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Volume 3 Caledonia North

Chapter 2 Marine and Coastal Processes

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Acronyms and Abbreviations

BEIS	Department for Business, Energy and Industrial Strategy
BGS	British Geological Society
CaP	Cable Plan
CIA	Cumulative Impact Assessment
CMS	Construction Method Statement
DE	Design Envelope
DECC	Department of Energy and Climate Change
DSLP	Development Specification and Layout Plan
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EMODnet	European Marine Observation and Data Network
HDD	Horizontal Directional Drilling
H_s	Significant Wave Height
LAT	Lowest Astronomical Tide
MCZ	Marine Conservation Zone
MD-LOT	Marine Directorate - Licensing Operations Team
MHWS	Mean High Water Springs
MORL	Moray Offshore Renewables Limited
MPA	Marine Protected Area
NMP	Scotland's National Marine Plan
NMPi	National Marine Plan Interactive Mapping Tool
NTSLF	National Tide and Sea Level Facility

OECC	Offshore Export Cable Corridor
OESEA4	Offshore Energy Strategic Assessment 4
OSP	Offshore Substation Platform
OWF	Offshore Wind Farm
RCP	Representative Concentration Pathway
SSC	Suspended Sediment Concentrations
SSSI	Site of Special Scientific Interest
TSHD	Trailer Suction Hopper Dredger
UKCP	UK Climate Projections
UKHO	United Kingdom Hydrographic Office
WTG	Wind Turbine Generator
ZoI	Zone of Influence

Executive Summary

This Marine and Coastal Processes Chapter of the Caledonia Offshore Wind Farm Environmental Impact Assessment Report, specifically of relevance to Caledonia North, presents an overview of the existing marine environmental characteristics, up to Mean High Water Springs, for:

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

The study area has been determined based upon the Caledonia North location and proposed infrastructure, alongside spring tidal excursions and expert judgement. Caledonia North, located in water depths up to 60m below Lowest Astronomical Tide within the Moray Firth, is primarily under the control of the wave regime, with tidal currents that are relatively benign and unable to transport material larger than fine-grained sediments. Surficial sediments are primarily composed of sands and the presence of mobile bedforms in discreet locations indicates an active sediment transport regime.

A consideration of the Caledonia North Design Envelope has been undertaken to identify worst-case scenario with respect to Marine and Coastal Processes. Adopting a source-pathway-receptor approach, the potential impacts associated with Caledonia North have been assessed, in accordance with the Scoping Opinion and subsequent stakeholder engagement, using a suite of methodologies which include numerical modelling, the evidence-base and expert judgement. Receptors identified include both designated sites with qualifying coastal and marine features and non-designated sites, such as seabed morphological features. Specifically, the following impacts have been considered:

- Increases in Suspended Sediment Concentration (SSC) and change to seabed levels;
- Potential impacts to seabed morphology (sandbanks and notable bathymetric depressions);
- Modifications to littoral transport, coastal behaviour (erosion), including at the Landfall Site;
- Potential impacts to seabed morphology;
- Seabed scouring;
- Modifications to the wave and tidal regimes and associated impacts to morphological features;
- Cumulative increases in SSC and change to seabed levels; and
- Cumulative modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime.

The results of this impact assessment demonstrate that Caledonia North may have a negligible to minor impact upon the identified receptors, which is considered not significant in Environmental Impact Assessment terms.

2 Marine and Coastal Processes

2.1 Introduction

2.1.1.1 This chapter of the Environmental Impact Assessment Report (EIAR) identifies the potential effects on Marine and Coastal Processes associated with the construction, operation and maintenance (O&M) and decommissioning of the Caledonia Offshore Wind Farm (OWF), specifically Caledonia North. This includes the Caledonia North Site (i.e., Array Area) as well as the Caledonia North Offshore Export Cable Corridor (OECC) seaward of Mean High Water Spring (MHWS).

2.1.1.2 This chapter is supported by the following Technical Appendices:

- Volume 7B, Appendix 2-1: Marine and Coastal Processes Baseline Technical Report; and
- Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report.

2.1.1.3 The following supporting studies relate to and should be read in conjunction with this chapter:

- Volume 3, Chapter 3: Marine and Water Sediment Quality;
- Volume 3, Chapter 4: Benthic Subtidal and Intertidal Ecology;
- Volume 3, Chapter 5: Fish and Shellfish Ecology;
- Volume 3, Chapter 7: Marine Mammals; and
- Volume 3, Chapter 8: Commercial Fisheries.

2.2 Legislation, Policy and Guidance

2.2.1.1 Volume 1, Chapter 2: Legislation and Policy, of this EIAR sets out the policy and legislation associated with Caledonia North.

2.2.1.2 Legislation and guidance that relate to the Marine and Coastal Processes assessment are identified and described in Table 2–1.

Table 2–1: Legislation and Guidance.

Relevant Legislation and Guidance	Description
Legislation	
Scotland's National Marine Plan (NMP) (Scottish Government, 2015[1])	The NMP objectives relevant to this Marine and Coastal Processes assessment include: ▪ Sustainable development of offshore wind, wave and tidal renewable energy in the most suitable locations; and ▪ Good environmental status descriptors.
Marine (Scotland) Act 2010 (Scottish Parliament, 2010[2])	This framework helps to balance competing demand on Scotland's sea. It introduces a duty to protect and enhance the marine environment and includes measures to help boost economic investment and growth in areas such as marine renewables.
Marine and Coastal Access Act 2009 (UK Parliament, 2009[3])	This framework establishes a new legislative and management for the marine environment, allowing the competing demands on the sea to be managed in a sustainable way across all of Scotland's seas. It applies to Caledonia North as the offshore limit is beyond 12nm.
Guidance	
Marine Scotland Consenting and Licensing Guidance for Offshore Wind, Wave and Tidal Energy Applications (Marine Scotland, 2018[4])	This guidance provides information on the EIA Process and the information to be contained within an EIAR.
Coastal Process Modelling for Offshore Wind Farm EIA; Best Practice Guide (Lambkin *et al*., 2009[5])	This guidance provides the best practice on the identification, development, calibration, validation and scenarios to be applied for OWF developments.
Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects (Cefas, 2011[6])	These guidelines contain generic advice for the acquisition of data to support environmental assessments for offshore renewable energy developments. Guidance is provided on the design, review and implementation of environmental data collection and analytical activities associated with all stages of offshore renewable energy developments.
National Resources Wales (NRW) Monitoring Evidence Report No: 243 Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Monitoring Requirements to inform EIA of Major Development	This guidance on marine, coastal and estuarine physical processes was developed from a review of existing published guidance relevant to physical processes EIA studies, consideration of relevant examples and from the experience gained by the authors during work on large scale marine developments. Information is included on: ▪ EIA baseline survey and monitoring requirements for: o Hydrodynamics (waves, tidal currents and water levels); o Sediments, sediment transport and geology; and

Relevant Legislation and Guidance	Description
Projects. (Brooks *et al.*, 2018[7])	o Morphology. ▪ The pathways for change and potential impacts for each of the development stages; and ▪ The potential magnitude of these changes, identifying for which development types and development stages they are likely to be greatest.
Review of Cabling Techniques and Environmental Effects applicable to the Offshore Wind farm Industry. Department for Business Enterprise and Regulatory Reform in association with Defra (BERR, 2008[8])	This review provides a description of the range of techniques used to install and maintain subsea cables. Information is also provided on a range of commonly applied cable protection measures, in addition to the technical information on cable design and installation. Discussion is also afforded on the physical changes or effects to the seabed and sub-surface sediments expected to occur during cabling activities are also described. This includes consideration of the relative extent/ magnitude of sediment disturbance that is likely to occur during cable burial for each technique as well as potential sediment plume characteristics. The latter is discussed with reference to direct field monitoring during cable installation activities.
Nature conservation considerations and environmental best practice for subsea cables for English Inshore and UK offshore waters (Natural England and Joint Nature Conservation Committee, 2022[9])	This report identifies the main pressures, sensitive habitats, and best practice for the placement, installation and maintenance of subsea cables in English inshore and UK offshore waters.
Best Practice Advice for Evidence and Data Standards for offshore renewables projects (Natural England, 2022[10])	This report provides the provision of best practice advice on the use of data and evidence to support OWF development and consenting in English waters. Focus is made on the key ecological receptors which pose a consenting risk for projects, namely seabirds, marine mammals, seafloor habitats and species and fish.
Further review of sediment monitoring data (COWRIE ScourSed-09). (ABPmer *et al.*, 2010[11])	This report provides a review of available physical processes monitoring data, any lessons learnt and recommendations for future sediment monitoring. The review focuses upon: ▪ Suspended sediments; ▪ Seabed morphology; and ▪ Scour. Monitoring data available from within built arrays is considered and recommendations are provided for refining monitoring strategies (for example those associated with bathymetric survey timing, consistency and extent) to enable robust determination of change between pre- and post-construction survey.

Relevant Legislation and Guidance	Description
Handbook of Scour and Cable Protection Methods (Deltares, 2023[12])	This handbook provides detail on: - Scour development and mitigation strategies; - Scour protection methods; and - Ecological impacts.
Dynamics of scour pits and scour protection - Synthesis report and recommendations (Sed02). (HR Wallingford *et al.*, 2007[13]).	This report provides a synthesis of the following: - Identification, collation and review of all available field evidence for scour from Round 1 wind farm projects and other relevant European marine projects; - UK and European research relating to scour and scour protection for the wind farm industry; - Publications and guidance relating to scour and scour protection within other marine industries, including types of scour protection and their potential impact on coastal processes and navigation; - Design and installation of scour protection for Scroby Sands against the performance as recorded by previous DTI funded investigations; - Design and installation of scour protection for other UK and European sites, potentially including scour in relation to cabling as well as foundations; and - Gaps in the scour and scour protection knowledge base, especially on mobile sandbanks.
General advice on assessing potential impacts of and mitigation for human activities on Marine Conservation Zone (MCZ) features, using existing regulation and legislation (JNCC and Natural England, 2011[14]).	General advice is provided on the potential impacts of eight sectors, two areas of recreational activity and two thematic areas relating to human activities in the marine environment, encompassing licensed and unlicensed activities. This includes cables and offshore wind activities.
Review of environmental data associated with post-consent monitoring of licence conditions of offshore wind farms. MMO Project No: 1031 (Fugro-Emu, 2014[15]).	This review presents outcomes and conclusions from monitoring regimes undertaken as a result of statutory requirements imposed on developers of OWFs in UK waters through consent conditions.
Guidelines in the use of metocean data through the lifecycle of a marine renewable development (ABPmer *et al*., 2008[16]).	These guidelines identify and provide recommendations on the uses of metocean data through the life cycle of a marine renewable energy development.

