Bowdun Offshore Wind Farm, Offshore EIA Report

Volume 2, Chapter 7: Physical Processes

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Glossary

Defined term	Definition
Additional Mitigation	Also referred to as secondary mitigation which is defined by The Institute of Sustainability and Environmental Professionals (ISEP) (formerly Institute of Environmental Management and Assessment (IEMA)) as: Actions that will require further activity in order to achieve the anticipated outcome. These may be imposed as part of the planning consent, or through inclusion in the Environmental Impact Assessment (EIA) Report (sic).
Applicant (the)	Bowdun Offshore Wind Farm Limited (BOWFL).
Array Area	The Array Area is the area in which the Offshore Generation Assets will be located.
Benthic	Living on or in the seabed.
Crown Estate Scotland (CES)	Public corporation accountable to Scottish Government, responsible for the management of land and property, including marine assets in Scotland owned by the monarch.
Embedded Mitigation	Measures that are adopted as part of the Proposed Development and therefore assessed within the Environmental Impact Assessment (EIA). The proposed approach for the EIA for the Proposed Development is that Embedded Mitigation includes both primary mitigation and tertiary mitigation. These are defined by the ISEP as follows: Primary: Modifications to the location or design of the development made during the pre-application phase that are an inherent part of the project, and do not require additional action to be taken. Tertiary: Actions that would occur with or without input from the EIA feeding into the design process. These include actions that will be undertaken to meet other existing legislative requirements, or actions that are considered to be standard practices used to manage commonly occurring environmental effects.
Environmental Impact Assessment (EIA)	Process for the assessment of likely significant environmental effects of a project on the physical, biological and human environment during construction, Operation and Maintenance (O&M) and decommissioning.
Environmental Impact Assessment Regulations (EIA Regulations)	Terminology used in this Offshore EIA Report to refer to three sets of regulations: • The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017; • The Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017; and • The Marine Works (Environmental Impact Assessment) Regulations 2007.
Export Cable Corridor	The area seaward of MHWS which connects the Array Area with the Landfall within which the Offshore Export Cables will be installed.
Inter-Array Cables (IAC)	Cables which link the Wind Turbines to each other and with the Offshore Substation Platforms (OSPs).
Intertidal Area	The area between MHWS and Mean Low Water Springs (MLWS).

Defined term	Definition
Landfall	The area in which the Offshore Export Cables make landfall and is also the transitional area between the Offshore Transmission Assets and the Onshore Transmission Assets. Located in the Intertidal Area at Benholm beach.
Marine Directorate (MD)	The Marine Directorate of the Scottish Government, formerly known as Marine Scotland. The planning and licensing authority for Scotland's seas and custodian of Scotland's National Marine Plan (NMP). The Marine Directorate - Licensing and Operations Team (MD-LOT) are specifically responsible for managing Section 36 Consent and Marine Licence Applications seaward of MHWS.
Marine Directorate – Science, Evidence, Data and Digital (MD-SEDD)	The scientific division of the MD, which provides expert scientific, economic and technical advice and services on issues relating to marine fisheries, aquaculture, marine renewable energy, and the aquatic environment and its flora and fauna.
Marine Protected Areas (MPAs)	MPAs are designated under the Marine (Scotland) Act 2010 and the Marine and Coastal Access Act (MCAA) 2009. The MPA network protects nationally and internationally important marine wildlife, habitats, geology, and underwater landforms. Scotland's MPAs are significantly important for European, North-East Atlantic, and global MPA networks.
Maximum Design Scenario (MDS)	The scenario within the design envelope likely to result in the greatest impact on a particular topic receptor, and therefore the one that should be assessed for that topic receptor.
Mean High Water Springs (MHWS)	The average tidal height throughout the year of two successive high waters during those periods of 24 hours when the range of the tide is at its greatest.
Mean Low Water Springs (MLWS)	The average tidal height throughout the year of two successive low waters during those periods of 24 hours when the range of the tide is at its greatest.
Mitigation	Measures to avoid, prevent, reduce or control effects on the environment. See also definitions for Embedded Mitigation and Additional Mitigation.
Offshore Substation Platform(s) (OSPs)	OSPs comprise the support structure, topside and electrical components used for collecting and/or converting electricity generated by the Wind Turbines for transmission by the Offshore Export Cables.
Plan Option Area (POA)	A location identified in the Sectoral Marine Plan (SMP) as a preferred area for commercial scale offshore wind development.
Project (the)	An overarching term for the Bowdun Offshore Wind Farm (Bowdun OWF) comprising the offshore and onshore infrastructure required to generate and transmit electricity from the Array Area to the onshore Grid Connection Point (GCP). The Project includes the Offshore Generation Assets, the Offshore Transmission Assets and the Onshore Transmission Assets.
Proposed Development	Term used to define the Offshore Infrastructure associated with the Project seaward of MHWS for which consent is being sought. Further details of the parameters are included in Volume 1, Chapter 3: Project Description.
Special Areas of Conservation (SACs)	SACs are areas designated for the conservation of certain plant and animal species listed in the Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora.

Defined term	Definition
Special Protection Areas (SPAs)	SPAs are sites that are designated to protect rare or vulnerable birds (as listed on Annex I of the Directive 2009/147/EC on the conservation of wild birds), as well as regularly occurring migratory species.
Spring Tidal Excursion	The distance suspended sediment is transported prior to being carried back on the returning tide.
Study Area	For each environmental topic, the baseline environment will be characterised, and the potential environmental impacts will be described within a topic-specific study area. Specific study areas are defined for each topic and are based on the maximum spatial extent across which potential impacts of the Project may be experienced by the relevant receptors (i.e. Zone of Influence).
Thistle Wind Partners Limited (TWP)	Company established for the development of the Project.
Tidal Ellipse	The illustration of the variance of tidal currents in horizontal space.
Wind Turbines	Structures comprising of a tubular tower, rotor blades, and a nacelle which houses the Wind Turbine generator.

Acronyms

Acronym	Definition
ABPmer	ABP Marine Environmental Research Limited
AODA	Anglian Offshore Dredging Association
BOWFL	Bowdun Offshore Wind Farm Limited
BERR	Department for Business, Enterprise and Regulatory Reform
BGS	British Geological Survey
BODC	British Oceanographic Data Centre
BSI	British Standards Institution
CBRA	Cable Burial Risk Assessment
CEA	Cumulative Effects Assessment
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CIRIA	Construction Industry Research and Information Association
COWRIE	Collaborative Offshore Wind Research into the Environment
CSIP	Cable Specification and Installation Plan
EIA	Environmental Impact Assessment
EMODnet	European Marine Observation and Data Network
et seq.	and the following [Latin: et sequens]
GEN	General Policy
GIS	Geographical Information System
HDD	Horizontal Directional Drilling
HRA	Habitats Regulations Appraisal
HVDC	High Voltage Direct Current
IAC	Inter-Array Cable
IMarEST	Institute of Marine Engineering, Science and Technology
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide
LNCS	Local Nature Conservation Site
MD	Marine Directorate
MD-LOT	Marine Directorate - Licensing Operations Team
MDS	Maximum Design Scenario
MD-SEDD	Marine Directorate – Science Evidence Data and Digital
MFE	Mass Flow Excavator
MHWS	Mean High Water Spring
MIKE	Suite of Tools for Modelling Water Environment (DHI Software)
MLWS	Mean Low Water Spring
MMO	Marine Management Organisation
MPA	Marine Protected Area
N/A	Not Applicable

Acronym	Definition
NTSLF	National Tide and Sea Level Facility
O&M	Operations and Maintenance
OSP	Offshore Substation Platform
OWF	Offshore Wind Farm
PDE	Project Design Envelope
PEA	Potential Energy Anomaly
RGI	Renewables Grid Initiative
RIAA	Report to Inform Appropriate Assessment
RPS	RPS Group
SAC	Special Area of Conservation
SCO	Scottish Coastal Observatory
ScotMER	Scottish Marine Energy Research
SEA	Strategic Environmental Assessment
SEPA	Scottish Environment Protection Agency
SSC	Suspended Sediment Concentration
SSSI	Site of Special Scientific Interest
SSW-RS	Scottish Shelf Waters Reanalysis Service
TCE	The Crown Estate
TKE	Turbulent Kinetic Energy
TSHD	Trail Suction Hopper Dredger
TWP	Thistle Wind Partners Limited
UK	United Kingdom
UKCP	United Kingdom Climate Projections
UKCP18	United Kingdom Climate Projections 2018
UKHO	United Kingdom Hydrographic Office
UTM	Universal Transverse Mercator
WaveNet	Strategic Wave Monitoring Network for the United Kingdom
ZoI	Zone of Influence

Table of Units

Units	Definition
GW	GigaWatt
J/m³	Joules per cubic metre
kg/m³	Kilograms per metre cubed
kg/s	Kilograms per second
km	Kilometre
km²	Square kilometre
kV	Kilovolt
m	Metre
Mm	Millimetre
m²	Square Metre
m³	Cubic Metre
mg/l	Milligram per litre
mLAT	Vertical level in metres relative to Lowest Astronomical Tide
MW	Megawatt
m/s	Metres per second
nm	Nautical mile
°	Degree
%	Percent
Hs	Significant Wave Height
s	Second

7 Physical Processes

7.1 Introduction

7.1.1 This chapter of the Offshore Environmental Impact Assessment (EIA) Report, prepared by ABP Marine Environmental Research Limited (ABPmer), presents the assessment of the likely significant environmental effects on physical processes, that may potentially occur as a result of the Proposed Development during the construction, Operation and Maintenance (O&M) and decommissioning phases.

7.1.2 The assessment presented is informed by the following technical appendices:

- Volume 3, Technical Appendix 7.1: Physical Processes Baseline Environment;
- Volume 3, Technical Appendix 7.2: Physical Processes Model Design and Validation;
- Volume 3, Technical Appendix 7.3: Physical Processes Technical Assessment; and
- Volume 3, Technical Appendix 7.4: Assessment of Potential Changes to Stratification and Frontal Systems.

7.2 Physical Processes Study Area

7.2.1 The Physical Processes Study Area is located off the east Aberdeenshire coast (Figure 7.1). It reflects the maximum spatial extent (up to 65 km from the Proposed Development) across which potential impacts of the Proposed Development may be experienced by the relevant receptors (i.e. the Zone of Influence (ZoI)). It has been defined on the basis of:

- the distance away from the Proposed Development which suspended sediment plumes may be advected (and interact with potentially sensitive receptors). This has been defined by a Spring Tidal Excursion buffer around the Array Area and Export Cable Corridor;
- the distance up/down drift from the Landfall, that littoral processes could theoretically be impacted by Offshore Infrastructure associated with the Proposed Development, has been defined through consideration of coastal sub-cell information set out in Ramsay and Brampton (2000); and
- the distance from the Array Area that wave blockage impacts could theoretically be detected has been informed by expert judgement, drawing upon (amongst other things), the evidence base from other projects (e.g. ABPmer, 2021) and consideration of the prevailing wave directions.

7.2.2 The Physical Processes Study Area overlaps with a number of nationally and internationally designated nature conservation sites, some of which are designated on the basis of the geological and geomorphological features contained within them. Their locations are shown in Figure 7.1.

7.2.3 The Physical Processes Study Area was presented to and agreed with Marine Directorate and NatureScot during Scoping and following consultation on the Physical Processes Method Statement (Marine Directorate, 2024a; TWP, 2024a).

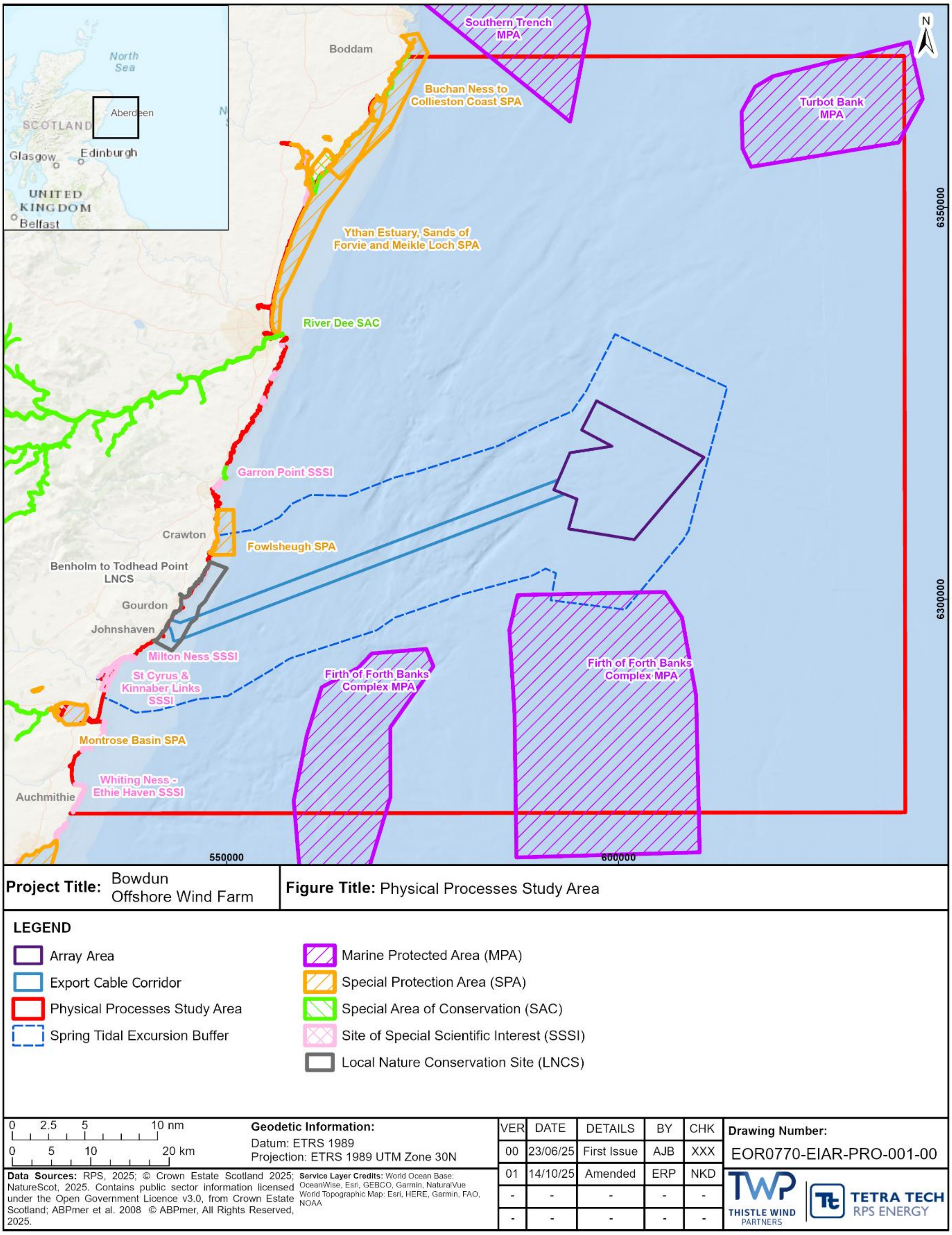

Figure 7.1: Physical Processes Study Area

7.3 Legislative and Policy Context

7.3.1 The overarching policy and legislation applicable to the Proposed Development is presented in Volume 1, Chapter 2: Policy and Legislation. A summary of the legislative provisions relevant to physical processes are provided in Table 7.1 below, with other relevant policy provisions set out in Table 7.2 and Table 7.3.

Table 7.1: Summary of Legislation Relevant to Physical Processes

Summary of Relevant Legislation	How and Where Considered in the Offshore EIA Report
The Conservation of Habitats and Species Regulations (2017) UK law protecting Special Area of Conservation (SAC), Special Protection Area (SPA) and Ramsar sites on land and Scottish Territorial Seas (up to 12 nm from the coast).	These legislation have been used to define designated sites in Section 7.5.
The Conservation of Offshore Marine Habitats and Species Regulations (2017) Implement the species protection requirements of the Habitats and Birds Directives offshore (more than 12 nm from the coast).	
The Conservation (Natural Habitats, &c.) Regulations (1994) (and amendments) Defines the species, habitats and types of sites that receive legal protection and described the protection that is afforded.	

Table 7.2: Summary of National and Local Policy Relevant to Physical Processes

Summary of Relevant Policy	How and Where Considered in the Offshore EIA Report
National Planning Framework 4 (NPF4) (2023) • Identifies North Sea interconnectors and offshore renewable energy development, many of which will need to be taken into consideration with the cumulative effects assessment. • Notes the need for major infrastructure investment to unlock the growth of Scotland's marine renewable energy sector.	A Cumulative Effect Assessment (CEA) of the Proposed Development with projects including North Sea interconnectors and other offshore renewable energy developments has been untaken and is outlined in Section 7.12.
Aberdeenshire Local Development Plan (2023) • Policy R1 states there should be no 'adverse impacts on natural coastal processes or habitats' due to a development.	The baseline assessment in Volume 3, Technical Appendix 7.1: Physical Processes Baseline Environment reviewed the erosion risk of the coastline at the Landfall. Assessment of the impact of the Proposed Development on coastal processes at the Landfall has been undertaken and is outlined in Section 7.10.

Table 7.3: Summary of Marine Policy Relevant to Physical Processes

Summary of Relevant Policy	How and Where Considered in the Offshore EIA Report
Sectoral Marine Plan - Offshore Wind Energy (2020) • Confirms Plan Option Area for ScotWind leasing (including E3) and provides a spatial strategy for offshore wind development. • Highlights the need for this strategy to minimise the potential adverse effect on other marine users, economic sectors and the environment. • Section 4.1 lists a range of potential adverse impacts identified through plan level Strategic Environmental Assessment (SEA), Habitats Regulations Assessment (HRA) and Strategic Environmental Impact Assessment (SEIA) which require further consideration through project level assessments.	Assessment of impacts on physical processes arising from the Proposed Development has been undertaken and is outlined in Section 7.10. The potential for physical process changes to impact other EIA receptor groups are considered elsewhere within the Offshore EIA Report, in particular: • Volume 2, Chapter 8: Benthic Ecology; • Volume 2, Chapter 9: Fish and Shellfish Ecology; • Volume 2, Chapter 10: Marine Mammals; • Volume 2, Chapter 11: Offshore Ornithology; • Volume 2, Chapter 16: Infrastructure and Other Users; and • Volume 2, Chapter 19: Marine Archaeology. A CEA has been undertaken and is outlined in Section 7.12.
Scottish National Marine Plan (2015) • General Policy (GEN) 8 (Coastal process and flooding) requires that developments and activities in the marine environment should be resilient to coastal change and flooding and not have unacceptable adverse impact on coastal processes or contribute to coastal flooding. • GEN 9 (Natural Heritage) requires development to comply with legal requirements for protected areas; not to result in significant impact on the national status of Priority Marine Features (PMFs) (which includes geodiversity features); and to protect, and, where appropriate, enhance the health of the marine area. • GEN 21 (Cumulative Impacts) requires for cumulative impacts affecting the ecosystem to be addressed. • CABLES 2 requires the routing, protection, monitoring and mitigation to be taken into account when reaching decisions regarding cable development.	Assessment of impacts on physical processes arising from the Proposed Development has been undertaken and is outlined in Section 7.10. The potential for physical processes changes to impact other EIA receptor groups are considered elsewhere within the Offshore EIA Report, in particular: • Volume 2, Chapter 8: Benthic Ecology; • Volume 2, Chapter 9: Fish and Shellfish Ecology; • Volume 2, Chapter 10: Marine Mammals; • Volume 2, Chapter 11: Offshore Ornithology; • Volume 2, Chapter 16: Infrastructure and Other Users; and • Volume 2, Chapter 19: Marine Archaeology. A CEA has been undertaken and is set out in Section 7.12. Impact arising from installation, protection during O&M of the Offshore Export Cables and Inter-Array Cables (IACs) have been assessed and are outlined in Section 7.12.
UK Marine Policy Statement (2011) • Sets out high-level objectives for the marine space, including achieving a sustainable marine economy and identifies a wide range of relevant marine uses.	Assessment of impacts on physical processes arising from the Proposed Development has been undertaken and is outlined in Section 7.10. The potential for physical processes changes to impact other EIA receptor groups are

Summary of Relevant Policy	How and Where Considered in the Offshore EIA Report
• Requires that the use of the marine environment benefits society as a whole, contributing to resilient and cohesive communities that can adapt to coastal erosion and flood risk, as well as contributing to physical and mental wellbeing. • Requires use of the marine environment and its resources to maximise sustainable activity, prosperity and opportunities for all. • States that Offshore Wind Farm (OWF) fixed bottom foundation designs are likely to influence hydrodynamics and consequent sediment movement.	considered elsewhere within the Offshore EIA Report, in particular: • Volume 2, Chapter 8: Benthic Ecology; • Volume 2, Chapter 9: Fish and Shellfish Ecology; • Volume 2, Chapter 10: Marine Mammals; • Volume 2, Chapter 11: Offshore Ornithology; • Volume 2, Chapter 16: Infrastructure and Other Users; and • Volume 2, Chapter 19: Marine Archaeology.

7.4 Consultation

7.4.1 The approach to consultation for the Proposed Development is set out in Volume 1, Chapter 5: Consultation and Engagement. A summary of the issues raised during consultation activities undertaken to date specific to physical processes is presented in Table 7.4, together with how these issues have been considered in the production of this assessment. Further details are presented in Volume 1, Chapter 5: Consultation and Engagement, Volume 3, Technical Appendix 5.1: Consultation Log, and Volume 3, Technical Appendix 5.2: Pre-Application Consultation Report.

Table 7.4: Summary of Key Consultation Issues Raised During Consultation Activities Undertaken for the Proposed Development Relevant to Physical Processes

Date	Consultee and Type of Consultation	Summary of Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
25/04/2024	NatureScot Scoping Workshop	NatureScot recommended a post scoping consultation on the modelling methodology. This suggestion was supported by Marine Directorate.	A technical note setting out a Method Statement for the numerical modelling was provided (TWP, 2024a). This was reviewed and agreed by stakeholders (MD-SEDD, 2024).
		NatureScot requested that the risk of cable exposure (at the Landfall) due to coastal retreat or change should be addressed in the assessment.	The potential re-exposure of a trenched cable(s) at the Landfall has been assessed as an operational impact in Section 7.10. It is noted that since Horizontal Directional Drilling (HDD) or other trenchless techniques will be used, the risk of exposure is greatly reduced.
		NatureScot requested that changes to marine physical process impact pathways are clearly reported in the Offshore EIA Report with linkages to other chapters clearly articulated.	Potential changes to marine physical process pathways (such as sediment transport) have been described in Section 7.10. Where these changes have the potential to impact other EIA receptor groups (such as benthic and shellfish ecology), the reader has been signposted to the relevant chapter(s) within the Offshore EIA Report.
03/07/2024	Marine Directorate – Science Evidence Data and Digital (MD-SEDD) Response to Physical Processes Method Statement	MD-SEDD note that the Scoping Workshop proposed the use of vertical temperature and salinity profiles from Copernicus Marine Service and confirm that this would be essential for the baseline description of stratification.	Baseline understanding of the existing temporal/spatial pattern of stratification and positioning of tidal mixing fronts has been developed using readily available three-dimensional numerical model outputs from Copernicus Marine Service. The use of Copernicus reanalysis data has allowed for a detailed examination of spatial and temporal variability over a range of scales, from broader seasonal and interannual changes to shorter term fluctuations occurring over a tidal cycle. The potential for change in water column stratification and the position of frontal systems has been reported in Section 7.10.

Date	Consultee and Type of Consultation	Summary of Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
		The proposed (mainly modelling) methodologies, and scenarios, are adequate for the assessment of most potential impacts. MD-SEDD advise that the proposed modelling methodologies are not suitable for the assessment of potential change to stratification and frontal systems.	To assess the impact of Wind Turbine structures on water column mixing and stratification, the method outlined by Carpenter *et al.* (2016) has been employed. This is considered in Section 7.10 and Volume 3, Technical Appendix 7.4: Assessment of Potential Changes to Stratification and Frontal Systems. The approach taken has enabled a quantitative assessment.
		MD-SEDD advise that no details were provided on how the Wind Turbine structures will be represented in either the hydrodynamic or wave models, other than as “a blockage”.	To assess impact on the tidal regime the Maximum Design Scenario (MDS) for depth-average blockage is applied in the hydrodynamic model as a sub-grid scale MIKE pier structure. To assess impact on the wave regime the MDS for near-surface blockage is applied in the spectral wave model as a sub-grid scale MIKE point structure.
		MD-SEDD recommend the use of existing three-dimensional ocean model output, (e.g. data available from the Copernicus Marine Service or The Scottish Shelf Waters Reanalysis Service (SSW-RS)), and observational data, to characterise the water column structure within the region throughout the year, paying particular attention to the onset/decay of seasonal stratification and fronts.	Baseline understanding of the existing temporal/spatial pattern of stratification and positioning of tidal mixing fronts has been developed using readily available three-dimensional numerical model outputs from Copernicus Marine Service. The use of Copernicus reanalysis data has allowed for a detailed examination of spatial and temporal variability over a range of scales, from broader seasonal and interannual changes to shorter term fluctuations occurring over a tidal cycle.
		MD-SEDD recognise there is no clear methodology or guidance available on how to assess the impact of wind farm structures on stratification. MD-SEDD advise the potential impact on stratification should be assessed as this would influence the timing of plankton blooms and the wider ecosystem.	To assess the impact of Wind Turbines on water column mixing and stratification, the method outlined by Carpenter *et al.* (2016) has been employed. This approach uses empirical equations to estimate two key timescales: the mixing timescale, which predicts the time required for complete mixing of stratified layers due to increased Turbulent Kinetic Energy (TKE) generated by the Wind Turbines, and the advective timescale, which quantifies how long a water parcel

Date	Consultee and Type of Consultation	Summary of Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
			remains within the Array Area, experiencing enhanced TKE. This is considered in Section 7.10.
		A qualitative assessment of potential impacts of changes to wind wakes (on stratification) should be performed using the published research findings (e.g. Christiansen *et al.* (2022)).	A qualitative assessment has been performed to consider the potential impacts of changes to wind wakes (on stratification).
11/07/2024	NatureScot Response to Physical Processes Method Statement	NatureScot agrees that the proposed modelling approach (in conjunction with other data sources) provides an acceptably reliable basis for the description of baseline conditions for the purpose of EIA. NatureScot also agrees that the proposed modelling approach provides an acceptably reliable basis for the quantification of the identified impact types. The assessment of the tidal regime should take account of that regarding scour, to provide a more holistic analysis across these spatial scales.	Section 7.10 contains a detailed assessment of potential changes to hydrodynamics, as well as the potential for the development of scour around marine structures. The former has been undertaken using numerical modelling, whilst the latter has been carried out through the use of published empirical relationships to quantify the maximum potential dimensions of scour. The outputs from both of these investigations have been used to assess the potential for wider morphological change, in accordance with established methods for offshore wind farm EIA (Section 7.8).
25/11/2024	Marine Directorate – Licensing Operations Team (MD-LOT) (2024 Bowdun Offshore Wind Farm (OWF) Scoping Opinion)	The Scottish Ministers are content with the study area noted in Section 7.2 of the Scoping Report and with the data sources provided in Table 7.1 of the Scoping Report. However, outputs from Dynamic Coast Phase 2 should be considered, as well as data relating to stratification and frontal systems outlined by MD-SEDD.	The updated outputs from Dynamic Coast Phase 2 (including new reports and web mapping of coastal change) have been used as a data source for the Offshore EIA Report. The additional publications cited in the MD-SEDD advice (from 09 October 2024) will also be used.
		The potential re-exposure of a trenched cable(s) at Landfall(s) should be assessed as an additional operational impact.	The potential re-exposure of a trenched cable(s) at the Landfall is assessed as an operational impact in Section 7.10.

Date	Consultee and Type of Consultation	Summary of Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
		The Scottish Ministers acknowledge Section 7.7.4 within the Scoping Report which notes that a combination of analytical methods will be used to assess the potential changes to physical processes within the Offshore EIA Report. The Scottish Ministers advise that the NatureScot advice issued to the Developer on 11 July 2024 regarding the required greater detail for the modelling proposed is considered in full within the Offshore EIA Report.	The NatureScot advice (issued on 11 July 2024) has been considered in full within the Offshore EIA Report. The potential blockage effect of seabed infrastructure has been investigated at a resolution of ~100 m using numerical modelling, whilst scour around structures has been considered at a finer scale (metres to tens of metres) using empirical-based methods and evidence from analogous projects.
		The Scottish Ministers acknowledge Section 7.9.2 of the Scoping Report which identifies several impacts from the Proposed Development which have the potential to act cumulatively with impacts from other developments to contribute to cumulative effects. The Scottish Ministers are content with the impacts proposed.	A full CEA is presented in Section 7.12.
		The Scottish Ministers agree with the MD-SEDD advice that potential changes to water column mixing processes arising from alterations to near sea surface wind speeds should be considered in the Offshore EIA Report, both for the project alone and acting cumulatively with other wind farms.	Potential changes to water column mixing processes arising from alterations to near sea surface wind speeds are set out in Section 7.10 and Section 7.12.
		The Scottish Ministers, in line with the NatureScot representation, agree that transboundary impacts can be scoped out from further consideration in the Offshore EIA Report.	Comment acknowledged, no action required.
09/10/2024	MD-SEDD	MD-SEDD agree with the impacts scoped into the Proposed Development assessment for physical processes, and the development phases indicated.	Comment acknowledged, no action required.

