Cenos Offshore Windfarm Limited

Cenos EIA

EIAR Chapter 8 – Marine Geology, Oceanography and Coastal Processes

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CONTENTS

ACRONYMS 4

GLOSSARY 7

8 MARINE GEOLOGY, OCEANOGRAPHY AND COASTAL PROCESSES 13

8.1 Introduction 13
8.2 Legislation, policy, and guidance 15
8.3 Scoping and consultation 17
8.4 Baseline characterisation 26
8.4.1 Study Area 26
8.4.2 Data sources 27
8.4.3 Project site-specific surveys and studies 30
8.4.4 Existing baseline 37
8.4.5 Future baseline 104
8.4.6 Summary and key issues 106
8.4.7 Data gaps and uncertainties 107
8.5 Impact assessment methodology 107
8.5.1 Impacts requiring assessment 107
8.5.2 Impacts scoped out of the assessment 109
8.5.3 Assessment methodology 109
8.5.4 Embedded mitigation 112
8.5.5 Worst-case scenario 117
8.6 Assessment of potential effects 128
8.6.1 Potential effects during construction 128
8.6.2 Potential effects during operation and maintenance 142
8.6.3 Potential effects during decommissioning 152
8.6.4 Summary of potential effects 153
8.7 Assessment of cumulative effects 157
8.7.1 Introduction 157
8.7.2 Cumulative construction effects 160
8.7.3 Cumulative operation and maintenance effects 163
8.7.4 Cumulative decommissioning effects 164
8.7.5 Summary of cumulative effects 164
8.8 Inter-related effects 166
8.8.1 Inter-related effects between Project phases 166
8.8.2 Inter-related effects within a Project phase 166
8.8.3 Inter-relationships 166
8.9 Whole Project assessment 167
8.10 Transboundary effects 167
8.11 Summary of mitigation and monitoring 168
8.12 References 169

ACRONYMS

ACRONYM	DEFINITION
2D	Two Dimension
3D	Three Dimension
AC	Alternating Current
AODA	Anglian Offshore Dredging Association
BGS	British Geological Survey
BODC	British Oceanographic Data Centre
CaP	Cable Plan
CBRA	Cable Burial Risk Assessment
CEA	Cumulative Effects Assessment
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CES	Crown Estate Scotland
CMS	Construction Method Statement
CNS	Central North Sea
CPA	Coast Protection Act 1949
CPT	Cone Penetration Test
CTD	Conductivity, Temperature and Depth
DC	Direct Current
DEICC	Department of Energy & Climate Change
DoL	Depth of Lowering
DSLP	Development Specification and Layout Plan
DVV	Double Van Veen
EBS	Environmental Baseline Survey
EICC	Export/Import Cable Corridor
EICB	Export/Import Cable Bundle
EEA	European Economic Area
EEZ	European Exclusion Zone
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EMF	Electromagnetic Field
EMP	Environmental Management Plan
FEPA	Food and Environmental Protection Act 1985

ACRONYM	DEFINITION
FTU	Floating Turbine Unit
GCR	Geological Conservation Review
GHG	Greenhouse Gas
HAT	Highest Astronomical Tide
HDD	Horizontal Directional Drilling
HG	Hamon Grab
HRA	Habitat Regulations Appraisal
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IAC	Inter-Array Cables
ICES	International Council for the Exploration of the Seas
INNS	Invasive Non-Native Species
INNSMP	Invasive Non-Native Species Management Plan
INTOG	Innovation and Targeted Oil & Gas
IPF	Initial Plan Framework
JNCC	Joint Nature Conservation Committee
JUV	Jack-Up Vessel
KP	Kilometre Point
LAT	Lowest Astronomical Tide
MAG	Magnetometer
MD-LOT	Marine Directorate Licence and Operations Team
MD-SEDD	Marine Directorate Science, Marine Directorate Evidence Data and Digital
MBES	Multibeam Echo Sounder
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLA	Marine Licence Application
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MNR	Mean Neap Range
MPA	Marine Protected Area
MPCP	Marine Pollution Contingency Plan
MSL	Mean Sea Level
MSR	Mean Spring Range

ACRONYM	DEFINITION
NCMPA	Nature Conservation Marine Protected Area
NFU	Nephelometric Formazin Units
NM	Nautical Mile
NRW	Natural Resource Wales
NTSLF	National Tidal and Sea Level Facility
NTU	Nepholometric Turbidity Units
OSCP	Offshore Substation Platform
OWF	Offshore Wind Farm
PLGR	Pre-lay Grapnel Runs
PSA	Particle Size Analysis
PSU	Practical Salinity Unit
RCP	Representative Concentration Pathways
SBP	Sub-Bottom Profiler
SD	Standard Deviation
SNH	Scottish Natural Heritage
SPM	Suspended Particulate Matter
SSC	Suspended Sediment Concentration
SSS	Side Scan Sonar
SSSI	Site of Special Scientific Interest
TLP	Tension Leg Platform
TKE	Turbulent Kinetic Energy
TSS	Total Suspended Solids
UHR	Ultra-High Resolution
UNCLOS	The United Nations Convention on the Law of the Sea
UK	United Kingdom
UKCP	UK Climate Projections
UKCS	United Kingdom Continental Shelf
WCS	Worst Case Scenario
WTG	Wind Turbine Generator
ZOI	Zone of Influence

GLOSSARY

TERM	DEFINITION
2023 Scoping Opinion	Scoping Opinion received in June 2023, superseded by the 2024 Scoping Opinion.
2023 Scoping Report	Environmental Impact Assessment (EIA) Scoping Report submitted in 2023, superseded by the 2024 Scoping Report.
2024 Scoping Opinion	Scoping Opinion received in September 2024, superseding the 2023 Scoping Opinion.
2024 Scoping Report	EIA Scoping Report submitted in April 2024, superseding the 2023 Scoping Report.
Area of Opportunity	The area in which the limits of electricity transmission via High Voltage Alternating Current (HVAC) cables can reach oil and gas assets for decarbonisation. This area is based on assets within a 100 kilometre (km) radius of the Array Area.
Array Area	The area within which the Wind Turbine Generators (WTGs), floating substructures, moorings and anchors, Offshore Substation Converter Platforms (OSCPs) and Inter-Array Cables (IAC) will be present.
Cenos Offshore Windfarm ('the Project')	'The Project' is the term used to describe Cenos Offshore Windfarm. The Project is a floating offshore windfarm located in the North Sea, with a generating capacity of up to 1,350 Megawatts (MW). The Project which defines the Red Line Boundary (RLB) for the Section 36 Consent and Marine Licence Applications (MLA), includes all offshore components seaward of Mean High Water Springs (MHWS) (WTGs, OSCPs, cables, floating substructures moorings and anchors and all other associated infrastructure). The Project is the focus of this Environmental Impact Assessment Report (EIAR).
Cenos Offshore Windfarm Ltd. (The Applicant)	The Applicant for the Section 36 Consent and associated Marine Licences.
Cumulative Assessment	The consideration of potential impacts that could occur cumulatively with other relevant projects, plans, and activities that could result in a cumulative effect on receptors.
Developer	Cenos Offshore Windfarm Ltd., a Joint Venture between Flotation Energy and Vårgrønn As (Vårgrønn).

TERM	DEFINITION
Environmental Impact Assessment (EIA)	The statutory process of evaluating the likely significant environmental effects of a proposed project or development. Assessment of the potential impact of the proposed Project on the physical, biological and human environment during construction, operation and maintenance and decommissioning.
Environmental Impact Assessment Regulations	This term is used to refer to the Environmental Impact Assessment Regulations which are of relevance to the Project. This includes the Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017, the Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017 (as amended); and the Marine Works (Environmental Impact Assessment) Regulations 2007.
Environmental Impact Assessment Report	A report documenting the findings of the EIA for the Project in accordance with relevant EIA Regulations.
Export/Import Cable	High voltage cable used to export/import power between the OSCPs and Landfall.
Export/Import Cable Bundle (EICB)	Comprising two Export/Import Cables and one fibre-optic cable bundled in a single trench.
Export/Import Cable Corridor (EICC)	The area within which the Export/Import Cable Route will be planned and the Export/Import Cable will be laid, from the perimeter of the Array Area to MHWS.
Export/Import Cable Route	The area within the Export/Import Export Corridor (EICC) within which the Export/Import Cable Bundle (EICB) is laid, from the perimeter of the Array Area to MHWS.
Floating Turbine Unit (FTU)	The equipment associated with electricity generation comprising the WTG, the floating substructure which supports the WTG, mooring system and the dynamic section of the IAC.
Flotation Energy	Joint venture partner in Cenos Offshore Windfarm Ltd.
Habitats Regulations	The Habitats Directive (Directive 92/43/ECC) and the Wild Birds Directive (Directive 2009/147/EC) were transposed into Scottish Law by the Conservation (Natural Habitats &c) Regulations 1994 ('Habitats Regulations') (up to 12 NM); by the Conservation of Offshore Marine Habitats and Species Regulations 2017 ('Offshore Marine Regulations') (beyond 12 NM); the Conservation of Habitats and Species Regulations

TERM	DEFINITION
	2017 (of relevance to consents under Section 36 of the Electricity Act 1989); the Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001; and the Wildlife and Countryside Act 1981. The Habitats Regulations set out the stages of the Habitats Regulations Appraisal (HRA) process required to assess the potential impacts of a proposed project on European Sites (Special Areas of Conservation, Special Protection Areas, candidate SACs and SPAs and Ramsar Sites).
Habitats Regulations Appraisal	The assessment of the impacts of implementing a plan or policy on a European Site, the purpose being to consider the impacts of a project against conservation objectives of the site and to ascertain whether it would adversely affect the integrity of the site.
High Voltage Alternating Current (HVAC)	Refers to high voltage electricity in Alternating Current (AC) form which is produced by the WTGs and flows through the IAC system to the OSCPs. HVAC may also be used for onward power transmission from the OSCPs to assets or to shore over shorter distances.
High Voltage Direct Current (HVDC)	Refers to high voltage electricity in Direct Current (DC) form which is converted from HVAC to HVDC at the OSCPs and transmitted to shore over longer distances.
Horizontal Directional Drilling (HDD)	An engineering technique for laying cables that avoids open trenches by drilling between two locations beneath the ground's surface.
Innovation and Targeted Oil & Gas (INTOG)	In November 2022, the Crown Estate Scotland (CES) announced the Innovation and Targeted Oil & Gas (INTOG) Leasing Round, to help enable this sector-wide commitment to decarbonisation. INTOG allowed developers to apply for seabed rights to develop offshore windfarms for the purpose of providing low carbon electricity to power oil and gas installations and help to decarbonise the sector. Cenos is an INTOG project and in November 2023 secured an Exclusivity Agreement as part of the INTOG leasing round.
Inter-Array Cable (IAC)	The cables which connect the WTGs to the OSCPs. WTGs may be connected with IACs into a hub or in series as a 'string' or a 'loop' such that power from the connected WTGs is gathered to the OSCPs via a single cable.
Joint Venture	The commercial partnership between Flotation Energy and Vårgrønn, the shareholders which hold the Exclusivity Agreement with CES to develop the Cenos site as an INTOG project.

TERM	DEFINITION
Landfall	The area where the Export/Import Cable from the Array Area will be brought ashore. The interface between the offshore and onshore environments.
Marine Licence	Licence required for certain activities in the marine environment and granted under the Marine and Coastal Access Act 2009 and/or the Marine (Scotland) Act 2010.
Marine Protected Area (MPA)	Marine sites protected at the national level under the Marine (Scotland) Act 2010 out to 12 NM, and the Marine and Coastal Access Act 2009 between 12-200 NM. In Scotland MPAs are areas of sea and seabed defined so as to protect habitats, wildlife, geology, underseas landforms, historic shipwrecks and to demonstrate sustainable management of the sea.
Marine Protected Area (MPA) Assessment	A three-step process for determining whether there is a significant risk that a proposed development could hinder the achievement of the conservation objectives of an MPA.
Mean High Water Springs (MHWS)	The height of Mean High Water Springs is the average throughout the year, of two successive high waters, during a 24-hour period in each month when the range of the tide is at its greatest.
Mean Low Water Springs (MLWS)	The height of Mean Low Water Springs is the average throughout a year of the heights of two successive low waters during periods of 24 hours (approximately once a fortnight).
Mitigation Measures	Measures considered within the topic-specific chapters in order to avoid impacts or reduce them to acceptable levels. • Primary mitigation - measures that are an inherent part of the design of the Project which reduce or avoid the likelihood or magnitude of an adverse environmental effect, including location or design; • Secondary mitigation – additional measures implemented to further reduce environmental effects to 'not significant' levels (where appropriate) and do not form part of the fundamental design of the Project; and • Tertiary mitigation – measures that are implemented in accordance with industry standard practice or to meet legislative requirements and are independent of the EIA (i.e. they would be implemented regardless of the findings of the EIA). Primary and tertiary mitigation are referred to as embedded mitigation. Secondary mitigation is referred to as additional mitigation.

TERM	DEFINITION
Mooring System	Comprising the mooring lines and anchors, the mooring system connects the floating substructure to the seabed, provides station-keeping capability for the floating substructure and contributes to the stability of the floating substructure and WTG.
Nature Conservation Marine Protected Area (NCMPA)	MPA designated by Scottish Ministers in the interests of nature conservation under the Marine (Scotland) Act 2010.
Offshore Substation Converter Platforms (OSCPs)	An offshore platform on a fixed jacket substructure, containing electrical equipment to aggregate the power from the WTGs and convert power between HVAC and HVDC for export/import via the export/import cable to/from the shore. The OSCPs will also act as power distribution stations for the Oil & Gas platforms.
Onward Development	Transmission projects which are anticipated to be brought forward for development by 3rd party oil and gas operators to enable electrification of assets via electricity generated by the Project. All Onward Development will subject to separate marine licensing and permitting requirements.
Onward Development Area	The area within which oil and gas assets would have the potential to be electrified by the Project.
Onward Development Connections	Oil and gas assets located in the waters surrounding the Array Area will be electrified via transmission infrastructure which will connect to the Project's OSCPs. These transmission cables are referred to as Onward Development Connections.
Project Area	The area that encompasses both the Array Area and EICC.
Project Design Envelope	A description of the range of possible elements that make up the Project design options under consideration and that are assessed as part of the EIA for the Project.
Study Area	Receptor specific area where potential impacts from the Project could occur.
Transboundary Assessment	The consideration of impacts from the Project which have the potential to have a significant effect on another European Economic Area (EEA) state's environment. Where there is a potential for a transboundary effect, as a result of the Project, these are assessed within the relevant EIA chapter.

TERM	DEFINITION
Transmission Infrastructure	The infrastructure responsible for moving electricity from generating stations to substations, load areas, assets and the electrical grid, comprising the OSCPs, and associated substructure, and the Export/Import Cable.
Vårgrønn As (Vårgrønn)	Joint venture partner in Cenos Offshore Windfarm Ltd.
Wind Turbine Generator (WTG)	The equipment associated with electricity generation from available wind resource, comprising the surface components located above the supporting substructure (e.g., tower, nacelle, hub, blades, and any necessary power transformation equipment, generators, and switchgears).
Worst-Case Scenario	The worst-case scenario based on the Project Design Envelope which varies by receptor and/or impact pathway identified.

8 MARINE GEOLOGY, OCEANOGRAPHY AND COASTAL PROCESSES

8.1 Introduction

This chapter of the Environmental Impact Assessment Report (EIAR) presents the Marine Geology, Oceanography and Coastal Processes receptors of relevance to the Project and assesses the potential impacts from the construction, operation and maintenance and decommissioning of the Project on these receptors. Where required, mitigation is proposed, and the residual impacts and their significance are assessed. Potential cumulative impacts are also considered.

Marine geology, oceanography, and coastal processes is a collective term for the following:

- Water levels;
- Currents;
- Waves (and winds);
- Water column stratification and frontal systems;
- Sediments and geology (including seabed sediment distribution and sediment transport);
- Seabed morphology; and
- Coastal morphology.

Table 8-1 provides a list of all the supporting studies which relate to and should be read in conjunction with the Marine Geology, Oceanography and Coastal Processes impact assessment. All supporting studies are appended to this EIAR. Where information is used to inform the Marine Geology, Oceanography, and Coastal Processes impact assessment, reference to the relevant report is given.

Table 8-1 Supporting studies

DETAILS OF STUDY	LOCATIONS OF SUPPORTING STUDY (WHERE RELEVANT)
Marine Geology, Oceanography, and Coastal Processes Technical Annex	EIAR Vol. 4, Appendix 7: Marine & Physical Processes Modelling Report
Final Survey Report: NorthConnect–- UK Nearshore, North Sea, and Norwegian Ford Survey	MMT Sweden AB ('MMT')., (2018a)
Geotechnical Report: NorthConnect–- UK Nearshore, North Sea, and Norwegian Ford Survey	MMT Sweden AB ('MMT')., (2018b)
Benthic Survey Report: NorthConnect–- UK Nearshore, North Sea, and Norwegian Ford Survey	MMT Sweden AB ('MMT')., (2018c)
Cenos Metocean Criteria Volume 1 – Design Criteria	PhysE, (2023a)
Cenos Metocean Criteria Volume 2 – Operational Presentations	PhysE, (2023b)
Cenos Metocean Criteria Volume 2 - Supporting Information	PhysE, (2023c)
Cenos Offshore Windfarm (OWF) Array Geophysical Results Report	Rovco Ltd., (2023a)
Export / Import Cable Corridor (EICC) Geophysical Results Report	Rovco Ltd., (2023b)
Cenos OWF Inshore Survey Environmental Field Report	EIAR Vol. 4, Appendix 8: Habitat Assessment Report – OWF
Cenos OWF Environmental Baseline Report	EIAR Vol. 4, Appendix 11: Environmental Baseline Report - OWF
Cenos EICC Environmental Baseline Report	EIAR Vol. 4, Appendix 12: Environmental Baseline Report - EICC

The Marine Geology, Oceanography, and Coastal Processes impact assessment also informs other impact assessments. This interaction between the impacts assessed within different topic-specific chapters on a receptor is defined as an 'inter-relationship'. The chapters and impacts related to the assessment of potential impacts on marine geology, oceanography, and coastal processes are provided in Section 8.8.3.

The results of the assessment have been used to inform the impact assessments for other environmental receptors, considered within the following chapters:

- EIAR Vol. 3, Chapter 9: Marine Water and Sediment Quality;
- EIAR Vol. 3, Chapter 10: Benthic Ecology;
- EIAR Vol. 3, Chapter 11: Marine Mammal Ecology;
- EIAR Vol. 3, Chapter 12: Offshore Ornithology;
- EIAR Vol. 3, Chapter 13: Fish and Shellfish Ecology; and
- EIAR Vol. 3, Chapter 15: Shipping and Navigation.

Where information from other chapters is used to inform the impact assessment, reference to the relevant EIAR Chapter is given.

The following specialists have contributed to the assessment:

- Tony Brooks, ABPmer
- David Lambkin, ABPmer
- Christina McIntyre, Xodus
- Jack Poleykett, Xodus
- Anna Chaffey, Xodus

8.2 Legislation, policy, and guidance

The wider marine planning, legislation, policy and guidance is discussed in EIAR Vol. 2, Chapter 3: Policy and Legislative Context. Legislation and policy of relevance to the assessment of impacts from the Project on Marine Geology, Oceanography and Coastal Processes alongside relevant guidance:

- Legislation:
  - Conservation (Natural Habitats, &c.) Regulations 1994 (and amendments);
- Policy:
  - National Planning Framework 4 (NPF4) (Scottish Government, 2023):
    - Policy 4 (relating to Natural Places) states that development proposals which by virtue of type, location or scale will have an unacceptable impact on the natural environment, will not be supported.
    - Policy 10 (relating to Coastal Development) states that development proposals in developed (and undeveloped) coastal areas will only be supported where the proposal:
      - Does not result in the need for further coastal protection measures taking into account future sea level change; or increase the risk to people of coastal flooding or coastal erosion, including through the loss of natural coastal defences including dune systems; and
      - Is anticipated to be supportable in the long-term, taking into account projected climate change.
    - Where a design statement is submitted with any planning application that may impact on the coast it will take into account, as appropriate, long-term coastal vulnerability and resilience;
  - Initial Plan Framework (IFP) Sectoral Marine Plan for Offshore Wind for Innovation and Targeted Oil and Gas Decarbonisation (INTOG) (Scottish Government, 2022):
    - Outlines the process for development of the Sectoral Marine Plan for INTOG and the areas that will be used for seabed leasing which “encompasses spatial opportunities and the strategic framework for future offshore wind deployment in sustainable and suitable locations that will help deliver projects to meet the above goal and our wider net zero commitments”.
  - The following policies of Scotland’s National Marine Plan (Scottish Government, 2015)[1] which was prepared in accordance with the United Kingdom (UK) Marine Policy Statement, apply to this Marine Geology, Oceanography and Coastal Processes assessment:

[1] *Following the most recent review of the NMP in 2021, the Scottish Ministers announced, in 2022, their intention to update the National Marine Plan. This update is underway but has not yet reached a draft consultation stage. A stakeholder engagement strategy and statement of public participation was published in August 2024.*

  - GEN 8 Coastal process and flooding: *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: *Development and use of the marine environment must: (a) Comply with legal requirements for protected areas and protected species. (b) Not result in significant impact on the national status of Priority Marine Features. (c) Protect and, where appropriate, enhance the health of the marine area;*
  - GEN 21 Cumulative impacts: *Cumulative impacts affecting the ecosystem of the marine plan area should be addressed in decision making and plan implementation*;
  - CABLES 2: *The following factors will be taken into account on a case by case basis when reaching decisions regarding submarine cable development and activities:*
    - *Cables should be suitably routed to provide sufficient requirements for installation and cable protection;*
    - *New cables should implement methods to minimise impacts on the environment, seabed and other users, where operationally possible and in accordance with relevant industry practice;*
    - *Cables should be buried to maximise protection where there are safety or seabed stability risks and to reduce conflict with other marine users and to protect the assets and infrastructure;*
    - *Where burial is demonstrated not to be feasible, cables may be suitably protected through recognised and approved measures (such as rock or mattress placement or cable armouring) where practicable and cost-effective and as risk assessments direct; and*
    - *Consideration of the need to reinstate the seabed, undertake post-lay surveys and monitoring and carry out remedial action where required.*

- Guidance:
  - Metocean Procedures Guide for Offshore Renewables (IMarEST, 2024): Guidance to support metocean characterisation data acquisition and assessments to inform developments.
  - Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Monitoring Requirements to Inform EIA of Major Development Projects. Report No 243 (Brooks *et al.*, 2018): Sets out best practice for baseline data needed to inform marine and coastal processes impact assessments including describing the appropriate approach to the acquisition and interpretation of relevant survey data
  - EIA for offshore renewable energy projects (BSI, 2015): Provides a summary of marine physical process impact pathways, potential assessment methods and tools. Also provides guidance on the development of impact assessment matrices.
  - Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects (Cefas, 2012): These guidelines assist in the design, review and implementation of environmental data collection and analytical activities associated with all phases of offshore renewable energy developments. There is a specific section covering ‘physical and sedimentary process studies’, setting out guidance on data acquisition and adequacy, survey design and impact assessment techniques (including modelling).
  - Coastal Process Modelling for Offshore Wind farm EIA: Best Practice Guide (Lambkin *et al.*, 2009): Provides an update to existing best practice guidance on the application and use of numerical models to predict the potential impact from offshore wind farms on coastal processes.
  - Guidelines in the use of metocean data through the lifecycle of a marine renewables development (CIRIA, 2008): This guide has been developed to identify and recommend on the uses of metocean data through the life cycle of a marine renewable energy development. It includes a review of metocean data types, data sources and identifies the importance of good data management.

- Review of Cabling Techniques and Environmental Effects applicable to the Offshore Wind farm Industry Technical Report (BERR, 2008): This report considers the physical changes or effects to the seabed and sub-surface sediments that could occur during cabling activities.
- Offshore Windfarms: Guidance note for Environmental Impact Assessment in Respect of Food and Environmental Protection Act 1985 (FEPA) and Coast Protection Act 1949 (CPA) requirements (Cefas, 2004): This report provides scientific guidance to those involved with the gathering, interpretation and presentation of data within an EIA. The Marine Geology, Oceanography and Coastal Processes parameters which require assessment are set out and divided into direct and indirect impacts, guidance is given regarding the key parameters which need documenting in the baseline and recommendations are set out for mitigation and monitoring.

8.3 Scoping and consultation

Stakeholder consultation has been ongoing throughout the EIA process and has played an important part in ensuring the scope of the baseline characterisation and impact assessment are appropriate with respect to the Project and the requirements of the regulators and their advisors.

A Scoping Workshop was held on the 29th February 2024 (as detailed in EIAR Vol. 2, Chapter 1: Introduction). Relevant points specific to Marine Geology, Oceanography and Coastal Processes are provided in Table 8-2 below, which sets out how these points have been addressed within the EIAR.

The 2024 Scoping Report was submitted to Marine Directorate – Licensing Operations Team (MD-LOT) in April 2024, relevant stakeholders were consulted. The Scoping Opinion was received in September 2024. The 2024 Scoping Report and Scoping Opinion supersedes the 2023 Scoping Report and Scoping Opinion for the Project. Relevant comments from the Scoping Opinion and other consultation specific to Marine Geology, Oceanography and Coastal Processes are provided in Table 8-2 below, which provides a high-level response on how these comments have been addressed within the EIAR. No other consultation specific to Marine Geology, Oceanography and Coastal Processes has been undertaken

Table 8-2 Comments from the Scoping Opinion relevant to Marine Geology, Oceanography and Coastal Processes

REGULATOR/CONSULTEE	COMMENT	RESPONSE
Scottish Ministers	The Study Area is defined in section 7.3 of the Scoping Report. A 30 km Zone of Influence ("ZOI") is proposed with the intention to refine this within the EIA. The Scottish Ministers advise that this should be refined pre-application.	The Study Area has been further refined from Scoping. The justification for this is set out in Section 8.4.1.
Scottish Ministers	The Scottish Ministers advise that the protected features of the East of Gannet and Montrose Fields Nature Conservation Marine Protected Area ("NCMPA") are offshore deep sea muds and ocean quahog aggregations (including sands and gravels as their supporting habitat), this must be correctly reflected in the EIA Report.	Mapping of key designated sites and features (such as offshore deep sea muds and ocean quahog aggregations (including sands and gravels as their supporting habitat) within the East of Gannet and Montrose Fields NCMPA) are presented in EIAR Vol. 3, Chapter 10: Benthic Ecology, with outputs from this chapter (Marine Geology, Oceanography and Coastal Processes) used to help inform the assessment.
Scottish Ministers	The Scottish Ministers highlight the MD-SEDD advice with regard to the data sources listed in table 7-4 of the Scoping Report and advise that this is fully considered.	Additional datasets have been acquired from that stated in the 2024 Scoping Report, as presented in Section 8.4.2. In particular and with respect to temperature and salinity, there is both site-specific conductivity, temperature, depth (CTD) profiling data and water sampling (salinity only) at 16 locations across the Project. Furthermore, water column temperature and salinity values, at up to 21 depth layers have been extracted from the Copernicus Marine (2024) 3D NWSHELF_ANALYSISFORECAST_PHY_004_013 model for 10 locations across the Project. The above information has been used to inform the baseline characterisation presented in Section 8.4 and impact assessment in Section 8.6.
Scottish Ministers	The Scottish Ministers are broadly content with the potential likely significant effects scoped in as summarised in table 7-8 of the Scoping Report however,	The subtidal sand and gravels in the East of Gannet and Montrose Fields NCMPA have been considered in relation to

REGULATOR/CONSULTEE	COMMENT	RESPONSE
	the subtidal sand and gravels in the East of Gannet and Montrose Fields NCMPA should also be considered in relation to potential modifications to sediment transport pathways.	potential modifications to sediment transport pathways in Section 8.6.2.
Scottish Ministers	Further to the advice above to scope in the Quaternary of Scotland protected feature of the Southern Trench NCMPA, the Scottish Ministers advise that no further assessment is required if the cable route avoids the landforms. The assessment should be a qualitative assessment against the relevant conservation objectives of the NCMPA.	The assessment of potential impacts to the Quaternary of Scotland features within the Southern Trench NCMPA are considered in Section 8.6.1. A separate assessment considering the potential for Project interaction with NCMPA features has also been provided within the MPA Assessment.
Scottish Ministers	The Scottish Ministers agree that "potential changes to wave and tidal regime" can be scoped out of the EIA Report relative to the areas out with the array area and that modifications to stratification and frontal features can also be scoped out for the construction and decommissioning phases of the Proposed Development.	Owing to the close linkages with sediment transport, NatureScot has questioned whether "*potential changes to wave and tidal regime*" should be scoped out entirely. Accordingly, this impact has been scoped in for the operational phase (which represents the worst-case scenario) see Section 8.6.2. Modifications to stratification and frontal features during the operational phase of the Project were assessed using quantitative and semi-quantitative techniques.
Scottish Ministers	The Developer is directed to the advice provided by MD-SEDD with regard to the approach to the assessment of "modifications to stratification and frontal feature" as outlined in table 7-8 of the Scoping Report, and advised that this is given full consideration in producing the EIA Report.	Modifications to stratification and frontal features during the operational phase of the Project has been assessed in Section 8.6.2 using quantitative and semi-quantitative techniques.
Scottish Ministers	The Developer acknowledges in section 9.6 of the Scoping Report that scour protection may be required around the foundations, the Scottish Ministers advise that this must be considered in the EIA Report in relation to the resulting impact that scour protection will have on the East of Gannet and Montrose Fields NCMPA.	Rock placement will not be used for scour protection. Alternative scour protection methods may include scour reduction vortex induced vibration strakes and tubular sleeves, with no additional seabed footprint to the existing seabed area of the piles. Scour allowance may also be factored into the

REGULATOR/CONSULTEE	COMMENT	RESPONSE
		design of the piles. However, as described in the baseline characterisation in Section 8.4.4.2, the seabed sediment thickness across much of the Array Area is less than 0.5 m, with denser Quaternary units beneath this, likely negating the occurrence of scour or need for scour protection.
Scottish Ministers	The Scottish Ministers note the embedded mitigation measures detailed in section 7.7 of the Scoping Report and advise that further mitigation may be required following assessment should impacts be predicted.	Embedded mitigation is set out in Table 8-31. The list of measures included builds upon those identified at Scoping and includes a number of further measures.
Scottish Ministers	With regard to the cumulative impact assessment, the Developer is advised to engage with the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) to ensure that all relevant projects and activities are included in the assessment relative to the East of Gannet and Montrose Fields NCMPA	An assessment of the potential for cumulative effects associated with the Project and oil and gas infrastructure is set out in Section 8.7.
Scottish Ministers	The Scottish Ministers agree that transboundary impacts on marine and coastal processes can be scoped out of the EIA Report. This is a view supported by NatureScot in its representation.	Transboundary effects have been scoped out of the assessment. This is confirmed in Section 8.9.
Marine Directorate Science, Marine Directorate Evidence (MD-SEDD)	The only mention of temperature and salinity data in Table 7-4 are climatologies from International Council for the Exploration of the Seas (ICES). Whilst these are useful, MD-SEDD advise the use of CTD data (e.g. from ICES, BODC, etc.) and existing 3D hydrodynamic model outputs (e.g. from Copernicus Marine, Met Office, or MD-SEDD). The use of the Scottish Shelf Model (SSM) and CTD data are mentioned in Table 7-8 though, as we suggest relevant citations are added to Table 7-4. The best SSM data are the SSW-RS 27 year reanalysis: https://doi.org/10.7489/12423-1	Additional datasets have been acquired from that stated in the 2024 Scoping Report, as presented in Section 8.4.2. In particular and with respect to temperature and salinity, there is both site-specific CTD profiling data and water sampling (salinity only) at 16 locations across the Project. Furthermore, water column temperature and salinity values, at up to 21 depth layers have been extracted from the Copernicus Marine (2024) 3D NWSHELF_ANALYSISFORECAST_PHY_004_013 model for 10 locations across the Project. The above information has been used to inform the baseline

REGULATOR/CONSULTEE	COMMENT	RESPONSE
		characterisation presented in Section 8.4 and impact assessment in Section 8.6.
MD-SEDD	MD-SEDD agree that "potential changes to wave and tidal regime" (Table 7-8) can be scoped out. Similarly, "modifications to stratification and frontal features" can be scoped out for construction and decommissioning as they will only have an impact during the operational phase.	Owing to the close linkages with sediment transport, NatureScot has questioned whether "*potential changes to wave and tidal regime*" should be scoped out entirely. Accordingly, this impact has been scoped in for the operational phase (which represents the worst-case scenario) and assessed in Section 8.6.2. Modifications to stratification and frontal features during the operational phase of the Project has been assessed in Section 8.6.2 using quantitative and semi-quantitative techniques.
MD-SEDD	MD-SEDD agree that the measures related to the cable burial outlined are sensible.	Comment noted.
MD-SEDD	Regarding the potential for "modifications to stratification and frontal feature" MD-SEDD advise that, in addition to the approach outlined in Table 7-8, the following questions are considered within the EIA: • How might the wind farm floating structures [e.g. 2] and wind-wakes [e.g. 3] change mixing? • How might this change in mixing influence the timing of seasonal stratification and frontal positions? • What impacts could this have on primary production and the wider ecosystem (e.g. potential for this change in physical processes acting as a pathway of change to biological receptors)? MD-SEDD recognise that these research questions are being considered within the academic community and that there is no clear pragmatic	The assessment of the potential for "*modifications to stratification and frontal features*" is semi-quantitative in nature and presented in Section 8.6.2. The methodological approach uses empirical equations relating drag on turbine structures to turbulent kinetic energy (TKE). It involves a comparison of TKE conversion by structure to baseline conditions, quantified by either potential energy anomaly or ambient bed shear. The potential spatial extent of wind farm impacts has been investigated using available hydrodynamic data. The potential for impacts on the wider marine ecosystem is considered in a number of separate chapters including EIAR

REGULATOR/CONSULTEE	COMMENT	RESPONSE
	assessment methodology available to perspective applicants. Therefor a robust description of baseline conditions, including the timing of stratification, frontal positions etc., should be combined with an assessment of potential impact based on current state of the art knowledge. One approach could be to consider how turbine structures could change turbulent kinetic energy (TKE) [e.g. 4] and how wind wakes might also change TKE. These values could then be compared with background/baseline values and the potential impact on the timing of stratification and whether front are likely to be effected. Potential impacts on biological receptors, e.g. plankton and the wider ecosystem should also be considered.	Vol. 3, Chapter 12: Ornithology and EIAR Vol. 3, Chapter 13: Fish and Shellfish Ecology.
NatureScot	The EIA Report should consider the impact of all aspects and all phases of the proposed development on the receiving environment, including effects from pre-construction activities as well as the construction, operation and maintenance and decommissioning phases.	A full impact assessment is provided in Section 8.6.1 (for the construction phase), Section 8.6.2 (for the operational phase) and Section 8.6.3 (for the decommissioning phase). Pre-construction activities are assessed within Section 8.6.1.
NatureScot	We are concerned with the likelihood of multiple offshore export cables making landfall in the area around Fraserburgh/Peterhead and the potential for cumulative impacts arising from construction and associated geophysical, geotechnical and environmental survey programmes. Therefore, we recommend that this is considered further.	A full landfall impact assessment is provided in Section 8.6.1 (for the construction phase), Section 8.6.2 (for the operational phase) and Section 8.6.3 (for the decommissioning phase).
NatureScot	The study area is described in Section 7.3 of the Scoping Report. A 30 km Zone of Influence (ZoI) is proposed. This is based on an evaluation of the variation of tidal ellipses along the EICC and across the Array Area, as well as a comparison with study areas of adjacent offshore wind farm projects. Following further analysis within the EIA, the ZoI will be refined. This refinement should take place pre-application.	The Study Area has been further refined from Scoping. The justification for this is set out in Section 8.4.1.
NatureScot	We highlight that Section 7.3.4 of the Scoping Report has incorrectly named the East of Gannet and Montrose Fields NCMPA. The designations listed for	The potential for changes to marine geology, oceanography and coastal processes within the East of Gannet and Montrose

REGULATOR/CONSULTEE	COMMENT	RESPONSE
	the site are also incorrect. The site is designated for "Offshore deep sea muds" and "Ocean quahog aggregations (including sands and gravels as their supporting habitat)". In addition, Figure 7-3 does not show all the current marine assets within the East of Gannet and Montrose Fields NCMPA and its surroundings. We suggest that this information is updated.	Fields NCMPA is considered within Section 8.6, with the potential for impacts to its designated biodiversity features ("Offshore deep sea muds" and "Ocean quahog aggregations (including sands and gravels as their supporting habitat)") presented in EIAR Vol. 3, Chapter 10: Benthic Ecology. Locations of current marine assets within the East of Gannet and Montrose Fields NCMPA and its surroundings is shown in Figure 8-24 within the MPA Assessment.
NatureScot	We agree that the data sources listed in Table 7-4 are sufficient to inform the marine and coastal processes baseline.	The data sources set out in the 2024 Scoping Report and subsequently used to inform the assessment of changes to marine geology, oceanography and coastal processes are summarised in Section 8.4.2
NatureScot	• The Scoping Report (Section 7.3.4.1) acknowledges that the EICC crosses the south-east part of the Southern Trench NCMPA. In this area there are moraines and/or small sub-glacial tunnel valleys. Both of these component elements of the Quaternary of Scotland feature are sensitive to physical damage, e.g. from cable trenching, and obscuring, e.g. by cable protection. We advise that the potential effects on the Quaternary of Scotland feature should be scoped in. • We agree with the scoping in of "potential modifications to sediment transport pathways". Note this pathway should also be considered with respect to the subtidal sand and gravels that are a feature of (or support the Ocean quahog feature of) the East of Gannet and Montrose Fields NCMPA. Since sediment transport at the depths concerned is largely by tidal currents, scoping in this effect acknowledges that changes to tidal currents are possible. In that sense, the proposal to scope out "potential changes to wave and tidal regime" seems inconsistent. If this impact was	The assessment of potential impacts to designated seabed interest features within the protected sites that directly intersect the Project are set out in Section 8.6 and include potential effects on Quaternary of Scotland features within the Southern Trench NCMPA. The potential for changes to marine geology, oceanography and coastal processes within the East of Gannet and Montrose Fields NCMPA is considered within Section 8.6, with the potential for impacts to biodiversity features (including Ocean quahog) presented in EIAR Vol. 3, Chapter 10: Benthic Ecology. The assessment of "*potential changes to the wave and tidal regime*" has been scoped in for the operational phase (which represents the worst-case scenario) see Section 8.6.2.

REGULATOR/CONSULTEE	COMMENT	RESPONSE
	altered to "potential changes to wave & tidal regime out with the Array Area", we would agree with scoping it out based on the arguments made in Table 7-8.	
NatureScot	We note that landfall will be via Horizontal Directional Drilling (HDD), as detailed in Section 3.5.5.3. This will avoid potential impacts on the Coastal Geomorphology feature of the Bullers of Buchan Coast SSSI.	HDD is an embedded mitigation measure and will avoid potential impacts on the Coastal Geomorphology features of the Bullers of Buchan Coast SSSI. A full landfall impact assessment is provided in Section 8.6.1 (for the construction phase), Section 8.6.2 (for the operational phase) and Section 8.6.3 (for the decommissioning phase).
NatureScot	With regards to the potential effects on the Quaternary of Scotland feature of the Southern Trench NCMPA, which we have advised be scoped in, if the cable route can avoid the landforms in question, no further assessment is required. Otherwise, the assessment method should be the use of expert geodiversity analysis to undertake a qualitative MPA assessment against the relevant Conservation Objectives.	Consideration of the potential for impacts to designated seabed interest features within protected sites associated with the Project is scoped in for all Project phases, as set out in Section 8.5.1. A separate assessment considering the potential for Project interaction with NCMPA features has also been produced.
NatureScot	The approach to the cumulative assessment is described in Section 7.9. Discussion may be required with OPRED to ensure that all relevant projects/activities located within the East of Gannet and Montrose Fields NCMPA are included in the cumulative assessment.	An assessment of the potential for cumulative effects associated with the Project and oil and gas infrastructure is set out in Section 8.7.
NatureScot	The embedded mitigation measures are detailed in Section 7.7 of the Scoping Report. In principle, we agree that the embedded mitigation measures described provide a suitable means for managing and mitigating the potential effects of the Project on marine and coastal processes receptors. However, we note that most proposed mitigation measures are based around future plans rather than specific measures. In addition, further mitigation and monitoring may be needed if impacts are predicted.	Embedded mitigation is set out in Table 8-31.

REGULATOR/CONSULTEE	COMMENT	RESPONSE
NatureScot	Potential transboundary effects on physical processes is considered in Section 7.10 of the Scoping Report and Appendix 5D: Transboundary Screening Matrix. We agree that physical processes should be scoped out for the assessment of transboundary effects.	Transboundary effects have been scoped out of the assessment. This is confirmed in Section 8.9.
Scoping Workshop – 29th February 2024		
MD-SEDD	Discussions were held with MD-SEDD on Modifications to stratification and frontal features and how this would be considered within the assessment.	The assessment of the potential for "*modifications to stratification and frontal features*" is semi-quantitative in nature and presented in Section 8.6.2.

8.4 Baseline characterisation

This Section outlines the current baseline for Marine Geology, Oceanography, and Coastal Processes within the Project and surrounding area, providing a description of properties of the marine environment which may be influenced by the Project activities. These properties, or receptors, include the local seabed and its underlying geology, surficial sedimentology and morphology, adjacent coastline and processes occurring at the coast, prevailing metocean and hydrodynamic regimes and water column characteristics. The baseline characterisation helps to establish the reference condition against which the potential physical effects of the Project are assessed.

In addition, the baseline represents the Marine Geology, Oceanography and Coastal Processes conditions that are expected to prevail without the Project taking place and with consideration of a duration equivalent to that of the Project. Given that the Project timescale spans several decades (e.g. an anticipated 35 years of operation), baseline variability over this period is also a consideration, including the likely effects of climate change.

The baseline characterisation has been informed by a combination of desk-based studies and site-specific surveys and is informed by stakeholder engagement and consultation (as detailed in Section 8.3 above). A number of publicly available datasets and published scientific literature have also been utilised throughout the baseline. The publicly available data sources and site-specific survey information which have contributed to the characterisation of the baseline are presented in full in Sections 8.4.2 and 8.4.3, respectively.

8.4.1 Study Area

The Marine Geology, Oceanography and Coastal Processes Study Area ("Study Area") has been defined based on:

- The distance away from the Project which suspended sediment plumes may be advected (and meaningfully interact with potentially sensitive receptors). This has been defined by a spring tidal excursion ellipse buffer around the Array Area and the EICC, which for the Array Area is approximately 4.5 km, 7.5 km in the middle of the EICC and 8 to 12 km inshore;
- The distance up/down drift from the landfall, that littoral processes could theoretically be impacted by Project infrastructure, has been defined through consideration of coastal processes data and understanding including sub-cell information set out in Ramsay and Brampton (2000) and Dynamic Coast (2024);
- The coastal boundary at the Mean High Water Springs (MHWS) mark, noting that no works are to be completed within the intertidal zone, instead Horizontal Direct Drilling (HDD) will be used to transition between the onshore cable landing pit located on top of the cliff above MHWS, to the marine exit point, located approximately 200 metres (m) offshore; and
- The distance from the Array Area that wave blockage impacts could theoretically be detected has been informed by expert judgment, drawing upon (amongst other things), the evidence base from analogous projects and consideration of the prevailing wave directions, which at the offshore location of the Array Area is predominantly from the north and northwest sectors. The resulting distance that is used to inform the Study Area, is approximately a 50 km buffer around the Array Area.

This is reflected in a Zone of Influence (ZoI) around the Project (Figure 8-1) which defines the area within which changes to Marine Geology, Oceanography and Coastal Processes could theoretically occur.

The Marine Geology, Oceanography and Coastal Processes temporal scope is defined as the entire lifetime of the Project including construction, operation and maintenance and decommissioning.

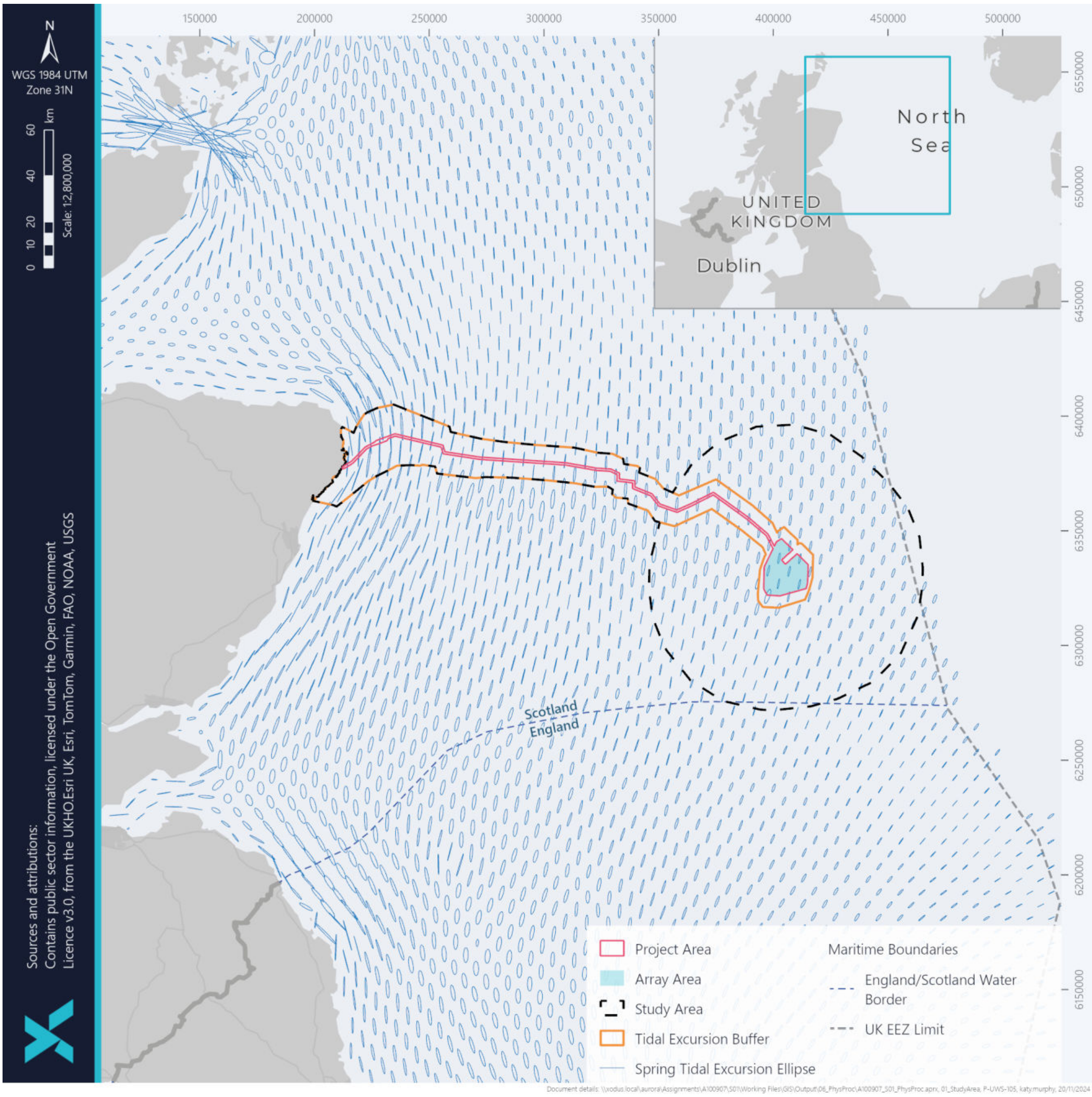


Figure 8-1 Marine Geology, Oceanography and Coastal Processes Study Area

8.4.2 Data sources

The existing datasets and literature with relevant coverage to the Project, which have been used to inform the baseline characterisation for Marine Geology, Oceanography and Coastal Processes are outlined in Table 8-3. Project specific data obtained and used to inform this topic assessment are presented in Section 8.4.3.

