416	85%	50%	85%	50%
	Fine Sand	0.25	5	0.189	0.391	87%	54%	88%	54%
	Very Fine Sand	0.125	5	0.153	0.388	88%	55%	88%	55%
	Coarse Silt	0.0625	5	0.120	0.379	89%	57%	89%	57%
12	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%
	Very Coarse Sand	2	15	1.166	0.844	46%	10%	46%	10%
	Coarse Sand	1	15	0.481	0.598	68%	42%	68%	42%
	Medium Sand	0.5	15	0.262	0.487	75%	56%	75%	56%
	Fine Sand	0.25	15	0.189	0.458	77%	60%	77%	60%
	Very Fine Sand	0.125	15	0.153	0.454	78%	60%	78%	60%
	Coarse Silt	0.0625	15	0.120	0.444	79%	62%	79%	62%
13	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%
	Very Coarse Sand	2	15	1.166	0.844	24%	0%	24%	0%
	Coarse Sand	1	15	0.481	0.598	58%	21%	58%	21%
	Medium Sand	0.5	15	0.262	0.487	69%	40%	69%	40%
	Fine Sand	0.25	15	0.189	0.458	71%	45%	71%	45%
	Very Fine Sand	0.125	15	0.153	0.454	71%	46%	71%	46%
	Coarse Silt	0.0625	15	0.120	0.444	72%	48%	72%	48%
14	Granule Gravel	4	5	3.007	1.049	8%	0%	8%	0%
	Very Coarse Sand	2	5	1.166	0.721	53%	15%	53%	15%
	Coarse Sand	1	5	0.481	0.511	71%	49%	71%	49%
	Medium Sand	0.5	5	0.262	0.416	77%	62%	77%	62%
	Fine Sand	0.25	5	0.189	0.391	79%	65%	79%	65%

	Very Fine Sand	0.125	5	0.153	0.388	79%	66%	79%	66%
	Coarse Silt	0.0625	5	0.120	0.379	80%	66%	80%	66%
15	Granule Gravel	4	35	3.007	1.385	0%	0%	0%	0%
	Very Coarse Sand	2	35	1.166	0.952	8%	0%	8%	0%
	Coarse Sand	1	35	0.481	0.675	45%	9%	45%	9%
	Medium Sand	0.5	35	0.262	0.55	58%	23%	58%	23%
	Fine Sand	0.25	35	0.189	0.517	62%	28%	62%	28%
	Very Fine Sand	0.125	35	0.153	0.513	62%	30%	62%	30%
	Coarse Silt	0.0625	35	0.120	0.501	63%	32%	63%	32%
16	Granule Gravel	4	25	3.007	1.32	0%	0%	0%	0%
	Very Coarse Sand	2	25	1.166	0.908	2%	0%	2%	0%
	Coarse Sand	1	25	0.481	0.643	30%	1%	30%	1%
	Medium Sand	0.5	25	0.262	0.524	49%	9%	49%	9%
	Fine Sand	0.25	25	0.189	0.492	53%	12%	53%	12%
	Very Fine Sand	0.125	25	0.153	0.489	53%	12%	53%	12%
	Coarse Silt	0.0625	25	0.120	0.477	56%	14%	56%	14%
17	Granule Gravel	4	25	3.007	1.32	0%	0%	0%	0%
	Very Coarse Sand	2	25	1.166	0.908	17%	0%	17%	0%
	Coarse Sand	1	25	0.481	0.643	50%	6%	50%	6%
	Medium Sand	0.5	25	0.262	0.524	64%	18%	64%	18%
	Fine Sand	0.25	25	0.189	0.492	67%	23%	67%	23%
	Very Fine Sand	0.125	25	0.153	0.489	67%	23%	67%	24%
	Coarse Silt	0.0625	25	0.120	0.477	68%	26%	68%	26%
18	Granule Gravel	4	25	3.007	1.32	0%	0%	0%	0%
	Very Coarse Sand	2	25	1.166	0.908	22%	0%	22%	0%
	Coarse Sand	1	25	0.481	0.643	56%	10%	56%	10%
	Medium Sand	0.5	25	0.262	0.524	68%	27%	68%	27%