Date	Consultee and Type of Consultation	Summary of Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
	(2024 Bowdun OWF Scoping Opinion – Scoping Response)	MD-SEDD advise that the hydrodynamic model used to assess impacts to stratification needs to resolve the vertical water column (e.g. using a three-dimensional or one-dimensional-vertical model).	To assess the impact of Wind Turbines on water column mixing and stratification, the method outlined by Carpenter *et al*. (2016) has been employed. This approach uses empirical equations to estimate two key timescales: the mixing timescale, which predicts the time required for complete mixing of stratified layers due to increased TKE generated by the Wind Turbines, and the advective timescale, which quantifies how long a water parcel remains within the Array Area, experiencing enhanced TKE. This is considered in Section 7.10.
		MD-SEDD consider the structure induced mixing is more likely to have near-field effects, whereas the wind speed deficit is likely to have more subtle far-field effects. There is potential for both these effects to be important cumulatively, when considering multiple OWFs in a region, and this should be considered with the EIA.	A full CEA is presented in Section 7.12, Paragraph 7.12.85 *et seq*.
		MD-SEDD advise the baseline description should include a description of prevailing baseline water column conditions, including the timing of stratification and frontal positions. This should include the evolution of water column structure through the year (e.g. weekly to monthly temperature, salinity, density profiles) and when typically the region stratifies, and how key parameters change through the year (e.g. surface mixed layer depth and potential energy anomaly (PEA)).	Baseline understanding of the existing temporal/spatial pattern of stratification and positioning of tidal mixing fronts has been developed using readily available three-dimensional numerical model outputs from Copernicus Marine Service. The use of Copernicus reanalysis data has allowed for a detailed examination of spatial and temporal variability over a range of scales, from broader seasonal and interannual changes to shorter term fluctuations occurring over a tidal cycle.
		For baseline characterisation MD-SEDD advise the use of existing three-dimensional ocean model output (e.g. data available from the Copernicus Marine Service or the SSW-RS	Baseline understanding of the existing temporal/spatial pattern of stratification and positioning of tidal mixing fronts has been developed using readily available three-dimensional numerical model outputs from Copernicus Marine Service. The

Date	Consultee and Type of Consultation	Summary of Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
		(https://tinyurl.com/SSW-Reanalysis)) and observational data.	use of Copernicus reanalysis data has allowed for a detailed examination of spatial and temporal variability over a range of scales, from broader seasonal and interannual changes to shorter term fluctuations occurring over a tidal cycle.
		MD-SEDD recommend the EIA investigates whether the potential change in mixing could delay the onset of stratification and what pathways to impact this could have on biological receptors. The potential impact of the structures (e.g. Dorrell *et al*. 2022) and the potential wind wake impact (e.g. Christiansen *et al*. 2022) should be assessed and compared with one-another.	The potential for change in water column stratification and the position of frontal systems has been reported in the Physical Processes assessment of this Offshore EIA Report (Section 7.10). The findings from this assessment have been used to inform significance of effect assessments presented in other chapters of this Offshore EIA Report, notably Volume 2, Chapter 9: Fish and Shellfish Ecology and Volume 2, Chapter 11: Offshore Ornithology.
		MD-SEDD advocate the approach set out in Carpenter *et al*. (2016) for the assessment of potential impacts to stratification and frontal systems.	To assess the impact of Wind Turbines on water column mixing and stratification, the method outlined by Carpenter *et al*. (2016) has been employed. This approach uses empirical equations to estimate two key timescales: the mixing timescale, which predicts the time required for complete mixing of stratified layers due to increased TKE generated by the Wind Turbines, and the advective timescale, which quantifies how long a water parcel remains within the Array Area, experiencing enhanced TKE. This is considered in Section 7.10.
		MD-SEDD recognise there is no pragmatic method, or modelling guidance, available for modelling the potential impact of the wind wake, and therefore suggest that a qualitative assessment be performed using published research findings (e.g. Christiansen *et al*. (2022)).	A qualitative assessment has been performed to consider the potential impacts of changes to wind wakes (on stratification). This is included in Volume 3, Technical Appendix 7.4: Assessment of Potential Changes to Stratification and Frontal Systems.
		MD-SEDD advise that changes to mixing have the potential to impact other receptors, such as productivity as well as higher trophic levels	The potential for change in water column stratification and the position of frontal systems has been reported in the Physical Processes assessment

Date	Consultee and Type of Consultation	Summary of Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
		and should also be qualitatively assessed in the EIA.	of the Offshore EIA Report (Section 7.10). The findings from this assessment have been used to inform significance of effect assessments presented in other chapters of the Offshore EIA Report, notably Volume 2, Chapter 9: Fish and Shellfish Ecology and Volume 2, Chapter 11: Offshore Ornithology.
		MD-SEDD advise the potential impact on Nature Conservation Marine Protected Areas where fronts are a designated feature should be included.	Outputs from the assessment of potential changes to stratification and frontal systems presented in the Physical Processes chapter of the Offshore EIA Report have been used to inform the MPA assessment presented in Volume 3, Technical Appendix 8.3: Marine Protected Area Assessment.
11/10/2024	NatureScot (2024 Bowdun OWF Scoping Opinion – Scoping Response)	NatureScot is content with the study area proposed.	Comment acknowledged, no action required.
		The physical processes chapter in the Offshore EIA Report should consider outputs from Dynamic Coast Phase 2.	The updated outputs from Dynamic Coast Phase 2 (including new reports and web mapping of coastal change) are used as a data source for this chapter of the Offshore EIA Report.
		NatureScot welcomes the acknowledgement that changes to the physical characteristics of designated sites have the potential to impact the habitats they support and, therefore, consideration will be given to them in the marine physical processes assessment.	Comment acknowledged, no action required.
		The potential re-exposure of a trenched cable(s) at Landfall(s) should be assessed as an additional operational impact.	The potential re-exposure of a trenched cable(s) at the Landfall has been assessed as an operational impact in Section 7.10.
		Definitions of Magnitude and Sensitivity for the Marine and Coastal Processes impact assessment should be provided at this Scoping stage.	Comment acknowledged. Definitions have been provided in full in Section 7.8.

Date	Consultee and Type of Consultation	Summary of Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
		NatureScot welcomes the acknowledgement that physical processes can be both pathways and receptors and that information on physical processes will be used to inform other receptors.	Comment acknowledged.
		NatureScot agrees with the list of potential cumulative impacts identified.	Comment acknowledged.
		NatureScot advises that the full range of mitigation and monitoring measures, and published guidance, are considered and discussed in the Offshore EIA Report.	Section 7.9 of this EIA Chapter sets out the Embedded Mitigation that will help avoid or reduce the potential for significant adverse environmental effects of the Proposed Development. These measures have been developed with reference to published guidance.
		NatureScot agrees that transboundary impacts can be scoped out from further consideration.	Comment acknowledged.
24/10/2024	Aberdeenshire Council (2024 Bowdun OWF Scoping Opinion – Scoping Response)	The Benholm to Todhead Point Local Nature Conservation Site (LNCS) extends to 2 km offshore. The impact on this area - which is of regional importance should be considered in order to minimise any disturbance or damage to this zone in any Landfall and cabling work.	The significance of impacts to the Benholm to Todhead LNCS are considered in Section 7.10.

7.5 Data Sources

7.5.1 Project-specific and publicly available data have been reviewed and analysed to inform this physical processes baseline.

Desktop Study

7.5.2 Information on physical processes within the Physical Processes Study Area was collected through a detailed desktop review of existing studies and datasets, which are summarised in Table 7.5.

7.5.3 Both the literature review of the reports and numerical modelling using the datasets were used to characterise the baseline. The Physical Processes Technical Report (Volume 3, Technical Appendix 7.1: Physical Processes Baseline Environment) includes full details of the analysis undertaken to develop the physical processes baseline.

Table 7.5: Summary of Key Desktop Datasets and Reports for the Physical Processes Baseline

Title	Source	Extent	Year	Author
ABPmer SEASTATES	ABPmer	Full coverage of the Physical Processes Study Area	2025	ABPmer
British Geological Survey (BGS) maps	BGS	Partial coverage of the Physical Processes Study Area	2024a	BGS
British Oceanographic Data Centre (BODC)	BODC	Partial coverage of the Physical Processes Study Area	2024	BODC
Centre for Environment, Fisheries and Aquaculture Science (Cefas) WaveNet data	Cefas	Partial coverage of the Physical Processes Study Area	2024	Cefas
Copernicus Atlantic-European Northwest Shelf- Ocean Physics Reanalysis	Copernicus Marine Service	Full coverage of the Physical Processes Study Area	2024a	Copernicus Marine Service
Copernicus Atlantic-European Northwest Shelf- Ocean Biogeochemistry Reanalysis	Copernicus Marine Service	Full coverage of the Physical Processes Study Area	2024b	Copernicus Marine Service

Title	Source	Extent	Year	Author
European Marine Observation and Data Network (EMODnet) Data Layers	EMODnet	Full coverage of the Physical Processes Study Area	2024	EMODnet
Marine Directorate Data Portal	Marine Directorate	Partial coverage of the Physical Processes Study Area	2024	Marine Directorate
National Tide and Sea Level Facility (NTSLF)	NTSLF	Partial coverage of the Physical Processes Study Area	2024	NTSLF
Scottish Coastal Observatory (SCO)	SCO	Partial coverage of the Physical Processes Study Area	2024	SCO
Scottish Environment Protection Agency (SEPA)	SEPA	Partial coverage of the Physical Processes Study Area	2024	SEPA
Scottish Remote Sensing Portal	Scottish Government and Joint Nature Conservation Committee (JNCC)	Partial coverage of the Physical Processes Study Area	2024	Scottish Government and JNCC
Strategic Environmental Assessment (SEA) Data Portal	SEA	Partial coverage of the Physical Processes Study Area	2024b	BGS
United Kingdom Hydrographic Office (UKHO) Bathymetric Data	UKHO	Full coverage of the Physical Processes Study Area	2024	UKHO
Dynamic Coast (Phase 1&2)	Rennie *et al.* (2021) Hansom *et al.* (2017)	Partial coverage of the Physical Processes Study Area	2017, 2021	Hansom *et al.* Rennie *et al.*
United Kingdom Climate Projections 2018 (UKCP18)	UKCP	Partial coverage of the Physical Processes Study Area	2018	Palmer *et al.*
Suspended Particulate Matter mapping	Cefas	Full coverage of the Physical Processes Study Area	2016	Cefas

Title	Source	Extent	Year	Author
MPA Geodiversity Mapping	Brooks *et al.*	Partial coverage of the Physical Processes Study Area	2013	Brooks *et al.*
Marine Renewables Atlas	ABPmer	Full coverage of the Physical Processes Study Area	2008	ABPmer *et al.*
Coastal Cells in Scotland: Cell 2 – Fife Ness to Cairnbulg Point	Ramsey and Brampton	Partial coverage of the Physical Processes Study Area	2000	Ramsey and Brampton
(Key publications)	Public and grey literature	Partial coverage of the Physical Processes Study Area	n/a	n/a

Identification of Designated Sites

7.5.4 The Physical Processes Study Area contains several nationally and internationally designated sites. With the exception of Benholm to Todhead Point LNCS, none of the designated sites identified in Figure 7.1 overlap with the Array Area or Export Cable Corridor. The sites are designated for the habitats they contain as well as (in some instances) for the presence of geological and geomorphological features. This is the case with the Milton Ness Site of Special Scientific Interest (SSSI), which is located approximately 6 km to the south of the Landfall and has been designated for its nationally important Devonian and Quaternary geology (NatureScot, 2025). This is also the case with the Firth of Forth Banks Complex MPA which is located approximately 7 km to the south of the Array Area and contains moraines considered to be representative of the Wee Bankie Key Geodiversity Area (JNCC, 2021). At all sites, changes to the physical characteristics of these sites have the potential to impact the habitats they support and, therefore, consideration is given to them in the physical processes assessment.

7.5.5 A three-step process was used to identify all designated sites within the Physical Processes Study Area and qualifying interest features that could be affected by the construction, O&M, and decommissioning phases of the Proposed Development. This process is described below:

- Step 1: All designated sites of international, national, and local importance within the Physical Processes Study Area were identified using a number of sources. These sources included the Marine Directorate Data Portal (2024b) and JNCC MPA Mapper web Geographical Information System (GIS).
- Step 2: Information was compiled on the relevant physical and ecological features for each of these sites.
- Step 3: Using the above information and professional judgement, sites were included for further consideration if:

- a designated site directly overlaps with the Proposed Development and therefore has the potential to be directly affected by the Proposed Development; or
- sites and associated features were located within the Physical Processes Study Area (Figure 7.1) for impacts associated with the Proposed Development.

Site-Specific Surveys

7.5.6 Site-specific surveys were undertaken to inform this assessment. A summary of the surveys is outlined in Table 7.6.

Table 7.6: Summary of Site-Specific Survey Data

Title	Extent of Survey	Overview of Survey	Survey Contractor	Date	Reference to Further Information
Geophysical survey campaign	Across the Array Area and 1 km wide corridor within the Export Cable Corridor	High resolution side scan sonar and multibeam bathymetry.	G-TEC	2025	G-TEC, 2025a, 2025b
Intertidal survey	Intertidal (from MHWS to approximately Mean Low Water Spring (MLWS) at the Landfall	Phase 1 Walk-over survey	RPS	2024	Volume 3, Technical Appendix 4.1: Scoping Report Appendix E Benthic Phase 1 Intertidal Walkover Survey Report
Subtidal Benthic survey	Across the Array Area and Export Cable Corridor	Drop-Down Video (DDV) and grab samples, to determine biotopes and sediment contamination	Ocean Ecology Limited	2024	Volume 3, Technical Appendix 8.2: Bowdun OWF Benthic Characterisation Survey 2024: Survey Report

7.6 Baseline Environment

Overview of Baseline Environment

7.6.1 An overview of the physical processes baseline environment is provided in this section, with a conceptual understanding of the Physical Processes Study Area summarised in Figure 7.2. A full description of the physical processes baseline is provided in Volume 3, Technical Appendix 7.1: Physical Processes Baseline Environment.

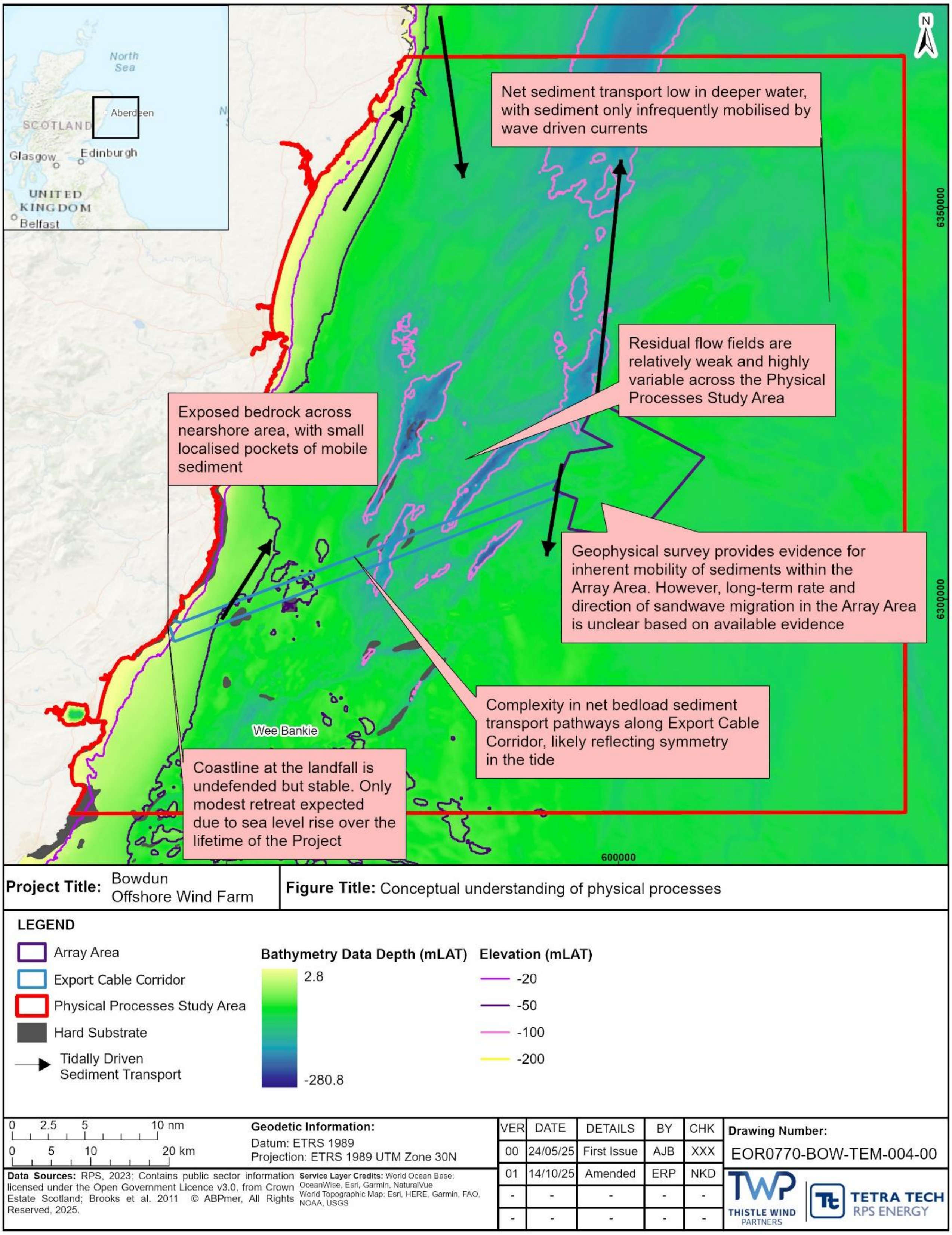

Figure 7.2: Conceptual Understanding of Physical Processes Study Area

Hydrodynamics

7.6.2 The Physical Processes Study Area is located within a semi-diurnal tidal environment with tidal range increasing from north-east to south-west. Within the Array Area, the mean spring tidal range is typically between 2.7 m and 3.0 m, with a mean neap range of approximately 1.5 m. Tidal currents are generally of moderate strength, with mean spring peak current speeds typically less than approximately 0.7 m/s. Some of the strongest currents are found just to the north of the Landfall, with peak current speeds on spring tide reaching ~0.8 m/s.

Waves

7.6.3 Waves within the Physical Processes Study Area are a combination of locally generated wind waves and waves generated elsewhere in the North Sea. Within the Array Area, waves predominantly come from southwesterly through south-southeasterly directions, although waves from northerly directional sectors are also common. Wave heights in the Array Area are typically 1 m to 3 m, tending to reduce with proximity to the coast, owing to decreasing water depth, decreasing fetch length in the predominant wind direction, and generally greater protection from waves generated elsewhere in the North Sea.

Stratification and frontal systems

7.6.4 Stratification is a naturally occurring seasonal hydrodynamic feature related to the vertical and horizontal distribution of sea water temperature and salinity, which influences the availability of nutrients, and the distribution and growth rates of pelagic flora and fauna. During the winter months (October to April), reduced solar heating and increased turbulent mixing from wind and waves result in well-mixed waters in the Array Area, characterised by homogeneous temperature and density profiles, with PEA values around 10 J/m^3 to 15 J/m^3. With the onset of spring and summer, calmer weather and longer, warmer days enhance stratification, overcoming the mixing effects of tides. From May to September, this leads to a vertical temperature gradient.

7.6.5 Fronts are relatively widespread features within the North Sea and (at certain times during the year) may extend for a distance of several hundred kilometres. During the summer months, elevated chlorophyll-a concentrations (likely linked to a tidal mixing front) are observed east of the Array Area. This is consistent across all years analysed (2010 to 2023) and suggests that higher primary productivity is occurring at the boundary between the more strongly stratified waters located further offshore, as opposed to the weakly stratified waters in the Array Area. In the Array Area, stratification appears to be a more transient feature, leading to lower and less sustained phytoplankton growth compared to the stable stratification further offshore.

Sediments and Geology

7.6.6 Seabed sediments across the Physical Processes Study Area are dominated by coarse-grained material, with sands and gravels encountered in most areas. Muddy sand is present in places. Close to the coast (including at the Landfall), exposed rock is encountered. Where present, the seabed sediments overlie extensive Quaternary sequences, deposited during glacial episodes over the past 2.6 million years.

7.6.7 Approximately half of the Array Area is composed of sand and silty sand. Boulders cover around 20% of the area, particularly in the northern and central regions. The Export Cable Corridor is similarly dominated by sand and silty sand, with occurrences of outcropping glacial till and boulders. Nearshore zones around the Landfall feature exposed Silurian or Devonian bedrock, while glacial outwash sediments are locally present further offshore (G-TEC, 2025a; 2025b).

7.6.8 Across nearshore areas within the Physical Processes Study Area, net sediment transport is understood to be dominated by tidally driven processes. Further offshore (including areas immediately to the east of the Array Area), net rates of tidally driven sediment transport become negligible, with mobilisation of material at the bed only occurring on shoals during large storm events.

7.6.9 Sediment transport at the coast is described within the context of coastal cells and sub-cells in Ramsay and Brampton (2000). The Physical Processes Study Area is within Cell 2 (Fife Ness to Cairnbulg Point). The volume of beach material in many areas is limited meaning net littoral drift is often low. Even where sand is present rates of net littoral drift are often low, reflecting a balance between wave and tidally driven processes and/or coastal aspect relative to the prevailing waves.

Seabed Geomorphology

7.6.10 A range of active and relict (i.e. no longer active) bedforms and geomorphological features are present within the Physical Processes Study Area, reflecting contemporary seabed processes and past glacial and geological activity. Extensive (relict) glacial moraine complexes have been mapped within the Physical Processes Study Area, as well as tunnel valleys. Active bedforms - namely sandwaves and megaripples - comprising mobile Holocene sediments are also present, including locally within the Array Area and Export Cable Corridor where they can exceed 4 m in height. Ripple and smaller megaripple features are known to be mobile within the Array Area and Export Cable Corridor, as demonstrated through bathymetric comparisons in areas with overlapping survey data collected during the 2023 to 2024 geophysical survey campaign. However, a comparison between the recent (2023 to 2024) survey data and older (2009) United Kingdom Hydrographic Office (UKHO) survey data has not shown clear evidence for consistent migration of the larger sandwave features.

Coastal Geomorphology

7.6.11 The coastline within the Physical Processes Study Area extends from Auchmithie (in the south) to Boddam (in the north). Large stretches are characterised by the presence of erosion resistant rock although beaches with dune systems are also present. In several areas where these softer, erodible sediments front urban areas (such as Montrose and Aberdeen), coastal defences are present. However, most of the coastline within the Physical Processes Study Area is undefended, reflecting a combination of generally low rates of erosion and a sparsely populated coastal zone. Owing to the erosion resistant nature of the coastline, relatively little change is expected at the Landfall over the lifetime of the Proposed Development and the position of the MHWS contour is predicted to remain largely unaltered.

Designated Sites

7.6.12 Designated sites and relevant qualifying features identified for the Physical Processes Study Area are summarised in Table 7.7 and presented in Figure 7.1.

Table 7.7: Designated Sites and Relevant Qualifying Features for the Physical Processes Study Area

Designated Site	Closest Distance to Proposed Development (km)	Relevant Qualifying Interest Feature(s)
Benholm to Todhead Point LNCS	0	Wavecut platform
Milton Ness SSSI	5.6	Non-marine Devonian (geology) Quaternary of Scotland (geology)
St Cyrus and Kinnaber Links SSSI	6.1	Saltmarsh
Firth of Forth Banks Complex MPA	6.7	Ocean quahog aggregations Offshore subtidal sands and gravels Quaternary of Scotland Shelf banks and mounds
Crawton Bay SSSI	7.9	Non-marine Devonian (geology) Old Red Sandstone Igneous (geology)
Garron Point SSSI	14	Maritime cliff Dalradian (geology) Non-marine Devonian (geology)
Rickle Craig - Scurdie Ness SSSI	14	Maritime cliff Old Red Sandstone Igneous (geology) Mineralogy of Scotland
Whiting Ness - Ethie Haven SSSI	23	Maritime cliff
Cove SSSI	25	Maritime cliff
Nigg Bay SSSI	28	Quaternary of Scotland (geology)
Southern Trench MPA	36	Fronts Burrowed mud Quaternary of Scotland Minke whale

Designated Site	Closest Distance to Proposed Development (km)	Relevant Qualifying Interest Feature(s)
Turbot Bank MPA	36	Sandeels
Foveran Links SSSI	44	Coastal geomorphology of Scotland sand dunes
Buchan Ness to Collieston SAC	45	Vegetated sea cliffs
Sands of Forvie SAC	45	Humid dune slacks Shifting dunes Shifting dunes with marram Lime-deficient dune heathland with crowberry
Collieston to Whinnyfold Coast SSSI	45	Dalradian (geology)
Sands of Forvie and Ythan Estuary SSSI	45	Coastal geomorphology of Scotland
Bullers of Buchan Coast SSSI	47	Coastal geomorphology of Scotland Maritime cliff

Future Baseline Scenario

7.6.13 The EIA Regulations require that '*a description of the relevant aspects of the current state of the environment (baseline scenario) and an outline of the likely evolution thereof without implementation of the Proposed Development as far as natural changes from the baseline scenario can be assessed with reasonable effort, on the basis of the availability of environmental information and scientific knowledge*' is included within the Offshore EIA Report.

7.6.14 An assessment of the 'without development' future baseline conditions has also been carried out and is described within this section.

7.6.15 The baseline environment for physical processes is expected to vary and evolve in response to natural variation (e.g. lunar nodal cycle, North Atlantic Oscillation etc.), wider changes in climate expected over the lifetime of the Proposed Development, and anthropogenic management of the coast.

7.6.16 Average sea level rise around the UK is expected to increase by 1 m by 2100, though a lesser rise is anticipated in the north of the UK. The north-east coast of Scotland can expect to see an average sea level rise of approximately up to 0.7 m by 2100 under Representative Concentration Pathway (RCP) 8.5 (Palmer *et al.*, 2018). The average wave height is predicted to decrease around much of the UK at a factor of about 10% to 20% over the 21st century, with average wave heights in the North Sea decreasing by approximately 0.1 m. However, owing to variation between different models, confidence in projected sea wave height changes is low (Jaroszweski *et al.*, 2021).

7.6.17 Model projections suggest that by 2100, the thermal stratification period in UK shelf seas will extend by approximately two weeks (Sharples *et al.*, 2022; 2025). The northern North Sea will also experience greater surface-to-bottom temperature differences as the seasonal heating cycle intensifies (Tinker *et al.*, 2016), resulting in stronger stratification.

7.6.18 These changes are unlikely to significantly alter tidal patterns and sediment transport regimes offshore in the Array Area.

Data Limitations and Assumptions

7.6.19 Although the geophysical survey achieved 100% coverage of the Array Area, coverage of approximately 50% was achieved within the Export Cable Corridor (the coverage extent is shown in Figure 3.1 within Volume 3, Technical Appendix 7.1: Physical Processes Baseline Environment). However, this limitation has been overcome through the use of existing UKHO bathymetry data (UKHO, 2024), which is available for the area not covered by the Proposed Development geophysical survey.

7.6.20 Uncertainty exists regarding the characterisation of the future baseline with respect to global climate change. Key areas of uncertainty include actual future rates of sea level rise and the extent to which future changes in the wave regime may occur. There is also related uncertainty regarding how the coastline may respond to a future wave climate acting in combination with higher than present sea levels. More detail on the future baseline is provided in Volume 3, Technical Appendix 7.1: Physical Processes Baseline Environment.

7.6.21 It is recognised that all data (including survey data) is subject to varying levels of uncertainty. The datasets have been reviewed and levels of accuracy considered in the assessment process along with the application of appropriate assessment methods and the use of multiple datasets where available. More detail on the assessment methodologies is provided in Volume 3, Technical Appendix 7.3: Physical Processes Technical Assessment.

7.6.22 There is uncertainty associated with the specific construction methodology and timing of construction works. The methodology in this chapter accounts for this by assessing a realistic Maximum Design Scenario (MDS). This approach ensures that all other potential construction options fall within the assessed envelope, meaning their impacts will not exceed those predicted for the MDS.

7.6.23 The assessments have included the development and use of numerical wave, hydrodynamic and sediment models. These models are robust tools but are subject to a number of assumptions. These include the input parameters (e.g. using a representative sediment grain size for sediment transport, for example), scenario assumptions (e.g. the volume and location of drilling spoil released under different release scenarios) as well as uncertainty in the underpinning datasets (e.g. wave data and bathymetry data). Such uncertainty is managed through conservatism in the design of the modelling study and the interpretation of the model results in the context of the baseline and using expert judgement. Discussion relating to the performance of the models developed to support the assessment is also set out in Volume 3, Technical Appendix 7.2: Physical Processes Model Design and Validation.

7.7 Key Parameters for Assessment

Maximum Design Scenario

7.7.1 The MDS identified in Table 7.8 are those parameters expected to have the potential to result in the greatest effect on an identified receptor or receptor group. Any other development scenario within the Project Design Envelope (PDE) will result in the same, or less, level of environmental effect. The MDS has been selected from the details provided in Volume 1, Chapter 3: Project Description.