2.3 Stakeholder Engagement

2.3.1 Overview

2.3.1.1 The Offshore Scoping Report (Volume 7, Appendix 2) was submitted to Marine Directorate - Licensing Operations Team (MD-LOT)[i] in September 2022, who then circulated the report to relevant consultees. A Scoping Opinion (Volume 7, Appendix 3) was received from MD-LOT on 13 January 2023. Relevant comments from the Scoping Opinion specific to Marine and Coastal Processes are provided in Table 2–2.

2.3.1.2 Further consultation has been undertaken throughout the pre-application stage. Table 2–3 summarises the consultation activities carried out relevant to Marine and Coastal Processes.

[i] In 2023, Marine Scotland was renamed Marine Directorate, and thus the marine licensing and consents team is now referred to as Marine Directorate - Licensing Operations Team (MD-LOT).

Table 2–2: Scoping Opinion response.

Consultee	Comment	Response
MD-LOT	The Scottish Ministers are broadly content with the baseline data sources regarding marine and coastal processes used by the Developer in Table 6.1 of the Scoping Report. The Scottish Ministers are otherwise content with the approach to the baseline environment.	Caledonia Offshore Wind Farm Limited (hereafter referred to as 'the Applicant') welcomes the Scottish Ministers approval of the baseline data sources.
MD-LOT	In line with the NatureScot representation, the Scottish Ministers advise that the baseline conditions for Caledonia North should be informed by the EIA Reports of existing projects. To be clear, this means conditions prior to construction of any Moray Firth Offshore Wind Farms ("OWFs"). The Scottish Ministers agree with NatureScot and therefore the Developer must adopt this approach in the EIA Report.	Following further consultation and agreement with NatureScot (see Table 2–3), the Applicant considers the existing environment to include those Moray Firth OWFs which are constructed at the time of writing this EIAR.
MD-LOT	The Scottish Ministers broadly agree with the impacts scoped in to and out of the EIA Report with the exception of the three impact pathways: ▪ Modifications to the wave and tidal regime, and associated impacts to morphological features; ▪ Cumulative modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime; and ▪ Potential impacts to seabed morphology must be scoped in for all aspects.	The Applicant agrees to scope these impacts into the EIAR: ▪ Modifications to the wave and tidal regime, and associated impacts to morphological features (see Section 2.7.2); ▪ Cumulative modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime (see Section 2.7.3.10); and ▪ Potential impacts to seabed morphology for all aspects (see Section 2.7.1, Section 2.7.2 and Section 2.7.3).
MD-LOT	Advise that there should be further consultation with NatureScot on methods for numerical modelling and definition of the Zone of Influence in advance of submission of the EIA Report.	Further consultation with NatureScot was undertaken on 7 June 2023 (see Table 2–3).

Consultee	Comment	Response
MD-LOT	For the impact pathways scoped in for marine and costal processes, the full range of mitigation techniques and published guidance should be considered and discussed in the EIA Report.	The full range of mitigation options applicable to Marine and Coastal Processes can be found in Section 2.5.6 and Table 2–11. The full suite of published guidance can be found in Table 2–1.
MD-LOT	The operational effects of existing projects on the wave, tidal and sediment transport regime should be explicitly included within the Cumulative Impact Assessment (CIA).	The Cumulative Impact Assessment (CIA) is presented in Section 2.7.3.10.
NatureScot, 4 November 2022	Study areas: We are content with the study areas proposed.	The Applicant welcomes NatureScots' agreement of the study area proposed.
NatureScot, 4 November 2022	Baseline information: We agree that the relevant data sources have been included in Table 6.1 (Section 2.1.3).	The Applicant welcomes NatureScots' approval of the baseline data sources.
NatureScot, 4 November 2022	The operational effect Modifications to the wave and tidal regime, & associated impacts to morphological features is scoped out "due to generally low tidal currents, as well as distance offshore". However no detail is provided to justify this. We advise that this effect should be scoped in. Alternatively, the developer may wish to submit, for our consideration, further justification in terms of the significance of low tidal currents, any relevant evidence (observations or modelling results) from nearby and/or analogous offshore wind farms, and which if any receptors are being taken into account (with regards to paras 6.5.1.2 and 6.5.1.4).	The Applicant agrees to scope these impacts into the EIAR and this is presented in Section 2.7.2.
NatureScot, 4 November 2022	The operational effect Impacts to seabed morphology is scoped in only for the export corridor, for potential impacts on the Southern Trench MPA. We advise that this effect should also be assessed for the other 'aspects' of the development (Table 6.2), in keeping with an approach of assessing effects as pathways. Alternatively, the developer may	The Applicant agrees to scope these impacts into the EIAR and this is presented inSection 2.7.2 .

Consultee	Comment	Response
	wish to submit, for our consideration, further justification in terms of potential receptors (across all EIA topics).	
NatureScot, 4 November 2022	The operational effect Cumulative modifications to the wave and tidal regime, & associated impacts to sediment transport is scoped out because there is "no likelihood of local or regional changes in sediment transport regime". However no detail is provided to justify this. We advise that this effect should be scoped in. Alternatively, the developer may wish to submit, for our consideration, further justification in terms of any relevant evidence (observations or modelling results) from nearby and/or analogous offshore wind farms.	The Applicant agrees to scope these impacts into the EIAR and this is presented in Section 2.7.3.10.
NatureScot, 4 November 2022	We advise that operational effects of existing projects on the wave, tide and sediment transport regime should be explicitly included within the CIA. Baseline conditions for Caledonia should be informed by the EIAs of those existing projects, i.e., by conditions before any of the Moray Firth OWFs were constructed.	Following further consultation and agreement with NatureScot (see Table 2–3), the Applicant considers the existing environment to include those Moray Firth Offshore Wind Farms which are constructed at the time of writing this EIAR. The CIA is presented in Section 2.7.3.10.
NatureScot, 4 November 2022	We advise there should be further consultation on methods for numerical modelling especially considering the points above, in advance of the application submission. This should also cover the definition of the Zone of Influence.	Further consultation with NatureScot was undertaken on 7 June 2023 (see Table 2–3).
NatureScot, 4 November 2022	We advise that the full range of mitigation techniques and published guidance is considered and discussed in the EIA Report	The full range of mitigation options applicable to Marine and Coastal Processes can be found in Section 2.5.6 and see Table 2–11. The full suite of published guidance can be found in Table 2–1.
NatureScot, 4 November 2022	We advise that there are unlikely to be any transboundary impacts.	The Applicant notes NatureScots' consideration of transboundary impacts. in the

Consultee	Comment	Response
		Applicant explained why transboundary impacts were scoped out in Section 2.10.
Scottish Fishermen's Federation, 30 October 2022	Expect to see an assessment of the loss to fishing of these areas and an assessment of the long term damage to the seabed of anchors, ropes, chains and scour protection, up to and including decommissioning. All of this contributes to a lack of evidence on suspended sediments, and impacts on spawning.	The effects of Caledonia North's infrastructure upon the seabed, including impacts to suspended sediment concentrations are presented in Section 2.7.1 and Section 2.7.2.

Table 2–3: Stakeholder Engagement Activities.

Date	Consultee and Type of Consultation	Summary
7 June 2023	NatureScot; Meeting	NatureScot, in the current absence of a Marine and Coastal Processes advisor, welcomed the following information: - Numerical modelling to involve sediment plume and wave modelling; - Zone of influence (ZoI) is usually based on tidal excursion, and for the Caledonia North this is likely to be 10km or less. NatureScot suggested investigating work undertaken by the ScotMER processes receptor group, which listed evidence gaps on the impact of offshore renewable energy related to physical processes but noted that the timescales may not align with those for Caledonia North. The Physical Processes ScotMER receptor group has worked together to identify and prioritise evidence gaps associated with the planning and consenting processes for offshore renewable developments, which are detailed in the ScotMER Physical Processes Evidence Map. NatureScot would prefer a consistent approach to modelling across proposed developments, but appreciated this may not be possible.
7 June 2023	NatureScot; Meeting	NatureScot welcomed the confirmation that additional impact pathways were to be considered as part of the EIA, based on Scoping Opinion feedback. This included, using the existing evidence base: - modifications to the wave and tidal regime, and associated impacts to morphological features - cumulative modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime - potential impacts to seabed morphology would be scoped in for all aspects within the EIA, using a combination of numerical modelling and evidence-based approaches.
7 June 2023	NatureScot; Meeting	NatureScot highlighted the subtle difference between baseline and existing environment. In terms of what should and should not be included, the baseline does not always take account of baseline plus change. With Beatrice and Moray East OWFs now in operation, this forms part of existing environment for this receptor. The ZoI using tidal excursion will likely bring in aspects of both Beatrice and Moray East OWFs, plus potentially the Moray West OWF (consented, under construction). NatureScot suggested considering what and whether there is anything arising from

Date	Consultee and Type of Consultation	Summary
		these OWFs to help inform Caledonia North. For physical processes, it is likely to be localised to individual turbines, with perhaps little to be picked up on cumulative effects. NatureScot confirmed not to use the term ‘baseline’ for Marine and Coastal Processes, with Beatrice/Moray East OWFs forming part of the existing environment for this receptor.