	Fine Sand	0.25	25	0.189	0.492	71%	31%	70%	31%

	Very Fine Sand	0.125	25	0.153	0.489	71%	32%	71%	32%
	Coarse Silt	0.0625	25	0.120	0.477	72%	34%	72%	34%
19	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%
	Very Coarse Sand	2	15	1.166	0.844	32%	1%	32%	1%
	Coarse Sand	1	15	0.481	0.598	62%	23%	62%	23%
	Medium Sand	0.5	15	0.262	0.487	71%	41%	71%	41%
	Fine Sand	0.25	15	0.189	0.458	73%	47%	73%	47%
	Very Fine Sand	0.125	15	0.153	0.454	73%	48%	73%	48%
	Coarse Silt	0.0625	15	0.120	0.444	74%	49%	74%	49%
20	Granule Gravel	4	25	3.007	1.32	0%	0%	0%	0%
	Very Coarse Sand	2	25	1.166	0.908	5%	0%	5%	0%
	Coarse Sand	1	25	0.481	0.643	40%	2%	40%	2%
	Medium Sand	0.5	25	0.262	0.524	56%	15%	56%	15%
	Fine Sand	0.25	25	0.189	0.492	60%	20%	60%	20%
	Very Fine Sand	0.125	25	0.153	0.489	60%	20%	60%	20%
	Coarse Silt	0.0625	25	0.120	0.477	61%	23%	61%	23%
21	Granule Gravel	4	15	3.007	1.227	1%	0%	1%	0%
	Very Coarse Sand	2	15	1.166	0.844	39%	3%	39%	3%
	Coarse Sand	1	15	0.481	0.598	67%	29%	67%	29%
	Medium Sand	0.5	15	0.262	0.487	76%	48%	76%	48%
	Fine Sand	0.25	15	0.189	0.458	78%	52%	78%	52%
	Very Fine Sand	0.125	15	0.153	0.454	78%	53%	78%	54%
	Coarse Silt	0.0625	15	0.120	0.444	79%	55%	79%	55%
22	Granule Gravel	4	5	3.007	1.049	0%	0%	0%	0%
	Very Coarse Sand	2	5	1.166	0.721	34%	1%	35%	1%
	Coarse Sand	1	5	0.481	0.511	67%	19%	67%	20%
	Medium Sand	0.5	5	0.262	0.416	79%	39%	79%	39%
	Fine Sand	0.25	5	0.189	0.391	82%	46%	82%	46%

	Very Fine Sand	0.125	5	0.153	0.388	82%	46%	83%	46%
	Coarse Silt	0.0625	5	0.120	0.379	83%	49%	83%	49%
23	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%
	Very Coarse Sand	2	15	1.166	0.844	6%	0%	6%	0%
	Coarse Sand	1	15	0.481	0.598	41%	4%	41%	4%
	Medium Sand	0.5	15	0.262	0.487	56%	14%	56%	14%
	Fine Sand	0.25	15	0.189	0.458	60%	17%	60%	17%
	Very Fine Sand	0.125	15	0.153	0.454	60%	18%	61%	18%
	Coarse Silt	0.0625	15	0.120	0.444	62%	20%	62%	20%
24	Granule Gravel	4	25	3.007	1.32	0%	0%	0%	0%
	Very Coarse Sand	2	25	1.166	0.908	2%	0%	2%	0%
	Coarse Sand	1	25	0.481	0.643	27%	1%	27%	1%
	Medium Sand	0.5	25	0.262	0.524	46%	6%	46%	6%
	Fine Sand	0.25	25	0.189	0.492	51%	10%	51%	10%
	Very Fine Sand	0.125	25	0.153	0.489	52%	10%	52%	10%
	Coarse Silt	0.0625	25	0.120	0.477	54%	12%	54%	12%
25	Granule Gravel	4	25	3.007	1.32	0%	0%	0%	0%
	Very Coarse Sand	2	25	1.166	0.908	7%	0%	7%	0%
	Coarse Sand	1	25	0.481	0.643	41%	4%	41%	5%
	Medium Sand	0.5	25	0.262	0.524	57%	14%	57%	15%