Table 7.8: MDS Considered for Each Potential Impact as Part of the Assessment on Physical Processes

Potential Impact	Phase*			Maximum Design Scenario (MDS)	Justification
	C	O	D		
Changes to Suspended Sediment Concentrations (SSC), bed levels and sediment type	✓	✓	✓	**Construction phase** Drilling for pile installation Up to 318,086 m^3 of drill arising for all piles in the Array Area for the 40 x 25 MW monopile Wind Turbine layout, comprising: • Maximum number of drilled piles: 40 (max foundations = 40; max piles per foundation = 1); • Maximum dimensions of drilled pile section: 15 m diameter, 45 m maximum penetration depth; • Maximum volume of drill arisings per pile: 7,952.12 m^3; and • Maximum concurrent drilling events: 2. IAC installation • Maximum total length of IAC on the seabed for the whole Array Area: 151 km for the 40 x 25 MW and 50 x 20 MW Wind Turbine Layouts; • Trench dimensions: up to 6 m wide; 1.5 m deep (average); 'V' shape profile; • Trench excavation method: Jetting, Mass Flow Excavation (MFE), Ploughing/Pre-Ploughing, Trenching/Pre-Trenching (incl. dredging, cutting); and • MFE pre-lay trenching rate: 400 m/hour. Offshore Export Cables installation • Maximum number of Export Cables: 3; • Maximum total length of each Export Cable: 70 km; • Trench dimensions: up to 6 m wide; 1.5 m deep (average) 'V' shape profile;	The MDS corresponds to (a combination of) the greatest amount of material disturbed and the greatest geographical extent of the impact. **Construction phase** Drilling for pile installation Based on the greatest amount of material disturbed in a drilling event, considering the largest pile dimension, largest pile penetration depth and number of concurrent drilling events. Assumes two concurrent drilling events can occur for neighbouring foundations, resulting in the MDS for instantaneous SSC. Piles relating to OSP's are smaller in diameter and require less drilling depth than Wind Turbine foundations therefore do not represent the MDS. IAC installation Pre-lay trenching by MFE will give MDS for sediment disturbance. Conservatively assumes 100% fluidisation of material expelled from trench. In reality, pre-lay jetting will move a proportion of material rather than bringing it fully into suspension. Modelling was carried out for sediment release along a Section of an indicative cable route which runs parallel and then perpendicular to the tidal axis for two full tidal cycles. Offshore Export Cable installation

Potential Impact	Phase*			Maximum Design Scenario (MDS)	Justification
	C	O	D		
				• Excavation method: Jetting, MFE, Ploughing/Pre-Ploughing, Trenching/Pre-Trenching (incl. dredging, cutting); and • MFE pre-lay trenching rate: 400 m/hour. <u>Interconnector Cable installation</u> • Maximum number of Interconnector Cables: 3; • Maximum total length of each Export Cable: 12 km; • Trench dimensions: up to 6 m wide; 1.5 m deep (average) 'V' shape profile; • Excavation method: Jetting, MFE, Ploughing/Pre-Ploughing, Trenching/Pre-Trenching (incl. dredging, cutting); and • MFE Pre-lay trenching rate: 400 m/hour. <u>Sandwave clearance</u> • Sandwave clearance width along IAC: 58.6 m; • Area of IAC sandwave clearance: 49,552 m^2 for the 40 x 25 MW and 50 x 20 MW Wind Turbine Layouts; • Area of Interconnector cable sandwave clearance: 11,814 m^2; • Area of OSP scour protection sandwave clearance: 24,359 m^2 for up to three OSP option; • Area of Wind Turbine foundation sandwave clearance: 172,220 m^2 for the 67 x 15 MW Wind Turbine Layouts; • Sandwave clearance width along Offshore Export Cable: 58.6 m; • Area of Offshore Export Cable sandwave clearance: 609,147 m^2; and • Clearance method: MFE and/or Dredger.	Pre-lay trenching by MFE will give MDS for sediment disturbance. Conservatively assumes 100% fluidisation of material expelled from trench. In reality pre-lay jetting will move a proportion of material rather than bringing it fully into suspension. Export Cable Corridor pre-lay trenching modelling assumes sediment release along the whole Export Cable Corridor. <u>Interconnector Cable installation</u> Pre-lay trenching by MFE will give MDS for sediment disturbance. Conservatively assumes 100% fluidisation of material expelled from trench. In reality pre-lay jetting will move a proportion of material rather than bringing it fully into suspension. Covered by Offshore Export Cable and Inter-Array Cable installation model scenarios. <u>Sandwave clearance</u> Sandwave clearance/levelling activities may be undertaken using a range of techniques – MFE and suction hopper dredging. Releases via both are modelled. A MFE near-bed sediment release rate of 1,000 kg/s is conservatively estimated based on the MDS trench cross section dimensions, the speed of progress of the tool, and the bulk density of the local sediment type. Dredge spoil release is simulated as an instantaneous release at

Potential Impact	Phase*			Maximum Design Scenario (MDS)	Justification
	C	O	D		
				Trenchless techniques (e.g. HDD) exit pit excavation • Number of exit pits: up to 3; • 2,800 m^3 excavated material for each pit for the 220 kV scenario (8,400 m^3 for all pits); and • Exit pit dimensions: 2.2 m x 50 m. Trenchless techniques (e.g. HDD) drilling fluid release (at Landfall) • Number of exit/release events: up to 3; • Up to 2,870 m^3 drilling mud generated per trenchless technique duct, based on bore diameter of 2.2 m and duct length of 755 m (8,610 m^3 total for all three ducts); • 100,000 mg/l (100 kg/m^3) assumed conservative maximum concentration of bentonite in drilling mud; and • Wet punch-out. **O&M phase** Cable repairs • Number of annual IAC repairs: 1; • Maximum annual length of IAC reburial: 4,915 m; • Number of annual Interconnector Cable repairs: 0.18; • Maximum annual length of Interconnector Cable reburial: 2,040 m; • Number of annual static Offshore Export Cable repairs: 1; and • Maximum annual length of Offshore Export Cable reburial: 6,390 m.	the water surface. 10% of a representative large (11,000 m^3) hopper is assumed to form the passive phase of the plume (ABPmer, 2011). Other seabed preparation such as boulder clearance is not considered here as the activity does not represent the MDS in terms of potential increases in SSC and associated changes to seabed substrate. Trenchless techniques exit pit excavation Based on maximum exit pit dimensions. Trenchless techniques drilling fluid release (at Landfall) Based on maximum trenchless technique duct dimensions. Assumes a conservative bentonite concentration of 100 kg/m^3 in drilling mud. Other stages of drilling (pilot hole drilling and stages of reaming) may result in smaller release events separated in time. But the MDS is considered as a release of drilling mud from a single conduit. **O&M phase** The MDS for sediment disturbance during operation will be no greater than that set out for the construction phase of the Proposed Development. Cable repairs These limited activities would disturb a much smaller volume of material for each

Potential Impact	Phase*			Maximum Design Scenario (MDS)	Justification
	C	O	D		
				Decommissioning phase A Decommissioning Programme will be submitted to MD-LOT for consultation and approval. The Decommissioning Programme will be updated during the Project's lifespan to take account of changing best practice and new technologies. The approach for decommissioning is yet to be determined, however, for the purposes of this MDS, total removal of all infrastructure including buried cables and cable protection has been assumed, and as such the environmental impact of decommissioning will be the same if not lower than construction.	repair/reburial event than simulated for the construction phase. **Decommissioning phase** The removal of infrastructure is expected to result in some localised seabed disturbance accompanied by temporary increases in SSC. Leaving the infrastructure in place will create less sediment disturbance. Therefore, the MDS is for the removal of all infrastructure. The MDS for sediment disturbance during decommissioning will be no greater than that set out for the construction phase of the Proposed Development.
Potential impacts to seabed morphology	✓	✓	✓	**Construction phase** Sandwave clearance • Sandwave clearance width along IAC: 58.6 m; • Area of IAC sandwave clearance: 49,552 m^2 for the 40 x 25 MW and 50 x 20 MW Wind Turbine Layouts; • Area of Interconnector cable sandwave clearance: 11,814 m^2; • Area of OSP scour protection sandwave clearance: 24,359 m^2 for up to three OSP option; • Area of Wind Turbine foundation sandwave clearance: 172,220 m^2 for the 67 x 15 MW Wind Turbine Layouts; • Sandwave clearance width along Offshore Export Cable: 58.6 m; • Area of Offshore Export Cable sandwave clearance: 609,147 m^2; and • Clearance method: MFE and/or Dredger.	**Construction phase** Sets out construction activities that give rise to the greatest (direct) disturbance to the seabed. Sandwave clearance Direct changes to the seabed through sandwave clearance. Areas estimated based on geophysical interpretation of sandwaves. Sandwave clearance activities may be undertaken using a range of techniques – MFE and suction hopper dredging. Dredged spoil release creates disposal mounds through the active phase of the plume, assumed to be 90% of the material released.

Potential Impact	Phase*			Maximum Design Scenario (MDS)	Justification
	C	O	D		
				Boulder clearance and pre-lay grapnel run • Width of seabed disturbance from boulder clearance: 25 m; • Area of boulder clearance for foundations: 172,220 m^2 for the 67 x 15 MW Wind Turbine Layout; • Area of IAC boulder clearance: 89,050 m^2 for the 67 x 15 MW Wind Turbine Layout; • Area of interconnector cables boulder clearance: 23,400 m^2; and • Area of Offshore Export Cable boulder clearance: 254,289 m^2. **O&M phase** Cable protection • Length of IAC requiring protection: 75.5 km for the 40 x 25 MW and 50 x 20 MW Wind Turbine Layouts; • Total IAC protection footprint for the array: 755,000 m^2; • Length of Offshore Export Cable requiring protection: 105 km (up to 50% of total length); • Total Offshore Export Cable protection footprint for the export cable corridor: 1,050,000 m^2; • Length of Interconnector Cables requiring protection: 18 km (up to 50% of total length) ; • Total Interconnector Cable protection footprint: 180,000 m^2; • Cable protection height ABSL: 2 m; and • Cable protection width: Up to 10 m. **Decommissioning phase** A Decommissioning Programme will be submitted to MD-LOT for consultation and approval. The Decommissioning	Boulder clearance and pre-lay grapnel run Direct changes to the seabed through boulder clearance and pre-lay grapnel run. Areas estimated based on geophysical interpretation of boulders. **O&M phase** During operation the maximum change of seabed morphology will result from scour. Cable protection Direct changes to seabed morphology through the presence of cable protection. Secondary scour will be highly localised and within the MDS assessed for primary scour. **Decommissioning phase** The coastal and seabed morphology could evolve to a new equilibrium state including the influence and presence of infrastructure. Removal of structures which have been in place for a long time could lead to changes in morphodynamics.

<table>
<tr><th rowspan="2">Potential Impact</th><th colspan="3">Phase*</th><th rowspan="2">Maximum Design Scenario (MDS)</th><th rowspan="2">Justification</th></tr>
<tr><th>C</th><th>O</th><th>D</th></tr>
<tr><td></td><td></td><td></td><td></td><td>Programme will be updated during the Project's lifespan to take account of changing best practice and new technologies.

The approach for decommissioning is yet to be determined, however, for the purposes of this MDS total removal of all infrastructure including buried cables and cable protection has been assumed, and as such the environmental impact of decommissioning will be the same if not lower than construction.</td><td></td></tr>
<tr><td>Potential impacts to coastal morphology</td><td>✓</td><td>✓</td><td>✓</td><td>Construction phase
<u>Cable protection (nearshore areas)</u>
• Maximum number of Offshore Export Cables: 3;
• Cable protection height ABSL: 2 m; and
• Cable protection width: Up to 10 m.

<u>Trenchless techniques (e.g. HDD) exit pit excavation</u>
• Subtidal punch-out of all trenchless technique cable ducts;
• Number of exit pits: up to 3;
• 2,800 m^3 excavated material for each pit for the 220 kV scenario (8,400 m^3 for all pits); and
• Exit pit dimensions: 2.2 m x 50 m.

O&M phase
<u>Cable protection (nearshore areas)</u>
• Maximum number of Export Cables: 3;
• Cable protection height ABSL: 2 m; and
• Cable protection width: Up to 10 m.
Decommissioning phase
A Decommissioning Programme will be submitted to MD-LOT for consultation and approval. The Decommissioning</td><td>Construction phase
Sets out construction activities that give rise to the greatest (direct) disturbance to the coast and provide the greatest potential to interact with coastal processes responsible for maintaining the baseline form and function of the coast.

O&M phase
During operation the maximum permanent change of coastal morphology will result from blockage of waves.

Decommissioning phase
The coastal and seabed morphology could evolve to a new equilibrium state including the influence and presence of infrastructure. Removal of structures which have been in place for a long time could lead to changes in morphodynamics.</td></tr>
</table>

Potential Impact	Phase*			Maximum Design Scenario (MDS)	Justification
	C	O	D		
				Programme will be updated during the Project's lifespan to take account of changing best practice and new technologies. The approach for decommissioning is yet to be determined, however, for the purposes of this MDS total removal of all infrastructure including buried cables and cable protection has been assumed, and as such the environmental impact of decommissioning will be the same if not lower than construction.	
Potential changes to the tidal regime	×	✓	×	**O&M phase** Wind Turbine foundation • Maximum number of Wind Turbines: 67; • Four-legged jacket foundation on pin piles for the 67 x 15 MW Wind Turbine layout; • Four piles per foundation (268 in total for Array Area) ; • Pile diameter: 3.8 m; • Pile height above seabed level (ABSL): 5 m; • Jacket primary member diameter: 3.1 m; • Scour protection height ABSL: 1 m; • Scour protection diameter (including pile): 28.8 m; • Total cross-sectional area within the water column per Wind Turbine foundation (including pin piles and scour protection): 1,647 m^2; • Depth-average blockage width per Wind Turbine foundation (including pin piles and scour protection): 25 m; • Depth-average blockage width for all Wind Turbine foundations (including pin piles and scour protection): 1,690 m; and • Minimum separation between Wind Turbines: 1,038 m.	**O&M phase** Wind Turbine foundation The MDS for changes to the tidal regime is given by the greatest depth-average blockage width for the Array Area as a whole. This considers the number of Wind Turbine foundations, foundation type, foundation components, and scour protection. Depth-averaged blockage is calculated assuming a representative (mean) water depth across the Array Area of 65 m. OSP foundation The MDS option is given by the greatest OSP depth-average blockage for the Array Area as a whole. This considers the number of OSP foundations, primary and secondary jacket member diameters. The MDS for potential changes to the tidal regime are two OSPs.

Potential Impact	Phase*			Maximum Design Scenario (MDS)	Justification
	C	O	D		
				OSP Foundation • Six-legged jacket on pin piles; • Maximum number of OSPs: 2; • Jacket primary member diameter: 3 m; • Total cross-sectional area within the water column per OSP foundation: 3,890 m^2; • Depth-average blockage width per OSP foundation: 60 m; and • Depth-average blockage width for all OSP foundations: 119 m.	

Potential Impact	Phase*			Maximum Design Scenario (MDS)	Justification
	C	O	D		
Potential changes to the wave regime	×	✓	×	**O&M phase** Wind Turbine foundation • Maximum number of Wind Turbines: 67; • Four-legged jacket foundation on pin piles for the 67 x 15 MW Wind Turbine layout; • Four piles per foundation (268 in total for Array Area) ; • Pile diameter: 3.8 m; • Pile height ABSL: 5 m; • Jacket primary member diameter: 3.1 m; • Scour protection height ABSL: 1 m; • Scour protection diameter (including pile): 28.8 m; • Total cross-sectional area within the water column per Wind Turbine foundation: 1,647 m^2; • Depth-average blockage width per Wind Turbine foundation: 25 m; • Depth-average blockage width for all Wind Turbine foundations: 1,690 m; and • Minimum separation between Wind Turbines: 1,038 m. OSP Foundation • Six-legged jacket on pin piles; • Maximum number of OSPs: 2; • Jacket primary member diameter: 3 m; • Total cross-sectional area within the water column per OSP foundation: 3,890 m^2; • Depth-average blockage width per OSP foundation: 60 m; and • Depth-average blockage width for all OSP foundations: 119 m.	**O&M phase** Wind Turbine foundation The MDS for changes to the wave regime is given by the greatest depth-average blockage width for the Array Area as a whole. This considers the number of Wind Turbine foundations, foundation type, foundation components, mooring configuration (if present), piles and scour protection. Depth-averaged blockage is calculated assuming a representative (mean) water depth across the Array Area of 65 m. OSP foundation The MDS option is given by the greatest OSP depth-average blockage for the Array Area as a whole. This considers the number of OSP foundations, primary and secondary jacket member diameters and piles. The MDS for potential changes to the wave regime are two OSPs.

Potential Impact	Phase*			Maximum Design Scenario (MDS)	Justification
	C	O	D		
Potential changes to the sediment transport regime	×	✓	×	**O&M phase** Wind Turbine foundation • Maximum number of Wind Turbines: 67; • Four-legged jacket foundation on pin piles for the 67 x 15 MW Wind Turbine layout; • Four piles per foundation (268 in total for Array Area); • Pile diameter: 3.8 m; • Pile height above seabed level (ABSL): 5 m; • Jacket primary member diameter: 3.1 m; • Scour protection height ABSL: 1 m; and • Scour protection diameter (including pile): 28.8 m. OSP Foundation • Six-legged jacket on pin piles; • Maximum number of OSPs: 2; and • Jacket primary member diameter: 3 m. Cable protection (nearshore areas) • Maximum number of Export Cables: 3; • Cable protection height ABSL: 2 m; and • Cable protection width: Up to 10 m.	**O&M phase** Sediment transport is driven by the combination of waves and tides. The relative contribution of these driving processes will vary spatially and temporally in response to, amongst other things, variation in water depth, tidal strength and meteorological events. Wind Turbine foundation The MDS for changes to the sediment transport regime is given by the MDS definition for potential changes to the wave and tidal regime during the operational phase. OSP foundation The MDS for changes to the sediment transport regime is given by the MDS definition for potential changes to the wave and tidal regime during the operational phase. Cable protection The presence of cable protection measures may have the potential to cause a blockage to sediment transport.

Potential Impact	Phase*			Maximum Design Scenario (MDS)	Justification
	C	O	D		
Potential changes to stratification and frontal systems	×	✓	×	**O&M phase** See MDS definitions above for potential changes to the tidal regime during the operational phase.	**O&M phase** The MDS for impacts to stratification and frontal systems is associated with the largest hydrodynamic blockage. This is represented by the combination of number of Wind Turbine foundations, foundation type, foundation components, and scour protection that gives the largest combined depth-average blockage within the water column.
Potential for scour of seabed sediment	×	✓	×	**O&M phase** Wind Turbine foundation • 3-legged jacket foundations for the 67 x 15 MW Wind Turbine layout; • Maximum number of Wind Turbines: 67; • Width of structure base: 37 m; • Diameter of jacket legs: 3.3 m; and • Diameter of pile: 4.1 m. OSP foundation • 4-legged jacket foundations for the 3 x OSP option; • Maximum number of OSPs: 3; • Width of structure base: 48 m; • Diameter of jacket legs: 3 m; and • Diameter of pile: 4.5 m. Cable protection • Maximum number of Export Cables: 3; • Cable protection height ABSL: 2 m; and • Cable protection width: Up to 10 m.	Each foundation type may produce different scour patterns. The foundation type, size and number producing the greatest area and/ or volume of influence is defined based on the outputs of the scour assessment in Volume 3, Technical Appendix 7.3: Physical Processes Technical Assessment. Scour Protection may be used to protect the stability of foundations if necessary. Where scour protection is used, primary scour is unlikely to occur, although a small amount of secondary scour may develop at the edges of the scour. However, the extent and volume of secondary scour will be considerably less than the MDS calculated for primary scour.

* Proposed Development Phase refers to construction (C), O&M (O) and decommissioning (D).

Impacts Scoped Out of the Assessment

7.7.2 The Scoping Workshop (see Table 7.4) was used to facilitate stakeholder engagement on topics to be scoped out of the assessment. On the basis of the baseline environment and the Project Description outlined in Volume 1, Chapter 3: Project Description, no impacts have been fully scoped out at this stage, principally due to the potential for indirect impacts on other topic receptors. However, the assessment focuses on those Proposed Development phases in which impacts will potentially be greatest. This was agreed with key stakeholders through consultation (see Table 7.4) and no concerns were raised by key consultees within the Scoping Opinion.

7.8 Methodology for Assessment of Effects

Overview

7.8.1 The Physical Processes assessment of effects has followed the methodology set out in Volume 1, Chapter 4: Environmental Impact Assessment Methodology. Specific to the Physical Processes assessment, the following guidance documents have also been considered:

- Metocean Procedures Guide for Offshore Renewables: Guidance to support metocean characterisation data acquisition and assessments to inform developments (Institute of Marine Engineering Science and Technology (IMarEST), 2024);
- Nature conservation considerations and environmental best practice for subsea cables for English Inshore and UK offshore waters (Natural England and JNCC, 2022);
- Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Monitoring Requirements to Inform EIA of Major Development Projects. Natural Resources Wales Report No 243 (Brooks *et al.*, 2018);
- EIA for offshore renewable energy projects (British Standards Institution (BSI), 2015);Review of post consent offshore wind farm monitoring data associated with licence conditions. A report produced for the Marine Management Organisation (MMO), Marine Management Organisation Project No: 1031. MMO, Newcastle (MMO, 2014);
- Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects (Cefas, 2012);
- Further review of sediment monitoring data: ScourSed-09. Collaborative Offshore Wind Research into the Environment (COWRIE) (ABPmer *et al.*, 2010);
- Coastal Process Modelling for Offshore Wind Farm EIA: Best Practice Guide (ABPmer and HR Wallingford, 2009);
- Review of Cabling Techniques and Environmental Effects applicable to the Offshore Wind Industry Technical Report. Department for Business

Enterprise and Regulatory Reform in association with Defra (Department for Business, Enterprise and Regulatory Reform (BERR), 2008);

- Guidelines in the use of metocean data through the lifecycle of a marine renewables development (Construction Industry Research and Information Association (CIRIA), 2008);
- Review of Round 1 Sediment process monitoring data - lessons learnt: Sed01. ABPmer, Southampton (ABPmer *et al*., 2007);
- Dynamics of scour pits and scour protection - Synthesis report and recommendations: Sed02. HR Wallingford, Wallingford (HR Wallingford *et al*., 2007); and
- Potential effects of offshore wind developments on coastal processes. Department of Trade and Industry, London (Cooper and Beiboer, 2002).

7.8.2 Consideration has also been given to the work of the Physical Processes ScotMER (Scottish Marine Energy Research) Receptor Group which is concerned with evidence gaps related to hydrology and geomorphology (see Scottish Government, 2025).

7.8.3 For the most part, physical processes are not in themselves receptors but are instead 'pathways'. However, changes to physical processes have the potential to indirectly impact other environmental receptors (ABPmer and HR Wallingford, 2009). For instance, the creation of sediment plumes (the potential for which is considered in the Physical Processes assessment) may lead to the settling of material onto benthic habitats. The potential significance of this particular impact is assessed in Volume 2, Chapter 8: Benthic Ecology.

7.8.4 Whilst physical processes can largely be considered as pathways, a small number of features have been identified as potentially sensitive physical processes receptors. These are:

- the coast; and
- seabed areas contained within nationally or internationally important sites. The locations of these sites are shown in Figure 7.1.

7.8.5 These receptors have been identified on the basis of:

- professional judgement and local and regional specialist experience;
- the Scoping Opinion (Marine Directorate, 2024);
- outcomes from the consultation process (Table 7.4); and
- reference to best practice guidance (see Paragraph 7.8.1).

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

7.8.7 Finally, the assessment of impacts on the marine physical environment has been considered over two spatial scales. These are:

- far-field. Defined as the area surrounding the Array Area and Export Cable Corridor across which indirect changes may occur (i.e. the Physical Processes Study Area); and
- near-field. Defined as the footprint of the Array Area and Export Cable Corridor.

Criteria for Assessment

7.8.8 When determining the significance of effects, a process is used which involves defining the magnitude of the potential impacts and the sensitivity of the receptors. This section describes the criteria applied in this chapter to assign values to the magnitude of potential impacts and the sensitivity of the receptors. The terms used to define magnitude and sensitivity are based on those which are described in further detail in Volume 1, Chapter 4: Environmental Impact Assessment Methodology.

7.8.9 The criteria for defining magnitude in this chapter are outlined in Table 7.9. Each assessment considered the spatial extent, duration, frequency and reversibility of impact when determining magnitude which are outlined within the magnitude section of each impact assessment (e.g. a duration of hours or days would be considered for most receptors to be of short-term duration, which is likely to result in a low magnitude of impact).

Table 7.9: Definition of Terms Relating to Magnitude of Impact

Magnitude of Impact	Definition
High	Permanent adverse change/deterioration across the near- and large parts of the far-field to key characteristics or features of the particular environmental aspect's character or distinctiveness. Impact likely irreversible (Adverse).
	Permanent beneficial change/improvement across the near- and large parts of the far-field to key characteristics or features of the particular environmental aspect's character or distinctiveness (Beneficial).
Medium	Permanent adverse change/deterioration, over the near- and parts of the far-field, to key characteristics or features of the particular environmental aspect's character or distinctiveness. Impact likely to be partially reversible (Adverse).
	Permanent beneficial change/improvement over the near- and parts of the far-field to key characteristics or features of the particular environmental aspect's character or distinctiveness (Beneficial).

Magnitude of Impact	Definition
Low	Noticeable, temporary (for part of the Proposed Development duration) adverse change 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 likely to be reversible (Adverse).
	Noticeable, temporary (for part of the Proposed Development duration) beneficial change 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 (Beneficial).
Negligible	Adverse changes which are not (or are barely) discernible from background conditions. Impact will be reversible (Adverse).
	Beneficial changes which are not (or are barely) discernible from background conditions (Beneficial).

7.8.10 The criteria for defining sensitivity in this chapter are outlined in Table 7.10. The sensitivity of each receptor has been assessed using expert judgement and is closely guided by the conceptual understanding of regional-scale physical processes, developed during the baseline characterisation process (Volume 3, Technical Appendix 7.1: Physical Processes Baseline Environment).

Table 7.10: Definition of Terms Relating to the Sensitivity of the Receptor

Sensitivity of the Receptor	Definition
Very High	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.
High	Very low 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.

7.8.11 The magnitude of the impact and the sensitivity of the receptor are combined when determining the significance of the effect upon physical process receptors. The particular method employed for this assessment is presented in Table 7.11 and Table 7.12.

7.8.12 Where a range is suggested for the significance of effect, for example, minor to moderate, it is possible that this may span the significance threshold. The technical specialist's professional judgement will be applied to determine which outcome defines the most likely effect, which takes in to account the sensitivity of the receptor and the magnitude of impact. Where professional judgement is applied to quantify final significance from a range, the assessment will set out the factors that result in the final assessment of significance. These factors may include the likelihood that an effect will occur, data certainty and relevant information about the wider environmental context.

7.8.13 The EIA Regulations require the identification and reporting of significant environmental effects. For the purposes of this assessment:

- a level of moderate or more will be considered a 'significant' effect in terms of the EIA Regulations; and
- a level of minor or less will be considered 'not significant' in terms of the EIA Regulations.

Table 7.11: Matrix Used for the Assessment of the Significance of the Effect

Sensitivity of Receptor	Magnitude of Impact			
	Negligible	**Low**	**Medium**	**High**
Negligible	Negligible	Negligible or Minor	Negligible of Minor	Minor
Low	Negligible or Minor	Negligible or Minor	Minor	Minor or Moderate
Medium	Negligible or Minor	Minor	Moderate	Moderate or Major
High	Minor	Minor or Moderate	Moderate or Major	Major
Very High	Minor	Moderate or Major	Major	Major

Table 7.12: Definition of Significance

Impact	Justification
Negligible	No effects or those that are beneath levels of perception, within normal bounds of variation, or within the margin of forecasting error.
Minor	These beneficial or adverse effects are generally, but not exclusively, raised as local factors. They are unlikely to be critical in the decision-making process but are important in enhancing the subsequent design of the Proposed Development.
Moderate	These beneficial or adverse effects have the potential to be important and may influence the decision-making process. The cumulative effects of such factors may influence decision-making if they lead to an increase in the overall adverse or beneficial effect on a particular resource or receptor.
Major	These beneficial or adverse effects are very important and are likely to be material in the decision-making process. These effects are generally, but not exclusively, associated with sites or features of international, national, or regional importance. However, a major change in a site or feature of local importance may also enter this category.

Designated Sites

7.8.14 This physical processes chapter assesses the likely significant environmental effects in EIA terms on designated sites. The Report to Inform Appropriate Assessment (RIAA) for the Proposed Development includes the assessment of the likely significant effect on the qualifying features of European sites. A summary of the outcomes reported in the RIAA is provided in the RIAA, Part 1: Introduction (TWP-BOW-RPS-ENV-RPT-00013).

7.8.15 Where locally designated sites and national designations (other than European sites) fall within the boundaries of a European site, and where qualifying features are the same, only the European site has been taken forward for assessment. Potential impacts on the integrity and conservation status of the locally or nationally designated site are assumed to be inherent within the assessment of the European site so a separate assessment for the local or national site is not undertaken.

7.8.16 However, assessment of the likely significant environmental effects on a local or nationally designated site which falls outside the boundaries of a European site, but within the Physical Processes Study Area, has been undertaken within this chapter using Volume 1, Chapter 4: Environmental Impact Assessment Methodology.

7.9 Embedded Mitigation

7.9.1 As part of the Proposed Development design process, a number of Embedded Mitigation measures have been proposed to reduce the potential for impacts on physical processes (see Table 7.13). They are considered at every stage of the Proposed Development through design and best practice, and as there is a commitment to implementing these measures, these have been considered in the assessment presented in Section 7.10 (i.e. the determination of magnitude and therefore significance assumes implementation of these measures). Many of these Embedded Mitigation measures are considered standard industry practice for this type of development – see Volume 3, Technical Appendix 4.6: Schedule of Mitigation and Commitments for more details.

Table 7.13: Embedded Mitigation Adopted as Part of the Proposed Development

ID*	Embedded Mitigation Adopted as Part of the Proposed Development	Justification
1	Development of, and adherence to, a Cable Specification and Installation Plan (CSIP) post consent.	This sets out measures to reduce adverse impacts to potentially sensitive receptors. It will also set out appropriate cable burial depth in accordance with industry good practice, reducing the risk of cable exposure.
2	Use of anti-corrosion protective coatings and Scour Protection where there is potential for scour to develop around the Offshore Infrastructure, and it is appropriate to do so.	Following the completion of a scour assessment, where there is the potential for scour to develop around Offshore Infrastructure, including Wind Turbines, OSP and cables, the appropriate Scour Protection will be put in place. Reducing the potential for changes to the morphology of the seabed due to scour.
4	Development of, and adherence to, a Cable Burial Risk Assessment (CBRA) and the Cable Burial Assessment (CBA). Implementation, management and monitoring of cable protection, via burial or external protection where adequate burial depth is not feasible, will be undertaken as informed by these assessments. Results of these assessments, and commitments to post construction monitoring, will be provided in the Cable Plan (CaP).	Will help ensure that all cables will be buried to an appropriate depth (or surface laid and protected) to minimise the chance of exposure during the lifetime of the Proposed Development.
5	Development of, and adherence to, an Environmental Management Plan (EMP), including a Marine Pollution Contingency Plan (MPCP) and a Biosecurity Plan with commitments to monitoring and actions to minimise Invasive Non-Native Species (INNS).	The EMP will set out procedures to ensure all activities with the potential to affect the environment are appropriately managed.
7	Development of, and adherence to, a Construction Method Statement (CMS) along with a Code of Construction Practice (CoCP).	The CMS will specify the Proposed Development's construction methods, setting out good practice construction measures and how agreed mitigation measures from the Offshore EIA Report, will be implemented during construction.
34	Drafting and implementation of a decommissioning programme, prepared in accordance with requirements of the Energy Act 2004, which will set out the extent of infrastructure to be removed as well as the methods and processes which will be used.	A Decommissioning Programme will be developed to cover the decommissioning phase as required under Chapter 3 of Part 2 of the Energy Act 2004. As the decommissioning phase will be a similar process to the construction phase but in reverse (i.e., increased project vessels on-site, partially deconstructed structures) the mitigation measure will be similar to those for the construction phase.
40	Creation of a Waste Management Plan (WMP), which will describe the processes for handling and managing any waste materials.	The WMP will set out procedures to ensure all waste processing and handling activities with the potential to affect the environment are appropriately managed.

ID*	Embedded Mitigation Adopted as Part of the Proposed Development	Justification
43	Use of a trenchless technique (e.g. Horizontal Directional Drilling or pipe jack tunnelling) as the Landfall installation option.	Landfall installation methodology will avoid direct impacts to the Intertidal Area.

*see Volume 3, Technical Appendix 4.6: Schedule of Mitigation and Commitments

7.10 Assessment of Significance

7.10.1 Table 7.8 summarises the potential effects arising from the construction, O&M and decommissioning phases of the Proposed Development, as well as the MDS against which each impact has been assessed. An assessment of the likely significance of the effects of the Proposed Development on the physical processes receptors and pathways caused by each identified impact is given below.

IMPACT 1 - POTENTIAL CHANGES TO SUSPENDED SEDIMENT CONCENTRATION, BED LEVELS AND SEDIMENT TYPE

7.10.2 During the construction, O&M and decommissioning phases of the Proposed Development, 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. The disturbances will occur within the Array Area, Export Cable Corridor and/or Landfall. The measurable impacts of these disturbances are limited to the distance of the Spring Tidal Excursion. Therefore, this assessment involves the near-field of the Physical Processes Study Area.

7.10.3 The main activities resulting in disturbance of seabed sediments during construction are:

- pre-lay cable trenching using a MFE tool at the seabed;
- sandwave clearance using an MFE tool at the seabed;
- release of dredged material at the water surface related to seabed preparation for cables or foundations (including sandwave clearance);
- drill arisings release at the water surface during drilling for pin piles for foundations; and
- drilling fluid discharge during trenchless technique punch-out.

7.10.4 The main activities resulting in disturbance of seabed sediments during the operational phase are:

- remedial works to installed cables.

7.10.5 The following decommissioning activities could potentially give rise to increases in SSC and associated deposition of material within the Array Area and the Export Cable Corridor:

- removal of foundation structures; and
- removal of cables from the Intertidal Area.

7.10.6 Details of the MDS for sediment disturbance events are set out in Table 7.8. These sediment release events have subsequently been considered using numerical modelling, at locations in the Array Area, along the length of and in the middle of the Export Cable Corridor, and near to the Landfall and occurring (separately) on and around representative spring and neap tidal periods. A total of 20 release events for the Proposed Development have been considered which together, capture the full range of sediment disturbance activities as defined under the MDS.

7.10.7 A full description and discussion of each event is set out in Volume 3, Technical Appendix 7.3: Physical Processes Technical Assessment, whilst details of the sediment plume model design are set out in Volume 3, Technical Appendix 7.2 Model Design and Validation. A desk-based assessment of the potential persistence of spoil mounds has been presented in Paragraph 7.10.26 *et seq*.

7.10.8 The modelled sediment release events described in Volume 3, Technical Appendix 7.3: Physical Processes Technical Assessment have been designed to capture the MDS, in terms of:

- maximum plume concentrations;
- maximum plume extent;
- maximum vertical change in bed level; and
- maximum spatial extent of change in bed level.