2.4 Baseline Characterisation

2.4.1 Study Area

2.4.1.1 The Marine and Coastal Processes study area is shown in Figure 2-1. A Zone of Influence (ZoI) has been used to identify those Marine receptors which have the potential to be affected by Caledonia North and its associated activities. The ZoI (see Figure 2-1) has been defined using the outputs from the site-specific numerical modelling (see Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report), and has been scaled to conservatively represent the equivalent distance of tidal excursion on a mean spring tide and comprises a distance of 10km.

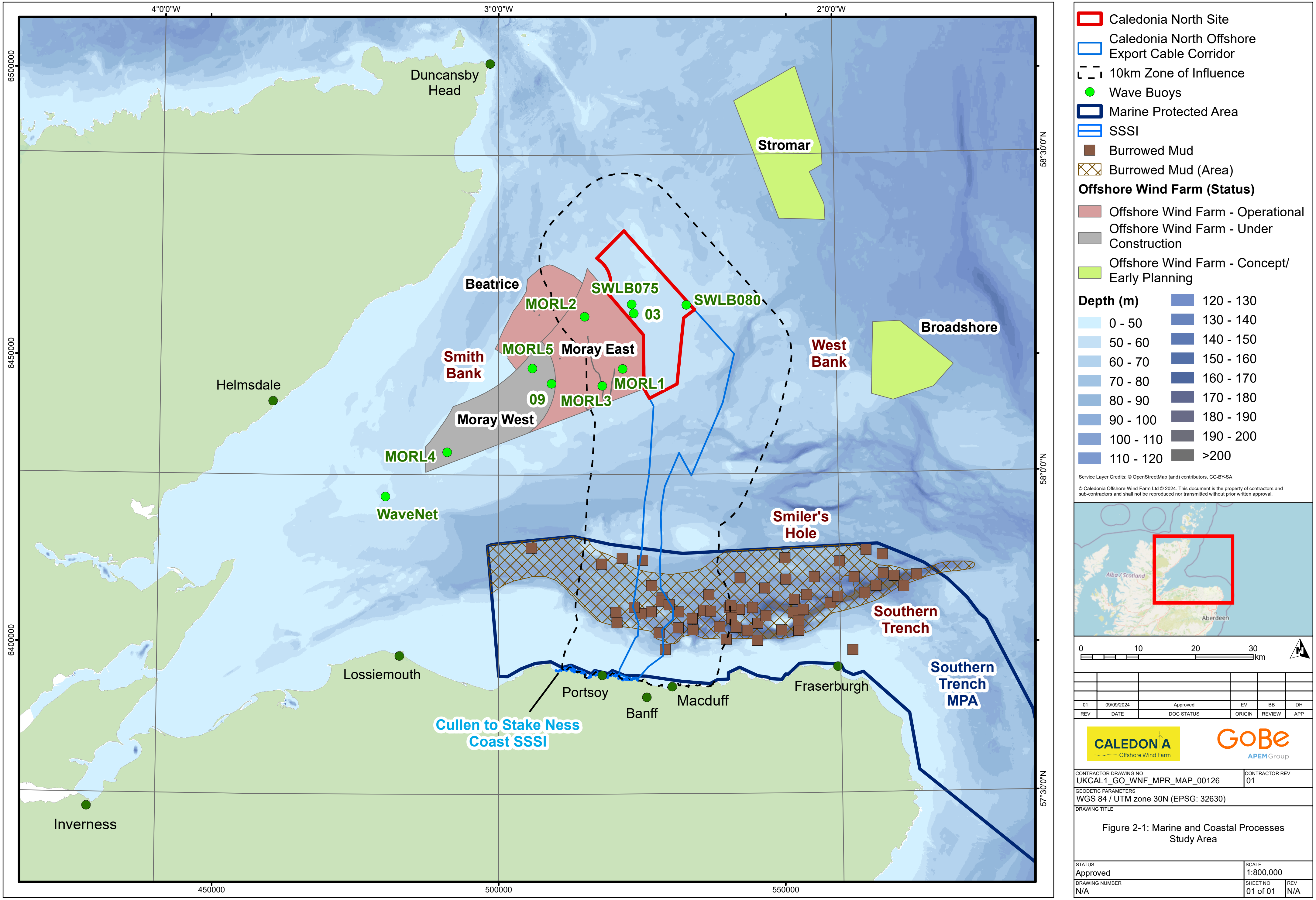


Figure 2-1: Marine and Coastal Processes Study Area

2.4.2 Data Sources

2.4.2.1 A baseline understanding of Marine and Coastal Processes has been developed through consideration of a range of data sources and existing process investigations from the study area, summarised in Table 2–4. This includes:

- Data available from a number of marine data portals;
- Existing physical processes investigations within the Caledonia North and in the vicinity of the study area (also see Table 2–4);
- Metocean preliminary design criteria, including modelled wave (direction, height and period) and tidal currents (speed and direction) data within the study area;
- Survey data from other OWFs and marine industries; and
- A desk-based geological and geotechnical survey, including the use of site-specific and publicly available data to establish the likely ground conditions and create a preliminary ground model of the area (in order to provide recommendations for future site surveys).

Desk Study

2.4.2.2 The data sources that have been used to inform this Marine and Coastal Processes chapter are presented within Table 2–4.

Table 2–4: Summary of key publicly available datasets for Marine and Coastal Processes.

Title	Author	Year
Cefas Wavenet	Cefas[17]	2022
United Kingdom Hydrographic Office (UKHO) Admiralty Tide Tables	UKHO[18]	2022
UKHO Admiralty Chart data	UKHO[19]	2022
Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report: Impacts, Adaption and Vulnerability	IPCC[20]	2022
Marine Scotland National Marine Plan Interactive Mapping Tool (NMPi)	Marine Scotland[21]	2022
Marine Scotland Regional Assessments	Marine Scotland[22]	2022
Offshore Energy Strategic Assessment 4 (OESEA4)	Department for Business, Energy and Industrial Strategy (BEIS)[23]	2022b

Title	Author	Year
New Leasing Geological Consultancy Support: OWF Ground Conditions Feasibility Assessment – NE4 Soil Thickness Study	Caledonia North data archive	2021
Coastal Futures Interactive Map	IHE Delft 2021[24]	2021
Dynamic Coast: Scotland's Coastal Change Assessment	Centre of Expertise for Waters[25]	2021
UK FUTURECOAST Project	Centre of Expertise for Waters[26]	2021
Sea Level Projection Tool –NASA Sea Level Change Portal	NASA[27]	2021
National Tide and Sea Level Facility (NTSLF)	NTSLF[28]	2020
British Geological Society (BGS) Offshore GeoIndex Map	BGS[29]	2020
European Marine Observation and Data Network (EMODnet) Bathymetry data	EMODnet[30]	2020
Seabed and Subsurface Geological Features (GS2_NE4 – Geology Chart)	Caledonia North data archive	2020
SEASTATES Metocean Data and Statistics Interactive Map	ABPmer[31]	2018
UK Climate Projections Science Report (UKCP18) Marine Report	Palmer *et al.*[32]	2018
Beatrice O&G Field Decommissioning Environmental Impact Assessment (EIA)	Repsol Sinopec Resources UK Limited[33]	2018
Moray West OWF EIAR	Moray OWF (West) Limited[34]	2018
Atlas of UK Marine Renewable Energy Resources	ABPmer[35]	2017
Moray East OWF Scoping Report	Moray OWF (East) Limited[36]	2017
Cefas Suspended Sediment Climatologies around the UK	Cefas[37]	2016
Moray West OWF Scoping Report	Moray OWF (West) Limited[38]	2016
Offshore Oil and Gas Licensing 28th Seaward Round Moray Firth – Habitats Regulations Assessment Stage 2 –Appropriate Assessment	Department for Energy and Climate Change (DECC)[39]	2015

Title	Author	Year
Beatrice OWF Environmental Statement	BOWL[40]	2012
Moray East OWF Environmental Statement	Moray OWF (East) Limited[41]	2012
Beatrice OWF Scoping Report	BOWL[42]	2010
Strategic Environmental Assessment – SEA5 Seabed and Superficial Geology and Sediments Survey Report	Holmes *et al*.[43]	2004
Strategic Environmental Assessment – SEA5	DECC[44]	2004
JNCC Coastal Directory Series: Regional Report 3 North East Scotland: Cape Wrath to St. Cyrus	Barne *et al*.[45]	1996
Moray East OWF associated survey results and reports (bathymetry, geotechnical, geophysical, and pre-construction)	Moray OWF (East) Limited[46]	2010; 2014; 2017; 2018; 2019
Moray West OWF associated survey results and reports (geophysical and geotechnical)	Moray OWF (West) Limited[47]	2010; 2018; 2019; 2021
Beatrice OWF associated survey results and reports	BOWL[48]	Assorted

Table 2–5: Hydrodynamic instruments deployed in the vicinity of the study area.

Data Source	Latitude (°N)	Longitude (°E)	Period Analysed	Duration
Directional wave buoys in Caledonia North Site (SWLB075 and SWLB080; see Figure 2-1 for wave buoy locations)	58.265290	-2.443283	June 2023 to October 2023	5 months (ongoing data collection)
	58.266700	-2.605290		
Directional wave buoy in the MORL Eastern Development Area	58.166	-2.634	June 2010 to May 2011	~11 months
Acoustic Wave and Current Profilers (AWACs) in the MORL R3 zone	58.248	-2.746	July 2010 to December 2010	100 days
	58.140	-2.695	July 2010 to December 2010	106 days
	58.036	-3.152	July 2010 to January 2011	124 days
	58.167	-2.900	July 2010 to February 2011	103 days
Acoustic Wave and Current Profilers (AWACs) in the MORL R3 zone	58.248	-2.746	July 2010 to December 2010	100 days
	58.140	-2.695	July 2010 to December 2010	106 days
	58.036	-3.152	July 2010 to January 2011	124 days
	58.167	-2.900	July 2010 to February 2011	103 days
Directional wave buoy in BOWL application site	58.307	-2.810	February 2010 to November 2010	~9 months
WaveNet Moray Firth wave buoy (Cefas)	57.97	-3.33	August 2008 to January 2011	~2 years
Jacky platform wave buoy	58.183	-2.979	September 2008 to March 2009	~6 months

Data Source	Latitude (°N)	Longitude (°E)	Period Analysed	Duration
Beatrice Alpha Oil Platform (Comber, 1993)	58.12	-3.09	Summer to winter 1990	<1 year
Outer Moray Firth Geosat Altimeter (NERC, 1992)			1986-1989	~3 years

Site-specific Surveys

2.4.2.3 The technical baseline environment has been established through an extensive review of the available primary data (information that is collected directly from the original sources for a specific research project or purpose) and secondary sources (information that has been collected, processed, and published by another source and then being applied), including the following site-specific surveys:

- Metocean measurements: wave (period, height and direction) and current (speed direction) within the Caledonia North Site (SWLB075 and SWLB080; Table 2–5); and
- Geophysical, geotechnical and benthic surveys across the Caledonia North Site and within Caledonia North OECC (see Volume 7B, Appendix 4-1: Environmental Baseline Report (Array Area) and Volume 7B, Appendix 4-2: Environmental Baseline Report (Offshore Export Cable Corridor).