	Fine Sand	0.25	25	0.189	0.492	60%	18%	60%	18%
	Very Fine Sand	0.125	25	0.153	0.489	61%	19%	61%	19%
	Coarse Silt	0.0625	25	0.120	0.477	61%	20%	62%	20%
26	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%
	Very Coarse Sand	2	15	1.166	0.844	7%	0%	7%	0%
	Coarse Sand	1	15	0.481	0.598	42%	4%	42%	4%
	Medium Sand	0.5	15	0.262	0.487	57%	15%	57%	15%
	Fine Sand	0.25	15	0.189	0.458	60%	19%	60%	19%

	Very Fine Sand	0.125	15	0.153	0.454	60%	20%	61%	19%
	Coarse Silt	0.0625	15	0.120	0.444	62%	21%	62%	21%
27	Granule Gravel	4	25	3.007	1.32	2%	0%	2%	0%
	Very Coarse Sand	2	25	1.166	0.908	42%	2%	42%	2%
	Coarse Sand	1	25	0.481	0.643	65%	19%	65%	19%
	Medium Sand	0.5	25	0.262	0.524	74%	39%	74%	39%
	Fine Sand	0.25	25	0.189	0.492	77%	44%	77%	44%
	Very Fine Sand	0.125	25	0.153	0.489	77%	45%	77%	45%
	Coarse Silt	0.0625	25	0.120	0.477	77%	46%	77%	46%

~~Point~~	~~Size Class~~	~~Grain Size (upper boundary) (mm)~~	~~Approximate Water Depth (m)~~	~~Threshold of Bed Shear Stress (N/m^2)~~	~~Corresponding Critical Depth-averaged Current Speeds (m/s)~~	~~Baseline Sediment Mobility[9] (Spring)~~	~~Baseline Sediment Mobility (Neap)~~	~~Scheme Sediment Mobility (Spring)~~	~~Scheme Sediment Mobility (Neap)~~
~~1~~	~~Granule Gravel~~	~~4~~	~~25~~	~~3.007~~	~~1.32~~	~~6%~~	~~0%~~	~~6%~~	~~0%~~
	~~Very Coarse Sand~~	~~2~~	~~25~~	~~1.166~~	~~0.908~~	~~32%~~	~~2%~~	~~32%~~	~~2%~~
	~~Coarse Sand~~	~~1~~	~~25~~	~~0.481~~	~~0.643~~	~~56%~~	~~13%~~	~~56%~~	~~13%~~
	~~Medium Sand~~	~~0.5~~	~~25~~	~~0.262~~	~~0.524~~	~~65%~~	~~30%~~	~~64%~~	~~30%~~
	~~Fine Sand~~	~~0.25~~	~~25~~	~~0.189~~	~~0.492~~	~~66%~~	~~35%~~	~~66%~~	~~35%~~
	~~Very Fine Sand~~	~~0.125~~	~~25~~	~~0.153~~	~~0.489~~	~~66%~~	~~36%~~	~~66%~~	~~36%~~
	~~Coarse Silt~~	~~0.0625~~	~~25~~	~~0.120~~	~~0.477~~	~~67%~~	~~38%~~	~~67%~~	~~38%~~
~~2~~	~~Granule Gravel~~	~~4~~	~~5~~	~~3.007~~	~~1.049~~	~~9%~~	~~0%~~	~~9%~~	~~0%~~
	~~Very Coarse Sand~~	~~2~~	~~5~~	~~1.166~~	~~0.721~~	~~42%~~	~~6%~~	~~42%~~	~~6%~~
	~~Coarse Sand~~	~~1~~	~~5~~	~~0.481~~	~~0.511~~	~~66%~~	~~33%~~	~~66%~~	~~33%~~
	~~Medium Sand~~	~~0.5~~	~~5~~	~~0.262~~	~~0.416~~	~~74%~~	~~50%~~	~~74%~~	~~50%~~

[9] ~~Percentage of time that sediment is mobile. %~~

Point	Size Class	Grain Size (upper boundary) (mm)	Approximate Water Depth (m)	Threshold of Bed Shear Stress (N/m²)	Corresponding Critical Depth-averaged Current Speeds (m/s)	Baseline Sediment Mobility[9] (Spring)	Baseline Sediment Mobility (Neap)	Scheme Sediment Mobility (Spring)	Scheme Sediment Mobility (Neap)