Table 8-3 Summary of key datasets and reports

TOPIC	TITLE	SOURCE	YEAR	AUTHOR
General	Marine Scotland Nation Marine Plan Interactive (NMPi)	https://marinescotland.atkinsgeospsatial.com/nmpi/	2024	Marine Directorate
Geology, Seabed Sediments	British Geological Survey (BGS) Offshore GeoIndex Map	http://mapapps2.bgs.ac.uk/geoindex_offshore/home.html	2024	BGS
	EMODnet Map Viewer	https://emodnet.ec.europa.eu/geoviewer/#!/	2024	EMODnet
Water Levels, Currents and Waves	British Oceanographic Data Centre (BODC) UK Tide Gauge Network	https://www.bodc.ac.uk/data/hosted_data_systems/sea_level/uk_tide_gauge_network/	2024	BODC
	National Tidal and Sea Level Facility (NTSLF) Water Level Records	https://www.ntslf.org/	2024	NTSLF
	Renewables Atlas	https://www.renewables-atlas.info/explore-the-atlas/	2008	ABPmer
	Copernicus Marine data service (see Section 8.4.3.3.2 for a summary of which models were used to extract site-specific data)	https://data.marine.copernicus.eu/products	2024	Copernicus Marine
	SEASTATES Data Explorer	https://www.seastates.net/explore-data/	2018	ABPmer
Suspended Sediment Concentrations	Centre for Environment, Fisheries and Aquaculture Science (Cefas) Suspended Sediment Climatologies around the UK	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/584621/CEFAS_2016_Suspended_Sediment_Climatologies_around_the_UK.pdf	2016	Cefas

TOPIC	TITLE	SOURCE	YEAR	AUTHOR
	UK Marine Monitoring and Assessment Strategy: Sea surface suspended sediments and turbidity	https://moat.cefas.co.uk/ocean-processes-and-climate/turbidity/	2018	Cefas
Fronts and Stratification	Copernicus Marine data service (see Section 8.4.3.3.2 for a summary of which models were used to extract site-specific data)	https://data.marine.copernicus.eu/products	2024	Copernicus Marine
	Frequent locations of oceanic fronts as an indicator of pelagic diversity: Application to marine protected areas and renewables	https://www.sciencedirect.com/science/article/abs/pii/S0308597X13002066?via%3Dihub	2014	Miller and Christodoulou
	Seasonal shelf-sea front mapping using satellite ocean colour to support development of the Scottish MPA network	https://www.nature.scot/doc/naturescot-commissioned-report-538-seasonal-shelf-sea-front-mapping-using-satellite-ocean-colour	2014	Miller, Xu and Lonsdale
	Conservation and Management Advice: Southern Trench NCMPA	https://www.nature.scot/sites/default/files/nature-conservation-mpa/10477/conservation-and-management-advice.pdf	2024a	NatureScot
Coastal Characteristics	Coastal Cells in Scotland: Cell 2–- Fife Ness to Cairnbulg Point	https://www.dynamiccoast.com/files/Ramsay_Brampton_Cell_02.pdf	2000	Ramsay and Brampton
	Dynamic Coast – National Coastal Change Assessment: Cell 2 – Fife Ness to Cairnbulg Point	https://www.dynamiccoast.com/files/reports/NCCA%20-%20Cell%202%20-%20Fife%20Ness%20to%20Cairnbulg%20Point.pdf	2017	Fitton *et al.*
	Dynamic Coast 2 Webmaps	https://www.dynamiccoast.com/webmaps	2024	Dynamic Coast
	Google Earth Pro (Software)	https://www.google.com/earth/about/versions/	2024	Google Earth

TOPIC	TITLE	SOURCE	YEAR	AUTHOR
Designated Sites	JNCC Marine Protected Area (MPA) Mapper	https://jncc.gov.uk/our-work/marine-protected-area-mapper/	2024	JNCC
	Geological Conservation Review (GCR) sites	https://webarchive.nationalarchives.gov.uk/ukgwa/20190301132753/http://jncc.defra.gov.uk/page-2949-theme=default	2019	JNCC
	NatureScot Site Link	https://sitelink.nature.scot/home	2024 b	NatureScot
	Monitoring survey of East of Gannet and Montrose Fields NCMPA and Norwegian Boundary Sediment Plain Scottish Nature Conservation Marine Protected Areas JNCC Report No. 580	https://data.jncc.gov.uk/data/6d620e89-89f7-45b8-b44d-52c4f07cc232/JNCC-Report-580-FINAL-r.pdf		O'Connor et al. (2016)
Future Baseline	UK Climate Projections (UKCP) 18	https://www.metoffice.gov.uk/research/approach/collaboration/ukcp	2018	Palmer *et al.*
	Climate change impacts on storms and waves relevant to the UK and Ireland	https://nora.nerc.ac.uk/id/eprint/527112/	2020	Wolf *et al.*
	Impacts of climate change on storms and waves relevant to the coastal and marine environment around the UK	https://www.mccip.org.uk/storms-and-waves	2023	Bircheno *et al.*

8.4.3 Project site-specific surveys and studies

In addition to the above publicly available information, site-specific surveys and studies have been conducted which have been used to characterise the baseline conditions within the Project Area. Inshore and offshore surveys, and their respective geophysical and environmental survey aspects are detailed in the proceeding Sections. Inshore is taken to describe the region between the coast and approximately 12 Nautical Miles (12 NM), associated with NorthConnect project, offshore is used to represent the region from the 12 NM to and around the Array Area.

8.4.3.1 Geophysical survey

8.4.3.1.1 Inshore

MMT was commissioned on behalf of NorthConnect[2] to undertake geotechnical and geophysical surveys along the NorthConnect cable route (MMT, 2018a, b). The geophysical data was acquired to determine water depths, seabed features, shallow geology, and object detection on the seabed using a system which included a Multibeam Echo Sounder (MBES), Side Scan Sonar (SSS), Sub-Bottom Profiler (SBP), and Magnetometer (MAG), respectively. The inshore survey encompassed the EICC route from landfall (i.e. Kilometre Point (KP) 0) to KP 27.970 (where the offshore survey, described in Section 8.4.3.1.2 below, begins). The survey was conducted in two phases. A vessel mounted system was utilised in deeper waters. Where water depths restricted vessel access, an ROV mounted system was used. In the very shallowest waters, the survey was conducted in a shore parallel direction to maximise the data coverage for the HDD approaches. The inshore survey was completed in December 2016.

For the geotechnical investigations VibroCores (VC) and Cone Penetration Tests (CPT) were completed at eight locations along the EICC to characterise the sediment and geological characteristics. Particle size analysis (PSA) was completed on the material from the VC samples recovered from multiple depths. The sampled geotechnical locations are illustrated in Figure 8-2.

The survey reporting was undertaken by MMT and the following have been referenced throughout the characterisation of the environmental baseline:

- MMT (2018a). NorthConnect – UK Nearshore, North Sea and Norwegian Fjord Survey. Geophysical, Benthic, and Geotechnical Route Survey: Final Survey Report. Doc: 102273-NOC-MMT-SUR-REP-SURVEYRE (Rev C); and
- MMT (2018b). NorthConnect – UK Nearshore, North Sea and Norwegian Fjord Survey. Geophysical, Benthic, and Geotechnical Route Survey: Geotechnical Report. Doc: 102273-NOC-MMT-SUR-REP-GEOTECH (Rev B).

8.4.3.1.2 Offshore

Rovco performed an offshore geophysical survey on behalf of the Project. The survey remit encompassed the EICC from KP 27.970 to KP 228.000, and the Array Area. The section of EICC not included in this survey extent was targeted by the inshore survey (see Section 8.4.3.1.1).

The geophysical survey for the EICC and Array Area were conducted during the survey period 21st July to 28th September 2023. The geophysical work package involved the acquisition of MBES, SSS, MAG, SBP and multi-channel ultra-high resolution seismic data (2D UHR) data. These provided information on the seabed bathymetry and morphology, seabed sediment distribution and shallow geological properties. The findings of the geophysical survey effort are detailed in two reports, one each for the EICC and Array Area. These reports are as follows, and have been used in characterising the baseline environment:

- Rovco (2023a). EICC Geophysical Results Report. Cenos OWF Array and Export/Import Cable Corridor (EICC) Geophysical Survey. Doc: CEN001-ROV-01-CON-GPH-RPT-0015; and

[2] The section of the EICC from MHWS to 12 NM was surveyed and assessed within the EIAR submitted for NorthConnect Limited (application reference number 06771 & 06870) and judged acceptable through the consenting of NorthConnect. The survey data obtained for NorthConnect has been made available to Cenos and is used herein to provide characterisation of the inshore section of the EICC.

- Rovco (2023b). OWF Geophysical Results Report. Cenos OWF Array and EICC Geophysical Survey. Doc: CEN001-ROV-01-CON-GPH-RPT-0013.

8.4.3.2 Environmental Baseline Survey

8.4.3.2.1 Inshore

MMT also undertook the Environmental Baseline Survey (EBS) and associated reporting for the inshore EICC (MMT, 2018c). Environmental data acquisition comprised sediment sampling, photography and video recording in order to gather data on habitats and species present within the inshore. Samples were acquired using a Day Grab and a Box Corer which were deployed from the survey vessels. Imagery was obtained using an ROV, mounted with a high-definition camera and a drop down video camera. No water sampling or water column profiling for water column properties or Suspended Sediment Concentrations (SSC) were completed as part of the NorthConnect EBS survey.

For the completed sediment sampling, five samples were taken within the inshore section of the EICC during the MMT NorthConnect survey effort (S01, S02, S03, S04, S05). The location of these samples is shown in Figure 8-2, as distinct from sample locations taken during the offshore survey (described further in Section 8.4.3.2.2). Grab samples were collected and seabed photography performed at each of these stations. Samples S01 to S03 were collected during surveys completed on the 11th and 12th December 2016, while samples S04 and S05 were collected during surveys completed between the 19th and 27th December 2016. These activities were reported as follows, and have been used in characterising the baseline environment:

- MMT (2018c). NorthConnect – UK Nearshore, North Sea and Norwegian Fjord Survey. Geophysical, Benthic, and Geotechnical Route Survey: Benthic Survey Report. Doc: 102273-NOC-MMT-SUR-REP-ENUKNSNF (Rev A).

8.4.3.2.2 Offshore

An EBS and a Habitat Assessment Survey, consisting of seabed imagery, sediment particle size analysis (PSA), sediment contamination analysis, sediment macrofaunal analysis, and water quality analysis, were conducted for both the EICC and Array Area. Environmental data were acquired between August and September 2023.

Seabed sediment samples were acquired using a Double Van Veen grab (DVV) or mini-Hamon Grab (HG), whilst seawater samples were collected using 5 L Niskin bottles in tandem with a Conductivity, Temperature and Depth (CTD) and turbidity probes to yield corresponding water column profiles. Seabed photography/videography was used to ground-truth (provide direct visual observation/information of the seabed) each environmental sampling location and at all key seabed features identified from review of the analogue data. A total of 50 locations were sampled across the EICC and Array Area, with the environmental sampling locations illustrated in Figure 8-2.

Twenty environmental stations were sampled across the EICC. Grab samples and seabed photography was undertaken at each of the stations. Six of the 20 sampling stations were also sampled for water column properties including Total Suspended Solids (TSS), temperature, salinity, pH and contaminants. For these water sampling locations, samples were acquired at bottom, mid and surface depths with corresponding water column profiles obtained for each (EICC_02, EICC_06, EICC_09, EICC_18, EICC_24, and EICC_37).

Thirty environmental stations were sampled across the Array Area, with 10 of the sampling stations also sampled for water column properties, as described for the EICC above. Water column properties were obtained at sample locations OWF_02, OWF_03, OWF_05, OWF_09, OWF_10, OWF_15, OWF_18, OWF_22, OWF_32, OWF_49.

Benthic Solutions was commissioned to provide the analysis and reporting of the environmental data. The findings of the environmental survey effort are detailed in the following reports, which have been used in characterising the baseline environment:

- EIAR Vol. 4, Appendix 8: Habitat Assessment Report – OWF;
- EIAR Vol. 4, Appendix 9: Habitat Assessment Report – EICC;
- EIAR Vol. 4, Appendix 11: Environmental Baseline Report – OWF; and
- EIAR Vol. 4, Appendix 12: Environmental Baseline Report – EICC.

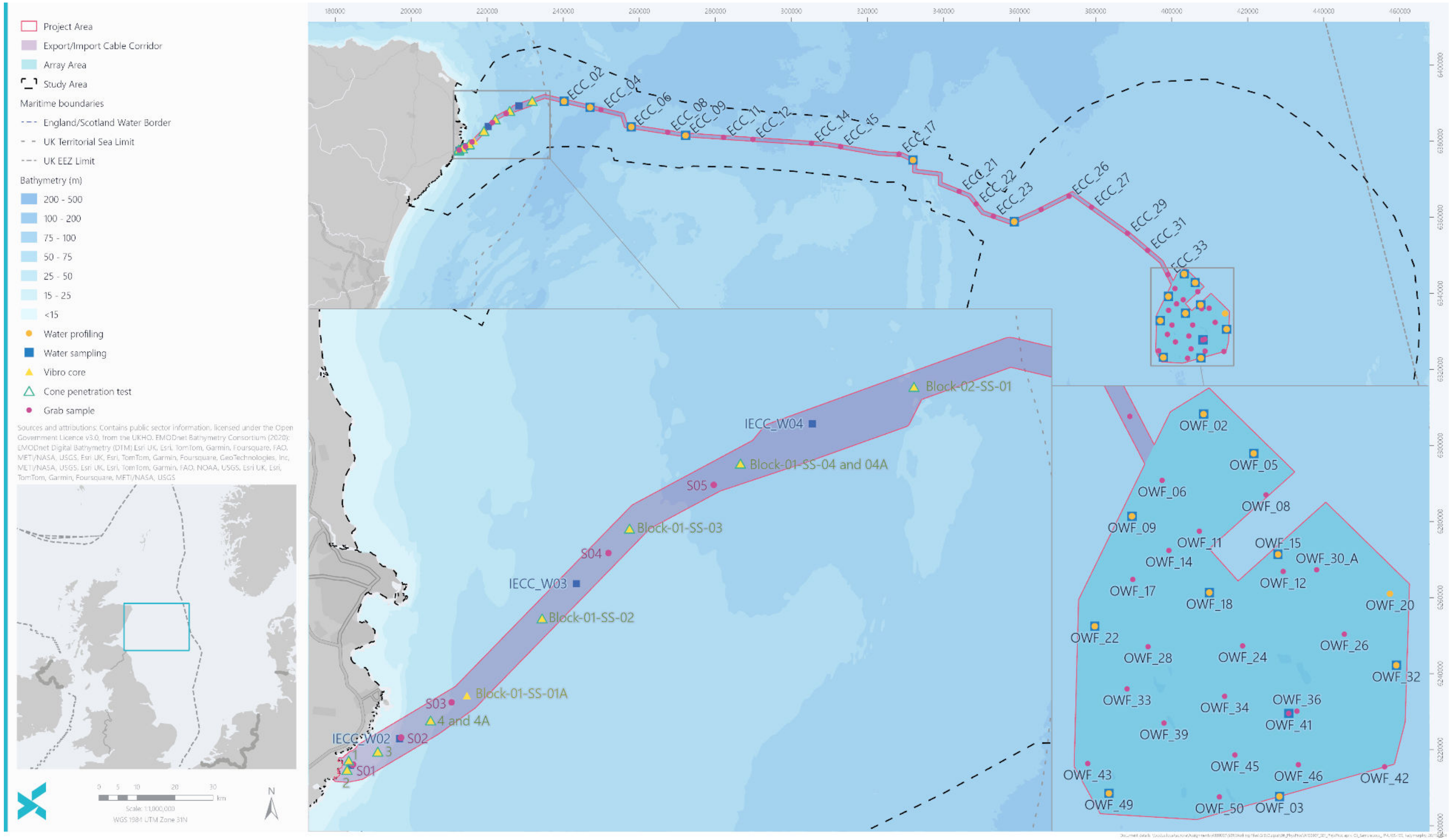


Figure 8-2 Environmental sampling locations from Project site-specific surveys

8.4.3.3 Metocean data

8.4.3.3.1 Site-specific hindcast data

On behalf of the Project, PhysE prepared a three volume report detailing varying metocean design criteria and properties (PhysE, 2023a; 2023b; 2023c). The metocean analyses completed by PhysE were based on hindcast data for locations within the Array Area only, with the hindcast information being validated by measured wind and wave data from the Forties, Gannet and Sleipner oil platforms and short duration current meter datasets from the British Oceanographic Data Centre (BODC). No equivalent information was prepared for the EICC. The hindcast datasets used to inform the metocean studies and subsequently provided to inform the baseline characterisation and impact assessment for this Marine Geology, Oceanography and Coastal Processes topic includes the following:

- Wind and waves: wind and wave presentations are based on the Metoceanworks (MoW) hindcast model. The MoW grid square 57.252°N 1.402°E is considered characteristic of the Array Area. This dataset provides a continuous record of winds and waves for a 43-year period from 03/01/1979 to 31/12/2022. Parameters acquired include wind speed and direction and significant wave height, peak period and mean wave directions for locally generated, swell and total sea states, at hourly intervals; and
- Current and water levels: current and water level parameters are produced through a European, basin-scale flexible mesh hydrodynamic hindcast model by MoW. This data has been extracted from the MoW modelled data at location 57.248°N 1.399°E and provides a continuous record of still water levels and depth-average total, tidal and residual currents for a 41-year period from 03/01/1979 to 31/12/2020, at hourly intervals.

In addition to the hindcast timeseries provided above, measured wave data has been provided by PhysE from the Forties platform located 63 km north of the Array Area, with a data coverage from July 1974 to October 2021. The data provided included significant wave height and peak period only. The metocean (hindcast and measured) data locations used to inform the baseline characterisation and impact assessment completed for this topic are illustrated in Figure 8-3.

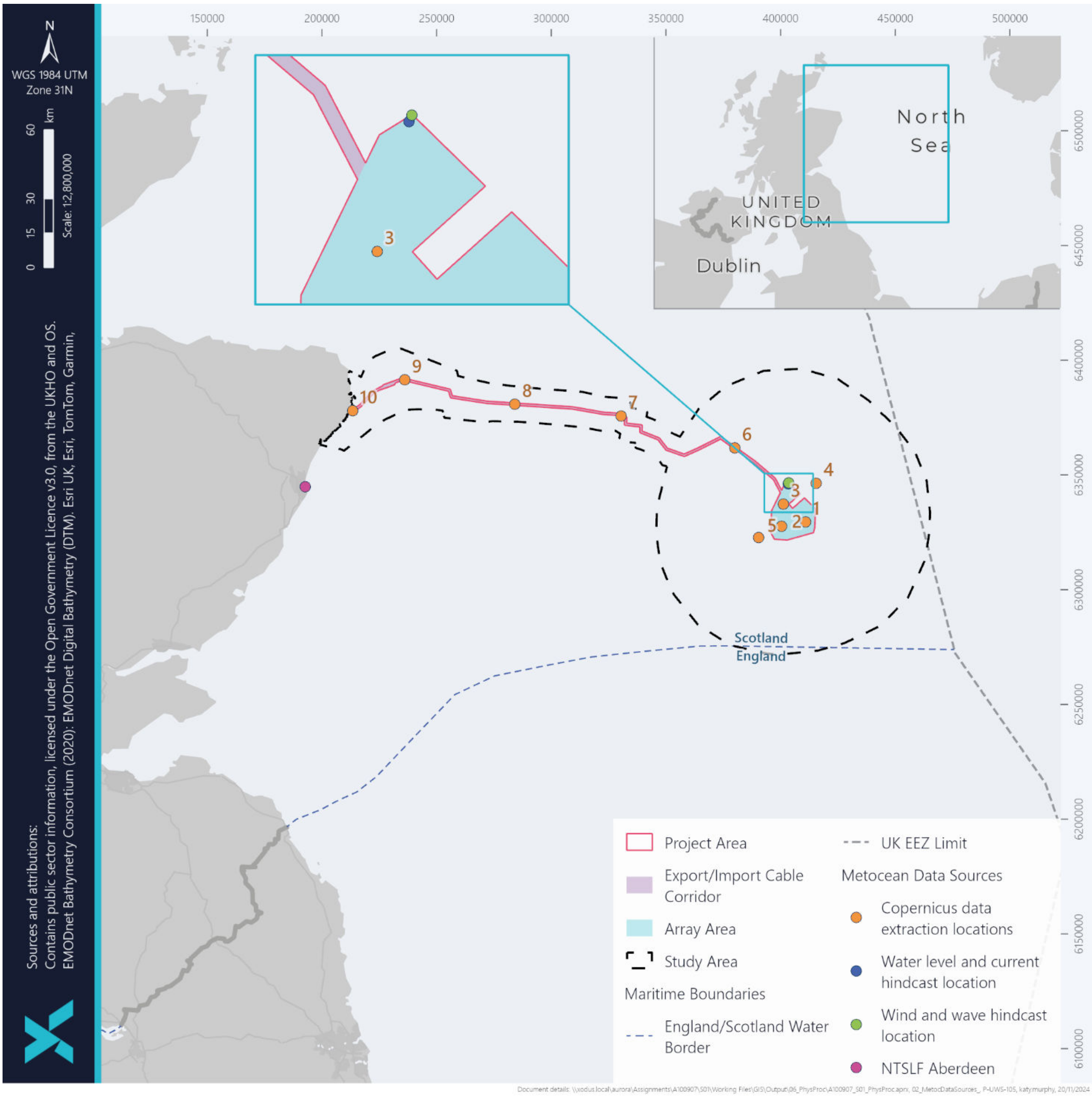


Figure 8-3 Metocean data locations informing the Marine Geology, Oceanography and Coastal Processes assessment

8.4.3.3.2 Secondary metocean data from Copernicus Marine

To further inform the metocean and water column properties across the Array Area and EICC, ten locations (three within the Array Area, two surrounding the Array Area and five along the EICC) have been selected for which the following information has been extracted from the Copernicus Marine data service (https://data.marine.copernicus.eu/products):

- Two-dimensional depth-averaged current speed and direction and water levels from the cmems_mod_nws_phy_anfc_0.027deg-2D_PT15M-I dataset from the NWSHELF_ANALYSISFORECAST_PHY_004_013 model (Tonani, *et al.*, 2022; Aznar, *et al.*, 2023), for a time period between October 2022 and July 2024, with information at 15-min intervals. Information is referenced as Copernicus Marin (2024) within this chapter, to account for the period of data extraction;
- Total wave significant wave height, zero-crossing period and mean direction from NORTHWESTSHELF_ANALYSIS_FORECAST_WAV_004_014 model (Tonani, *et al.*, 2022), for a time period between October 2022 and July 2024, with information at hourly intervals. Information is referenced as Copernicus Marin (2024) within this chapter, to account for the period of data extraction; and
- Three-dimensional (3D) water column temperature and salinity at up to 21 depth layers from the cmems_mod_nws_phy_anfc_0.027deg-3D_PT1H-m dataset from the NWSHELF_ANALYSISFORECAST_PHY_004_013 model (Tonani, *et al.*, 2022; Aznar, *et al.*, 2023), for a time period between October 2022 and July 2024, with information at hourly intervals. Information is referenced as Copernicus Marine (2024) within this chapter, to account for the period of data extraction.

The ten Copernicus Marine data extraction locations along with the site-specific hindcast data locations are illustrated in Figure 8-3.

8.4.3.4 Marine Geology, Oceanography, and Coastal Processes Technical Study

A site-specific marine physical processes technical study has been completed for the Project and included as EIAR Vol. 4, Appendix 7: Marine & Physical Processes Modelling Report. The completed technical study using available best practice and guidance, provides a detailed analysis and assessment of potential impacts during the various Project phases. The study considers the potential increases in SSC, bed levels and changes to sediment type as a consequence of sediment disturbance and potential changes to stratification and frontal systems. The results of the technical study are used to inform this topic assessment, in addition the assessments for other ecological and human receptor groups that may be sensitive to changes in SSC, bed levels (sediment deposition) and water column stratification.

8.4.4 Existing baseline

A review of literature and available data sources, and information gathered by consultation and Project site-specific surveys has been undertaken to describe the current baseline environment for Marine Geology, Oceanography and Coastal Processes.

8.4.4.1 Geology

8.4.4.1.1 Solid Geology

The basic structural framework bedrock geology throughout the North Sea is a result of Upper Jurassic / Lower Cretaceous rifting, with partial control from older structural elements (Norwegian Petroleum Directorate, 2021).

The dominant bedrock geology varies across the Marine Geology, Oceanography and Coastal Processes Study Area. At the coast, the geology is more variable starting as igneous granitic rock along the cliffs at Longhaven, where the EICC landfall is located (Figure 8-4). Progressing further offshore along the EICC are variable bands of metasedimentary rock belonging to the Southern Highland Group, conglomerate Old Red Sandstone, Permian aged mudstone and gypsum-stone, a band of chalk, and Pleistocene mudstone and undifferentiated sandstone and lignite (BGS, 2024).

From approximately 30 km offshore to the boundary of the Scottish Economic Exclusion Zone (EEZ) (approximately 230 km from coast), the geology is characterised by siliciclastic, argillaceous and sandstone of Eocene to Pliocene age (BGS, 2024), with the bedrock geology generally occurring at depths >30 m below the seabed. The above described solid geology is characteristic of the EICC and the Array Area too.

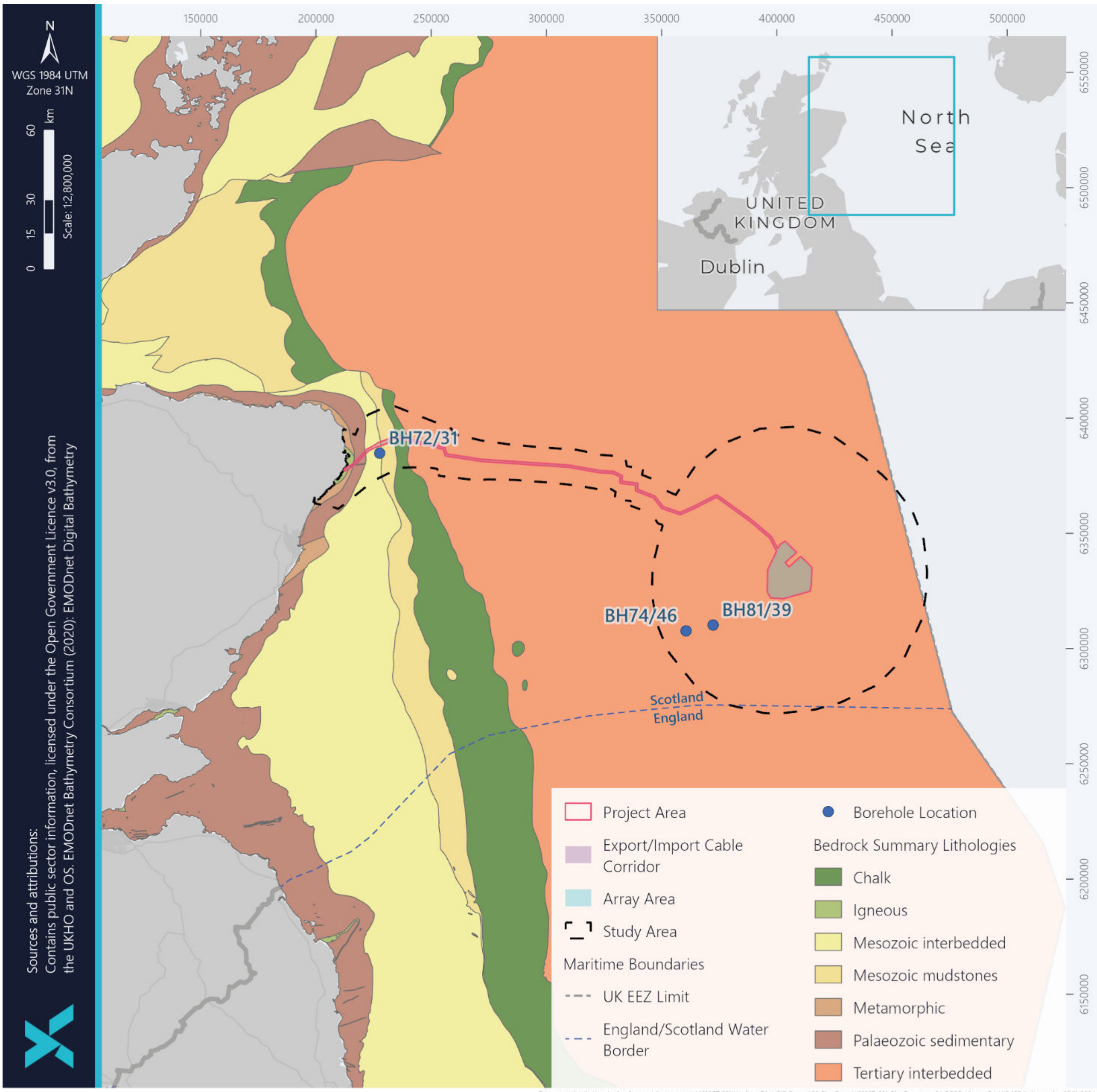


Figure 8-4 Geology across the Marine Geology, Oceanography and Coastal Processes Study Area

Borehole data obtained by the British Geological Survey (BGS) is used to corroborate the summary lithologies shown in Figure 8-4. Borehole data from a location to the north of Peterhead described the first 24 m of sediment to be largely dark grey-black sticky boulder clay. Below this was a loose sandy and gravelly material with large pebbles of igneous rock. Analysis of the samples retrieved from the borehole defined the depth at which bedrock was reached as approximately 35 m below the seabed. The bedrock was described as flat bedded brick red sandstone (BGS, 1972).

Two close borehole records, approximately 12 km apart and with the closest being about 35 km southeast of the Array Area are illustrated in Figure 8-4. The first of these borehole records is located in 94 m of water, with the borehole reaching a total depth of 83 m of sediments, however much of this was not recovered and so was not described. The most superficial layers of sediment were classed as fine sands or coarse silts. Approximately 30 m down the core, the sediments were described as slightly clayey fine sand which then transitioned into highly plastic dark grey clay which continued to 50 m. Beyond this, there was no recovery of sediments. The depth at which bedrock was reached is not known (BGS, 1975).

The second borehole, in a water depth of 126 m, obtained a 64.1 m core which described five layers of variable thickness. The most superficial layers of sediment were described as fine grained, silty sands. At a depth of 20.8 m, is a 31.7 m thick layer of dark, soft, plastic clay interbedded with fine sands. Below this is another band of poorly sorted sand. At the bottom of the core is a layer of very dark, hard and heavily over consolidated clay belonging to the Aberdeen Ground Beds. The depth at which bedrock was reached is not known (BGS, 1981a).

Another borehole record corresponds to a location approximately 40 km southeast of the Array Area, in a water depth of 95 m. The record describes the borehole reaching a depth of 114 m without having reached bedrock. The majority of the core was described as very dark clay interbedded with thin layers of sands and silts. At the maximum depth of the record, at 114 m below the seabed, the substrate was heavily over-consolidated clay (BGS, 1981b).

8.4.4.1.2 Quaternary Geology

Available BGS data indicates that the thickness of overlying Quaternary deposits varies across the Marine Geology, Oceanography and Coastal Processes Study Area (Figure 8-5). At the coast, the depth of Quaternary sediments varies and is typically shallower than offshore. At the EICC landfall, the Quaternary deposits are between 5 m and 30 m thick. Further offshore, along the majority of the EICC, and at the Array Area, deposits exceed >50 m (BGS, 2024). This is consistent with the results of the above borehole results.

A summary of the Quaternary geological units across the EICC and Array Area as identified from the site-specific geophysical surveys is presented in Table 8-4 and also illustrated in Figure 8-5. Surficial seabed sediments described further in Section 8.4.4.2 are relatively thin at <3 m thickness across the majority of the Project, with the majority (2/3rds) of the site having less than 0.5m of surface sediment. In instances across the Project there are outcropping and sub-cropping older Quaternary units of varying thicknesses characteristic of glacial and post-glacial till sediment, although the units tend be thinner and shallower along the EICC compared with the Array Area (Table 8-4 and Figure 8-5). The geophysical survey interpretation for the Project would suggest there is a frequent occurrence of boulders both on the sediment surface and throughout the Quaternary geological units.

Shallow gas pockets were identified during the geophysical survey. These features are often associated with the Whitehorn member of the Forth Formation geological unit occurring at the seabed across the Project and up to depths of 122 m below the seabed within the Array Area (Table 8-4). The largest example of potential shallow gas occurring across the Project is in the west of the Array Area (Rovco, 2023b).

Table 8-4 Interpreted Quaternary geology units across the EICC and Array Area, with depths below the seabed (Rovco, 2024a; 2024b)

NAME		GEOLOGICAL AGE	EICC QUATERNARY GEOLOGICAL UNITS		OWF QUATERNARY GEOLOGICAL UNITS	
			UNIT DESCRIPTION	DEPTH[1]	UNIT DESCRIPTION	DEPTH[1]
Surficial Sediment		Holocene	Clayey, silty sand with occasional gravel and isolated to scattered cobbles and boulders.	0 – 2.4[2] m	Clayey, silty sand with occasional gravel and isolated to scattered cobbles and boulders.	0 – 3 m
Witch Ground Formation		Holocene	Clays, fine sands and silts.	0 - 2.3 m	Absent across Array Area	
Forth Formation	Upper Unit (Whitethorn)	Holocene	Clayey, silty sands with occasional gravel and isolated to scattered cobbles and boulders.	0 - >21.5[3] m	Slightly gravelly silty clayey sand with isolated to scattered cobbles and boulders.	0 – 122 m
Forth Formation	Undifferentiated Forth	Holocene/ Weichselian	Clays and silty clays to sands and gravelly sands with scattered boulders.	0 - 18.2 m	Absent across Array Area	
Forth Formation	Lower Unit (Fitzroy)	Late Weichselian	Interbedded clays and silty clays with isolated to scattered cobbles and boulders.	0 – 21.5[3] m	Interbedded clays and silty clays with isolated to scattered cobbles and boulders.	0 – 156 m
Wee Bankie Formation		Weichselian	Till interbedded with thin layers of sand, silty clay, coarse sand and gravel deposits.	0 - 20.6 m	Absent across Array Area	
Coal Pit Formation		Late Saalian to Weichselian	Sandy silty clay, interlaminated clay and fine-grained silty sand, and stiff and over consolidated clays with some pebbles and boulders.	0 - >21.5 m	Sandy silty clay and interlaminated clay and fine-grained silty sand; clay generally stiff and over consolidated with some pebbles and boulders. Shell and shell fragments abundant in places.	0 – 183 m
Fisher Formation		Late Saalian	Very stiff over consolidated Poorly sorted sandy, clayey silt.	0.5 - >21.5[3] m	Very stiff over-consolidated silty and sandy clay. Clay is generally sandy with pebbles.	N/A
Ling Bank		Elsterian to Late Saalian	Not Interpreted		Silt with interbedded clay and sand.	N/A
Aberdeen Ground		Tiglian to Elsterian	Not Interpreted		Hard, heavily over consolidated clay.	N/A

[1]: Minimum and maximum depths below the seabed; [2]: Surficial sediment thickness, may be very locally thicker in locations of bedforms and seabed feature; [3]:Limits of interpretation

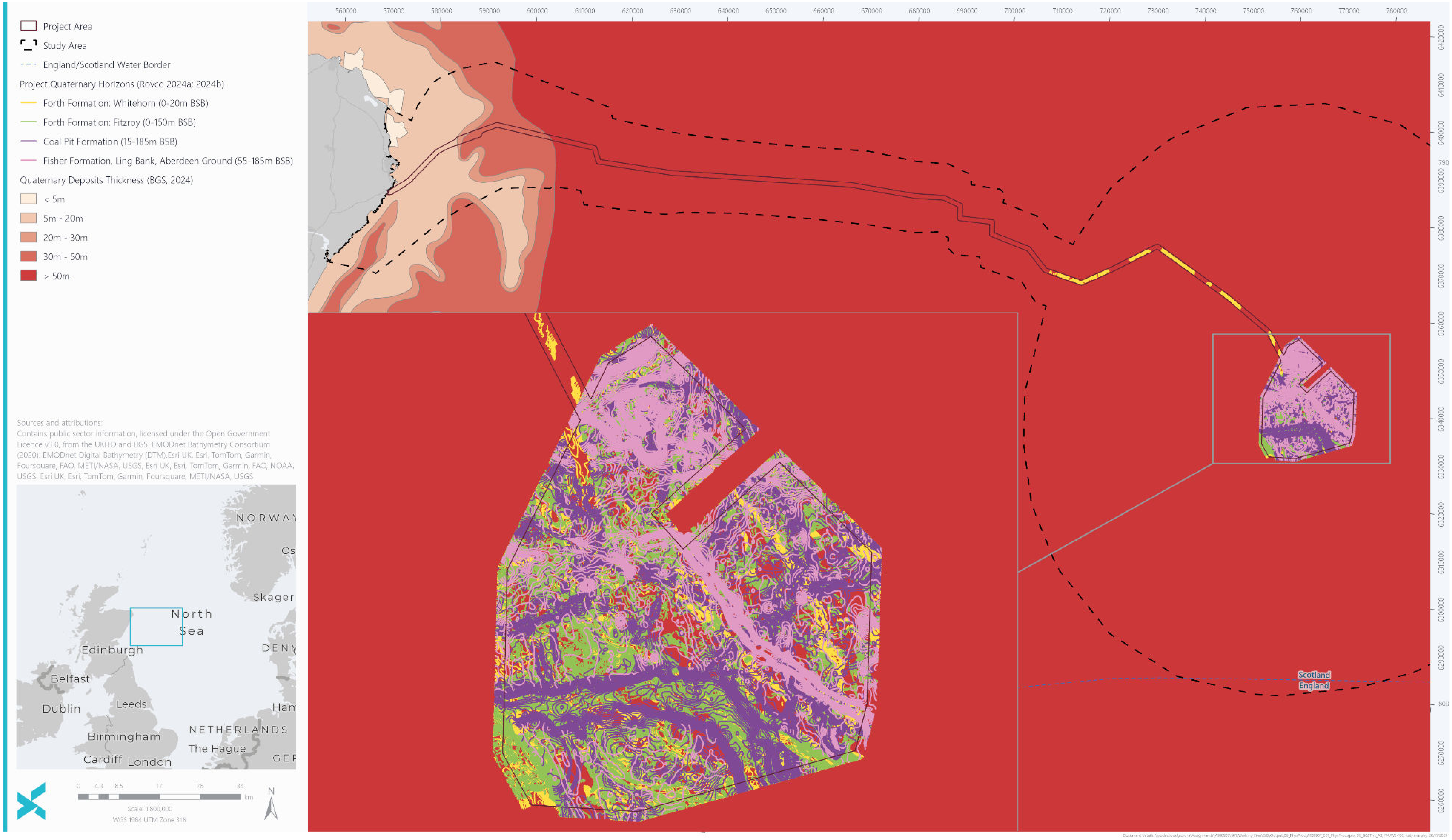


Figure 8-5 Quaternary geology thickness across the Marine Geology, Oceanography and Coastal Processes Study Area

8.4.4.2 Seabed Sediments

Geophysical survey information in the inshore region of the EICC (i.e. between the coast and the 12 NM offshore) indicated sediment thickness is generally very thin, ranging between a veneer of material up to a maximum thickness of 2 m, particularly in locations towards the coast (Figure 8-6) (MMT, 2018a). Where present the surficial sediment overlays sub-cropping Quaternary geological units as introduced in Section 8.4.4.1.2. The geophysical survey indicated that the surficial sediments are comprised of gravelly sand and sandy gravel along the majority of the EICC, with isolated bands of coarser sediment and occurrences of exposed bedrock (MMT, 2018a). For a very short section near the landfall from the HDD exit to circa 30 mLAT, the seabed is noted as being comprised of silt with medium sand. Whereas further along the EICC and towards the 12 NM boundary, the seabed sediment is noted as being more sandy, with isolated occurrences of gravelly sand and sandy gravel (MMT, 2018a). However, information interpreted from the geotechnical and grab sampling would suggest sediment to be finer along the EICC and being dominantly comprised of sand (MMT, 2018b; 2018c). Grab sampling completed for the NorthConnect inshore survey at sample S01 was classed as very silty fine sand, while samples S03 to S05 were classed as gravelly medium to coarse sand. Sample S02 was an exception, comprising a coarser homogenous sediment which was classed as slightly silty sandy gravel (MMT, 2018b; 2018c2018a). The surficial sediment characteristics expressed as a percentage sediment fraction (fines, sands, gravels) derived from analysis of sediments recovered as part of the inshore grab sampling campaign are illustrated in Figure 8-7.

PSA of sub-samples from the vibrocores (i.e. at eight locations, with PSA completed at multiple depths) associated with the NorthConnect inshore survey (MMT, 2018b) demonstrate that the surficial sediment, at depths less than 0.5 m below the seabed mainly comprises sand, corroborating the analyses of sediments recovered from the grab sampling campaign. However, at depth, i.e. at depths greater than 1 m below the seabed there is a prevalence for gravel (MMT, 2018b). A summary of the PSA data from the vibrocore sample locations (Figure 8-2) at the analysed depths below the seabed are presented in Table 8-5.

Table 8-5 Summary of PSA results from vibrocore samples acquired in the inshore region of the EICC (MMT, 2018b)

VIBROCORE ID	KP	TOP (m)	BASE (m)	FINES (%)	SANDS (%)	GRAVELS (%)
VC_A_001	0.195	0.00	0.56	14	86	
VC_A_001		0.56	0.97	21	76	3
VC_A_001		0.97	1.71	3	60	37
VC_A_002	0.08	0.00	0.65	7	92	1
VC_A_002		0.65	0.96	8	89	3
VC_A_002		0.96	1.63	2	76	22
VC_A_002		1.82	2.67	2	53	45
VC_A_003	1.279	0.00	0.60	15	84	1
VC_A_003		0.60	1.20	17	83	
VC_A_003		1.20	1.70	8	90	2
VC_A_004A	3.376	0.00	0.49	9	34	57
VC_A_004A		0.49	0.76	57	26	17
Block-01-SS-02	8.571	0.00	0.35	3	45	52
Block-01-SS-02		1.00	1.55	38	45	17
Block-01-SS-02		1.55	2.00	7	90	3
Block-01-SS-03	12.856	0.00	0.45	4	52	44
Block-01-SS-03		0.45	0.60	84	12	4
Block-01-SS-04	17.28	0.20	0.40	16	62	22
Block-01-SS-04		0.55	0.80	82	17	1
Block-02-SS-01	23.872	0.36	0.84	21	79	

Generally, offshore, the geophysical interpretation of seabed sediment indicated relatively thin seabed sediment cover along the EICC (Figure 8-6). Within the surficial sediment is the occurrence of cobbles and boulders, which range between being isolated and scattered in some locations, to areas of numerous boulders where surficial sediment is thin to absent (MMT, 2018a; 2018b). Where sediment is present along the EICC, it is broadly grouped into three sediment types which characterises much of the corridor:

1. Silty, clayey sand with occasional gravel and isolated to scattered cobbles and boulders;
2. Sand with occasional gravel and scattered boulders; and
3. Sandy silty clay with isolated cobbles and boulders.

Completed PSA of sediment smaller than boulders acquired as part of the site-specific offshore environmental surveys are, summarised in Table 8-6, with the sediment fraction and distribution illustrated in Figure 8-7. The PSA results indicated that sediments within the EICC (beyond the inshore region) are predominantly sands and fines, with minimal proportions of gravel present with the exception of one sample location (EICC_27) where a much higher gravel content was noted (Figure 8-7). The proportion of sands were fairly consistent along the EICC (with a mean proportion of 78.31% ±18.50Standard Deviation (SD)) with the exception of two stations, which comprised lower proportions of sand (i.e. EICC_27 with 41.59% and EICC_29 with 17.52%) (EIAR Vol. 4, Appendix 12: Environmental Baseline Report - EICC). The proportion of fines are variable across the EICC ranging from 2.10% at station EICC_02 to 82.43% at EICC_29 with a mean of 19.48% (±16.37 SD). Although the proportions of gravel in the sediment samples are minimal along the EICC, where present, the percentage of the gravel fraction is highly variable, with 16 stations having <1% gravel and the remaining four stations having a gravel content of between 1.45% (EICC_01) and 34.69% (i.e. EICC_27 as introduced above), respectively (EIAR Vol. 4, Appendix 12: Environmental Baseline Report - EICC).

Overall, surficial sediments along most of the EICC is classed as muddy sand according to the modified Folk classification. Sediment particle size range between 0.02 mm (EICC_29) and 0.67 mm (EICC_27), with a mean of 0.19 mm, equivalent to medium silt (Table 8-6; EIAR Vol. 4, Appendix 12 Environmental Baseline Report - EICC).

BGS seabed sediments show much of the EICC corridor to be a mix between sand, gravelly sand, and slightly gravelly sand. This is somewhat at odds with the PSA which suggests sediments are much finer along the EICC, therefore, greater weight of evidence is given to the site-specific sampled data, which is used to inform the sediment transport potential properties in Section 8.4.5.4. The PSA results from the survey are shown in Figure 8-8 superimposed on BGS sediment data.

The seabed within the Array Area is primarily characterised by Holocene sediments, which are interpreted to comprise clayey silty Sand with occasional gravel and isolated to scattered cobbles and boulders and large regions of exposed Quaternary geology as described in Section 8.4.4.1.2 above (Rovco, 2023b). Where present, the surficial sediment cover across the Array Area is relatively thin at most, being absent or as a thin veneer of at (or less than) 0.5 m thickness. It is only in the southwestern corner of the Array Area where a pocket of thicker sediment occurs, with a maximum thickness of up to 3 m. The distribution and thickness of the surficial sediment across the Array Area is illustrated in Figure 8-6 (Rovco, 2023 b). For the sampled sediment across the Array Area, the results of the PSA indicate a sediment type primarily composed of sand and fines and minimal gravels across most stations (Table 8-7 and Figure 8-7) (EIAR Vol. 4, Appendix 11 Environmental Baseline Report - OWF). The proportions of sand found within sediment samples are consistent across the Array Area (mean 55.7% ± 8.44 SD) with the exception of two stations (OWF_42; 20.83% and OWF_49; 39.08%) sampled in the southeastern and southwestern extent of the survey area (Table 8-7). Within these samples, the proportion of fines range from 18.45% at OWF_42 to 60.8% at OWF_49 with an average of 41.9% (±6.83 SD) for the Array Area. The proportion of gravel is variable, as out of the 30 stations surveyed, 27 stations have less than 1% gravel content. The remaining three stations, OWF_15, OWF_32, OWF_43, have gravel contents of 1.55%, 2.7% and 60.72%, respectively (Table 8-7).

With the exception of three sample locations, sediments across the whole Array Area are described as muddy sand. OWF_05, OWF_42, and OWF_49 are the exception, classed as very fine sand, very coarse sand, and medium silt, respectively (Table 8-7). Sediment particle size range between 0.03 mm (OWF_49) and 1.84 mm (OWF_42), with a mean of 0.11 mm (EIAR Vol. 4, Appendix 11 Environmental Baseline Report - OWF). Generally, most samples have a mean particle size of 0.05 mm, representative of fine silt (Table 8-7). Overall, the sediments across the Array Area are relatively homogenous.

When compared against the BGS sediment classification shown in Figure 8-8, the survey results are broadly corroborating. According to the BGS data, much of the Array Area is classed as sand, with the southeastern extent of the Array Area characterised as mud (BGS, 2024). The survey data classes the whole of the Array Area as muddy sand (with the exception of a few locations). This suggests that the muddy and sandy sediments within the Array Area are more mixed based on the site-specific sampled data rather than distinctly separate as the BGS regional characterisation would suggest. The PSA results are shown alongside the BGS sediment data in Figure 8-8.

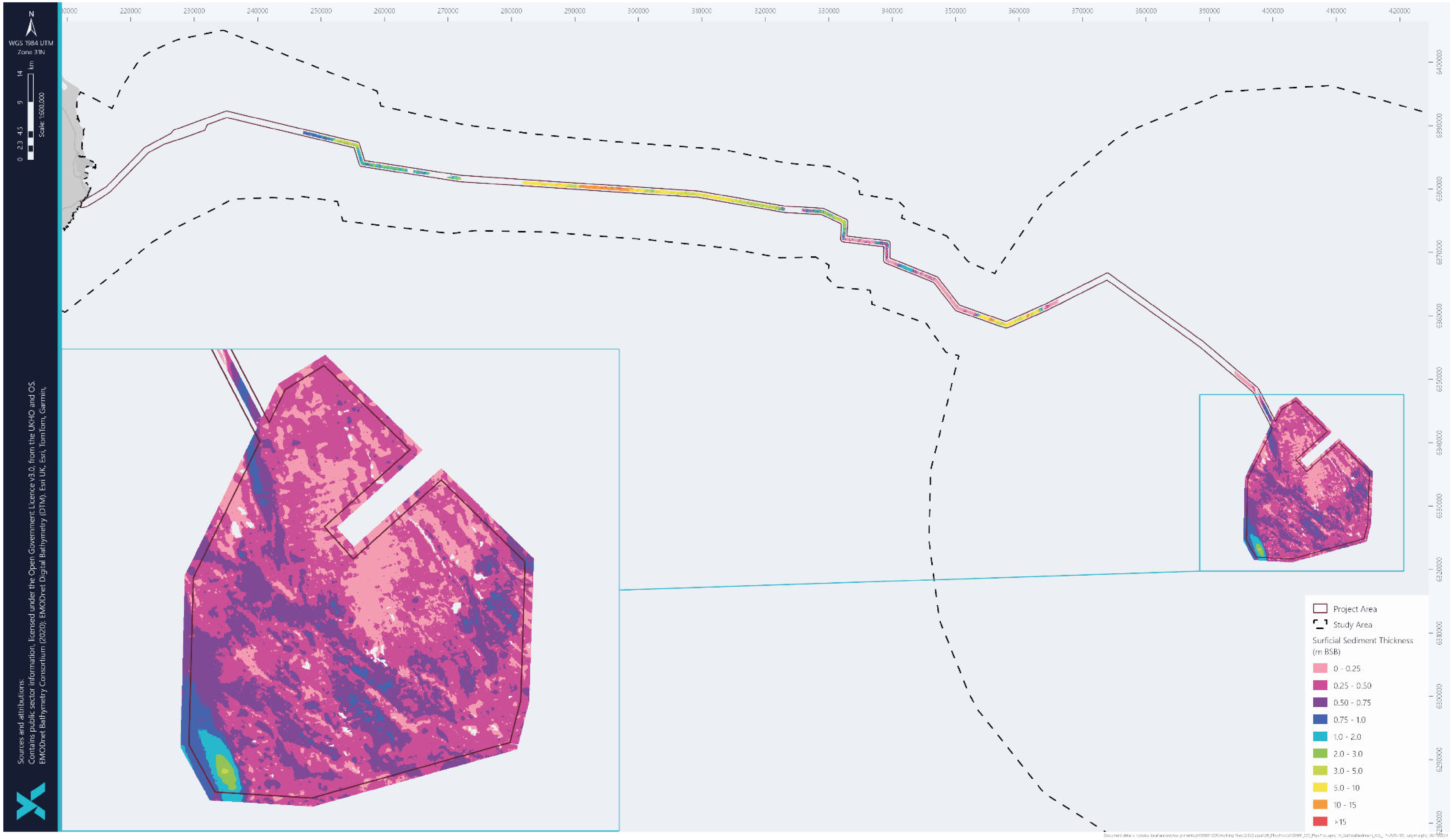


Figure 8-6 Surficial sediment thickness along the EICC and Array Area from site specific surveys

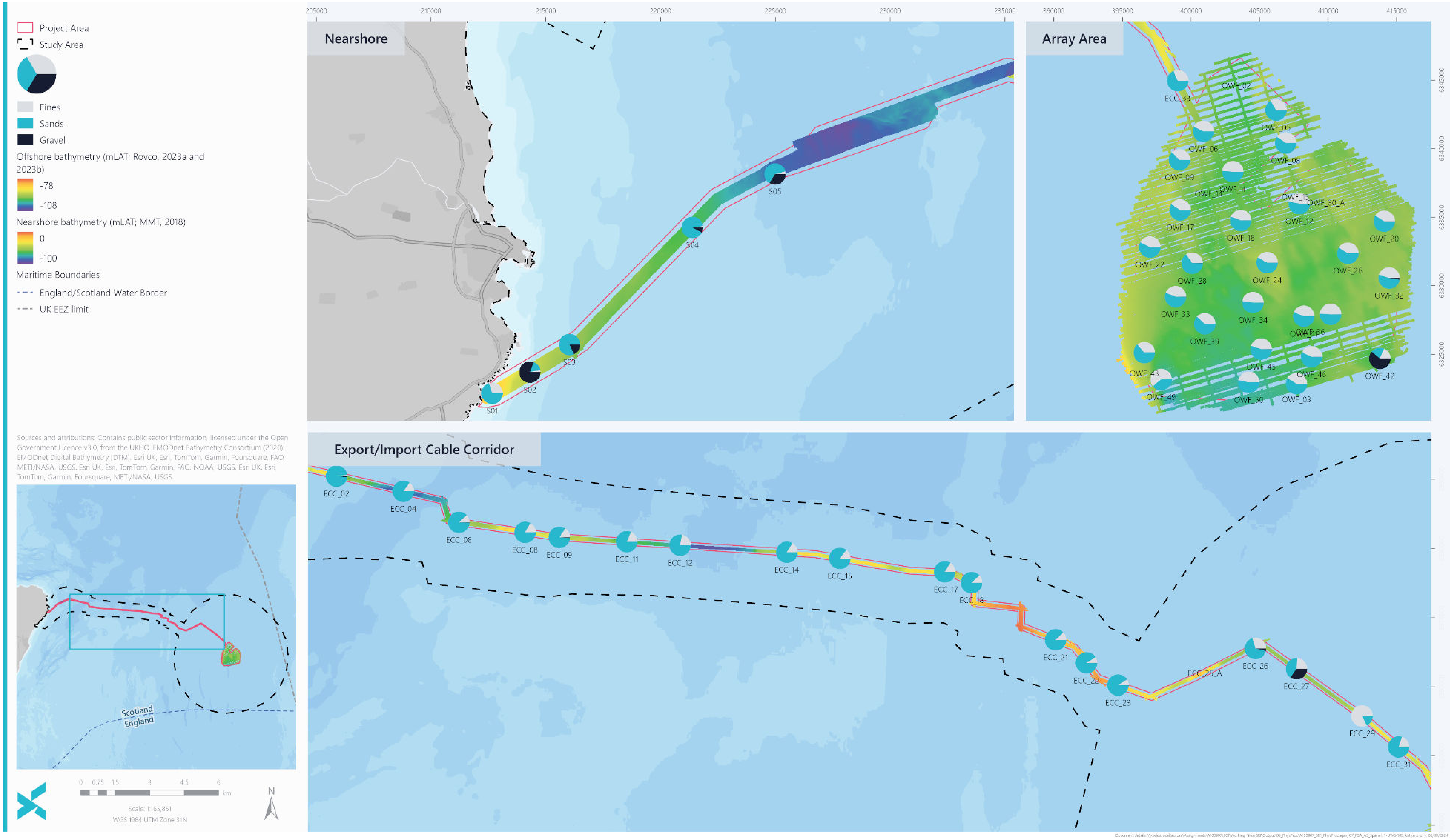


Figure 8-7 Spatial representation of the surficial sedimentology expressed as a percentage of fines, sands and gravels along the EICC and across the Array Area

*Table 8-6 Summary of PSA results along the EICC (**EIAR Vol. 4, Appendix 12: Environmental Baseline Report - EICC**), with inshore samples from MMT (2018c)*

STATION	DEPTH (m)	MEAN PARTICLE SIZE (mm)	WENTWORTH CLASSIFICATION	FINES (%)	SANDS (%)	GRAVELS (%)	MODIFIED FOLK CLASSIFICATION
S01	-	-	-	30	70	0	-
S02	-	-	-	4	15	81	-
S03	-	-	-	0	82	18	-
S04	-	-	-	2	90	8	-
S05	-	-	-	4	62	34	-
EICC_02	89	0.39	Medium Sand	2.10	96.45	1.45	Muddy Sand
EICC_04	106	0.15	Fine Sand	15.20	84.76	0.04	Muddy Sand
EICC_06	96	0.22	Fine Sand	11.77	87.61	0.62	Muddy Sand
EICC_08	89	0.14	Fine Sand	16.60	83.33	0.07	Muddy Sand
EICC_09	91	0.18	Fine Sand	15.37	83.34	1.29	Muddy Sand
EICC_11	97	0.09	Very Fine Sand	18.58	81.38	0.04	Muddy Sand
EICC_12	99	0.08	Very Fine Sand	22.24	77.65	0.10	Muddy Sand
EICC_14	89	0.16	Fine Sand	16.19	83.78	0.03	Muddy Sand
EICC_15	90	0.18	Fine Sand	14.32	85.53	0.15	Muddy Sand
EICC_17	75	0.15	Fine Sand	16.22	83.65	0.14	Muddy Sand
EICC_18	75	0.21	Fine Sand	11.87	88.05	0.09	Muddy Sand
EICC_21	75	0.20	Fine Sand	12.19	87.70	0.11	Muddy Sand
EICC_22	85	0.26	Medium Sand	8.81	90.77	0.42	Sand
EICC_23	85	0.21	Fine Sand	8.93	90.88	0.19	Sand
EICC_25_A	90	0.22	Fine Sand	11.84	87.67	0.50	Muddy Sand
EICC_26	97	0.09	Very Fine Sand	29.72	66.52	3.77	Slightly Gravelly Muddy Sand
EICC_27	100	0.67	Coarse Sand	23.72	41.59	34.69	Muddy Sandy Gravel
EICC_29	95	0.02	Medium Silt	82.43	17.52	0.05	Sandy Mud
EICC_31	100	0.09	Very Fine Sand	19.84	79.81	0.36	Muddy Sand
EICC_33	100	0.06	Very Fine Sand	31.72	68.18	0.10	Muddy Sand
Mean	-	0.19	-	19.48	78.31	2.21	-
SD	-	0.14	-	16.37	18.50	7.69	-
Minimum	-	0.02	-	2.10	17.52	0.03	-
Maximum	-	0.67	-	82.43	96.45	34.60	-
The summary statistics are in relation to the offshore sampling completed for the EICC.							