2.4.3 Baseline Description

2.4.3.1 The Baseline environment description across the study area is described in detail within Volume 7B, Appendix 2-1: Marine and Coastal Processes Baseline Technical Report and a summary provided in the following sections. This has been achieved through the combined analysis of site specific survey data (including metocean and geophysical), information previously collected to inform the construction and operation of nearby OWFs including Moray East and Moray West (as shown in Figure 2-1) and data collected as part of the regional coastal and seabed monitoring programmes.

Caledonia North Site

Metocean

2.4.3.2 Data collected from June to October 2023 revealed a mean significant wave height of 1.2m, with a maximum of 10.5m and a minimum of 0.2m. Wave period showed little variation between the two wave buoys, with a maximum and minimum reading of 11.3 to 2.8 seconds respectively.

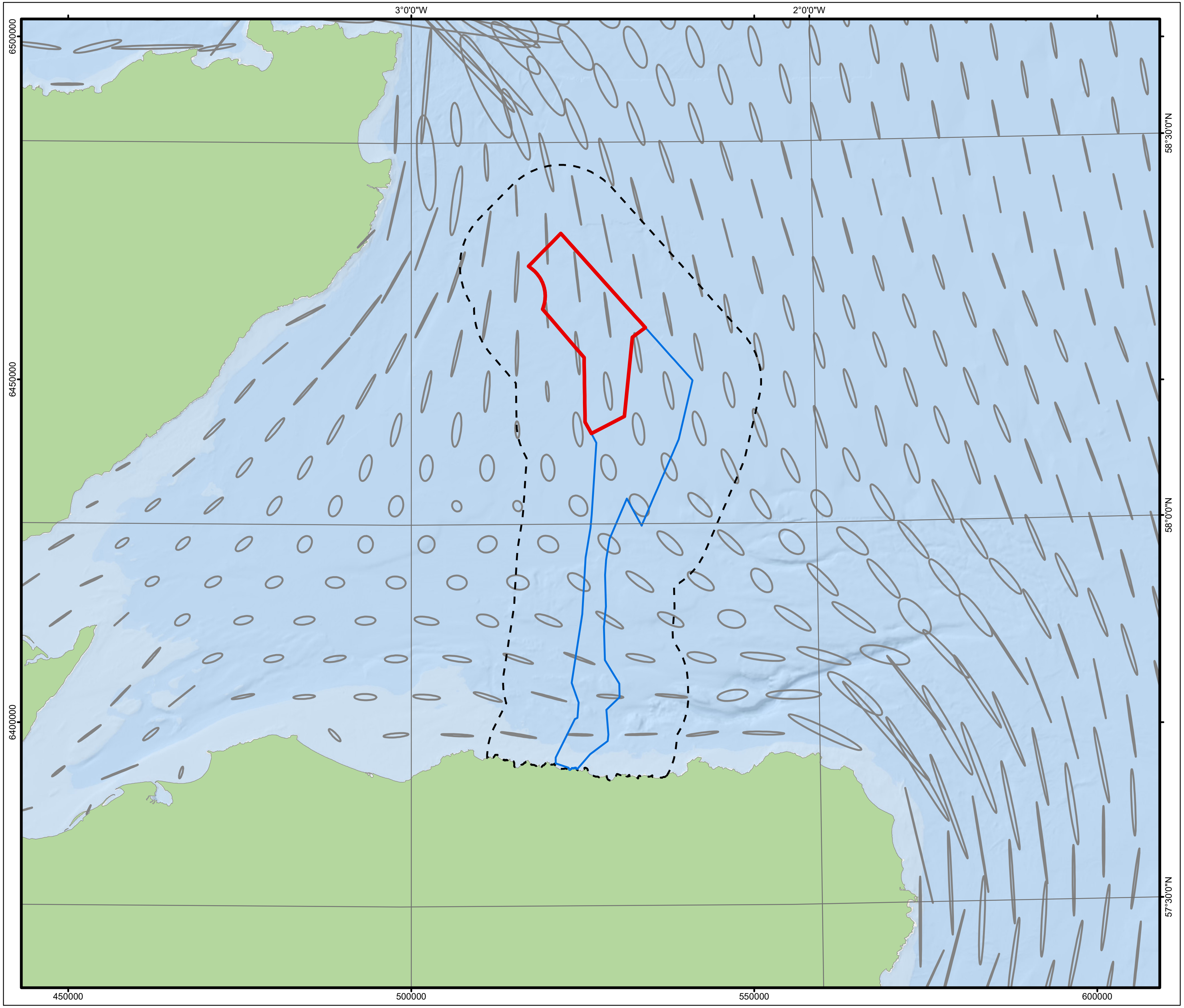
2.4.3.3 Wave buoy SWLB075, located within the Caledonia North Site, showed that the highest proportion of waves originated from the north-east (36%), with only 7.8% of waves coming from the south-east. Waves originating from the north have a frequency of 18% (Figure 2-1 and Table 2–5).

2.4.3.4 Spring tidal range varies between 2 and 3m within the Caledonia North Site whereas the neap tidal range varies between 1 and 2m (ABPmer, 2017[49]). The tidal excursion ellipses within the Caledonia North Site are 6km at the most northern point, decreasing southward, with a north-south orientation (ABPmer, 2017[49]; see Figure 2-2).

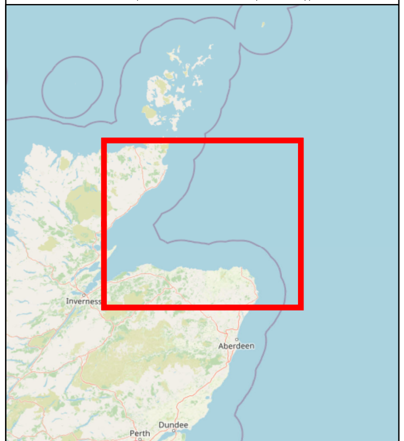
2.4.3.5 Within the Caledonia North Site average surface current speed is 0.19m/s with a maximum of 0.57 metres per second (m/s). The highest current speeds were observed flowing southward, whereas the lowest observed flow eastward. Surface current direction was predominantly southward for 28% of the time and northward for 18.5%. Near-bed current flows in the south and west 26% on average with currents to the north 17.5% of the time and south-east 12.5% of the time (Volume 7B, Appendix 2-1: Marine and Coastal Processes Baseline Technical Report). These differ with SWLB080 (Figure 2-1 and Table 2–5) which has a much larger proportion flowing to the south-west, south-east and east in comparison, which is due to localised bathymetry.

2.4.3.6 Large storm surges in the Moray Firth are reported to be of relatively small amplitude (approximately 1m to 1.25m). Storm surges can cause a surface tidal flow reaching up to 1m/s in the Caledonia North Site during a storm event (ABPmer, 2017[49]; Flather *et al.*, 1998[50]).

2.4.3.7 The majority of the Caledonia North is stratified with a well-mixed layer extending an average of 10m in depth. A thermocline is present between 5m and 20m depth. One isolated location towards the east of the Caledonia North Site is identified to be well mixed (see Volume 7B, Appendix 4-1: Environmental Baseline Report (Array Area); Miller *et al.*, 2014[51]).



Caledonia North Site
Caledonia North Offshore Export Cable Corridor
10km Zone of Influence
Tidal Excursion Ellipses



0 10 20 30 km

REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	09/09/2024	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm

GoBe APEM Group

CONTRACTOR DRAWING NO UKCAL1_GO_WNF_MPR_MAP_00127	CONTRACTOR REV 01
GEODETIC PARAMETERS WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE Figure 2-2: Tidal Excursion Ellipses (ABPmer, 2008)	
STATUS Approved	SCALE 1:750,000
DRAWING NUMBER N/A	SHEET NO 01 of 01 / REV N/A