	Fine Sand	0.25	5	0.189	0.391	76%	54%	76%	54%
	Very Fine Sand	0.125	5	0.153	0.388	76%	54%	76%	54%%
	Coarse Silt	0.0625	5	0.120	0.379	77%	56%	77%	56%
3	Granule Gravel	4	15	3.007	1.227	12%	0%	12%	0%
	Very Coarse Sand	2	15	1.166	0.844	51%	7%	51%	7%
	Coarse Sand	1	15	0.481	0.598	69%	33%	69%	33%
	Medium Sand	0.5	15	0.262	0.487	76%	49%	76%	49%
	Fine Sand	0.25	15	0.189	0.458	78%	53%	78%	53%
	Very Fine Sand	0.125	15	0.153	0.454	78%	54%	78%	54%
	Coarse Silt	0.0625	15	0.120	0.444	79%	55%	79%	55%
4	Granule Gravel	4	5	3.007	1.049	4%	0%	4%	0%
	Very Coarse Sand	2	5	1.166	0.721	36%	3%	36%	3%
	Coarse Sand	1	5	0.481	0.511	64%	18%	63%	18%
	Medium Sand	0.5	5	0.262	0.416	74%	38%	74%	38%
	Fine Sand	0.25	5	0.189	0.391	78%	44%	78%	44%
	Very Fine Sand	0.125	5	0.153	0.388	78%	44%	78%	45%
	Coarse Silt	0.0625	5	0.120	0.379	78%	47%	78%	47%
5	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%
	Very Coarse Sand	2	15	1.166	0.844	32%	1%	32%	1%
	Coarse Sand	1	15	0.481	0.598	82%	25%	82%	25%
	Medium Sand	0.5	15	0.262	0.487	95%	50%	95%	50%
	Fine Sand	0.25	15	0.189	0.458	97%	57%	97%	57%
	Very Fine Sand	0.125	15	0.153	0.454	97%	58%	97%	58%
	Coarse Silt	0.0625	15	0.120	0.444	98%	60%	98%	60%

Point	Size Class	Grain Size (upper boundary) (mm)	Approximate Water Depth (m)	Threshold of Bed Shear Stress (N/m^2)	Corresponding Critical Depth-averaged Current Speeds (m/s)	Baseline Sediment Mobility[9] (Spring)	Baseline Sediment Mobility (Neap)	Scheme Sediment Mobility (Spring)	Scheme Sediment Mobility (Neap)
6	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%
	Very Coarse Sand	2	15	1.166	0.844	37%	4%	37%	4%
	Coarse Sand	1	15	0.481	0.598	68%	36%	68%	36%
	Medium Sand	0.5	15	0.262	0.487	82%	52%	82%	52%
	Fine Sand	0.25	15	0.189	0.458	85%	57%	85%	57%
	Very Fine Sand	0.125	15	0.153	0.454	85%	57%	85%	57%
	Coarse Silt	0.0625	15	0.120	0.444	86%	58%	86%	58%
7	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%
	Very Coarse Sand	2	15	1.166	0.844	39%	1%	39%	1%
	Coarse Sand	1	15	0.481	0.598	84%	23%	84%	23%
	Medium Sand	0.5	15	0.262	0.487	97%	45%	97%	45%
	Fine Sand	0.25	15	0.189	0.458	98%	53%	99%	53%
	Very Fine Sand	0.125	15	0.153	0.454	99%	54%	99%	54%
	Coarse Silt	0.0625	15	0.120	0.444	99%	57%	99%	58%
8	Granule Gravel	4	5	3.007	1.049	0%	0%	0%	0%