*Table 8-7 Summary of PSA results within the Array Area (**EIAR Vol. 4, Appendix 11: Environmental Baseline Report - OWF**)*

STATION	MEAN PARTICLE SIZE (mm)	WENTWORTH CLASSIFICATION	FINES (%)	SANDS (%)	GRAVELS (%)	MODIFIED FOLK CLASSIFICATION
OWF_02	0.05	Coarse Silt	36.94	62.91	0.15	Muddy Sand
OWF_03	0.05	Coarse Silt	41.31	59.58	0.35	Muddy Sand
OWF_05	0.06	Very Fine Sand	33.39	66.27	0.34	Muddy Sand
OWF_06	0.05	Coarse Silt	42.38	59.23	0.19	Muddy Sand
OWF_08	0.06	Coarse Silt	40.44	60.14	0.09	Muddy Sand
OWF_09	0.06	Coarse Silt	37.77	59.45	0.27	Muddy Sand
OWF_11	0.04	Coarse Silt	48.83	61.00	1.50	Muddy Sand
OWF_12	0.05	Coarse Silt	46.81	56.04	2.25	Muddy Sand
OWF_14	0.05	Coarse Silt	38.64	58.88	1.17	Muddy Sand
OWF_15	0.05	Coarse Silt	42.42	55.90	0.62	Sl. Gravelly
OWF_17	0.06	Coarse Silt	40.90	57.74	1.45	Muddy Sand
OWF_18	0.05	Coarse Silt	44.32	59.38	2.70	Muddy Sand
OWF_20	0.05	Coarse Silt	40.97	55.05	2.40	Muddy Sand
OWF_22	0.05	Coarse Silt	42.51	52.28	2.29	Muddy Sand
OWF_24	0.06	Coarse Silt	42.12	0.25	3.75	Muddy Sand
OWF_26	0.05	Coarse Silt	41.12	62.91	0.15	Muddy Sand
OWF_28	0.05	Coarse Silt	34.69	59.58	0.35	Muddy Sand
OWF_30_A	0.05	Coarse Silt	43.38	66.27	0.34	Muddy Sand
OWF_32	0.05	Coarse Silt	45.08	59.23	0.19	Muddy Sand
OWF_33	0.06	Coarse Silt	44.02	60.14	0.09	Slightly Gravelly Muddy Sand
OWF_34	0.05	Coarse Silt	47.81	59.45	0.27	Muddy Sand
OWF_36	0.04	Coarse Silt	49.05	61.00	1.50	Muddy Sand
OWF_39	0.05	Coarse Silt	38.27	56.04	2.25	Muddy Sand
OWF_41	0.05	Coarse Silt	44.13	58.88	1.17	Muddy Sand
OWF_42	1.84	Very Coarse Sand	18.45	55.90	0.62	Muddy Sand
OWF_43	0.05	Coarse Silt	36.08	57.74	1.45	Muddy Sandy

STATION	MEAN PARTICLE SIZE (mm)	WENTWORTH CLASSIFICATION	FINES (%)	SANDS (%)	GRAVELS (%)	MODIFIED FOLK CLASSIFICATION
OWF_45	0.05	Coarse Silt	44.87	59.38	2.70	Gravel
OWF_46	0.05	Coarse Silt	42.90	55.05	2.40	Muddy Sand
OWF_49	0.03	Medium Silt	60.80	52.28	2.29	Muddy Sand
OWF_50	0.04	Coarse Silt	46.55	0.25	3.75	Muddy Sand
Mean	0.11	-	41.09	55.70	2.40	-
SD	0.33	-	6.83	8.44	11.03	-
Minimum	0.03	-	18.45	20.83	0.09	-
Maximum	1.84	-	60.80	66.27	60.72	-

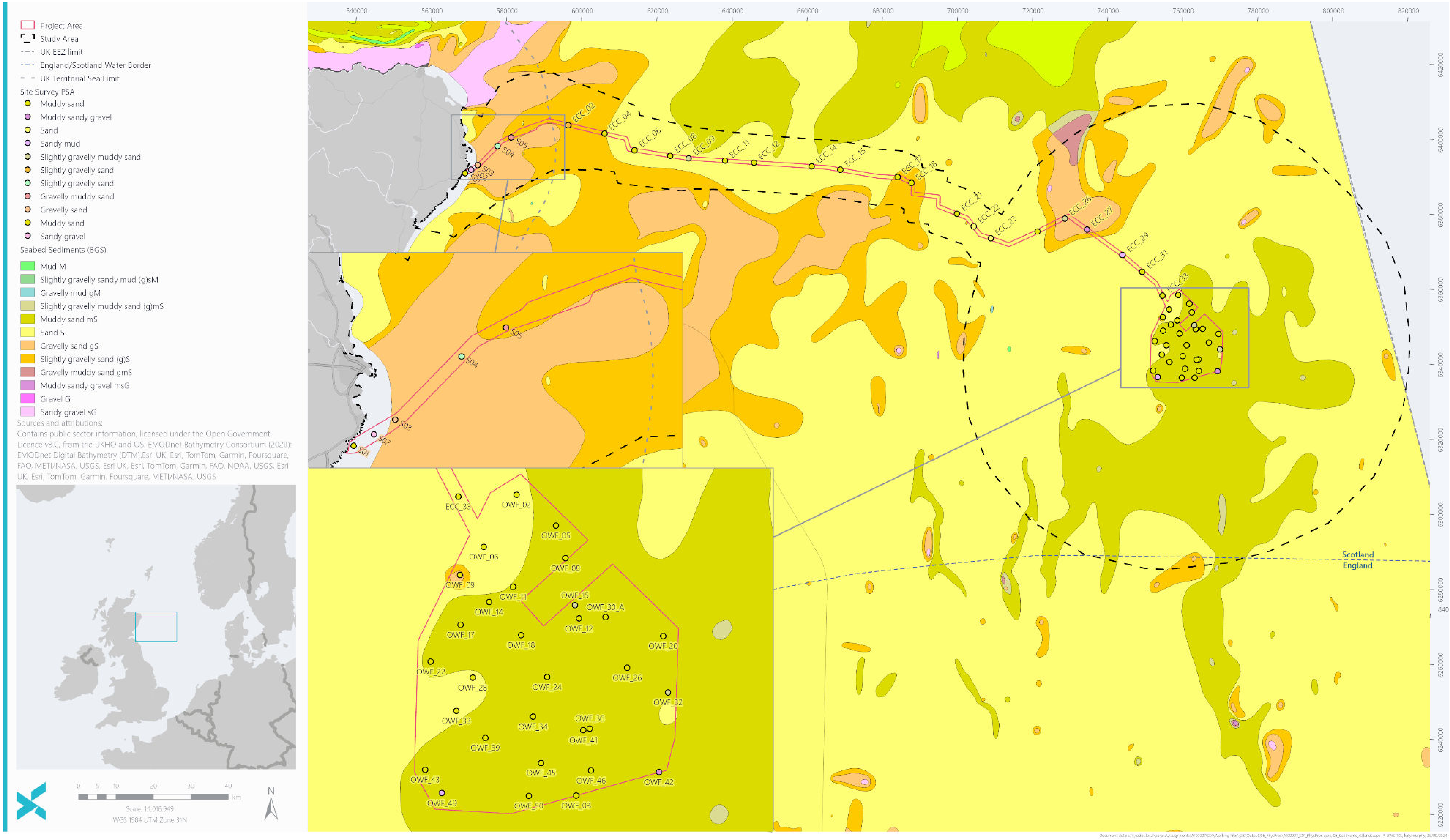


*Figure 8-8 Survey PSA results (**EIAR Vol. 4, Appendix 11: Environmental Baseline Report – OWF, EIAR Vol. 4, Appendix 12: Environmental Baseline Report - EICC**) overlain with the BGS (2024) surficial sediments map*

8.4.4.3 Bathymetry

The seabed bathymetry across the Project and wider Study Area is illustrated in Figure 8-9.

8.4.4.3.1 EICC

The inshore EICC bathymetry is characterised as being gently sloping with localised areas of higher gradients which are associated with features such as rocky outcrops. From KP 0 to KP 4.521 the water depth increases from 18.9 mLAT to 51.6 mLAT. Along this portion of cable, the minimum depth reached is 9.2 mLAT just beyond the start of the EICC. From KP 0 to KP 3 the water depth increases rapidly to around 40 m. From this point on, the seabed continues to deepen more gradually (MMT, 2018a). Between KP 4.521 and KP 19.141 the seabed profile continues to deepen from 54.5 mLAT to 92.7 mLAT. The bathymetry shows a relatively smooth seabed with a gentle to very gentle gradient, with slope values from 1° and 2°, until approximately KP 12.000, and wherein the slopes become more variable and slightly steeper, between 1° to 3° thereafter (MMT, 2018a). From KP 18.009, the bathymetry within the EICC is characterised by a very gentle to gently sloping seabed with localised occurrences of moderate to very steep gradients associated with sandwaves and ripple features, with the water depth being around 90 mLAT (MMT, 2018a).

Surveys of the offshore area begin at KP 27.971 as introduced in Section 8.4.3.1.2, with the minimum and maximum depths along the EICC ranging between 79.8 mLAT and 107.4 mLAT respectively (Rovco, 2023a). From KP 27.971, the seabed gently deepens from a depth of 86.1 mLAT to a maximum water depth of 107.4 mLAT at KP 90.034, after which the seafloor gently shallows to a minimum water depth of 79.8 m at KP 140.308, before very gently deepening again to 94.1 m at KP 228.000. Local topographic highs occur due to more consolidated underlying sediments approaching the surface between KP 28.000 to KP 34.534 and KP 118.481 to KP 121.176 (Rovco, 2023a).

The average seabed gradient along the proposed EICC is less than 1°, with localised seafloor gradients up to 10° associated with the lee and stoss side of bedforms, the steepest of which was observed in an area of sandwaves at the start of the survey corridor (seabed morphology including bedforms is discussed in full in Section 8.4.4.4). The maximum, natural gradient within the EICC is 37°, associated with a seabed depression at KP 130.706 (Rovco, 2023a).

8.4.4.3.2 Array Area

Within the Array Area, the water depth ranges from a minimum of 82 mLAT to a maximum of 105 mLAT. The maximum seabed gradient within the Array Area is 15°, which is associated with an uncharted wreck, however generally the Array Area displays a predominantly flat seabed, gently with an average gradient of <1° (Rovco, 2023b). The seabed gently deepens from the north western extent of the Array Area to the deepest area of the Array Area along the southwestern boundary (Rovco, 2023b). This southwestern boundary is closest to the Devil's Hole – a group of deep trenches.

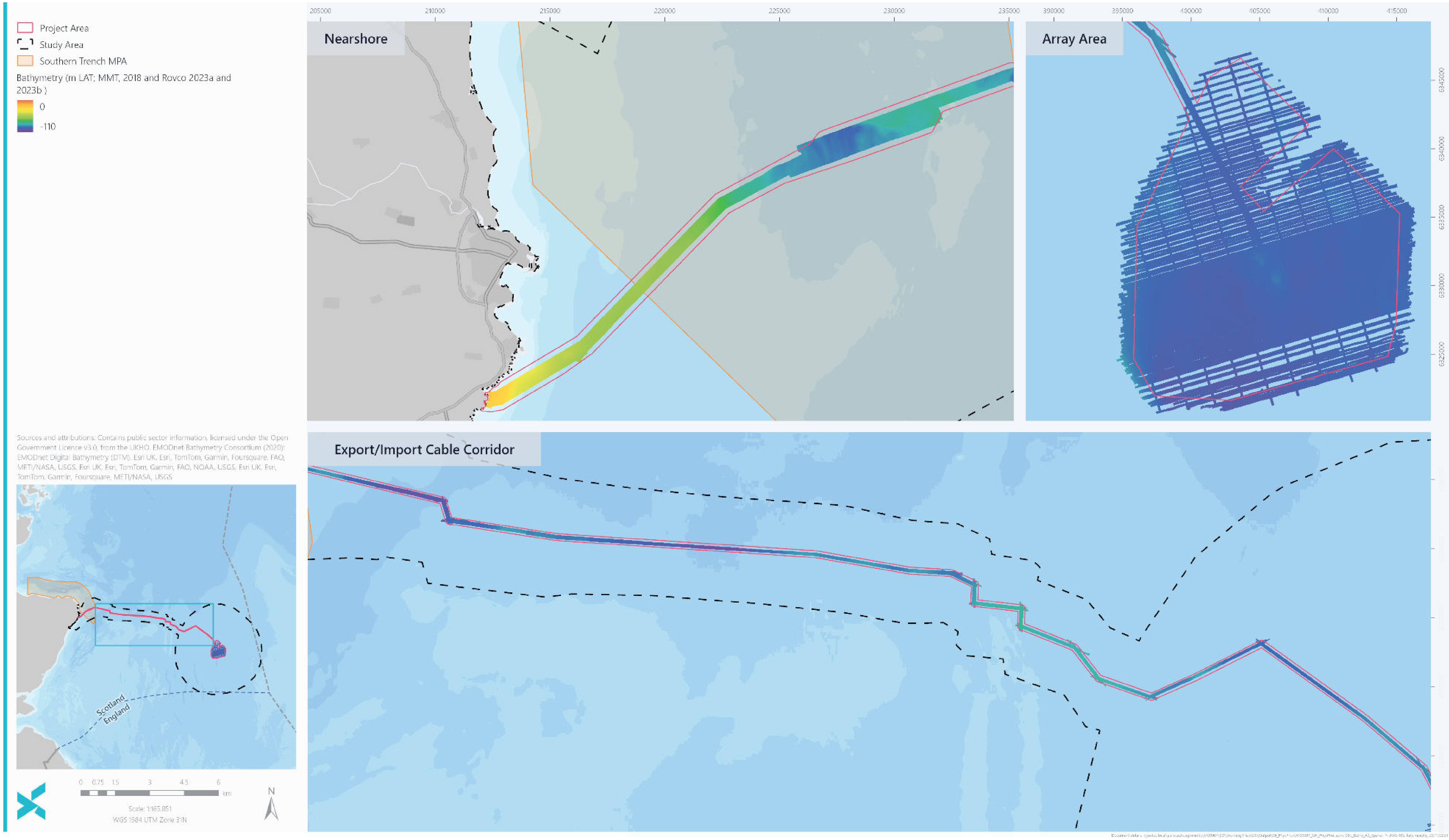


Figure 8-9 Bathymetry across the EICC and Array Area (Rovco, 2023b)

8.4.4.4 Seabed Morphology

Seabed morphology, identified geodiversity and seabed features, present within the Project are illustrated in Figure 8-10. Boulders frequently occur on the seabed across the entire Project (Section 8.4.4.2) as identified in the site-specific surveys and also illustrated in Figure 8-10. Sandwaves and linguoid sandwaves are commonly observed along the length of the EICC. The presence of these features are indicative of strong underwater currents. (Rovco, 2023a).

The inshore section of the EICC passes through several areas of bedforms including areas characterised by the presence of ripples, megaripples and sandwaves. Ripples, large ripples and megaripples are features which are almost omnipresent on the seabed within the central and southern regions of the North Sea. Within the inshore, between KP 4.080 and KP 14.878 ripples, large ripples and megaripples are observed (MMT, 2018a) Beyond this point, further offshore, ripples cover approximately 50% of the survey corridor.

At KP 21.060, the EICC crosses a set of large northwest to southeast trending seabed features interpreted to be sandwaves with superimposed ripples, with the interpreted sandwaves having a height of up to 8 m (MMT, 2018a). Due to the size, scale and orientation of the seabed features and the potential for glacial features, particularly moraines in the inshore region of the EICC, there is some uncertainty regarding the conclusive nature of the features. Between KP 27.320 and KP 27.730, there is a curvilinear bathymetric depression where large megaripples are present on the seabed (MMT, 2018a). Approximately between KP 8 and KP 21 (inshore of the 12 NM boundary, the EICC crosses the Southern Trench Nature Conservation Marine Protected Area (NCMPA) (Figure 8-10). Present within the NCMPA are protected geodiversity features including geological, glacial and geomorphological features (NatureScot, 2019). Of note and relevance to this topic is the fact that the inshore EICC crosses a small extent of a sub-glacial tunnel valley feature as illustrated in Figure 8-10. Further detail on the designated seabed interest features and properties of the NCMPA relevant to this topic are discussed further in Section 8.4.4.10 below.

Beyond the inshore section of the EICC, the sandwaves present along the EICC are regular, sinusoidal transverse bedforms characterised, by wavelengths between 6 m and 43 m. Wavelengths of <15 m are predominant between KP 27.974 – KP 37.507, whereas wavelengths of up to 40 m are common in other areas (Rovco, 2023a). Sandwaves within the EICC are shown in Figure 8-11.

Interrogation of the data acquired during the geophysical survey (Rovco, 2023a) identified the following along the EICC:

- Sandwaves are interpreted from KP 27.974 – KP 37.507, with this section of the EICC having a corresponding depth range of 83.6 mLAT to 97.5 mLAT. These sandwaves have associated slopes of up to 2°, with the exception of some steeper bedforms which have slopes of up to 3.5° (Rovco, 2023a).
- Sandwaves are also intermittently observed from KP 40.032 – KP 68.249 with associated slopes which increase with distance along the EICC. The sandwaves between KP 51 and KP 59 have slopes of up to 2°, whereas from KP 59 to KP 68 the slopes associated with the sandwaves reach up to 4° and are very regularly spaced and comparatively uniform compared to early features. This section of the EICC has an approximate depth range from 83.8 mLAT to 105.3 mLAT (Rovco, 2023a).
- Further sandwaves are observed between KP 109.877 and KP 144.066 (the water depth along this section of the EICC ranges from approximately 78.9 mLAT to 92.6 mLAT). Between KP 110 and KP 116, sandwaves are less

sharply defined and more rounded. Slopes reach gradients of 1.5°. From KP 116 to KP 144, sandwaves are more erratic and less uniform, reaching infrequent maximum slopes of 2.5° (Rovco, 2023a).

Linguoid sandwaves are also observed along the EICC, these are interpreted as crescent shaped waves associated with higher flow velocities, often occurring as a result of interfering current flows. They are characterised in the EICC by larger, crescent, or elongated waves (80 m – 278 m wavelength) overlain by smaller sandwaves (9 m – 29 m wavelength). The linguoid sandwaves are variable in shape, with those close to the coast being more elongated and those further offshore exhibiting a more crescent shape. The orientation of the larger crests' axes are generally north-northeast to south-southwest, whereas the smaller internal sandwaves are orientated northwest to southeast. Linguoid sandwaves are shown alongside sandwaves for comparison in Figure 8-11. Along the EICC, the linguoid sandwaves are interpreted to be intermittent from KP 35.507 – KP 40.032 (with a corresponding water depth range from 92.9 mLAT to 105.3 mLAT) and from KP 59.118 – KP 68.258 (with a corresponding depth from 83.8 mLAT to 92.8 mLAT). The linguoid sandwaves have associated slopes of 4 – 5°, suggesting they are steeper sided then the sinusoidal transverse sandwaves, described above.

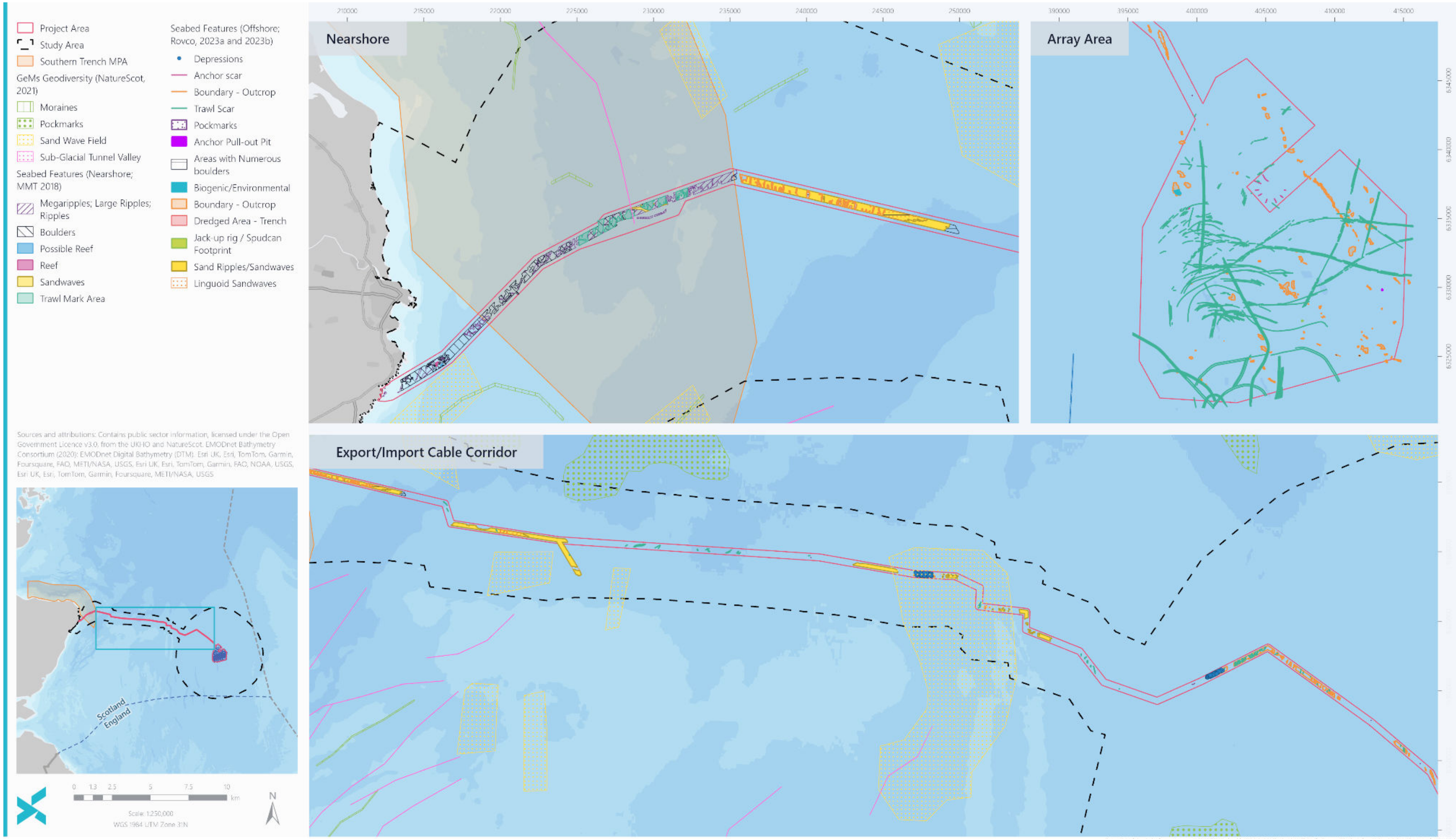


Figure 8-10 Morphological, geodiversity and seabed features along the EICC and Array Area

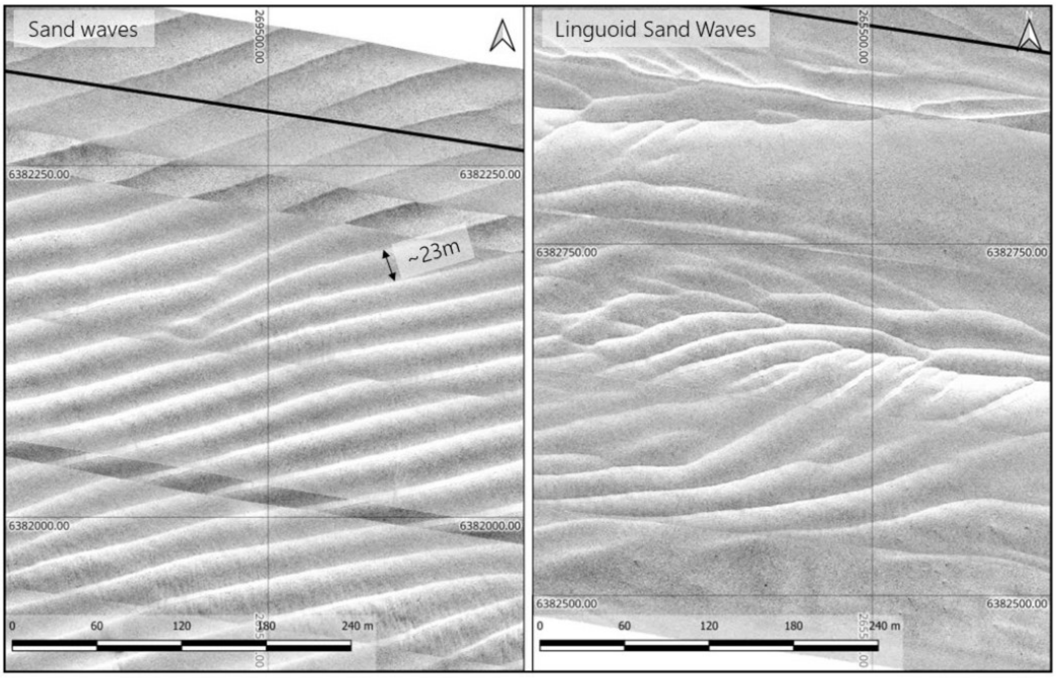


Figure 8-11 Bathymetry showing the difference between the sinusoidal transverse sandwaves (left) and linguoid sandwaves (right) present within the EICC (Rovco, 2023a)

A total of seven pockmarks were identified within the EICC, with sizes ranging from 7 – 32 m in diameter (Figure 8-12). Depressions, other than pockmarks, were also frequently observed throughout the EICC, with these often associated with the presence of boulders, which are also common across the EICC.

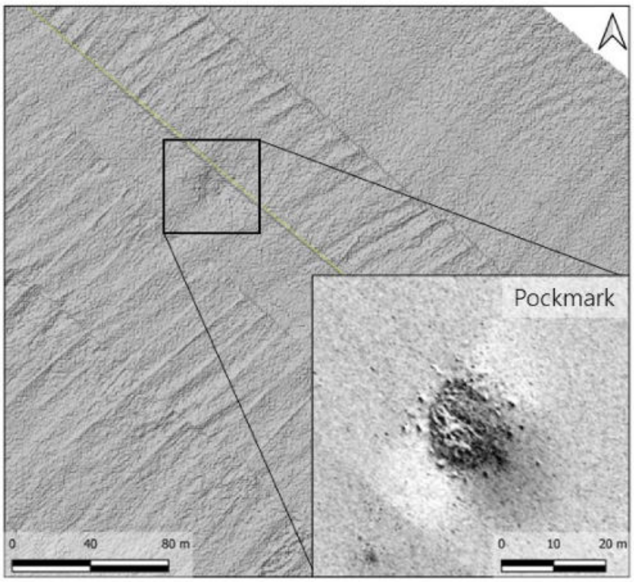


Figure 8-12 Bathymetry showing an example of a pockmark at KP 207.690 with a high frequency SSS inset (Rovco, 2023a)

As stated in Section 8.4.4.3, the seabed within the Array Area is relatively featureless and flat. Unlike the EICC, there are no notable bedforms within the Array Area. The geophysical survey did identify areas of outcropping Quaternary sediment which broke through the surficial sediment layers (Sections 8.4.4.1.2 and 8.4.4.2). However, these outcrops are of other subsurface Quaternary units and do not represent solid geology (Rovco, 2023b).

There are few natural morphological features on the seabed. However, 11 seabed features were interpreted as pockmarks. These depressions were typically in the centre, north, and southwest of the Array Area. Due to the abundance of shallow gas-filled sediments within the site (as described in Section 8.4.4.1), these depressions may have been formed by gas escaping at the seabed. However, no such gas escapes were observed during the survey (Rovco, 2023b).

Additionally, a total of 42 anchor pull out pits were identified across the Array Area in addition to numerous trawl scars as illustrated in Figure 8-10. The anchor pull out pits were typically associated with existing oil and gas wells in the area and were often accompanied by anchor scar(s). Three pipelines are also located in the vicinity of the Array Area (Rovco, 2023b).

8.4.4.5 Tidal Regime

8.4.4.5.1 Water Levels

The Project is located in an area characterised by a meso-tidal regime, although the extent of tidal variation differs across the Project Area. Across the Central North Sea (CNS), there is an east to west variation in tidal range, with tidal range decreasing in an offshore direction, and a larger range in water level occurring along the coast (ABPmer, 2008). At the EICC landfall, the spring tidal range is 3.18 m. The neap range is 1.57 m (ABPmer, 2008). Information from the long-term tidal observation station at Aberdeen (south of the EICC landfall) is used to provide an indication of the water level properties at the coast, with the statistics summarised in Table 8-8. Water level properties from Aberdeen indicate a mean spring and neap tidal range of 3.62 m and 1.76 m respectively. Historically, the highest tidal level recorded at Aberdeen occurred in January 2005 where the water level reached 5.31 m. All of the ten highest recorded water levels have been over 5 m. With regards to predicted tides at Aberdeen, the highest equinoctial spring tide was predicted for September 2015, reaching 4.85 m. The lowest tides were predicted for March 2024, when water levels were predicted to be 0.05 m (NTSLF, 2024).

Key water level parameters for the Array Area are shown in Table 8-8 as informed by the site specific metocean study (PhysE, 2023a; 2023b; 2023c). Water level statistics derived from the water level and current hindcast location within the Array Area (Section 8.4.3.3.1 and Figure 8-3) indicate that comparatively, the tidal range in the Array Area is smaller. The spring tidal range in the Array Area is 1.25 m, and the neap range is 0.61 m (PhysE, 2023a). This is corroborated by the water level data retrieved from the from the ten Copernicus Marine data extraction locations (Section 8.4.3.3.2 and Figure 8-3) which corroborate the decrease in tidal water levels moving offshore, with a maximum predicted water level height range of 4.8 m occurring at the landfall location (i.e. Location 10) decreasing to 3.4 m midway along the EICC at Location 8, and decreasing further to 2.25 m within the Array Area at Location 3.

Table 8-8 Tidal water level relative to Lowest Astronomical Tide (LAT) for the landfall (from Aberdeen, NTSLF, 2024) and the water level and current hindcast location within the Array Area (PhysE, 2023b)

		ABERDEEN (m)	WATER LEVEL AND CURRENT HINDCAST LOCATION (m)
Highest Astronomical Tide	HAT	4.85	1.64
Mean High Water Springs	MHWS	4.32	1.48
Mean High Water Neaps	MHWN	3.46	1.15
Mean Sea Level	MSL	-	0.87
Mean Low Water Neaps	MLWN	1.70	0.54
Mean Low Water Springs	MLWS	0.70	0.23
Lowest Astronomical Tide	LAT	0.05	0.00
Mean Spring Range	MSR	3.62	1.25
Mean Neap Range	MNR	1.76	0.61

8.4.4.5.2 Storm surges and extremes

Aberdeen is the closest long-term tidal gauge site to the EICC landfall. Data on tidal surges at Aberdeen have been recorded since 1930 (BODC, 2024). Surges associated with astronomic events area measured at the gauge as the difference between the measured height minus the predicted astronomical tidal height (i.e. surges highlight the difference, positive or negative, between the astronomical predicted and observed tides). Typically, surges at Aberdeen do not exceed +1 m. However, there has been one instance since 1930 where this has occurred, which saw a maximum positive surge of 1.276 m occurring in February 2011 (BODC, 2024).

Monthly extreme water levels have been recorded at Aberdeen since 1990. Extreme water levels differ from surges and represent the monthly maximum and minimum sea level height values, with surges related to astronomical events contributing to this. Aberdeen experiences larger positive extremes than negative extremes. Since 1990, the maximum extreme water level at Aberdeen has been 5.306 m occurring in 2005. Otherwise, extreme water levels typically range between 4 m and 5 m (BODC, 2024).

At the Array Area, surges and extreme water levels have been calculated by PhysE (2023a) for the water level and current hindcast location shown in Figure 8-3. These extremes parameters are shown in Table 8-9 for 1, 5, 10, 50 and 100-year return periods. The PhysE (2023a) 100-year return period surges range from a negative surge level of -0.93 m below mean sea level (MSL), to a positive surge of 1.30 m

Table 8-9 Extreme surges and water levels for the Array Area (PhysE, 2023a)

LEVELS (m)	1-YEAR	5-YEAR	10-YEAR	50-YEAR	100-YEAR
Positive Surge Levels (from MSL)	0.82	0.99	1.06	1.23	1.30
Negative Surge Levels (from MSL)	-0.65	-0.72	-0.78	-0.89	-0.93
Still Water Level (from LAT)	2.40	2.48	2.52	2.60	2.64
Extreme Water Level (from LAT)	11.0	12.8	13.4	15.1	15.7

8.4.4.5.3 Tidal Currents

The anti-clockwise nature of water movement throughout the North Sea originates from the influx of Atlantic water, via the Fair Isle Channel and around the north of Shetland. The main outflow of water is northwards towards the Norwegian coast (Department for Business, Energy & Industrial Strategy (BEIS), 2016). The direction of water movement throughout the CNS is generally in a southwards direction (Ramsay and Brampton, 2000; DTI, 2001; DEICC, 2016), with flood flow being in the same direction.

Figure 8-1 provides an indication of the orientation of tidal flows across the Project and within the Study Area based on the mean spring tidal ellipses (ABPmer, 2008). Across the Project, tidal flows are predominantly orientated north – south, becoming more north-northeast – south-southwest further offshore across the Array Area (Figure 8-1). The current rose plot presented in Figure 8-13 was developed using the data derived from the water level and current hindcast location and shows north – south oriented flows, with a lesser north-northeast to south-southwest component.,

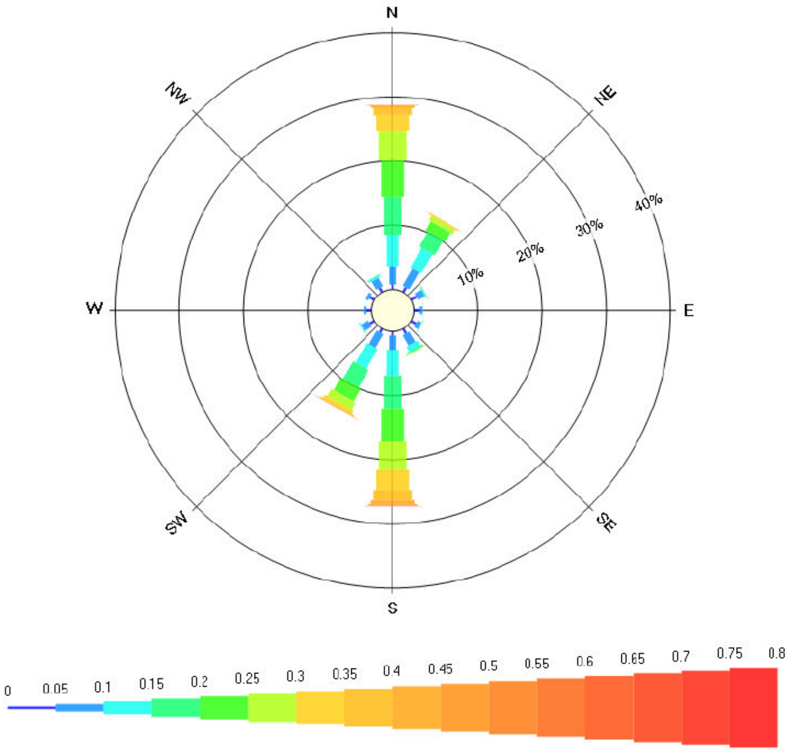


Figure 8-13 Current rose presenting current velocity (m/s) magnitude as a function of direction. The data was retrieved at the water level and current hindcast location within the Array Area, directions are towards (PhysE, 2023b).

Across the Project and Study Area, mean tidal flow speeds decrease as water depths increase offshore (Figure 8-14). Data from the Marine Renewables Atlas (ABPmer, 2008) indicates that the depth-averaged tidal stream speeds of over 1 m/s occur infrequently along the east coast of Scotland. These areas of increased speed occur predominantly around headlands, including along the coast around Peterhead. The EICC landfall will intersect with areas where flows exceed 1 m/s up to 31% of the time. At the landfall, spring flows are predicted in the region of 1.41 m/s, compared to speeds of 0.32 m/s at the Array Area. Neap flow speeds are approximately half the speed of spring flows, with speeds at the landfall and Array Area, reaching 0.73 m/s and 0.16 m/s, respectively (ABPmer, 2008).

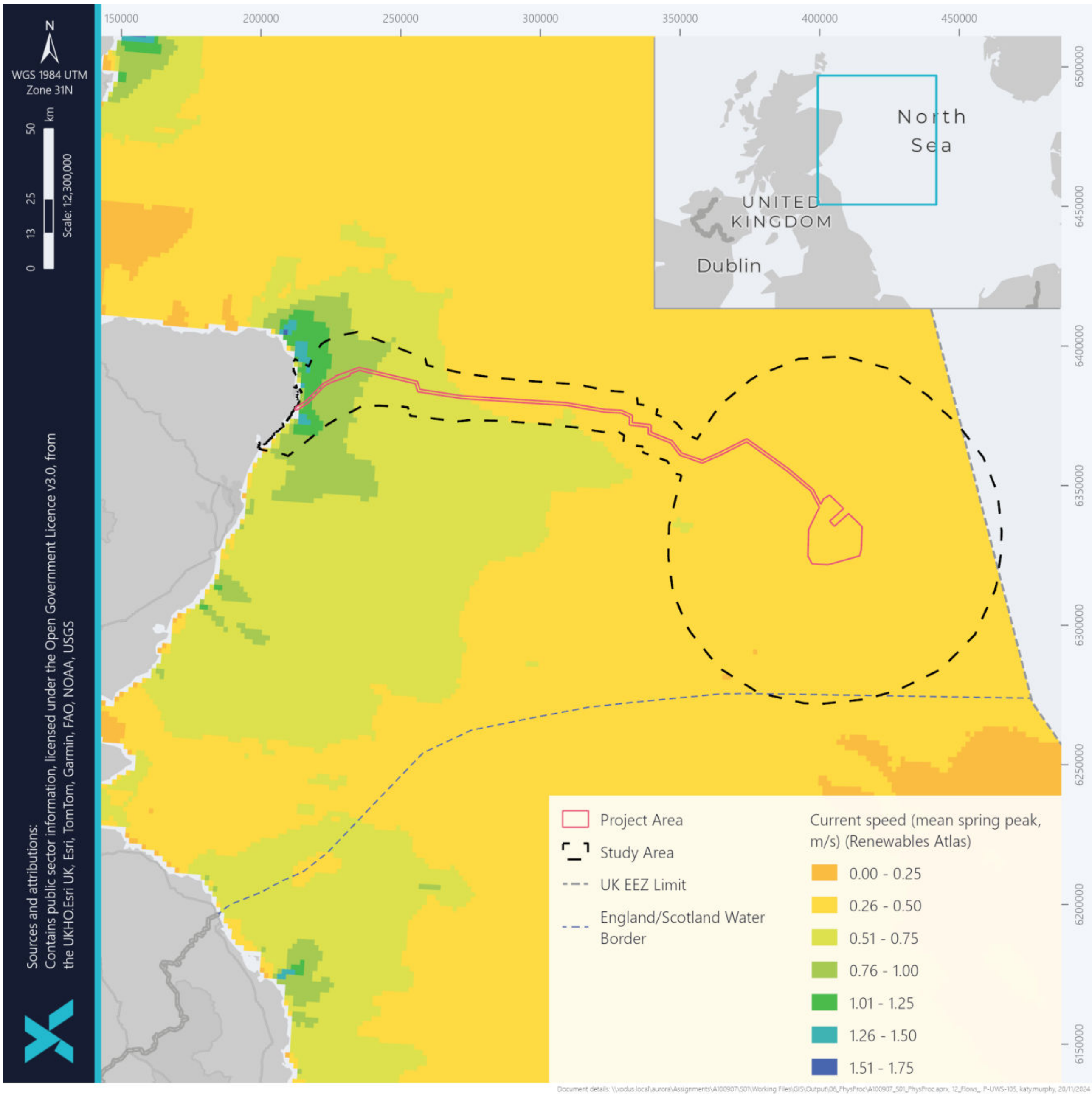


Figure 8-14 Spring flow speeds across the EICC and Array Area (ABPmer, 2008)

Copernicus Marine (2024) data on flow speeds and directions have been extracted at 10 locations across the Project as shown in Figure 8-3. This data covered a time series between January 2022 and June 2024 (2.5 years). Interpreted flow properties (i.e. speed and direction) for selected locations across the Project are summarised in Table 8-10, which demonstrate a reduction in current speeds in the offshore direction. At the landfall location (i.e. Location 10), the flow properties from the current timeseries indicate maximum spring and neap peak flows in the region of 1.20 m/s and 0.51 m/s respectively, with flows oriented approximately north-south. With increasing distance offshore, flow speeds reduce slowly. At Location 9, which is also relatively close to the coast, peak spring flows reach speeds of 1.17 m/s, with neaps of 0.51 m/s. At Location 7, approximately midway along the EICC, spring and neap flow speeds are 0.70 m/s and 0.40 m/s, respectively. Speeds associated with Location 3, located within the Array Area are discussed below.

Table 8-10 Flow properties for locations within Project (from Copernicus Marine (2024) and the water level and current hindcast location)

PARAMETER	HINDCAST LOCTION	LOC 3	LOC 7	LOC 10
Max spring peak tidal flow (m/s)	0.50	0.50	0.70	1.20
Max neap peak tidal flow (m/s)	0.20	0.28	0.40	0.51

The depth-averaged flow speeds in Table 8-11 represent directional and omnidirectional non-exceedance percentiles for the water level and current hindcast timeseries (PhysE, 2023b). This indicates the regularity with which certain flow speeds are exceeded. The omni-directional statistic is considered to be an average across all directional sectors. Most (99%) of the time, omni-directional flows do not exceed 0.42 m/s. Mean omni-directional flows are 0.17 m/s. In line with Figure 8-13 directional flows are fastest on a north-south axis (Table 8-11).

Similar to water levels, non-tidal effects have the potential to increase or decrease tidal currents within the Project. Flow speeds in the Array Area are relatively consistent throughout the year, however they are marginally higher in the winter months. In January, 99% of flows do not exceed 0.45 m/s, compared to 99% non-exceedance of 0.37 m/s in May, June, and July. Across the whole year the 50^{th} percentile non-exceedance ranges from 0.16 – 0.17 m/s. This suggests that most of the time throughout the year flows are relatively consistent. Only less frequently occurring (i.e. storm induced) flows result in elevated speeds in the winter months (PhysE, 2023b).

Information on the residual flows within the Array Area based on the water level and current hindcast location for the full 41-year timeseries indicated depth-averaged mean residual flow speeds of around 0.05 m/s and maximum residual speeds of up to 0.45 m/s, with a dominant direction towards the north as illustrated in Table 8-12, thereby indicating an ebb residual.

Table 8-11 Directional and omni-directional depth-averaged total flow speeds, directions are towards (PhysE, 2023b)

TOTAL CURRENT (m/s) SUMMARY STATISTIC	NON-EXCEEDANCE PERCENTILE											
	1	5	10	25	50	75	90	95	99	MAX	MEAN	MIN	STANDARD DEVIATION
North (N)	0.03	0.07	0.09	0.14	0.20	0.26	0.32	0.35	0.41	0.69	0.20	0.00	0.088
015-045	0.02	0.04	0.06	0.09	0.13	0.19	0.24	0.27	0.33	0.49	0.14	0.00	0.070
045-075	0.01	0.02	0.03	0.04	0.06	0.08	0.10	0.13	0.18	0.30	0.06	0.00	0.034
East (E)	0.01	0.02	0.02	0.03	0.05	0.06	0.08	0.10	0.15	0.26	0.05	0.00	0.028
105-135	0.01	0.02	0.02	0.03	0.05	0.07	0.09	0.11	0.16	0.30	0.05	0.00	0.030
35-165	0.01	0.03	0.04	0.05	0.08	0.11	0.15	0.18	0.26	0.46	0.09	0.00	0.050
South (S)	0.03	0.07	0.10	0.15	0.22	0.29	0.35	0.38	0.46	0.69	0.22	0.00	0.095
195-225	0.02	0.05	0.07	0.11	0.16	0.22	0.27	0.31	0.39	0.68	0.17	0.00	0.081
225-255	0.01	0.02	0.03	0.04	0.06	0.08	0.10	0.11	0.17	0.27	0.06	0.00	0.030
West (W)	0.01	0.02	0.02	0.03	0.04	0.06	0.07	0.08	0.12	0.16	0.05	0.00	0.021
285-315	0.01	0.01	0.02	0.03	0.04	0.06	0.07	0.08	0.11	0.20	0.05	0.00	0.021
315-345	0.01	0.02	0.03	0.05	0.07	0.09	0.11	0.13	0.18	0.30	0.07	0.00	0.034
Omni	0.02	0.04	0.05	0.09	0.16	0.24	0.31	0.34	0.42	0.69	0.17	0.00	0.097

Table 8-12 Residual current speed and direction from the 41-year hindcast timeseries from the water level and current hindcast location The Red, Amber, Green (RAG) colours assist visualisation of the frequency of occurrence (expressed as a percentage of time) of coincident residual current speed and direction of flow, with green indicating low occurrence and red indicating higher occurrence of conditions.