7.10.9 The above will be governed by a range of factors including:

- the rate at which material is disturbed;
- the total mass of material disturbed;
- the characteristics of material that is disturbed (e.g. coarse, fine, consolidated etc.);
- the height within the water column the material is released; and
- whether the sediment disturbance occurs in a fixed location or moves over time).

Construction phase

Magnitude of impact

7.10.10 Potential changes to SSC, bed levels and sediment type are considered to be pathways of effect, rather than an impact on receptors and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect. Instead, this section focuses on describing the spatial and temporal nature of change, with the potential for associated impacts to marine biodiversity assessed in other chapters.

7.10.11 The maximum distance (and therefore the overall spatial extent) that any local plume effects might be (temporarily) experienced can be reasonably estimated as the Spring Tidal Excursion distance. 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. Areas beyond the tidal excursion distance and footprint are unlikely to experience any measurable change in SSC from a sediment plume.

7.10.12 The tidal excursion distance varies in proportion to the peak current speed on a given tide. As such, the distance may also be smaller than quoted during smaller than average spring, intermediate and neap conditions, and only very occasionally may be larger than shown during larger than average spring conditions.

7.10.13 The values below have been determined based on the observed advection of the plume features in the sediment plume model results, based on an indicative Wind Turbine layout. The model has been run over multiple flood and ebb cycles, during representative neap and spring tidal range conditions.

7.10.14 In the Array Area:

- on neap tides, the tidal excursion distance is approximately 5 km to 7 km, depending on the peak flow speed during that half tidal cycle; and
- on spring tides, the tidal excursion distance is approximately 9 km to 11 km, depending on the peak flow speed during that half tidal cycle.

7.10.15 In the middle part of the Export Cable Corridor:

- on neap tides, the tidal excursion distance is approximately 5 km to 7 km, depending on the peak flow speed during that half tidal cycle; and
- on spring tides, the tidal excursion distance is approximately 9 km to 11 km, depending on the peak flow speed during that half tidal cycle.

7.10.16 In the nearshore area close to the Landfall of the Export Cable Corridor:

- on neap tides, the tidal excursion distance is approximately 5 km to 6 km, depending on the peak flow speed during that half tidal cycle; and
- on spring tides, the tidal excursion distance is approximately 6 km to 8 km, depending on the peak flow speed during that half tidal cycle.

SSC of Plumes from Longer Duration Disturbance (Moving and Static Point Sources Over Multiple Flood/Ebb Cycles)

7.10.17 The following activities are all associated with longer duration disturbance:

- pre-lay cable trenching using an MFE;
- sandwave clearance using an MFE; and
- drilling for foundation installation.

7.10.18 For these release scenarios (Figure 7.3), it is found that:

- The sediment releases associated with these activities result in a long, relatively thin plume extending downstream from the point of active disturbance.
- 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, with elevated SSC regions extending from this aligned with the tidal axis.

- The level of SSC caused by all sediment types together is realistically expected to be locally very high at the location of active drilling, sandwave clearance or trenching - within 5 m of the activity, SSC might be millions of mg/l or more (i.e. more sediment than water in parts of the local plume). The effect is very localised and of very short duration.
- As sediment in the plume is redeposited and dispersed both vertically and horizontally with distance and time downstream, SSC is expected to reduce to less than 1,000 mg/l within tens of metres.
- SSC is less than 5 mg/l everywhere three days after the disturbance has ended.
- During spring tidal conditions, 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 on a comparable neap tide.
- During slack water (on both neap and spring tides), water is not moving sediment away from the area of disturbance, resulting in suspended sediment accumulating in a local area of relatively higher SSC. This local area of higher SSC is subsequently advected by the tide and may take longer to reduce to background levels than other parts of the plume generated during non-slack water conditions.
- The path followed by the tidal ellipse is not the same on every tide, so it is unlikely that the same area of seabed will be affected by higher SSC within the localised plume for more than one or two consecutive tides.
- Sediment released at the southern boundary of the Array Area has the potential to reach the Firth of Forth Banks Complex MPA, when the release period coincides with spring tides.
- The Firth of Forth Banks Complex MPA is approximately 6.7 km from the closest point in the Array Area, meaning the plume SSC will be already greatly reduced due to re-settlement of sediment, by the time it is advected into the protected area. A maximum instantaneous SSC of <10 mg/l is predicted within a very small proportion of the MPA.
- One day after the release has ended, the plume has been fully dispersed and no elevated SSC is predicted within any of the protected areas.

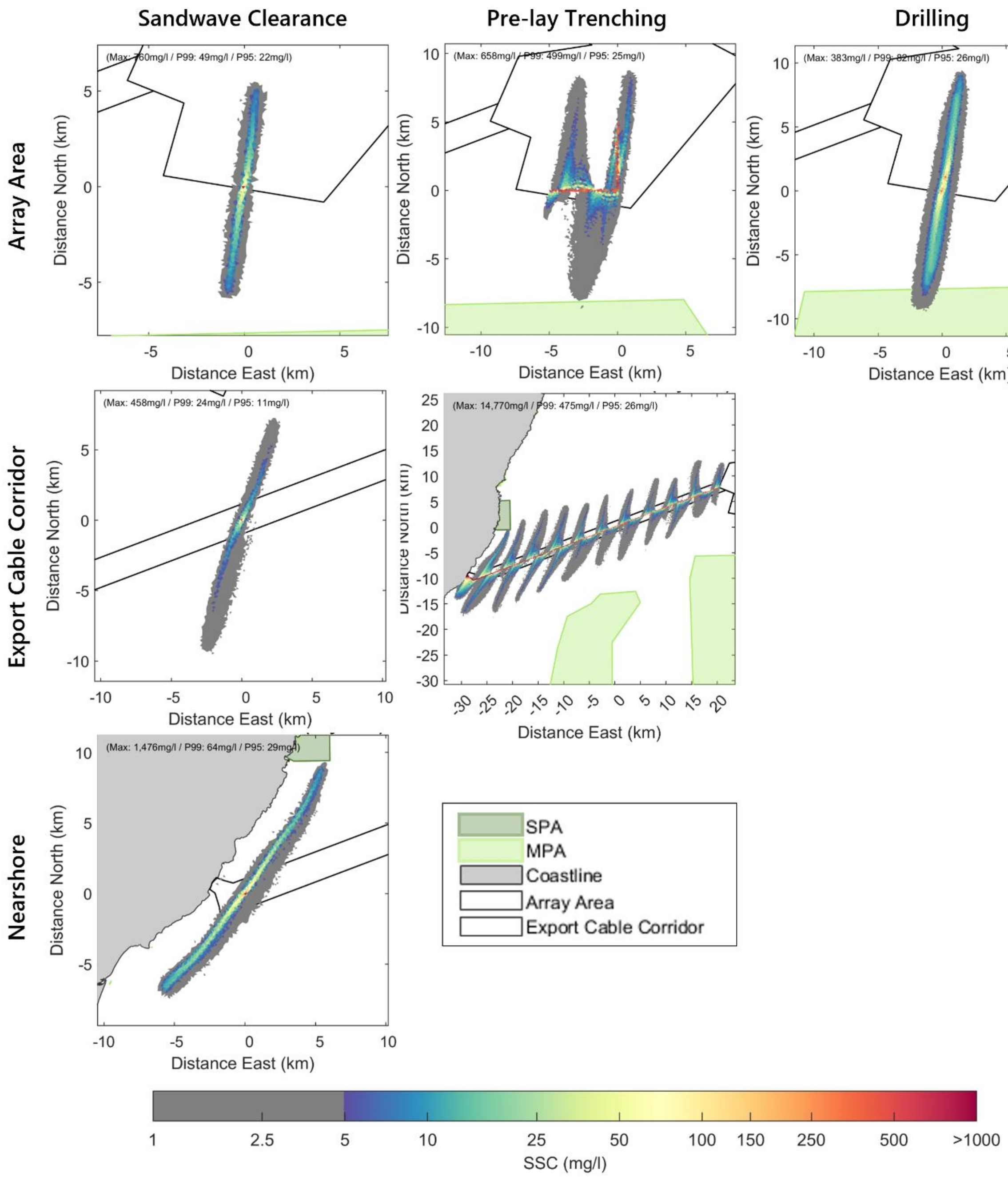

Figure 7.3: Maximum Instantaneous SSC from Longer Duration Disturbances on a Mean Spring Tide. Sandwave Clearance (Left), Pre-Lay Trenching (Centre) and Drilling (Right) Activities Within the Array Area (Top), Export Cable Corridor (Middle) and Nearshore (Bottom)

SSC of Plumes from Releases of Dredged Sediment

7.10.19 Seabed preparation via the use of a Trail Suction Hopper Dredger (TSHD) may be required prior to the installation of foundations. The release of the dredged sediment back to the seabed will take place at a nearby location within the Site Boundary.

7.10.20 During releases of dredged sediment, the TSHD opens large doors on the bottom of the hull and the full volume of dredged material is released into the water column near to the water surface in a relatively short time. It is assumed 90% of the total volume will descend rapidly and directly to the seabed as a single mass under gravity, forming the 'active phase' of the plume (ABPmer, 2011). The remaining 10% of material will enter suspension in the water column, settling out more slowly at the rate of the individual sediment grains, forming the 'passive phase' of the plume (ABPmer, 2011).

7.10.21 The active and passive phases will contain a similar representative distribution of all grain sizes present in the originally dredged sediments. The active phase is almost solid sediment and is rapidly deposited to the seabed, so is not assessed in terms of SSC. The following assessment mainly describes the SSC associated with the passive phase of the plume.

7.10.22 The following summary provides a general description of the resultant plumes (Figure 7.4):

- The level of SSC associated with the active and passive phases during the initial release is realistically expected to be locally very high at the location of the spoil release (millions of mg/l within 5 m of the activity, (i.e. more sediment than water in the local plume)).
- Gravels and sands will settle relatively rapidly towards the seabed. From the maximum expected height of initial suspension (approximately 65 m above the bed within the Array Area), these sediments are likely to resettle on the seabed, ceasing to increase SSC, within approximately 2 to 40 minutes.
- At a representative higher current speed of 0.6 m/s during spring tides, these sediments will settle to the bed within approximately 78 m for gravel, 390 m for coarse sand, 1,300 m for medium sand, and 3,900 m for finer sands from the release point. This distance will be proportionally shorter during periods of lower current speed, such as outside peak flow times and generally around neap tides.
- Fine sand and silt sized sediments persist in suspension for longer than relatively coarser sediment grain sizes (i.e. medium sand, coarse sand and gravels) and so control most of the effect on SSC beyond the above durations/distances.
- Due to ongoing dispersion and the settlement of non-silt sediment to the seabed during the first half tidal cycle, the level of SSC within the spoil plume reduces rapidly with time to less than 5 mg/l after one day, and to less than 2 mg/l after three days.

- Plumes generated by spoil disposal within Array Area and Export Cable Corridor (nearshore and offshore regions) do not reach, or directly impact, any designated areas.

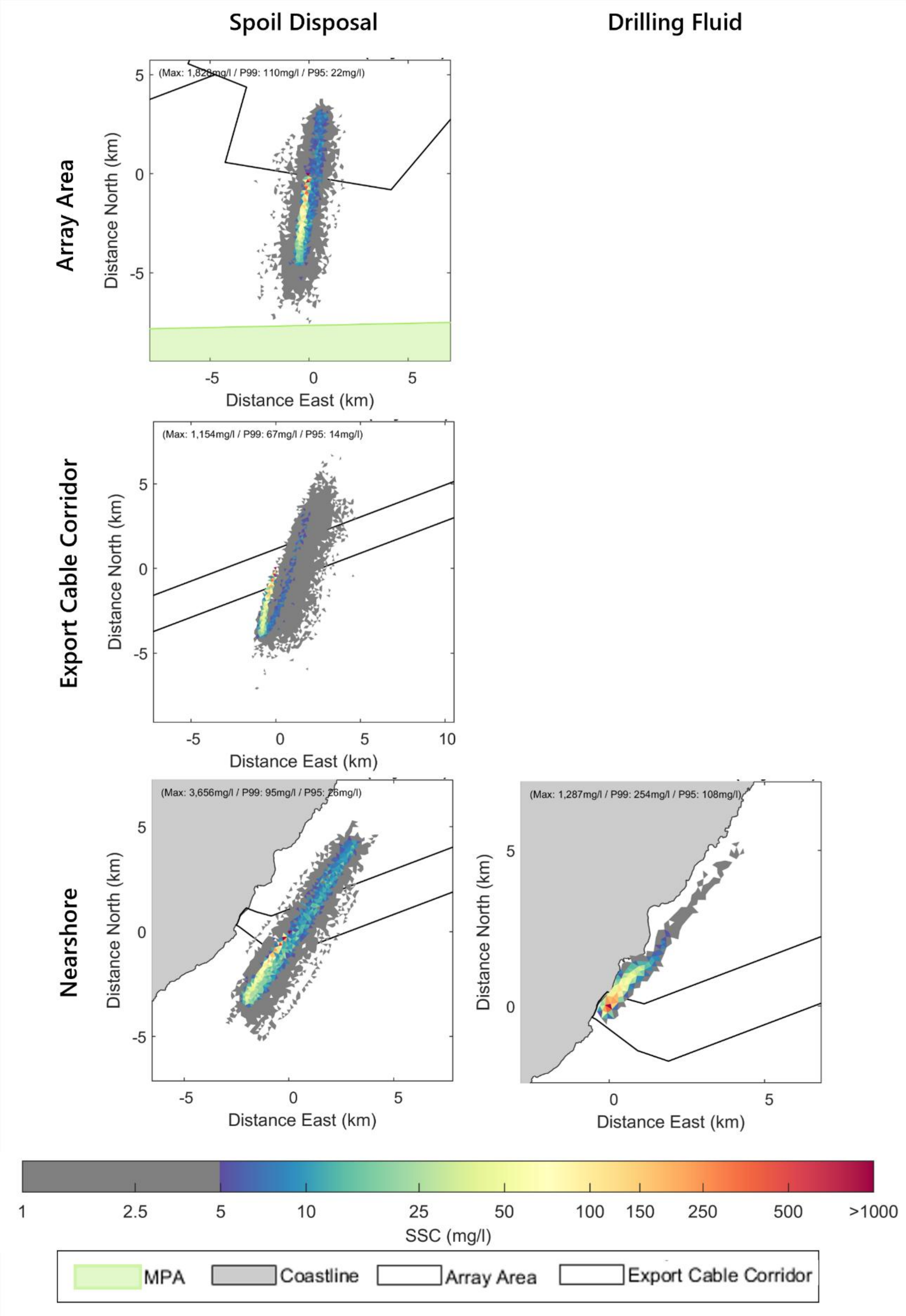

Figure 7.4: Maximum Instantaneous SSC from Shorter Duration Disturbances on a Mean Spring Tide. Dredged Sediment Releases (Left) Within the Array Area (Top), Export Cable Corridor (Middle) and Nearshore (Bottom) and Trenchless Technique Drilling Fluid Release in the Nearshore (Right)

SSC of Plumes from Drilling Fluid Discharge

7.10.23 The potential changes caused by a release of drilling fluid, which typically contain a lubricating natural clay mineral such as bentonite along with drill cuttings, at the trenchless technique punch-out near the Landfall (Figure 7.4) are set out below:

- The release of drilling will result in a localised and temporary plume of elevated SSC.
- The majority of the plume will be advected in the direction of the ambient tidal currents, which are broadly aligned to the coast. The direction of transport (either to the north-east or south-west) will depend on the state of the tide (flood or ebb) at the time of the release.
- It is expected that the plume would be dispersed to relatively low concentrations within hours of release and to background concentrations within a few tidal cycles.
- Due to the small particle size and low settling velocities, all of the bentonite released is held in suspension for days or longer and will be widely dispersed before settling. Therefore, it is not expected to accumulate anywhere in measurable thicknesses.
- If, drilling fluid and/or drill cuttings did accumulate initially in or around the trenchless technique exit pit, the volume of the pit could theoretically contain the majority of that material. Any such locally accumulated material is expected to be subsequently reworked and redistributed to not measurable concentrations and thicknesses over time by wave and tidal action.
- The lubricating clay in the drilling fluid (typically bentonite or similar) has an overall density and viscosity similar to seawater and so is expected to behave (advect, mix and disperse) in a similar manner. If the drilling fluid behaves as a slightly denser fluid, it may either accumulate in the trenchless technique exit pit or move over the adjacent seabed downslope under gravity, (i.e. in an offshore direction and away from nearshore areas).
- The bentonite plume does not reach, or directly impact, any designated areas.

Settlement Thickness Resulting from Plumes from MFE Trenching

7.10.24 Following disturbance of the seabed by MFE, it is found that:

- Coarser sand and gravel fractions at each site settle to the seabed within a limited time of release (from seconds up to five minutes, (i.e. within the ten minute timestep of the sediment plume model)) and so tend to be deposited within a relatively small footprint (from metres up to 200 m), resulting in a relatively greater local average thickness of <500 mm during spring tides in the Array Area and Export Cable Corridor; and <800 mm during neap tides.

- The maximum average sediment deposit thickness for a range of realistic downstream dispersion distances for coarse-grained material is set out in Table 7.14.
- The predicted thickness of settlement for only the finer sediments dispersed more widely in the passive phase plume is very limited, in the order of <2 mm in all sites, over a dispersed area of effect.
- Sediment accumulation of <1 mm would not cause a measurable change in bed level or sediment type in practice. Fine sediments that do settle are also likely to be subject to further erosion and dispersion during subsequent tides.
- There is no deposition due to MFE releases predicted within any of the surrounding designated areas.

Table 7.14: Maximum Average Sediment Deposit Thickness for a Range of Realistic Downstream Dispersion Distances

Downstream Dispersion Distance (m)	Maximum Average Thickness of Sediment Accumulation (mm) for Varying Trench Cross Sections		
	4 m²	5 m²	6 m²
5	800	1,000	1,200
10	400	500	600
25	160	200	240
50	80	100	120
100	40	50	60
150	27	33	40
200	20	25	30
250	16	20	24
300	13	17	20

Settlement Thickness Resulting from Plumes from Releases of Dredged Sediment

7.10.25 The actual shape and thickness of the seabed deposit resulting from the release of dredged material at the water surface cannot be predicted accurately in advance and in any case is likely to vary. A range of possible configurations of area and thickness are presented in Volume 3, Technical Appendix 7.3: Physical Processes Technical Assessment. From this range, the following examples represent a relatively widely spread deposit which is the MDS for the area of seabed affected (by a nominal average thickness of 50 mm). In practice, the deposit may comprise several individual releases from multiple dredging cycles and the deposits are likely to be relatively thicker (actual thickness dependant on the local thickness of each of the deposits in the area of overlap, which cannot be predicted in advance), with a correspondingly smaller area of effect. The results are summarised below:

- An area measuring up to 220,000 m^2 (nominally 469 m x 469 m) could potentially be covered by an average thickness of 50 mm, if up to 11,000 m^3 of material is released from a representative large hopper.
- A greater average thickness of material would lead to a smaller area of impact and vice versa. For example, a 100 mm average thickness deposit would affect an area half that described above (for an average deposition thickness of 50 mm).
- Deposits resulting from fine sediment that is much more widely dispersed in the passive phase of the plume will have an average thickness <2 mm, and therefore would not be measurable in practice. Furthermore, this material would be readily re-mobilised and dispersed further away from the release location, in the direction of the ambient tidal flow.
- There is no deposition due to passive phase spoil releases predicted within any of the surrounding designated areas.

Persistence of Spoil Mounds

7.10.26 The causes and dimensions of potential seabed deposits forming spoil mounds on the seabed is described in Paragraph 7.10.25. The persistence and evolution of these spoil mounds in either the Array Area or Export Cable Corridor will be dependent upon a range of factors, principally:

- the type of material in the mound;
- the size/shape of the mound; and
- the level of bed shear stress exerted on the mound by tidal currents and waves (water depth being a key determinant of the latter).

7.10.27 The type of material in the mound is one of the most important factors determining the persistence and evolution of a spoil mound, and this is likely to differ between the Array Area and Export Cable Corridor. For this reason, the potential evolution of spoil mounds in these two areas is considered separately, below.

Spoil Mounds in the Array Area

7.10.28 Foundations installed in the Array Area may require seabed preparation. The nature of the material to be dredged will vary, depending on foundation location within the Array Area, with some excavated material expected to largely comprise silty and gravelly sands whereas in other areas scattered boulders and glacially derived deposits are likely to be encountered (G-TEC, 2025a).

7.10.29 In those areas where spoil mounds comprise less mobile glacial material, boulders and gravels, it can reasonably be assumed that these mounds will become semi-permanent or permanent seabed features that persist for the lifetime of the Proposed Development and potentially beyond. The actual shape and thickness of spoil mounds resulting from the release of material from the dredger cannot be predicted accurately in advance and in any case is likely to vary. However, a range of possible configurations of area and thickness are presented in Volume 3, Technical Appendix 7.3: Physical Processes Technical Assessment. Over time, it can be expected that fine-grained material will be further disaggregated and winnowed away, lowering the profile of the mound. Ultimately, this could result in only (largely immobile) gravel sized material remaining, potentially forming an 'armoured' seabed layer.

7.10.30 It is noted however, that whilst the spoil mounds might be topographically different from the surrounding seabed, their surficial sediment character may be similar. This is because a thin veneer of surficial mobile sand is generally present overlying the pre-Holocene surface. This mobile sand would likely be transported onto the spoil mound, creating a similar surficial seabed type and smoothing local topography over time.

7.10.31 In those areas where spoil mounds are comprised largely of sandy material similar to the surrounding seabed, given the prevailing hydrodynamic and wave conditions, it can reasonably be expected that the sand will be re-incorporated into the sediment regime over time. The amount of time it would theoretically take to displace the volume of the mound can be broadly estimated using outputs from the baseline sediment transport model developed to inform baseline understanding (Volume 3, Technical Appendix 7.3: Physical Processes Technical Assessment). Estimates are set out in Table 7.15 for a nominal spoil mound for one full dredge hopper of ~0.5 m height with a footprint of 150 m x 150 m: given that rates of net sand transport in the Array Area are in the approximate range 0.01 to 0.1 m^3/day/m, spoil mounds comprising sand may be expected to persist (with a gradually decreasing volume) for a period of at least two years.

7.10.32 It is recognised that the timescales set out above are based on the assumption that material is removed from the mounds and not replaced by sediment transported towards the mounds. Actual timescales may therefore be longer as this assumption will not hold true for all areas. On the other hand, the estimates of mound persistence are based on sediment transport modelling which doesn't factor in the influence of waves which would naturally erode material in the mounds. This will become increasingly important in shallower water depths, such as those along inshore sections of the Export Cable Corridor, as discussed below.

Table 7.15: Indicative Estimates for the Persistence of Spoil Mounds in the Array Area and Export Cable Corridor Comprising Sand, Based on Modelled Rates of Net Tidally Driven Sediment Transport

Net rate of sediment transport (m^3/m/day)*	Time to displace mound**		
	Expressed in days	Expressed in months	Expressed in years
10	6.6	0.2	0.01
5	13.2	0.4	0.03
1	66	2.2	0.2
0.5	132	4.3	0.4
0.1	660	21.7	1.8
0.05	1,320	44	3.7
0.025	2,640	87	7.3
0.01	6,600	217	18.1

* Does not account for influence of waves which may reduce the likely time required to displace the mound.
** Based on a Spoil mound of ~0.5 m height with a nominal footprint of 150 m by 150 m.

Spoil Mounds in the Export Cable Corridor

7.10.33 Unlike within the Array Area, it can reasonably be expected that spoil mounds in the Export Cable Corridor will comprise entirely (or almost entirely) of sand. This is because any dredging will be associated with sandwave levelling/clearance and will not involve the excavation of stiff clays and gravels.

7.10.34 Estimates are set out in Table 7.15 for a nominal spoil mound for one full dredge hopper of ~0.5 m height with a footprint of 150 m x 150 m: given that rates of net sand transport in the Export Cable Corridor are in the approximate range 0.01 m^3/day/m (further offshore region) to 0.5 m^3/day/m (nearshore region), spoil mounds comprising sand may be expected to persist (with a gradually decreasing volume) for a period of 20 years in lower transport regions of the Export Cable Corridor to four months in higher transport regions of the Export Cable Corridor.

7.10.35 It is noted that the lowest rates of net (tidally driven) sediment transport are encountered further offshore, closer to the Array Area in deeper waters. Whilst net rates of tidally driven sediment transport may be low close to the Landfall, waves will also frequently stir the seabed and contribute to sediment mobility – especially during winter months where material contained within the mounds may be dispersed rapidly during storm events.

Multiple Sediment Disturbance Activities

7.10.36 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, then there is potential for overlap between the areas of change in SSC and sediment deposition. 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.

Sensitivity of the receptor

7.10.37 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.10.38 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the Offshore EIA Report, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals;
- Volume 2, Chapter 11: Offshore Ornithology;
- Volume 2, Chapter 16: Infrastructure and Other Users; and
- Volume 2, Chapter 19: Marine Archaeology.

O&M phase

Magnitude of impact

7.10.39 Potential changes to SSC, bed levels and sediment type are considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect. Instead, the potential for associated impacts to marine ecological receptors is assessed in other chapters as mentioned above.

Remedial works to installed cables

7.10.40 The repair of cables during the O&M phase is expected to result in some localised seabed disturbance accompanied by temporary increases in SSC. The MDS is for up to one IAC repair and reburial event, up to one interconnector cable repair and reburial event and up to one Offshore Export Cable repair and reburial event each year (Table 7.8). Using similar methods as those for cable installation activities.

7.10.41 The maximum length of the repair or reburial activity is 6.39 km for the Export Cable, 4.92 km for the IACs and 2.04 km for the interconnector cable; therefore, the magnitude of the impacts are expected to be far less than those quantified for the construction phase.

Sensitivity of the receptor

7.10.42 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.10.43 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals;
- Volume 2, Chapter 11: Offshore Ornithology;
- Volume 2, Chapter 16: Infrastructure and Other Users; and
- Volume 2, Chapter 19: Marine Archaeology.

Decommissioning phase

Magnitude of impact

7.10.44 Potential changes to SSC, bed levels and sediment type are considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect. Instead, the potential for associated impacts to marine biodiversity is assessed in other chapters.

7.10.45 The removal of Wind Turbine foundations is expected to result in some localised seabed disturbance accompanied by temporary increases in SSC.

7.10.46 During decommissioning cables in the Intertidal Area are likely be left *in situ*. Therefore, the area of seabed impacted during decommissioning will be less than the area impacted during the installation of the cables. If they were to be removed completely, the nature of the plume and area of seabed impacted will be similar to that described for construction.

7.10.47 For all of the above, the changes in SSC and accompanying changes to bed levels associated with decommissioning activities are expected to be less than or the same as that associated with construction.

7.10.48 The approach for decommissioning Interconnector Cables and Offshore Export Cables on the seabed is yet to be determined, however, this will be reviewed as required throughout the lifetime of the Proposed Development and best practice guidance at the time of decommissioning will be followed.

Sensitivity of the receptor

7.10.49 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.10.50 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals;
- Volume 2, Chapter 11: Offshore Ornithology;
- Volume 2, Chapter 16: Infrastructure and Other Users; and
- Volume 2, Chapter 19: Marine Archaeology.

IMPACT 2 - POTENTIAL IMPACTS TO SEABED MORPHOLOGY

7.10.51 Details of the MDS for impacts to seabed morphology are set out in Table 7.8. The closest designated area of seabed to the Proposed Development is the Firth of Forth Banks Complex MPA (which is located 6.7 km to the south of the Array Area), whilst the Offshore Export Cable makes Landfall within the Benholm to Todhead Point LNCS (Table 7.7 and Figure 7.1).

7.10.52 Megaripples and sandwaves are present in the Array Area and in some regions of the Export Cable Corridor (G-TEC, 2025a, 2025b). During the construction phase, to ensure effective burial below the level of the stable bed, it may (in places) be necessary to first remove sections of sandwaves using standard dredging techniques or through the use of a MFE, before trenching into the underlying bed. In addition to short term (minutes to a small number of days) elevations in SSC (discussed in Paragraph 7.10.18 *et seq*.), this sandwave clearance activity will not necessarily result in localised changes to seabed morphology. This section assesses the potential for longer term changes to sediment transport associated with these construction activities to impact areas of designated seabed within the Physical Processes Study Area.

7.10.53 During O&M the presence of cable protection, Wind Turbine foundations and OSP foundations all have the potential to impact seabed morphology indirectly through changes to the tidal regime (discussed separately in Paragraph 7.10.126 *et seq*.), wave regime (discussed separately in Paragraph 7.10.135 *et seq.*) and sediment transport regime (discussed separately in Paragraph 7.10.147 *et seq*.).

7.10.54 Decommissioning activities, such as removal of infrastructure, could also potentially give rise to increases in SSC (discussed in Paragraph 7.10.44 *et seq.)* as well as localised changes to morphology within the Array Area and the Export Cable Corridor. However, the potential for wider morphological change to designated seabed areas arising from these activities would be very limited and certainly no greater than that identified for the construction phase.

Construction phase

Magnitude of impact

<u>Sandwave Clearance</u>

7.10.55 Sandwaves are present in the Array Area and Export Cable Corridor. Based on understanding of the relationship between peak mean spring current speed and bedform formation (see Belderson *et al.,* 1982), the mapped sandwaves are expected to be mobile. The tidal current regime will not measurably change as a result of the localised levelling, or as a result of any other aspect of the

Proposed Development. The volume of sediment available in each local system will be locally redistributed by the levelling (via MFE and/or dredging and release of removed material back into the water column nearby) but will not change in an overall net sense. As the controlling factors will also not change, the levelled areas and sandwave features will have the potential to recover in time to a new (dynamically evolving) natural state.

7.10.56 The levelled area is considered to be 'recovered' in terms of form and function once the local crest level has re-established to a form that is within the range of natural variability observed in the other similarly sized surrounding bedforms, which may be of different dimensions than the original feature.

7.10.57 The rate and timescale of recovery will vary in proportion to the rate of sediment transport and accumulation. Faster infill and recovery rates will be associated with periods of higher local flow speeds and more frequent wave influence at the seabed. The exact timescale for recovery cannot be calculated with certainty although the following factors will all influence the rate of recovery:

- rates of bedform migration;
- the width of the dredged corridor (58.6 m);
- the wavelength of the features; and
- the volume of sediment being displaced, due to the height of sandwave features (up to ~6 m in the Array Area to ~4 m in the Export Cable Corridor).

7.10.58 Based on the available baseline evidence (set out in Volume 3, Technical Appendix 7.3 Physical Processes Technical Assessment) on rates of bedform migration and size of sandwave features, it is not unreasonable to assume that sandwave recovery may take a period of at least a decade in places.

7.10.59 The recovery may be gradual or episodic and can be expected to vary spatially. As the recovery is due to natural processes of sediment transport, the nature of the seabed surface sediments in the recovering area will not be measurably different to that on the surrounding seabed and adjacent sections of undisturbed sandwave. In all locations, surficial sediments will continue to be mobilised at the natural ambient rate and direction under sufficiently energetic current and wave conditions, with the associated development and migration of smaller (e.g. ripple and megaripple) bedforms. Where the dredge spoil is returned to the seabed in the vicinity of the dredged area, the volume and supply of sediment in the local system is not changed.