	Very Coarse Sand	2	5	1.166	0.721	55%	7%	55%	7%
	Coarse Sand	1	5	0.481	0.511	86%	40%	86%	40%
	Medium Sand	0.5	5	0.262	0.416	96%	59%	96%	59%
	Fine Sand	0.25	5	0.189	0.391	97%	63%	97%	63%
	Very Fine Sand	0.125	5	0.153	0.388	98%	64%	98%	64%
	Coarse Silt	0.0625	5	0.120	0.379	98%	66%	98%	66%
9	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%
	Very Coarse Sand	2	15	1.166	0.844	23%	0%	23%	0%
	Coarse Sand	1	15	0.481	0.598	81%	19%	81%	19%

Point	Size Class	Grain Size (upper boundary) (mm)	Approximate Water Depth (m)	Threshold of Bed Shear Stress (N/m^2)	Corresponding Critical Depth-averaged Current Speeds (m/s)	Baseline Sediment Mobility[9] (Spring)	Baseline Sediment Mobility (Neap)	Scheme Sediment Mobility (Spring)	Scheme Sediment Mobility (Neap)
	Medium Sand	0.5	15	0.262	0.487	96%	44%	96%	44%
	Fine Sand	0.25	15	0.189	0.458	98%	51%	98%	51%
	Very Fine Sand	0.125	15	0.153	0.454	98%	52%	98%	52%
	Coarse Silt	0.0625	15	0.120	0.444	99%	54%	99%	54%
10	Granule Gravel	4	25	3.007	1.32	0%	0%	0%	0%
	Very Coarse Sand	2	25	1.166	0.908	7%	0%	7%	0%
	Coarse Sand	1	25	0.481	0.643	56%	12%	56%	12%
	Medium Sand	0.5	25	0.262	0.524	69%	29%	69%	29%
	Fine Sand	0.25	25	0.189	0.492	73%	36%	73%	36%
	Very Fine Sand	0.125	25	0.153	0.489	74%	37%	74%	37%
	Coarse Silt	0.0625	25	0.120	0.477	76%	39%	76%	39%
11	Granule Gravel	4	5	3.007	1.049	0%	0%	0%	0%
	Very Coarse Sand	2	5	1.166	0.721	29%	1%	29%	1%
	Coarse Sand	1	5	0.481	0.511	74%	30%	74%	30%
	Medium Sand	0.5	5	0.262	0.416	85%	50%	85%	50%
	Fine Sand	0.25	5	0.189	0.391	87%	54%	88%	54%
	Very Fine Sand	0.125	5	0.153	0.388	88%	55%	88%	55%
	Coarse Silt	0.0625	5	0.120	0.379	89%	57%	89%	57%
12	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%
	Very Coarse Sand	2	15	1.166	0.844	46%	10%	46%	10%
	Coarse Sand	1	15	0.481	0.598	68%	42%	68%	42%
	Medium Sand	0.5	15	0.262	0.487	75%	56%	75%	56%
	Fine Sand	0.25	15	0.189	0.458	77%	60%	77%	60%
	Very Fine Sand	0.125	15	0.153	0.454	78%	60%	78%	60%

Point	Size Class	Grain Size (upper boundary) (mm)	Approximate Water Depth (m)	Threshold of Bed Shear Stress (N/m^2)	Corresponding Critical Depth-averaged Current Speeds (m/s)	Baseline Sediment Mobility[9] (Spring)	Baseline Sediment Mobility (Neap)	Scheme Sediment Mobility (Spring)	Scheme Sediment Mobility (Neap)
	Coarse Silt	0.0625	15	0.120	0.444	79%	62%	79%	62%
13	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%
	Very Coarse Sand	2	15	1.166	0.844	24%	0%	24%	0%