CURRENT DIRECTION (degrees)	RESIDUAL CURRENT SPEED (m/s)								
	0-0.05	0.05-0.1	0.1-0.15	0.15-0.2	0.2-0.25	0.25-0.3	0.3-0.35	0.35-0.4	0.4-0.45
North (N)	10.53%	9.26%	3.05%	0.91%	0.30%	0.09%	0.02%	<0.01%	
015-045	5.08%	2.23%	0.50%	0.11%	0.02%	<0.01%			
045-075	2.62%	0.46%	0.05%	0.01%					
East (E)	2.05%	0.27%	0.03%	<0.01%					
105-135	2.35%	0.49%	0.08%	0.03%	0.01%				
35-165	4.01%	1.94%	0.54%	0.17%	0.04%	0.01%	<0.01%	<0.01%	<0.01%
South (S)	6.82%	5.91%	2.84%	1.23%	0.49%	0.16%	0.07%	0.01%	<0.01%
195-225	6.02%	3.12%	1.01%	0.47%	0.25%	0.10%	0.04%	0.02%	<0.01%
225-255	3.88%	0.62%	0.13%	0.04%	0.01%	<0.01%			
West (W)	3.48%	0.26%	0.02%	<0.01%	<0.01%				
285-315	4.35%	0.33%	0.03%	<0.01%					
315-345	8.42%	2.37%	0.23%	0.02%	<0.01%				

8.4.4.5.4 Extremes

Extreme statistics related to tidal flow speed are available for the Array Area based on the metocean characterisation and design criteria analyses performed using the hindcast data retrieved from the water level and current hindcast location (PhysE 2023a; 2023b; 2023c). Omni-directional flow speeds at different return period intervals are summarised in Table 8-13. Across the Array Area, omni-directional extreme current speeds are estimated to reach up to 0.98 m/s at the surface and 0.54 m/s at the seabed based on a 5-year return period event. For a 100-year return period event, speeds of up to 1.09 m/s may occur at the surface and 0.61 m/s near the seabed. Extreme flows are fastest on a north-south orientation, especially when flowing south (PhysE, 2023a).

Table 8-13 Omni-directional extreme currents (PhysE, 2023a)

DEPTH BELOW SURFACE (m)	FLOW SPEED (m/s)				
	1-year	5-year	10-year	50-year	100-year
Surface	0.93	0.98	1.00	1.05	1.09
10	0.84	0.89	0.91	0.95	0.99
19	0.76	0.80	0.82	0.86	0.90
29	0.72	0.76	0.78	0.82	0.85
39	0.68	0.72	0.74	0.78	0.81
49	0.66	0.70	0.71	0.75	0.78
58	0.64	0.67	0.69	0.73	0.75
68	0.63	0.67	0.68	0.72	0.75
78	0.59	0.63	0.64	0.67	0.70
87	0.55	0.58	0.60	0.63	0.65
1 m above seabed	0.51	0.54	0.56	0.58	0.61

8.4.4.6 Wave Regime

There is large natural variability to Scotland's wave climate with seasonal variation as a result of large scale weather conditions such as autumnal and winter storms. Typically, the North Sea is sheltered from the particularly large, powerful waves originating in the Atlantic. However, large wave heights can still occur as a result of North Sea storms (DEICC, 2016).

The Aberdeenshire coastline is typically exposed to waves originating from 30° to 180°, i.e. approximately between the northeast, east and south directional sectors. North of Peterhead the coastline is more exposed to waves from the north and northeast, but the headland at Peterhead provides some shelter from waves coming from the north for the Aberdeen coastline and coastline further south (Ramsay and Brampton, 2000). As the EICC landfall is south of Peterhead, the waves affecting this area are more in-keeping with those waves which are characteristic of Aberdeen (i.e. waves are predominantly approaching the shore from the east and southeast directions).

Based on the 10 Copernicus Marine data locations, wave roses, which present wave height as a function of direction, are illustrated for three locations to demonstrate the wave regime across the Project. Waves roses for Locations 10, 7 and 3 are illustrated in Figure 8-15 corresponding to the landfall, midway along the EICC and within the Array Area respectively (Figure 8-3). Also presented in Figure 8-15 is the wave rose developed using the 43-year hindcast timeseries data derived from the wind and wave hindcast location introduced in Section 8.4.3.3.1.

The wave rose for the approximate landfall location, i.e. Location 10 (showing the direction from which waves originate) can be seen in Figure 8-15 (top left), demonstrating that larger waves (with a significant height >4 m) originate mostly from the east and southeast, while the majority of waves originate from the south (Copernicus Marine, 2024). There is also a much larger period of calm, i.e. waves with heights less than 0.5 m occurring close to the coast, at the landfall location. Further along the EICC, at Location 7, waves here typically come from the south and southwest (Figure 8-15, top right). However, larger waves (associated with stormier conditions) originate from the east (i.e. offshore) and from the northwest, likely having originated in the North Atlantic.

In comparison, at the Array Area waves originate mostly from the north and northwest, and to a lesser extent from the southwest (Figure 8-15, bottom figures). This is reflective of the diminished sheltering effect provided by the Peterhead headland, the influence of which is more visible at the coast. Being approximately 250 km offshore, the Array Area is exposed to waves coming from the north, possibly having originated in the Atlantic. While this applies across much of the year, there is evidence of some seasonality in wave climate at the Array Area. Throughout most of the year there is a clear trend in waves originating from the north. However, in the winter months (most notably in January), this dominance is reduced (PhysE, 2023b). At this time of year, wave distribution is much more even across sectors, with a greater proportion of waves originating from the west and southwest. (PhysE, 2023b). Figure 8-15 also shows that, comparatively, waves at the Array Area can be larger than those at the landfall. Within the Array Area, most waves are up to 5 m in height. At the landfall, most waves do not exceed a height of 2.5 m.

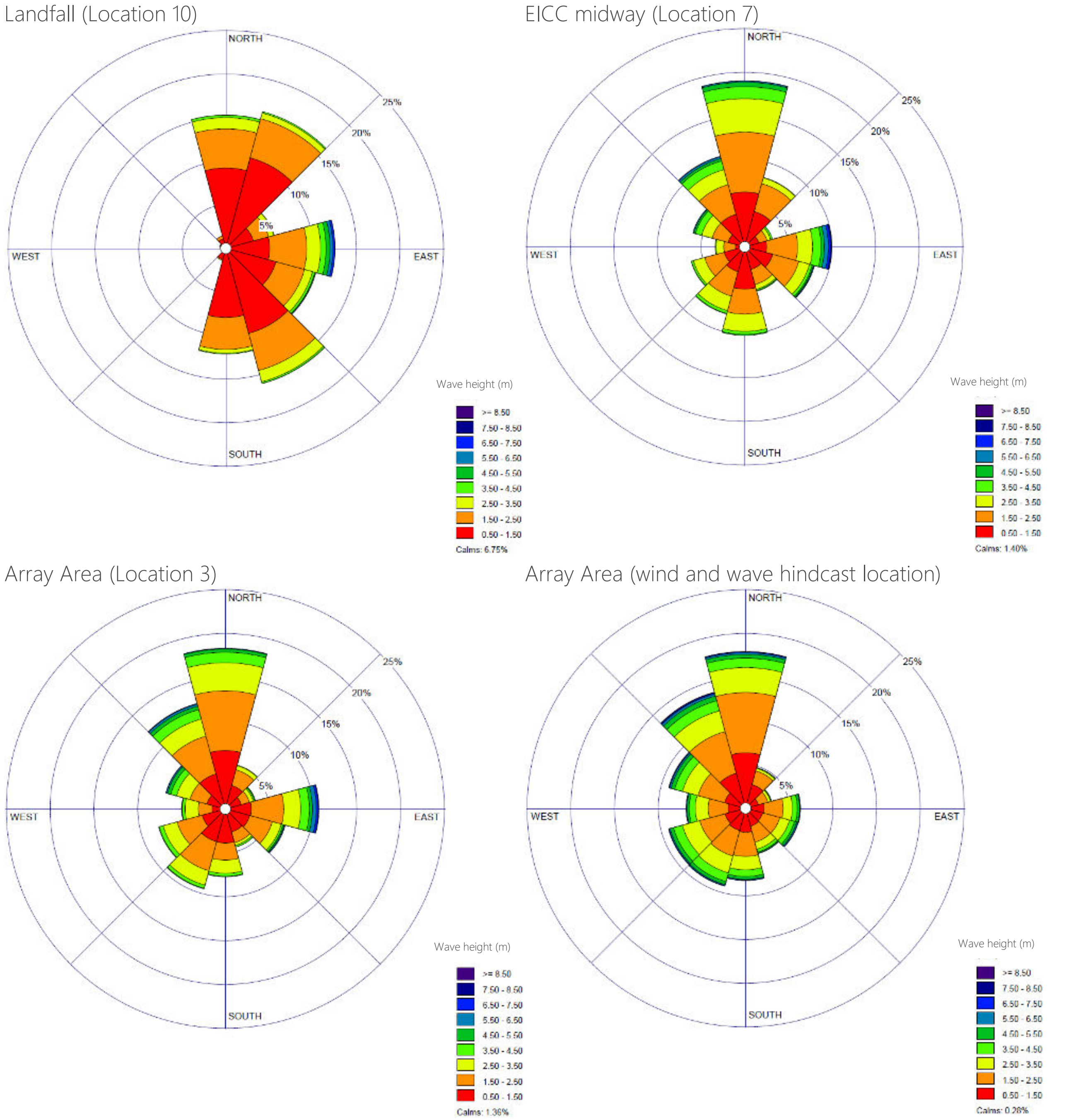


Figure 8-15 Wave roses for selected Copernicus Marine data Locations 3, 7 and 10 (Copernicus Marine, 2024) and from the wind and wave hindcast location within the Array Area, directions are from

The wave climate along the EICC changes with distance from the coast, as generally there is an increase in significant wave height and period moving further offshore. Using the timeseries data extracted from the Copernicus Marine data locations, wave parameters at Locations 6, 7, 8, 9 and 10 (Figure 8-3), along the EICC are shown in Table 8-14. At the landfall (Location 10), waves have a mean significant wave height of 1.39 m and a corresponding period of 7.69 s. This increases to significant wave heights of 1.99 m and periods of 7.94 s at Location 6 (just before the Array Area).

Table 8-14 Wave parameters along the EICC (Copernicus Marine, 2024)

	MEAN SIGNIFICANT WAVE HEIGHT (m)	MEAN PEAK WAVE PERIOD (s)	AVERAGE WAVE DIRECTION (°)
Loc 6	1.99	7.94	200
Loc 7	1.95	7.90	198
Loc 8	1.85	7.77	195
Loc 9	1.74	7.80	196
Loc 10	1.39	7.69	182

Based on the wind and wave hindcast timeseries analysed by PhysE (2023b), Table 8-15 shows the frequency of occurrence of significant wave height and peak period, for the full 43-year hindcast timeseries. Waves with a significant wave height between 1 m and 1.5 m, with a corresponding peak period of 5 s – 6 s, are the most frequently occurring, with these waves occurring 6.72% of the time (Table 8-15). This is closely followed by waves with a significant wave height between 1.5 m and 2 m, with a corresponding peak period of 6 s – 7 s, with a percentage occurrence of 6.2% across the 43-year timeseries. However, the distribution of frequencies represented in Table 8-15 also shows that waves with periods longer than 9 s are also likely to occur regularly in the Array Area. Waves with long periods (typically >9 s) are usually indicative of swell-dominated climatologies. Therefore, both locally generated waves and swell waves from further afield are influential over the wave climate within the Array Area.

Table 8-15 Wave properties and the frequency of their occurrence, as a percentage of all waves based on the timeseries from the wind and wave hindcast location

	PEAK WAVE PERIOD (s)																		
SIGNIFICANT WAVE HEIGHT (m)	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21
0-0.5	<0.01%	0.19%	0.23%	0.04%	0.01%	<0.01%	0.01%	0.01%	<0.01%	<0.01%		<0.01%	<0.01%	<0.01%					
0.5-1		0.40%	4.11%	3.75%	1.81%	0.94%	0.72%	0.47%	0.26%	0.19%	0.12%	0.09%	0.04%	0.02%	0.01%	<0.01%	<0.01%		
1-1.5			1.19%	6.72%	5.36%	2.92%	2.07%	1.90%	0.91%	0.44%	0.27%	0.24%	0.16%	0.06%	0.03%	0.01%	<0.01%	<0.01%	<0.01%
1.5-2			0.01%	1.95%	6.23%	3.92%	2.35%	1.77%	1.64%	0.89%	0.24%	0.16%	0.08%	0.06%	0.04%	0.01%	<0.01%	<0.01%	
2-2.5				0.07%	3.33%	4.45%	2.40%	1.31%	1.25%	1.12%	0.45%	0.13%	0.04%	0.02%	0.01%	0.01%	<0.01%		
2.5-3				<0.01%	0.38%	4.01%	2.53%	1.25%	0.73%	0.71%	0.41%	0.13%	0.03%	0.01%	0.01%	<0.01%	<0.01%		
3-3.5					0.01%	1.37%	2.87%	1.32%	0.58%	0.38%	0.28%	0.14%	0.04%	0.01%	<0.01%	<0.01%			
3.5-4						0.12%	2.03%	1.48%	0.53%	0.28%	0.18%	0.11%	0.02%	0.01%	<0.01%			<0.01%	
4-4.5						0.01%	0.58%	1.62%	0.55%	0.23%	0.10%	0.07%	0.02%	0.01%	<0.01%				
4.5-5							0.03%	1.00%	0.67%	0.20%	0.07%	0.04%	0.01%	<0.01%	<0.01%				
5-5.5						<0.01%	<0.01%	0.36%	0.61%	0.18%	0.06%	0.03%	0.01%	<0.01%	<0.01%				
5.5-6								0.04%	0.43%	0.18%	0.05%	0.02%	0.01%						
6-6.5								<0.01%	0.23%	0.17%	0.06%	0.02%	0.01%						
6.5-7									0.06%	0.15%	0.07%	0.02%	<0.01%						
7-7.5									0.01%	0.08%	0.05%	0.02%	<0.01%	<0.01%					
7.5-8									<0.01%	0.03%	0.03%	0.02%	0.01%	<0.01%					
8-8.5										0.01%	0.02%	0.02%	<0.01%	<0.01%					
8.5-9										0.01%	0.01%	0.02%	0.01%						
9-9.5											<0.01%	0.02%	<0.01%						
9.5-10											<0.01%	0.01%	<0.01%	<0.01%					
10-10.5												<0.01%	0.01%						
10.5-11													<0.01%						
11-11.5													<0.01%	<0.01%					
11.5-12														<0.01%					
12-12.5														<0.01%					

The wave parameters in Table 8-16 represent directional non-exceedance percentiles calculated by PhysE (2023b) using the 43-year hindcast data from the wind and wave hindcast location, which indicates the proportion of waves that will exceed a specified wave height. The yellow highlighted rows in Table 8-16, represent the two prevailing wave sectors (north and northwest; Figure 8-15, bottom right), although Table 8-16 shows that the largest waves can come from multiple directions. The omni-directional statistic is considered to be an average across all directional sectors. The majority (99%) of omni-directional waves do not exceed a height of 6.2 m. The omni-directional mean significant wave height within the Array Area is 2.2 m. This is broadly consistent with the trend shown in Table 8-14, wherein waves increase in significant height and in period along the EICC, moving in an offshore direction.

The equivalent statistics for wave periods is shown in Table 8-17. However, it should be noted that these periods are independent of the significant wave heights in Table 8-16; therefore, it cannot be assumed that for any wave height exceedance statistic in Table 8-16 the equivalent period in Table 8-17 corresponds directly. As before, the rows in bold highlight the prevailing wave sectors (north and northwest). The omni-directional mean wave period is 8.0 s. The majority (99%) of omni-directional waves do not exceed a period of 13.8 s.

Notably the mean omni-directional significant wave height and period of 2.2 m and 8 s represented in Table 8-15 and Table 8-14 respectively, have a greater height and period than the most frequently occurring waves (1 m – 1.5 m and corresponding 5 s – 6 s) represented in Table 8-15. This further supports the narrative that swell waves are important to the wave climate within the Array Area.

PhysE (2023b) prepared equivalent exceedance statistics by month for the significant wave height and peak period represented in Table 8-18 and Table 8-19 respectively. The largest waves occur in the winter months, between October and March. The greatest mean significant wave height of 3 m occurs in January. Mean significant wave heights of 1.3 m occur in July wherein 99% of waves do not exceed heights of 3.9 m. This is reflected in the wave period statistics across the year (Table 8-19). Wave periods are longest over winter and reach a peak of 9.1 s in December (PhysE, 2023b).

Table 8-16 Directional and omni-directional significant wave height statistics, wave directions are from (PhysE, 2023b)

H_S (m) SUMMARY STATISTIC	NON-EXCEEDANCE PERCENTILE									MAX	MEAN	MIN	STANDARD DEVIATION
	1	5	10	25	50	75	90	95	99				
North (N)	0.6	0.8	0.9	1.2	1.8	2.5	3.5	4.2	6.1	12.1	2.0	0.3	1.14
015-045	0.5	0.6	0.7	1.0	1.3	1.8	2.3	2.7	3.7	6.7	1.4	0.3	0.69
045-075	0.5	0.6	0.8	1.0	1.5	2.0	2.7	3.2	4.4	6.3	1.6	0.3	0.82
East (E)	0.5	0.7	0.9	1.3	1.8	2.8	3.9	4.6	5.8	9.0	2.2	0.3	1.22
105-135	0.5	0.8	0.9	1.3	1.9	2.9	4.0	4.8	6.3	8.6	2.2	0.3	1.28
35-165	0.5	0.7	0.9	1.2	1.7	2.4	3.4	4.0	5.5	8.1	1.9	0.3	1.07
South (S)	0.6	0.8	0.9	1.3	1.9	2.8	3.9	4.6	5.9	8.8	2.2	0.3	1.20
195-225	0.6	0.8	1.0	1.4	2.1	3.0	4.0	4.6	6.1	9.0	2.3	0.3	1.22
225-255	0.6	0.8	1.0	1.4	2.1	3.1	4.0	4.7	6.1	9.9	2.4	0.3	1.24
West (W)	0.6	0.8	0.9	1.3	2.1	2.9	3.9	4.5	5.9	9.8	2.3	0.3	1.20
285-315	0.6	0.8	1.0	1.4	2.1	3.0	4.2	4.9	6.7	10.2	2.4	0.3	1.33
315-345	0.6	0.8	1.0	1.3	1.9	2.8	4.1	4.9	7.0	11.7	2.3	0.3	1.35
Omni	0.6	0.8	0.9	1.3	1.9	2.7	3.8	4.5	6.2	12.1	2.2	0.3	1.22

Table 8-17 Directional and omni-directional wave period statistics, wave directions are from (PhysE, 2023b)

T_P (s) SUMMARY STATISTIC	NON-EXCEEDANCE PERCENTILE									MAX	MEAN	MIN	STANDARD DEVIATION
	1	5	10	25	50	75	90	95	99				
North (N)	4.6	5.6	6.3	7.6	9.2	10.7	11.9	12.4	13.9	18.7	9.1	3.0	2.10
015-045	4.2	4.8	5.2	6.3	7.6	9.3	10.7	11.5	13.5	19.0	7.9	2.9	2.12
045-075	3.9	4.6	5.1	6.2	7.5	8.9	10.1	11.0	12.8	18.3	7.6	3.0	1.97
East (E)	4.2	4.9	5.5	6.5	7.7	8.9	10.0	10.4	11.9	18.6	7.7	3.1	1.73
105-135	4.0	4.7	5.2	6.2	7.3	8.5	9.5	10.2	11.3	19.2	7.4	3.0	1.69
35-165	4.0	4.6	4.9	5.7	6.7	7.8	9.0	9.6	11.1	20.2	6.8	3.3	1.64
South (S)	4.0	4.7	5.0	5.8	6.9	8.3	9.4	10.1	11.3	18.7	7.1	3.3	1.72
195-225	4.1	4.6	5.0	5.8	7.0	8.3	9.2	9.9	11.2	18.0	7.1	3.3	1.64
225-255	4.1	4.7	5.1	5.9	7.0	8.2	9.2	9.9	12.0	18.7	7.1	3.2	1.69
West (W)	4.1	4.8	5.2	6.2	7.3	8.5	10.2	11.7	14.6	18.7	7.6	3.1	2.11
285-315	4.3	5.2	5.8	7.0	8.4	10.2	11.7	13.0	14.9	19.4	8.7	3.2	2.33
315-345	4.4	5.4	6.0	7.4	9.1	10.9	12.1	13.0	14.6	19.7	9.1	3.1	2.33
Omni	4.2	4.9	5.3	6.4	7.8	9.4	11.0	11.9	13.8	20.2	8.0	2.9	2.17

Table 8-18 Monthly exceedance significant wave height statistics (PhysE, 2023b)

H_S (m) SUMMARY STATISTIC	NON-EXCEEDANCE PERCENTILE									MAX	MEAN	MIN	STANDARD DEVIATION
	1	5	10	25	50	75	90	95	99				
January	1.0	1.3	1.5	2.0	2.7	3.8	4.9	5.8	7.3	10.5	3.0	0.7	1.41
February	0.8	1.1	1.3	1.8	2.5	3.6	4.6	5.2	6.7	10.0	2.8	0.4	1.31
March	0.8	1.1	1.3	1.7	2.2	3.1	4.1	4.6	6.0	8.9	2.5	0.5	1.13
April	0.6	0.8	1.0	1.2	1.7	2.3	3.1	3.8	5.5	9.9	1.9	0.4	1.00
May	0.6	0.7	0.8	1.0	1.4	1.9	2.6	3.0	4.0	6.8	1.6	0.4	0.74
June	0.4	0.6	0.7	0.9	1.3	1.7	2.3	2.7	3.8	6.7	1.4	0.3	0.70
July	0.4	0.6	0.7	0.9	1.1	1.5	2.1	2.5	3.9	6.1	1.3	0.3	0.67
August	0.5	0.6	0.7	0.9	1.3	1.8	2.4	2.9	4.1	7.4	1.4	0.3	0.76
September	0.6	0.8	1.0	1.2	1.7	2.4	3.2	3.8	5.3	8.9	1.9	0.5	0.98
October	0.7	1.1	1.3	1.6	2.2	3.0	3.9	4.6	6.0	10.5	2.4	0.5	1.12
November	0.9	1.2	1.4	1.8	2.5	3.4	4.3	5.0	6.6	10.5	2.7	0.7	1.22
December	0.9	1.2	1.4	1.9	2.6	3.5	4.6	5.3	7.1	12.1	2.9	0.5	1.32
All Year	0.6	0.8	0.9	1.3	1.9	2.7	3.8	4.5	6.2	12.1	2.2	0.3	1.22

Table 8-19 Monthly exceedance wave period statistics (PhysE, 2023b)

T_P (s) SUMMARY STATISTIC	NON-EXCEEDANCE PERCENTILE									MAX	MEAN	MIN	STANDARD DEVIATION
	1	5	10	25	50	75	90	95	99				
January	5.2	6.0	6.5	7.5	8.8	10.2	11.7	12.6	14.7	19.7	9.0	4.4	2.05
February	4.8	5.7	6.3	7.3	8.6	10.1	11.5	12.4	15.0	20.2	8.8	3.6	2.13
March	4.8	5.7	6.2	7.1	8.5	10.1	11.7	12.6	14.4	18.7	8.8	3.3	2.16
April	4.3	5.0	5.4	6.3	7.8	9.9	11.3	12.2	14.0	16.2	8.2	3.4	2.29
May	4.1	4.7	5.2	6.0	7.2	8.7	10.1	10.8	12.6	16.8	7.4	3.2	1.89
June	3.9	4.4	4.8	5.6	6.8	8.1	9.2	9.8	10.9	12.6	6.9	3.1	1.65
July	3.8	4.3	4.6	5.2	6.2	7.4	8.6	9.3	10.7	14.6	6.4	2.9	1.59
August	3.9	4.4	4.7	5.4	6.4	7.7	9.1	9.9	11.3	16.6	6.7	3.0	1.72
September	4.3	5.0	5.4	6.3	7.5	8.9	10.3	11.2	13.2	18.2	7.7	3.4	1.94
October	4.7	5.6	6.1	7.0	8.3	9.9	11.2	11.9	13.5	16.3	8.5	3.7	1.98
November	5.2	6.0	6.5	7.4	8.5	10.1	11.4	12.3	13.8	17.3	8.8	4.0	1.94
December	5.0	6.0	6.5	7.6	8.8	10.4	12.0	12.9	14.6	19.2	9.1	3.6	2.13
All Year	4.2	4.9	5.3	6.4	7.8	9.4	11.0	11.9	13.8	20.2	8.0	2.9	2.17

8.4.4.6.1 Extremes

Extreme statistics related to the wave regime are available for the Array Area based on the metocean characterisation and design criteria analyses performed using the hindcast data retrieved from the wind and wave hindcast location (PhysE, 2023a). Table 8-20 presents the omni-directional wave statistics under extreme event conditions. Within the Array Area, the extreme omni-directional wave height for a 1-year return period event is 8.8 m, with a corresponding (central) peak period of 12.9 s. For a 1 in 100-year event, the significant wave height is estimated to increase to 13.0 m, with a with a corresponding (central) peak period of 14.4 s (PhysE, 2023a).

Table 8-20 Omni-directional extreme waves, sea state duration three hours (PhysE, 2023a)

RETURN PERIOD	H_S (m)	T_P (s)			H_{MAX} (m)	CREST HEIGHT (m)
		LOWER	CENTRAL	UPPER		
1-year	8.8	11.0	12.9	15.7	16.0	9.7
5-years	10.4	11.9	14.0	17.0	19.0	11.5
10-years	11.0	12.2	14.4	17.5	20.1	12.2
50-years	12.4	13.0	15.3	18.6	22.7	13.7
100-years	13.0	13.3	15.7	19.1	23.8	14.4

Based on the Array Area wave rose (Figure 8-15, bottom right), waves generally come from the north. However, a considerable proportion of waves during winter (i.e. the most stormy period of the year) come from the southwest. Therefore, directional wave parameters have been shown in Table 8-21 for north/north westerly waves (330-0°) and south westerly waves (210-240°) in order to capture the extreme wave conditions which may originate from these directions.

Wave properties associated with 1-year return period storm events from the dominant northern sector (i.e. 0°) show a significant wave height of 8.0 m with a corresponding (central) wave peak period of 12.2 s. During a 1 in 100-year storm event, the significant wave height may reach 11.9 m with a corresponding (central) peak period of 14.9 s. Compared with the northerly approaching wave, the south westerly waves are marginally smaller in significant wave height and peak period under all return periods, which is a function of the limited fetch of the central and southern North Sea. Therefore, the northerly sector, which includes exposure to the North Atlantic, present the approach of the largest extreme waves, although large waves can approach from other sectors.

Table 8-21 Directional extreme waves for the prevailing wave directions, sea state duration three hours (PhysE, 2023a)

RETURN PERIOD	H_S (m)	T_P (s) LOWER	CENTRAL	UPPER	H_{MAX} (m)	CREST HEIGHT (m)
1-year						
0	8.0	10.4	12.2	14.9	14.7	8.9
210	7.6	10.2	12.0	14.6	14.0	8.4
240	7.7	10.2	12.0	14.6	14.1	8.5
330	8.8	11.0	12.9	15.7	16.0	9.7
5-years						
0	9.5	11.4	13.4	16.4	17.4	10.5
210	9.0	11.1	13.0	15.9	16.5	10.0
240	9.1	11.1	13.0	15.9	16.5	10.0
330	10.4	11.9	14.0	17.0	19.0	11.5
10-years						
0	10.1	11.8	13.8	16.8	18.4	11.1
210	9.6	11.4	13.4	16.4	17.5	10.6
240	9.6	11.4	13.4	16.4	17.6	10.7
330	11.0	12.2	14.4	17.5	20.1	12.2
50-years						
0	11.3	12.4	14.6	17.8	20.8	12.6
210	10.8	12.1	14.2	17.3	19.8	12.0
240	10.9	12.2	14.4	17.5	19.9	12.0
330	12.4	13.0	15.3	18.6	22.7	13.7
100-years						
0	11.9	12.7	14.9	18.1	21.8	13.2
210	11.3	12.4	14.6	17.8	20.7	12.5
240	11.4	12.4	14.6	17.8	20.9	12.6
330	13.0	13.3	15.7	19.1	23.8	14.4

8.4.4.7 Sediment Transport Regime

Seabed sediments are susceptible to resuspension by wave and tidal currents. Resuspension occurs when the mobilising forces (the 'bed stress'; t_0) exerted by currents and waves, separately (e.g. during summer months when waves are negligible) and in combination (e.g. during winter storms), exceeds the submerged weight of sediments which act to retain particles on the bed. For increasing values of bed stress (t_0) a threshold value is reached, called critical shear stress t_{crit}, at which sediments start moving. When t_0 exceeds t_{crit}. sediments are mobilised. The characteristics of unconsolidated surficial sediments determines how often sediments are mobilised, the way they are transported (i.e. bed load transport and/or suspended load transport), the rates and magnitude of sediment transport observed and the influence on seabed morphology (i.e. presence / absence of bedforms). Coarser sediments (i.e. sands and gravels) typically move as bedload transport in response to waves and tides – this is considered in Section 8.4.4.7.1 below. In addition to transport of the coarse sediment fraction, finer sediments are carried in suspension within the water column. This process, including description of SSC within the Marine Geology, Oceanography and Coastal Processes Study Area, is detailed in Section 8.4.4.7.4.

8.4.4.7.1 Coarse Sediment Fraction

To evaluate the sediment transport regime across the Project, the sediment mobility potential is calculated for the available data locations (i.e. the 10 Copernicus Marine data locations and the water level and current hindcast location due to the availability of a current timeseries). Calculation of the sediment mobility potential is based on the associated water levels and current speeds and the seabed sediment grain size interpreted from the site specific survey (Section 8.4.4.2) for each respective location, with further detail on properties used summarised below. Results for the sediment mobility estimates for the EICC are presented in Table 8-22, with the associated estimates for the Array Area presented in Table 8-23

8.4.4.7.2 EICC

The following information has been used to characterise the bedload sediment mobility potential within the EICC:

- Mean wave parameters extracted from Copernicus Marine (2024) represented in Table 8-14 for Locations 6, 7, 8, 9, and 10, which correspond to those shown on Figure 8-3;
- A time series of water levels and current speeds extracted from Copernicus Marine (2024) (for Locations 6, 7, 8, 9, and 10). From the 2.5-year available data, a representative month is used spanning two spring-neap cycles. Therefore, for the analyses, a time period between 1st March and 4th April 2024 is applied; and
- Sediment sizes characteristic of the EICC – the location of the extracted currents are aligned with survey sediment sample locations (Figure 8-8) as follows: Location 6 and EICC_27 (0.67 mm), Location 7 and EICC_17 (0.15 mm), Location 8 and EICC_11 (0.09 mm), Location 9 and EICC_02 (0.39 mm) and Location 10 and EICC_02 (0.39 mm).

Sediment mobility varies considerably along the EICC (Table 8-22). Generally, as would be expected based on the water level, current and wave parameters reported throughout Section 8.4.4.5 to 8.4.4.6 respectively, sediment transport increases closer to the coast, with the exception of the approximate landfall location itself (Location 10) where sediments are not anticipated to be mobile. Generally, the sediment transport regime is tidally dominated with currents acting in isolation likely to mobilise fine, medium and coarse sand at most locations along the EICC. These analyses indicate the highly dynamic nature of the sediment transport regime close to the coast. At Location 9, fine sands (particle size of 0.08 mm) are estimated to be mobile across the entire spring tidal phase and during peak neap flows (Table 8-22). Not only is transport of finer sands frequently occurring, but the currents at the assessed locations are also potentially sufficient to mobilise coarser sediments of medium and coarse sand, but only during the fastest current speeds observed during the spring tidal phase. At Location 8, very coarse sand (particle size of 1.4 mm) is mobilised up to 1% of the time, i.e. only on the highest peak spring tides. At Location 9, sediments up to very fine gravel (particle size of 2.5 mm) are also mobile up to 1% of the time.

Along the majority of the EICC, the contribution of waves in combination with currents does not influence the overall potential for sediment mobility which is a function of the water depths across the Project. However, in shallower waters (i.e. at the EICC landfall location (Location 10, 11 mLAT), the influence of waves on the sediment transport regime is enhanced. In shallow waters near bed wave generated orbital velocities increase the total bed stress resulting in enhanced sediment mobility. Coarse sediments would mostly be picked up by the oscillation of the wave and redeposited rapidly with respect to their settling velocity. Consequently, though sediment disturbance due to the influence of waves at location 10 is likely to occur regularly, significant sediment transport is not anticipated associated with the coarse sediment fraction that characterises that location.

Table 8-22 Sediment mobility potential as a percentage of time calculated using the formulae presented by Soulsby (1997), for locations along the EICC

		FINE SAND	MEDIUM SAND	COARSE SAND	VERY COARSE SAND	VERY FINE GRAVEL	FINE GRAVEL	MEDIUM GRAVEL
Loc 6 94 mLAT 0.67 mm 2.0 m Hs 7.9 s Tp	Currents only	17% Mobile on peak spring tides only	10% Mobile on peak spring tides only	4% Mobile on peak spring tides only	0% No mobility	0% No mobility	0% No mobility	0% No mobility
	Waves only	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility
	Waves and current	16% Mobile on peak spring tides only	10% Mobile on peak spring tides only	3% Mobile on peak spring tides only	0% No mobility	0% No mobility	0% No mobility	0% No mobility
Loc 7 88 mLAT 0.15 mm 2.0 m Hs 7.9 s Tp	Currents only	29% Mobile during spring tides	22% Mobile during spring tides	11% Mobile on peak spring tides only	0% No mobility	0% No mobility	0% No mobility	0% No mobility
	Waves only	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility
	Waves and current	29% Mobile during spring tides	22% Mobile during spring tides	11% Mobile on peak spring tides only	0% No mobility	0% No mobility	0% No mobility	0% No mobility
Loc 8 95 mLAT 0.09 mm 1.9 m Hs 7.8 s Tp	Currents only	32% Mobile during spring tides	24% Mobile during spring tides	13% Mobile on peak spring tides only	1% Mobile on peak spring tides only	0% No mobility	0% No mobility	0% No mobility
	Waves only	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility
	Waves and current	31% Mobile during spring tides	24% Mobile during spring tides	13% Mobile on peak spring tides only	1% No mobility	0% No mobility	0% No mobility	0% No mobility

		FINE SAND	MEDIUM SAND	COARSE SAND	VERY COARSE SAND	VERY FINE GRAVEL	FINE GRAVEL	MEDIUM GRAVEL
Loc 9 89 mLAT 0.39 mm 1.7 m Hs 7.8 s Tp	Currents only	61%	55%	43%	16%	1%	0%	0%
		Mobile during spring tides and peak neap tides	Mobile during spring tides	Mobile during spring tides	Mobile on peak spring tides only	Mobile on peak spring tides only	No mobility	No mobility
	Waves only	0%	0%	0%	0%	0%	0%	0%
		No mobility	No mobility	No mobility	No mobility	No mobility	No mobility	No mobility
	Waves and current	61%	55%	43%	16%	1%	0%	0%
		Mobile during spring tides and peak neap tides	Mobile during spring tides	Mobile during spring tides	Mobile on peak spring tides only	Mobile on peak spring tides only	No mobility	No mobility
Loc 10 11 mLAT 0.39 mm 1.4 m Hs 7.7 s Tp	Currents only	0%	0%	0%	0%	0%	0%	0%
		No mobility	No mobility	No mobility	No mobility	No mobility	No mobility	No mobility
	Waves only	100%	100%	100%	0%	0%	0%	0%
		Always mobile	Always mobile	Always mobile	No mobility	No mobility	No mobility	No mobility
	Waves and current	0%	0%	0%	0%	0%	0%	0%
		No mobility	No mobility	No mobility	No mobility	No mobility	No mobility	No mobility

8.4.4.7.3 Array Area

Sediment mobility potential under the prevailing tidal and wave regimes at a number of locations within the Array Area is shown in Table 8-23, with the following information being used to characterise the bedload sediment mobility potential:

- Omni-directional mean wave parameters from PhysE (2023b), taken to be representative of normal conditions within the Array Area, with a significant wave height of 2.2 m and a peak period of 8.0 s, i.e. from Table 8-18 and Table 8-19 respectively;
- A time series of water levels and current speeds extracted from the current hindcast (from the water level and current hindcast location) and from Copernicus Marine (2024), for Locations 1, 2, and 3, which correspond to the locations shown in Figure 8-3. The water level and current hindcast location timeseries spans from February to April 2020, and the Copernicus Marine timeseries uses the same period as applied for the EICC, with all the datasets capturing up to two full spring-neap cycles; and
- Sediment sizes characteristic of the Array Area – across most of the Array Area, sediments are typically of the diameter 0.05 mm (coarse silt), with the exception of one location (OWF_39; see Section 8.4.4.2 for further detail). Due to the location of the extracted flows, a mean grain size of 0.05 mm is applied across all analysis locations.

The calculated percentage of time that sediment of different sizes would be mobile at locations within the Array Area during the analysed time series is shown in Table 8-23. Overall, sediment mobility is consistently low across the Array Area, with mobility only predicted to occur during peak spring flows. Fine, medium, and coarse sands are mobile during peak spring tides at all Array Area locations. Fine sands in particular can be mobile up to 12% of the time at Location 2 and Location 3 within the Array Area. Sediments larger than coarse sands (i.e. particle sizes of >0.63 mm) are not mobile at any point in the tidal cycle. In comparison to the EICC, sediment transport is much lower in the Array Area which is due to the significant water depths observed across the site.

As described above, currents are usually the principal driving force behind sediment transport. The sediment transport results in Table 8-23 reflect this, as again currents acting in isolation are able to generate sediment mobility of fine, medium and coarse sand at all the analysis locations. The suggestion that the bed is occasionally mobile is consistent with the drop down video imagery presented in O'Connor *et al.*, (2016), which shows the presence of rippled muddy/sandy sediments within areas of the East Gannet and Montrose Fields NCMPA overlapping with the Array Area. These rippled bedforms are more pronounced at some locations, perhaps reflecting variation in water depth (and hence the influence of waves at the bed) and sediment composition, with the cohesive nature of more muddy sediments potentially limiting bedform development). (These images also show evidence of bioturbation which will re-work surficial sediments). Nonetheless, the primary mechanism for sediment mobility potential is in relation to currents.

Table 8-23 Sediment mobility potential as a percentage of time calculated using the formulae presented by Soulsby (1997), for locations across the Array Area

		FINE SAND	MEDIUM SAND	COARSE SAND	VERY COARSE SAND	VERY FINE GRAVEL	FINE GRAVEL	MEDIUM GRAVEL
Hindcast location 97 mLAT 0.05 mm 2.2 m Hs 8.0 s Tp	Currents only	9% Mobile on peak spring tides only	4% Mobile on peak spring tides only	1% Mobile on peak spring tides only	0% No mobility	0% No mobility	0% No mobility	0% No mobility
	Waves only	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility
	Waves and current	9% Mobile on peak spring tides only	4% Mobile on peak spring tides only	1% Mobile on peak spring tides only	0% No mobility	0% No mobility	0% No mobility	0% No mobility
Loc 1 97 mLAT 0.05 mm 2.2 m Hs 8.0 s Tp	Currents only	9% Mobile on peak spring tides only	4% Mobile on peak spring tides only	1% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility
	Waves only	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility
	Waves and current	9% Mobile on peak spring tides only	4% Mobile on peak spring tides only	1% Mobile on peak spring tides only	0% No mobility	0% No mobility	0% No mobility	0% No mobility
Loc 2 96 mLAT 1.84 mm 2.2 m Hs 8.0 s Tp	Currents only	12% Mobile on peak spring tides only	6% Mobile on peak spring tides only	1% Mobile on peak spring tides only	0% No mobility	0% No mobility	0% No mobility	0% No mobility
	Waves only	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility
	Waves and current	12% Mobile on peak spring tides only	6% Mobile on peak spring tides only	1% Mobile on peak spring tides only	0% No mobility	0% No mobility	0% No mobility	0% No mobility

		FINE SAND	MEDIUM SAND	COARSE SAND	VERY COARSE SAND	VERY FINE GRAVEL	FINE GRAVEL	MEDIUM GRAVEL
Loc 3 94 mLAT 0.05 mm 2.2 m Hs 8.0 s Tp	Currents only	12% Mobile on peak spring tides only	6% Mobile on peak spring tides only	1% Mobile on peak spring tides only	0% No mobility	0% No mobility	0% No mobility	0% No mobility
	Waves only	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility	0% No mobility
	Waves and current	12% Mobile on peak spring tides only	6% Mobile on peak spring tides only	1% Mobile on peak spring tides only	0% No mobility	0% No mobility	0% No mobility	0% No mobility

8.4.4.7.4 Fine Sediment Fraction

When finer sediments (i.e. silts and muds – the Array Area sample locations all show that the surface sediments are course silt, rather than muds, Section 8.4.4.2, Figure 8-7, Figure 8-8 and Table 8-7) are mobilised they are typically carried in suspension, contributing to higher concentrations of Suspended Particulate Matter (SPM) or SSC and increasing the turbidity of the water column until the material settles out and is deposited. Rivers, estuaries and coastal erosion can also provide local sources of fine sediments, increasing turbidity.

The Cefas Suspended Sediment Climatologies report (Cefas, 2016) and associated dataset provides the spatial distribution of average non-algal SPM for the majority of the United Kingdom Continental Shelf (UKCS). Long-term (1998 to 2015) monthly average concentration of sea surface SPM have been deduced from satellite data. The long-term monthly average SPM for the CNS is relatively stable and of very low concentrations. SPM for the NNS ranges from 0.0006 kg/m^3 in the summer, to 0.001 kg/m^3 in winter, with an annual average of 0.0008 kg/m^3 (Cefas, 2018). The non-algal SPM across the Project and Study Area is shown in Figure 8-16, with concentrations reducing with increasing distance from the coast. At the EICC landfall, SPM is up to 0.001 kg/m^3. This is consistent along the first half of the EICC. Past approximately the midway point of the EICC, SPM concentrations decrease to a minimum of 0.0006 kg/m^3 across the Array Area. This is attributed to the lower levels of seabed sediment mobility further offshore (see Section 8.4.4.7.1), and low levels of coastal erosion and remoteness to any large river or estuary source of fine sediment.

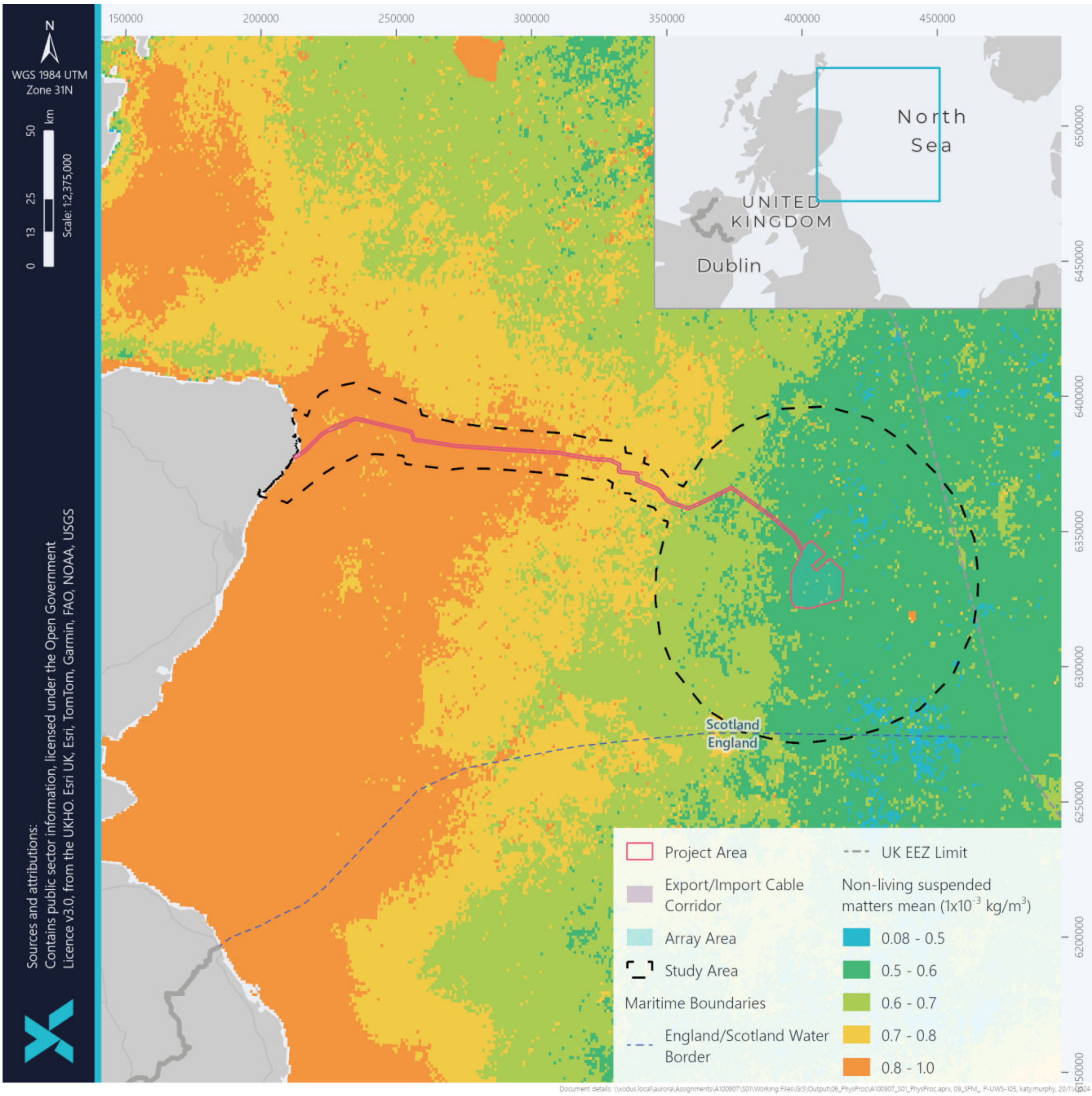


Figure 8-16 Annual mean non-living suspended matter concentrations across the Project and Study Area (Cefas, 2016)

SSC, as a component of SPM, in the water column are influenced by tidal currents, wind and wave action, with fluctuations observed, seasonally, across the spring-neap cycle and across the different tidal stages (high water, peak ebb, low water, peak flood). During high-energy events, SSC can increase near the seabed and throughout the water column. In the wake of such storm events, SSC levels will gradually decrease to baseline conditions, regulated by the ambient regional tidal regimes.

To characterise the water column within the Project Area, CTD water profiling has been completed as part of the site-specific environmental survey effort (Section 8.4.3). As introduced in Section 8.4.3.2, six water column CTD profiles were acquired from August to September 2023 along the EICC (EICC_02, EICC_06, EICC_09, EICC_18, EICC_24, EICC_37). A further ten were completed within the Array Area in August 2023 (OWF_02, OWF_03, OWF_05, OWF_09, OWF_15, OWF_18, OWF_22, OWF_32, OWF_41, OWF_49). Only the upcast profiles are used in the interpretation of the water column as it was considered to be more accurate. Results of the upcast water column profiles for varying water column properties including turbidity (addressed in this Section), temperature and salinity (considered further in Section 8.4.5.5) and pH and dissolved oxygen (considered further in the water and sediment quality chapter), for the EICC are shown in Figure 8-17.

Turbidity is a measure of the cloudiness or haziness of a water body due to either suspended particulates (both mineral and biological) in the water column, or discoloration of the water body (nominally expressed as Nephelometric Formazin Units (NFU) or Nepholometric Turbidity Units (NTU)). Turbidity data is regularly used to estimate the Total Suspended Solids (TSS) within the water column. Turbidity units have no intrinsic physical, chemical, or biological significance. They are a qualitative rather than a quantitative measurement. TSS (measured in milligrams per litre of water (mg L^{-1}), can be estimated from turbidity measurements by establishing the relationship between turbidity and suspended sediment using a linear regression analysis. These data are not available to the assessment and thus caution must be applied when considering these data. Turbidity remained fairly low and constant throughout the water column at around 2.5 NFU, largely falling within the accuracy limits of the turbidity meter, with occasional increases through spot readings of suspended material in the first 15 m of the water column. The minimum turbidity of 1.5 NFU is recorded at station EICC_18 whilst the maximum (3.8 NFU) is recorded at EICC_06. Turbidity increases towards the seabed at the majority of stations, most likely due to the resuspension of sediments caused by near-bed currents, the presence of plankton, and possibly disturbance from sampling operations (EIAR Vol. 4, Appendix 12: Environmental Baseline Report - EICC).

In addition to the CTD profiles, water sampling has also been completed at the same locations along the EICC, with sampling occurring at the surface, mid-point and at the bottom of the water column, close to the seabed. Calculated properties of the water column from the water samples include the measurement Total Suspended Solids (TSS) (described here) as well as salinity (described in Section 8.4.5.5) and pH (considered in the water and sediment quality chapter). Results of the water sampled TSS in milligrams per litre (mg/l) is presented in Table 8-24, according to the depth through the water column at which the samples were taken (top, middle or bottom). TSS in Table 8-24 are colour coded in accordance with the concentration, from 9 mg/l (darkest green) to 35 mg/l (red). Generally, TSS within the EICC is low, with most stations containing values close to or below the limit of detection of 5 mg/l or 10 mg/l, dependent on the analysis procedure (EIAR Vol. 4, Appendix 12: Environmental Baseline Report - EICC).

The CTD turbidity upcast profiles for locations within the Array Area are shown in Figure 8-18. Within the Array Area, turbidity remains low throughout, with only one outlier point recording comparatively elevated suspended material in the surface 5 m at OWF_05, reaching 7.48 NFU, which immediately fell back into alignment with remaining stations at a constant level between 1.3 NFU and 2.7 NFU (EIAR Vol. 4, Appendix 11 Environmental Baseline Report - OWF). The isolated reading of 7.48 NFU is considered to be a potential anomaly with the turbidity reading. TSS from water sampling within the Array Area (Table 8-24) has been recorded at the same locations described above for CTD profiling. TSS in the Array Area is again generally low (<10 mg/l), with just four stations containing values above the limit of detection with a maximum of 39 mg/l observed at OWF_22 (bottom) and OWF_49 (mid-point) (Table 8-24; EIAR Vol. 4, Appendix 11 Environmental Baseline Report - OWF).