7.10.60 The levelled areas are not considered likely to create a barrier to onward sediment transport to designated seabed areas elsewhere within the Physical Processes Study Area (Figure 7.2). Evidence from aggregate dredging activities indicates that if any changes occur to the flow conditions or the wave regime, these are localised in close proximity to the dredge pocket (e.g. Anglian Offshore Dredging Association (AODA), 2011). The proposed works will be at a much smaller scale and footprint, with trench widths expected to be in the order of up to 58.6 m, in water depths of at least 40 m. This means there is likely to be little to no influence on the flow or wave regime, which in turn means little to no change to the regional scale sediment transport processes across the Array Area and Export Cable Corridor.

Cable Installation

7.10.61 The Crown Estate (TCE) (2019) carried out a desk-based review to collate information on offshore electrical cable installation techniques and seabed recovery, in support of the Plan Level HRA for Offshore Wind Leasing Round 4. The monitoring data collated indicated that cabling results in localised disturbance to seabed sediments, with the level of initial disturbance dependent on the tool used (e.g. cable ploughs typically result in minimal displacement of sediments beyond the cable trench, while jetting may result in a greater sediment displacement).

7.10.62 The evidence reviewed and presented in TCE (2019) indicated that EIA predictions largely align with the monitoring data that is available on seabed impacts and recovery and historic industry evidence reviews (e.g. BERR, 2008; MMO, 2014; Renewables Grid Initiative (RGI), 2015). For most of the projects reviewed, monitoring data showed that cable installation resulted in trenches being recorded on the seabed in the geophysical datasets, although the proportions of the cable lengths where these remnant trenches were observed was variable across the projects. The monitoring data also showed that where these trenches were recorded, they infilled over time and that where these are present on the seabed after a number of years, the large majority of trenches are shallow depressions on the seabed (e.g. up to a few tens of cm). In a small number of cases, larger changes in seabed sediments/substrates were recorded (such as clay exposures in the Humber Gateway Export Cable), but for soft sediment habitats, there was clear evidence of recovery across a variety of sediment types and installation tools.

7.10.63 On the basis of the existing evidence base, all impacts are expected to be highly localised and will not extend to designated sites.

7.10.64 Overall, the impact to designated seabed morphology arising from seabed preparation and/or cable installation would be immeasurably small. Any impact is predicted to be of local spatial extent, short to medium term duration, intermittent and of medium to high reversibility. It is predicted that the impact could only affect designated seabed areas indirectly (through the interruption of sediment transport). The magnitude is therefore considered to be negligible. This assessment of magnitude is supported by the fact that no sediment is being removed from the local sediment transport system, only redistributed. Accordingly, net rates of sediment transport to/from areas of seabed will remain unaltered from the baseline.

Sensitivity of the receptor

7.10.65 The designated areas of seabed listed in Table 7.7 contain features which are potentially vulnerable to either direct disturbance from Project-related activities or indirect disturbance from changes to waves, tides and sediment transport processes. Given that these features are largely either relict (such as the glacial bedforms in the Firth of Forth Banks Complex MPA) or in relatively inactive areas of seabed (such as the sandy sediments within the Turbot Bank

MPA), the potential for recovery generally either doesn't exist or is limited. Given the designated status of these seabed areas, they are considered to be of high value.

7.10.66 On the basis of the above, designated areas of seabed are deemed to be of high vulnerability, low recoverability and high value. The sensitivity of the receptor is therefore, considered to be high.

Significance of the effect

7.10.67 Overall, the magnitude of the impact is deemed to be negligible, and the sensitivity of the receptor is considered to be high. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Additional mitigation and residual effect

7.10.68 No Additional Mitigation is considered necessary because the likely effect in the absence of Additional Mitigation is not significant in EIA terms.

O&M phase

Magnitude of impact

Presence of Cable Protection

7.10.69 The presence of Offshore Export Cable protection berms during the O&M phase has the potential to cause changes to the local seabed level as a result of local flow interaction between the body and surface of the berm, and any near-bed current and wave action. The potential for cable protection to cause larger scale changes to the tidal, wave or sediment transport regimes is very limited, far less than the effects of the Wind Turbines and OSPs as discussed in Paragraph 7.10.126 *et seq*.

7.10.70 The purpose of cable protection is to maintain stable cover over the lifetime of the Proposed Development. By design, it aims to minimise the risk of scour associated with both the Offshore Export Cable and the protection itself. The maximum berm dimensions (10 m base width x 2 m height) result in relatively low angle slopes and a low overall height relative to the water depth, which limits the potential for form-related flow disturbance and scour, even when flows are perpendicular to the berm.

7.10.71 Turbulence may become locally elevated in water flowing close to the surface of the berm, which may result in a limited depth and extent of secondary scour (order of a few tens of centimetres deep and up to a few metres from the berm). The seabed surface in the scoured area will generally be similar to the surrounding seabed but the texture may coarsen due to preferential winnowing of finer sediment grains.

Presence of Wind Turbine Foundations and OSP Foundations

7.10.72 On the basis of the discussion of potential changes to tides (set out in Paragraph 7.10.126 *et seq*.; Figure 7.6), waves (set out in Paragraph 7.10.135 *et seq*.; Figure 7.7) and sediment transport (set out in Paragraph 7.10.147 *et seq*.), there are not expected to be any detectable changes to any of these parameters at the location of designated sites. Indeed, changes to tidal currents will be highly localised to the Array Area and immediate surroundings, whilst the reduction in wave height (Hs) is <5% at the locations of designated sites for all scenarios tested. Accordingly, the rate (and direction) of sediment transport at these sites will remain unaltered from baseline conditions and therefore there will be no associated morphological change to the seabed in these areas.

7.10.73 Overall, the impact to seabed morphology within designated sites arising from the presence of cable protection measures and/or foundations would be immeasurably small. Any impact is predicted to be of local spatial extent, long term duration, intermittent and medium reversibility. It is predicted that the impact could only affect designated seabed areas indirectly. The magnitude is therefore considered to be negligible.

Sensitivity of the receptor

7.10.74 The designated areas of seabed listed in Table 7.7 contain features which are potentially vulnerable to either direct disturbance from Project-related activities or indirect disturbance from changes to waves, tides and sediment transport processes. Given that these features are largely either relict (such as the glacial bedforms in the Firth of Forth Banks Complex MPA) or in relatively inactive areas of seabed (such as the sandy sediments within the Turbot Bank MPA), the potential for recovery generally either doesn't exist or is limited. Given the designated status of these seabed areas, they are considered to be of high value.

7.10.75 Designated areas of seabed are deemed to be of high vulnerability, low to medium recoverability and high value. The sensitivity of the receptor is, therefore, considered to be high.

Significance of the effect

7.10.76 Overall, the magnitude of the impact is deemed to be negligible and the sensitivity of the receptor is considered to be high. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Additional mitigation and residual effect

7.10.77 No Additional Mitigation is considered necessary because the likely effect in the absence of Additional Mitigation is not significant in EIA terms.

Decommissioning phase

Magnitude of impact

7.10.78 Where some or all cable protection is left *in situ* during or following the decommissioning process, the potential for changes to local seabed morphology as well as regionally, within designated areas of seabed within the Physical Processes Study Area is the same as described and assessed for the presence of cable protection during the O&M phase (Paragraph 7.10.69 *et seq.*).

7.10.79 Any impression left following the removal of infrastructure from the seabed, will be no larger than the original infrastructure and scour footprint. Depressions will become infilled and high points (comprising mobile sediment) will be levelled out by ambient sediment transport over time. The seabed sediment type will either remain or return to the ambient baseline condition within a similar or shorter time period as new sediment is deposited or underlying (previously undisturbed) sediments are exposed.

7.10.80 Overall, the impact to designated sites seabed morphology from decommissioning impacts would be immeasurably small. Any impact is predicted to be of local spatial extent, short term duration, intermittent and medium reversibility. It is predicted that the impact could only affect designated seabed areas indirectly. The magnitude is therefore considered to be negligible.

Sensitivity of the receptor

7.10.81 The designated areas of seabed listed in Table 7.7 contain features which are potentially vulnerable to either direct disturbance from Project-related activities or indirect disturbance from changes to waves, tides and sediment transport processes. Given that these features are largely either relict (such as the glacial bedforms in the Firth of Forth Banks Complex MPA) or in relatively inactive areas of seabed (such as the sandy sediments within the Turbot Bank MPA), the potential for recovery generally either doesn't exist or is limited. Given the designated status of these seabed areas, they are considered to be of high value.

7.10.82 Designated areas of seabed are deemed to be of high vulnerability, low to medium recoverability and high value. The sensitivity of the receptor is therefore, considered to be high.

Significance of the effect

7.10.83 Overall, the magnitude of the impact is deemed to be negligible, and the sensitivity of the receptor is considered to be high. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Additional mitigation and residual effect

7.10.84 No Additional Mitigation is considered necessary because the likely effect in the absence of Additional Mitigation is not significant in EIA terms.

IMPACT 3 - POTENTIAL IMPACTS TO COASTAL MORPHOLOGY

7.10.85 The Offshore Export Cables will make Landfall at Benholm beach, near Johnshaven (Figure 7.1 and Figure 7.5). The physical characteristics of the beach at the Landfall have been described in Volume 3, Technical Appendix 7.1: Physical Processes Baseline Environment. The Landfall is characterised by a rocky foreshore, with exposed linear bedrock pavements, conglomerate rock, boulders and cobbles. Areas of loose boulders and cobbles are also present on the foreshore, typically contained in channels.

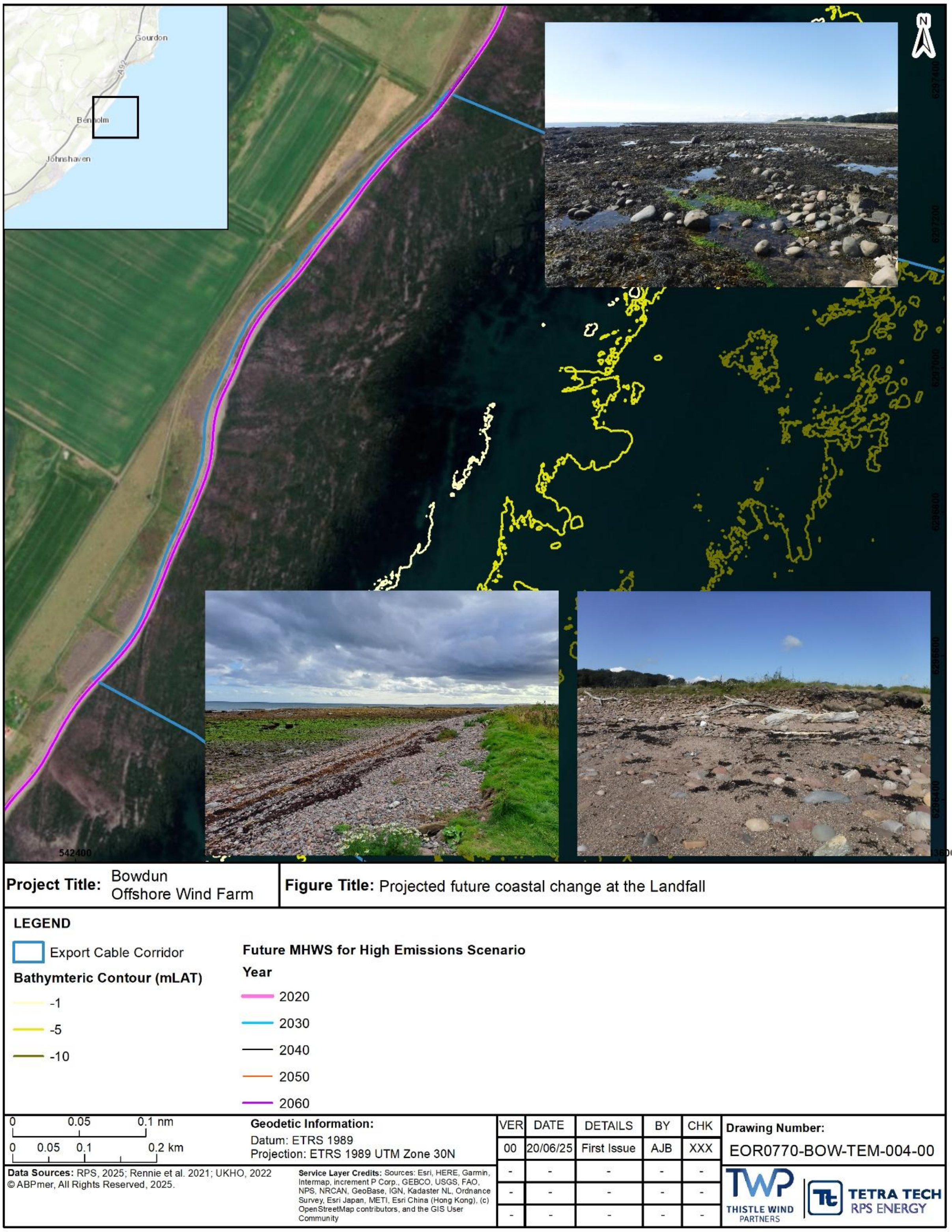

Figure 7.5: Project Future Coastal Change at the Landfall

7.10.86 The historic mapping evidence presented in Rennie *et al*. (2021) suggests that the position of MHWS has remained the same or slightly advanced in places over the past century. This pattern of stability is consistent with aerial imagery from the Landfall for the period between 2008 and 2023, available from Google Earth (Figure 7.5).

7.10.87 During the construction phase the Proposed Development could impact the coast through the following activities:

- trenchless cable installation techniques; and
- construction of trenchless technique exit pits.

7.10.88 During the O&M phase the Proposed Development could impact the coast through the following activities:

- modification of the wave regime due to Wind Turbine foundations, OSP foundations, cable and scour protection within the Array Area causing associated changes in longshore transport;
- exposure of buried Offshore Export Cables and associated infrastructure, locally modifying nearshore hydrodynamic, wave and sediment transport processes; and
- cable protection affecting wave transformation processes closer to shore.

7.10.89 During the decommissioning phase, the MDS in terms of the potential for impacts to coastal feature receptors would be the total removal of all Offshore Infrastructure (including foundations, scour protection, cables, and any cable protection).

7.10.90 The potential for the above to impact the shoreline is assessed within the following sections, through consideration of the MDS presented in Table 7.8.

Construction phase

Magnitude of impact

Trenchless Cable Installation Techniques

7.10.91 The coastline within the Landfall area is characterised by the presence of a rocky foreshore. Because of the erosion resistant nature of the coastline at the Landfall, negligible recession in the position of the MHWS contour is predicted by 2060, even under a high sea level rise scenario (Rennie *et al*., 2021).

7.10.92 Trenchless cable installation technique will be used at the Landfall, such as HDD, which is an established solution for trenchless installation and one of the most commonly used tools/methods for this type of operation. HDD (as well as other trenchless techniques) avoid direct impacts to the Intertidal Area.

7.10.93 HDD involves drilling a long borehole underground, using a drilling rig located above MHWS. 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: the length of cable ducts proposed for the Proposed Development is up to 755 m, with a burial depth of -3 m to -7 m.

7.10.94 Trenchless cable installation will cause minimal direct disturbance to the existing coastline because it will not interact directly with, or leave any infrastructure exposed in Intertidal Areas (between the entry and exit points of the drill). As such, it will not impact upon littoral processes in these areas. Provided that the cable remains buried beyond the exit point, there is no possibility for it to interact with nearshore processes or morphology. The design of the trenchless operations will take this into account.

7.10.95 The choice of location for the onshore trenchless operation works and jointing bay will take into consideration projected rates of coastal erosion to ensure that infrastructure is unaffected by the possibility of coastal retreat. However as previously stated, negligible change is anticipated (Rennie *et al.*, 2021).

Construction of Trenchless Technique Exit Pits

7.10.96 As trenchless installation is carried out between a defined start and end point, entry and exit pits (up to three) must be excavated at either end of the borehole - one in the compound above MHWS and one on the offshore side below MLWS.

7.10.97 The volume of excavated material for each exit pit is approximately 2,800 m^3 and approximately 8,400 m^3 in total. Exit pits will be excavated or dredged to the required depth, and side-cast material for backfilling will be stored adjacent to the exit pit. Once the drilling operation has taken place, the ducts will be installed in the drilled holes.

7.10.98 The potential mechanisms by which the presence of the exit pits could theoretically impact the coast at the Landfall are principally via the modification of waves and interception of sediment. Potential changes to the wave regime resulting from the presence of these exit pits in shallow subtidal areas are summarised as follows:

- changes to short period, low amplitude wind waves will be largely immeasurable at all states of the tide as the likely depth and footprint dimensions of the temporary changes to water depths will be insufficient to measurably alter short wave characteristics;
- longer period, higher amplitude storm waves could theoretically be more affected by the presence of the exit pits, possibly resulting in some wave refraction. However, the dimensions of the exit pits will be very small relative to the wavelengths of storm waves, greatly limiting the potential for measurable refraction. Any change to the wave regime will also diminish with increasing distance away from the exit pits and at higher states of the tide when water depths are greater; and
- the presence of the exit pits could potentially enable wave energy associated with storm waves to propagate slightly further inshore than would have been the case, as larger waves will shoal less, enabling them to remain marginally higher immediately in the lee of the exit pits. However as larger waves travel inshore from the exit pits, the shoreline gradient/water depths and rocky outcrops will increasingly become the limiting condition on wave form.

7.10.99 However, even with the possibility of some (highly localised) wave refraction, it is probable that only some of the waves reaching the beach will have passed across the footprint of the exit pits. Even allowing for the occurrence of waves passing across the footprint of the exit pits, associated morphological change to Intertidal Areas is expected to be limited owing to the underlying hard rock geology which is generally at or close to the surface here.

7.10.100 The exit pits are expected to be located within the theoretical active shore profile, as defined by the 'Depth of Closure'. This means that during storm events, material removed from the beach may be transported across the location of the exit pits. Given the likely high gradient of the pit side slopes, it is probable that any local material entering the pits could become trapped. This material would then not be available to replenish the beach during calmer conditions (when waves are generally constructive rather than destructive in nature).

7.10.101 The extent to which a very small section of beach morphology could potentially be altered by trapping of sediment will be dependent upon the frequency and magnitude of storms during the operational period of the exit pits, and their dimensions. If the exit pits were to be entirely infilled, this would represent up to only ~8,400 m^3 of material temporarily 'lost' from the local subtidal sedimentary system and beach. However, this is unlikely to happen given the relatively short duration of time that the exit pits will be open and operational (the Landfall works are conservatively assumed to take up to 18 months), and their distance from the beach.

7.10.102 Given that winter storms may occur during the operational period of the exit pits, it is theoretically possible that some maintenance dredging may be required prior to further access. Should this be required, any dredged material is likely to be deposited in reasonably close proximity to the exit pits. Accordingly, no mobile beach material will be lost from the local system but will instead remain available for beach resupply.

7.10.103 The impact to coastal morphology is predicted to be of local extent, short term duration, intermittent and medium reversibility. It is predicted that the impact will affect the coast indirectly. The magnitude is therefore considered to be low.

Sensitivity of the receptor

7.10.104 The coast within the Physical Processes Study Area contains both designated and undesignated features which are potentially vulnerable to either direct or indirect disturbance from Project-related activities (Table 7.7 and Figure 7.1). However, the shoreline is typically a dynamic environment which is subject to natural change under baseline conditions. Accordingly, it is assessed to have moderate capacity to recover from disturbance.

7.10.105 The coast is deemed to be of medium vulnerability, medium recoverability and medium value. The sensitivity of the receptor is therefore, considered to be medium.

Significance of the effect

7.10.106 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be medium. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Additional mitigation and residual effect

7.10.107 No Additional Mitigation is considered necessary because the likely effect in the absence of Additional Mitigation is not significant in EIA terms.

O&M phase

Magnitude of impact

Wind Turbine Foundations

7.10.108 On the basis of the discussion of potential changes to waves (set out in Paragraph 7.10.135 *et seq.*; Figure 7.7) and within Volume 3, Technical Appendix 7.3: Physical Processes Technical Assessment, there are not expected to be any detectable changes to the wave regime at the coast. The reduction in Hs is <2.5% at the coast for all scenarios tested. Accordingly, the rate (and direction) of net longshore sediment transport at the coast will remain unaltered from baseline conditions and therefore there will be no associated morphological change to the coast.

Exposure of Cables

7.10.109 As part of the Embedded Mitigation for the Proposed Development, a CBRA will be undertaken to ensure that all cables will be buried to an appropriate depth (or surface laid and protected) to minimise the chance of exposure during the lifetime of the Proposed Development. If exposure does occur, cables will be re-buried. However, no additional protection (outside that already outlined as the MDS in Table 7.8 and used as the basis for the assessment) will be applied. Where cable protection has been employed during the construction phase, this may be replenished during O&M, as necessary.

7.10.110 Once the Offshore Export Cables are buried in the (nearshore) seabed and not protected, there is no potential for cable related scour to occur. If and where the Offshore Export Cables becomes exposed due to natural seabed erosion, then a small, localised, area of additional scour may occur, as a result of currents interacting with the exposed part of the cable. The exact dimensions of the scour will depend on the height of the Offshore Export Cables relative to the seabed but will be in proportion to the relatively small diameter of the cable (up to 0.30 m diameter) and no more than described for the cable protection in Paragraph 7.10.111 *et seq.* (which states that scour could be up to a few tens of centimetres deep and up to a few metres from the cable protection).

Cable Protection

7.10.111 In nearshore subtidal areas, cable protection could potentially be used to protect the Offshore Export Cables. The exact location of cable protection and orientation relative to the beach is presently unknown. However, given the route of the Export Cable Corridor, it is probable that the long axis of the rock berms will be orientated generally across the main tidal current axis but broadly aligned with the direction of waves as they approach the coast.

7.10.112 Cable protection in shallow areas could, theoretically, work in a similar way to a submerged offshore breakwater, affecting wave transformation processes closer to shore. This, in turn, could potentially alter the wave approach to the shore, leading to wave focusing on areas of the beach not presently eroding. This could result in long-term lowering in areas where surficial mobile material is present whilst localised accretion may also occur in other areas, as material is redistributed. Where exposed bedrock platforms are present, the presence of any cable protection is not expected to lead to enhanced erosion.

7.10.113 The structures themselves could also locally intercept sediment being transported by wave and tidal driven currents. However, whilst it can reasonably be expected that there will be some localised change to waves and hydrodynamics in the immediate vicinity of the rock berms, the potential for wider morphological change at the coast at Landfall, especially to the upper beach, is considered to be very limited. This is primarily due to the fact that any rock berms would be relatively distant from the upper beach and have a relative low profile (<2 m), meaning the ability to trap sediment and modify waves would be limited. It is also noted here that Marine Guidance Note (MGN) 654 advises that changes in water depth should not exceed 5% of charted depths to ensure safety of navigation (Maritime & Coastguard Agency, 2021). This will likely be a limiting factor on cable protection height installed in shallow coastal waters at the Landfall, meaning the ability to trap sediment and modify waves would also be limited in these circumstances.

7.10.114 The impact to coastal morphology during the O&M phase is predicted to be of local spatial extent, long term duration, intermittent and medium reversibility. The impact would affect the coast indirectly. The magnitude is therefore considered to be low.

Sensitivity of the receptor

7.10.115 The coast within the Physical Processes Study Area contains both designated and undesignated features which are potentially vulnerable to either direct or indirect disturbance from Project-related activities (Table 7.7 and Figure 7.1). However, the shoreline is typically a dynamic environment which is subject to natural change under baseline conditions. Accordingly, it is assessed to have moderate capacity to recover from disturbance.

7.10.116 The coast is deemed to be of medium vulnerability, medium recoverability and medium value. The sensitivity of the receptor is therefore, considered to be medium.

Significance of the effect

7.10.117 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be medium. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Additional mitigation and residual effect

7.10.118 No additional mitigation is considered necessary because the likely effect in the absence of additional mitigation is not significant in EIA terms.

Decommissioning phase

Magnitude of impact

7.10.119 The removal of structures (especially rock protection) which have been in place for a long time could in theory, lead to longer-term effects on morphodynamics. This is because the coastal and seabed morphology could have evolved to a new equilibrium state including the influence and presence of that structure. However, it is not expected that the removal of any cable protection from shallow subtidal areas would lead to substantive morphological change. This is because the presence of any cable protection measures is not expected to result in widespread change to the beach at the Landfall in the first instance, for the reasons set out in Paragraph 7.10.111 *et seq*.

7.10.120 Should the cable system require removal at the end of its operational life, it will be removed through the same sediments and sub-strata disturbed during installation. This process could result in short term elevations in SSC and localised changes in bed level, as set out in Paragraph 7.10.44 *et seq*. Any change would be no greater in magnitude than for the construction phase. If the cables are left *in situ* at the end of the Proposed Development lifespan, impacts will be the same as those described previously for the O&M phase.

7.10.121 The impact to coastal morphology during the decommissioning phase is predicted to be of local spatial extent, short term duration, intermittent and medium reversibility. It is predicted that the impact will affect the coast directly. The magnitude is therefore considered to be low.

Sensitivity of the receptor

7.10.122 The coast within the Physical Processes Study Area contains both designated and undesignated features which are potentially vulnerable to either direct or indirect disturbance from Project-related activities (Table 7.7 and Figure 7.1). However, the shoreline is typically a dynamic environment which is subject to natural change under baseline conditions. Accordingly, it is assessed to have some capacity to recover from disturbance.

7.10.123 The coast is deemed to be of medium vulnerability, medium recoverability and medium value. The sensitivity of the receptor is therefore, considered to be medium.

Significance of the effect

7.10.124 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be medium. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Additional mitigation and residual effect

7.10.125 No Additional Mitigation is considered necessary because the likely effect in the absence of Additional Mitigation is not significant in EIA terms.

IMPACT 4 - POTENTIAL CHANGES TO THE TIDAL REGIME

7.10.126 The interaction between the tidal regime and the foundations of the Offshore Infrastructure will result in a slight reduction in current speed and an increase in levels of turbulence in a narrow, localised wake due to frictional drag and the shape of the structure. There exists a close relationship between flow speed and bedform type (Belderson *et al.*, 1982) and thus any changes to tidal flows have the potential to indirectly impact seabed morphology (including bedforms) over the lifetime of the Proposed Development.

7.10.127 Within the extent of the Array Area, 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 Wind Turbine foundations, the wake signature is expected to naturally dissipate within a distance in the order of ten to 20 obstacle diameters downstream (Li *et al.*, 2014; Cazaneve *et al.*, 2016; Rogan *et al.*, 2016). This wake length distance will be much less than the corresponding approximately 7 km to 8 km Spring Tidal Excursion distance in the Array Area – the distance over which water is displaced during each flood or ebb tide.

7.10.128 The MDS identified for the assessment is set out in Table 7.8 and corresponds to an Array Area comprising of 67 Wind Turbines on four-legged piled jacket foundations and two OSPs on six-legged piled jacket foundations. The minimum Wind Turbine spacing (centre to centre) is 1,038 m.

O&M phase

Magnitude of impact

7.10.129 Potential changes to tidal currents and water levels are considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect to them. Instead, this section focuses on describing the spatial and temporal nature of change to them, with the potential for associated impacts to marine biodiversity assessed in other chapters.

7.10.130 Hydrodynamic flow modelling has been undertaken to assess the potential extent of change to tidal currents associated with the MDS (Figure 7.6). Full details of the model used to inform the assessment are presented in Volume 3, Technical Appendix 7.2: Physical Processes Model Design and Validation.

7.10.131 The modelling results are summarised below:

- The potential for localised changes in current speed is spatially limited to narrow wakes of (slightly) reduced current speed and proportionally increased turbulence, extending downstream of individual foundations.
- Changes to current speed at the resolution of the model (at length scales greater than 100 m) will be less than 0.05 m/s (10%), which is very small in both absolute and relative terms.

- The greatest change, a reduction in current speeds, occur directly downstream of the foundation structure and are highly localised.
- The wake signature dissipates and recovers with distance downstream, becoming less than a 5% reduction (within the range of natural variability, and not measurable in practice) within ~300 m of the Wind Turbine foundation structures and within ~700 m of OSP foundation structures.
- Corresponding changes to current direction across the Physical Processes Study Area are <1°.
- Consistent with the very limited scale of change in instantaneous current speed and direction as a result of the MDS, no measurable change in residual current speed or direction is predicted either within the Array Area, or elsewhere.
- Local and regional water level variation will not be measurably affected by the presence of the Proposed Development (<0.01 m), including both tidal and non-tidal (surge) contributions.

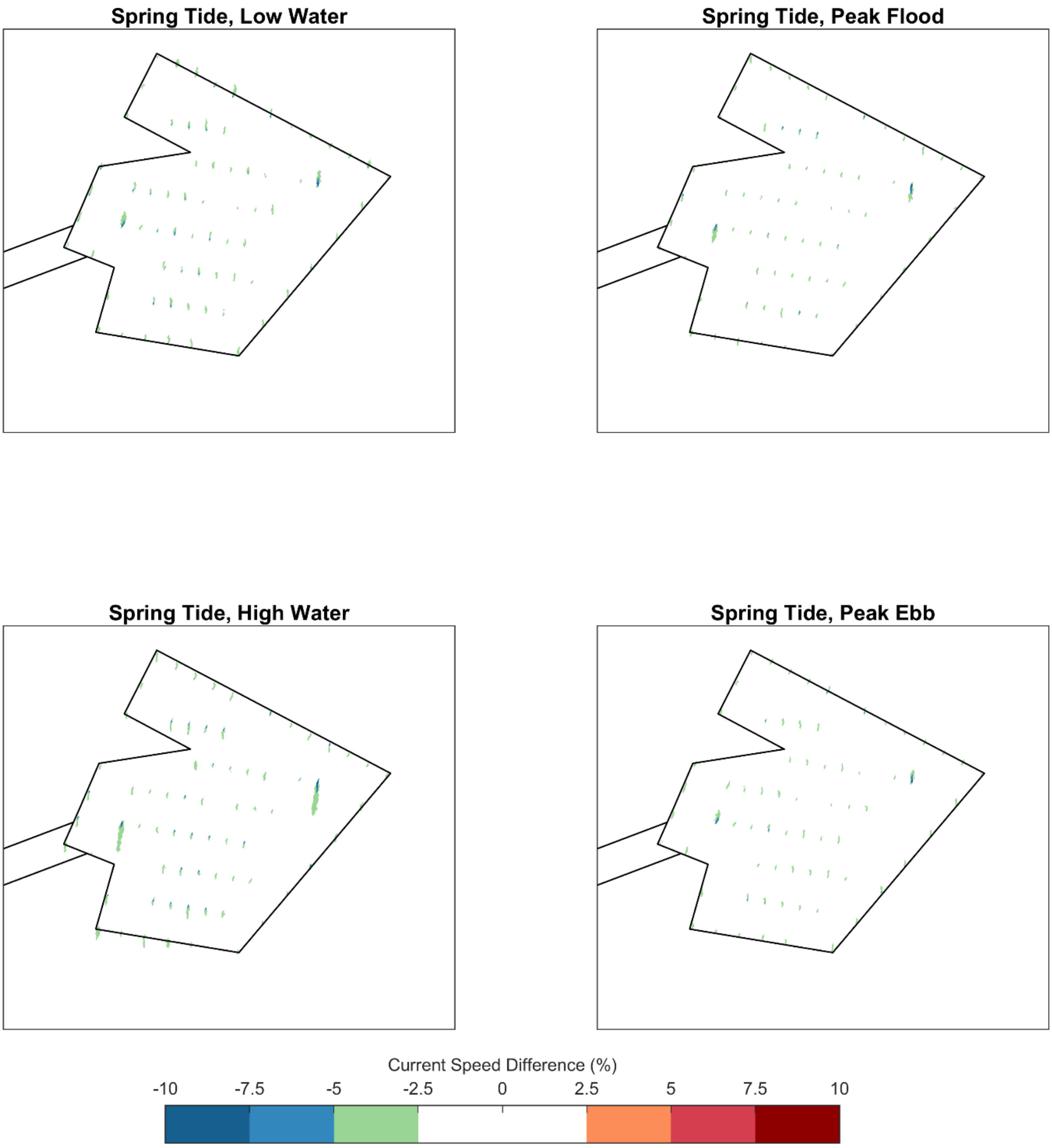

Figure 7.6: Absolute Difference in Tidal Current Speed (Scheme Minus Baseline), O&M Phase, During a Representative Spring Tidal Condition. Negative and Positive Values are a Reduction or Increase in Time Average Current Speed, Respectively, as a Result of the Installed Infrastructure: MDS for the Proposed Development

7.10.132 These conclusions are consistent with other numerical modelling studies previously undertaken to inform a wide range of UK OWF developments of comparable or larger scale (e.g. East Anglia Offshore Wind, 2012; Moray Offshore Renewables Limited, 2012; Navitus Bay Development Limited, 2014; Awel y Môr OWF Limited, 2022; Five Estuaries OWF Limited, 2024).