	Coarse Sand	1	15	0.481	0.598	58%	21%	58%	21%
	Medium Sand	0.5	15	0.262	0.487	69%	40%	69%	40%
	Fine Sand	0.25	15	0.189	0.458	71%	45%	71%	45%
	Very Fine Sand	0.125	15	0.153	0.454	71%	46%	71%	46%
	Coarse Silt	0.0625	15	0.120	0.444	72%	48%	72%	48%
14	Granule Gravel	4	5	3.007	1.049	8%	0%	8%	0%
	Very Coarse Sand	2	5	1.166	0.721	53%	15%	53%	15%
	Coarse Sand	1	5	0.481	0.511	71%	49%	71%	49%
	Medium Sand	0.5	5	0.262	0.416	77%	62%	77%	62%
	Fine Sand	0.25	5	0.189	0.391	79%	65%	79%	65%
	Very Fine Sand	0.125	5	0.153	0.388	79%	66%	79%	66%
	Coarse Silt	0.0625	5	0.120	0.379	80%	66%	80%	66%
15	Granule Gravel	4	35	3.007	1.385	0%	0%	0%	0%
	Very Coarse Sand	2	35	1.166	0.952	8%	0%	8%	0%
	Coarse Sand	1	35	0.481	0.675	45%	9%	45%	9%
	Medium Sand	0.5	35	0.262	0.55	58%	23%	58%	23%
	Fine Sand	0.25	35	0.189	0.517	62%	28%	62%	28%
	Very Fine Sand	0.125	35	0.153	0.513	62%	30%	62%	30%
	Coarse Silt	0.0625	35	0.120	0.501	63%	32%	63%	32%
16	Granule Gravel	4	25	3.007	1.32	0%	0%	0%	0%
	Very Coarse Sand	2	25	1.166	0.908	2%	0%	2%	0%

~~Point~~	~~Size Class~~	~~Grain Size (upper boundary) (mm)~~	~~Approximate Water Depth (m)~~	~~Threshold of Bed Shear Stress (N/m²)~~	~~Corresponding Critical Depth-averaged Current Speeds (m/s)~~	~~Baseline Sediment Mobility[9] (Spring)~~	~~Baseline Sediment Mobility (Neap)~~	~~Scheme Sediment Mobility (Spring)~~	~~Scheme Sediment Mobility (Neap)~~
	~~Coarse Sand~~	~~1~~	~~25~~	~~0.481~~	~~0.643~~	~~30%~~	~~1%~~	~~30%~~	~~1%~~
	~~Medium Sand~~	~~0.5~~	~~25~~	~~0.262~~	~~0.524~~	~~49%~~	~~9%~~	~~49%~~	~~9%~~
	~~Fine Sand~~	~~0.25~~	~~25~~	~~0.189~~	~~0.492~~	~~53%~~	~~12%~~	~~53%~~	~~12%~~
	~~Very Fine Sand~~	~~0.125~~	~~25~~	~~0.153~~	~~0.489~~	~~53%~~	~~12%~~	~~53%~~	~~13%~~
	~~Coarse Silt~~	~~0.0625~~	~~25~~	~~0.120~~	~~0.477~~	~~56%~~	~~14%~~	~~56%~~	~~14%~~
~~17~~	~~Granule Gravel~~	~~4~~	~~25~~	~~3.007~~	~~1.32~~	~~0%~~	~~0%~~	~~0%~~	~~0%~~
	~~Very Coarse Sand~~	~~2~~	~~25~~	~~1.166~~	~~0.908~~	~~17%~~	~~0%~~	~~17%~~	~~0%~~
	~~Coarse Sand~~	~~1~~	~~25~~	~~0.481~~	~~0.643~~	~~50%~~	~~6%~~	~~50%~~	~~6%~~
	~~Medium Sand~~	~~0.5~~	~~25~~	~~0.262~~	~~0.524~~	~~64%~~	~~18%~~	~~64%~~	~~18%~~
	~~Fine Sand~~	~~0.25~~	~~25~~	~~0.189~~	~~0.492~~	~~67%~~	~~23%~~	~~67%~~	~~23%~~
	~~Very Fine Sand~~	~~0.125~~	~~25~~	~~0.153~~	~~0.489~~	~~67%~~	~~23%~~	~~67%~~	~~23%~~
	~~Coarse Silt~~	~~0.0625~~	~~25~~	~~0.120~~	~~0.477~~	~~68%~~	~~26%~~	~~68%~~	~~26%~~