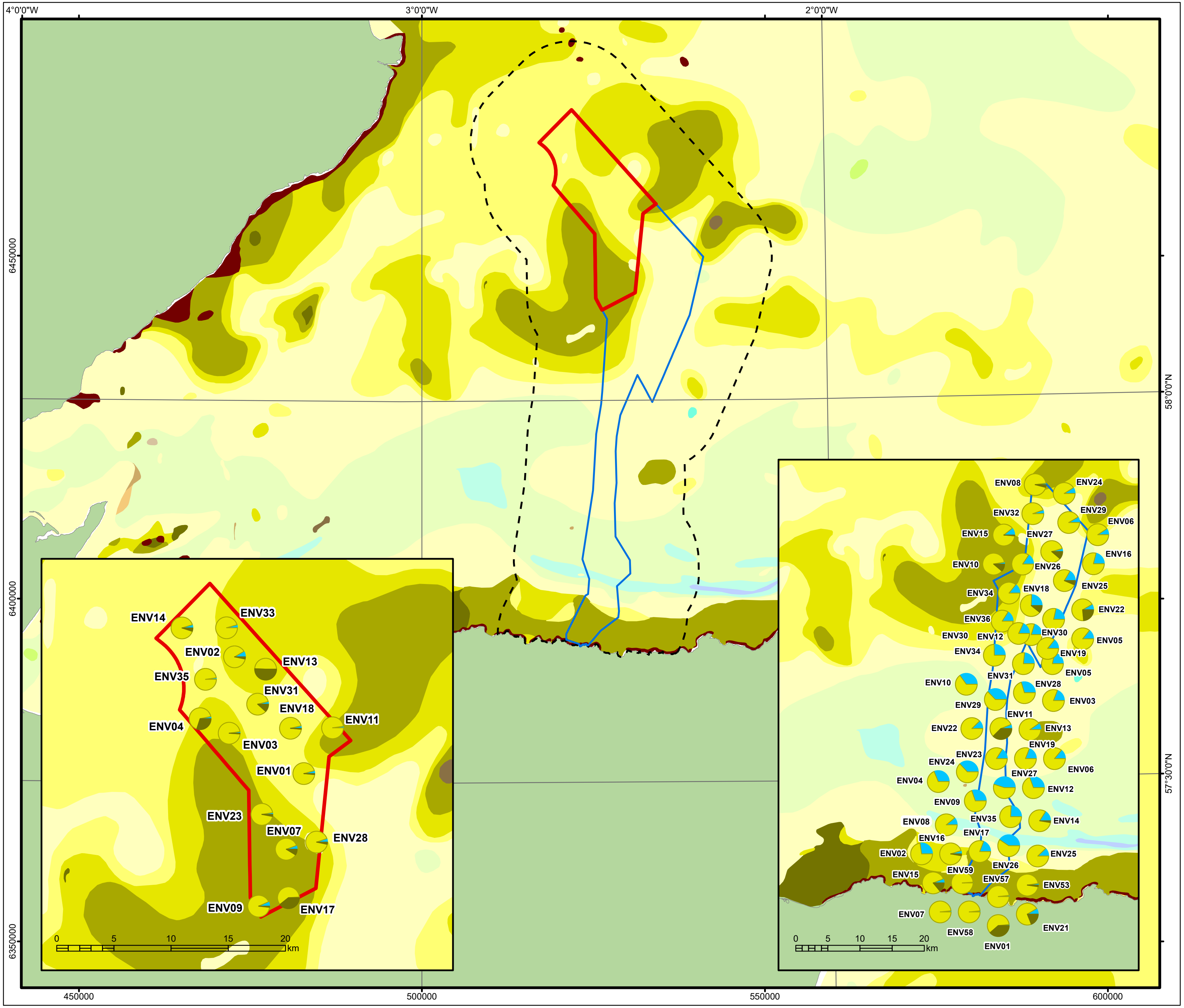
Seabed Features

2.4.3.8 The western part of the Caledonia North Site is underlain by Lower Cretaceous strata mostly calcareous argillite with local sandstones (Andrews *et al*., 1990[52]). The eastern part of the Caledonia North Site is underlain by Upper Cretaceous chalk and marl (Andrews *et al*., 1990[52]; BGS, 1984[53]). Quaternary deposit which overlay these lithologies are between 5m to 20m thick with thicker regions to the north, as well as rapid thickening to the west (BGS, 2020[54]; Vysus Group, 2021[55]). The presence of chalk correlates with the thinning of the quaternary deposit (10m or less) (Vysus Group, 2021[55]).

2.4.3.9 Under the modified Folk 16 classification (Folk, 1954[56]), stations ranged from sand to sandy gravel with sandy gravel sediments being dominant throughout the Caledonia North Site (see Volume 7B, Appendix 4-1: Environmental Baseline Report (Array Area); Figure 2-3). Finer sediment classified as 'Sand', according to the modified Folk 16 classification (Folk, 1954[56]), was found at three stations, two to the north and one to the east of the Caledonia North Site.

2.4.3.10 Across the Caledonia North Site, water depths range between approximately 35m and 60m Lowest Astronomical Tide (LAT); however, depths are mostly comprised between 50 and 60m LAT (see Volume 7B, Appendix 4-1: Environmental Baseline Report (Array Area); Figure 2-1). The shallowest depths are found in the north-eastern part of the Caledonia North Site, associated to the eastern edge of the Smith Bank (Figure 2-1).

2.4.3.11 Seabed features include soft ripples, ripples and geophysical data shows sand ridges on the edges of Smith Bank, and an active sediment transport in the north of the Caledonia North Site (see Volume 7B, Appendix 4-1: Environmental Baseline Report (Array Area); also see details in Volume 7B, Appendix 2-1: Marine and Coastal Processes Baseline Technical Report).



Caledonia North Site
Caledonia North Offshore Export Cable Corridor
10km Zone of Influence

Seabed Sediments (Folk, 1954)

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

PSA Results (%)

- Fines
- Sand
- Gravel

0 5 10 15 20 km

REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	09/09/2024	Approved	EV	BB	DH

CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_MPR_MAP_00128
CONTRACTOR REV: 01
GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)
DRAWING TITLE:

Figure 2-3: Surficial Seabed Sediments (Folk, 1954)

STATUS: Approved
SCALE: 1:750,000
DRAWING NUMBER: N/A
SHEET NO: 01 of 01
REV: N/A

Sediment Transport

2.4.3.12 Regional scale sediment transport indicates wave and tide dominated bedload sediment transport into the Moray Firth from the north, parallel to the tidal ellipses (Reid and McManus, 1987[57]; Holmes *et al*., 2004[58]). Sediment transport within the Moray Firth is wave-dominated, as tidal current energy is low and largely incapable of bedload sediment transport beyond fine sand-sized material and smaller (Holmes *et al*., 2004[58]; Moray Offshore Windfarm (East) Limited, 2012[59]).

2.4.3.13 Suspended Sediment Concentrations (SSCs) are typically low in the Caledonia North Site, approximately less than 5mg/l; however, near the seabed SSC levels may be significantly elevated during storm events, hence why the SSC looks higher during January (Cefas, 2016[60]). With SSC expected to be higher in the south due to finer sediments.

Caledonia North OECC

Metocean

2.4.3.14 Mean wave height along the Caledonia North OECC is approximately 1.5m, with most waves being between 0 and 1m (ABPmer, 2017[49]). The majority of waves originate from the west (25%) and the north-east (21%). Waves from the south-east are sheltered closer to the coast (ABPmer, 2017[49]).

2.4.3.15 The tidal ellipses increase along the Caledonia North OECC from approximately 2km to 4km (ABPmer, 2017[49]; Figure 2-2). The spring tidal range varies between 2m and 4m increasing towards the coast (ABPmer, 2017[49]). The neap tidal range varies from 1m to 2m. Peak spring flow varies between 0.11m/s to 0.50m/s (ABPmer, 2017[49]). Changes in tidal range and current speed along the Caledonia North OECC is due to bathymetric variation such as the presence of the Southern Trench.

2.4.3.16 Near-bed peak spring tidal currents in the Southern Trench are estimated to exceed 0.7m/s in some parts, oriented east-west, compared to adjacent 0.35m/s to 0.65m/s (DECC, 2004[61].)

2.4.3.17 Most waves at the coast have an annual significant wave height of less than 1m (50% of the record), although during storm events this may reach over 2m, particularly from the north and north-east. Waves predominately originate from the north-east (approximately 30%), followed by west and east (approximately 20% each) (ABPmer, 2018[62]).

2.4.3.18 Tidal currents along the south of the Moray Firth (up to 13km offshore) is predominantly eastward, with a 9-hour flood and a 3-hour ebb (BEIS, 2016[63]). Along the southern shore of the Moray Firth, tidal excursion ellipses are rectilinear, directed east-west, and vary from 1km to 10km from the inner Moray Firth to the outer Moray Firth (ABPmer, 2017[49]; see Figure 2-2).

Seabed Features

2.4.3.19 Bed rock geology increases in age towards the coast from Cretaceous to Permo-Triassic (Andrews *et al*., 1990[52]). Quaternary deposits are between 5m and 20m thick (BGS, 2020[54]).

2.4.3.20 Surficial sediments along the Caledonia North OECC are characterised mainly by sands and gravels close to the Caledonia North Site, with the mud content of sediments increasing towards the shore, as shown in Figure 2-3 (BGS, 2020[54]). Sediments generally become progressively finer as water depth increases, with isolated patches of coarser sediment associated with bathymetric highs (BGS, 2020[54]).

2.4.3.21 Water depth across the Caledonia North OECC vary up to 109m LAT in the southeast, approximately 10km from shore, with an average gradient of less than 1 degree (°). There are north to south orientated ridges of bedrock with localised gradients up to 70° found in the south of the Caledonia North Site. In the central part of the Caledonia North OECC, east to west orientated trenches are interpreted as furrows, with measured depths of less than 1m below the surrounding seabed and gradients up to 5° on the flanks (see Volume 7B, Appendix 4-2: Environmental Baseline Report (Offshore Export Cable Corridor)).

2.4.3.22 The geology at the Landfall Site is comprised of sedimentary Devonian Old Red Sandstone and metamorphic Precambrian Dalradian successions (Holmes *et al*., 2004[58]).

2.4.3.23 The Landfall Site, situated located at Stake Ness, exhibits isolated pocket beaches constrained by rocky headlands, with coastal areas characterized by plateau-like terrain, cliffs ranging from 30 to 90m high, rocky platforms, and occasional deep ravines (Barne *et al*., 1996[64]; Ramsay and Brampton, 2000[65]; see Figure 2-3).

Sediment Transport

2.4.3.24 Sandwaves and sand patches have been mapped in the inner Moray Firth aligned parallel to the southern coast of the Moray Firth, suggesting both eastward and westward sediment movement with an eastward dominant direction. This correlates both the flow direction and speed observed along this coast (Reid and McManus, 1987[57]; Andrews *et al*., 1990[52]).

2.4.3.25 The pocket beaches in the vicinity of the Landfall Site are effectively self-contained units with little gain or loss of beach material (Ramsay and Brampton, 2000[65]). However, the beach material within these bays is relatively dynamic, being redistributed depending upon storm conditions and river flows.