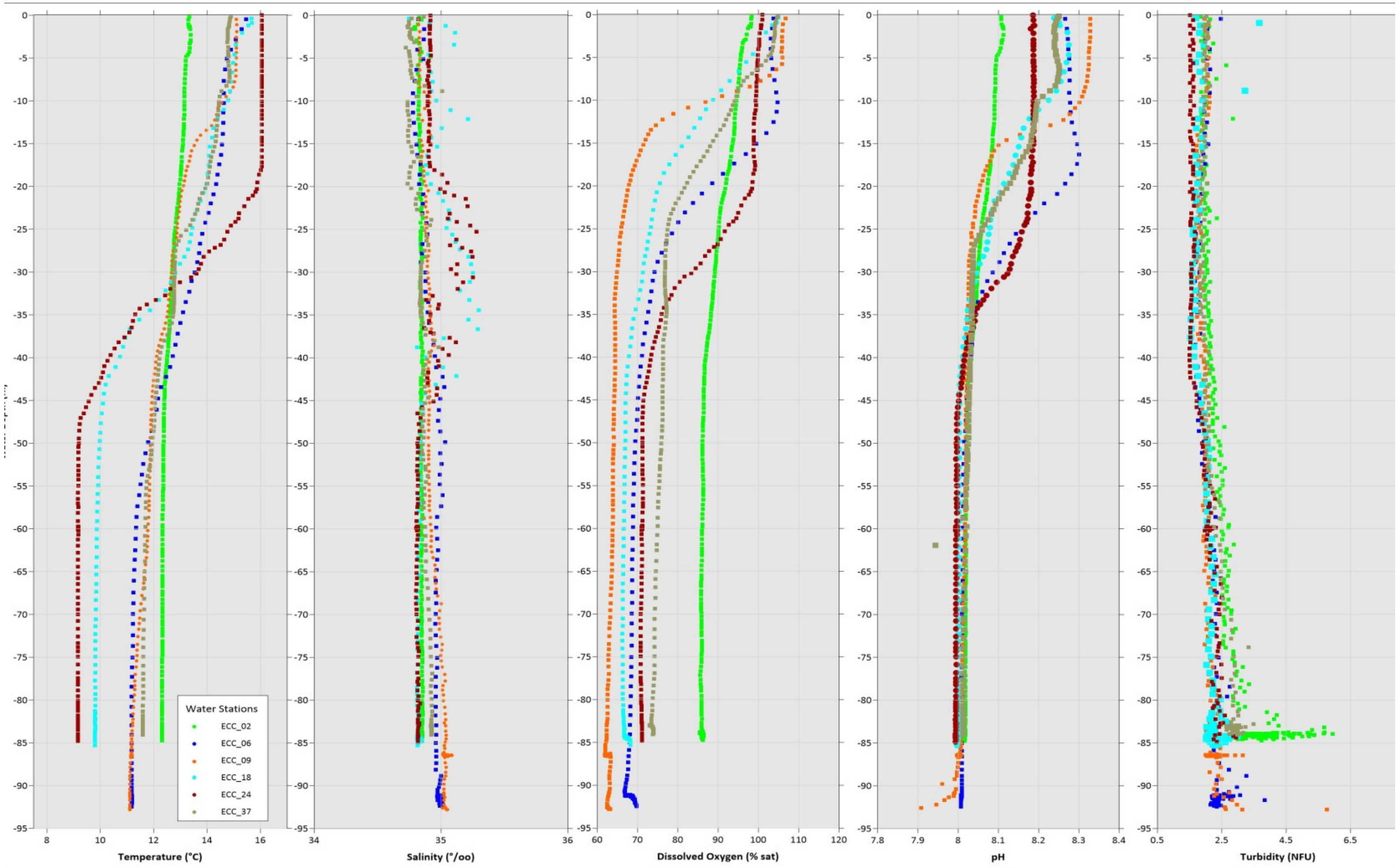


*Figure 8-17 CTD profiles for locations along the EICC (figure reproduced from **EIAR Vol. 4, Appendix 11 Environmental Baseline Report - OWF**).*

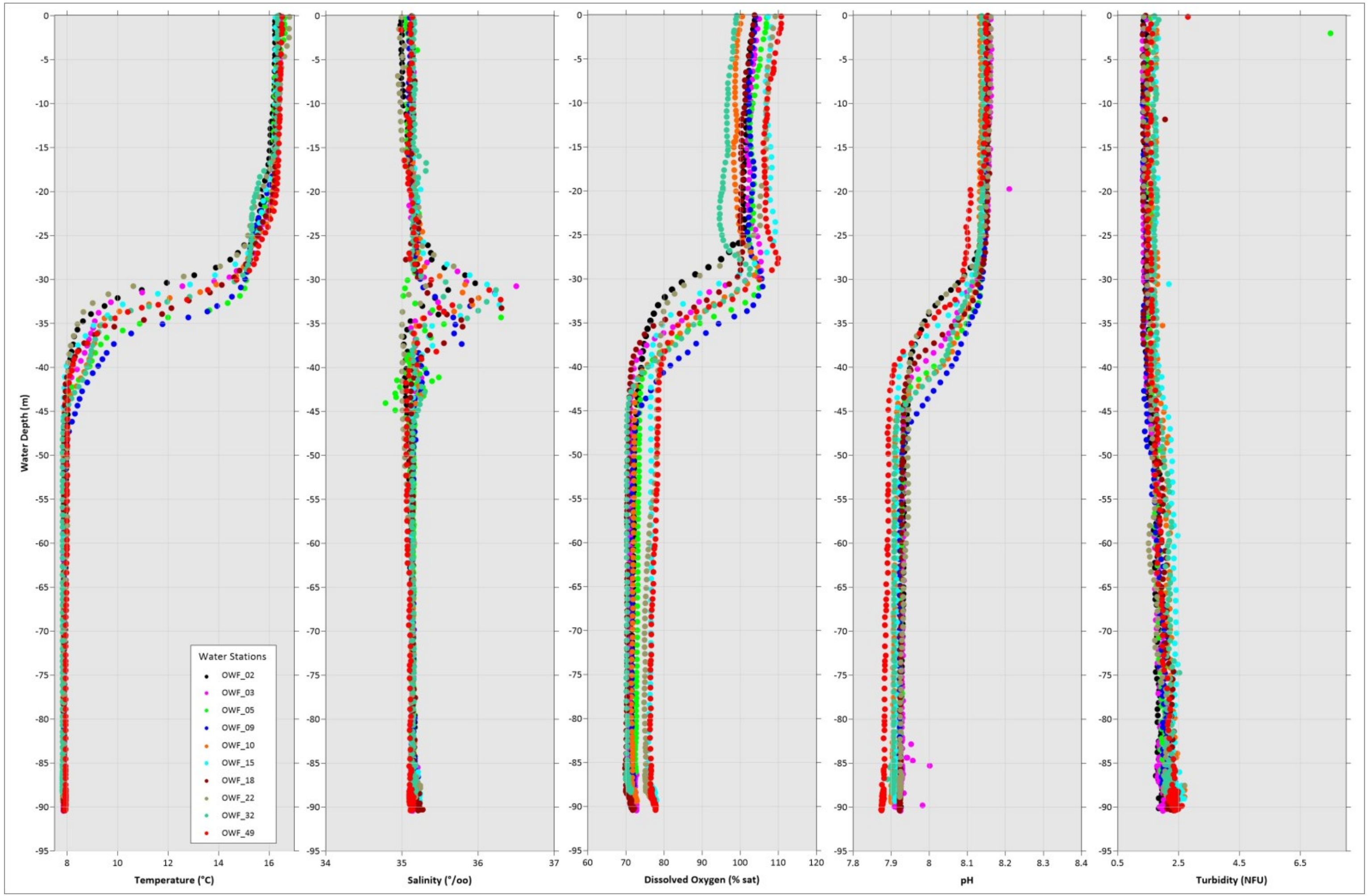


Figure 8-18 CTD profiles for locations across the Array Area (figure reproduced from ***EIAR Vol. 4, Appendix 12 Environmental Baseline Report - EICC)****.*

Table 8-24 TSS at locations sampled across the EICC and Array Area[3] *(**EIAR Vol. 4, Appendix 11: Environmental Baseline Report – OWF, EIAR Vol. 4, Appendix 12: Environmental Baseline Report - EICC**)*

SAMPLE LOCATION	TOTAL SUSPENDED SOLIDS (mg/l)		
	TOP	MIDDLE	BOTTOM
EICC_02	<10	13	<10
EICC_06	<10	11	10
EICC_09	17	<10	19
EICC_18	15	<10	<10
EICC_24	<10	<10	<10
EICC_37	<10	<10	<10
OWF_02	<10	<10	<10
OWF_03	<10	<10	<10
OWF_05	<10	<10	<10
OWF_09	<10	<10	<10
OWF_15	<10	<10	<10
OWF_18	<10	<5	<5
OWF_22	<5	9	39
OWF_32	<10	<10	16
OWF_41	<10	<10	<10
OWF_49	<10	39	<10

8.4.4.8 Fronts and Stratification

Thermal stratification is a process by which relatively stable distinct layers of warmer and colder water form within a water body. Typically, thermally stratified waters also show stratification in terms of salinity. Where well-mixed and stratified water bodies meet, they can develop a distinct density feature known as a front. Fronts can also be associated with higher concentrations of nutrients leading to higher rates of primary productivity. However, the presence of stratification does not always preclude the presence of a front. Van Leeuwen *et al.* (2015) found that much of the CNS is likely to undergo seasonal stratification, with large interannual variability.

8.4.4.8.1 Understanding of stratification from site-specific measurements

The environmental sampling completed between August and September 2023 acquired CTD casts, which recorded temperature and salinity properties through the water column (Section 8.4.3.2). Temperature profiles of the water column for selected water sample locations along the EICC are shown in Figure 8-17. The temperature profiles for most stations show the upper 25 m of the water column to be well mixed with temperatures of >12°C. Station

[3] *The difference in wash volume can alter the limits of detection of the analysis: both 5 mg/l and 10 mg/l are correct*

EICC_02, the closest profile taken to the coast, showed no evidence of a thermocline and remained well mixed through the entire water column, with little variation in temperature (min: 12.3°C and max: 13.4°C). For the remaining water stations, the temperature lowered with increasing depth at varying rates, with stations EICC_09 and EICC_37 lowering less rapidly between 10 m and 25 m, compared to stations EICC_06, EICC_18, and EICC_24 where a more rapid reduction from 20 m to 45 m depth noted the presence of a strong thermocline. The thermocline at EICC_24 was particularly prominent, reaching maximum depth at approximately 82.7 m and a minimum temperature of 9.2°C. The reduction in temperature continued at all stations (except EICC_02), albeit at a variable rate, to around 50 m where they remained constant at varying temperatures to the maximum profile depths (EIAR Vol. 4, Appendix 11 Environmental Baseline Report - OWF).

In the Array Area, the thermocline is more pronounced. Temperatures throughout the water column are consistent between sample locations (Figure 8-18). The temperature profiles show that the upper ~25 m of the water column are thermally well mixed across the Array Area, with temperatures exceeding 15°C. The highest temperature recorded was 16.8°C at station OWF_22. At water depths deeper than 35 m, there is a rapid reduction in temperature, which continues, albeit at a slower rate, until around 47 m where the change in temperature levels off and remains consistent to the seabed. Stations OWF_18 and OWF_49, sampled at a maximum depth of approximately 90.4 m, recorded a minimum temperature of 7.8°C. Overall, all stations exhibited similar rates of temperature decline (EIAR Vol. 4, Appendix 12: Environmental Baseline Report - EICC).

This is consistent with operational metocean criteria produced by PhysE (2023b) for the Array Area. The operational metocean criteria suggest a difference of 8.3°C in August between the top 10 m of the water column and the 10 m closest to the seabed. This temperature drop happens between 30 m and 40 m below sea level (PhysE, 2023b). This fits with the observations captured by the CTD profiles in Figure 8-18.

Salinity profiles within the EICC showed minimal variation within the water column with the majority of stations observing a relatively constant value at approximately 35 Practical Salinity Units (PSU) (Figure 8-17). Stations EICC_18 and EICC_24 observed slight increases in salinity between 20 m and 40 m below the surface, with a maximum salinity of 35.3 PSU recorded at both stations (EIAR Vol. 4, Appendix 11 Environmental Baseline Report - OWF). The salinity that was recorded by the water sampling taken at the three locations within the water column reported slightly lower values, ranging from 29.2 PSU to 33.3 PSU compared against those values acquired from CTD profiling. However, these differences are likely associated with the differences in methodologies used between CTD measurements and water sampling post-processed in a laboratory (EIAR Vol. 4, Appendix 12: Environmental Baseline Report - EICC).

Salinity within the Array Area was slightly more varied in accordance with the CTD profiles (Figure 8-18). Salinity remained consistent in the first 25 m of water ranging from 34.9 PSU at station OWF_49 to 35.2 PSU at OWF_32. At approximately 30 m water depth, the salinity increased slightly across all ten profiles before reducing to around 35 PSU at 45 m of water depth. Beyond this point, the salinity remained stable to the seabed (EIAR Vol. 4, Appendix 12: Environmental Baseline Report - EICC). This slight fluctuation in salinity aligns with the location of the thermocline in the water column and may represent the seasonal dissolution of the halocline, seeing as the survey was completed between August and September and secondary information presented in Section 8.4.4.8.2 indicates the dissipation of any stratification during this period.

8.4.4.8.2 Understanding of stratification from modelled sources

The coastline within the Study Area corresponds with a high potential for front formation, according to the work of Miller and Christodoulou (2014). Figure 8-19 shows a seasonally averaged front frequency map for summer months based on an interpretation of ten years of satellite data (between 1998 to 2008; Miller and Christodoulou, 2014). The front frequency (long-term summer average) is highest along the inshore section of the EICC. Here, over the analysed ten-year period, fronts occurred over 60 times during the summer. The potential for stratification is comparatively lower within the Array Area (Figure 8-19).

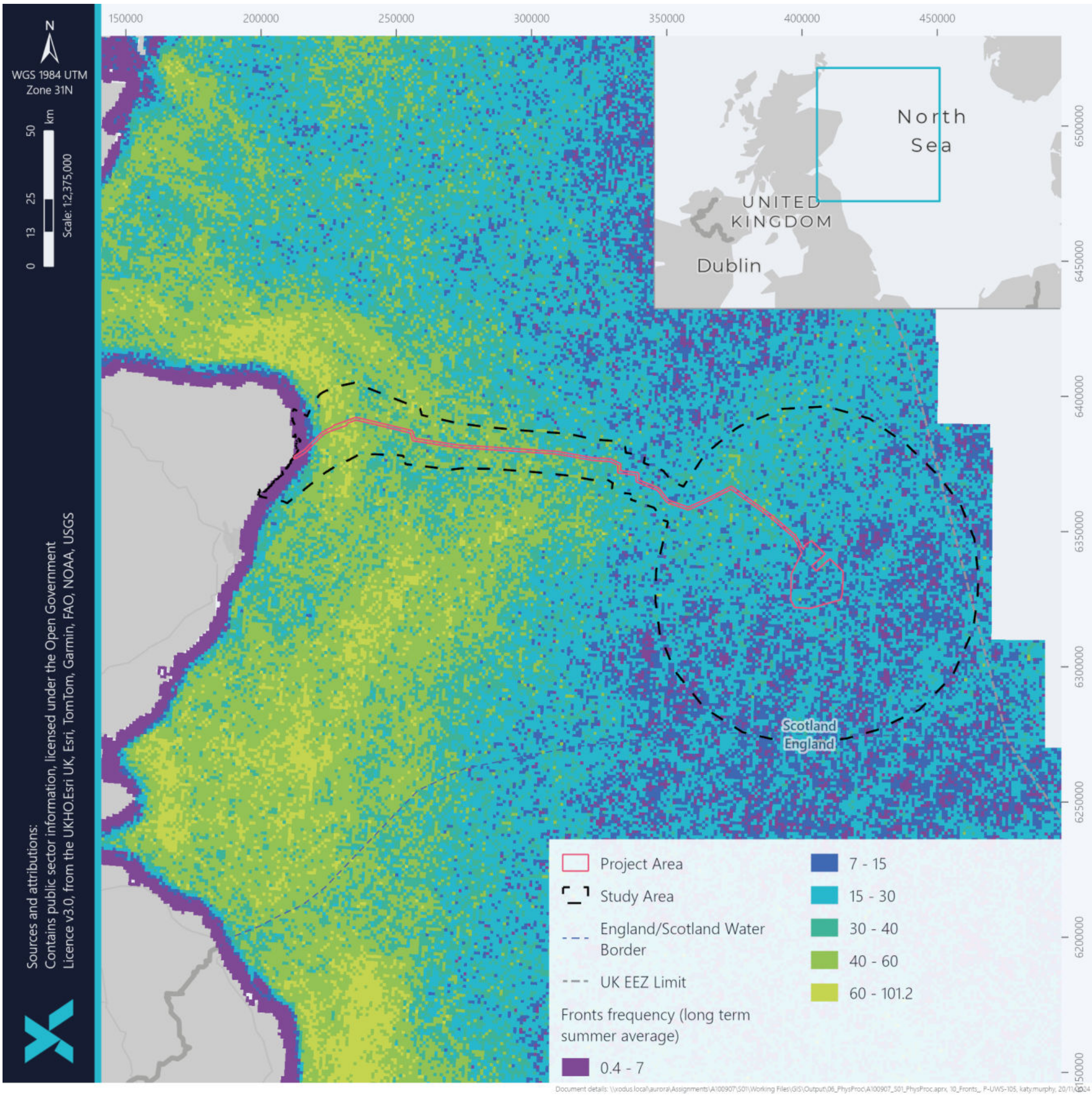


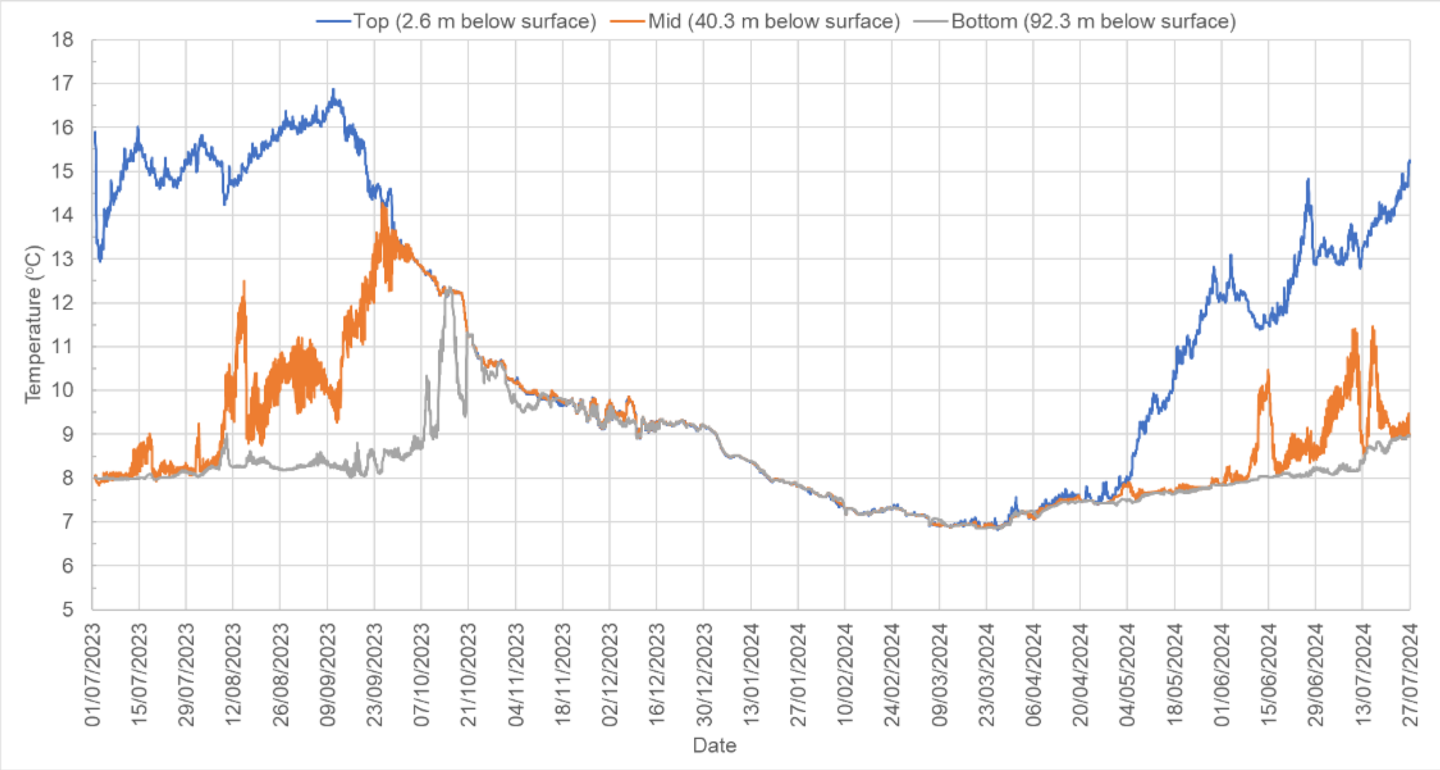
Figure 8-19 Potential for formation of fronts across the Marine Geology, Oceanography and Coastal Processes Study Area (Miller and Christodoulou, 2014)

As the CTD cast profiles were taken between August and September 2023, they only represent a point in time (in late summer) and do not provide any indication of change in stratification across the year. In order to understand the seasonal variation in temperature and salinity, this information was extracted for all Copernicus Marine (2024) data locations, from the 3D mems_mod_nws_phy_anfc_0.027deg-3D_PT1H-m dataset from the NWSHELF_ANALYSISFORECAST_PHY_004_013 model (Tonani *et al*., 2022; Aznar *et al*., 2023). Results for Locations 6, 9 and 10 along the EICC, and Location 1 within the Array Area are illustrated in Figure 8-20 to represent the properties at the various locations across the Project. The Copernicus Marine data timeseries covered a one year period from July 2023 to July 2024 at hourly intervals. The annual change in temperature at the sea surface, at a mid-point in the water column, and at the seabed at these locations is shown in Figure 8-20.

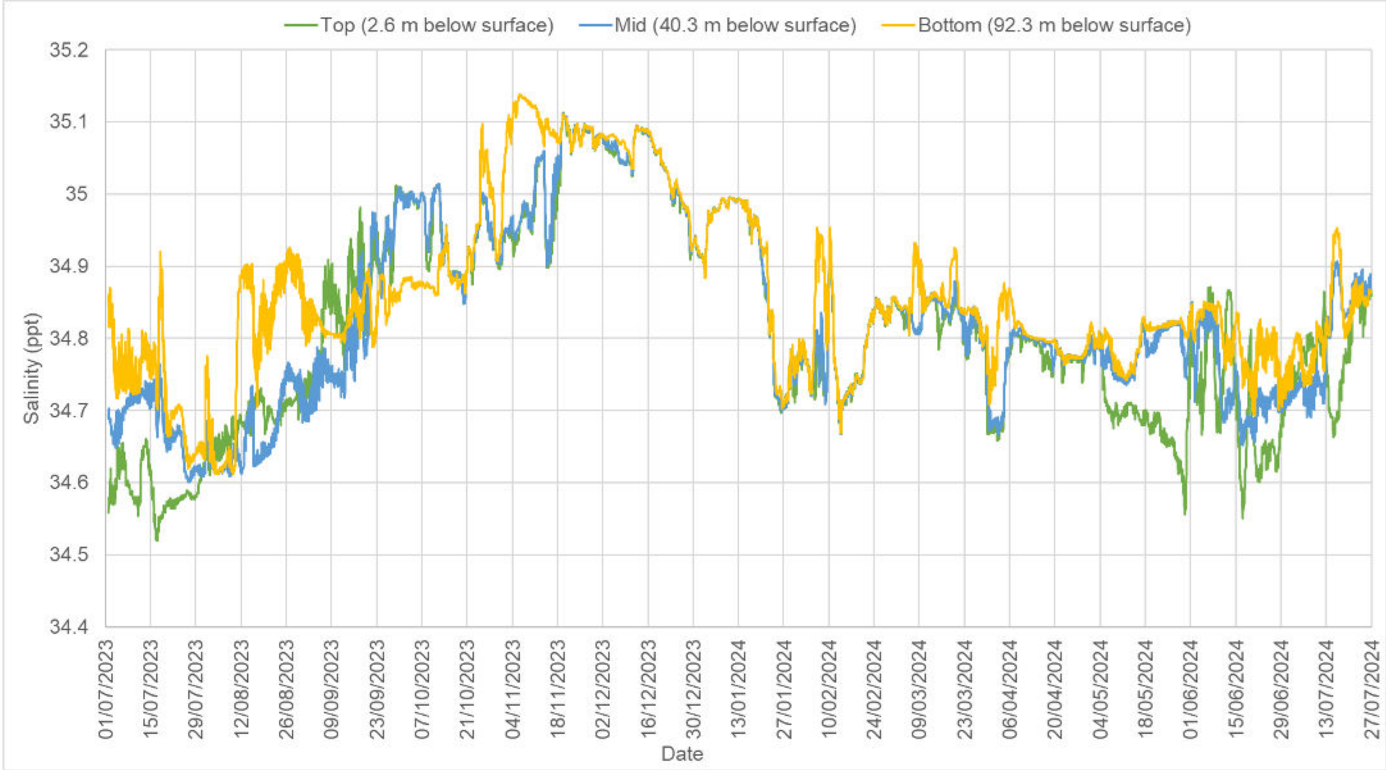
Across the analysed Copernicus Marine data locations presented in Figure 8-20, temperatures universally peak in late summer/early autumn (i.e. in September). Temperatures are higher further offshore, with surface temperatures in the Array Area reaching 17°C (Location 1), compared to temperatures closer to the coast (Location 9) and at the landfall (Location 10), which reached peaks of 15.6°C and 15.1°C, respectively. There is clear evidence of seasonal thermal stratification along the EICC (except at the landfall) and within the Array Area. The presence of the thermocline is also limited to the warmer months; it quickly disappears in September/October before returning in April. Over the winter months, the water column is evidently very well mixed such that temperatures are consistently low (around 7°C) throughout the water column. The landfall (Location 10) does experience a slightly cooler minimum temperature of approximately 6°C coinciding with February. The thermocline is also more evident offshore, with the disparity in temperature throughout the water column being greater within the Array Area and at Location 6 (which is within the EICC but close to the Array Area) compared to the locations nearer the coast. Closer to the coast, the thermocline is still apparent, but the temperature difference between the surface and the near-bed is reduced, as is the case as illustrated at Location 9. At the EICC landfall (Location 10 in 11 mLAT), temperatures vary throughout the year but remain consistent throughout the water column; the water depth here is insufficient for a thermocline to generate, and conditions are too dynamic to allow for stratification.

Based on the Copernicus Marine data locations, there is also evidence of salinity stratification through the year (Figure 8-20, right). Generally, salinity is lower over winter, following the initial drop in temperature in September/October. Salinity at the coast is also slightly lower on the whole than within the Array Area (reaching a minimum of 33.71 PSU at Location 10, compared to a minimum of 34.56 PSU at Location 1). Closer to the EICC landfall, salinity is less variable throughout the water column, with no evidence of stratification at all at Location 10. However, overall fluctuations in salinity throughout the year are more prominent at the landfall, i.e. salinity at Location 10 changes by 0.94 PSU across the analysed time series, in comparison, salinity in the Array Area (Location 1) changes by 0.57 PSU. The higher variability of salinity, but not apparent stratification at the coast is likely due to the potential for freshwater input and influence at the coast. On the whole, the change in salinity across the year at any of the locations is relatively small (<1 PSU).

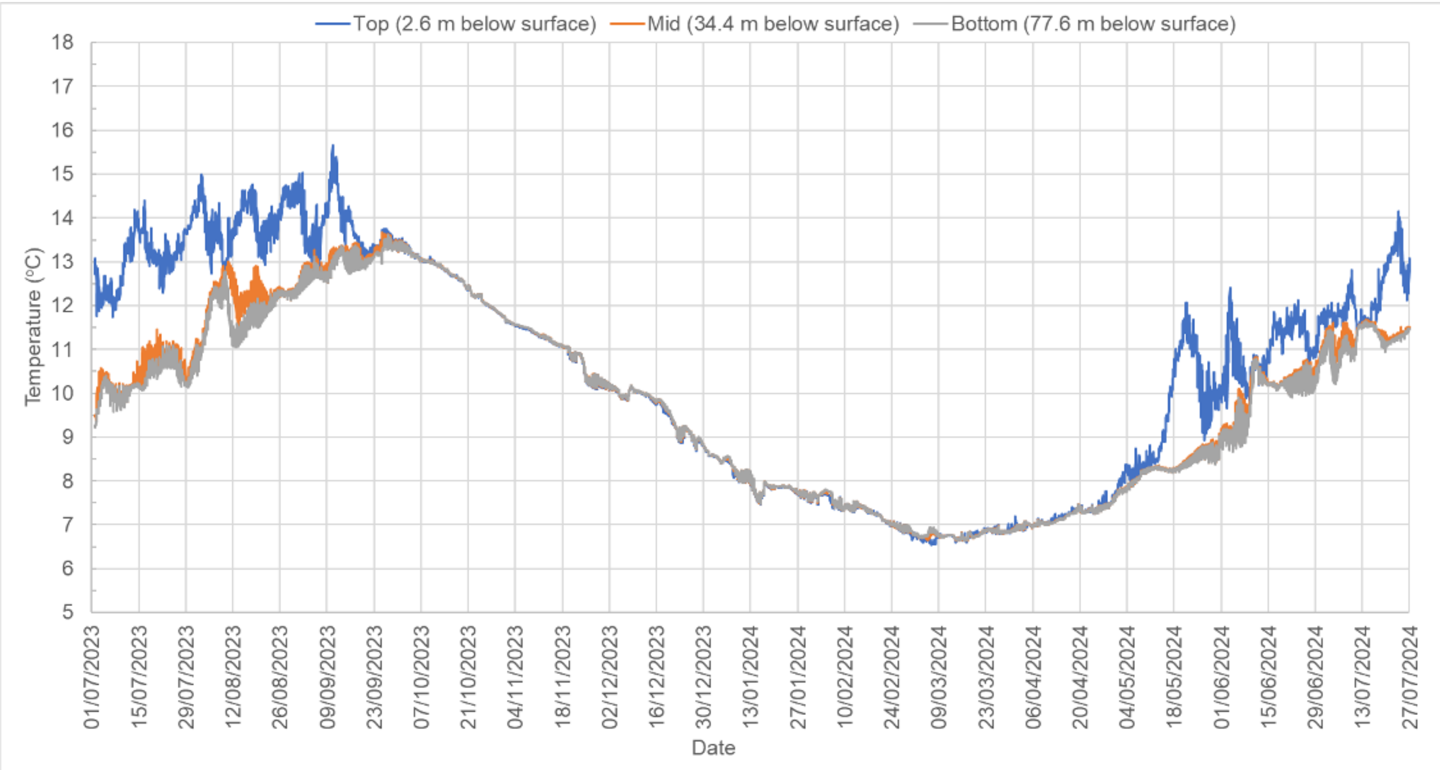
Location 6 (within the EICC): Temperature



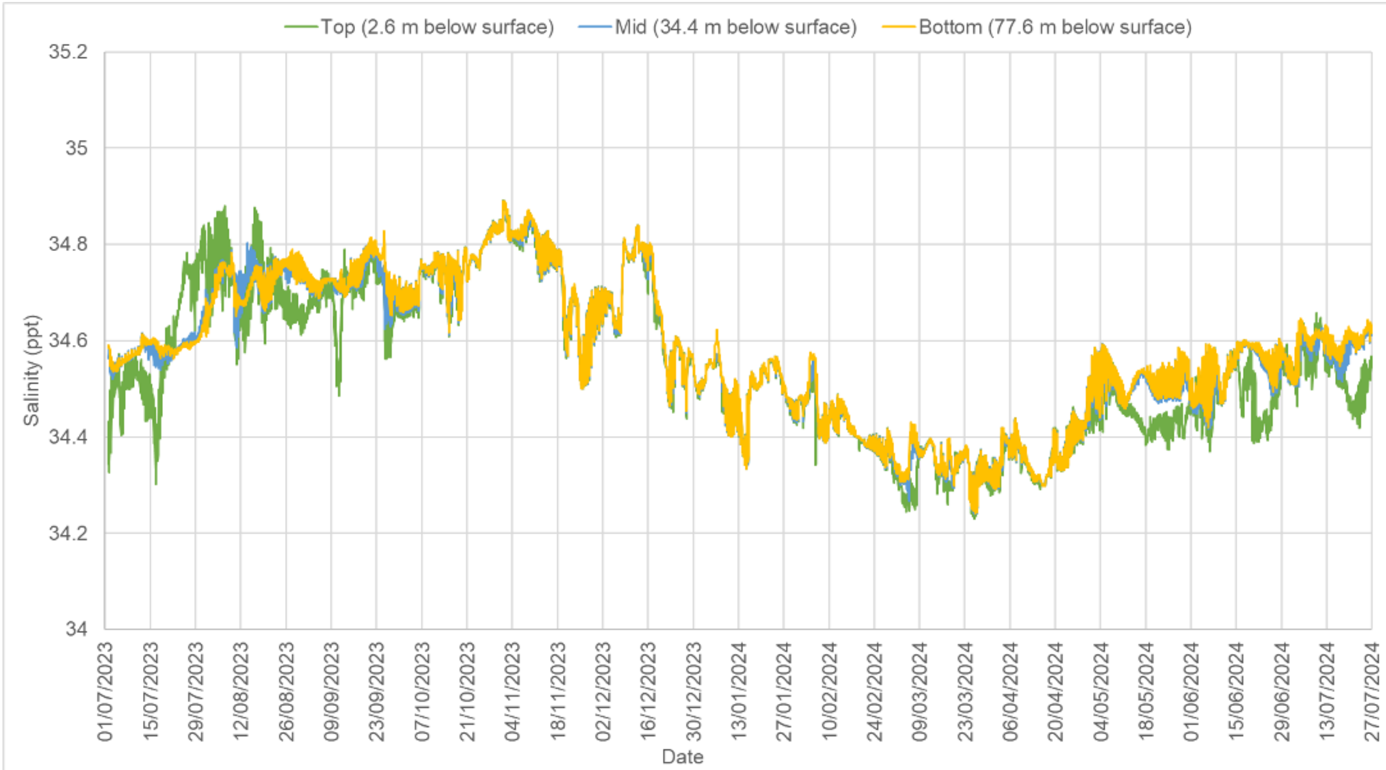
Location 6 (within the EICC): Salinity



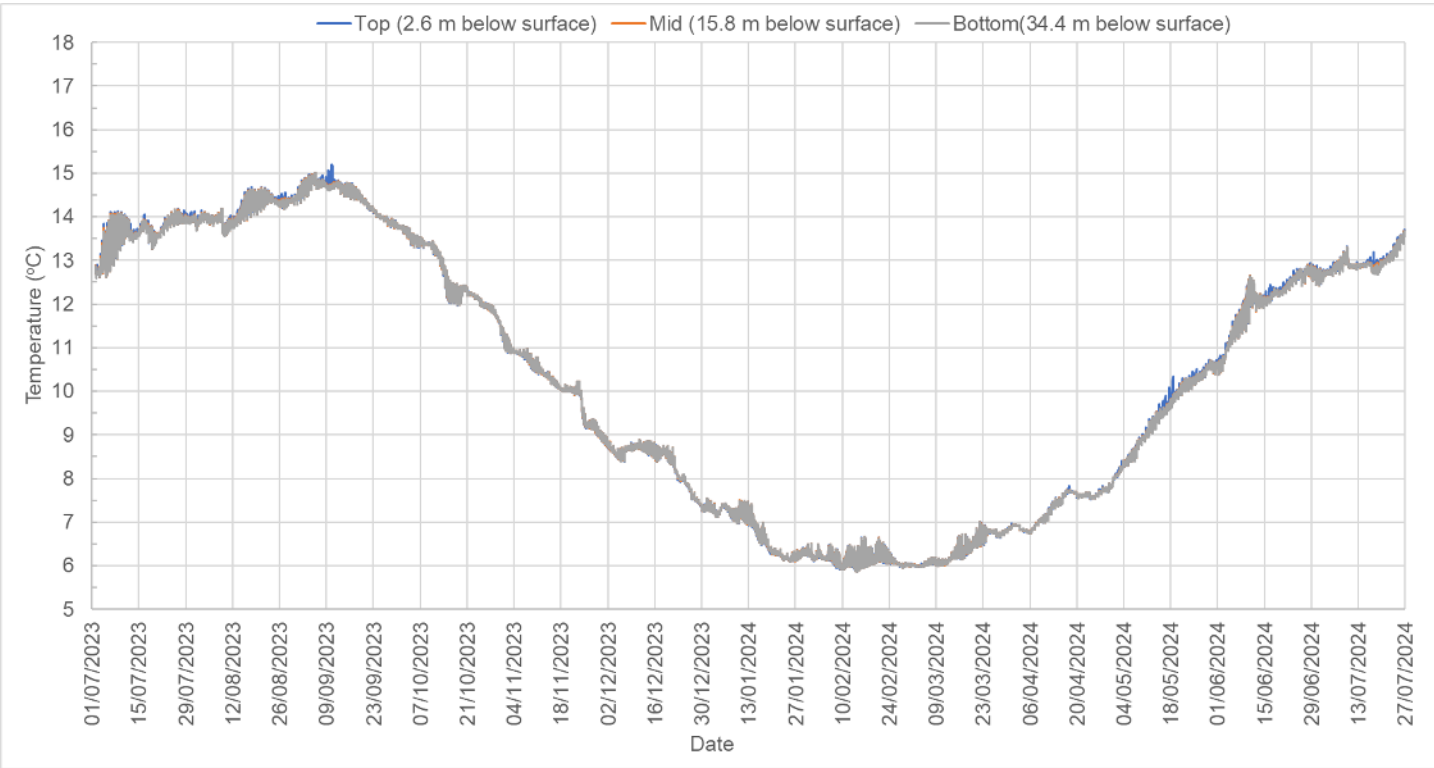
Location 9 (within the EICC): Temperature



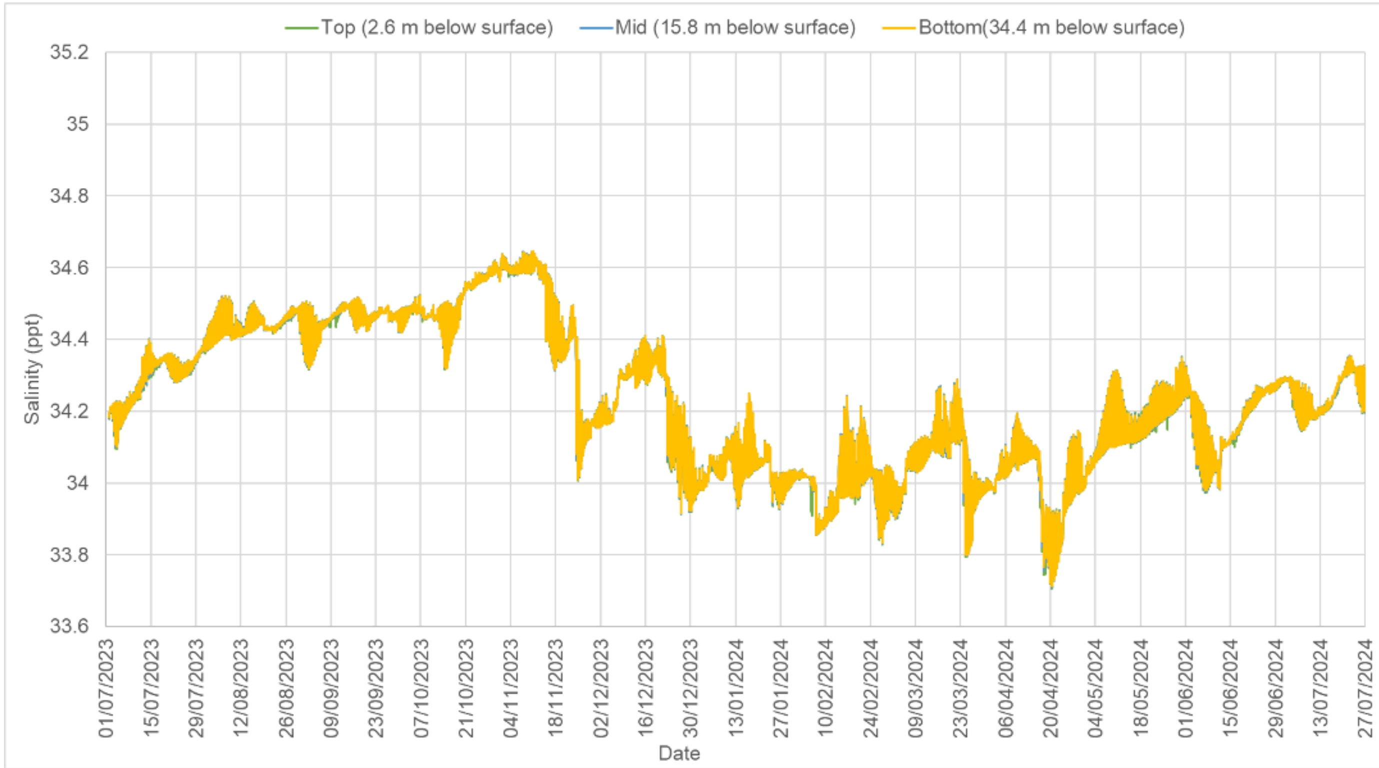
Location 9 (within the EICC): Salinity



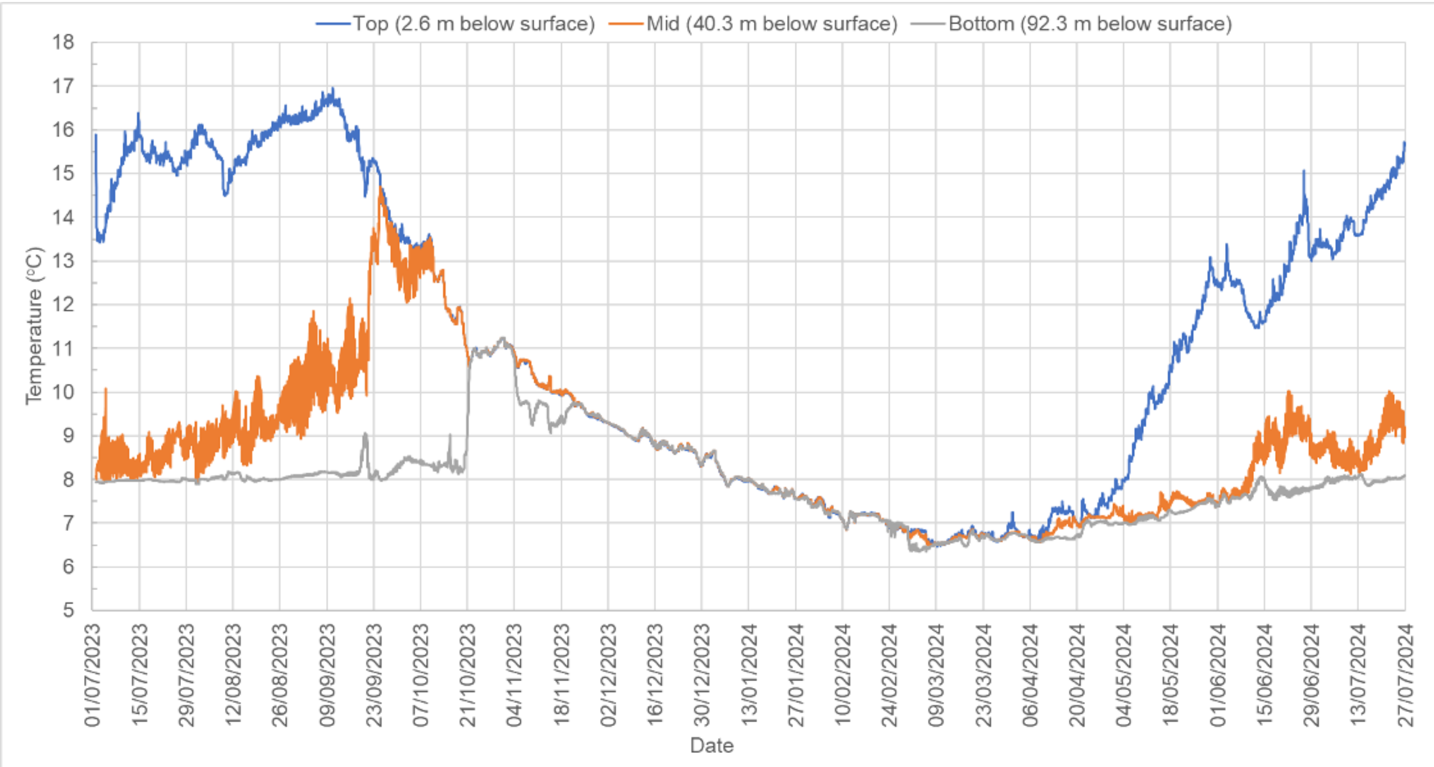
Location 10 (within the EICC, close to the landfall): Temperature



Location 10 (within the EICC, close to the landfall): Salinity



Location 1 (within the Array Area): Temperature



Location 1 (within the Array Area): Salinity

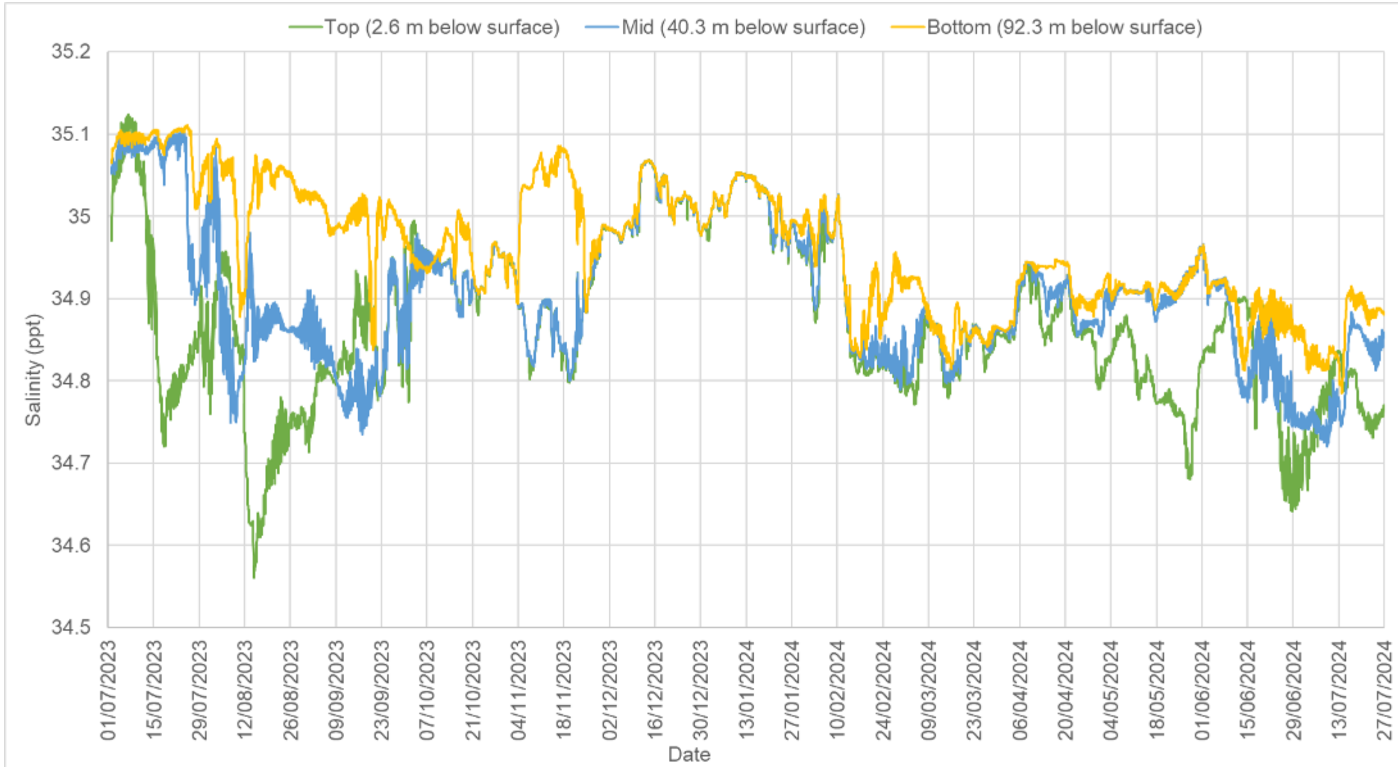


Figure 8-20 Annual temperature and salinity at locations along the EICC and within the Array Area (Copernicus Marine, 2024)

Fronts are one of five large-scale features included on the list of Marine Protected Area (MPA) search features. Miller, Xu and Lonsdale (2014), in a report commissioned by Scottish Natural Heritage (SNH) (now NatureScot), applied front detection and aggregation techniques to high resolution satellite ocean colour data to describe frequently occurring fronts near to the Scottish coast. Key frontal zones were selected through detailed analysis of the seasonal chlorophyll and thermal front distributions. The coast from Aberdeenshire to the Firth of Forth was identified as a potential frontal hotspot. The fronts along this section of coastline vary seasonally: in autumn and winter the thermal fronts are focused near to the coast, whereas in spring and summer there is evidence of stratification much further offshore (Miller, Xu and Lonsdale, 2014).

Fronts are a designated feature of the Southern Trench NCMPA, which the EICC will intersect at the southernmost extent of the NCMPA. The percentage of time that a strong front is present within the NCMPA boundary is shown in Figure 8-21. The front mainly corresponds to the location of the trench itself which lies to the northwest of the EICC, around the Aberdeenshire headland, approximately in line with Fraserburgh. Further detail on designated sites is provided in Section 8.4.4.10.