~~18~~	~~Granule Gravel~~	~~4~~	~~25~~	~~3.007~~	~~1.32~~	~~0%~~	~~0%~~	~~0%~~	~~0%~~
	~~Very Coarse Sand~~	~~2~~	~~25~~	~~1.166~~	~~0.908~~	~~22%~~	~~0%~~	~~22%~~	~~0%~~
	~~Coarse Sand~~	~~1~~	~~25~~	~~0.481~~	~~0.643~~	~~56%~~	~~10%~~	~~56%~~	~~10%~~
	~~Medium Sand~~	~~0.5~~	~~25~~	~~0.262~~	~~0.524~~	~~68%~~	~~27%~~	~~68%~~	~~27%~~
	~~Fine Sand~~	~~0.25~~	~~25~~	~~0.189~~	~~0.492~~	~~71%~~	~~31%~~	~~70%~~	~~31%~~
	~~Very Fine Sand~~	~~0.125~~	~~25~~	~~0.153~~	~~0.489~~	~~71%~~	~~32%~~	~~71%~~	~~32%~~
	~~Coarse Silt~~	~~0.0625~~	~~25~~	~~0.120~~	~~0.477~~	~~72%~~	~~34%~~	~~72%~~	~~34%~~
~~19~~	~~Granule Gravel~~	~~4~~	~~15~~	~~3.007~~	~~1.227~~	~~0%~~	~~0%~~	~~0%~~	~~0%~~
	~~Very Coarse Sand~~	~~2~~	~~15~~	~~1.166~~	~~0.844~~	~~32%~~	~~1%~~	~~32%~~	~~1%~~
	~~Coarse Sand~~	~~1~~	~~15~~	~~0.481~~	~~0.598~~	~~62%~~	~~23%~~	~~62%~~	~~23%~~
	~~Medium Sand~~	~~0.5~~	~~15~~	~~0.262~~	~~0.487~~	~~71%~~	~~41%~~	~~71%~~	~~41%~~
	~~Fine Sand~~	~~0.25~~	~~15~~	~~0.189~~	~~0.458~~	~~73%~~	~~47%~~	~~73%~~	~~47%~~

Point	Size Class	Grain Size (upper boundary) (mm)	Approximate Water Depth (m)	Threshold of Bed Shear Stress (N/m^2)	Corresponding Critical Depth-averaged Current Speeds (m/s)	Baseline Sediment Mobility[9] (Spring)	Baseline Sediment Mobility (Neap)	Scheme Sediment Mobility (Spring)	Scheme Sediment Mobility (Neap)
	Very Fine Sand	0.125	15	0.153	0.454	73%	48%	73%	47%
	Coarse Silt	0.0625	15	0.120	0.444	74%	49%	74%	49%
20	Granule Gravel	4	25	3.007	1.32	0%	0%	0%	0%
	Very Coarse Sand	2	25	1.166	0.908	5%	0%	6%	0%
	Coarse Sand	1	25	0.481	0.643	40%	2%	40%	2%
	Medium Sand	0.5	25	0.262	0.524	56%	15%	56%	15%
	Fine Sand	0.25	25	0.189	0.492	60%	20%	60%	20%
	Very Fine Sand	0.125	25	0.153	0.489	60%	20%	60%	21%
	Coarse Silt	0.0625	25	0.120	0.477	61%	23%	61%	23%
21	Granule Gravel	4	15	3.007	1.227	1%	0%	1%	0%
	Very Coarse Sand	2	15	1.166	0.844	39%	3%	40%	3%
	Coarse Sand	1	15	0.481	0.598	67%	29%	67%	30%
	Medium Sand	0.5	15	0.262	0.487	76%	48%	76%	48%
	Fine Sand	0.25	15	0.189	0.458	78%	52%	78%	53%
	Very Fine Sand	0.125	15	0.153	0.454	78%	53%	78%	54%
	Coarse Silt	0.0625	15	0.120	0.444	79%	55%	79%	55%
22	Granule Gravel	4	5	3.007	1.049	0%	0%	0%	0%
	Very Coarse Sand	2	5	1.166	0.721	34%	1%	33%	1%
	Coarse Sand	1	5	0.481	0.511	67%	19%	67%	19%
	Medium Sand	0.5	5	0.262	0.416	79%	39%	79%	39%
	Fine Sand	0.25	5	0.189	0.391	82%	46%	82%	45%
	Very Fine Sand	0.125	5	0.153	0.388	82%	46%	82%	46%