Future Baseline Environment

2.4.3.26 Consideration of the future baseline involves anticipating the operational lifespan of Caledonia North, with a focus on the Representative Concentration Pathway (RCP) 8.5 scenario for greenhouse gas emissions (Palmer *et al.*, 2018[66]). UKCP18 predicts a rise in mean sea level (MSL) by 0.5m to 0.6m by 2065 along the Moray Firth coast (Palmer *et al.*, 2018[66]), with an increase in extreme surge events (IPCC, 2021)[67].

2.4.3.27 The Moray Firth coast is comprised of 59% soft coastlines, with varying rates of coastal retreat, advance, and stability over the past 50 years (Hansom *et al.*, 2017[68]).

2.4.3.28 Significant wave height may decrease by approximately 10% in the Moray Firth, correlating with a larger decrease in wave energy by 2100 (RCP 8.5 scenario; Moray Offshore Windfarm (East) Limited, 2012[69]; Bonaduce *et al.*, 2019[70]; Meucci *et al.*, 2020[71]).

2.4.3.29 Rising sea levels may enhance erosion, especially in areas like Banff Bay, which is influenced by alternating marine and fluvial energies (Smith, 1986[72]).

Designated Sites and Protected Species

2.4.3.30 Designated sites in the vicinity of the study area, which are designated for the protection and conservation of marine habitats, species and features up to MHWS are shown in Figure 2-1. The Caledonia North OECC crosses the Southern Trench MPA, which is designated for the protection of the following features related to Marine and Coastal Processes:

- Burrowed mud;
- Fronts;
- Quaternary of Scotland (subglacial tunnel valleys and moraines);
- Shelf deeps; and
- Submarine mass movement (slide scars).

2.4.3.31 The proposed Landfall Site spatially overlaps the Cullen to Stake Ness Coast Site of Special Scientific Interest (SSSI), designated for habitats and notable geology.

2.4.4 Do Nothing Baseline

2.4.4.1 If Caledonia North does not come forward, an assessment of the future baseline conditions has also been carried out and is described within this section.

2.4.4.2 It is necessary to take account of potential effects of climate change on the marine environment. Mean sea levels are likely to rise during the 21st Century as a consequence of either vertical land (isostatic) movements or changes in eustatic sea level.

2.4.4.3 Tide gauge records from around Scotland's coast show a high degree of year-to-year change in coastal water levels (typically several centimetres). The long-term average mean sea-level change in the Moray Firth region, as estimated from a historical climate model run (UKCP18), was 5cm (likely range between 2cm and 8cm) higher in 2018 than the 1981-2000 average (Palmer *et al.*, 2018[66]). For reference, the Scottish average is estimated to be 5cm (likely range between 3 and 8cm). By 2065 (approximately 35 years of the Caledonia North lifetime), mean sea level rise in the Moray Firth region is anticipated to be between approximately 22 and 42cm for a medium emissions scenario (UKCP18 RCP4.5; Palmer *et al*., 2018[66]).

2.4.4.4 Sea surface temperature in the Moray Firth region has increased by 0.1°C per decade on average since 1870 (Cornes *et al*., 2023[73]). The rate of increase has not been constant, and in the last 30 years (1988-2017), the rate of change in temperature was +0.2°C per decade (Cornes *et al*., 2023[73]).

2.4.4.5 These changes in the physical environment are also having an impact on marine life, such as changes to their metabolism, changes in seasonality and the timing of events in natural cycles, and changes in their distribution. These changes have consequences for the growth, survival and abundance of species, including those of commercial importance or critical to conservation objectives. The inter-relationships of marine and coastal processes impacts on marine life are described in Section 2.9.

2.4.5 Data Gaps and Limitations

2.4.5.1 Uncertainty exists with regard to characterisation of the future baseline with respect to global climate change, such as the future rates of sea level rise and the extent to which future changes in the wave regime may occur. The consequential impact on how coastline may respond to a future wave climate acting in combination with higher than present sea levels is also uncertain.

2.4.5.2 The modelled sediment plume and associated sedimentation present some uncertainties as it is not sure how the seabed geology will respond to drilling and jetting. There are a number of factors which determine the exact sediment volume that is entrained into the water column; including the type of drilling/cable installation equipment used, the variability of the forcing conditions at the installation time (for example, the waves and tidal conditions) and the mechanical properties of the geological units. In the absence of this detailed information, a series of potential release scenarios have been considered in below assessment and can be found in details Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report. Together, these scenarios capture the worst-case impacts in terms of the highest concentration and persistent suspended sediment plumes, and the maximum and greatest spatial extent of changes in bed level elevation.

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

2.4.5.4 Despite the uncertainties presented above, the availability of robust data (as outlined in Section 2.4.2.1, Table 2–4 and Table 2–5) relevant for the characterisation and assessment of Marine and Coastal Processes, is sufficiently robust to underpin the assessment presented here and an overall high confidence is placed on the assessment.

2.5 EIA Approach and Methodology

2.5.1 Overview

2.5.1.1 This section outlines the methodology for assessing the likely significant effects on the relevant receptors from the construction, O&M and decommissioning of Caledonia North. Full details of the methodology, including relevant assumptions and limitations, can be found in Volume 1, Chapter 7: EIA Methodology.

2.5.2 Impacts Scoped into the Assessment

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

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

2.5.2.3 For the most part, physical processes are not in themselves receptors but are instead 'pathways'. However, changes to physical processes have the potential to indirectly impact other environmental receptors (Lambkin *et al.*, 2009[5]). For instance, the creation of sediment plumes (the potential for which is considered in this chapter) may lead to settling of material onto benthic habitats. The potential significance of this particular change is assessed in Volume 3, Chapter 4: Benthic Subtidal and Intertidal Ecology.

2.5.2.4 The Offshore Scoping Report (Volume 7, Appendix 2) was submitted to MD-LOT in September 2022. The Scoping Report set out the overall approach to assessment and allowed for the refinement of Caledonia North over the course of the assessment. The proposed scope of the assessment is set out in Table 2–6.

Table 2–6: Impacts Scoped into the Marine and Coastal Processes Assessment.

Potential Impact	Phase	Nature of Impact
Increases in suspended sediment concentrations (SSCs) and change to seabed levels	Construction and Decommissioning	Indirect
Potential impacts to seabed morphology (sandbanks and notable bathymetric depressions)	Construction and Decommissioning	Direct
Modifications to littoral transport, coastal behaviour (erosion), including at the Landfall Site	Construction and Decommissioning	Direct
Potential impacts to seabed morphology	O&M	Direct
Seabed scouring	O&M	Direct
Modifications to the wave and tidal regimes and associated impacts to morphological features	O&M	Indirect
Cumulative increases in SSC and changes to seabed levels	Construction and Decommissioning	Indirect
Cumulative modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime	O&M	Indirect

2.5.3 Impacts Scoped out of the Assessment

2.5.3.1 The impacts scoped out of the assessment and the justification for this, are listed in Table 2–7.

Table 2–7: Impacts Scoped Out for Marine and Coastal Processes.

Potential Impact	Justification
Modifications to stratification and frontal features	Available evidence suggests that modifications to turbulent mixing from Wind Turbine Generator (WTG) foundations would not be sufficient to cause significant changes to thermal stratification in the vicinity of the Caledonia North Site and furthermore would not reach the area of haline stratification located along the southern coast of the Moray Firth.

2.5.4 Assessment Methodology

2.5.4.1 The project-wide generic approach to assessment is set out in Volume 1, Chapter 7: EIA Methodology. The assessment methodology is consistent with that provided in the Offshore Scoping Report (Volume 7, Appendix 2). The assessment considers consultation undertaken throughout the pre-application stage presented in Table 2–3.

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

- Numerical modelling specific to Caledonia North (Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report);
- The 'evidence base' containing monitoring data collected during the construction and O&M of other OWF developments (Table 2–4);
- Analytical assessments of site-specific data (Table 2–5); and
- Standard empirical equations (e.g., the potential for scour development around structures).

2.5.4.3 The assessment also considers likely naturally occurring variability in, or long-term changes to, marine physical processes over the lifetime of Caledonia North due to natural cycles and/or climate change (e.g., sea level rise). This allows a reference baseline level to be established against which the potentially impacted environment relevant to Marine and Coastal Processes can be compared, throughout the project lifecycle. The existing Marine and Coastal Processes are described in detail within Volume 7B, Appendix 2-1: Marine and Coastal Processes Baseline Technical Report which accounts for the potential effects of climate change.

2.5.4.4 The assessment of impacts on Marine and Coastal Processes has been considered over two spatial scales. These are:

- Far-field - Defined as the area surrounding the Caledonia North Site and Caledonia North OECC over which indirect changes may occur (in this case the study area); and
- Near-field - Defined as the footprint of the Caledonia North Site and Caledonia North OECC.

2.5.4.5 The Marine and Coastal Processes features that are considered as potential receptors have been guided by tidal excursion. As shown in Figure 2-1, the following receptors are considered:

- Adjacent coastlines;
- Cullen to Stake Ness Coast SSSI;
- Nearby subtidal sandbanks and sandwave areas; and
- Southern Trench MPA.

2.5.4.6 These receptors have been identified on the basis of:

- Professional judgement, local and regional specialist experience;
- Outcomes from the consultation process; and
- Reference to best practice guidance.

2.5.4.7 The assessment of effects upon physical processes receptors is a systematic process that is determined by taking into account the 'magnitude of the impact' and 'sensitivity' of the receptor.

Magnitude of Impact

2.5.4.8 The magnitude of impact describes the extent or degree of change that is predicted to occur to a receptor. It has been assessed using expert judgement and described qualitatively with a standard semantic scale. Definitions for each term are provided in Table 2–8. These expert judgements regarding the magnitude of effect relative to baseline conditions have been made by experienced marine physical process specialists and formed following consideration of the information sources previously set out in Table 2–4.

Table 2–8: Impact Magnitude.