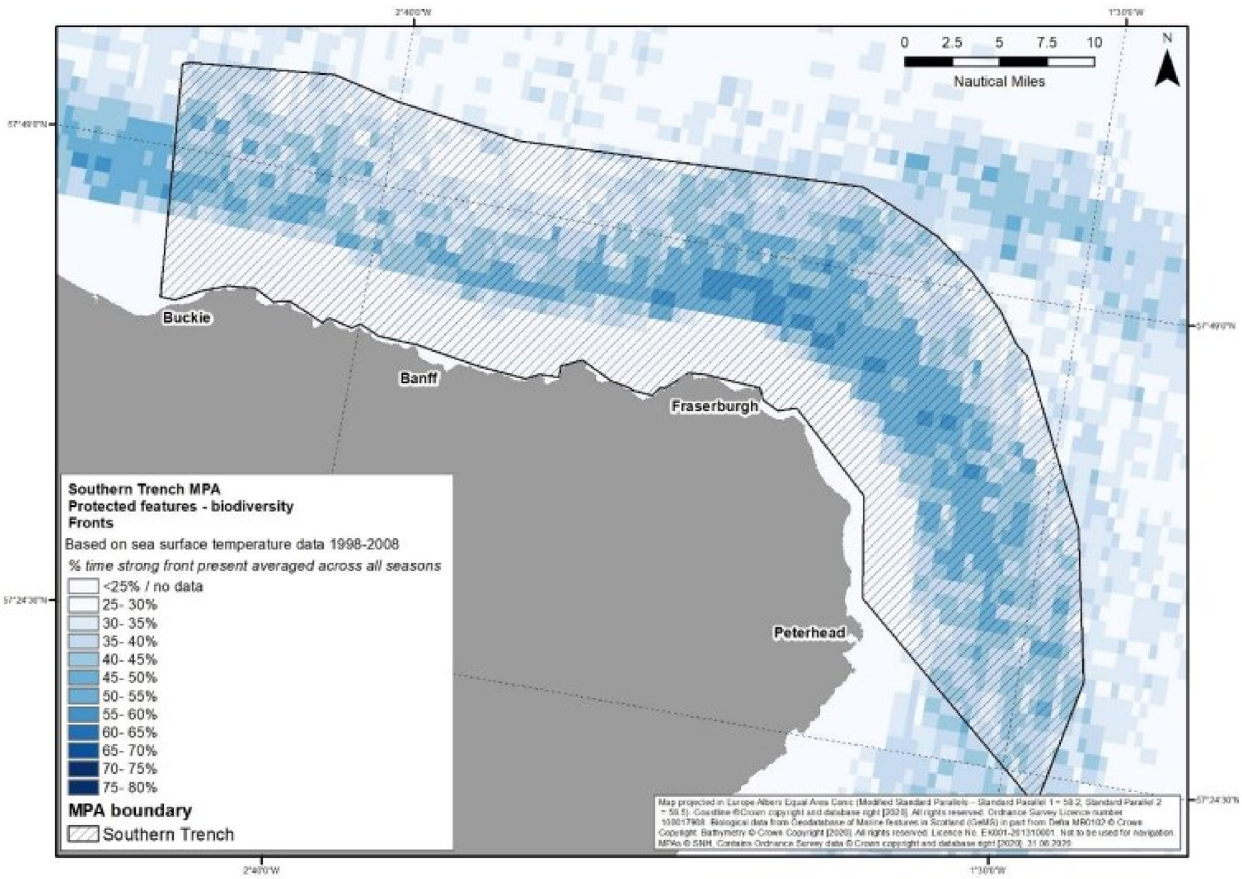


Figure 8-21 Percentage of time of strong front presence within the Southern Trench NCMPA (NatureScot, 2019)

8.4.4.9 Coastal Characteristics

The coastline landward of the marine HDD exit point is classed as erosion-resistant rock and / or cliff, without loose eroded material in the fronting sea, as illustrated in Figure 8-22 (EMODnet, 2024). The coastline at the landfall is characterised by a bedrock geology of granite, with no superficial deposits (BGS, 2024) and is therefore considered non-erodible (Figure 8-22) (Dynamic Coast, 2024). The stable sheer rocky cliff face, fringed by outcropping bedrock is devoid of sediment and therefore provides little sediment input into the marine environment (Gafeira *et. al*., 2010). Figure 8-23 shows the evolution of the coastline through time, from 2006 to September 2022 (Google Earth, 2024). Noting changes in the position of the sun and the differing state of the tide through the years, the coastline remains unchanged.

Under the high Greenhouse Gas emissions (GHG) emissions scenario (i.e. the worst-case scenario) out to the year 2100, coastal erosion at the EICC landfall location is not considered to be a risk. No eroded areas or potential areas of erosion are likely to be evident in 2100 (Dynamic Coast, 2024). Future changes to environmental baseline conditions, including the coastline, are discussed further in Section 8.4.5.

The EICC landfall is located within the CNS Regional Seas Cell 2 (Cairnbulg Point to Fife Ness) (Ramsay and Brampton, 2000) Sub cell 2d (Girdle Ness to Cairnbulg Point) (Fitton *et al*., 2017). The sediment transport regime is fully described in Section 8.4.4.7, but at a regional level Holmes *et al*. (2004) defined a bedload convergence zone close to the EICC landfall, at Rattray Head, where sediments travelling north along the Aberdeenshire coast meet those coming towards the south from the Northern North Sea. Ramsay and Brampton (2000) note that there was little evidence of net longshore drift north of Peterhead, compared to trends further south near Aberdeen. The longshore drift regime is heavily influenced by direction of wave approach and can occur in either direction at Cruden Bay. This aligns with the bedload convergence zone described by Holmes *et al*. (2004).

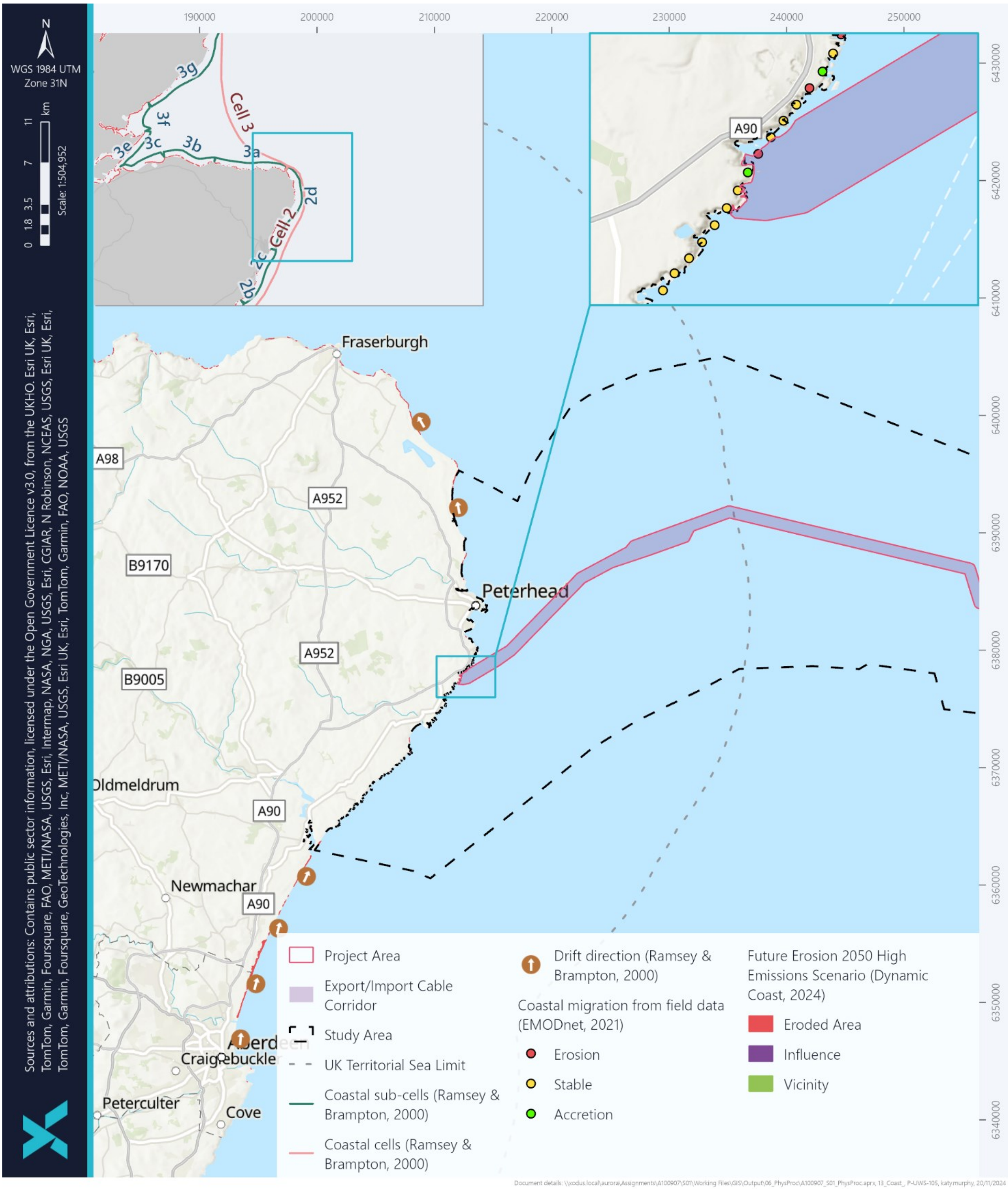


Figure 8-22 Coastal characteristics

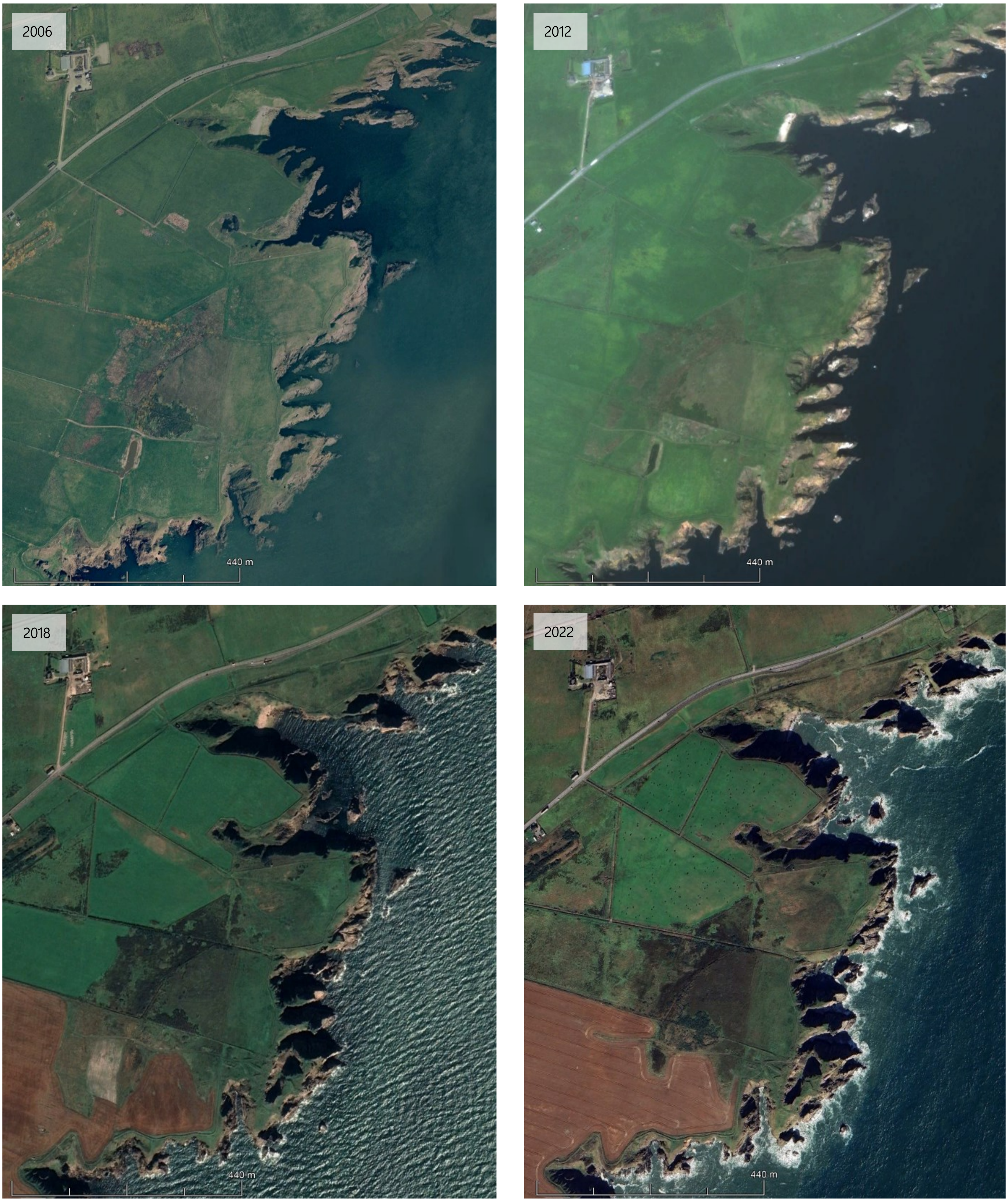


Figure 8-23 Coastline at the landfall location in 2006, 2012, 2018, 2022 (from Google Earth, 2024)

8.4.4.10 Designated Sites

There are seven designated sites which directly intersect the Marine Geology, Oceanography and Coastal Processes Study Area that contain designated features relevant to this assessment (Figure 8-24). Of the seven designated sites, four directly intersect the Project, which includes the Southern Trench NCMPA, the East of Gannet and Montrose Fields NCMPA and the Bullers of Buchan Site of Special Scientific Interest (SSSI) and Geological Conservation Review (GCR). Notably, of the designated sites that intersect the Study Area, all include relevant features of interest, with the addition of Turbot Bank NCMPA, which is designated for sandeel, which is highly dependent on seabed conditions and therefore directly influenced by, or dependent on, Marine Geology, Oceanography, and Coastal Processes.

Table 8-25 Designated sites with interest features relevant to the Marine Geology, Oceanography and Coastal Processes assessment.

SITE NAME AND ID	DESCRIPTION OF SITE	DESIGNATED FEATURE(S)	DISTANCE TO PROJECT (km)
Bullers of Buchan SSSI	Bullers of Buchan is the most important site for rock coast geomorphology in north Aberdeenshire. The site demonstrates an excellent and impressive range of rocky coast landforms developed in a relatively uniform, massive granite bedrock.	• Coastal Geomorphology of Scotland • Maritime cliff	0
East of Gannet and Montrose Fields NCMPA	The East of Gannet and Montrose Fields NCMPA lies to the east of Scotland within a relatively shallow sediment plain comprised mainly of sand and gravel habitats that support a range of benthic species.	• Offshore deep sea muds	0
Southern Trench NCMPA	The NCMPA features a dynamic mixing zone of warm and cold waters, known as a front, that attracts shoals of herring, mackerel and cod to the area. This in turn supports larger prey species, such as minke whale.	• Burrowed mud • Fronts • Quaternary of Scotland • Shelf deeps • Submarine mass movement	0
Turbot Bank NCMPA	The NCMPA lies within an area of sandy sediment, including part of the shelf bank and mound feature known as 'Turbot Bank'. This area is important for sandeels which are closely associated with sand habitats, living buried in the sand for months at a time.	• Sandeel	6
Strathbeg GCR	The dune forms of Strathbeg, north-east Scotland (contain some of the most impressive parallel linear dunes in Scotland. The aeolian processes that created this suite of linear dunes remain active in parts of the beach today. The Loch of Strathbeg lies separated from the open coast by a dune field.	• Coastal Geomorphology of Scotland	13
Collieston to Whinnyfold GCR	No site report available.	• Dalradian	14
Forvie GCR	The Sands of Forvie form the fifth largest and least-disturbed sand dune system in Britain. This vast site covers 810 ha and contains a remarkable assemblage of blown-sand landforms, some of which are unique in Britain.	• Coastal Geomorphology of Scotland	14

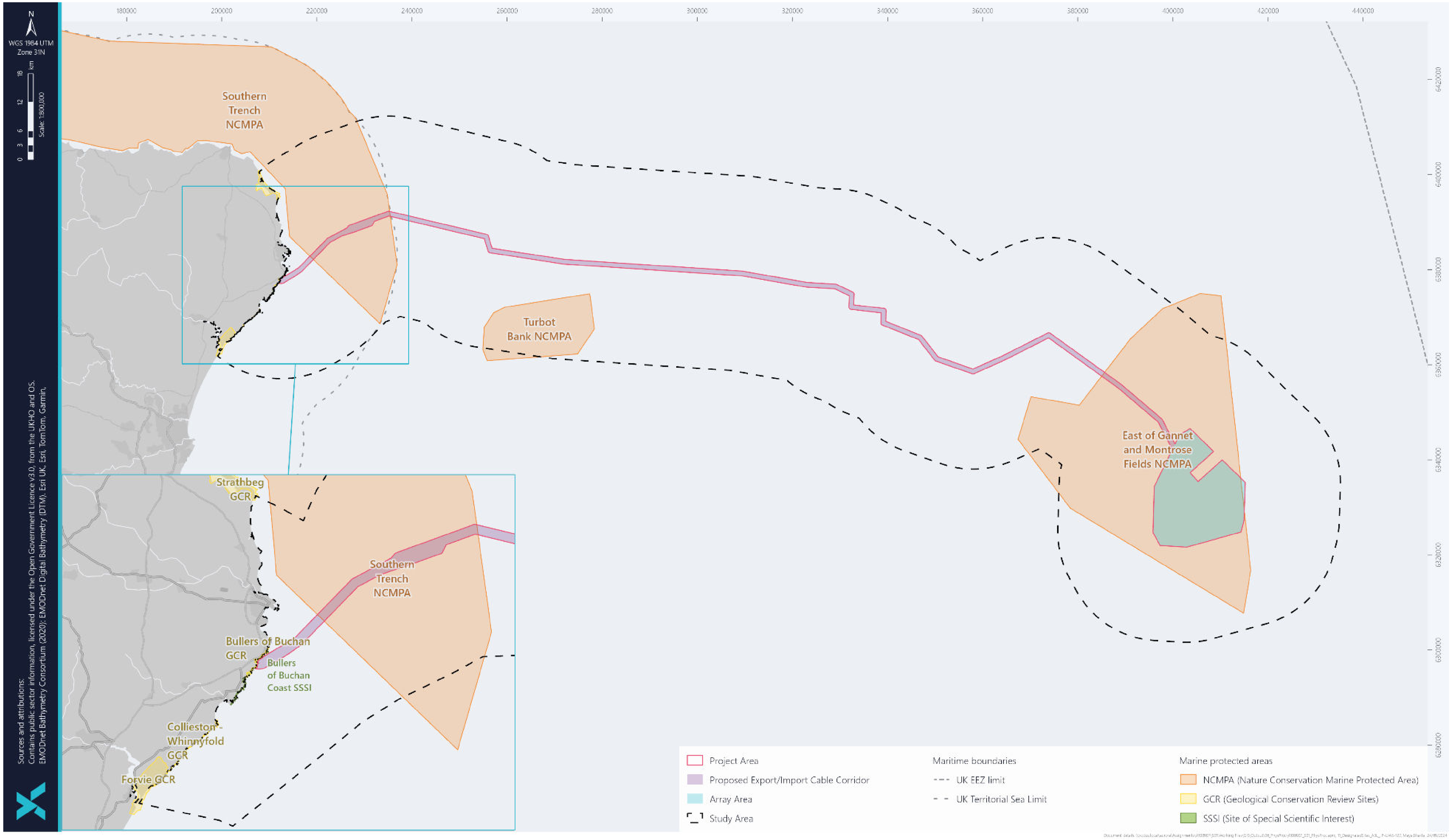


Figure 8-24 Designated sites with relevant designated features that intersect the Study Area

8.4.5 Future baseline

Aspects of the Marine Geology, Oceanography and Coastal Processes baseline are likely to change over time, largely due to climate change. However, the degree of change is uncertain. Certain features of the physical environment, such as the bedrock geology and subsurface sediments, will remain unchanged over time. These features have been consistent across the Project and Study Area for millennia and this will continue into the future. In contrast, metocean regimes within the area are likely to be influenced over time by the changing climate. This may have consequences for other dependant physical features and properties such as fronts, sediment transport etc. The following text focusses on the physical environment properties which may change over time.

8.4.5.1 Water Levels

With regards to changes in water level, the UK Climate Projections (UKCP) provide details of climate change projections for mean sea level at sites around the UK coastline. The projections extend to 2100 for various scenarios (Representative Concentration Pathways (RCP)). Under the high-emissions scenario, by 2100 the sea level at the EICC landfall location will have risen by approximately 1 m, based on the 95th percentile estimate (Figure 8-25). However, by the end of the proposed operational life of the Project around 2070, the sea level change under the same scenario is predicted to be approximately 0.5 m. This change is widely accepted to include contributions from global eustatic (water volume) changes in mean sea level and regionally varying vertical (isostatic) adjustments of the land / seabed following the effects of glaciation due to the thawing of the Scottish Ice Sheet (Dawson *et al.*, 2013).

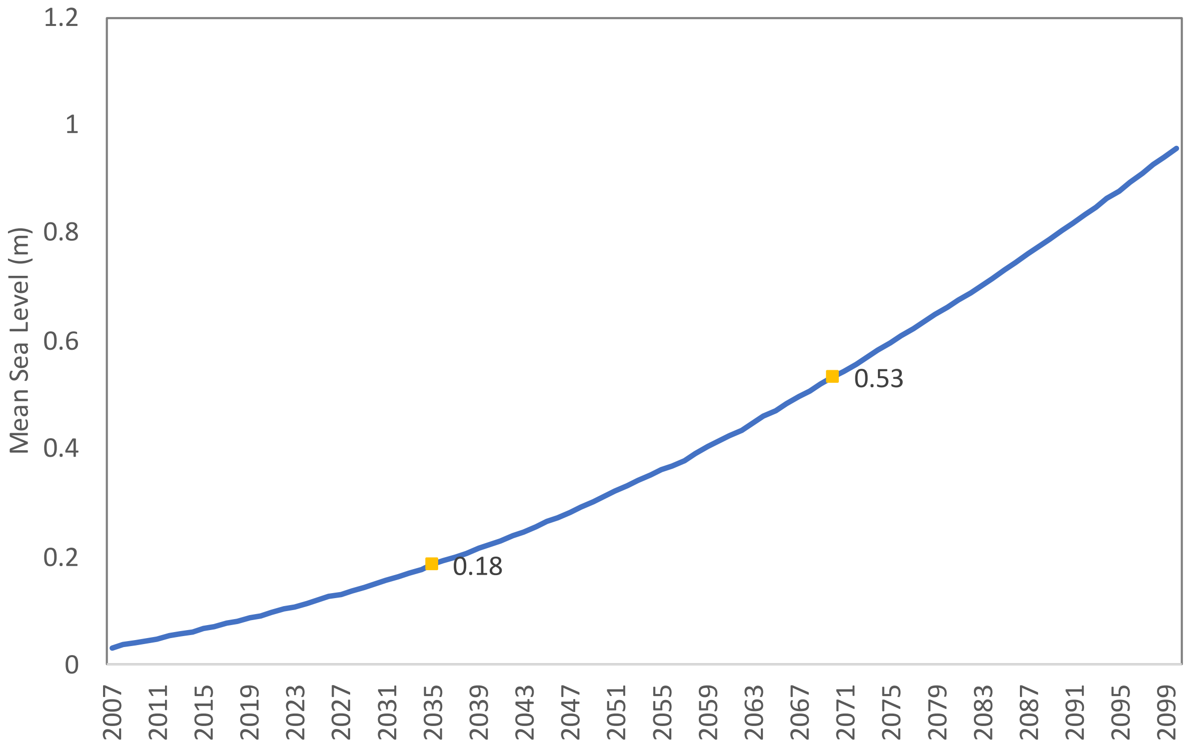


Figure 8-25 Sea level rise by 2100 at the landfall location under RCP8.5 (95th percentile) (Palmer et al., 2018)

8.4.5.2 Tidal Regime

There is not expected to be any change to tidal flows in the future. The tidal properties within the Study Area are associated with much larger regional scale tidal movement. Tidal flows are additionally independent of wind and wave conditions.

8.4.5.3 Waves

There is presently no clear consensus on future wave climates affecting the east coast of Scotland. On the whole, the most severe waves could increase in height by 2100 under a high emissions scenario, but there could be an overall reduction in mean significant wave height in the North Atlantic (Wolf *et al.*, 2020; Bircheno *et al.*, 2023). It is expected that natural variability will continue to contribute to the trends observed in the frequency and intensity of waves and storms within the North Sea.

8.4.5.4 Sediment Transport Regime

Given that there are not expected to be any changes to the regional scale tidal properties, and only natural variation to the wave climate in response to climate change is likely to occur, there is not anticipated to be any variation to the sediment transport characteristics in the future (beyond existing natural variability), especially within the operational life of the Project.

8.4.5.5 Fronts and Stratification

Seasonal stratification does occur within the Study Area, both in terms of temperature and salinity. In addition, fronts comprise an important part of the climate around the Aberdeenshire coast, in line with the Southern Trench NCMPA (Section 8.4.4.10). Any changes to the frequency of occurrence or properties of fronts and stratification will be dictated by mesoscale processes and regional changes to the water column, which would also be influenced by climate change. This would be dependent on the conditions described in previous Sections.

8.4.5.6 Coastal Characteristics

The Project and Study Area are located wholly within the CNS Regional Seas Cell 2 (Cairnbulg Point to Fife Ness) (Ramsay and Brampton, 2000) Subcell 2d (Girdle Ness to Cairnbulg Point) (Fitton *et al.*, 2017). At the coast, sea level rise could lead to an increase in the rate and / or magnitude of observed coastal recession. A Vulnerability Assessment has been undertaken for Cell 2 to project the rate and extent of future erosion out to the year 2050. The Vulnerability Assessment concluded that an anticipated 79.0 hectares (Ha) will be lost by 2050 if the current rates of coastal erosion continue (Fitton *et al.*, 2017). However, at the EICC landfall specifically, erosion is unlikely to occur owing to the hard, erosion resistant cliffs (Section 8.4.4.9). The impact on wider coastal processes is inherently linked to the anthropogenic response and the mitigation that may (or may not) be implemented at the coastline.

8.4.6 Summary and key issues

Table 8-26 Summary and key issues for the Marine Geology, Oceanography and Coastal Processes assessment

SUMMARY AND KEY ISSUES

PROJECT AREA

- A number of designated sites overlap with the Marine Geology, Oceanography and Coastal Processes Study Area.
- Although Quaternary deposits are more variable, outcropping or sub-cropping bedrock is consistent across the Project Area, at various depths below the seabed.
- Surficial sediment cover is relatively thin at <3 m thick, with the seabed sediment being typically coarse in nature along the EICC, dominantly comprising sands.
- Across the Array Area, surficial sediments are characterised by a greater fine sediment content, mainly comprising muddy sand, with a very thin sediment thickness of less than 0.5 m across approximately 230 km^2 of the 333 km^2 Array Area.
- Boulders are a common feature across the Project Area and are potentially a feature of the sub-cropping and outcropping Quaternary geology beneath the surficial seabed sediment across the Project Area.
- Water depths within the Array Area range between approximately 82 mLAT and 105 mLAT, deepening from the northwestern-most extent to the southwestern boundary and with seabed slopes being typically <1^{o}. Along the EICC water depths approximately range between 80 mLAT and 107 mLAT, with more variable seabed slopes associated with the presence of bedforms including sinusoidal transverse and linguoid sandwaves.
- Tidal water levels decrease in an offshore direction across the Project Area. Flow speeds also decrease in an offshore direction, with flow speeds during the spring tidal phase of up to 1.2 m/s occurring near the landfall, reducing to 0.7 m/s midway along the EICC and reducing further to 0.5 m/s within the Array Area. Equivalent flows during the neap tidal phase are typically around 50% less than those observed during the spring phase . Residual flow within the Array Area is towards the north, with residual speeds typically being <0.1 m/s. This is indicative of an ebb tidal dominance across the Project.
- Wave approach varies across the Project Area, approaching from the north – east – south sectors closer to the coast and most dominantly from the north along the EICC and within the Array Area. This is due to wave modification and sheltering effects at the coastline. Wave height and wave period increase in the offshore direction, ranging from about 1.4 m and 7.7 seconds at the landfall, to up to 2 m and 7.9 seconds offshore towards and within the Array Area.
- Sediment mobility potential decreases in the offshore direction associated with the reduction in flow speeds.
- There is evidence of seasonal thermal and salinity stratification across the Project Area, evident from late spring until autumn and occurring at a depth between 20 mLAT to 40 mLAT. Changes in salinity correspond to the variation in temperature.
- The coastline where the EICC landfalls is characterised as erosion-resistant rock and / or cliff, without loose eroded material in the fronting sea.

8.4.7 Data gaps and uncertainties

Complementary evidence has been collated from various sources to support the development of the baseline characterisation. Whilst good overall understanding is achieved, there remain some data limitations across the Project in the quantification of measured flows and waves, which places reliance on hindcast timeseries and existing models to provide these details.

Uncertainty exists with regard to characterisation of the future baseline with respect to global climate change. Key areas of uncertainty include future rates of sea level rise and the extent to which an increase in storminess will be manifested at local scales. There is also related uncertainty with regard to how the sediment transport regime, coastal processes and shoreline morphology may respond to an increase (or decrease) in higher energy events and the future wave climate acting in combination with higher than present sea levels.

8.5 Impact assessment methodology

8.5.1 Impacts requiring assessment

The impacts identified as requiring consideration for the Marine Geology, Oceanography, and Coastal Processes assessment are listed in Table 8-27. Information on the nature of impact (i.e. direct or indirect) is also described.

It is important to note that for the most part, marine geology, oceanography, and coastal processes are not in themselves receptors but are instead 'pathways'. However, changes to these processes have the potential to indirectly impact other environmental receptors (Lambkin et al., 2009). For instance, the creation of sediment plumes (the potential for which is considered in this assessment) may lead to settling of material onto benthic habitats. The potential significance of this particular change is assessed in EIAR Vol. 3, Chapter 10: Benthic Ecology. This distinction between assessments of pathways and receptors is summarised in Table 8-27, for each of the potential impacts/ changes considered within the assessment Section.

Whilst marine geology, oceanography, and coastal 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 inshore seabed morphology) at the landfall;
- Seabed areas contained within nationally or internationally important sites. The locations of these sites are shown in Figure 8-24 and include the Southern Trench NCMPA and East of Gannet and Montrose Fields NCMPA.

These receptors have been identified on the basis of:

- Professional judgement, local and regional specialist experience;
- The Scoping Opinion (Scottish Government, 2024);
- Outcomes from the consultation process; and
- Reference to best practice guidance.

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.

Table 8-27 Impacts requiring assessment within with Marine Geology, Oceanography, and Coastal Processes chapter

POTENTIAL IMPACT/ CHANGE	NATURE OF IMPACT/ CHANGE
Construction and decommissioning	
Potential changes to suspended sediment concentrations, bed levels and sediment type (pathway)	Indirect
Potential modifications to sediment transport pathways (pathway)	Indirect
Potential impacts to designated seabed interest features within protected sites (receptor)	Direct/ indirect
Potential changes to coastal /inshore seabed morphology (receptor)	Direct/ indirect
Operation and maintenance	
Potential changes to suspended sediment concentrations, bed levels and sediment type (pathway)	Indirect
Potential changes to wave and tidal regime (pathway)	Indirect
Potential modifications to sediment transport pathways (pathway)	Indirect
Modifications to stratification and frontal features (pathway)	Indirect
Potential impacts to designated seabed interest features within protected sites (receptor)	Indirect
Potential changes to coastal /inshore seabed morphology (receptor)	Indirect

8.5.2 Impacts scoped out of the assessment

No impacts have been scoped out, principally due to the potential for indirect impacts on other topic receptors.

8.5.3 Assessment methodology

An assessment of potential impacts is provided separately for the construction, operation and maintenance and decommissioning phases.

In order to assess the potential changes to marine geology, oceanography and coastal processes, relative to the existing baseline, a combination of analytical methods have been used. These methods are summarised in Table 8-28. The assessments consider likely naturally occurring variability in, or long-term changes to, Marine Geology, Oceanography, and Coastal Processes within the lifetime (35 years) of the Project due to natural cycles and/or climate change (e.g. sea level rise). This is important as it enables a reference baseline level to be established, against which the potentially modified processes can be compared, throughout the Project lifecycle.

Table 8-28 Summary of assessment approach for each potential impact considered within the Marine Geology, Oceanography and Coastal Processes assessment

POTENTIAL IMPACT/ CHANGE	SUMMARY OF ASSESSMENT APPROACH
Potential changes to suspended sediment concentrations, bed levels and sediment type (pathway)	A large evidence base exists with regards to the potential environmental effects of cable installation activities (including increases in suspended sediment concentrations (SSC), e.g. BERR, 2008). This has been considered in conjunction with spreadsheet-based tools (providing estimates of plume extent, concentration and associated changes in bed levels) to inform the assessment. Spring tidal excursion ellipse buffers (based on outputs from the Atlas of UK Marine Renewable Energy (ABPmer *et al.*, 2008) have also been used to help inform the potential spatial extent of suspended sediment plumes associated with project-related construction/decommissioning activities.
Potential changes to wave and tidal regime (pathway)	The maximum surface and subsurface cross section of each floating substructure foundation and OSCPs foundation have been considered, to assess the potential local extent and scale of effect on waves or currents. The assessment is a semi-quantitative, desk-based, consideration of the potential for local wave energy or current blockage and recovery downstream.
Potential modifications to sediment transport pathways (pathway)	The potential for array scale effects has been considered with respect to the spacing of the individual FTU, in conjunction with the predicted extent of effect from individual FTU. The potential for array scale effects to extend to the seabed (locally) has also been considered. The desktop assessment has been informed by knowledge of the local wave and current regimes, relevant wave and hydrodynamic theory, and the many offshore wind farm EIA and engineering related studies that have considered the effect of windfarm development.

POTENTIAL IMPACT/ CHANGE	SUMMARY OF ASSESSMENT APPROACH
	Potential changes to patterns of sediment transport have been assessed, on the basis of the extent and scale of any predicted changes to the wave and current regimes, relative to the normal natural range of variability in these parameters. Both cable protection measures, and (to a much lesser extent) the anchors, have the potential to interact with sediment transport pathways locally. This has been assessed as a semi-quantitative desktop exercise, based on the local (baseline) sediment transport potential and the dimensions of the structures. Reference has also been made to a range of existing evidence that has been developed in relation to the assessment of cable protection measures over the last four years for other wind farm projects.
Modifications to stratification and frontal features (pathway)	Methodological approach similar to that of Carpenter, et al. (2016) and Dorrell, et al. (2022) which uses empirical equations relating drag on turbine structures to turbulent kinetic energy (TKE). Involves a comparison of TKE conversion by structure to baseline conditions, quantified by either potential energy anomaly or ambient bed shear. The potential spatial extent of wind farm impacts investigated using available hydrodynamic data.
Potential impacts to designated seabed interest features within protected sites (receptor)	Desk based assessment approach which draws on outputs from the assessments outlined above (relating to the potential for blockage of waves, tides and sediment transport processes.) Also informed by the evidence from analogous projects and activities.
Potential changes to coastal /inshore seabed morphology (receptor)	Desk based assessment approach. The physical nature and extent of the likely disturbance has been characterised using the information in EIAR Vol. 2, Chapter 5: Project Description and with reference to the wider evidence base. The potential impact on coastal morphology, hydrodynamics and sediment transport has been assessed by an experienced coastal geomorphologist in the context of the baseline environment of the landfall site.

The assessment has been undertaken in accordance with industry best practice and guidance, as previously described in Section 8.2. Full details of the methodological approach to the assessment of (i) potential changes to SSC, bed levels and sediment type; and (ii) modifications to stratification and frontal features are set out in EIAR Vol. 4, Appendix 7: Marine & Physical Processes Modelling Report.

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 EICC over which indirect changes may occur (i.e. the Study Area); and
- Near-field. Defined as the footprint of the Array Area and EICC.

The assessment for Marine Geology, Oceanography, and Coastal Processes is undertaken following the principles set out in EIAR Vol. 2, Chapter 7: EIA Methodology. The sensitivity of the receptor is combined with the magnitude to determine the impact significance. Topic-specific sensitivity and magnitude of effect criteria are assigned based on professional judgement, as described in Table 8-29 and Table 8-30.

Table 8-29 Sensitivity criteria

SENSITIVITY OF RECEPTOR	DEFINITION
High	Very low or no capacity to accommodate the proposed form of change; and/ or receptor designated and/ or of international level importance. Likely to be rare with minimal potential for substitution. May also be of very high socioeconomic importance.
Medium	Moderate to low capacity to accommodate the proposed form of change; and/ or receptor designated and/ or of regional level importance. Likely to be relatively rare. May also be of moderate socioeconomic importance.
Low	Moderate to high capacity to accommodate the proposed form of change; and/ or receptor not designated but of district level importance.
Negligible	High capacity to accommodate the proposed form of change; and/ or receptor not designated and only of local level importance.

Table 8-30 Magnitude of effect criteria

MAGNITUDE CRITERIA	DEFINITION
High	Permanent changes across the near- and large parts of the far-field to key characteristics or features of the particular environmental aspect's character or distinctiveness.
Medium	Permanent changes, over the near- and parts of the far-field, to key characteristics or features of the particular environmental aspect's character or distinctiveness
Low	Noticeable, temporary (for part of the project duration) change, or barely discernible change for any length of time, restricted to the near-field and immediately adjacent far-field areas, to key characteristics or features of the particular environmental aspect's character or distinctiveness.
Negligible	Changes which are not discernible from background conditions.
No change	No change from baseline conditions.

The consequence and significance of effect is then determined using the matrix provided in EIAR Vol. 2, Chapter 7: EIA Methodology.

8.5.4 Embedded mitigation

Certain measures (primary and tertiary mitigation) have been adopted as part of the Project development process in order to reduce the potential for impacts to the environment, as presented in Table 8-31. These have been accounted for in the assessment presented below. The requirement for additional mitigation measures (secondary mitigation) will be dependent on the significance of the effects on Marine Geology, Oceanography, and Coastal Processes receptors.

Table 8-31 Embedded mitigation measures relevant to Marine Geology, Oceanography, and Coastal Processes

CODE	MITIGATION MEASURE	TYPE	DESCRIPTION	SECURED BY
MM-001	Use of HDD as the landfall cable installation option	Primary	Landfall installation methodology (HDD) will avoid direct impacts to the intertidal area.	Landfall installation methodology will be detailed within the Construction Method Statement (CMS), required under Section 36 Consent and/or Marine Licence conditions.
MM-002	Mooring and anchor design to ensure reduction of habitat loss and disturbance	Primary	FTU mooring designs considered for the project have excluded the catenary mooring which was identified as the design with the largest seabed footprint, therefore minimising footprint within the East of Gannet and Montrose Fields NCMPA. Semi-taut and taut mooring designs options for semi-submersible substructure and tendon mooring designs for Tension Leg Platform (TLP) substructures have been retained as mooring design options for the Project because these design options produce the least disturbance and minimise potential for habitat loss. Additionally, anchor designs considered for the Project have excluded the drag embedment anchor, which was identified as the design with the greatest potential for seabed disturbance and habitat loss. Suction and driven pile anchor designs have been retained as anchor design options for the Project because they have the smallest footprint and minimise potential seabed disturbance during installation. Anchors will be installed through suction embedment or piling, rather than drilling, in order to minimise sediment disturbance. Novel anchor solutions with equivalent or similar seabed footprint have also been retained as options.	Commitment made within Project design. The final design will be detailed within the CMS, required under Section 36 Consent and/or Marine Licence conditions.

CODE	MITIGATION MEASURE	TYPE	DESCRIPTION	SECURED BY
			Localised habitat loss during the installation phase is an unavoidable consequence of the Project. Best practices will be followed to ensure that potential habitat loss is reduced (e.g. micro-siting and reducing the benthic footprint of the Project), including during the operational phase (e.g. from mobile mooring chains on the seabed). The amount of rock armour, grout bags, and concrete mattresses used to protect the Export/Import Cable(s) and the IACs will be kept to a minimum where possible, especially in the NCMPAs.	
MM-003	Design of scour protection to minimise introduction of hard substrate	Primary	Rock placement will not be used for scour protection because it maximises the introduction of hard substrate and is difficult to remove. Alternative scour protection methods are being considered (e.g. scour reduction strakes and tubular sleeves) which would not increase the maximum footprint of the piles. The mean surface sediment thickness across the entire site is less than 0.5 m indicating scour protection requirements are likely to be negligible or not required within the Project Area.	Final scour requirements will be informed by the scour assessment and detailed within the CMS, required under Section 36 Consent and/or Marine Licence conditions.
MM-004	Micro-siting of FTUs and associated offshore infrastructure, including cable routes	Primary	Pre-construction cable route survey to confirm the condition of the seabed and that no significant changes have occurred from previous surveys, confirm the presence of morphological features and the requirement for micro-siting around these or completion of seabed preparation works. The final Array Area layout (including IACs) and Import / Export Cable Route will be presented within the Development Specification and Layout Plan (DSLP) and will include micro-siting of infrastructure to avoid sensitive habitats or features. Where possible, the Export/Import Cable Route will aim to avoid sensitive habitats and,	Final layout will be captured in the DSLP, required under Section 36 Consent and/or Marine Licence conditions.

CODE	MITIGATION MEASURE	TYPE	DESCRIPTION	SECURED BY
			where this is not practicable, the route will be designed to achieve the least impact to sensitive habitats or features.	
MM-005	Target Depth of Lowering (DoL)	Primary	Static cables will be trenched and buried to a minimum depth of 0.4 m. Where this cannot be achieved, remedial cable protection will be applied. The cable burial target depth is informed by a Cable Burial Risk Assessment (CBRA) and implemented through the Cable Plan (CaP), which will be produced post-consent. Electromagnetic Field (EMF) emissions associated with the cabling will be reduced by burial of between 90-100% of the cables at the depth between 0.4 – 1.5 m.	Final cable design will be informed by the CBRA and detailed within the CaP, required under Section 36 Consent and/or Marine Licence conditions.
MM-006	Environmental Management Plan (EMP)	Tertiary	The Environmental Management Plan (EMP) will set out procedures to ensure all activities with the potential to affect the environment are appropriately managed and will include a description of planned activities and procedures, roles and responsibilities, pollution control and spillage response plans, incident reporting, chemical usage requirements, waste management plans, plant service procedures, communication and reporting structures, and programme of work. It will detail the final design selected and take into account Marine Licence conditions and commitments. The EMP will additionally include an Invasive Non-Native Species (INNS) Management Plan (INNSMP) and a Marine Pollution Contingency Plan (MPCP) and will be developed in consultation with stakeholders.	The EMP, including the INNSMP and MPCP, will be required under Section 36 Consent and/or Marine Licence conditions. An outline EMP is provided as part of the Application EIAR Vol. 4 Appendix 32: Outline EMP.

CODE	MITIGATION MEASURE	TYPE	DESCRIPTION	SECURED BY
MM-007	CMS	Tertiary	A CMS will be developed to manage the construction process so as to avoid harm to construction personnel and third parties. The CMS will specify the Project's construction methods, setting out good practice construction measures and how agreed mitigation measures from the EIAR, associated documents, Section 36 Consent, Marine Licences and those stated within the EMP are implemented during construction.	The CMS will be required under Section 36 and/or Marine Licence conditions.
MM-008	CaP	Tertiary	The CaP will be provided post-consent and will detail the location/route and cable laying techniques of the IACs and Export/Import Cable and detail the methods for cable surveys during the operational life of the cables for the Project. This will be supported by survey results from the geotechnical, geophysical and benthic surveys. The CaP will also detail EMF of the cables deployed and methods to mitigate against any effects of EMF. A CBRA will also be undertaken and results included within the CaP which will detail cable specifications, cable installation, cable protection, target burial depths/DoL and any hazards the cable will present during the lifespan of the cable. The CaP will also include methodologies of post construction and operational surveys and methodologies for cable inspection with measures to address and report any exposure of cables.	Final cable design will be informed by the CBRA and detailed within the CaP, required under Section 36 Consent and/or Marine Licence conditions.

8.5.5 Worst-case scenario

As detailed in EIAR Vol. 2, Chapter 7: EIA Methodology, this assessment considers the worst-case scenario for the Project parameters which are predicted to result in the greatest environmental impact, known as the 'realistic worst-case scenario'. The worst-case scenario represents, for any given receptor and potential impact on that receptor, the scenario that would result in the greatest potential for change.

Given that the worst-case scenario is based on the design option (or combination of options) that represents the greatest potential for change, confidence can be held that development of any alternative options within the design parameters will give rise to no worse effects than assessed in this impact assessment. Table 8-32 presents the worst-case scenario for potential impacts on Marine Geology, Oceanography, and Coastal Processes during construction, operation and maintenance and decommissioning.

Table 8-32 Worst-case scenario specific to Marine Geology, Oceanography, and Coastal Processes impact assessment

POTENTIAL IMPACT	WORST-CASE SCENARIO	JUSTIFICATION
Construction		
Potential changes to suspended sediment concentrations, bed levels and sediment type (pathway)	Pre-Lay Grapnel Runs (PLGR) • Coverage: entire length of seabed section of IACs (280 km) and Export/Import Cable (230 km); • Maximum width of seabed disturbed during PLGR: 10 m; and • Width of grapnel: 1 m and depth of disturbance: typically 0.5 m. Boulder clearance • Clearance using plough along IACs and Export/Import Cable (maximum width of disturbance to the seabed: 20 m with any disturbance from PLGR within this corridor); • Maximum boulder clearance area along IACs: 5.6 km^2 (assumes up to 100% of IACs length will require clearance i.e. 20 m x 280 km); and • Maximum boulder clearance area along Export/Import Cable: 1.2 km^2. IACs installation • Maximum total length of cable trenches: 280 km; • Maximum trench dimensions: 2 m wide (at seabed); 1.8 m deep; • Installation via jet trenching, mechanical trenching and/or ploughing; Export/Import Cable installation • Bundle of two High Voltage Direct Current (HVDC) cables and one fibre-optic cable in a single trench with a total route length of 230 km; • Maximum trench dimensions: 2 m wide (at seabed); 1.8 m deep [except within 12 NM where 3 m wide trench for sections of pre-lay trenching via a plough]; • Installation via jet trenching, mechanical trenching and/or ploughing; and	Cable installation may require some combination of (e.g.) jetting, mechanical trenching and/or ploughing techniques. Of these, jetting type tools will most energetically disturb the greatest volume of sediment in the trench profile and as such is considered to be the maximum adverse scenario for sediment dispersion. PLGR and boulder clearance are expected to (locally) displace less sediment than cable installation. However, a wider area of seabed could potentially be impacted.

POTENTIAL IMPACT	WORST-CASE SCENARIO	JUSTIFICATION
	• 100% cable burial within East of Gannet and Montrose Fields NCMPA (except at cable/pipeline crossings). HDD / Drilling fluid release (at landfall) • Number of release events: 3; • Total HDD drilled length: 409 m; • Maximum volume of drilling fluid in one borehole: 1,000 m^3 of fluid, with 6 m^3 of total solids (most likely bentonite). The maximum total release of fluid for all three HDDs is 3,000 m^3, with 18 m^3 of solid losses); • Representative maximum concentration of bentonite in drilling fluid: ~80,000 mg/l; • Exit point below MLWS in a water depth of approximately 26.5 m below MHWS.	
Potential modifications to sediment transport pathways (pathway)	The realistic worst-case for blockage/ scour associated with partially installed cable protection, FTUs and / or the presence of anchoring structures cannot readily be defined. However, it will be no greater than that set out for the fully built and operational project. Refer to the operation and maintenance Section of this table (below).	N/A
Potential impacts to designated seabed interest features within protected sites (receptor)	PLGR • Coverage: entire length of seabed section of IACs and Export/Import Cable within the bounds of the NCMPAs; • Maximum width of seabed disturbed during PLGR: 10 m; • Width of grapnel: 1 m and depth of disturbance: typically 0.5 m. Boulder clearance • Clearance using plough along IACs and Export/Import Cable (maximum width of disturbance to the seabed: 20 m) within the bounds of the NCMPAs;	Corresponds to (a combination of) the greatest amount of material disturbed and the greatest area of impact from installed infrastructure across each NCMPA.

POTENTIAL IMPACT	WORST-CASE SCENARIO	JUSTIFICATION
	• Maximum boulder clearance area along IAC: 5.6 km^2 (assumes up to 100% of IACs static seabed length will require clearance i.e. 20 m x 280 km); • Maximum boulder clearance area along EICC within East of Gannet and Montrose Fields NCMPA: 0.07 km^2 (assumes up to 10% of EICC within NCMPA will require clearance i.e. 20 m x 35 km x 10%), with any disturbance from PLGR within this corridor. Pre-lay mooring lines • Temporary footprint of pre-lay mooring lines on the seabed: 376,200 m^2 (95 FTU x 3,960 m of mooring line per FTU x 1 m disturbance width) FTU mooring system and anchors (maximum combined footprint) • Type: suction pile; • For semi-submersible, a total of six anchors per FTU, with a maximum seabed footprint of 198 m^2 per FTU or 15,840 m^2 for Array Area; • For TLP, a total of three clusters of piles, up to nine piles, with a maximum seabed footprint of 297 m^2 per floating substructure or 28,215 m^2 for Array Area. IACs installation • IACs seabed length: 280 km; • Maximum cable trench dimensions: 2 m wide (at seabed), 1.8 m deep; • Maximum width of seabed disturbance from cable installation tool: 20 m; • Installation via jet trenching, mechanical trenching and/or ploughing; • Footprint of temporary mattresses: 54,000 m^2 (18 m^2 per mattress x 60 mattresses per cable x 50 cables); • Max duration of temporary mattresses: 2 years; • Maximum total footprint area of concrete mattress cable protection for IACs touchdown location (190 dynamic IACs sections; per FTU, protection area for each touchdown locations is 90 m^2, total =17,100 m^2).	

POTENTIAL IMPACT	WORST-CASE SCENARIO	JUSTIFICATION
	IACs anchors • Maximum number of gravity anchors for all cables: 190 (i.e. 95 FTU x 2 gravity anchors per structure); • Maximum seabed footprint: 2,280 m^2 (i.e. 12 m^2 per anchor x 190). Subsea hubs • Maximum number: 19; • Maximum seabed footprint: 1,710 m^2 (90 m^2 per hub x 19). OSCPs foundations • Foundation type: Jacket; • Number of foundations: 2 (HVDC and HVAC); • Number of legs: 6 at surface (4 at mudline); • Leg pile diameter: 3.05 m; • Total OSCPs seabed footprint (which is defined by footprint of mud mats, inclusive of footprint of piles): 2,418 m^2 (1,209 m^2 per OSCP). OSCPs • Use of Jack-Up Vessels (JUVs) in commissioning. IACs cable protection at base of OSCPs: • Maximum dimensions of rock protection at OSCPs: 7 m base width x 1 m height above seabed; • Maximum length of rock protection at OSCPs: 2.2 km (100 m for up to 22 cables); • Total rock protection footprint: 15,400 m^2 (2.2 km x 7 m width). Cable/pipeline crossings (Array Area and Export/Import Cable): • Maximum number of cable/pipeline crossings for the Array Area: 8; • Crossing protection: rock berm; • Maximum crossing dimensions: 500 m length x 2.25 m height per crossing x (up to) 15.2 m width	

POTENTIAL IMPACT	WORST-CASE SCENARIO	JUSTIFICATION
	- Maximum volume of (rock) protection material for the Array Area: 3,056 m^3 per crossing, total for Array Area 24,448 m^3. • Maximum number of cable/pipeline crossings for the EICC: 20 - Crossing protection: rock berm; - Maximum crossing dimensions: 520 m length x 3.5 m height per crossing x (up to) 24 m width (reducing to 17 m over the first 50 m rock berm); - Maximum volume of (rock) protection material for the Export/Import Cable: 252,377 m^3.	
Potential changes to coastal /inshore seabed morphology (receptor)	HDD / Drilling fluid release (at landfall) • Number of boreholes: 3; • Exit point below MLWS in a water depth of approximately 26.5 m below MHWS; • Temporary use of concrete mattressing during construction to protect HDD marine exit point (up to 10 no. mattresses of approximately 5x10m); • Permanent use of rock protection at each marine exit point for 35 year lifetime of the Project. Dimensions for each exit (3 no.): 20 m width x 10 m length x 1.5 m height.	Sets out construction activities that give rise to the greatest (direct) disturbance to the inshore seabed and provide the greatest potential to interact with coastal processes responsible for maintaining the baseline form and function of the coast.
Operation and maintenance		
Potential changes to suspended sediment concentrations, bed levels and sediment type (pathway)	• Potential number of IACs repairs during operational lifetime of Project: 19 (equivalent to 10% of all cables); • Potential number of IACs replacements during operational lifetime of Project: 19 (equivalent to 10% of all cables); • Potential number of Export/Import Cable repairs during operational lifetime of Project: 4.	The worst-case scenario for sediment disturbance will be no greater than that set out for the construction phase of the proposed Project. Refer to the construction Section of this table (above).