	Coarse Silt	0.0625	5	0.120	0.379	83%	49%	83%	49%
23	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%

Point	Size Class	Grain Size (upper boundary) (mm)	Approximate Water Depth (m)	Threshold of Bed Shear Stress (N/m²)	Corresponding Critical Depth-averaged Current Speeds (m/s)	Baseline Sediment Mobility[9] (Spring)	Baseline Sediment Mobility (Neap)	Scheme Sediment Mobility (Spring)	Scheme Sediment Mobility (Neap)
	Very Coarse Sand	2	15	1.166	0.844	24%	0%	23%	0%
	Coarse Sand	1	15	0.481	0.598	55%	12%	54%	11%
	Medium Sand	0.5	15	0.262	0.487	67%	29%	66%	28%
	Fine Sand	0.25	15	0.189	0.458	70%	33%	70%	33%
	Very Fine Sand	0.125	15	0.153	0.454	70%	34%	70%	34%
	Coarse Silt	0.0625	15	0.120	0.444	71%	36%	70%	36%
24	Granule Gravel	4	25	3.007	1.32	0%	0%	0%	0%
	Very Coarse Sand	2	25	1.166	0.908	7%	0%	7%	0%
	Coarse Sand	1	25	0.481	0.643	45%	6%	45%	6%
	Medium Sand	0.5	25	0.262	0.524	58%	19%	59%	19%
	Fine Sand	0.25	25	0.189	0.492	62%	25%	62%	25%
	Very Fine Sand	0.125	25	0.153	0.489	63%	25%	63%	25%
	Coarse Silt	0.0625	25	0.120	0.477	64%	27%	64%	27%
25	Granule Gravel	4	25	3.007	1.32	0%	0%	0%	0%
	Very Coarse Sand	2	25	1.166	0.908	15%	0%	16%	0%
	Coarse Sand	1	25	0.481	0.643	53%	12%	53%	13%
	Medium Sand	0.5	25	0.262	0.524	65%	28%	65%	28%
	Fine Sand	0.25	25	0.189	0.492	68%	34%	68%	34%
	Very Fine Sand	0.125	25	0.153	0.489	68%	34%	68%	34%
	Coarse Silt	0.0625	25	0.120	0.477	69%	36%	69%	36%
26	Granule Gravel	4	15	3.007	1.227	0%	0%	0%	0%
	Very Coarse Sand	2	15	1.166	0.844	21%	0%	21%	0%
	Coarse Sand	1	15	0.481	0.598	54%	12%	54%	12%
	Medium Sand	0.5	15	0.262	0.487	67%	29%	67%	29%

Point	Size Class	Grain Size (upper boundary) (mm)	Approximate Water Depth (m)	Threshold of Bed Shear Stress (N/m^2)	Corresponding Critical Depth-averaged Current Speeds (m/s)	Baseline Sediment Mobility[9] (Spring)	Baseline Sediment Mobility (Neap)	Scheme Sediment Mobility (Spring)	Scheme Sediment Mobility (Neap)
	Fine Sand	0.25	15	0.189	0.458	70%	34%	70%	34%
	Very Fine Sand	0.125	15	0.153	0.454	70%	35%	71%	35%
	Coarse Silt	0.0625	15	0.120	0.444	72%	37%	72%	37%
27	Granule Gravel	4	25	3.007	1.32	2%	0%	2%	0%
	Very Coarse Sand	2	25	1.166	0.908	42%	2%	42%	2%
	Coarse Sand	1	25	0.481	0.643	65%	19%	65%	19%
	Medium Sand	0.5	25	0.262	0.524	74%	39%	74%	39%
	Fine Sand	0.25	25	0.189	0.492	77%	44%	77%	44%
	Very Fine Sand	0.125	25	0.153	0.489	77%	45%	77%	45%
	Coarse Silt	0.0625	25	0.120	0.477	77%	46%	77%	46%