Magnitude	Description/Reason
High	Permanent changes across the near- and large parts of the far-field to key characteristics or features of the particular environmental aspect's character or distinctiveness. Impact is of long-term duration (i.e, over the lifetime of Caledonia North).
Medium	Permanent changes, over the near- and parts of the far-field, to key characteristics or features of the particular environmental aspect's character or distinctiveness. Impact is of medium-term duration (i.e., during the operational phase of Caledonia North).
Low	Noticeable, temporary (for part of the Caledonia North lifetime) change, or barely discernible change for any length of time, restricted to the near-field and immediately adjacent far-field areas, to key characteristics or features of the particular environmental aspect's character or distinctiveness. Impact is of short- to medium-term duration (i.e., during the construction period of Caledonia North).
Negligible	Changes which are not discernible from background conditions. Impact is of short-term duration (i.e., duration of individual construction works).

Receptor Sensitivity

2.5.4.9 The importance and sensitivity of each receptor has been assessed using expert judgement and described with a standard semantic scale using the terms negligible, low, medium and high (Table 2–9). The scale of sensitivity for a receptor has been determined based on several criteria listed in Volume 1, Chapter 7: EIA Methodology.

Table 2–9: Receptor sensitivity.

Receptor Sensitivity	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.

Determining Significance of Effect

2.5.4.10 The consideration of the magnitude of a potential impact and sensitivity of the receptor determines an expression for the overall significance of the adverse or positive effect (Table 2–10). This determination may be quantitative or qualitative and is often informed by expert judgement.

2.5.4.11 Negligible and minor effects are categorised as 'not significant' in EIA terms, and major or moderate effects are categorised as 'significant' in EIA terms (Table 2–10).

Table 2–10: Significance of effect matrix.

Significance of Effect		Sensitivity of Receptor			
		Negligible	Low	Medium	High
Impact Magnitude	Negligible	Negligible	Negligible	Negligible	Negligible
	Low	Negligible	Negligible	Minor	Minor
	Medium	Negligible	Minor	Moderate	Moderate
	High	Negligible	Minor	Moderate	Major

2.5.5 Approach to Cumulative Impacts

2.5.5.1 The Cumulative Impact Assessment (CIA) assesses the impact associated with Caledonia North together with other relevant plans, projects and activities. Cumulative effects are therefore the combined effect of Caledonia North in combination with the effects from a number of different projects, on the same receptor or resource.

2.5.5.2 The approach to the CIA for Marine and Coastal Processes follows the process outlined in Volume 1, Chapter 7: EIA Methodology.

2.5.5.3 The list of relevant developments for inclusion within the CIA is outlined in Volume 7A, Appendix 7-1: Cumulative Impact Assessment Methodology.

2.5.5.4 Developments which are located within 10km of Caledonia North have the potential to result in a cumulative effect. Developments which are either operational or in the decommissioning stage are considered to be part of the baseline and are not considered within the assessment.

2.5.6 Embedded Mitigation

2.5.6.1 Where possible, mitigation measures have been embedded into the design of Caledonia North. Where embedded mitigation measures have been developed into the design with specific regard to Marine and Coastal Processes, these are described in Table 2–11.

2.5.6.2 The subsequent impact assessment presented in Sections 2.7 to 2.10 take into account this embedded mitigation.

Table 2–11: Embedded Mitigation.

Code	Mitigation Measure	Securing Mechanism
M-1	Development of and adherence to a Cable Plan (CaP). The CaP will confirm planned cable routing, burial and any additional protection and will set out methods for post-installation cable monitoring.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences.
M-2	Development of and adherence to a Development Specification and Layout Plan (DSLP). The DSLP will confirm the layout and design parameters of Caledonia North.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences.
M-3	Development of and adherence to a Construction Method Statement (CMS). The CMS will confirm construction methods and the roles and responsibilities of parties engaged in construction. It will detail any construction-related mitigation measures.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences.
M-4	Scour protection where there is the potential for scour to develop around infrastructure (foundations and cables).	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences.
M-5	Where practicable, cable burial will be the preferred means of cable protection. Cable burial will be informed by the cable burial risk assessment and detailed within the CaP.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences.
M-7	Suitable implementation and monitoring of cable protection (via burial, or external protection where adequate burial depth as identified via risk assessment is not feasible), as detailed within the CaP.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences.
M-106	Landfall installation methodology (Horizontal Directional Drilling) will avoid direct impacts to the intertidal area.	To be secured as a condition of the Transmission Asset Marine Licence.

2.6 Key Parameters for Assessment

2.6.1.1 Volume 1, Chapter 3: Proposed Development Description (Offshore) details the parameters of Caledonia North using the Rochdale Envelope approach. This section identifies those parameters during construction, O&M and decommissioning relevant to potential impacts on Marine and Coastal Processes.

2.6.1.2 This section identifies the worst-case-scenario for Marine and Coastal Processes. This is provided in Table 2–12 for each of the potential effects identified during Scoping and from subsequent discussions with stakeholders as part of the pre-application consultation process.

2.6.1.3 Defining the worst-case-scenario for sediment disturbance activities is highly complex as the actual disturbance will be temporally and spatially variable (and dependant upon the metocean conditions at the time of activity). For sediment plumes, the worst-case-scenario is intended to be representative in terms of peak concentration, plume extent and plume duration but will not correspond to a single sediment disturbance activity.

2.6.1.4 The same holds true for sediment deposition at the bed, where the worst-case-scenario is a representation of maximum deposit thickness, maximum footprint extent or likely duration.

Table 2–12: Worst Case Assessment Scenario Considered for Each Impact as Part of the Assessment of Likely Significant Effects.

Potential Impact	Assessment Parameter	Explanation
Construction		
Impact 1: Temporary increases in SSC and change to seabed levels	**Construction/installation:** ▪ Dredging of WTG and OSP foundations: o 77 jacket with suction caissons WTG foundations; o The volume of sediment disturbed per WTG is estimated to be 90,750m^3, which corresponds to a total of 6,987,750m^3; o Two jacket with suction caissons OSP foundations; o The volume of sediment disturbed per OSP is estimated to be 90,750m^3, which corresponds to a total of 181,500m^3; o Overall total sediment disturbed by dredging = **7,169,250m^3**. ▪ 77 inter-array cables with a total length of 360km; o Circular cross section trench shape; o Maximum affected seabed width of 15m; o Maximum burial depth of 3m; o Jet trencher installation method; o Assumed installation rate of 700m/hr; o Total volume of disturbance = **16,200,000m^3**; ▪ One interconnector cables with a length of 30km; o Circular cross section trench shape; o Maximum affected seabed width of 15m; o Maximum burial depth of 3m; o Jet trencher installation method; o Assumed installation rate of 700m/hr; o Total volume of disturbance = **1,350,000m^3**; ▪ Two offshore export cables with a total length of 180km; o Circular cross section trench shape;	The worse-case-scenario for sediment disturbance activities will be temporally and spatially variable (depending upon the metocean conditions at the time). For sediment plumes, the worse-case-scenario is intended to be representative in terms of peak concentration, plume extent and plume duration but will not correspond to a single sediment disturbance activity (see details in Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report). The same applies for sediment deposition at the bed, where the worse-case-scenario is a representation of maximum deposit thickness, maximum footprint extent or likely duration. The creation of biogenic reef is not expected to result in any increases in SSC. Seabed preparation works would be required prior to installation. The use of a Trailer Suction Hopper Dredger (TSHD) is the realistic worst-case-scenario option. Sediment volumes disturbed through seabed levelling are greatest for the WTGs with monopile foundations option, and for OSPs with jackets with suction buckets foundations.

Potential Impact	Assessment Parameter	Explanation
	o Maximum affected seabed width of 15m; o Maximum burial depth of 3m; o Jet trencher installation method; o Assumed installation rate of 700m/hr; o Total volume of disturbance = **8,100,000m³**; ▪ Savewave clearance via dredging (cables within the Caledonia North Site); ▪ Sandwave clearance via dredging (offshore export cables); ▪ Horizontal Directional Drilling (HDD) drilling fluid release: o Volume and mass of drilling fluid release per HDD conduit: 450m³; o Number of HDD conduits: 2; and o Total volume and mass of drilling fluid released = **900m³**.	It is noted that the drilling of monopile WTG and OSP foundations could give rise to increased SSCs; however, the worst-case scenario in terms of maximum temporary disturbance has been assumed to be dredging associated with the installation of jacket with suction caisson foundations. Cable installation may require some combination of jetting, ploughing, trenching and/or cutting type installation techniques. The realistic worst-case-scenario option is the use of jet trenching methods, which develops the largest trench cross-section with the greatest potential to displace fine sediments into the water column to the same height as the depth of the trench. The fastest trenching rate represents the highest release rate of sediments operating in locations with the largest contribution of fine sediments. HDD operations are expected to have localised and short-term effects on SSC concentrations due to the potential release of bentonite during punch-out in the nearshore exit pit. The period of release for bentonite is estimated to be 12 hours to accommodate both initial punch-out and the subsequent reaming processes. Accordingly, the release rate has been estimated at 3,195g/s over this period.
Impact 2: Potential impacts to seabed morphology	Refer to Impact 1.	During the construction phase, the primary means by which sandbanks and sandwaves

Potential Impact	Assessment Parameter	Explanation
(sandbanks and notable bathymetric depressions)		could be impacted is through the interruption of sediment transport patterns via sandwave clearance and other seabed preparation activities.
Impact 3: Modifications to littoral transport, coastal behaviour (erosion), including at the Landfall Site	Horizontal Directional Drilling (HDD): ▪ Exit pit location for HDD: Subtidal; ▪ Two HDD exit pits (one per offshore cable), excavated to a depth of up to 10m; ▪ Estimated maximum excavated material volume = 611m^3 per pit and total = **1,222m^3**; ▪ Exit pits remain open for up to nine months and then backfilled on completion.	The primary means by which the Landfall Site morphology could potentially be impacted during the construction phase is through sediment disturbance during the HDD exit pit excavation within the subtidal area, resulting in associated changes to bed levels and modification of hydrodynamic/sediment transport processes.
Operation and Maintenance		
Impact 4: Potential impacts to seabed morphology	**Operation:** ▪ 77 jacket with suction caisson foundations WTGs, with a minimum WTG foundation spacing of 944m; ▪ Two OSPs with jacket with suction caissons foundations. ▪ Standard cable protection options include rock placement, concrete mattresses, grout bags, iron cast, etc; and o Maximum cable protection height for all cable type = 1.5m. Total surface of disturbance for all cable type together = **4,140,000m^2**. ▪ Inter-array cables protection: o 30% of maximum cable protection required, which is equivalent to 108km; o Maximum protection width = 20m;	An individual foundation will locally interfere with passing waves, currents and sediment transport with a group of foundation structures having the potential to develop an array-scale blockage effect, taking into account the number, arrangement, and spacing of foundations. The 77 jacket with suction caisson WTG foundations scenario is identified as having the highest individual blockage due to the dimensions of the foundations. The greatest total in-water column blockage to currents, waves and sediment transport processes is therefore represented by an array comprising of 77 jacket foundations with