POTENTIAL IMPACT	WORST-CASE SCENARIO	JUSTIFICATION
Potential changes to wave and tidal regime (pathway)	*Worst-case for Wave Blockage* FTU substructure • Type: semi-submersible; • Maximum number of units: 95 (15 MW FTUs); • Maximum length of sides: 112 m; and • Maximum draught (during operation): 20 m. OSCPs • Foundation type: Jacket; • Number of foundations: 2; • Foundation width at surface: 50 m; • Number of legs: 6 at surface (4 at mudline); • Diameter of jacket leg: 4 m. *Worst-case for Hydrodynamic Blockage* FTU substructure • Type: TLP; • Maximum number of units: 80 (18 MW FTUs); • Maximum side length: 93 m; • Maximum draught (during operation): 30 m. OSCPs • Foundation type: Jacket; • Number of foundations: 2 (HVDC and HVAC); • Foundation width at surface: 50 m; • Number of legs: 6 at surface (4 at mudline); • Diameter of jacket leg: 4 m. Mooring system and IACs	The worst-case for wave blockage is represented by the floating substructure presenting the greatest blockage in the upper water column (i.e. at/ close to the sea surface). It is conservatively assumed here that this is represented by semi-submersible substructures since they have the greatest side length of all substructure options within the design envelope. In practice, blockage is unlikely to occur across the full 112 m side length of the substructure as it is made up of columns and braces with space in between each. Greatest blockage in the upper water column was established to be associated with 95 x 15 MW FTUs with semi-submersible substructure. The worst-case for hydrodynamic blockage is represented by the combination of substructure type, mooring configuration, anchor system and electrical cabling which is associated with the largest combined overall blockage within the water column. Greatest combined blockage was established to be associated with 80 x 18 MW FTUs with TLP substructure.

POTENTIAL IMPACT	WORST-CASE SCENARIO	JUSTIFICATION

	• Maximum number of moorings and IACs present in the water column: 720 (i.e. 80 FTUs x 9 tendons per floating substructure); 160 dynamic IACs (i.e. 80 FTUs x 2 per FTU);
	• Maximum mooring line diameter: 300 mm (synthetic rope);
	• Maximum dynamic IACs diameter: 300 mm.
	Anchors
	• Type: suction pile (three clusters of piles);
	• Maximum diameter: 6.5 m (up to 3 m height above the bed);
	• Maximum number: 720 (80 FTUs x 9 suction piles per FTU).
	Subsea hubs
	• Maximum number: 19;
	• Maximum dimensions: 15 m length x 6 m wide x 4 m height.
	Cable protection (Array Area and Export/Import Cable)
	• Maximum dimensions of IACs rock protection at OSCPs: 7 m base width x 1 m height above seabed x 22 cables each of 0.1 km length rock protection;
	• Maximum dimensions of Export/Import Cable rock protection: 11 m base width x 1.75 m height above seabed;
	• Maximum length of Export/Import Cable rock protection: up to 8.35 km (out with 12 NM limit); up to 18 km of cable will require rock placement backfill (within 12 NM limit).
	Cable/pipeline crossings (Array Area and Export/Import Cable):
	• Maximum number of cable/pipeline crossings for the Array Area: 8;
	  - Crossing protection: rock berm;
	  - Maximum dimensions: 500 m x 2.25 m height x (up to) 15.2 m width.
	  - Array Area maximum volume of (rock) protection material: 24,448 m^3.
	• Maximum number of cable/pipeline crossings for the Export/Import Cable: 20
	  - Crossing protection: rock berm;	

POTENTIAL IMPACT	WORST-CASE SCENARIO	JUSTIFICATION
	- Maximum crossing dimensions: 520 m x 3.5 m height x (up to) 24 m width (reducing to 17 m over the first 50 m rock berm); - Maximum volume of (rock) protection material: 252,377 m^3.	
Potential modifications to sediment transport pathways (pathway)	See worst-case scenario definitions for potential changes to the wave and tidal regime during the operational phase – above.	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.)
Modifications to stratification and frontal features (pathway)	See worst-case scenario definitions for potential changes to the tidal regime during the operational phase – above.	The worst-case for impacts to stratification and frontal systems is associated with the largest hydrodynamic blockage. This is represented by the combination of floating substructure type, mooring configuration, anchor system and electrical cabling which is associated with the largest combined overall blockage within the water column.
Potential impacts to designated seabed interest features within protected sites (receptor)	East of Gannet and Montrose Fields NCMPA FTU mooring system and anchors (maximum combined footprint) • Substructure Type: Semi-submersible; • Anchor Type: suction pile; • Maximum number of piles: 570 (95 FTUs x 6 suction piles per FTU); • Maximum seabed footprint of piles: 13,680 m^2 (144 m^2 footprint per FTU x 95 FTU);	Maximum potential for seabed disturbance either directly - through sweeping of mooring lines across seabed, or indirectly - through modification of sediment transport pathways. (See above for definition of worst-case scenario for potential modifications to sediment transport pathways).

POTENTIAL IMPACT	WORST-CASE SCENARIO	JUSTIFICATION

	• Maximum area disturbed by chain: 1.44 km^2 (0.43% of Array Area (i.e. swept area of 2,531 m^2 per chain x 6 mooring legs = 15,188 m^2 per FTU; 95 FTU in total);
	• Total combined footprint (mooring swept area and anchors combined): 1,46 km^2.
	IACs anchors
	• Maximum number of gravity anchors for all cables: 190 (i.e. 95 FTUs x 2 per structure);
	• Maximum seabed footprint: 2,280 m^2 (i.e. 12m^2 per anchor x 190).
	Subsea hubs:
	• Maximum number: 19;
	• Maximum seabed footprint: 1,710 m^2 (90 m^2 per hub x 19).
	OSCPs foundations:
	• Foundation type: Jacket;
	• Number of jacket foundations: 2 (HVDC and HVAC);
	• Number of legs: 6 at surface (4 at mudline);
	• Number of piles per leg (corner legs only): 3 piles per corner (12 piles total per jacket);
	• Pile diameter: 3.05 m;
	• Maximum seabed footprint of mud-mats (inclusive of pile seabed footprint): 1,209 m^2 per jacket (2,418 m^2 total).
	IACs cable protection at OSCPs:
	• Maximum dimensions of rock protection: 7 m base width x 1 m height above seabed;
	• Maximum length of rock protection at OSCPs: 2.2 km (100 m for up to 22 cables);
	• Total rock protection footprint: 15,400 m^2 (2.2 km x 7 m width).
	Cable/pipeline crossings (Array Area and Export/Import Cable):
	• Maximum number of cable/pipeline crossings for the Array Area: 8;
	  - Crossing protection: rock berm;
	  - Maximum crossing dimensions: 500 m x 2.25 m height x (up to) 15.2 m width;
	  - Maximum volume of (rock) protection material: 24,448 m^3.
		Established to be associated with semi-submersible substructure.
		
		The worst-case for potential impacts to designated seabed interest features within protected sites is the maximum quantity of FTUs with semi-submersible floating substructures, semi-taut mooring lines and suction piles.

POTENTIAL IMPACT	WORST-CASE SCENARIO	JUSTIFICATION
	• Maximum number of cable/pipeline crossings for the Export/Import Cable: 20 - Crossing protection: rock berm; - Maximum crossing dimensions: 520 m x 3.5 m height x (up to) 24 m width (reducing to 17 m over the first 50 m rock berm). - Maximum volume of (rock) protection material: 252,377 m^3. Southern Trench NCMPA • Maximum total length of Export/Import Cable trench within NCMPA: 19.2 km; and • Four cable/pipeline crossings within NCMPA	
Potential changes to coastal /inshore seabed morphology (receptor)	HDD marine exit point: • Number of boreholes: 3; • Rock protection dimensions at exit point: 20 m width x 10 m length x 1.5 m height; • Duration: 35 years (proposed Project lifespan). Cable protection (inshore areas): • Protection type: rock berm (for cable/pipeline crossings) and rock placement in (pre-ploughed) trench to the seabed level. • Cable/pipeline crossing dimensions: up to 7 no. measuring 520 m long x 24 m wide (reducing to 17 m over the first 50 m rock berm) x 3.5 m high.	Maximum permanent change of coastal morphology resulting from blockage of waves
Decommissioning		
In the absence of detailed decommissioning activities, the implications for marine geology, oceanography and coastal processes are similar, or likely less, to the worst-case scenarios for those outlined during the construction phase. Therefore, the worst-case parameters defined for the construction phase also apply to the decommissioning phase. More details are available on the decommissioning approach in EIAR Vol. 2, Chapter 5: Project Description.		

8.6 Assessment of potential effects

8.6.1 Potential effects during construction

8.6.1.1 Potential changes to suspended sediment concentrations, bed levels and sediment type (pathway)

8.6.1.1.1 Overview

During construction of the Project, 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 main activities resulting in disturbance of seabed sediments are:

- Seabed preparation by PLGR prior to cable burial;
- Seabed preparation by boulder clearance prior to cable burial;
- Cable burial by ploughing, trenching and jetting (including initial installation and any subsequent cable repairs and/or remediation in the operation and maintenance phase); and
- Release of drilling fluid during HDD punch out at the landfall.

The Project has committed to a number of measures to limit the extent of sediment disturbance and therefore potential effects on designated features. These measures are set out in Table 8-31 and include:

- The use of piling (rather than drilling) of FTU pile anchors;
- Micro-siting of cables to avoid the requirement for sandwave pre-sweeping (either by dredging or mass flow excavator); and
- Use of HDD as the landfall cable installation option (this option may be associated with the release of drilling fluid which is considered in the list of activities above).

Details of the Worst Case Scenario (WCS) for sediment disturbance events are set out in Table 8-32. The potential changes to SSC and associated sediment deposition caused by these activities have been assessed using numerical spreadsheet models. The full details and results of each assessment are set out in EIAR Vol. 4, Appendix 7: Marine & Physical Processes Modelling Report.

The sediment release events considered in this assessment have been designed to capture the full range of WCS scenario outcomes in terms of:

- Maximum plume concentrations;
- Maximum plume (spatial) extent;
- Maximum vertical change in bed level; and
- Maximum spatial extent of change in bed level.

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;
- Whether the sediment disturbance occurs at a fixed location or moves over time);
- The oceanographic conditions prevailing at point of release, as well as local bathymetry and morphology.

8.6.1.1.2 Determination of sensitivity

All of the identified Marine Geology, Oceanography and Coastal Processes receptors are insensitive to elevated levels of SSC and have therefore not been assigned a sensitivity rating.

8.6.1.1.3 Determination of magnitude

Marine Geology, Oceanography and Coastal Processes receptors are insensitive to elevated levels of SSC and as such, it is not appropriate to carry out an assessment of significance which considers the magnitude of effect to a receptor and the sensitivity of that receptor. Instead, this section focuses on describing the spatial and temporal characteristics of potential sediment plumes, which are a 'pathway' connecting an impact source (i.e. construction activities) with potential receptors (such as designated benthic habitats, water quality, fish and shellfish ecology and archaeology).

Where sediment is disturbed, the sediment plume which is generated increases SSC within the water column. The initial local increase in SSC is directly proportional to the mass of sediment disturbed or released, and the volume of water it is initially dispersed into. The evolution of SSC over time is then dependent on the rate of dilution and dispersion of the sediment that remains in suspension, and the rate at which sediment settles out of suspension. The sediment plume may be also advected at the speed and in the direction of any ambient tidal currents, which tends to limit the duration of time that changes to SSC are experienced at any one location. The thickness of sediment that may be redeposited locally is dependent on the area over which the (limited) total volume of sediment is deposited. A smaller area will correspond to a greater thickness and vice versa; however, the maximum area of effect for a given thickness of deposit is fundamentally limited by the volume of sediment released or disturbed.

This wider range of results can be summarised broadly in terms of four main zones of effect, based on the distance from the activity causing sediment disturbance. These zones are consistent with the results of observational (monitoring) evidence and recent numerical modelling of analogous activities (e.g. BERR, 2008; RWE, 2022):

- 0 to 50 m – zone of highest SSC increase and greatest likely thickness of deposition. All gravel sized sediment likely deposited in this zone, and a large proportion of any coarser sand grains that are not resuspended high into the water column. Plume dimensions and SSC, and deposit extent and thickness, are primarily controlled by the volume of sediment released and the manner in which the deposit settles.
  - at the time of active disturbance - very high SSC increase (tens to hundreds of thousands of mg/l) lasting for the duration of active disturbance plus up to 30 minutes following end of disturbance; where dominant (e.g. areas of outcropping glacial material), coarse sands and gravels, or larger clasts of still consolidated cohesive silts, may deposit in local thicknesses of tens of centimetres to several metres; unconsolidated finer sediment (i.e. muddy fine sands) is unlikely to deposit in measurable thickness.
  - more than one hour after the end of active disturbance – no remaining change to SSC; no measurable ongoing deposition.
- 50 to 500 m – zone of measurable SSC increase and measurable but lesser thickness of deposition. Mainly sands that are released or resuspended higher in the water column and resettling to the seabed whilst being advected

by ambient tidal currents. Plume dimensions and SSC, and deposit extent and thickness, are primarily controlled by the volume of sediment released, the height of resuspension or release above the seabed, and the ambient current speed and direction at the time.
  - at the time of active disturbance - high SSC increase (hundreds to low thousands of mg/l) lasting for the duration of active disturbance plus up to 30 minutes following end of disturbance; sands and gravels may deposit in local thicknesses of up to tens of centimetres; fine sediment is unlikely to deposit in measurable thickness.
  - more than one hour after end of active disturbance – no change to SSC; no measurable ongoing deposition.
- 500 m to the tidal excursion[4] buffer distance – zone of lesser but measurable SSC increase and no measurable thickness of deposition. Mainly fines that are maintained in suspension for more than one tidal cycle and are advected by ambient tidal currents. Plume dimensions and SSC are primarily controlled by the volume of sediment released, the patterns of current speed and direction at the place and time of release and where the plume moves to over the following 24 hours.
  - at the time of active disturbance – low to intermediate SSC increase (tens to low hundreds of mg/l) as a result of any remaining fines in suspension, only within a narrow plume (tens to a few hundreds of metres wide, SSC decreasing rapidly by dispersion to ambient values within one day after the end of active disturbance; fine sediment is unlikely to deposit in measurable thickness.
  - one to six hours after end of active disturbance – decreasing to low SSC increase (tens of mg/l); fine sediment is unlikely to deposit in measurable thickness.
  - six to 24 hours after end of active disturbance – decreasing gradually through dispersion to background SSC (no measurable local increase); fine sediment is unlikely to deposit in measurable thickness. No measurable change from baseline SSC after 24 to 48 hours following cessation of activities.
- Beyond the tidal excursion buffer distance or anywhere not tidally aligned to the active sediment disturbance activity – there is no expected measurable effect or change to SSC nor any measurable sediment deposition.

Figure 8-26 provides a summary of the maximum spatial extent of these zones in relation to the whole of the Array Area and EICC, and in relation to selected receptors in the surrounding area. In practice the WCS impact will be a limited number of discrete areas of effect (associated with the locations of individual activities causing sediment disturbance), separated by areas of lesser impact.

Further details are provided below for East of Gannet and Montrose Fields NCMPA and Southern Trench NCMPA.

East of Gannet and Montrose Fields NCMPA

Within the extent of the NCMPA, 280 km of IACs and 35 km of Export/Import Cable will be installed, potentially requiring PLGR, boulder clearance and cable burial.

The footprint of *direct* physical disturbance effect is quantified within Section 8.6.1.3.

The absolute and relative spatial footprint of *indirect* effects due to sediment disturbance (deposition) can be estimated as follows:

[4] The approximate distance over which water (or a section of plume with elevated SSC) is advected during one flood or ebb tide. It varies in proportion to the peak current speed on a given tide

- The total footprint of the East of Gannet and Montrose Fields NCMPA is 1,839,000,000 m2;
- The total footprint of the Array Area is 332,709,534 m2 (333 km2);
  - PLGR (WCS details in Table 8-32)
    - Total distance of PLGR in NCMPA = (280,000 m + 35,000 m) x 10 runs = 3,150,000 m
    - Volume of sediment disturbed per metre progress = 0.15 m^3/m
    - Total volume of sediment disturbed in NCMPA = 3,150,000 m x 0.15 m^3/m = 472,500 m^3
    - Maximum area that can be subject to 0.05 m thick deposition in NCMPA = 472,500 m^3 / 0.05 m = 9,450,000 m^2
    - Maximum area as a proportion of the East of Gannet and Montrose Fields NCMPA = 9,450,000 m^2 / 1,839,000,000 m^2 = 0.514%
    - Maximum area as a proportion of the Array Area = 9,450,000 m^2 / 332,709,534 m^2 = 2.840%
  - Pre-lay Boulder Clearance (WCS details in Table 8-32)
    - Total distance of boulder clearance by plough in NCMPA = (280,000 m + 35,000 m) x 1 run = 315,000 m
    - Volume of sediment disturbed per metre progress = 2.6 m^3/m
    - Total volume of sediment disturbed in NCMPA = 315,000 m x 2.6 m^3/m = 819,000 m^3
    - Maximum area that can be subject to 0.05 m thick deposition in NCMPA = 819,000 m^3 / 0.05 m = 16,380,000 m^2
    - Maximum area as a proportion of the East of Gannet and Montrose Fields NCMPA = 16,380,000 m^2 / 1,839,000,000 m^2 = 0.891%
    - Maximum area as a proportion of the Array Area = 16,380,000 m^2 / 332,709,534 m^2 = 4.923%.
  - IACs and Export/Import Cable burial (WCS details in Table 8-32)
    - Total distance of IACs and Export/Import Cable burial in NCMPA = (280,000 m + 35,000 m) x 1 run = 315,000 m
    - Volume of sediment disturbed per metre progress = 3.6 m^3/m
    - Total volume of sediment disturbed in NCMPA = 315,000 m x 3.6 m^3/m = 1,134,000 m^3
    - Maximum area that can be subject to 0.05 m thick deposition in NCMPA = 1,134,000 m^3 / 0.05 m = 22,680,000 m^2
    - Maximum area as a proportion of the East of Gannet and Montrose Fields NCMPA = 22,680,000 m^2 / 1,839,000,000 m^2 = 1.233%
    - Maximum area as a proportion of the Array Area = 22,680,000 m^2 / 332,709,534 m^2 = 6.817%.

The mobility potential of surficial sediments within the Array Area is very low, due to the weak tidal currents and infrequent wave action at the seabed due to the water depth. This means that the seabed has limited ability to recover to its 'natural' state following site preparation activities and/or cable laying, with natural recovery of surface scars etc potentially taking many years/ decades. However, it is important to note that the activities described will locally disturb or displace, rather than remove sediment and the physical disturbance action itself will only be temporary. The significance of this for the designated biodiversity interests within the East of Gannet and Montrose Fields NCMPA (in particular ocean quahog (*Arctica islandica*) is considered separately, within EIAR Vol. 3, Chapter 10: Benthic Ecology.

Southern Trench NCMPA

The EICC passes through the Southern Trench NCMPA. Within the extent of the NCMPA, 19.2 km of Export/Import Cable will be installed, potentially requiring PLGR, boulder clearance and cable burial.

The footprint of *direct* physical disturbance effect is quantified within Section 8.6.1.3.

The absolute and relative spatial footprint of indirect effects due to sediment disturbance (deposition) can be estimated as follows:

- The total footprint of the Southern Trench NCMPA is 2,398,000,000 m2;
  - PLGR (WCS details in Table 8-32)
    - Total distance of PLGR in NCMPA = (19,200 m) x 10 runs = 192,000 m
    - Volume of sediment disturbed per metre progress = 0.15 m^3/m
    - Total volume of sediment disturbed in NCMPA = 192,000 m x 0.15 m^3/m = 28,800 m^3
    - Maximum area that can be subject to 0.05 m thick deposition in NCMPA = 28,800 m^3 / 0.05 m = 576,000 m^2
    - Maximum area as a proportion of the Southern Trench NCMPA = 576,000 m^2 / 2,398,000,000 m^2 = 0.024%
  - Pre-lay boulder clearance (WCS details in Table 8-32)
    - Total distance of boulder clearance by plough in NCMPA = (19,200 m) x 1 run = 19,200 m
    - Volume of sediment disturbed per metre progress = 2.6 m^3/m
    - Total volume of sediment disturbed in NCMPA = 19,200 m x 2.6 m^3/m = 49,920 m^3
    - Maximum area that can be subject to 0.05 m thick deposition in NCMPA = 49,920 m^3 / 0.05 m = 998,400 m^2
    - Maximum area as a proportion of the Southern Trench NCMPA = 998,400 m^2 / 2,398,000,000 m^2 = 0.042%
  - Export/Import Cable burial (WCS details in Table 8-32)
    - Total distance of cable burial in NCMPA = (19,200 m) x 1 run = 19,200 m
    - Volume of sediment disturbed per metre progress = 3.6 m^3/m
    - Total volume of sediment disturbed in NCMPA = 19,200 m x 3.6 m^3/m = 69,120 m^3
    - Maximum area that can be subject to 0.05 m thick deposition in NCMPA = 69,120 m^3 / 0.05 m = 1,382,400 m^2
    - Maximum area as a proportion of the Southern Trench NCMPA = 1,382,400 m^2 / 2,398,000,000 m^2 = 0.06%

Evaluation of significance

All the identified Marine Geology, Oceanography and Coastal Processes receptors are insensitive to elevated levels of SSC. However, the potential for these changes to impact other receptor groups is considered elsewhere within the EIAR, in particular:

- EIAR Vol. 3, Chapter 9: Marine Water and Sediment Quality;
- EIAR Vol. 3, Chapter 10: Benthic Ecology; and
- EIAR Vol. 3, Chapter 13: Fish and Shellfish Ecology.

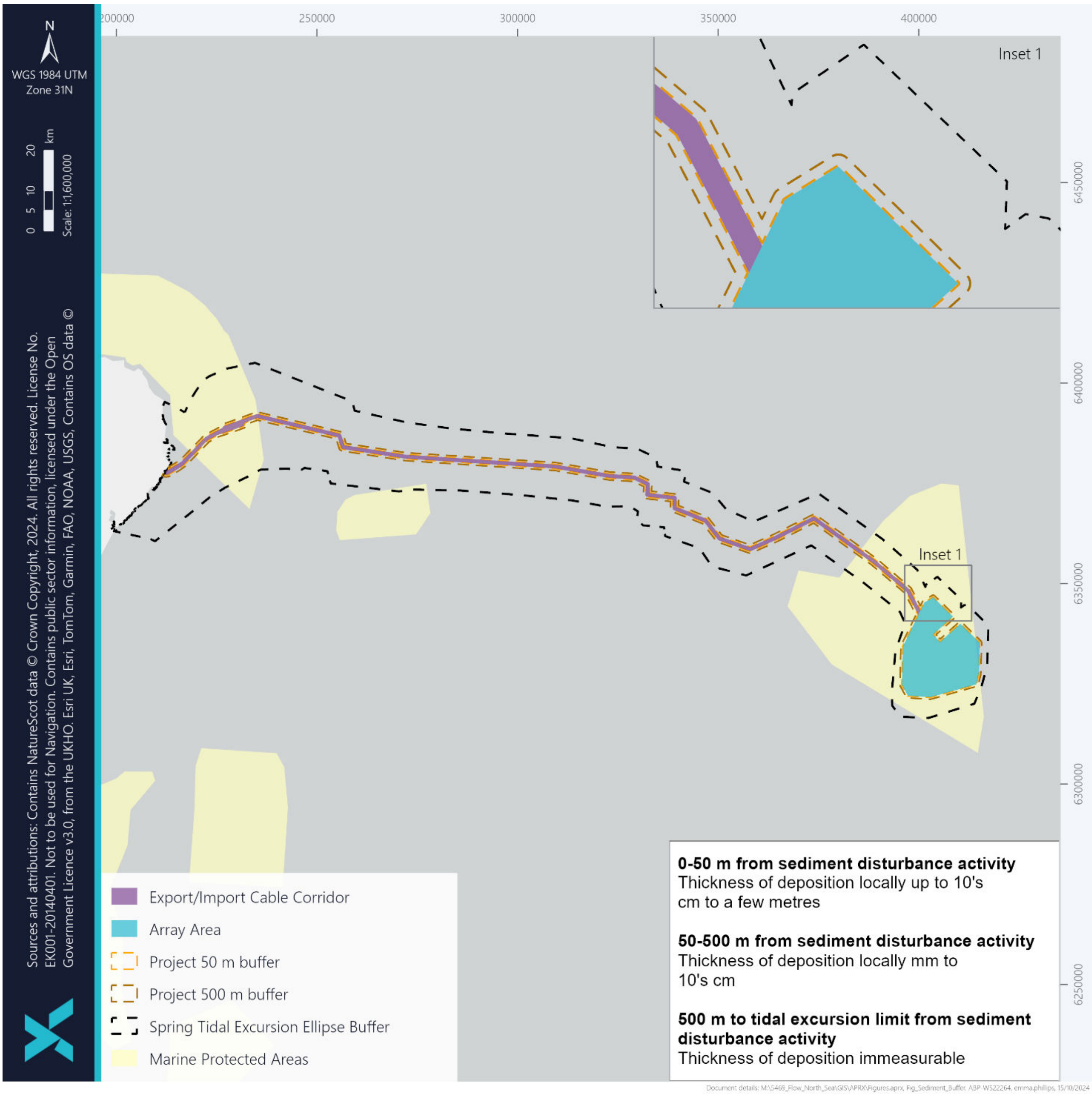


Figure 8-26 Spring tidal excursion buffer, 50 m and 500m Project buffers outside of the EICC and Array Area

8.6.1.2 Potential modifications to sediment transport pathways (pathway)

8.6.1.2.1 Overview

The installation of Export/Import Cable protection, FTUs, OSCPs and/or the presence of anchoring structures all have the potential to result in a localised blockage of waves, tides and sediment transport. This blockage will commence when construction begins, increasing incrementally up to the WCS, which is represented by the fully operational Project.

All changes to sediment transport systems due to modification of the wave and current climate will be no greater than that identified for the operational phase (see Section 8.6.2.3) and, therefore, is not considered further here.

8.6.1.3 Potential impacts to designated seabed interest features within protected sites (receptor)

8.6.1.3.1 Overview

The Array Area is located almost entirely within the East of Gannet and Montrose Fields NCMPA which is designated for its biodiversity interests. The NCMPA is dominated by sands and gravels (which are the preferred habitat of the ocean quahog (*Arctica islandica*)) and offshore deep-sea mud (which contain many types of worm and mollusc that are an important food source for fish). The EICC passes through the Southern Trench NCMPA and cable installation will be undertaken inside the boundary of the NCMPA. The geodiversity features of interest within the Southern Trench NCMPA are relict (subglacial tunnel valleys, moraines and scars evidencing mass movement).

The installation of Project infrastructure within the Array Area will lead to a direct loss/change of seabed habitat within the East of Gannet and Montrose Fields NCMPA. Site preparation activities and cable installation also have the potential to directly disturb sediments within the Array Area and EICC, potentially impacting both the East of Gannet and Montrose Fields NCMPA and Southern Trench NCMPA.

These *direct* effects are discussed within this Section, with the assessment based upon the Worst-case Scenario, set out in Table 8-32. Longer-term *indirect* effects to designated seabed interest features within protected sites arising from the presence of Project infrastructure (such as from scour around Project seabed structures and from any change to sediment transport processes) will be no greater than that identified for the operational phase and, therefore, is discussed in Sections 8.6.2.3 and not considered further here.

It is noted here that outputs from this assessment have been used to inform the MPA Assessment. The assessment considers the conservation objectives for each site and the extent to which the Project could impede these objectives being met. The conservation objectives for both the East of Gannet and Montrose Fields NCMPA and Southern Trench NCMPA are as follows:

- so far as already in favourable condition, remain in such condition; and
- so far as not already in favourable condition, be brought into such condition, and remain in such condition.

Favourable condition with respect to a feature of geomorphological interest (such as the geodiversity interests within the Southern Trench NCMPA) means that a) its extent, component elements and integrity are maintained; b) its structure and functioning are unimpeded; and c) its surface remains sufficiently unobscured for the purposes of determining whether the criteria in paragraphs (a) and (b) are satisfied. This assessment presented in this section gives consideration to these criteria.

8.6.1.3.2 Determination of sensitivity

The East of Gannet and Montrose Fields NCMPA is of national importance. As a result of the weak tidal currents (and wave induced orbital currents at the bed) sediment mobility within the site is low meaning the seabed has limited ability to recover from an effect. Accordingly, the site is assessed to be of high sensitivity.

The Southern Trench NCMPA is also of national importance. The geodiversity features of interest contained within it are relict with no ability to recover from and effect. Accordingly, the site is assessed to be of high sensitivity.

8.6.1.3.3 Determination of magnitude

Installation of Project infrastructure within the East of Gannet and Montrose Fields NCMPA

Project activities which could potentially cause direct impacts to the East of Gannet and Montrose Fields NCMPA are summarised in Table 8-33.

Table 8-33 Summary of Project activities potentially impacting the East of Gannet and Montrose Fields NCMPA

ACTIVITY/ INFRASTRUCTURE	IMPACT SOURCE	SEABED DISTURBANCE OR LOSS	DURATION OF ACTIVITY (SHORT OR LONG-TERM)*
Site preparation	PLGR	Disturbance	Short-term
	Boulder clearance	Disturbance	Short-term
Floating substructure moorings and anchors and OSCPs jackets	Presence of floating substructure, mooring lines, anchors, and OSCPs jackets	Loss	Long-term
	Pre-lay mooring lines on the seabed	Loss	Short-term
	Sweeping of seabed by floating substructure moorings	Disturbance	Long-term
	Indentations on the seabed from JUVs vessels commissioning OSCPs	Disturbance	Short-term
IACs and Export/Import Cable	Cable installation (ploughing, jetting, trenching)	Disturbance	Short-term
	Presence of IACs anchors and sub-sea hubs	Loss	Long-term
Cable protection	Presence of temporary mattresses on IACs	Loss	Short-term
	Presence of OSCPs cable rock protection	Loss	Long-term
	Presence of IACs mattressing at cable touchdown locations	Loss	Long-term
	Presence of cable/pipeline crossing rock protection	Loss	Long-term

* Short-term = up to the duration of the construction period (3 years); Long-term = lifetime of the Project

<u>Site preparation activities.</u> Prior to the installation of Project infrastructure, site preparation activities will be required. These include boulder clearance and PLGR to prepare the seabed for IACs and Export/Import Cable installation. The Project geophysical survey has found that boulders occur frequently within the Array Area, both in the seabed surficial sediment and throughout the Quaternary geological units (see Section 8.4.4.1.2 and Table 8-4) (Rovco, 2023b). These boulders will be cleared by plough or by grab with preference given to micro-siting to avoid boulders where possible (Table 8-31). The consequence for marine physical processes is a low level of direct mechanical disturbance of the

seabed for the duration of the operation and an increased density of boulders to the adjacent seabed. This could lead to a slight increase in bed roughness.

A PLGR operation will also be executed shortly prior to the installation of the IACs and Export/Import Cable to clear the seabed of surface debris. PLGR operations are normally carried out along the proposed cable route centre line to provide 100% coverage of the centre-line route, with the exception of in-service cable and pipeline exclusion zones. Additional passes will be completed in any area where anomalies and/or debris are expected or located. The WCS for these site preparation activities is defined in Table 8-32. In total an area of up to 6,300,000 m^2 within the East of Gannet and Montrose Fields NCMPA could be disturbed by these activities.

Floating substructure moorings and anchors and OSCPs jackets. The installation of floating substructure anchors as well as OCSPs jackets will all lead to a direct loss/change of seabed habitat within the East of Gannet and Montrose Fields NCMPA which will last for the lifetime of the Project (up to 35 years). In total, an area of up to 16,098 m^2 could experience a loss/change of habitat.

During the construction period, mooring lines for the FTUs may be temporarily stored on the seabed within the Array Area. This could lead to a temporary loss of seabed habitat of up to 376,200 m^2. Once installed, the mooring lines will periodically come in contact with the seabed in response to fluctuations in water level. It is anticipated that during the periods when the mooring lines may be touching down or lifting off the seabed, there is likely to be some seabed disturbance. In total, an area of up to 1.44 km^2 could be disturbed.

JUVs may be used to support OSCPs commissioning. The JUV spud cans have the potential to disturb seabed sediments and leave indentations on the seabed although the footprint of any impact will be encompassed within the total temporary Project footprint within the East of Gannet and Montrose Fields NCMPA boundary (Table 8-34).

As the jack-up leg is inserted, the seabed sediments would primarily be compressed downwards and then displaced laterally sideways. This may cause the seabed around the inserted leg to be raised in a series of concentric pressure ridges. The seabed response is dependent upon the actual dimensions of the leg and the local geotechnical properties of the soils. As the leg is subsequently retracted, the force which is holding the sediments laterally would be reduced. Some of the surficial material that has been previously pushed sideways may return to the hole via mass slumping under gravity. Any loose sediment would avalanche back into the depression until a maximum stable slope angle is achieved.

Owing to the potentially stiff or cohesive soils and very low rates of sediment transport in this region, it is probable that any depressions would take a long period of time (order of years to decades) to infill. However, across most of the Array Area consolidated Quaternary deposits are either exposed at the seabed or covered by a very thin veneer of surficial material (Figure 8-6); in these areas, it is possible that depression dimensions would be limited. It is also the case that the presence of a depression feature does not necessarily imply a difference in sedimentary environment in the area of the effect, but this would depend upon the nature and depth of the subsurface sediments, and the rate of infill.

IACs and Export/Import Cable. The installation of cables will result in direct mechanical disturbance of the seabed, via either jetting, trenching or ploughing. Jetting tools will have greater potential to energetically fluidise and eject material from the trench, with up to circa 50% of material released into suspension. However, the material displaced by jetting is expected to largely comprise finer grained sediments (fine sand and mud) which will enter into suspension, disperse in the water column and settle over a wide area, limiting the amount of deposition immediately adjacent to the trench (Section 8.6.1.1.3). Regardless of exactly which cable installation method is used, the total area of seabed which may be directly disturbed by IACs and Export/Import Cable laying activities within the East of Gannet and Montrose Fields NCMPA will be 6,300,000 m^2[5].

Weights will be attached to tie the dynamic IACs to the seabed, whilst the dynamic IACs from several floating substructures will be connected into subsea hubs. The maximum total footprint of the IACs anchors and sub-sea hubs will be 3,990 m^2.

<u>Cable protection.</u> Up to 3,000 concrete mattresses (60 mattresses per IAC for up to 50 IACs) with a total combined area of 54,000 m^2 may be required for IACs installation. These mattresses would be placed on the seabed for IACs pre-lay and installation works and then subsequently retrieved following hook-up. Mattresses may be left in-situ for up to two years but would be recovered. A further 17,100 m^2 of mattressing may be installed at IACs touch down points. This would remain in-situ for the lifetime of the Project.

As part of the embedded mitigation measures (Table 8-31), the Project is minimising the amount of hard (rock) cable protection installed within the Array Area. However, up to 2.2 km of hard cable protection may be required at the base of the OSCPs, with 100 m sections for each of (up to) 22 cables): the combined footprint of these is 15,400 m^2. A further 54,606 m^2 of rock protection may be required at IACs and Export/Import Cable crossings.

Based on all of the above, the maximum total area of seabed within the East of Gannet and Montrose Fields NCMPA which may experience direct (short or long-term) seabed loss or disturbance is 10,911,739 m^2. However, the overall impact footprint is small in relation to the area of the NCMPA as a whole. Indeed, the East of Gannet and Montrose Fields NCMPA has an area of 1,839 km^2 km (1,839,000,000 m^2) and therefore the maximum extent of direct (short or long-term) seabed loss or disturbance due to the Project is <1% of the area of the NCMPA.

As described in Section 8.4.4.7, seabed mobility within the Array Area is low due to the weak tidal currents and infrequent wave action at the seabed due to the water depth. This means that the seabed has limited ability to recover to its 'natural' state following site preparation activities and/or cable laying, with removal of surface scars etc potentially taking many years/decades (It is noted that the survey data gathered from the Array Area evidences considerable fishing trawl scour marks and also the effects of anchoring associated with oil and gas exploration and extraction). However, it is important to note that the activities described will disturb, rather than remove sediment and, with the exception of the disturbance associated with the movement of mooring chains, the physical disturbance itself will only be temporary. The significance of this for the designated biodiversity interests within the East of Gannet and Montrose Fields NCMPA (in particular ocean quahog, *Arctica islandica)* is considered separately, within EIAR Vol. 3, Chapter 10: Benthic Ecology.

On the basis of the discussion in this Section, the magnitude of effect to the East of Gannet and Montrose NCMPA is predicted to be low.

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[5] This area of disturbance is the same as the footprint of site preparation activities (i.e. no additional area is disturbed during IACs and Export / Import Cable lay).

Table 8-34 Metrics of seabed disturbance and loss for the East of Gannet and Montrose Fields NCMPA

METRIC	AREA (m^2) OR % COVERAGE	ACTIVITIES/ INFRASTRUCTURE INCLUDED
Maximum total area of direct short-term seabed loss (m^2)	430,200 m^2	IACs temporary mattresses Pre-lay mooring lines
Maximum total area of direct long-term seabed loss (m^2)	107,194 m^2	Presence of floating substructure anchors, OSCPs jackets and subsea hubs Presence of IACs anchors Presence of OSCPs cable rock protection Presence of IACs mattressing at touchdown points Presence of cable/pipeline crossing rock protection
Maximum total area of direct short-term seabed disturbance (m^2)	9,450,000 m^2	Cable installation (ploughing) PLGR (boulder clearance excluded as will occur within the footprint of the cable plough)
Maximum total area of direct long-term seabed disturbance (m^2)	1,442,860 m^2	Sweeping of bed by FTU moorings
Maximum total area of direct (short or long-term) seabed loss or disturbance (m^2)	11,289,148 m^2	(Maximum total area of direct short-term seabed loss (associated with IACs temporary mattresses) excluded as will occur within the footprint of the cable plough. Likewise, OSCPs cable rock protection, IACs mattressing at touchdown points and cable/pipeline crossing rock protection also excluded for the same reason.)
Maximum total area of direct seabed loss or disturbance (% Array Area footprint)	3.39%	(As above)
Maximum total area of direct seabed loss or disturbance (% NCMPA footprint)	1.23%	(As above)

Installation of Export/Import Cable within the Southern Trench NCMPA

A total of 19.2 km of the EICC is situated within the Southern Trench NCMPA (Figure 8-24). Cables within this Section of the route may either be buried into surficial sediments or more consolidated Quaternary material.

Site preparation activities. Prior to Export/Import Cable installation, boulder clearance and PLGR will be required to prepare the seabed. A maximum seabed area of 384,000 m^2 may be (directly) disturbed by these activities within the Southern Trench NCMPA.

Export/Import Cable installation. Cable installation will be achieved via either jetting, trenching or ploughing. Installation of the Export/Import Cable itself may directly disturb up to 384,000 m^2 of seabed within the Southern Trench NCMPA (noting that the Export/Import Cable will be laid into the same areas previously disturbed by the site preparation activities).

Cable protection[6]. There may be a total of four cable/pipeline crossings within the Southern Trench NCMPA. Each cable/pipeline crossing could have a footprint of (up to) 9,063 m^2 – 36,252 m^2 in total.

Based on the above, the maximum total area of seabed within the Southern Trench NCMPA which may experience direct (short or long-term) seabed loss or disturbance is 576,000 m^2. It is important to note however, that only a small proportion of this area is expected to overlap with interest features for which the Southern Trench NCMPA is designated. This is discussed further below.

The Export/Import Cable may be installed into Quaternary units (rather than surficial sediments) and these units could be associated with moraines, tunnel valleys and/or slide scars which are protected geodiversity features within the Southern Trench NCMPA. Based on existing mapping of geodiversity features within the Southern Trench NCMPA (Bradwell et al., 2008; NatureScot, 2019), the Export/Import Cable may cross the southern end of a tunnel valley feature. This is supported by the MMT (2018a) high resolution multibeam data available to the project (Figure 8-9). However, the localised nature of any works will be very small relative to the size and extent of the tunnel valley feature (which is at least 40 km) and the overall favourable condition should be maintained, according to the criteria set out in Section 8.6.1.3.1. The magnitude of any effect will also be minimised through the embedded mitigation measures set out in Table 8-31.

A series of east-west trending ridges are visible immediately to the east of the tunnel valley feature and these features have been classified as sandwaves by MMT (2018a) (Figure 8-10). Sandwave crests form perpendicular to the main axis of flow, in areas where sand is available and mean spring peak near surface current speeds exceed approximately 0.5 m/s (Belderson et al. 1982). Although these hydrodynamic and sedimentary conditions are met here, the ridge features have morphological characteristics which could equally be interpreted as moraines. It is also noted that the cross-sectional asymmetry of the ridge features likely infers sediment transport in the opposite direction to that suggested by numerical modelling of sand transport in this region (see Ørsted and Simply Blue Group, 2024). The available geophysical and geotechnical information does not resolve whether the features comprise sand (i.e. sand waves) or consolidated quaternary deposits (i.e. moraines). However, even if the features are indeed moraines, the localised nature of any works will be small relative to the size of the features and the overall favourable condition should be maintained.

[6] *Cable protection (rock) used to backfill the trench created during installation will not protrude above the seabed and therefore is not considered to impact the geodiversity features beyond that assessed via the maximum total area of seabed disturbance.*

On the basis of the discussion in this Section, the magnitude of effect to the Southern Trench NCMPA is predicted to be low.

Evaluation of significance

Taking the high sensitivity of the seabed habitats within both the East of Gannet and Montrose Fields NCMPA and Southern Trench NCMPA and the low magnitude of the effect, the overall effect on the designated seabed interest features within both protected sites is considered to be minor and not significant in EIA terms.

Sensitivity	Magnitude of effect	Consequence
High	Low	Minor

Impact significance - NOT SIGNIFICANT

8.6.1.4 Potential changes to coastal /inshore seabed morphology (receptor)

8.6.1.4.1 Overview

The landfall is located at Longhaven, just to the south of Peterhead. This is a rocky coastline comprising granite cliffs which are considered to be resistant to erosion (BGS, 2022). The preferred cable installation method at the landfall is HDD. Both HDD drilling operations and the use of any cable protection at the HDD marine exit point are source/pathways via which the morphology of the landfall at Longhaven could theoretically be impacted. These are discussed individually, below.

8.6.1.4.2 Determination of sensitivity

The coast at Longhaven is considered to be of medium sensitivity. Although nationally designated (since it is within the Bullers of Buchan Coast SSSI), the granite cliffs and immediately adjacent seabed will be insensitive to changes in waves, tides and sediment transport (as they are resistant to erosion).

All of the other designated sites listed in Table 8-25 are too distal from the source of effect for any change to occur. Accordingly, they are not considered further within this assessment.

8.6.1.4.3 Determination of magnitude

HDD operations

HDD at the landfall are an embedded mitigation measure that the Project has adopted to minimise coastal impacts (Table 8-31). As set out in EIAR Vol. 2, Chapter 5: Project Description and Table 8-32, cables will be routed through HDD, each with a drilled length of 409 m. These will emerge approximately 26.5 m below MHWS at a distance of circa 190 m offshore from the MHWS contour. There will be three boreholes drilled: one for each of the HVDC cables; and one for the fibre optic cable.

HDD will cause minimal direct disturbance to the existing coastline because it will not interact directly with, or leave any infrastructure exposed between the entry and exit points of the drill. Provided that the cables remain buried beyond the exit of the HDD, there is no possibility for the ducts to interact with, or have any effect on coastal morphology, including the designated geodiversity interests of the Bullers of Buchan Coast SSSI. The design of the HDD operation will take this into account.

Installation of cable protection at HDD marine exit points

The HDD marine exit point will be located (approximately) 26.5 m below MHWS and may require the installation of rock protection measuring (up to) 10 m in length, 20 m in width and 1.5 m in height above the seabed. Given the water depths, no temporary flotation pits for installation vessels will be required.

The potential mechanisms by which the presence of any HDD marine exit point rock protection could theoretically impact the coast at the landfall is principally via the modification for waves and interception of sediment. However, the coastline here comprises erosion resistant granite cliffs (rather than soft (erodible) sediments and associated inter-tidal habitats) and as such, the potential for associated morphological change to the coast is minimal.

Available geophysical and geotechnical data suggests that rippled gravelly sand/sandy gravel and silty sand is likely to be present at the HDD marine exit point (MMT, 2018a). In theory, the presence of rock protection at the seabed could cause inshore seabed change as a result of modification to waves, tides and sediment transport processes. However, any longer term change is expected to be highly localised (order of metres to tens of metres) owing to the small-scale/ low profile of the rock berms.

On the basis of the discussion in this Section, the magnitude of effect to the Bullers of Buchan Coast SSSI is predicted to be **negligible**. Where direct disturbance takes place to the sub-tidal seabed (e.g. via jetting), the effect will only be present for the duration of the construction works and will therefore be temporary in nature. Indirect effects of longer-term duration (e.g. any changes to coastal morphology arising from modification of the hydrodynamic/wave regime in response to short sections of cable (rock) protection) will be negligible, given the erosion resistant nature of rock.

Evaluation of significance

Taking the medium sensitivity of the coast at the landfall and the negligible magnitude of the effect, the overall effect of potential changes to coastal /inshore seabed morphology is considered to be **negligible** and **not significant** in EIA terms.

Sensitivity	Magnitude of effect	Consequence
Medium	Negligible	Negligible

Impact significance - **NOT SIGNIFICANT**

8.6.2 Potential effects during operation and maintenance

8.6.2.1 Potential changes to suspended sediment concentrations, bed levels and sediment type (pathway)

8.6.2.1.1 Overview

The WCS assumes a series of cable repairs and/or cable remediation will be required over the lifetime of the Project, with up to 19 IACs and four Export/Import Cable repairs anticipated.

IACs and Export/Import Cable repairs and/or remediation activities are expected to result in some localised seabed disturbance accompanied by temporary increases in SSC. It is expected that equipment similar to that used to install the cables will be used for re-burial/remediation. Accordingly, the area of seabed impacted during the removal of a cable would be similar to (but no greater than) the area impacted during the original installation. For all of the above, the changes in SSC and accompanying changes to bed levels associated are expected to be no greater than that associated with the construction phase (Section 8.6.1.1) and, therefore, is not considered further here.

8.6.2.2 Potential changes to wave and tidal regime (pathway)

8.6.2.2.1 Overview

The presence of floating substructure foundations with associated moorings and dynamic sections of IACs, OSCPs foundations and cable protection on the seabed has the potential to present local blockage or resistance to the passage of currents and waves. The direct change is most likely to appear as a wake or shadow feature in the lee of the obstacle, where the baseline or ambient conditions may be modified. Due to the limited depth, height, or other dimensions of the obstacles being introduced as part of the Project, changes are likely to be of limited scale and extent.

Details of the WCS for sediment disturbance events are set out in Table 8-32. It is noted that the WCS for wave and hydrodynamic blockage differ, with the worst-case for wave blockage represented by the floating substructure foundation presenting the greatest blockage in the upper water column (i.e. at/ close to the sea surface). The worst-case for hydrodynamic blockage is represented by the combination of substructure type, mooring configuration, anchor system and dynamic IACs which is associated with the largest combined overall blockage within the water column.

8.6.2.2.2 Determination of sensitivity

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

8.6.2.2.3 Determination of magnitude

Waves and tides are pathways, rather than 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 changes to them, with consequential changes to sediment transport pathways and any associated impacts to Marine Geology, Oceanography and Coastal Processes receptors described in Section 8.6.2.3 and Section 8.6.2.5, respectively.

Change due to presence of substructures, moorings and dynamic IACs

Changes to tidal currents: The effect of the floating substructure foundations on tidal currents within the Array Area will be to locally reduce current speed and increase turbulence in a narrow wake behind the cross section of each TLP (maximum width of 93 m). The wake features/effects will recover rapidly with distance downstream, likely becoming not measurable within a few hundreds of metres (less than the distance between the floating substructure, min. 928 m). The maximum distance to which any (cumulative) effect might propagate from the Array Area is, in any case, limited to one tidal excursion distance (the distance over which water is displaced during one flood or ebb tidal cycle), approximately between 4 to 6 km under mean spring conditions for the Array Area (Figure 8-1). Wakes would extend in the ebb or flood direction, depending on the state of the tide.

Currents passing underneath the floating substructure will not be directly affected by the main structure but will interact to a much lesser extent with the very small blockage presented by the mooring lines (up to nine per substructure, 300 mm diameter) and dynamic IACs (up to two per substructure, up to 300 mm diameter) between the base of each floating substructure and the seabed. The main body of any anchors will be buried and so will not interact with currents. It is the case that the top 3 m of suction piles (6.5 m diameter) could project above the seabed and so may theoretically interact with currents locally. However, they are individually of relatively small scale and so are unlikely to cause a change in overall patterns of flow or sediment transport through the Array Area. Any associated seabed scour is also expected to be very limited (Section 8.6.2.5).