Sensitivity of the receptor

7.10.133 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.10.134 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals;
- Volume 2, Chapter 11: Offshore Ornithology; and
- Volume 2, Chapter 19: Marine Archaeology.

IMPACT 5 - POTENTIAL CHANGES TO THE WAVE REGIME

7.10.135 The interaction between waves and the foundations of the Proposed Development infrastructure may result in a reduction in wave energy locally around foundations. The combined changes arising from all foundations may give rise to an array-scale change that could extend outside of the Array Area and into the wider Physical Processes Study Area. Where the wave climate is important to local processes and is persistently modified, these changes may potentially alter the frequency or pattern of sediment transport and therefore seabed morphology in affected offshore areas, and/or the rate and direction of longshore sediment transport and therefore coastal morphology on affected coastlines.

7.10.136 An array comprising 67 4-legged piled jacket Wind Turbine foundations and two OSPs on 6-legged piled jacket foundations represents the MDS for the blockage of waves through the Array Area. Further details regarding the MDS are provided in Table 7.8. Cumulative blockage to the wave regime arising from operation of the Proposed Development with other planned and operational wind farms in the Physical Processes Study Area are considered separately, in Section 7.12.

O&M phase

Magnitude of impact

7.10.137 Potential changes to waves are considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect to them. Instead, this section focuses on describing the spatial and temporal nature of change to them, with the potential for associated impacts to marine biodiversity assessed in other chapters.

7.10.138 The Proposed Development has the potential to impact on the wave regime as individual waves interact with the foundation structures. The blockage caused by the foundation structures has the potential to impact on the following wave characteristics:

- wave height;
- wave period; and
- wave direction.

7.10.139 To quantify the likely magnitude and extent of interaction between the O&M phase and the wave regime, a numerical wave model has been developed (Volume 3, Technical Appendix 7.2: Physical Processes Model Design and Validation).

7.10.140 The assessment of potential changes to the wave regime has been undertaken for a series of frequently occurring and extreme return period conditions with and without the Wind Turbine foundations in place, in order to obtain a generic measure of the extent and magnitude of any change likely to occur during the lifetime of the Proposed Development. These are presented in terms of the difference between the baseline wave environment and that predicted to occur with the Proposed Development. The full set of results is presented in Volume 3, Technical Appendix 7.3: Physical Processes Technical Assessment, with a subset of results (associated with a range of frequently occurring and extreme return period conditions for easterly waves – the direction which aligns with the shortest distance to the coast) shown in Figure 7.7.

7.10.141 The assessment is informed by the ABPmer SEASTATES wave hindcast database (seastates.net), which provides hourly timeseries and derivative climatic statistics for the period January 1979 to near-present. Typically, at least 30 years of hourly data are used to describe the long-term wind and wave climate. The hindcast model is validated using historical measured wave data from ~20 coastal and offshore locations around the UK. The validity of the model (and therefore the data it produces) is not affected by the age of the historical data used for validation – only the quality and quantity of that data, which is considered sufficient.

7.10.142 Potential impacts of the Proposed Development on the wind and therefore the wave field downwind of the Array Area are normally considered to be a very low magnitude change. This is based on general understanding of the nature of the impact on the wind field, a small number of observational studies demonstrating no measurable impact (Cefas, 2007), and consistent with reasonable theoretical consideration. As such this is not normally identified or scoped into OWF marine Physical Process EIA studies as a realistically relevant potential impact.

7.10.143 From the outset, it is noted that changes of less than 5% of the baseline wave height would be indistinguishable from natural variability both within the seastate (difference between individual waves) and compared to normal rates of change (over timescales of one hour or less); such small differences would not be measurable in practice. Changes less than 2.5% are also less than the reasonably expected accuracy of the model and so are excluded from the colour scale.

7.10.144 The modelling results shown in Figure 7.7 and in Volume 3, Technical Appendix 7.3: Physical Processes Technical Assessment, are summarised below:

- Due to the cumulative effect of local interaction with individual foundations, absolute wave height is progressively decreased with distance travelled by waves through the Array Area. As a result, the maximum reduction in wave height (approximately 7.5% to 10% from baseline values) is found on the central downwind part of the Array Area.
- The maximum reduction outside of the Array Area in the full range of wave directions and return periods considered is <5%.
- The scale of the change is dependent on the particular wave height/period and the main direction of the wave energy with respect to the shape/thickness of the Array Area and the alignment of the foundations.
- The maximum corresponding changes to wave period and wave direction are less than 0.1 s and 3° respectively, at all locations, in all cases.
- Wave height begins to recover immediately downwind of the Array Area. Recovery occurs mainly due to lateral wave energy spreading from areas to the side of the Array Area where waves are less or completely unaffected by interaction with the Array Area. For smaller seastates, recovery of the dominant wave condition can also occur more rapidly as a result of ongoing wind energy input.

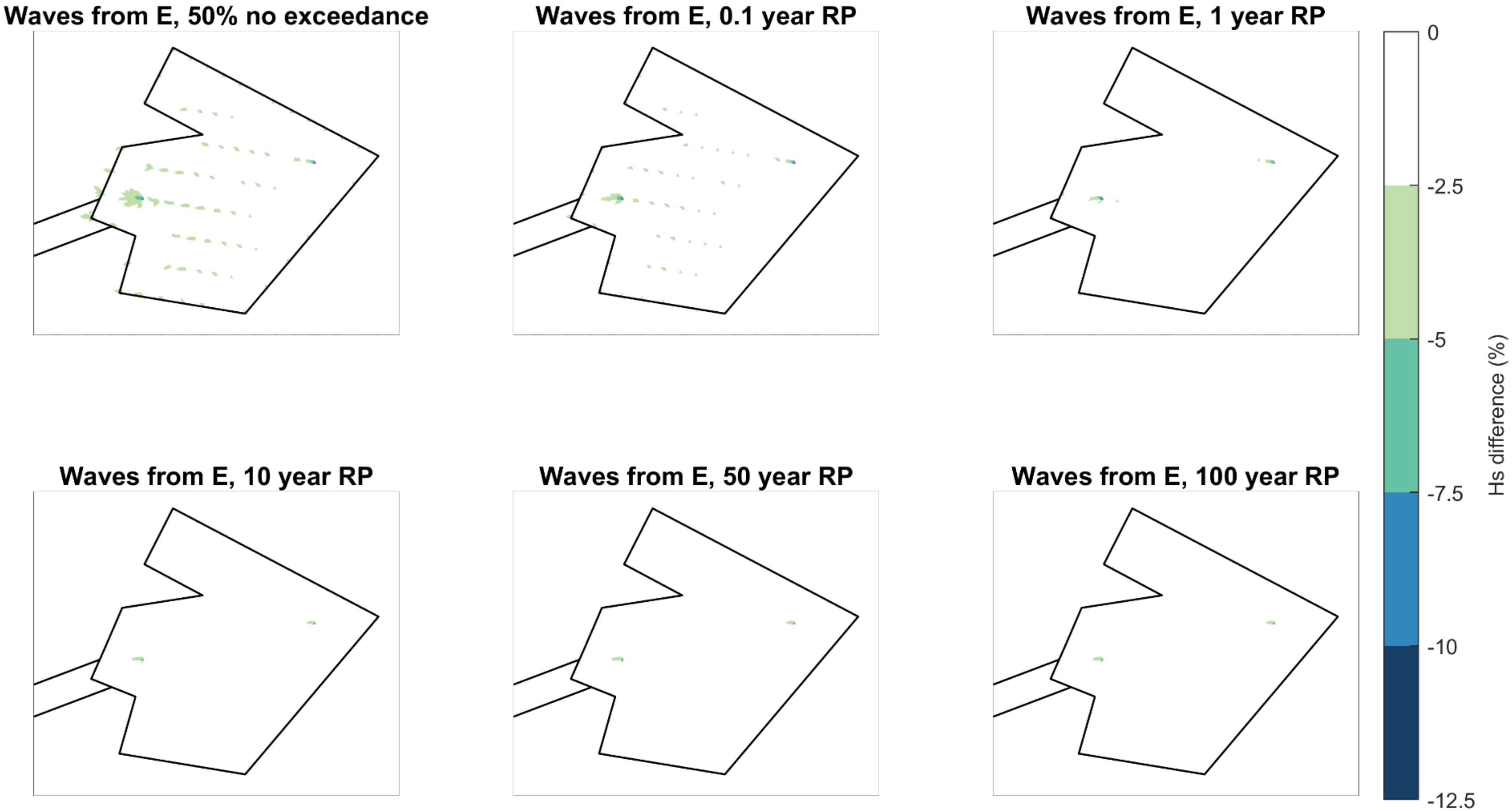

Figure 7.7: Percentage Difference in Significant Wave Height (Scheme Minus Baseline as a Proportion of Baseline Values), O&M Phase, Waves from the East (E), All Return Periods. Negative Values are a Reduction in Wave Height as a Result of the Installed Infrastructure: MDS for the Proposed Development

Sensitivity of the receptor

7.10.145 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.10.146 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals; and
- Volume 2, Chapter 11: Offshore Ornithology.

IMPACT 6 - POTENTIAL CHANGES TO THE SEDIMENT TRANSPORT REGIME

7.10.147 Modification of existing sediment transport pathways could occur in response to changes in the wave and tidal regimes resulting from the presence of

- Wind Turbine and OSP foundations; and/or
- cable protection measures.

7.10.148 The presence of cable protection measures may also have the potential to cause a direct (albeit very localised and limited volume) blockage to sediment transport. The above changes could potentially occur over a range of timescales, depending on location and the specific project infrastructure that is interacting with the sediment transport regime.

7.10.149 The MDS with respect to the potential for changes to the sediment transport regime is set out in Table 7.8.

O&M phase

Magnitude of impact

7.10.150 Potential changes to sediment transport are considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect. Instead, this section focuses on describing the spatial and temporal nature of change, with the potential for associated impacts to marine biodiversity assessed in other chapters.

<u>Wind Turbine and OSP Foundations</u>

7.10.151 Additional numerical modelling of sediment transport (driven by tidal currents) was carried out in order to consider the changes associated with the MDS for blockage due to foundations within the Array Area (described in Table 7.8). These are described in full in Volume 3, Technical Appendix 7.3: Physical Processes Technical Assessment.

7.10.152 Consistent with the very limited scale of change in instantaneous current speed and direction described in Paragraph 7.10.129 *et seq.*, no measurable change in residual sand transport rate or direction is predicted either within the Array Area, or elsewhere, at the resolution of the model (approximately 100 m). Localised narrow wake features not resolved by the model may have a similarly localised effect on the texture (but not the morphology) of the seabed within their footprint; the wake is only likely to result in changes to seabed morphology immediately around the foundation bases in the form of scour (described in Paragraph 7.10.186 *et seq.*).

7.10.153 The differences in wave height, period and direction described in Paragraph 7.10.137 *et seq.* and Figure 7.7 are small in absolute and relative terms and (as a small additional contribution to the tidally dominated transport) could only cause an even smaller change to overall instantaneous sediment transport rates or directions. The differences would not be measurable in practice and are easily within the range of natural variability in wave height from wave to wave, from hour to hour during the passage of a storm, and in the context of seasonal and interannual variation of wave climate.

7.10.154 In the areas where changes to wave height are greatest (typically within the Array Area), water depths are also relatively large (~65 mLAT) in such water depths, a minimum wave period (approximately 9 s and larger in 65 m depth) is required to penetrate deeply enough to cause any water movement at the seabed. Even longer waves in conjunction with a sufficient wave height are needed to cause sufficient motion at the seabed to contribute to sediment transport.

7.10.155 As the wave period will not be affected (by more than 0.1 s), the ability of individual waves to reach the seabed will be unaffected. Where an individual wave is large enough to reach the seabed, the predicted change in wave height (proportional to the resulting amplitude of water movement) is locally only up to 5% to 10%. The difference is therefore unlikely to result in a measurably different motion of water.

7.10.156 Finally, it is noted that on the basis of the numerical wave modelling, measurable changes to wave height (as well as period and direction) will not extend to adjacent coastlines. Accordingly, there will be no associated change in wave driven longshore sediment transport.

<u>Cable Protection</u>

7.10.157 Installation of cable protection could result in a local increase in the elevation of the seabed (Table 7.8). Cable protection would be placed onto the seabed surface above the cable and therefore could directly trap sediment, locally impacting down drift locations.

7.10.158 The monitoring data reviewed in TCE (2019) presented little or no information on the effects of cable protection either on the seabed or on associated benthic ecology communities (e.g. colonisation of installed protection measures). However, research initiatives are currently underway which should help address this data gap.

7.10.159 Following installation and under favourable conditions, an initial period of sediment accumulation would be expected to occur against cable protection measures which could have a height of up to 2 m above the bed (Table 7.8). This accumulation would likely create a smooth slope against the cable protection. The process of wedge formation may take place over a period of a few weeks to months, depending on rates of sediment transport.

7.10.160 Sandy sediments are transported in two modes: bedload and saltation. Saltation is the process by which sands are moved up into the water column. These suspended sands would be expected to move relatively freely over the top of the armour although to begin with would regularly be deposited upon it, filling void spaces. 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 bed form migration) will remain unaffected.

7.10.161 The process of void infilling is expected to occur relatively quickly (in the order of a few months). This is due to saltation as well as the anticipated high rates of transport in areas of mobile seabed (which is where much of the cable protection is anticipated).

7.10.162 Bedload is the process by which sands move while still in contact with the seabed. Bedload will be temporarily affected up until such time that the armour is covered by sand and the slope gradient either side has been reduced in response to the accumulation of a sediment wedge with stable slope angles (approximately 30°). Following this, bedload will continue because the slope angle presented by sections of protected cable would be within the natural range of bed slope angles associated with bed forms mapped within the Array Area.

7.10.163 Accordingly, for all areas in which cable protection is used (including where sandwaves are present), it is not expected that the presence of the cable protection devices will continuously affect patterns of sediment transport following the initial period of accumulation. It follows that any changes on seabed morphology away from the cable protection will also be very small. The extent of the cable protection measures does not constitute a continuous blockage along the Export Cable Corridor.

Sensitivity of the receptor

7.10.164 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.10.165 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals; and
- Volume 2, Chapter 11: Offshore Ornithology.

IMPACT 7 - POTENTIAL CHANGES TO STRATIFICATION AND FRONTAL SYSTEMS

7.10.166 As currents move water past the individual substructures, a turbulent wake is formed. Within the turbulent wake, vertical mixing can be enhanced above ambient levels: the full depth draft of fixed foundations penetrates the thermocline and directly mix seasonally stratified water passing in close proximity. This increase in turbulence intensity has the potential to contribute to a local reduction in the strength of vertical stratification and change the position of tidal mixing fronts (e.g. Carpenter *et al*., 2016; Cazenave *et al*., 2016; and Dorrell *et al*., 2022).

7.10.167 In addition to the potential for direct disturbance of the water column by Offshore Infrastructure, it has also been suggested that atmospheric wakes associated with Wind Turbines have the potential to affect sea surface currents, altering the temperature and salinity distribution in areas of wind farm operation (Christiansen *et al*., 2022).

7.10.168 This section considers the potential for structures (Wind Turbine and OSP) within the Array Area to influence regional scale patterns of stratification via the mechanisms outlined above and any resulting change in the location of fronts. It is a summary of a more detailed assessment presented in Volume 3, Technical Appendix 7.4: Assessment of Potential Changes to Stratification and Frontal Systems.

7.10.169 The methodological approach is similar to that adopted by Carpenter *et al*. (2016) and uses empirical equations to estimate two key timescales: the mixing timescale, which predicts the time required for complete mixing of stratified layers due to increased TKE generated by the foundations, and the advective timescale, which quantifies how long a water parcel remains within the Array Area, experiencing enhanced TKE.

O&M phase

Magnitude of impact

7.10.170 Potential changes to stratification and frontal systems are considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect to them. Instead, this section focuses on describing the spatial and temporal nature of change to them, with the potential for associated impacts to marine biodiversity assessed in other chapters.

7.10.171 The baseline characteristics of stratification and tidal mixing fronts have been described in detail within Volume 3, Technical Appendix 7.4: Assessment of Potential Changes to Stratification and Frontal Systems and is summarised below:

- The Array Area experiences weak seasonal stratification, with significant tidal, seasonal and interannual variability.
- The boundary between weakly stratified and more strongly stratified waters occurs to the east of the Array Area and supports higher levels of primary production, indicative of a tidal mixing front.
- In contrast, the Array Area itself is characterised by weaker stratification and lower levels of primary productivity.
- Model projections suggest that by 2100, the thermal stratification period in UK shelf seas will extend by approximately two weeks, with stratification occurring about one week earlier and breaking down five to ten days later than present (Sharples *et al.,* 2022).
- Climate warming is also expected to lead to more frequent Marine Heat Waves. These will act to strengthen seasonal stratification through more intense heating of the surface ocean (Sharples *et al.,* 2025).

7.10.172 The assessment of potential changes to stratification and frontal systems caused by the Proposed Development is set out in Volume 3, Technical Appendix 7.4: Assessment of Potential Changes to Stratification and Frontal Systems. This indicates that the Proposed Development will have very limited impacts, with effects falling within the range of natural variability.

7.10.173 The installation of Wind Turbine foundations will generate additional turbulence alongside naturally occurring turbulence generated at the seabed by tidal currents and the surface by wind/wave action. The foundation induced TKE will enhance vertical mixing in the water column, acting to weaken stratification. However, this mixing effect is expected to be spatially limited, occurring in narrow wakes extending downstream of Wind Turbine foundations.

7.10.174 The estimated mixing timescales for the Array Area for weaker (2015), intermediate (2012) and stronger (2023) stratification years are given in Table 7.16. The estimated time a water parcel spends within the Array Area experiencing enhanced mixing is 13.9 days. This indicates that a parcel of water is not exposed to the elevated TKE from OWF structures for a sufficiently long time to completely break down the stratification present in the water column, even for more weakly stratified years such as 2015.

Table 7.16: Mixing Timescales for Stronger (2023), Intermediate (2012) and Weaker (2015) Stratification Years

	Stronger stratification year	Intermediate stratification year	Weaker stratification year
Year	2023	2012	2015
T_{mix} (days)	40.2	26.8	20.1
T_{adv} (days)	13.9	13.9	13.9
T_{adv}/T_{mix}	0.35	0.52	0.69

7.10.175 To better understand the predicted impact in the context of natural variability, hourly PEA values were calculated for the Array Area during the peak stratification month of July 2023. Stratification strength fluctuates significantly over short timescales, with variations of in PEA of ±15 J/m³ within a tidal cycle (12 hours). This indicates that the stratification weakening caused by elevated turbulent mixing in the wake of Wind Turbine foundation structures falls within the natural variability of the system.

7.10.176 The Proposed Development is not expected to significantly influence the timing of seasonal stratification or the positioning of tidal mixing fronts. While additional mixing may theoretically delay the onset of stratification in spring or accelerate its breakdown in autumn, any changes would be subtle and fall within the bounds of natural variability. Similarly, shifts in frontal systems—regions where mixed and stratified waters meet—are expected to be highly localised.

7.10.177 Effects on primary production and the wider ecosystem are also expected to be minimal. The most productive area, located east of the Array Area at the boundary between areas of relatively weaker and more strongly stratified waters, is located outside the direct influence of the Array Area, with no clear hydrodynamic pathway connecting the two locations.

7.10.178 Finally, some modelling studies provide theoretical evidence for atmospheric OWF wakes to effect water column stratification through changes in near-surface wind speeds (e.g. Christiansen et al., 2022). However, these findings are based on the presence of a large number of wind farms with several hundred Wind Turbines in place across the model domain. The Proposed Development is small in comparison and the scale of these changes is expected to be very limited.

7.10.179 Whilst Christiansen et al. (2022) provides some evidence on the effects of Wind Turbines on near surface wind speeds and water column mixing. It is noted that this work focused on a region of the North Sea that does not strongly seasonally stratify, so is not completely analogous to the location of the Array Area. Other literature and methodology focusing on this wind wake effect on mixing and stratification is limited. Therefore, some uncertainty remains regarding the potential impact in the northern North Sea.

Sensitivity of the receptor

7.10.180 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.10.181 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals; and
- Volume 2, Chapter 11: Offshore Ornithology.

IMPACT 8 – POTENTIAL FOR SCOUR OF SEABED SEDIMENTS

7.10.182 The term scour refers here to the development of pits, troughs, or other depressions in the seabed sediments around the base of Wind Turbine and OSP foundations. Minor scour might also occur at the edges of scour protection for foundations and cables, including cable crossings. 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 flow (depth, magnitude, orientation and variation including tidal currents, waves, or combined conditions); and
- seabed sediment (geotextural and geotechnical properties).

7.10.183 Scour assessment for EIA purposes is considered here for four foundation types: piled jacket foundations (a 4-legged version); piled jacket foundations (a 3-legged version); suction bucket jacket (a 3-legged version) and monopile foundations. The potential concerns include the seabed area that may be modified from its natural state (potentially impacting sensitive receptors through habitat alteration) and the volume and rate of additional sediment resuspension, as a result of scour.

7.10.184 The seabed area directly affected by scour may be modified from the baseline or ambient state in several ways, including:

- a different (coarser) surface sediment grain size distribution could develop due to winnowing of finer material by the more energetic flow within the scour pit;
- seabed slopes could be locally steeper in the scour pit; and
- flow speed and/or turbulence would be locally elevated, on average.

7.10.185 The scale of change would vary depending upon the foundation type, the local baseline oceanographic and sedimentary environments and the type of scour protection implemented (if needed). In some cases, the modified sediment character within a scour pit may not be so different from the surrounding seabed. However, changes relating to bed slope and elevated flow speed and (near-field) turbulence are still likely to apply. As such, depending upon the sensitivities of the particular ecological receptor, not all scouring necessarily correspond to a loss of habitat. This is discussed further in Volume 2, Chapter 8: Benthic Ecology.

O&M phase

Magnitude of impact

7.10.186 Potential scouring of the seabed is considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect. Instead, this section focuses on describing the spatial and temporal nature of change, with the potential for associated impacts to marine biodiversity assessed in other chapters.

7.10.187 To quantify the area of seabed that might be affected by scour (either the footprint of scour or scour protection), the following provides an estimate of the theoretical maximum depth and extent of scour. This assessment is based upon empirical relationships described in Whitehouse (1998) and more recent observations summarised in Deltares (2023). Volume 3, Technical Appendix 7.3: Physical Processes Technical Assessment provides a full description of the scour assessment methods and results summarised below. Importantly, these estimates are highly conservative as they assume an unlimited depth of erodible sediment at all final foundation locations. In practice, the more erosion resistant material (e.g. boulders inferring glacially derived deposits) in some areas, will naturally limit the maximum potential scour depth and volume for foundations located in these areas.

7.10.188 Results conservatively assume that the maximum likely ('equilibrium') scour dimensions are present around the perimeter of the structures. Derivative calculations of scour extent, footprint and volume assume an angle of internal friction of 32°. Scour extent is measured from the structure's edge. Scour footprint excludes the footprint of the structure. Scour pit volumes for jacket foundation structures are calculated as the sum of the volume of an inverted truncated cone, minus the structure volume, for each of the corner piles.

7.10.189 The term 'local scour' refers to the local response to individual structure members. 'Global scour' refers to a region of shallower but potentially more extensive scour around or associated with a multi-member foundation resulting from the change in flow velocity through the gaps between members of the structure and turbulence shed by the entire structure. Global scour does not imply scour at the scale of the Array Area.

7.10.190 Key findings are summarised below and in Table 7.17 and Table 7.18.

- Overall, scour development within the Array Area is expected to be dominated by the action of tidal currents.
- In practice, the thickness of unconsolidated (and more easily erodible) surficial Holocene sediment is relatively thin (0 m to 2 m thick), or absent).
- Of all the Wind Turbine foundation options under consideration, a 15 m diameter monopile has the potential to cause the greatest equilibrium local scour depth (19.5 m), footprint (4,530 m^2) and volume (up to 34,224 m^3), but only in areas where the seabed is potentially erodible by the action of scour to that depth.

- The greatest individual Wind Turbine foundation global scour footprint is associated with the 3-legged jacket foundation, with 43 m base and 4.5 m diameter legs (5,750 m^2), although with a relatively small average depth (1.8 m).
- for the Array Area as a whole, the greatest total foundation local scour footprint is associated with an array of 67 x 15 MW Wind Turbine monopile foundations (13 m diameter) and three OSP 4-legged jacket foundations (48 m base, 4.5 m near bed diameter) (232,894 m^2), equivalent to only approximately 0.125% of the total Array Area; and
- for the Array Area as a whole, the greatest total Wind Turbine foundation global scour footprint is associated with an array of 67 Wind Turbine on three-legged piled jacket foundations (37 m base, 3.3 m diameter legs) and three OSP four-legged piled jacket foundations (48 m base, 4.5 m near bed diameter) (307,012 m^2), equivalent to only approximately 0.164% of the total Array Area.

7.10.191 Where scour protection is used, primary scour is unlikely to occur, although a small amount of secondary scour may develop at the edges of the scour protection in response to the interaction between the scour protection materials and foundation, and the hydrodynamic and sediment transport regimes. However, the extent and volume of secondary scour will be considerably less than that described for the multileg jacket foundations.

7.10.192 The footprint area of scour protection is also considered. At most, the maximum footprint of scour protection for the MDS (which is an array comprising 67 x 15 MW with 13 m diameter monopile Wind Turbine foundations and two OSP foundations) is equivalent to only approximately 0.119% of the Array Area (0.124% including the footprint of the foundations also).

7.10.193 Scour depth can vary significantly under combined current and wave conditions through time (Harris *et al.*, 2010). Monitoring of scour development around monopile foundations in UK OWF sites suggest that the timescale to achieve equilibrium conditions can be of the order of 60 days in environments where the seabed is mobile (Harris *et al.*, 2011). These values account for tidal variations as well as the influence of waves. (Near) symmetrical scour will only develop following exposure to both flood and ebb tidal directions.

7.10.194 Under waves or combined waves and currents an equilibrium scour depth for the conditions existing at that time may be achieved over a period of minutes, whilst typically under tidal flows alone equilibrium scour conditions may take several months to develop.

7.10.195 Any elevations in SSC because of scour will be short lived and localised and within the range of natural variability.

7.10.196 Finally, highly localised scour may also occur in areas where rock placement is used to protect cables. The raised profile of the cable protection may cause a limited amount of localised secondary scouring at the edges of the protection in line with the dominant flow or wave direction. The depth and extent of scour will be limited in proportion to the diameter of the individual rocks used (typically graded between 0.05 m to 0.5 m) which may be reduced by embedment or settling over time.

Table 7.17: Summary of Predicted Maximum Scour Dimensions for Largest Individual Wind Turbine Foundation Structures

Parameter		Foundation Type							
		4-legged Jacket on Piles (35 m base, 3.1 m diameter) 67 x 15 MW option	4-legged Jacket on Piles (41 m base, 4.3 m diameter) 40 x 25 MW option	3-legged Jacket on Piles (37 m base, 3.3 m diameter) 67 x 15 MW option	3-legged Jacket on Piles (43 m base, 4.5 m diameter) 40 x 25 MW option	3-legged Jacket on SB (37 m base, 3.3 m diameter) 67 x 15 MW option	3-legged Jacket on SB (43 m base, 4.5 m diameter) 40 x 25 MW option	Monopile (13 m diameter) 67 x 15 MW option	Monopile (15 m diameter) 40 x 25 MW option
Equilibrium Scour Depth* (m)	**Steady current**	4	5.6	4.3	5.9	4.9	6.7	16.9	19.5
	Waves	Insufficient for scour	Insufficient for scour	Insufficient for scour	Insufficient for scour	Insufficient for scour	Insufficient for scour	Insufficient for scour	Insufficient for scour
	Waves and current	4	5.6	4.3	5.9	4.9	6.7	16.9	19.5
	Global scour	1.24	1.72	1.32	1.8	1.32	1.8	NA	NA
Extent from foundation (m)**	**Local scour**	6.4	8.9	6.9	9.4	7.9	10.8	27	31.2
	Global scour	35	41	37	43	37	43	NA	NA
Footprint (m^2)**	**Structure alone**	45	79	40	59	681	851	133	177
	Local scour (exc. structure)	831	1,568	710	1,267	1,852	3,020	3,403	4,530
	Global scour (exc. structure)	3,803	5,202	4,261	5,750	3,620	4,958	NA	NA
Volume (m^3)**	**Local scour (exc. structure)**	1,208	3,225	1,093	2,772	1,572	3,986	22,279	34,224
	Global scour (exc. Local scour and structure)	4,716	8,948	5,625	10,350	4,778	8,925	NA	NA

* Results assume erodible bed and absence of geological controls
** Based upon the scour depth for steady currents. Footprint and volume values are per foundation.

Table 7.18: Total Seabed Footprint of the Different Foundation Types With and Without Scour

Parameter	Foundation Type							
	4-legged Jacket on Piles (35 m base, 3.1 m diameter) 67 x 15 MW option	4-legged Jacket on Piles (41 m base, 4.3 m diameter) 40 x 25 MW option	3-legged Jacket on Piles (37 m base, 3.3 m diameter) 67 x 15 MW option	3-legged Jacket on Piles (43 m base, 4.5 m diameter) 40 x 25 MW option	3-legged Jacket on SB (37 m base, 3.3 m diameter) 67 x 15 MW option	3-legged Jacket on SB (43 m base, 4.5 m diameter) 40 x 25 MW option	Monopile (13 m diameter) 67 x 15 MW option	Monopile (15 m diameter) 40 x 25 MW option
Maximum number of foundations	67 Wind Turbine + 3 OSP	40 Wind Turbine + 3 OSP	67 Wind Turbine + 3 OSP	40 Wind Turbine + 3 OSP	67 Wind Turbine + 3 OSP	40 Wind Turbine + 3 OSP	67 Wind Turbine + 3 OSP	40 Wind Turbine + 3 OSP
Seabed footprint of all foundations (m^2)	3,207	3,352	2,872	2,552	45,819	34,232	9,083	7,260
Proportion of Array Area* (%)	0.002	0.002	0.002	0.001	0.025	0.018	0.005	0.004
Seabed footprint of all local scour (m^2)	60,570	67,613	52,463	55,573	128,977	125,693	232,894	186,093
Proportion of Array Area* (%)	0.032	0.036	0.028	0.030	0.069	0.067	0.125	0.100
Seabed footprint of all foundations + local scour (m^2)	63,777	70,965	55,335	58,125	174,796	159,925	241,977	193,353
Proportion of Array Area* (%)	0.034	0.038	0.030	0.031	0.093	0.086	0.129	0.103
Seabed footprint of all global scour (m^2)	276,326	229,605	307,012	251,525	264,065	219,845	NA	NA

Parameter	Foundation Type							
	4-legged Jacket on Piles (35 m base, 3.1 m diameter) 67 x 15 MW option	4-legged Jacket on Piles (41 m base, 4.3 m diameter) 40 x 25 MW option	3-legged Jacket on Piles (37 m base, 3.3 m diameter) 67 x 15 MW option	3-legged Jacket on Piles (43 m base, 4.5 m diameter) 40 x 25 MW option	3-legged Jacket on SB (37 m base, 3.3 m diameter) 67 x 15 MW option	3-legged Jacket on SB (43 m base, 4.5 m diameter) 40 x 25 MW option	Monopile (13 m diameter) 67 x 15 MW option	Monopile (15 m diameter) 40 x 25 MW option
Proportion of Array Area* (%)	0.148	0.123	0.164	0.135	0.141	0.118	NA	NA
Seabed footprint of all scour protection (m²)	189,491	162,880	177,580	144,492	221,100	144,000	222,306	176,720
Proportion of Array Area* (%)	0.101	0.087	0.095	0.077	0.118	0.077	0.119	0.095
Seabed footprint of all foundation + scour protection (m²)	192,698	166,232	180,452	147,044	266,919	178,232	231,389	183,980
Proportion of Array Area* (%)	0.103	0.089	0.097	0.079	0.143	0.095	0.124	0.098

* Total Array Area = 186.98 km²

Sensitivity of the receptor

7.10.197 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.10.198 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology.

7.11 Inter-Related Effects

7.11.1 A description of the likely inter-related effects arising from the Proposed Development on Physical Processes is provided in Volume 2, Chapter 23: Inter-Related Effects.

7.11.2 Inter-relationships are considered to be the impacts and associated effects of different aspects of Bowdun OWF on the same receptor. Inter-related effects are considered to be either:

- lifetime effects: Assessment of the scope for effects that occur throughout more than one phase of Bowdun OWF (construction, O&M and decommissioning), to interact to potentially create a more significant effect on a receptor than if just assessed in isolation in these three project stages (e.g. underwater sound effects from piling, operational Wind Turbines, vessels and decommissioning); or
- 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 Infrastructure and Other Users, such as displacement of recreational activities and impacts to cables or pipelines or restrictions on access to these assets, 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 effects, or incorporate longer-term effects.

7.11.3 For physical processes, the following potential impacts have been considered within the inter-related assessment:

- project lifetime effects: potential changes to SSC, bed levels and sediment type;
- project lifetime effects: potential impacts to seabed morphology;
- project lifetime effects: potential impacts to coastal morphology;
- project lifetime effects: potential changes to the tidal regime;
- project lifetime effects: potential changes to the wave regime;
- project lifetime effects: potential changes to the sediment transport regime;

- project lifetime effects: potential changes to stratification and frontal systems; and
- project lifetime effects: potential for scour to seabed sediments.

7.11.4 Table 7.20 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, O&M phase, and decommissioning of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for physical processes receptors.

7.11.5 As noted above, effects on physical processes also have the potential to have secondary effects on other receptors and these effects are fully considered in the topic-specific chapters. These receptors and effects are summarised in Table 7.19.

Table 7.19: Receptors and Secondary Effects Matrix

Receptor and Chapter	Effect – Potential Changes to:			
	SSC	Bed levels	Seabed morphology	Stratification
Volume 2, Chapter 8: Benthic Ecology	✓	✓	✓	×
Volume 2, Chapter 9: Fish and Shellfish Ecology	✓	✓	×	✓
Volume 2, Chapter 10: Marine Mammals	✓	✓	×	✓
Volume 2, Chapter 11: Offshore Ornithology	✓	×	×	✓
Volume 2, Chapter 16: Infrastructure and Other Users	✓	✓	✓	×
Volume 2, Chapter 19: Marine Archaeology	✓	✓	✓	×

Table 7.20: Summary of Likely Significant Inter-Related Effects for Physical Processes from Individual Effects Occurring Across the Construction, O&M and Decommissioning Phase of the Proposed Development (Project Lifetime Effects) and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase			Likely Significant Inter-Related Effects
	C	O	D	
Project Lifetime Effects				
Potential changes to SSC, bed levels and sediment type	✓	×	✓	**This change relates to a pathway, rather than an impact on a receptor. Accordingly, no statement is made with regards to the likelihood of Significant Inter-Related Effects** The effects of increased SSC caused by seabed disturbance will primarily occur during the construction and decommissioning phases of the Proposed Development. The spatial extent of meaningful seabed disturbance and associated increase of SSC and deposition is expected to be localised, mainly within the near-field and intermediate impact zones of the activity (up to 500 m). The cumulative effects of the impact over the Proposed Development lifetime are not expected to result in greater significance than those assessed separately.
Potential impacts to seabed morphology	✓	✓	✓	**No Likely Significant Inter-Related Effects** The morphology of designated areas of seabed and the coast could theoretically be subject to the Proposed Development lifetime inter-related effects, with direct seabed disturbance occurring in the construction and decommissioning phase and indirect disturbance occurring during the O&M phase due to hydrodynamic, wave and sediment transport blockage related effects. However, in all cases the extent of change is expected to be negligible and even if combined over the Proposed Development lifetime, the magnitude of change (and therefore overall significance of effect) would be no greater than if assessed in isolation.
Potential impacts to coastal morphology	✓	✓	✓	
Potential changes to the tidal regime	✓	✓	✓	**This change relates to a pathway, rather than an impact on a receptor. Accordingly, no statement is made with regards to the likelihood of Significant Inter-Related Effects** Changes to the tidal, wave and sediment regime will be greatest when all Proposed Development infrastructure is in place. Although some change may occur during the construction and decommissioning phase (when the Proposed Development is partially built/decommissioned), the cumulative effects of the impact over the Proposed Development lifetime are not expected to result in greater significance than those assessed separately.
Potential changes to the wave regime	✓	✓	✓	
Potential changes to the sediment transport regime	✓	✓	✓	
Potential changes to stratification and frontal systems	✓	✓	✓	**This change relates to a pathway, rather than an impact on a receptor. Accordingly, no statement is made with regards to the likelihood of Significant Inter-Related Effects** Changes to stratification will be greatest when all Proposed Development infrastructure is in place. Although some change may occur during the construction and decommissioning phase (when the Proposed Development is partially built/decommissioned), the cumulative effects of the impact over the Proposed Development lifetime are not expected to result in greater significance than those assessed separately.
Potential for scour to seabed sediments	✓	✓	✓	**This change relates to a pathway, rather than an impact on a receptor. Accordingly, no statement is made with regards to the likelihood of Significant Inter-Related Effects** The greatest scour footprint will likely occur when all Proposed Development infrastructure is in place. Although scour may occur during the construction and decommissioning phase (when the Proposed Development is partially built/ decommissioned), the cumulative effects of the impact over the Proposed Development lifetime are not expected to result in greater significance than those assessed separately.
Receptor-led Effects				
[None identified]	NA	NA	NA	The different physical processes studied are already inter-related; in particular, sediment transport is dependent on currents and waves and therefore these linked processes have already been considered within the assessment. In turn, this information on changes to physical processes has been used to inform other EIA Report topics. Assessments have been undertaken separately within these individual topic chapters and are not reported here as additional inter-relationships.

*Proposed Development phase refers to construction (C), O&M (O) and decommissioning (D).

7.12 Cumulative Effects Assessment

Methodology

7.12.1 The CEA assesses the impact associated with the Proposed Development together with other relevant projects and activities. Cumulative effects are defined as the effect of the Proposed Development in combination with the effects from a number of different projects, on the same receptor or resource. Further details on CEA methodology are provided in Volume 1, Chapter 4: Environmental Impact Assessment Methodology.

7.12.2 The projects selected as relevant to the CEA presented within this chapter are based upon the results of a screening exercise, Volume 3, Technical Appendix 4.4: Cumulative Effects Assessment - Screening, which provides further information in relation to other projects and how this information is obtained and applied to the assessment. Each project has been considered on a case-by-case basis for screening in or out of this chapter's assessment based upon data confidence, effect-receptor pathways and the spatial/temporal scales involved.

7.12.3 In undertaking the CEA for the Proposed Development, it is important to bear in mind that other projects under consideration will have differing potential for proceeding to an operational stage and hence a differing potential to ultimately contribute to a cumulative impact alongside the Proposed Development. Therefore, a tiered approach has been adopted. This provides a framework for placing relative weight upon the potential for each project to be included in the CEA to ultimately be realised, based upon the project's current stage of maturity and certainty in the projects' parameters. The tiered approach which will be utilised within the Proposed Development CEA employs the following tiers:

- Tier 1 – The onshore elements of the Project;
- Tier 2 – Projects that have an application submitted, are consented, under construction or operational to the extent not already captured with the baseline;
- Tier 3 – Projects which have submitted a scoping report and/or have received a scoping opinion; and
- Tier 4 – Reasonably foreseeable projects including those with Crown Estate Scotland option or lease agreements.

7.12.4 The specific projects scoped into the CEA for physical processes, are outlined in Figure 7.8 and Table 7.21.

7.12.5 The range of potential cumulative impacts that are identified and included below, is a subset of those considered for the Proposed Development alone assessment. This is because some of the potential impacts identified and assessed for the Proposed Development alone, are localised and temporary in nature (such as the potential for scour development). It is considered therefore, that these potential impacts have limited or no potential to interact with similar changes associated with other projects. These have therefore been scoped out of the CEA.

7.12.6 Similarly, some of the potential impacts considered within the Proposed Development alone assessment are specific to a particular phase of development (e.g. construction, O&M or decommissioning). Where the potential for cumulative effects with other projects only have potential to occur where there is spatial or temporal overlap with the Proposed Development during certain phases of development, impacts associated with a certain phase may be omitted from further consideration where no projects have been identified that have the potential for cumulative effects during this period.

7.12.7 In order to determine the potential for cumulative changes to SSC, bed levels and sediment type, other projects and activities located within a Spring Tidal Excursion buffer of the Proposed Development which may themselves generate elevated levels of SSC were scoped into the assessment.

7.12.8 In order to determine potential cumulative changes to the tidal, wave and sediment transport regimes, as well as cumulative changes to water column stratification, other nearby projects with the potential to cause meaningful blockage of these parameters were scoped into the assessment. Expert judgement was used to determine the list of other projects to scope in and was based on the existing evidence base of blockage effects from other planned and operational wind farms. Blockage effects were assessed using numerical modelling, as described in Volume 3, Technical Appendix 7.2: Physical Processes Model Design and Validation and Volume 3, Technical Appendix 7.3: Physical Processes Technical Assessment.

Table 7.21: List of Other Projects Considered Within the CEA for Physical Processes

Project	Status	Distance from Array Area (km)	Distance from Export Cable Corridor (km)	Description of Project	Dates of Construction (If Applicable)	Dates of Operation (If Applicable)	Overlap with the Proposed Development
Tier 2							
Kincardine OWF	Operational	20.14	7.63	Kincardine Offshore Wind Farm is consented for up to 7 wind turbines with 6 currently operational. Capacity of 50 MW.	N/A	2021 to 2045	Project O&M phase overlaps with the Proposed Development construction and O&M phases.
Seagreen 1 OWF	Operational	27.87	19.88	Seagreen 1 Offshore Wind Farm consists of up to 114 wind turbines at a capacity of 1,075 MW. Seagreen was consented with permission to install 150 wind turbines. The remaining 36 wind turbines are consented but not yet constructed (Seagreen 1A project).	N/A	2023 to 2047	Project O&M phase overlaps with the Proposed Development construction and O&M phases.
Seagreen 1A Project	Consented	36.30	19.47	Seagreen 1A is made up of the 36 remaining wind turbines consented as part of the Seagreen 1 Offshore Wind Farm. Seagreen 1A submitted a variation in consent to allow construction to take place between 2029 and 2032.	2029-2032	2033 to 2057	Project construction and O&M phases overlap with the Proposed Development construction and O&M phases.
Aberdeen OWF	Operational	38.60	34.71	Aberdeen Offshore Wind Farm consists of up to 11 turbines at a capacity of 96.8 MW.	N/A	2018 to 2042	Project O&M phase overlaps with the Proposed Development construction and O&M phases.
Eastern Green Link 2	Under Construction	0.00	12.33	2 GW subsea cable connecting Peterhead in Aberdeenshire and Drax in North Yorkshire.	2025 to 2028	2029 onwards	Project O&M phase overlaps with the Proposed Development construction and O&M phases.
Ossian OWF	Application submitted but not yet determined	25.36	40.14	The Ossian Floating Wind project is proposed for up to 265 floating wind turbines with a capacity of 3,600 MW. Operational lifetime 35 years. Additional information submitted to MD-LOT October 2025 and January 2026.	2031 to 2038	2039 - 2073	Project construction and O&M phases overlap with the Proposed Development construction and O&M phases.
Tier 3							
Eastern Green Link 3	Pre-Application	6.28	23.76	Eastern Green Link is a new primarily offshore high voltage electricity link between Scotland and England. Approximately 555 km of subsea High Voltage Direct Current (HVDC) cable from the Lincolnshire coastline to Scotland.	2028 to 2030	2031 onwards	Project O&M phase overlaps with the Proposed Development construction and O&M phase.
Morven North OWF	Pre-Application	10.03	22.20	Morven North Offshore Wind Array Project is proposed for up to 96 wind turbines at a capacity of 1,500 MW. Application of relevant consents and licences expected in 2026 with decision in 2027.	2030 to 2036	2037 - 2061	Project construction and O&M phases overlap with the Proposed Development construction and O&M phases.
Morven South OWF	Pre-Application	43.61	53.83	Morven South Offshore Wind Array Project is proposed for up to 95 wind turbines at a capacity of 1,500 MW. Application of relevant consents and licences expected in 2026 with decision in 2027.	2030 to 2036	2037 - 2061	Project construction and O&M phases overlap with the Proposed Development construction and O&M phases.

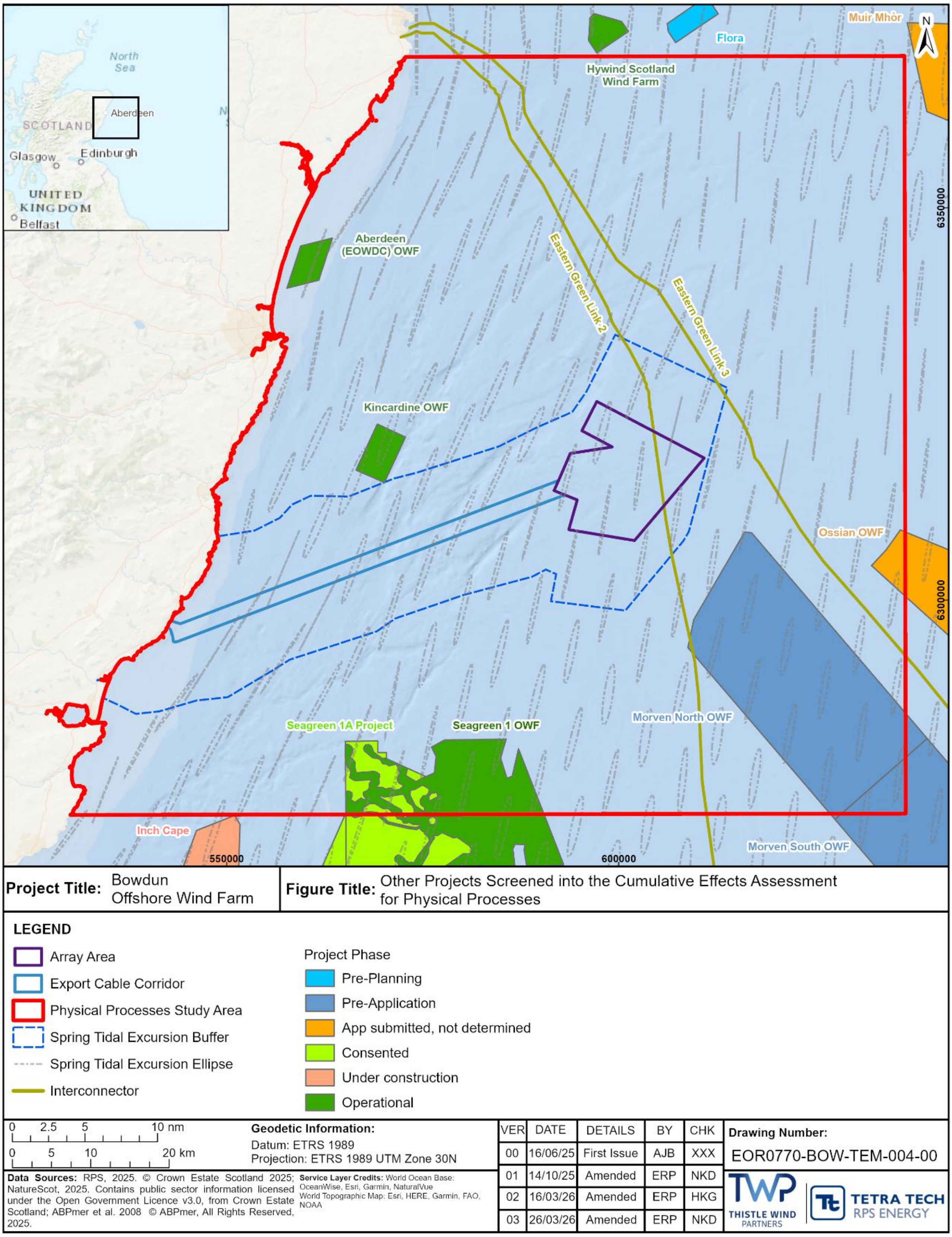

Figure 7.8: Other Projects Screened into the Cumulative Effects Assessment for Physical Processes

Maximum Design Scenario

7.12.9 The MDS identified in Table 7.22 have been selected as those having the potential to result in the greatest effect on an identified receptor or receptor group. The cumulative effects presented and assessed in this section have been selected from the details provided in Volume 1, Chapter 3: Project Description as well as the information available on other projects (see Volume 3, Technical Appendix 4.4: Cumulative Effects Assessment - Screening), to inform a 'MDS'. Any other development scenario within the PDE, will result in the same, or less, level of environmental effect.

Table 7.22: MDS for Each Impact as Part of the Assessment of Likely Significant Cumulative Effects on Physical Processes

Potential Cumulative Effect	Phase*			Maximum Design Scenario	Justification
	C	O&M	D		
Potential cumulative changes to SSC, bed levels and sediment type	✓	×	×	The MDS is as detailed for the Proposed Development alone in Table 7.8, cumulatively with the following projects: **Tier 2** Offshore Wind Projects, Associated Cables & Interconnectors • Ossian OWF (construction phase); and • Seagreen 1A Project (construction phase). **Tier 3** Offshore Wind Projects, Associated Cables & Interconnectors • Morven North OWF (construction phase); and • Morven South OWF (construction phase).	The construction periods of Ossian OWF and Morven North/South OWFs may overlap with the Proposed Development construction period. Consequently, sediment-disturbing activities such as drilling foundations, MFE sandwave clearance, and dredging could occur simultaneously.
Potential cumulative impacts to seabed morphology	×	✓	×	The MDS is as detailed for the Proposed Development alone in Table 7.8, cumulatively with the following projects: **Tier 2** Offshore Wind Projects, Associated Cables & Interconnectors • Aberdeen OWF (O&M phase); • Kincardine OWF (O&M phase); • Seagreen 1 OWF (O&M phase); • Seagreen 1A Project (O&M phase); • Ossian OWF (O&M phase); and • Eastern Green Link 2 (O&M phase). **Tier 3** Offshore Wind Projects, Associated Cables & Interconnectors • Morven North OWF (O&M phase); • Morven South OWF (O&M phase); and • Eastern Green Link 3 (O&M phase).	The operational periods of Aberdeen, Kincardine, Seagreen 1, Seagreen 1A, Ossian and Morven North/South OWFs and the Eastern Green Link 2 and 3 projects overlap with the Proposed Development O&M period. Consequently, the presence of Wind Turbine and OSP foundations for OWF projects and cable protection for the HVDC project could cause cumulative blockage of waves, tides and changes to sediment transport. These changes could, in turn, impact seabed morphology in the designated sites identified in Paragraph 7.5.4 *et seq.*

Potential Cumulative Effect	Phase*			Maximum Design Scenario	Justification
	C	O&M	D		
Potential cumulative impacts to coastal morphology	×	✓	×	The MDS is as detailed for the Proposed Development alone in Table 7.8, cumulatively with the following projects: **Tier 2** Offshore Wind Projects, Associated Cables & Interconnectors • Aberdeen OWF (O&M phase); • Kincardine OWF (O&M phase); • Seagreen 1 OWF (O&M phase); • Seagreen 1A Project (O&M phase); and • Ossian OWF (O&M phase). **Tier 3** Offshore Wind Projects, Associated Cables & Interconnectors • Morven North OWF (O&M phase); and • Morven South OWF (O&M phase).	The operational periods of Aberdeen, Kincardine, Seagreen 1, Seagreen 1A, Ossian and Morven North/South OWFs overlap with the Proposed Development O&M period. Consequently, the presence of Wind Turbine and OSP foundations from different OWF projects could cause cumulative blockage of waves. These changes could, in turn, impact coastal morphology.
Potential cumulative changes to the tidal regime	×	✓	×	The MDS is as detailed for the Proposed Development alone in Table 7.8, cumulatively with the following projects: **Tier 2** Offshore Wind Projects, Associated Cables & Interconnectors • Aberdeen OWF (O&M phase); • Kincardine OWF (O&M phase); • Seagreen 1 OWF (O&M phase); • Seagreen 1A Project (O&M phase); and • Ossian OWF (O&M phase).	The operational periods of Aberdeen, Kincardine, Seagreen 1, Seagreen 1A, Ossian and Morven North/South OWFs overlap with the Proposed Development O&M period. Consequently, the presence of Wind Turbine and OSP foundations from different OWF projects could cause cumulative blockage of tides.

Potential Cumulative Effect	**Phase***			**Maximum Design Scenario**	**Justification**
	C	**O&M**	**D**		
				Tier 3 Offshore Wind Projects, Associated Cables & Interconnectors • Morven North OWF (O&M phase); and • Morven South OWF (O&M phase).	
Potential cumulative changes to the wave regime	×	✓	×	The MDS is as detailed for the Proposed Development alone in Table 7.8, cumulatively with the following projects: **Tier 2** Offshore Wind Projects, Associated Cables & Interconnectors • Aberdeen OWF (O&M phase); • Kincardine OWF (O&M phase); • Seagreen OWF 1 (O&M phase); • Seagreen OWF 1A (O&M phase); and • Ossian OWF (O&M phase). **Tier 3** Offshore Wind Projects, Associated Cables & Interconnectors • Morven North OWF (O&M phase); and • Morven South OWF (O&M phase).	The operational periods of Aberdeen, Kincardine, Seagreen 1, Seagreen 1A, Ossian and Morven North/South OWFs overlap with the Proposed Development O&M period. Consequently, the presence of Wind Turbine and OSP foundations from different OWF projects could cause cumulative blockage of waves.
Potential cumulative changes to the sediment transport regime	×	✓	×	The MDS is as detailed for the Proposed Development alone in Table 7.8, cumulatively with the following projects: **Tier 2** Offshore Wind Projects, Associated Cables & Interconnectors • Aberdeen OWF (O&M phase); • Kincardine OWF (O&M phase); • Seagreen 1 OWF (O&M phase); • Seagreen 1A Project (O&M phase); and	The operational periods of Aberdeen, Kincardine, Seagreen 1, Seagreen 1A, Ossian and Morven North/South OWFs overlap with the Proposed Development O&M period. Consequently, the presence of Wind Turbine and OSP foundations from different OWF projects could cause

Potential Cumulative Effect	Phase*			Maximum Design Scenario	Justification
	C	O&M	D		
				• Ossian OWF (O&M phase). **Tier 3** Offshore Wind Projects, Associated Cables & Interconnectors • Morven North OWF (O&M phase); and • Morven South OWF (O&M phase).	cumulative changes to sediment transport.
Potential cumulative changes to stratification and frontal systems	×	✓	×	The MDS is as detailed for the Proposed Development alone in Table 7.8, cumulatively with the following projects: **Tier 2** Offshore Wind Projects, Associated Cables & Interconnectors • Aberdeen OWF (O&M phase); • Kincardine OWF (O&M phase); • Seagreen 1 OWF (O&M phase); • Seagreen 1A Project (O&M phase); and • Ossian OWF (O&M phase). **Tier 3** Offshore Wind Projects, Associated Cables & Interconnectors • Morven North OWF (O&M phase); and • Morven South OWF (O&M phase).	The operational periods of Aberdeen, Kincardine, Seagreen 1, Seagreen 1A, Ossian and Morven North/South OWFS overlap with the Proposed Development O&M period. Consequently, the presence of Wind Turbine and OSP foundations from different OWF projects could cause cumulative blockage of tides. These changes could, in turn, impact stratification and frontal systems.

* Proposed Development phase refers to construction (C), O&M (O) and decommissioning (D).

Cumulative Effects Assessment

7.12.10 An assessment of the likely significance of the cumulative effects of the Proposed Development upon physical processes receptors and pathways arising from each identified impact is given below. Only tier 2 and tier 3 projects have been identified with the potential for cumulative effects. No Tier 1 or 4 projects are carried through to the CEA, as there are none.

POTENTIAL CUMULATIVE CHANGES TO SSC, BED LEVELS AND SEDIMENT TYPE

Tier 2

Construction phase

7.12.11 The construction periods of Ossian OWF and Seagreen 1A Project, may overlap with the Proposed Development. Consequently, sediment-disturbing activities such as drilling foundations, MFE sandwave clearance, and dredging could occur simultaneously. This overlap may potentially result in cumulative changes in SSC and bed levels.

Magnitude of impact

7.12.12 The Ossian array area is located ~25 km to the east of the Array Area. The distance between the Ossian array area and the Proposed Development is greater than the extent of the Spring Tidal Excursion and they are not aligned in the direction of the tidal axis. Similarly, Seagreen 1A is located ~19 km from the Proposed development ECC, which is greater than the extent of the tidal excursion ellipse. This therefore suggests any cumulative impacts are very unlikely. This conclusion is underpinned by and consistent with the relevant available guidance set out in Section 7.8, notably Brooks *et al*. (2018).

Sensitivity of the receptor

7.12.13 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.12.14 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals;
- Volume 2, Chapter 11: Offshore Ornithology;
- Volume 2, Chapter 16: Infrastructure and Other Users; and
- Volume 2, Chapter 19: Marine Archaeology.

Tier 3

Construction phase

7.12.15 The construction periods of the closest neighbouring OWFs, Morven North OWF, and the Proposed Development may overlap. Consequently, sediment-disturbing activities such as drilling foundations, MFE sandwave clearance, and dredging could occur simultaneously. This overlap may potentially result in cumulative changes in SSC and bed levels.

Magnitude of impact

7.12.16 The Morven North array area is located ~10 km to the south-east of the Array Area. The distance between the two projects is greater than the extent of the Spring Tidal Excursion and they are not aligned in along the direction of the tidal axis. This is confirmed by the modelled scenarios (presented in Volume 3, Technical Appendix 7.3: Physical Processes Technical Assessment) that show the limited spatial footprint and transient nature of the plumes created from disturbance activities in these individual locations. This therefore suggests any cumulative impacts are very unlikely and will be of low magnitude and short duration if they do occur. There are no designated sites located in the potential area of cumulative influence between releases originating from the Morven North OWF and the Proposed Development (Array Area and Export Cable Corridor).

Sensitivity of the receptor

7.12.17 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.12.18 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals;
- Volume 2, Chapter 11: Offshore Ornithology;
- Volume 2, Chapter 16: Infrastructure and Other Users; and
- Volume 2, Chapter 19: Marine Archaeology.

POTENTIAL CUMULATIVE IMPACTS TO SEABED MORPHOLOGY

Tier 2

O&M phase

7.12.19 There are several operational (Aberdeen, Kincardine, Seagreen 1 OWFs) and planned (Ossian and Seagreen 1A OWFs) within the Physical Processes Study Area. During the O&M phase the presence of Wind Turbine foundations and OSP foundations associated with the Proposed Development could potentially interact with similar infrastructure from other OWF projects in the Physical Processes Study Area, resulting in cumulative blockage of waves, tides and sediment transport. These changes could, in turn, impact seabed morphology within designated sites located in the Physical Processes Study Area (Figure 7.1). This is discussed further in this section. Consideration is also given to the potential for interaction with cable protection measures associated with the Eastern Green Link 2.

Magnitude of the receptor

7.12.20 On the basis of the discussion of potential changes to tides (set out in Paragraph 7.12.49 *et seq*.), waves (set out in Paragraph 7.12.60 *et seq*.; Figure 7.9) and sediment transport (set out in Paragraph 7.12.73 *et seq*.), there are not expected to be any detectable changes to any of these parameters at the location of designated sites. Indeed, changes to tidal currents will be highly localised to the Array Area and immediate surroundings, whilst the reduction in wave height is <2.5% at the locations of designated sites for all scenarios tested. Accordingly, the rate (and direction) of sediment transport at these sites will remain unaltered from baseline conditions and therefore there will be no associated cumulative morphological change to the seabed in these areas.

7.12.21 Any blockage to waves, tides and sediment transport pathways arising from cable protection measures associated with the Eastern Green Link 2 will be extremely small and highly localised to the infrastructure. These changes will not extend to areas of designated seabed which, even at their closest point, are located approximately 6.7 km from the Proposed Development. Accordingly, there is no potential for cumulative change.

7.12.22 Overall, the impact to designated areas with seabed morphology arising from the presence of cable protection measures and/or Wind Turbine/OSP foundations would be immeasurably small. Any impact is predicted to be of local spatial extent, short term duration, intermittent and medium reversibility. It is predicted that the impact could only affect designated seabed areas indirectly. The magnitude is therefore considered to be negligible.

Sensitivity of the receptor

7.12.23 The designated areas of seabed listed in Table 7.7 contain features which are potentially vulnerable to either direct disturbance from Project-related activities or indirect disturbance from changes to waves, tides and sediment transport processes. Given that these features are largely either relict (such as the glacial bedforms in the Firth of Forth Banks Complex MPA) or in relatively inactive areas of seabed (such as the sandy sediments within the Turbot Bank

MPA), the potential for recovery generally either doesn't exist or is limited. Given the designated status of these seabed areas, they are considered to be of high value.