Measurable effects on currents are therefore likely to only be associated with the floating substructure and so largely confined to surface and near surface waters. Accordingly, any change to currents caused by individual substructures or the array as a whole will have no consequential effect on the overall rate or direction of sediment transport at the seabed.

Changes to waves: The local effects of the floating substructures on waves will be limited to an area downwind of the Array Area, to a distance up to approximately the width of the site (relative to the wave coming direction). Beyond that distance, the sea state will recover to the ambient condition through a combination of natural spreading, dispersion and growth of wave energy (see impact modelling studies including Five Estuaries (RWE, 2024) and Awel y Môr (RWE, 2022)). The minimum spacing of 928 m between adjacent FTU is judged to be sufficient to minimise the chance of any wave interactions between structures, with changes localised to each floating substructure.

A larger proportion of smaller waves (wave periods <8 s) are more likely to be blocked (by reflection or breaking) within the cross section presented by the floating substructure; whereas larger waves (wave periods >10 s) will tend to bypass the floating substructure with less interaction and consequential energy loss. In any case, for the vast majority of the time, waves in the Array Area are not large enough (in comparison to the relatively large water depth) to cause any measurable contribution to sediment transport, therefore, any changes to waves that are caused by the presence of the Array Area are unlikely to have any consequential effect on the rate or direction of sediment transport, in the Array Area, along the EICC and/or at the shoreline. This is discussed further in Section 8.6.2.3.

Change due to presence of IACs and Export/Import Cable protection

In order to minimise direct loss of seabed habitat within the East of Gannet and Montrose Fields NCMPA and Southern Trench NCMPA, the use of rock protection to cables will be minimised (Table 8-31). At the OSCPs within the Array

Area, up to 2.2 km of IACs may require protecting, with the rock berm having a trapezoidal profile with a height of 1 m above seabed and a base width of up to 7 m. Up to 8.35 km of the Export/Import Cable between the Array Area and the 12 NM limit may require rock protection to be installed, with a maximum height of up to 1.75 m above the seabed and a base width of up to 11 m. Up to 20 cable/pipeline crossings along the Export/Import Cable and 8 crossings in the Array Area may require rock protection, with a maximum berm height of up to 3.5 m above the seabed and a base width of up to 15 m (Table 8-32).

Water depths are between approximately 80 mLAT and 105 mLAT within the Array Area and along the EICC, seaward of the 12 NM limit (Figure 8-9). On the few occasions, during large storm events, when waves are sufficiently large to interact at all with the berm, it is very unlikely that the berm will present a sufficient obstacle to cause changes to their size or direction. The long axis of any potential berm may be more or less aligned to, or perpendicular to, the main tidal current axis, depending on exact location within the Array Area or along the EICC. However, the cable protection height (max. 1.75 m) is a very small proportion of the total water depth and so, together with the sloped sides of the berm, will present a minimal obstruction to tidal currents (no measurable effect more than a few tens of metres from the berm and restricted only to the near-bed);

Up to 64% of the Export/Import Cable between MHWS and 12 NM will require cable protection. Rock berm protection will also be required for cable/pipeline crossings, seven of which are located landward of the 12 NM limit. However, any associated changes to the wave and tidal regime arising from blockage related effects are expected to be limited for the same reasons previously set out in the paragraph above.

Evaluation of significance

The changes to waves and currents described in this Section are to 'pathways' as opposed to receptors, with these changes having the potential to influence patterns of sediment transport. The significance of potential impacts to Marine Geology, Oceanography and Coastal Processes receptors arising from modification of the sediment transport regime is considered within Section 8.6.2.5.

8.6.2.3 Potential modifications to sediment transport pathways (pathway)

8.6.2.3.1 Overview

Sediment transport is driven by the combination of waves and tides and 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. This assessment considers the potential for modification of sediment transport pathways arising from the following, with particular attention given to the subtidal sand and gravels in the East of Gannet and Montrose Fields NCMPA:

- Changes due to hydrodynamic/ wave blockage effects associated with the presence of floating substructures, moorings, OSCPs foundations, dynamic IACs, IACs anchors and cable protection (described in Section 8.6.2.2); and
- Changes due to increased suspended sediment transport associated with sweeping of the bed by mooring lines.

Details of the WCS for potential modifications to sediment transport are set out in Table 8-32 and are the same as for the assessment of potential changes to waves and tides.

8.6.2.3.2 Determination of sensitivity

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

8.6.2.3.3 Determination of magnitude

Sediment transport is a pathway, rather than a receptor and as such, it is not appropriate to carry out an assessment of significance which determines the magnitude of effect to it. Instead, this Section focuses on describing the spatial and temporal nature of change to sediment transport pathways, with any associated impacts to Marine Geology, Oceanography and Coastal Processes receptors described in Section 8.6.2.5, respectively.

Changes due to hydrodynamic/ wave blockage effects

Wave/ hydrodynamic blockage related effects arising from the presence of floating substructures, OSCPs foundations, moorings, IACs anchors and dynamic IACs are expected to be minimal at the bed (Section 8.6.2.2). It therefore follows that any associated changes in sediment transport will be equally limited and almost entirely unchanged from the baseline.

Cable protection (in the form of rock berms) may be installed at the base of OSCPs foundations and along parts of the Export/Import Cable (Table 8-32). Preliminary Cable Burial Risk Assessment (CBRA) results indicate that up to 5% of the Export/Import Cable between 12 NM and the East of Gannet and Montrose Fields NCMPA boundary will require cable protection, and up to 64% of the Export/Import Cable Route between MHWS and 12 NM will require cable protection. There is no cable protection required on the Export/Import Cable between the NCMPA boundary and the OSCPs, excluding at cable/pipeline crossings. In theory, the berm may intersect natural sediment transport pathways, which may present some obstruction to sediment transported as bedload (sediment transport in suspension will be less affected). However, any change is expected to be minimal:

- Within the Array Area, rates of sediment transport are extremely low, due to the very weak tidal currents and deep water (Section 8.4.4.5). Accordingly, the absolute volume of sediment which could potentially be blocked by the presence of any rock berms would be very small. It is noted here that the only sediment which could theoretically be intercepted by the presence of any rock berms is the muddy sand which is occasionally mobile. Any larger material (inc. the gravels which are occasionally present and which are an interest feature of the East of Gannet and Montrose Fields NCMPA) are found to be immobile and will therefore be unaffected; and
- Along the Export/Import Cable (where rates of sediment transport are higher), an initial period of sediment accumulation may occur within and around the rock berm, as a limited volume of sediment in bedload transport is trapped within any open surface voids. A surface accumulation of sediment may develop over the updrift side (appearing similar to a groyne on a beach). The volume of sediment accumulated will vary in proportion to the size of the voids and so the clast size used but will be a small absolute volume and is expected to occur in a relatively short period of time (order of weeks to a few months). The slope of the berm (1:3) already provides an approximate 18˚ slope angle, which is within the range of naturally stable bed slopes (<32˚ for sands). When sufficient sediment volume has been accumulated on the updrift surface to present a naturally stable sediment slope and surface, sediment transport will thereafter continue over the berm at the natural ambient rate and direction. No measurable change to the seabed is expected more than a few metres from the updrift edge of the berm. Due to the limited extent of the berms no measurable change to wider seabed morphology will be observed as the supply of sediment will be broadly maintained.

Changes due to increased suspended sediment transport

During the operational life of the Project, the mooring lines for semi-submersible substructures may come into contact with the seabed, gently sweeping the surface. Theoretically, this has the potential to cause short-term and localised increases in SSC, with finer particles entering into suspension.

As set out in Table 8-32, in total, an area of up to 1,442,860 m^2 may be disturbed by mooring lines sweeping the seabed. The degree of disturbance and increase in suspended sediment is expected to be spatially and temporarily variable in response to (for instance) the variation in water level, local flow speed and sediment type at the bed. The overall level of disturbance is expected to be small, however, as the relative speed of movement of the mooring lines at the bed is likely to be low.

It is estimated that the disturbed material could potentially be elevated up to 1-2 metres above the seabed. Any coarser material will settle out suspension relatively quickly and therefore within a few metres from the point of disturbance. Finer grained (i.e. muddy) material – which is present in relatively high concentration across the Array Area would persist in suspension for longer and therefore potentially be advected further from the point of disturbance by ambient flows. It is not possible to quantify the volume of material that could theoretically be mobilised through the process of mooring lines agitating the seabed over the Project lifetime. However, it is noted that the amount of surficial sediment cover is very limited within the Array Area, being less than 0.5 m in most areas and often entirely absent, with (consolidated) Quaternary material exposed at the bed.

Evaluation of significance

The changes to sediment transport described in this Section are to 'pathways' as opposed to receptors. The significance of any potential impacts to Marine Geology, Oceanography and Coastal Processes receptors arising from modification of the sediment transport regime is considered within Section 8.6.2.5.

8.6.2.4 Modifications to stratification and frontal features (pathway)

8.6.2.4.1 Overview

As currents move water past the individual floating substructures, a turbulent wake is formed. Within the turbulent wake, vertical mixing can be enhanced above ambient levels: the >20 m draft of floating substructures is large enough to penetrate 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 position of tidal mixing fronts (e.g. Carpenter et al., 2016; Cazenave et al., 2016; and Dorrell et al., 2022).

In addition to the potential for direct disturbance of the water column by wind farm 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).

This Section considers the potential for floating substructures 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 EIAR Vol. 4, Appendix 7: Marine & Physical Processes Modelling Report, which addresses the following key questions:

- How might the FTUs and OSCPs change mixing?
- How might this change in mixing influence the timing of seasonal stratification and frontal positions?
- What impacts could this have on primary production and the wider ecosystem?
- What impacts could change in near-surface wind speeds have on water column mixing and stratification?

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 turbulent kinetic energy (TKE) generated by the FTU, and the advective timescale, which quantifies how long a water parcel remains within the Array Area, experiencing enhanced TKE.

8.6.2.4.2 Determination of sensitivity

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

8.6.2.4.3 Determination of magnitude

Stratification and frontal systems are considered to be pathways, rather than 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.

Stratification and tidal mixing fronts have been described in detail within the baseline (Section 8.4.4.5) and in EIAR Vol. 4, Appendix 7: Marine & Physical Processes Modelling Report. In brief:

- The Array Area experiences strong seasonal stratification, but with significant seasonal and inter-annual variability.
- The boundary between stratified and weakly stratified/mixed waters occurs to the west 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 stronger 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 5 to 10 days later than present (Sharples et al., 2022).

The assessment of potential changes to stratification and frontal systems caused by the Project and set out in EIAR Vol. 4, Appendix 7: Marine & Physical Processes Modelling Report indicates that the project will have very limited impacts, with effects generally falling within the range of natural variability.

The installation of FTU (floating substructures) and OSCPs jacket foundations will generate additional turbulence alongside naturally occurring turbulence generated at the seabed by tidal currents and the surface by wind/wave action. The substructure 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 the FTUs.

The estimated mixing timescale for the area during a strong stratification period (August 2022) is approximately 7.7 days. The estimated time a water parcel spends within the Array Area experiencing enhanced mixing is 5.8 days. This indicates that a parcel of water is not exposed to the elevated TKE from the FTUs for a sufficient duration to fully break down the strong stratification present in the water column.

The FTUs are 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.

Effects on primary production and the wider ecosystem are also expected to be minimal. The most productive area, located west of the Array Area within the more weakly stratified waters, is located outside the direct influence of the Array Area. Small pockets of elevated primary production maybe generated within the Array Area, where mixing and weakening of the stratification in the turbine wakes acts to vertically mix nutrients into the nutrient depleted, sunlit surface layers of the surrounding stratified waters.

Finally, some modelling studies provide theoretical evidence for atmospheric offshore wind farm 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 turbines in place across the model domain. The Project is small in comparison and the scale of these changes is expected to be very limited.

Evaluation of significance

All the identified Marine Geology, Oceanography and Coastal Processes receptors are insensitive to changes in stratification and frontal systems. However, the potential for these changes to impact marine biodiversity is considered elsewhere within the ES, in particular:

- EIAR Vol. 3, Chapter 10: Benthic Ecology;
- EIAR Vol. 3, Chapter 11: Marine Mammal Ecology;
- EIAR Vol. 3, Chapter 12: Offshore Ornithology; and
- EIAR Vol. 3, Chapter 13: Fish and Shellfish Ecology.

8.6.2.5 Potential impacts to designated seabed interest features within protected sites (receptor)

8.6.2.5.1 Overview

The direct loss/change of seabed habitat within the East of Gannet and Montrose Fields NCMPA and Southern Trench NCMPA arising from the installation of Project infrastructure has previously been quantified in Section 8.6.1.3. This Section focuses on the potential indirect changes to seabed habitat which could arise during the (35 year) operational lifetime of the Project in response to the presence of Project infrastructure. These indirect changes include scour effects around infrastructure on the bed as well as wider morphological change arising from changes in waves, tides and associated sediment transport processes (see Section 8.6.2.28.6.2.3 and Section 8.6.2.3, respectively).

It is noted that the Marine Geology, Oceanography and Coastal Processes Study Area partially intersects Turbot Bank NCMPA. However, given the distances from the Project – approximately 6 km from the EICC and 170 km from the Array Area - there will be no potential for impacts to occur here. Accordingly, potential impacts to this NCMPA are not considered further here.

8.6.2.5.2 Determination of sensitivity

The East of Gannet and Montrose Fields NCMPA is of national importance. As a result of the weak tidal currents (and wave induced orbital currents at the bed) sediment mobility within the site is low meaning the seabed has limited ability to recover from an effect. Accordingly, the site is assessed to be of high sensitivity.

The Southern Trench NCMPA is also of national importance. The geodiversity features of interest contained within it are relict with no ability to recover from an effect. Accordingly, the site is assessed to be of high sensitivity.

8.6.2.5.3 Determination of magnitude

Presence of Project infrastructure within the East of Gannet and Montrose Fields NCMPA

Scour. Up to 570 suction pile anchors with a diameter of 6.5 m may be installed within the Array Area, each protruding (up to) 3 m above the bed. Jacket foundations will also be used for (up to) two OSCPs foundations.

As part of the embedded mitigation measures set out in Table 8-31, scour protection will not be installed around seabed infrastructure in the Array Area, thereby minimising the loss of seabed habitat within the East of Gannet and Montrose Fields NCMPA. In theory, this could mean that scour could develop, potentially leading to a loss/ change in seabed habitat immediately adjacent to the unprotected structure. Indeed, geophysical survey data collected from the Array Area provides some evidence of scour (order of 1 m deep and 2-3 m extent) around a shipwreck (Rovco, 2023b). However, extensive scour around structures within the Array Area is not expected to occur for the following reasons:

- Surficial sediment cover is extremely limited across the Array Area being less than 0.5 m in most areas and often entirely absent or very thin in coverage, with Quaternary material exposed at the bed. The Quaternary units typically comprise consolidated silt/sand/gravel units (Table 8-4) which will be resistant to erosion. Accordingly, the spatial footprint of any change is expected to be minimal.
- Whilst scour could theoretically develop around some suction pile anchors located in areas where surficial sediment is present, the depth and extent of scour is much reduced for cylinders that stand less than one diameter above the seabed compared to tests with a surface-piercing cylinder (such as a fixed bottom monopile foundation). This is because the limited height of these obstacles disrupts and limits the patterns of flow acceleration that can form, reducing the likely maximum dimensions of scour.
- In areas where scour beyond a depth of (approximately) 0.5m could theoretically be anticipated – in the southwest corner of the Array Area for instance, other mitigating measures will be taken to avoid the use of scour protection. These mitigation measures include re-locating FTUs and micro-siting piles to areas with an acceptable level of anticipated scour and increasing pile depth / diameter / wall thickness to compensate for anticipated scour effects (Table 8-31).
- Nearbed current speeds within the Array Area are very low, limiting scour potential (Section 8.4.4.5). Water depths will also greatly limit the strength of wave induced orbital currents at the bed, further limiting scour potential.

Modification of sediment transport. As set out in Section 8.6.2.3, mooring lines for semi-submersible substructures may come into contact with the seabed, sweeping the surface. This has the potential to cause short-term and localised increases in SSC, with finer particles entering into suspension. Over the lifetime of the Project, it is theoretically possible that this could lead to a slight coarsening (i.e. trend towards higher sand concentration) of material within the area swept by moorings. Given the very thin cover of surficial sediment, it is also possible that over time the underlying Quaternary material could become exposed at the bed. As stated in Table 8-32 and Section 8.6.1.3, the maximum area that could theoretically be affected is 1,442,860 m^2; this is small relative to both the Array Area (0.13%) and East of Gannet and Montrose Fields NCMPA (0.08%).

As stated in Section 8.6.2.3, the potential for changes to sediment transport processes as a consequence of the presence of floating substructures, OSCPs foundations, cable protection and other Project related infrastructure is considered to be very limited. It follows that any associated change to seabed morphology will be similarly limited.

On the basis of the discussion in this Section, the magnitude of effect to the East of Gannet and Montrose Fields NCMPA is predicted to be low.

Presence of Export/Import Cable within the Southern Trench NCMPA

Within the Southern Trench NCMPA (as well as all other seabed areas landward of the 12 NM limit), the use of rock berm protection is expected to be limited to cable/pipeline crossings[7]. Up to four crossings are expected to be located within the boundary of the Southern Trench NCMPA, each measuring up to 520 m long x 24 m wide x 3.5 m high.

The purpose of cable protection is to provide protection to the Export/Import Cable and remove risk to local sea users. It is also designed to prevent sediment scour. Where protection is applied, no scour will be caused by the protected cable itself. However, where surficial sediment is present, a small amount of localised secondary scour may form at the edges of the berm, in proportion to the overall berm dimensions and the clast size used. The patterns and dimensions of sediment accumulation or scour may vary over the operational lifetime of the berm, due to natural fluctuations in sediment supply and transport rates and directions. Changes may be seasonal or episodic in nature (e.g. during or following larger storms, then gradually returning to another state associated with purely tidal conditions). However, the nature of the seabed (sediment type and texture) around the berm, including within any areas of local accretion or scour, is not expected to be measurably very different to the surrounding seabed. No associated changes are expected to the morphology of the (relict) Quaternary geodiversity features within the Southern Trench NCMPA.

On the basis of the discussion in this Section, the magnitude of effect to the Southern Trench NCMPA is predicted to be low.

[7] *Cable protection (rock) used to backfill the trench created during installation will not protrude above the seabed.*

Evaluation of significance

Taking the high sensitivity of the seabed habitats within both the East of Gannet and Montrose Fields NCMPA and Southern Trench NCMPA and the low magnitude of the effect, the overall effect on the designated seabed interest features within both protected sites is considered to be minor and not significant in EIA terms.

Sensitivity	Magnitude of effect	Consequence
High	Low	Minor
Impact significance - NOT SIGNIFICANT		

8.6.2.6 Potential changes to coastal /inshore seabed morphology (receptor)

8.6.2.6.1 Overview

This Section describes potential impacts to the coast and inshore seabed morphology at the landfall, arising from changes to currents, waves and associated sediment transport (or other coastal processes) potentially caused by the presence of hard infrastructure.

Potential impacts on the morphology of the coast from other Project infrastructure further offshore (including all the infrastructure within the Array Area) have been scoped out. This is due to the distance between any effects created by these structures and adjacent coastlines which are beyond the range of any potential impact.

8.6.2.6.2 Determination of sensitivity

The coast at Longhaven is considered to be of medium sensitivity. Although nationally designated (since it is within the Bullers of Buchan Coast SSSI), the granite cliffs and immediately adjacent seabed will be insensitive to changes in waves, tides and sediment transport (as they are resistant to erosion).

All of the other designated sites listed in Table 8-25 are too distal from the source of an effect for any change to occur. Accordingly, they are not considered further within this assessment.

8.6.2.6.3 Determination of magnitude

Presence of cable protection

The HDD marine exit point will be located (approximately) 26.5 m below MHWS (circa 190 m offshore from the MHWS contour) and may require the installation of rock protection measuring (up to) 10 m in length, 20 m in width and 1.5 m in height above the seabed. Rock protection may also be used at cable/pipeline crossings, with a rock berm up to 520 m long, 24 m wide and 3.5 m potentially installed. The closest crossing to shore is situated approximately 3.5 km from the coast and is associated with the Eastern Green Link 2 HVDC cable.

In theory, the presence of rock protection at the seabed could cause inshore seabed change as a result of modification to waves, tides and sediment transport processes. However, (and as set out in Section 8.6.1.4), any longer term change to the seabed is expected to be highly localised (order of metres to tens of metres from the rock protection) owing to the small-scale/ low profile of the rock berms. Given both the highly localised nature of change to wave and hydrodynamic processes, coupled with the erosion resistant nature of the granite cliff coastline, no change would be expected to occur to the Bullers of Buchan Coast SSSI.

If the Export/Import Cable were to become exposed, then a small, localised, area of 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 Export/Import Cable relative to the seabed but a conservative estimate for all cases is that the maximum depth of scour will be between one and three times the cable diameter (i.e. up to 0.9 m) and the maximum horizontal extent of any scour effect will be up to fifty times the cable diameter (i.e. up to circa 15 m).

Presence of landfall infrastructure

Due to the erosion resistant nature of the coastline, coastal recession is expected to minimal here over the 35 year lifetime of the Project (Dynamic Coast, 2024). Accordingly, the risk to Project infrastructure located landward of MHWS (such as cable jointing bays) from erosion is considered to be minimal.

On the basis of the discussion in this Section, the magnitude of effect to the Bullers of Buchan Coast SSSI is predicted to be negligible.

Evaluation of significance

Taking the medium sensitivity of the coast at the landfall and the negligible magnitude of the effect, the overall effect of potential changes to coastal /inshore seabed morphology is considered to be negligible and not significant in EIA terms.

Sensitivity	Magnitude of effect	Consequence
Medium	Negligible	Negligible

Impact significance - NOT SIGNIFICANT

8.6.3 Potential effects during decommissioning

Effects on Marine Geology, Oceanography and Coastal Processes receptors associated with decommissioning are anticipated to result from the full removal of the Project components. Decommissioning activities will be subject to consultations and further assessments closer to the time of decommissioning to understand technical feasibility, safety and risk, and environmental considerations in detail. These details will be included in a Decommissioning Programme which will be developed post-consent and updated over the life of the Project.

The decommissioning of the Project intends to complete the full removal of offshore infrastructure to below the mudline (where safe/practicable to do so), in line with the OSPAR Convention and forthcoming guidance from OSPAR's North-East Atlantic Environmental Strategy 2030. The majority of decommissioning works are likely to be undertaken in reverse to the sequence of construction works and involve similar or lesser levels of effects to construction.

A Decommissioning Programme will be prepared prior to construction, in line with the requirements of Section 105 of the Energy Act 2004 (as amended) and any applicable guidance available at the time. Currently it is assumed that:

- FTU substructure and WTG components will be removed and towed to port;
- Mooring lines will be removed, and where possible piles will be removed or cut to a suitable distance below the mudline such that the upper portion is removed;
- Cables no longer required will be removed where safe to do so; where they cross live third-party assets, they may be cut and left in situ to prevent damage to third-party operations; and
- The OSCPs will be decommissioned and the jacket and topside(s) will be towed to shore. The piles will be cut a suitable distance below the mudline.

The sensitivities and effect magnitudes for decommissioning are considered to be comparable to those identified for the construction phase. Therefore, in the absence of detailed information regarding decommissioning works, the effects during the decommissioning of the Project are considered analogous with, or likely less than, those of the construction phase.

8.6.4 Summary of potential effects

A summary of the outcomes of the assessment of potential effects from the construction, operation and maintenance and decommissioning of the Project is provided in Table 8-35.

No significant effects on Marine Geology, Oceanography and Coastal Processes receptors were identified. Therefore, mitigation measures in addition to the embedded mitigation measures listed in Section 8.5.4 are not considered necessary. Because no significant effects on Marine Geology, Oceanography and Coastal Processes receptors were found, no additional monitoring requirements have been identified.

Table 8-35 Summary of potential effects

POTENTIAL EFFECT	RECEPTOR	SENSITIVITY OF RECEPTOR	MAGNITUDE OF EFFECT	CONSEQUENCE (SIGNIFICANCE OF EFFECT)	SECONDARY MITIGATION REQUIREMENTS	RESIDUAL CONSEQUENCE (SIGNIFICANCE OF EFFECT)
Construction						
Potential changes to suspended sediment concentrations, bed levels and sediment type	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]	N/A [Potential pathway of effect for other topics]	None required above existing embedded mitigation measures.	N/A
Potential modifications to sediment transport pathways	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]	N/A [Potential pathway of effect for other topics]	None required above existing embedded mitigation measures.	N/A
Potential impacts to designated seabed interest features within protected sites	Designated seabed interest features within protected sites	High	Low	Minor (not significant)	None required above existing embedded mitigation measures.	N/A

POTENTIAL EFFECT	RECEPTOR	SENSITIVITY OF RECEPTOR	MAGNITUDE OF EFFECT	CONSEQUENCE (SIGNIFICANCE OF EFFECT)	SECONDARY MITIGATION REQUIREMENTS	RESIDUAL CONSEQUENCE (SIGNIFICANCE OF EFFECT)
Potential changes to coastal /inshore seabed morphology	Coastal/inshore seabed morphology	Medium	Negligible	Negligible (not significant)	None required above existing embedded mitigation measures.	N/A
Operation and maintenance						
Potential changes to suspended sediment concentrations, bed levels and sediment type	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]	N/A [Potential pathway of effect for other topics]	None required above existing embedded mitigation measures.	N/A
Potential changes to wave and tidal regime	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]	N/A [Potential pathway of effect for other topics]	None required above existing embedded mitigation measures.	N/A
Potential modifications to sediment transport pathways	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]	N/A [Potential pathway of effect for other topics]	None required above existing embedded mitigation measures.	N/A

POTENTIAL EFFECT	RECEPTOR	SENSITIVITY OF RECEPTOR	MAGNITUDE OF EFFECT	CONSEQUENCE (SIGNIFICANCE OF EFFECT)	SECONDARY MITIGATION REQUIREMENTS	RESIDUAL CONSEQUENCE (SIGNIFICANCE OF EFFECT)
Modifications to stratification and frontal features	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]	N/A [Potential pathway of effect for other topics]	None required above existing embedded mitigation measures.	N/A
Potential impacts to designated seabed interest features within protected sites	Designated seabed interest features within protected sites	High	Low	Minor (not significant)	None required above existing embedded mitigation measures.	N/A
Potential changes to coastal /inshore seabed morphology	Coastal/inshore seabed morphology	Medium	Negligible	Negligible (not significant)	None required above existing embedded mitigation measures.	N/A
Decommissioning*						

* In the absence of detailed information regarding decommissioning works, the effects during the decommissioning of the Project are considered analogous with, or likely less than, those of the construction phase.

8.7 Assessment of cumulative effects

8.7.1 Introduction

Potential impacts from the Project have the potential to interact with those from other projects (developments), plans and activities, resulting in cumulative effects on Marine Geology, Oceanography and Coastal Processes receptors. The general approach to the Cumulative Effects Assessment (CEA) is described in EIAR Vol. 2, Chapter 7: EIA Methodology and in EIAR Vol. 4, Appendix 31: Cumulative Effects Assessment Methodology and further detail is provided below.

As part of the cumulative process, a long list of plans, activities and projects (developments) was first defined. Upon review of this long list, the construction period of some of the identified developments did not overlap with the construction phase of the Project, so these plans, activities and projects (developments) will not be considered further in this cumulative assessment.

The initial long list was subsequently refined using Zones of Influence (ZoIs) for each receptor group. For the Marine Geology, Oceanography and Coastal Processes chapter, this was defined by the extent of spring tidal ellipses along the EICC and a 50 km buffer around the Array Area (in order to account for blockage effects).

Typically, operational projects (developments) are considered part of the baseline environment (please see EIAR Vol. 4, Appendix 31: Cumulative Effects Assessment Methodology). Marine Geology, Oceanography and Coastal Processes is an exception to this. Marine Geology, Oceanography and Coastal Processes does consider blockage effects which may arise during the operational phase of the Project cumulatively with other active exiting oil and has infrastructure (assessed in Section 8.7.3.1).

The projects that will be considered for the cumulative impact assessment are listed in Table 8-36 and illustrated in Figure 8-27.

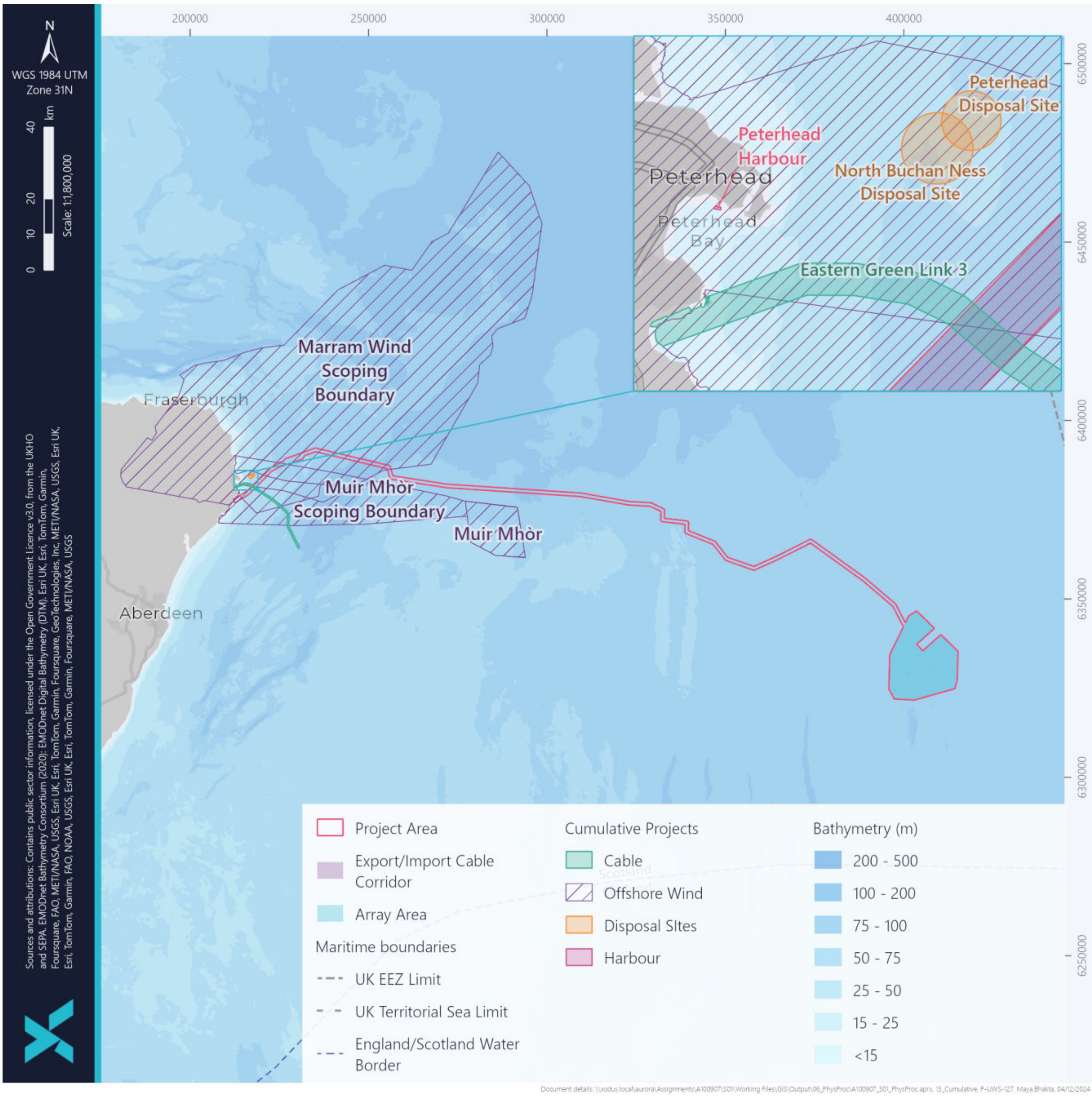

Figure 8-27 Cumulative developments within and nearby to the Marine Geology, Oceanography and Coastal Processes Study Area

Table 8-36 List of developments considered for the Marine Geology, Oceanography and Coastal Processes CEA

LOCATION	PROJECT TYPE	PROJECT NAME	DISTANCE TO PROJECT (km)	STATUS	CONFIDENCE[8]
United Kingdom	Oil and Gas	Various (including the Madoe field, ETAP assets, and Culzean 22" Gas Export Flowline)	Various	Operational	High
United Kingdom	Cable	Eastern Green Link 3	0	Pre-Application (Scoping)	Low
United Kingdom	Offshore Wind	Muir Mhòr Offshore Wind Farm	0	Application	Low
United Kingdom	Offshore Wind	MarramWind	0	Pre-Application (Scoping)	Low
United Kingdom	Disposal	Peterhead	1.57	Operational	Low
United Kingdom	Disposal	Peterhead Harbour	4.06	Operational	Low
United Kingdom	Disposal	North Buchan Ness	1.56	Operational	Low

The potential cumulative effects considered within this Section are:

- The potential for cumulative changes to suspended sediment concentrations, bed levels and sediment type (during Project construction); and
- The potential for cumulative impacts to designated seabed interest features within protected sites (during Project operation).

Section 8.6.1.1 considered the potential for floating substructures and OSCPs jacket foundations to influence regional-scale patterns of stratification and any resulting change in the location of fronts. Although a number of other planned and operational offshore wind farms are present within the Study Area, none are within a distance of one spring tidal excursion ellipse from the Array Area (Figure 8-27). Accordingly, it is considered that there is no potential for

[8] Confidence ratings have been applied to each cumulative project where: 'Low' = pre-application or application, 'Medium' = consented and 'High' = under construction or operational. Disposal sites are an exception to this; despite being operational, they are marked as 'Low' owing to uncertainty over frequency of use.

cumulative effects on stratification arising from interaction with these other developments and therefore no further assessment has been undertaken.

The potential for changes in water column stratification arising from Project infrastructure in the Array Area interacting cumulatively with offshore oil and gas infrastructure is considered to be extremely low. This is due to the highly localised nature of blockage related change arising from the oil and gas infrastructure and as such, has not been assessed any further here. For the same reason, the potential for cumulative interaction with the Culzean Floating Offshore Wind Turbine Pilot Project – a single 3 MW floating wind turbine with mooring system, located 16.71 km from the Array Area, has also been scoped out.

In theory, the Export/Import Cable from both the Project and all of the other scoped-in export/import cables, interconnectors and electricity transmission cables listed in Table 8-36 could be installed within the Southern Trench NCMPA. This could theoretically result in cumulative pressures on moraines, tunnel valleys and slide scars which are protected geodiversity features within the NCMPA. However, in the absence of detailed routing information (accompanied by high resolution mapping of protected geodiversity features within the Southern Trench NCMPA), it is not possible to accurately determine the potential for cumulative effects to any features of geomorphological interest. Accordingly, this hasn't been considered further within the assessment.

Export/Import Cable repairs and/or remediation activities are expected to result in some localised seabed disturbance accompanied by temporary increases in SSC (Section 8.6.2.1). However, the potential for cumulative effects is expected to be less than or equal to the construction phase (Section 8.7.2) and so has not been considered further within the cumulative effects Section.

Finally, owing to the highly erosion resistant nature of the coast at the landfall (Section 8.4.4.9) the potential for cumulative changes to coastal/inshore seabed morphology arising from interaction with other projects (notably cables and associated protection) is considered extremely low and has not been assessed further in this Section.

8.7.2 Cumulative construction effects

8.7.2.1 Potential cumulative changes to suspended sediment concentrations, bed levels and sediment type

8.7.2.1.1 Overview

The following projects and activities listed in Table 8-36 could, potentially, intersect the spring tidal excursion buffer around the Project:

- Construction of other wind farm arrays;
- Installation of wind farm export/import cables and inter-connectors;
- Licenced dredge disposal.

Since the construction and/or operation period of these proposed developments and activities also overlaps with the proposed Project construction period, the potential for cumulative temporary increases in SSC and seabed levels has been assessed here.

Projects beyond the range of the spring tidal excursion ellipse buffer are unlikely to experience any measurable change and as such, are not included in the cumulative assessment.

8.7.2.1.2 Determination of sensitivity

All of the identified Marine Geology, Oceanography and Coastal Processes receptors are insensitive to elevated levels of SSC and have therefore not been assigned a sensitivity rating.

8.7.2.1.3 Determination of magnitude

This Section focuses on describing the spatial and temporal characteristics of potential sediment plumes, which are a 'pathway' connecting an effect source (i.e. construction activities) with potential receptors (such as designated benthic habitats).

Cumulative changes associated with Array Area construction. Muir Mhòr Offshore Wind Farm is located within one spring tidal excursion ellipse from the Project and construction of Muir Mhòr Offshore Wind Farm could overlap with that of the Project. Accordingly, the potential for cumulative changes in SSC is considered here.

The interaction between sediment plumes generated by Project construction activities (namely PLGR, boulder clearance and cable installation) and those from construction of nearby wind farms could theoretically occur in two ways:

- Where plumes generated from the two different activities meet and coalesce to form one larger plume; or
- Where other wind farm construction activities occur within the plume generated by Project construction activities (or *vice versa*).

For two or more separately formed plumes that meet and coalesce, the physical laws of dispersion theory mean concentrations within the plumes are not additive but instead a larger plume is created with regions of potentially differing concentration representative of the separate respective plumes (e.g. Anglian Offshore Dredging Association (AODA), 2011). In contrast, in the case of plumes formed directly within the footprint of another plume, the two plumes would be additive, creating a plume with higher SSC.

On the basis of the assessment considering potential changes in SSC associated with various types of site preparation and cable installation activities (Section 8.6.1.1), it is found that any fine grained sediment plume will be subject to rapid dispersion, both laterally and vertically, returning to near-background levels (tens of mg/l) within hundreds to a few thousands of metres at the point of release. These concentration increases will be experienced only while the installation activity occurs and only in the streamline of the bed disturbance activity. As a result, for the vast majority of the time and at any given point in the study region there will be no increases in SSC above background levels.

In addition to the above, it is noted that in line with UNCLOS (The United Nations Convention on the Law of the Sea) a safety zone is expected to be in place around the cable installation vessel to minimize collision risk. (The size of the safety zone varies between projects but is typically around 500 m). Accordingly, whilst plume interaction may still occur, the potential for much higher concentration and more persistent plumes than that previously described in the Project-alone assessments of SSC is considered to be low. Cumulative increases in bed level could still theoretically occur although are expected to be small, given the separation of activities outlined above.

It is also worth noting that spring tidal excursion ellipses are relatively strongly rectilinear for much of the EICC. This means that although at times during the construction phase some plume interaction may occur, the number of occurrences is expected to be less than for an equivalent setting with more rotary tidal excursion characteristics.

Cumulative changes associated with wind farm export/import cables and interconnectors. Given that proposed interconnectors (Eastern Green Link 3) and wind farm export/import cables (Muir Mhòr Offshore Wind Farm and MarramWind) are (i) within a spring tidal excursion distance of the Project; and (ii) could have overlapping construction periods, there is some potential for sediment plume interaction during construction phases. However, and as stated in the previous Section, it is noted that cable installation vessels typically request a vessel safety zone when installing or handling cables. As set out in Section 8.6.1.1, at a distance of greater than 500 m from the source of bed disturbance, any increases in SSC are expected to be modest (tens to low hundreds of mg/l) and fine sediment is unlikely to deposit in measurable thickness. These levels fall within the bounds of natural variation, reflecting SSC's which may be observed during a storm event which stir material at the bed. Accordingly, whilst plume interaction may still theoretically occur, the potential for much higher concentration and/or more persistent plumes than that previously described in the Project-alone assessments of SSC is small.

Cumulative changes associated with dredge disposal activities. The EICC is located within a spring tidal excursion ellipse of dredge disposal sites CR070 (Peterhead), CR071 (Peterhead Harbour) and CR080 (North Buchan Ness), off Peterhead. Should Export/Import Cable installation occur at the same time as dredge disposal activities at these sites, there could theoretically be the potential for cumulative changes in SSC and bed levels.

Dredge disposal sites CR070 and CR080 are located at a distance of circa 2 km from the EICC, in relation to the orientation of the tidal axis, whilst disposal site CR071 is located circa 4 km away. At this distance apart, any cumulative increase in either the spatial footprint or peak concentration of sediment plumes is expected to be indistinguishable from that previously reported for the Export/Import Cable installation in Section 8.6.1.1. Any associated cumulative changes in bed level will also be immeasurable.

It is also worth noting that spring tidal excursion ellipses are strongly rectilinear within the vicinity of the dredge disposal sites nearby to the EICC. This means that although at times during the construction phase some plume interaction may occur, the number of occurrences is expected to be less than for an equivalent setting with more rotary tidal excursion characteristics.

8.7.2.1.4 **Evaluation** of significance

All the identified Marine Geology, Oceanography and Coastal Processes receptors are insensitive to elevated levels of SSC. However, the potential for these changes to impact other EIA receptor groups is considered elsewhere within the ES, in particular:

EIAR Vol. 3, Chapter 9: Marine Water and Sediment Quality;
EIAR Vol. 3, Chapter 10: Benthic Ecology; and
EIAR Vol. 3, Chapter 13: Fish and Shellfish Ecology.

8.7.3 Cumulative operation and maintenance effects

8.7.3.1 Potential cumulative impacts to designated seabed interest features within protected sites

8.7.3.1.1 Overview

This Section focuses on the potential for cumulative changes to seabed habitat within the East of Gannet and Montrose Fields NCMPA which could arise during the (35 year) operational lifetime of the Project in response to the presence of Project infrastructure interacting with oil and gas infrastructure. Cumulative interaction could potentially occur between Project and oil and gas infrastructure at the surface, in the water column and on the seabed. Seabed changes could potential arise from cumulative modifications to waves, tides and associated sediment transport processes, leading to a morphological response. As stated in Section 8.7.1 (and detailed further in EIAR Vol. 4, Appendix 31: Cumulative Effects Assessment Methodology), typically operational projects (developments) are not considered in cumulative assessment. However, due to the nature of blockage effects arising due to presence of existing infrastructure, operational oil and gas infrastructure is considered herein.

8.7.3.1.2 Determination of sensitivity

The East of Gannet and Montrose Fields NCMPA is of national importance. As a result of the weak tidal currents (and wave induced orbital currents at the bed) sediment mobility within the site is low meaning the seabed has limited ability to recover from an effect. Accordingly, the site is assessed to be of high sensitivity.

8.7.3.1.3 Determination of magnitude

There is no surface infrastructure directly interacting with the Project Area, with the closest being the Kittiwake platform, located 7 km north of the EICC.

The Array Area overlaps with the bp owned Madoes oil and gas field, one of the Eastern Trough Area Project (ETAP) fields. The Madoes field lies within the boundaries of the licenced blocks 22/23b, 22/28d, and 22/28a and consists of a three-well subsea cluster which ties back to the ETAP QU and PDR platforms via the Madoes manifold and a 10" production pipeline (see below). The Array Area is situated ~ 1 km from the subsurface infrastructure located within this field (Marine Directorate, 2024; NSTA, 2023). The closest infrastructure associated with the Madoes field is a wellhead (W156) located approximately 1.2 km from the Array Area.

The Array Area directly overlaps with the Culzean 22" Gas Export Flowline, while other pipelines such as the Cats 36" Gas Export Pipeline are situated directly adjacent to the north-east of the Array Area (NSTA, 2023). As explained above, the Madoes Field ties back into the ETAP surface infrastructure and production facilities through the ETAP Madoes 10" production pipeline and ETAP Madoes 4" Gas Lift which are approximately 1.2 km from the Array Area (NSTA, 2023).

Any blockage related change to waves and tides (and associated sediment transport) arising from the presence of oil and gas infrastructure in the water column will be highly localised. As there is no surface oil and gas infrastructure directly overlapping with (or in immediate proximity to) the Project Area, there is no potential for cumulative change.

Project infrastructure at the seabed (especially rock berms) could theoretically cumulatively interact with oil and gas seabed infrastructure (such as the Culzean pipeline) to obstruct sediment transport. However, any cumulative change is expected to be minimal for the same reasons previously set out in Section 8.6.2.3: within the Array Area, rates of sediment transport are extremely low, due to the very weak tidal currents and deep water (Section 8.4.4.5). Accordingly, the absolute volume of sediment which could potentially be blocked by the presence of any rock berms would be very small. The only sediment which could theoretically be intercepted by the presence of any rock berms is the muddy sand which is occasionally mobile. Any larger material (inc. the gravels which are occasionally present and which are an interest feature of the East of Gannet and Montrose Fields NCMPA are found to be immobile and will therefore be unaffected

On the basis of the discussion in this Section, the magnitude of effect to the East of Gannet and Montrose Fields NCMPA is predicted to be low.

Evaluation of significance

Taking the high sensitivity of the seabed habitats within the East of Gannet and Montrose Fields NCMPA and the low magnitude of the effect, the overall effect on the designated seabed interest features within the protected site is considered to be minor and not significant in EIA terms.

Sensitivity	Magnitude of effect	Consequence
High	Low	Minor

Impact significance - NOT SIGNIFICANT

8.7.4 Cumulative decommissioning effects

The decommissioning of the Project intends to complete the full removal of offshore infrastructure to below the mudline (where safe/practicable to do so). The majority of decommissioning works are likely to be undertaken in reverse to the sequence of construction works. However, there is limited information on the details around decommissioning of the Project and around the lifecycle of other developments. Considering this, it is assumed that decommissioning involves similar or lesser levels of effects to construction.

A Decommissioning Programme will be prepared prior to construction, in line with the requirements of Section 105 of the Energy Act 2004 (as amended) and any applicable guidance available at the time.

8.7.5 Summary of cumulative effects

A summary of the outcomes of the assessment of potential effects from the construction, operation and maintenance and decommissioning of the Project is provided in Table 8-37.

No significant effects on Marine Geology, Oceanography and Coastal Processes receptors were identified. Therefore, mitigation measures in addition to the embedded mitigation measures listed in Section 8.5.4 are not considered necessary.

Table 8-37 Summary of assessment of cumulative effects

POTENTIAL IMPACT	RECEPTOR	SENSITIVITY OF RECEPTOR	MAGNITUDE OF EFFECT	CONSEQUENCE (SIGNIFICANCE OF EFFECT)	SECONDARY MITIGATION REQUIREMENTS	RESIDUAL CONSEQUENCE (SIGNIFICANCE OF EFFECT)
Construction						
Potential cumulative changes to suspended sediment concentrations, bed levels and sediment type	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]	N/A [Potential pathway of effect for other topics]	None required above existing embedded mitigation measures.	N/A
Operation and maintenance						
Potential cumulative impacts to designated seabed interest features within protected sites	Designated seabed interest features within protected sites	High	Low	Minor (not significant)	None required above existing embedded mitigation measures.	N/A
Decommissioning						
[None identified]	N/A	N/A	N/A	N/A	N/A	N/A

8.8 Inter-related effects

Inter-related effects are the potential effects of multiple impacts, effecting one receptor or a group of receptors. Inter-related effects include interactions between the impacts of the different phases of the Project (i.e. interaction of impacts across construction, operation and maintenance and decommissioning), as well as the interaction between impacts on a receptor within a Project phase. The potential inter-related effects for Marine Geology, Oceanography, and Coastal Processes receptors are described below.

8.8.1 Inter-related effects between Project phases

The effects of increased SSC caused by seabed disturbance will primarily occur during the construction and decommissioning phases of the Project. 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 Project lifetime are not expected to result in greater significance than those assessed separately.

The morphology of designated areas of seabed and the coast could theoretically be subject to project life time inter-related effects, with direct seabed disturbance occurring in the construction and decommissioning phase and indirect disturbance occurring during the operational 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 project lifetime, the magnitude of change (and therefore overall significance of effect) would be no greater than if assessed in isolation.

8.8.2 Inter-related effects within a Project phase

The different Marine Geology, Oceanography, and Coastal 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 Marine Geology, Oceanography, and Coastal Processes has been used to inform other EIAR topics. Assessments have been undertaken separately within these individual topic chapters and are not reported here as additional inter-relationships.

8.8.3 Inter-relationships

Inter-relationships are defined as the interaction between the effects assessed within different topic assessment chapters on a receptor. The other chapters and effects related to the assessment of potential effects on Marine Geology, Oceanography, and Coastal Processes are provided in Table 8-38.

Table 8-38 Marine Geology, Oceanography, and Coastal Processes inter-relationships

CHAPTER	POTENTIAL EFFECT	DESCRIPTION
EIAR Vol. 3, Chapter 9: Marine Water and Sediment Quality EIAR Vol. 3, Chapter 10: Benthic Ecology and EIAR Vol. 3, Chapter 13: Fish and Shellfish Ecology.	Changes to suspended sediment concentrations, bed levels and sediment type (pathway)	Changes to water column SSC and associated sediment deposition to the bed could potentially impact water quality, benthic ecology and fish/ shellfish.
Chapter 12: Ornithology and EIAR Vol. 3 Chapter 13: Fish and Shellfish Ecology.	Changes to stratification and frontal features (pathway)	Floating substructures could influence water column mixing in stratified waters, potentially altering primary production, marine ecosystem and biogeochemical cycling.

8.9 Whole Project assessment

Please refer to EIAR Vol. 2, Chapter 7: EIA Methodology for the full description of the whole Project assessment.

The onshore aspects of the Project (i.e., those landwards of MLWS), including the onshore HDD entry point and the Export/Import Cable pull through, have been consented through the NorthConnect HVDC Cable Planning Consent. Details of the onshore project infrastructure which has been acquired through NorthConnect is presented within EIAR Vol. 2, Chapter 5: Project Description.

The onshore project will undertake HDD operations above MHWS, with an HDD exit point offshore. The impacts from the HDD exit point on Marine Geology, Oceanography and Coastal Processes have been assessed in full in Section 8.6.1.4. It is not anticipated that there will be any additional impacts from the onshore project on Marine Geology, Oceanography and Coastal Processes receptors as all other activities from the onshore project are fully terrestrial.

8.10 Transboundary effects

Transboundary effects arise when impacts from a development within one European Economic Area (EEA) state's territory affects the environment of another EEA state(s).

There is no potential for transboundary impacts upon Marine Geology, Oceanography, and Coastal Processes receptors due to construction, operation and maintenance and decommissioning of the Project. The potential impacts are localised and are not expected to affect other EEA states. Therefore, transboundary effects for Marine Geology, Oceanography, and Coastal Processes receptors are not considered further.

8.11 Summary of mitigation and monitoring

No secondary mitigation, over and above the embedded mitigation measures proposed in Section 8.5.4, is either required or proposed in relation to the potential effects of the Project on Marine Geology, Oceanography, and Coastal Processes as no adverse significant impacts are predicted. No monitoring is currently proposed for marine geology, oceanography, and coastal processes.

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