7.12.24 Designated areas of seabed are deemed to be of high vulnerability, low to medium recoverability and high value. The sensitivity of the receptor is therefore, considered to be high.

Significance of the effect

7.12.25 Overall, the magnitude of the impact is deemed to be negligible and the sensitivity of the receptor is considered to be high. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Additional mitigation and residual effect

7.12.26 No Additional Mitigation is considered necessary because the likely effect in the absence of Additional Mitigation is not significant in EIA terms.

Tier 3

O&M phase

7.12.27 During the O&M phase the presence of Wind Turbine foundations and OSP foundations associated with the Proposed Development could potentially interact with similar infrastructure at Morven North and Morven South OWFs, resulting in cumulative blockage of waves, tides and sediment transport. These changes could, in turn, impact seabed morphology within designated sites located in the Physical Processes Study Area (Figure 7.1). This is discussed further in this section. Consideration is also given to the potential for interaction with cable protection measures associated with the Eastern Green Link 3.

Magnitude of the receptor

7.12.28 On the basis of the discussion of potential changes to tides (set out in Paragraph 7.12.49 *et seq*.), waves (set out in Paragraph 7.12.60 *et seq*.; Figure 7.9) and sediment transport (set out in Paragraph 7.12.73 *et seq*.), there are not expected to be any detectable changes to any of these parameters at the location of designated sites. Indeed, changes to tidal currents will be highly localised to the Array Area and immediate surroundings (both for Bowdun and other OWF projects). The reduction in wave height is <2.5% at the locations of designated sites for all scenarios tested. Accordingly, the rate (and direction) of sediment transport at these sites will remain unaltered from baseline conditions and therefore there will be no associated morphological change to the seabed in these areas.

7.12.29 Any blockage to waves, tides and sediment transport pathways arising from cable protection measures associated with the Eastern Green Link 3 will be extremely small and highly localised to the infrastructure. These changes will not extend to areas of designated seabed which, even at their closest point, are located approximately 6.7 km from the Proposed Development. Accordingly, there is no potential for cumulative change.

7.12.30 Overall, the impact to designated areas with seabed morphology arising from the presence of cable protection measures and/or Wind Turbine/OSP foundations would be immeasurably small. Any impact is predicted to be of local spatial extent, short term duration, intermittent and medium reversibility. It is predicted that the impact could only affect designated seabed areas indirectly. The magnitude is therefore considered to be negligible.

Sensitivity of the receptor

7.12.31 The designated areas of seabed listed in Table 7.7 contain features which are potentially vulnerable to either direct disturbance from Project-related activities or indirect disturbance from changes to waves, tides and sediment transport processes. Given that these features are largely either relict (such as the glacial bedforms in the Firth of Forth Banks Complex MPA) or in relatively inactive areas of seabed (such as the sandy sediments within the Turbot Bank MPA), the potential for recovery generally either doesn't exist or is limited. Given the designated status of these seabed areas, they are considered to be of high value.

7.12.32 Designated areas of seabed are deemed to be of high vulnerability, low to medium recoverability and high value. The sensitivity of the receptor is therefore, considered to be high.

Significance of the effect

7.12.33 Overall, the magnitude of the impact is deemed to be negligible and the sensitivity of the receptor is considered to be high. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Additional mitigation and residual effect

7.12.34 No Additional Mitigation is considered necessary because the likely effect in the absence of Additional Mitigation is not significant in EIA terms.

POTENTIAL CUMULATIVE IMPACTS TO COASTAL MORPHOLOGY

Tier 2

O&M phase

7.12.35 There are several operational (Aberdeen, Kincardine, Seagreen 1 OWFs) and planned (Ossian and Seagreen 1A OWFs) within the Physical Processes Study Area. Potential changes to coastal morphology could also arise from cumulative changes (blockage) to the wave regime, arising from operation of the Proposed Development and other offshore wind farms within the Physical Processes Study Area. This potential change is also considered within this section.

Magnitude of impact

7.12.36 Measurable changes in wave height do not extend to any coastal location within the Physical Processes Study Area, regardless of prevailing wave direction (Figure 7.9). Accordingly, there is no potential for change in either the rate or direction of longshore sediment transport.

7.12.37 The impact to coastal morphology during the O&M phase is predicted to be of local extent, short term duration, intermittent and medium reversibility. It is predicted that the impact will affect the coast directly. The magnitude is therefore considered to be low. This assessment of magnitude is based on the fact that the extent to which infrastructure from the Proposed Development and other OWF projects will interact with coastal processes will be extremely limited and therefore there is considered to be very little potential for morphological change.

Sensitivity of the receptor

7.12.38 The coast within the Physical Processes Study Area contains both designated and undesignated features which are potentially vulnerable to either direct or indirect disturbance from Project-related activities (Table 7.7 and Figure 7.1). However, the shoreline is typically a dynamic environment which is subject to natural change under baseline conditions. Accordingly, it is assessed to have some capacity to recover from disturbance.

7.12.39 The coast is deemed to be of medium vulnerability, medium recoverability and medium value. The sensitivity of the receptor is therefore, considered to be medium.

Significance of the effect

7.12.40 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be medium. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Additional mitigation and residual effect

7.12.41 No Additional Mitigation is considered necessary because the likely effect in the absence of Additional Mitigation (is not significant in EIA terms.

Tier 3

O&M phase

7.12.42 Potential changes to coastal morphology could also arise from cumulative changes (blockage) to the wave regime, arising from operation of the Proposed Development and Morven North and Morven South OWFs. This potential change is also considered within this section.

Magnitude of impact

7.12.43 Measurable changes in wave height do not extend to any coastal location within the Physical Processes Study Area, regardless of prevailing wave direction (Figure 7.9). Accordingly, there is no potential for change in either the rate or direction of longshore sediment transport.

7.12.44 The impact to coastal morphology during the O&M phase is predicted to be of local extent, short term duration, intermittent and medium reversibility. It is predicted that the impact will affect the coast directly. The magnitude is therefore considered to be low. This assessment of magnitude is based on the fact that the extent to which infrastructure from the two projects will interact with coastal processes will be extremely limited and therefore there is considered to be very little potential for morphological change.

Sensitivity of the receptor

7.12.45 The coast within the Physical Processes Study Area contains both designated and undesignated features which are potentially vulnerable to either direct or indirect disturbance from Project-related activities (Table 7.7 and Figure 7.1). However, the shoreline is typically a dynamic environment which is subject to natural change under baseline conditions. Accordingly, it is assessed to have some capacity to recover from disturbance.

7.12.46 The coast is deemed to be of medium vulnerability, medium recoverability and medium value. The sensitivity of the receptor is therefore, considered to be medium.

Significance of the effect

7.12.47 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be medium. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Additional mitigation and residual effect

7.12.48 No Additional Mitigation is considered necessary because the likely effect in the absence of Additional Mitigation is not significant in EIA terms.

POTENTIAL CUMULATIVE CHANGES TO THE TIDAL REGIME

Tier 2

O&M phase

7.12.49 There are several operational (Aberdeen, Kincardine, Seagreen 1 OWFs) and planned (Ossian and Seagreen 1A OWFs) within the Physical Processes Study Area. Potential cumulative changes to the tidal regime arising from the operational presence of the Proposed Development and neighbouring OWFs are considered. The potential for these cumulative changes to impact either designated areas of seabed or the coast are discussed in Paragraph 7.12.19 *et seq*. and Paragraph 7.12.35 *et seq.*, respectively.

7.12.50 It is noted here that the dredge disposal sites, all outside the Spring Tidal Excursion buffer, only have the potential to cause very localised changes to tidal currents, with minimal potential for cumulative interaction with the Proposed Development. As such, these projects have not been carried through to the CEA for this impact.

Magnitude of impact

7.12.51 Potential changes to tidal currents and water levels are considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect to them. Instead, this section focuses on describing the spatial and temporal nature of change to them, with the potential for associated impacts to marine biodiversity assessed in other chapters.

7.12.52 The presence of Wind Turbine foundations has the potential to cause localised blockage of tidal currents and the creation of wakes in the water column. However, this blockage is localised and will not extend to a distance of more than one Spring Tidal Excursion from the Array Area. This has been demonstrated for the Proposed Development using hydrodynamic modelling (Figure 7.6) which shows that measurable wakes associated with the foundations will be narrow and of limited length, extending far less than the distance between the Array Area and any surrounding OWFs.

Sensitivity of the receptor

7.12.53 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.12.54 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals; and
- Volume 2, Chapter 11: Offshore Ornithology.

Tier 3

O&M phase

7.12.55 Morven North and Morven South OWFs are in the pre-planning phase and within the Physical Processes Study Area. Potential cumulative changes to the tidal regime arising from the operational presence of the Proposed Development and Morven North and Morven Souths OWFs are considered. The potential for these cumulative changes to impact either designated areas of seabed or the coast are discussed in Paragraph 7.12.19 *et seq.* and Paragraph 7.12.35 *et seq.*, respectively.

Magnitude of impact

7.12.56 Potential changes to tidal currents and water levels are considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect to them. Instead, this section focuses on describing the spatial and temporal nature of change to them, with the potential for associated impacts to marine biodiversity assessed in other chapters.

7.12.57 The cumulative impact of Morven North and Morven South OWFs was considered alongside the tier 2 OWFs within the Physical Processes Study Area, therefore is covered in the section above (Paragraph 7.12.49 *et seq.*).

Sensitivity of the receptor

7.12.58 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.12.59 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals; and
- Volume 2, Chapter 11: Offshore Ornithology.

POTENTIAL CUMULATIVE CHANGES TO THE WAVE REGIME

Tier 2

O&M phase

7.12.60 There are several operational and planned OWFs (Aberdeen, Kincardine, Seagreen 1, Seagreen 1A and Ossian OWFs) within the Physical Processes Study Area. Potential cumulative changes to the wave regime arising from the operational presence of the Proposed Development and surrounding OWFs are considered. The potential for these cumulative changes to impact either designated areas of seabed or the coast are discussed in Paragraph 7.12.19 *et seq*. and Paragraph 7.12.35 *et seq.*, respectively.

7.12.61 It is noted here that the dredge disposal sites only have the potential to cause very localised changes to waves, with minimal potential for cumulative interaction with the Proposed Development. As such, these projects have not been carried through to the CEA for this impact.

Magnitude of impact

7.12.62 Potential changes to waves are considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect to them. Instead, this section focuses on describing the spatial and temporal nature of change to them, with the potential for associated impacts to marine biodiversity assessed in other chapters.

7.12.63 The same numerical wave model setup used to assess wave blockage effects arising from the Proposed Development alone was also used to consider the potential for cumulative interaction with other operational and planned OWFs within the Physical Processes Study Area. Results are reported in Volume 3, Technical Appendix 7.3: Physical Processes Technical Assessment.

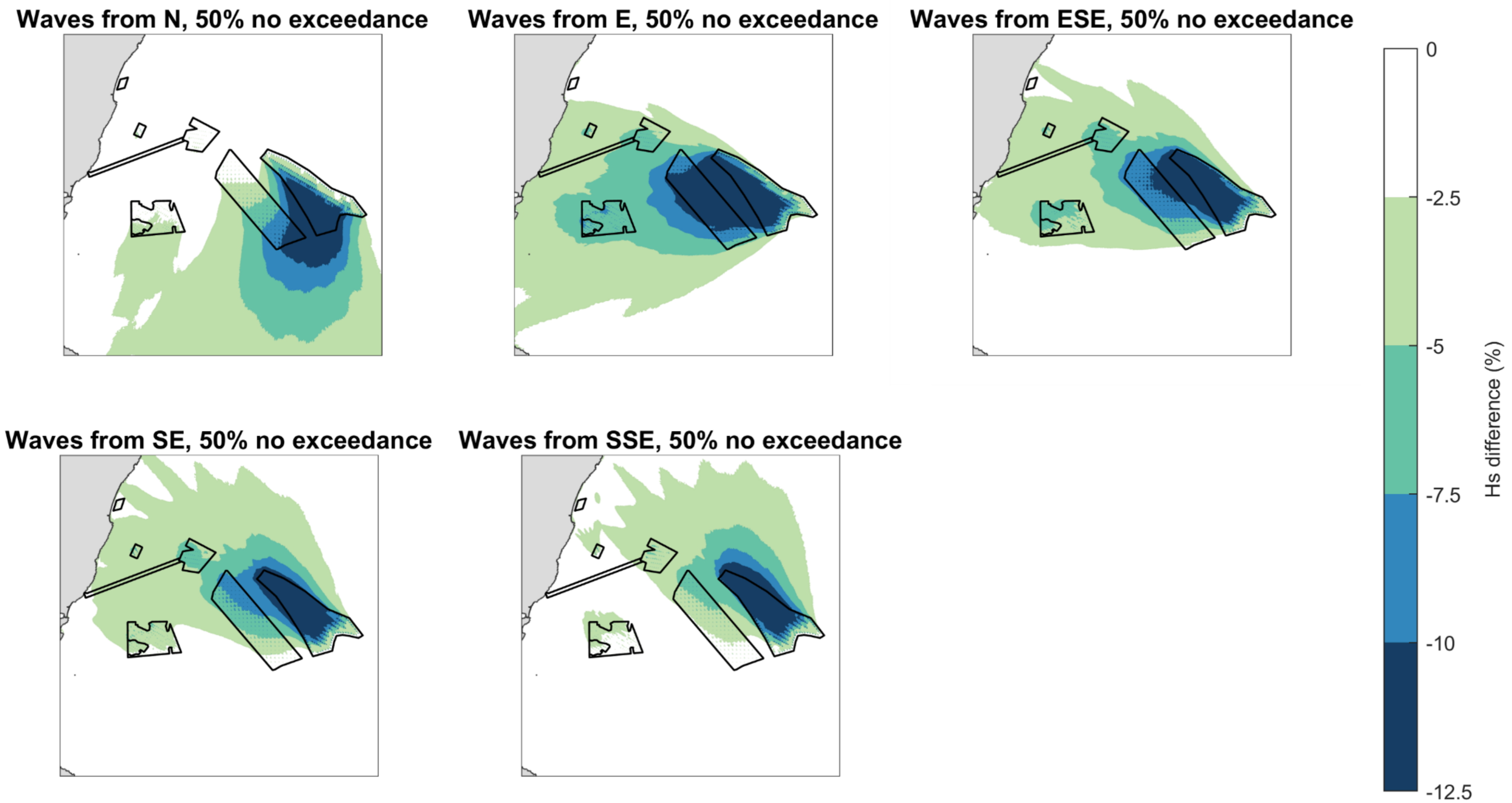

Figure 7.9: Percentage Difference in Significant Wave Height (Scheme Minus Baseline as a Proportion of Baseline Values), O&M Phase, Waves from all Simulated Directions, 50% Non-Exceedance Wave Height. Negative Values are a Reduction in Wave Height as a Result of the Installed Infrastructure: MDS for Bowdun, Aberdeen, Kincardine, Seagreen 1, Seagreen 1A, Ossian, Morven North and Morven South OWFs

7.12.64 The most common wave directions within the Array Area are from the south-east and north. Potential changes to waves from these directions, and all directions tested, are shown in Figure 7.9. The MDS for other OWFs is based on the known maximum number of Wind Turbines in combination with the largest near-surface dimension found in relevant project-specific EIA documents. Where available the actual or planned layout of other OWFs have been used, where this information is unavailable the layout has been assumed with a distribution that achieves maximum cumulative interaction with the Proposed Development. The results are summarised below:

- Developments with a large number of floating foundations (e.g. Ossian) have a greater impact on the wave regime, resulting in a greater relative reduction of wave height (12.5%), effecting a larger spatial area.
- The contribution of the relatively small number of smaller fixed foundations considered for Bowdun are minimal in comparison to these large floating projects.
- The presence of Wind Turbine foundations in the Bowdun Array Area and other OWF Array Areas do have the potential to cause a cumulative reduction in wave height across a wider area than is the case for the Proposed Development alone.
- The wider area of cumulative effect is defined by a reduction in wave height of less than 5%, this is indistinguishable from natural variability both within the seastate (difference between individual waves) and compared to normal rates of change (over timescales of one hour or less); such small differences would not be measurable in practice.
- Cumulative differences in wave height are less than 5% in nearshore areas (up to 5 km from the coast) and at the adjacent coastlines.
- There is no measurable cumulative change in wave height (>5%) in any designated areas.

7.12.65 These small theoretical cumulative changes in wave characteristics should be set in the wider context of climate change and natural variability. Predicted changes in wave height, as well as alterations to the directional wave climate driven by changes in large scale climate variability are likely to result in spatial modifications (erosion and accretion) to coastlines and seabed morphology due to deviations in sediment transport and supply (e.g. Palmer *et al*., 2018; Splinter *et al*., 2012). Such future changes are expected to far exceed those which theoretically could occur as a result of the presence of the operational wind farms.

Sensitivity of the receptor

7.12.66 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.12.67 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals; and
- Volume 2, Chapter 11: Offshore Ornithology.

Tier 3

O&M phase

7.12.68 Morven North and Morven South OWFs are in the pre-planning phase and within the Physical Processes Study Area. Potential cumulative changes to the wave regime arising from the operational presence of the Proposed Development and Morven North and Morven South OWFs have been considered. The potential for these cumulative changes to impact either designated areas of seabed or the coast are discussed in Paragraph 7.12.19 *et seq*. and Paragraph 7.12.35 *et seq*., respectively.

Magnitude of impact

7.12.69 Potential changes to waves are considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect to them. Instead, this section focuses on describing the spatial and temporal nature of change to them, with the potential for associated impacts to marine biodiversity assessed in other chapters.

7.12.70 The cumulative impact of Morven North and South OWFs was considered alongside the Tier 2 OWFs within the Physical Processes Study Area, therefore is covered in the section above (Paragraph 7.12.60 *et seq.*).

Sensitivity of the receptor

7.12.71 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.12.72 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals; and
- Volume 2, Chapter 11: Offshore Ornithology.

POTENTIAL CUMULATIVE CHANGES TO THE SEDIMENT TRANSPORT REGIME

Tier 2

O&M phase

7.12.73 Cumulative change to existing sediment transport pathways could occur in response to blockage of waves and tidal currents resulting from the presence of infrastructure associated with the Proposed Development and other operational (Aberdeen, Kincardine, Seagreen 1 OWFs) and planned OWFs (Ossian and Seagreen 1A OWFs), notably:

- Wind Turbine and OSP foundations; and/or
- cable protection measures.

7.12.74 It is noted here that the dredge disposal sites only have the potential to cause very localised changes to sediment transport, with minimal potential for cumulative interaction with the Proposed Development. As such, these projects have not been carried through to the CEA for this impact.

Magnitude of impact

7.12.75 Potential changes to sediment transport are considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect to them. Instead, this section focuses on describing the spatial and temporal nature of change to them, with the potential for associated impacts to marine biodiversity assessed in other chapters.

7.12.76 As stated in Paragraph 7.12.49 *et seq.*, the potential for cumulative changes to tidal currents arising from the presence of the Proposed Development and other OWFs is considered to be extremely small. It follows that any cumulative changes to tidally driven sediment transport will be similarly limited.

7.12.77 On the basis of the numerical wave modelling shown in Figure 7.9 and discussed in Paragraph 7.12.60 *et seq.*, it is theoretically possible that cumulative interaction between the Proposed Development and other OWFs could lead to a reduction in wave heights across a wider area than for the Proposed Development acting alone. However, the contribution of Bowdun to cumulative changes in wave height remains small (<2.5%) and such small differences would not be measurable in practice. It is considered extremely unlikely that such modest changes in waves would manifest in measurable changes to sediment transport and seabed morphology, especially given the water depths in affected areas (>50 m LAT). It is also noted that any affected seabed areas would, at various times, be influenced by storm waves which have not travelled through the OWF arrays.

Sensitivity of the receptor

7.12.78 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.12.79 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals; and
- Volume 2, Chapter 11: Offshore Ornithology.

Tier 3

O&M phase

7.12.80 Cumulative change to existing sediment transport pathways could occur in response to blockage of waves and tidal currents resulting from the presence of infrastructure associated with the Proposed Development and Morven North and Morven South OWFs, notably:

- Wind Turbine and OSP foundations; and/or
- cable protection measures.

Magnitude of impact

7.12.81 Potential changes to sediment transport are considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect to them. Instead, this section focuses on describing the spatial and temporal nature of change to them, with the potential for associated impacts to marine biodiversity assessed in other chapters.

7.12.82 As stated in Paragraph 7.12.49 *et seq.*, the potential for cumulative changes to tidal currents arising from the presence of the Proposed Development and other OWFs (including Morven North and Morven South) is considered to be extremely small. It follows that any cumulative changes to tidally driven sediment transport will be similarly limited.

Sensitivity of the receptor

7.12.83 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.12.84 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals; and

- Volume 2, Chapter 11: Offshore Ornithology.

POTENTIAL CUMULATIVE CHANGES TO STRATIFICATION AND FRONTAL SYSTEMS

Tier 2

O&M phase

7.12.85 As discussed in Paragraph 7.10.166 *et seq*. OWFs have the potential to influence stratification and frontal systems through changes to water column mixing processes. This section considers the potential for cumulative changes to stratification as a result of the Proposed Development interacting with other operational (Aberdeen, Kincardine Seagreen 1) and planned (Ossian and Seagreen 1A) OWFs within the Physical Processes Study Area.

7.12.86 It is noted here that the dredge disposal sites will not influence regional-scale water column mixing processes and will therefore have no potential for cumulative interaction with the Proposed Development. As such, these projects have not been carried through to the CEA for this impact.

<u>Magnitude of impact</u>

7.12.87 Potential changes to stratification and frontal systems are considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect to them. Instead, this section focuses on describing the spatial and temporal nature of change to them, with the potential for associated impacts to marine biodiversity assessed in other chapters.

7.12.88 Although the other OWFs are present within the Physical Processes Study Area, it has also been shown that measurable wakes in the water column associated with the foundations will be narrow and of limited length, extending far less than the distance between the Array Area and other OWFs (Figure 7.6). Accordingly, it is considered that there is very limited potential for cumulative changes to stratification arising from the interaction of water column wakes associated with the two OWFs. As such, no further assessment has been undertaken.

7.12.89 The modelling analyses of Christiansen *et al*. (2022) provides theoretical evidence for atmospheric OWF wakes to impact water column stratification. However, the findings are based on the presence of a very large number of OWFs (>50) in relatively close proximity with a large total number of Wind Turbines (>2,500) present within the theoretical scenario study area. In contrast, the Array Area is further offshore and is not part of such a large group of closely spaced OWFs and is itself much smaller (up to 67 Wind Turbines). Even when considering cumulative changes associated with the Proposed Development and operational and planned OWFs, together the number of Wind Turbines is considerably lower than those considered by Christiansen *et al*. (2022). Based on this, any associated wind wake effects are expected to be limited.

7.12.90 Whilst Christiansen *et al.* (2022) provides some evidence on the effects of Wind Turbines on near surface wind speeds and water column mixing. It is noted that this work focused on a region of the North Sea that does not strongly seasonally stratify, so is not completely analogous to the location of the Array Area. Other literature and methodology focusing on this wind wake effect on mixing and stratification is limited. Therefore, some uncertainty remains regarding the potential impact in the northern North Sea.

Sensitivity of the receptor

7.12.91 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.12.92 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals; and
- Volume 2, Chapter 11: Offshore Ornithology.

Tier 3

O&M phase

7.12.93 This section considers the potential for cumulative changes to stratification as a result of the Proposed Development interacting with Morven North and Morven South OWFs within the Physical Processes Study Area.

Magnitude of impact

7.12.94 Potential changes to stratification and frontal systems are considered to be pathways of effect, rather than an impact on receptors, and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect to them. Instead, this section focuses on describing the spatial and temporal nature of change to them, with the potential for associated impacts to marine biodiversity assessed in other chapters.

7.12.95 The cumulative impact of Morven North and South OWFs was considered alongside the tier 2 OWFs within the Physical Processes Study Area, therefore is covered in the section above (Paragraph 7.12.85 *et seq.*).

Sensitivity of the receptor

7.12.96 All of the changes described in this section are to 'pathways' as opposed to receptors and therefore sensitivity ratings have not been assigned.

Significance of the effect

7.12.97 The assessment set out in this section has considered potential changes to a pathway, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA, in particular:

- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals; and
- Volume 2, Chapter 11: Offshore Ornithology.

7.13 Proposed Monitoring

7.13.1 All of the potential effects to physical processes receptors are identified as not significant in terms of the EIA Regulations, with the current acknowledgement of the Embedded Mitigation (Table 7.13). Accordingly, no monitoring is required as no significant effects have been identified.

7.13.2 However, monitoring relevant to Physical Processes is proposed for engineering purposes and to contribute to the body of knowledge on the influence of offshore renewable energy developments. Table 7.23 outlines these proposed monitoring measures.

Table 7.23: Proposed Monitoring and the Method of Implementation for Physical Processes

Potential Environmental Effect	Monitoring Commitment	Means of Implementation
Support engineering	During the O&M phase, monitoring will be undertaken to identify if the seabed morphology has changed and/or cables become exposed.	Detailed monitoring commitments will be agreed with MD-LOT post-construction, as required, and included in the OMP secured in the Section 36 Consent and/or Marine Licences and submitted to MD-LOT for approval.
Regional monitoring	Engage and contribute to relevant regional and strategic monitoring, where appropriate to do so for the Proposed Development, giving due consideration to the Scottish Marine Energy Research (ScotMER) programme (Scottish Government, 2024a) (or any successor programme formed to facilitate these research interests), or any developer lead regional groups.	Secured in the Section 36 Consent and/or Marine Licences via the requirement for a Project Environmental Monitoring Plan (PEMP).

7.14 Transboundary Effects

7.14.1 A screening of transboundary effects has been carried out (see Volume 3, Technical Appendix 4.5: Transboundary Effects Screening) and has identified that there were no likely significant transboundary effects with regard to physical processes from the Proposed Development upon the interests of European Economic Area (EEA) states. Scottish Ministers, in line with the NatureScot Scoping representation are in agreement with this finding (Table 7.4).

7.15 Summary of Impacts, Mitigation, Likely Significant Environmental Effects and Monitoring

7.15.1 Information on the physical marine environment within the Physical Processes Study Area was collected through a combination of desktop reviews, site surveys and consultation with stakeholders. This information is summarised in Table 7.5 and Table 7.6.

7.15.2 Table 7.24 presents a summary of the potential impacts, Embedded Mitigation and the conclusion of likely significant environmental effects in EIA terms in respect to physical processes. The impacts assessed include:

- potential changes to SSC, bed levels and sediment type;
- potential impacts to seabed morphology;
- potential impacts to coastal morphology;
- potential changes to the tidal regime;
- potential changes to the wave regime;
- potential changes to the sediment transport regime;
- potential changes to stratification and frontal systems; and
- potential for scour of seabed sediments.

7.15.3 Overall, it is concluded that there will be no likely significant environmental effects on Physical Processes arising from the Proposed Development during the construction, O&M or decommissioning phases.

7.15.4 Table 7.25 presents a summary of the potential impacts, Embedded Mitigation and the conclusion of likely significant cumulative environmental effects on physical processes in EIA terms. The cumulative effects assessed include:

- potential cumulative changes to SSC, bed levels and sediment type;
- potential cumulative impacts to seabed morphology;
- potential cumulative impacts to coastal morphology;
- potential cumulative changes to the tidal regime;
- potential cumulative changes to the wave regime;
- potential cumulative changes to the sediment transport regime; and
- potential cumulative changes to stratification and frontal systems.

7.15.5 Overall, it is concluded that there will be no likely significant cumulative effects from the Proposed Development alongside other projects/plans in relation to physical processes.

7.15.6 No likely significant transboundary effects on physical processes have been identified in regard to effects of the Proposed Development.

Table 7.24: Summary of Assessment of Significance

Description of Impact	Embedded Mitigation ID	Magnitude of Impact	Sensitivity of Receptor	Significance of Effect	Additional Mitigation	Significance Residual Effect	Proposed Monitoring
Construction Phase							
Impact 1: Potential changes to SSC, bed levels and sediment type	1	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	None required.	N/A	None
Impact 2: Potential impacts to seabed morphology	1	Negligible	High	Minor adverse	None required.	Minor adverse	None
Impact 3: Potential impacts to coastal morphology	43	Low	Medium	Minor adverse	None required.	Minor adverse	None
O&M Phase							
Impact 1: Potential changes to SSC, bed levels and sediment type	NA	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	None required.	N/A	None
Impact 2: Potential impacts to seabed morphology	NA	Negligible	High	Minor adverse	None required.	Minor adverse	None
Impact 3: Potential impacts to	43	Low	Medium	Minor adverse	None required.	Minor adverse	None

Description of Impact	Embedded Mitigation ID	Magnitude of Impact	Sensitivity of Receptor	Significance of Effect	Additional Mitigation	Significance Residual Effect	Proposed Monitoring
coastal morphology							
Impact 4: Potential changes to the tidal regime	NA	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	None required.	N/A	None
Impact 5: Potential changes to the wave regime	NA	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	None required.	N/A	None
Impact 6: Potential changes to the sediment transport regime	NA	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	None required.	N/A	None
Impact 7: Potential changes to stratification and frontal systems	NA	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	None required.	N/A	None
Impact 8: Potential scour of seabed sediments	2	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	None required.	N/A	None
Decommissioning Phase							
Impact 1: Potential changes to SSC, bed levels and sediment type	NA	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	None required.	N/A	None

Description of Impact	Embedded Mitigation ID	Magnitude of Impact	Sensitivity of Receptor	Significance of Effect	Additional Mitigation	Significance Residual Effect	Proposed Monitoring
Impact 2: Potential impacts to seabed morphology	NA	Negligible	High	Minor adverse	None required.	Minor adverse	None
Impact 3: Potential impacts to coastal morphology	NA	Low	Medium	Minor adverse	None required.	Minor adverse	None

Table 7.25: Summary of Cumulative Effects Assessment

Description of Impact	Cumulative Effects Assessment Tier	Magnitude of Impact	Sensitivity of Receptor	Significance of Effect	Additional Mitigation	Significance Residual Effect	Proposed Monitoring
Construction Phase							
Potential changes to SSC, bed levels and sediment type	Tier 2 and Tier 3	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	None required.	N/A	None
O&M Phase							
Potential cumulative impacts to seabed morphology	Tier 2 and Tier 3	Negligible	High	Minor adverse	None required.	Minor adverse	None
Potential cumulative impacts to	Tier 2 and Tier 3	Low	Medium	Minor adverse	None required.	Minor adverse	None

Description of Impact	Cumulative Effects Assessment Tier	Magnitude of Impact	Sensitivity of Receptor	Significance of Effect	Additional Mitigation	Significance Residual Effect	Proposed Monitoring
coastal morphology							
Potential cumulative changes to the tidal regime	Tier 2 and Tier 3	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	None required.	N/A	None
Potential cumulative changes to the wave regime	Tier 2 and Tier 3	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	None required.	N/A	None
Potential cumulative changes to the sediment transport regime	Tier 2 and Tier 3	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	None required.	N/A	None
Potential cumulative changes to stratification and frontal systems	Tier 2 and Tier 3	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	N/A [Potential pathway of effect for other topics]	None required.	N/A	None
Decommissioning Phase							
N/A							

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