Potential Impact	Assessment Parameter	Explanation
	o Total surface of disturbance for inter-array cable protection = 2,160,000m²; ▪ Interconnector cable protection: o 30% of maximum cable protection required, which is equivalent to 9km; o Maximum protection width = 20m; o Total surface of disturbance for interconnector cables = 180,000m²; ▪ Offshore export cable protection: o 50% of maximum cable protection required, which is equivalent to 90km; o Maximum protection width = 20m; o Total surface of disturbance for OECs = 1,800,000m². ▪ Eight export cable crossing; ▪ Ten inter-array cable crossing; ▪ Two interconnector cable crossing; and ▪ Rock berm and/or concrete mats protection with height up to 1.5m, length up to 150m and width up to 20m per crossing. Overall, Caledonia North Site affected up to **36,000m²** and up to **24,000m²** within the Caledonia North OECC.	suction caissons WTGs. This is in addition to two OSPs. Cable protection in the Caledonia North OECC has the potential to change the form and function of the seabed.
Impact 5: Seabed scouring	**Operation:** ▪ 77 WTG monopile foundations (14m diameter) or jacket with suction caisson foundations (15m diameter); and ▪ Two OSPs with monopile foundations (14m diameter) or jacket with suction caisson foundations (15m diameter).	Each foundation type may produce different scour patterns. Monopiles and jacket foundations with suction caissons have been considered as the worse-case-scenario. The foundation type, size and number producing the greatest area and/or volume of influence cannot be identified in advance of the assessment.

Potential Impact	Assessment Parameter	Explanation
Impact 6: Modifications to the wave and tidal regimes and associated impacts to morphological features	**Foundations:** ▪ For the modification on tidal regime: o 77 fixed WTG jacket with suction caissons foundations with a minimum WTG foundation spacing of 944m; o Two OSPs with jacket with suction caissons foundations. ▪ For both WTG and OSP foundations, jackets with suction caissons are composed of: o A maximum of four legs, with each leg having a diameter of 5m; and o Suction bucket diameter of 15m and suction bucket height 30m above seabed. **Cable Protection:** ▪ Standard options include rock placement, concrete mattresses, grout bags, iron cast, etc; o Maximum cable protection width of 20m and height of 1.5m; ▪ Total length of cables which may require seabed protection (see Impact 4): o 108km of inter-array cable length, for a total area of 2,160,000m^2; o 9km of interconnector cable length, for a total area of 180,000m^2; o 90km of export cable length within the array area, for a total area of 1,800,000m^2; and o Overall cable protection area of **2,340,000m^2** within the Caledonia North Site and **1,800,000m^2** within the Caledonia North OECC. **Cable Crossing:**	The 77 WTG scenario of jacket with suctions caissons foundations is identified as having the highest individual blockage due to their wider diameter at the seafloor. The greatest total in-water column blockage to currents, waves and sediment transport processes is therefore presented by an array comprising of 77 jacket with suction caissons foundations. This is in addition to two OSPs. The creation of biogenic reef will not significantly modify the wave and tidal regimes.

Potential Impact	Assessment Parameter	Explanation
	▪ Eight offshore export cable crossings; ▪ Ten inter-array cable crossings; ▪ Two interconnector cable crossings; ▪ Rock berm and/or concrete mats protection with height up to 1.5m, length up to 150m and width up to 20m per crossing; and ▪ Overall, the Caledonia North Site affected up to **36,000m²** and up to **24,000m²** within the Caledonia North OECC.	
Decommissioning		
Impact 7: Increases in SSCs and change to seabed levels	The worst-case design scenario will be equal to (or less than) that of the construction phase. Refer to Impact 1.	When removing foundations, the greatest disturbance will be associated with the layout containing the greatest number of structures. The worst case scenario assumes complete removal of all infrastructure, including cables and cable protection where it is possible and appropriate to do so. If any infrastructure is left *in situ*, this will result in reduced levels of suspended sediment and associated deposition during decommissioning.
Impact 8: Potential impacts to seabed morphology (sandbanks and notable bathymetric depressions)	The worst-case design scenario will be equal to (or less than) that of the construction phase. Refer to Impact 2.	Maximum disturbance of seabed/inter-tidal and change in blockage resulting from removal of infrastructure. The worst case scenario assumes complete removal of all infrastructure, including cables and cable protection where it is possible and appropriate to do so. If any infrastructure is left *in situ*, this will result in reduced levels of suspended sediment

Potential Impact	Assessment Parameter	Explanation
		and associated deposition during decommissioning.
Impact 9: Modifications to littoral transport, coastal behaviour (erosion), including at the Landfall Site	▪ The worst-case design scenario will be equal to (or less than) that of the construction phase. Refer to Impact 3.	Maximum disturbance of seabed/inter-tidal and change in blockage resulting from removal of infrastructure. The worst case scenario assumes complete removal of all infrastructure, including cables and cable protection where it is possible and appropriate to do so. If any infrastructure is left *in situ*, this will result in reduced levels of suspended sediment and associated deposition during decommissioning.

2.7 Potential Effects

2.7.1 Construction

Impact 1: Increase in SSCs and Changes to Seabed Levels

2.7.1.1 During the construction of Caledonia North, sediment will be disturbed and released into the water column. This will give rise to suspended sediment plumes and localised changes in seabed levels as material settles out of suspension. The activities associated with the construction of Caledonia North which will result in the greatest disturbance of seabed sediments are:

- Pre-lay cable trenching using a jet trencher tool at the seabed;
- Seabed preparation (including both seabed levelling for WTG foundations and sandwave clearance) including spoil disposal via a TSHD;
- Foundation installation using drilling techniques; and
- Drilling fluid release during HDD operations.

2.7.1.2 The worst case scenario used for each of these scenarios is provided in Table 2–12, and each has been considered using numerical modelling both within the Caledonia North Site and along the Caledonia North OECC, for both spring and neap tides.

2.7.1.3 The release events that have been simulated within the numerical model, as described in document Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report, have been specifically designed to capture the full range of realistic worst-case outcomes in terms of:

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

2.7.1.4 The methodology applied to assess the characteristics of sediment plumes and associated changes in bed level arising from settling of material is set out in document Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report.

Conceptual Understanding of Change

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

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

2.7.1.7 Tidal ellipses are asymmetrical, and the path followed by flow change on every tide. Consequently, it is unlikely that the same seabed area will be affected by the higher SSC over more than one consecutive tide (approximately six hours) and so sediment deposition resulting from increased SSC is highly unlikely to occur in the exact same area over more than one or two tides.

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

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

Cable Installation

2.7.1.10 The main cable installation methodologies available are described in document Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report. As outlined in Table 2–12, the use of jet trencher is considered to represent the realistic worst-case scenario in terms of displacing sediment into the water column. It has been conservatively assumed that jetting will hydraulically force 30% (spill factor) of the trenched sediment into suspension at 5m above seabed, with the fastest trenching rate of 700m/hr representing the highest sediment release rate. Also, considering the highest percentage of fines in the south of the Caledonia North Site, the installation of cables has been simulated to the south of the Caledonia North Site exclusively as this area has the highest potential of sediment dispersal. Consequently, the plume resulting from cable installation is expected to be smaller and more localised to the area of disturbance within the Caledonia North Site. Full details of the assumptions and parameters used in the modelling scenario are provided in Volume 7B, Appendix 2-2: Marine and Coastal Processes Modelling Report.

2.7.1.11 Cable installation is required along both the Caledonia North OECC (up to 180km of offshore export cables) and within the Caledonia North Site (one interconnector cable of up to 30km, 77 inter-array cables with a total length of up to 360km). All cables are to be buried to a maximum depth of 3m within a rectangular shaped trench of 15m width, resulting in a total sediment displacement of the order shown in Table 2–13.

Table 2–13: Sediment displacement volumes due to cable installation.

Cable ID	Total Length (km)	Number of Cables	Total Sediment Displacement Volume (m^3)	Sediment Displacement Volume (per m of Cable; m^3)
Offshore export cables	180	2	8,100,000	45
Interconnector cables	30	1	1,350,000	45
Inter-array cables	360	1 per WTG	16,200,000	45

2.7.1.12 The values below have been determined based on the observed advection of the plume features in the sediment plume model results:

- SSC resulting from the disturbance of all sediment types located at any one location can be expected to be very high at, and in the immediate locality of, jet trenching activities. Immediately adjacent to, and within several metres of the activity, SSC can be expected to be of the order of millions of mg/l or more (Construction Industry Research and Information Association (CIRIA), 2000[74]). Notably, the effect is very localised and of very short (temporary) duration;
- The sediment suspended in the plume will be continually deposited, re-suspended and dispersed in response to the magnitude of the tidal regime. The SSC is expected to reduce to hundreds of mg/l within tens to low hundreds of metres;
- During the cable installation activity, the plume width might extend, approximately, 15km to the south and 5km to the north from Caledonia

North, with SSC above 50mg/l only at the location of jetting activities. The SSC will reduce to less than 50mg/l within approximately 2.5km from the activity of disturbance (see Figure 2-4). Within the Caledonia North OECC, at the time of activity, SSC is simulated to be less than 20mg/l, except at the Landfall Site[ii]. Of relevance to this assessment is that the numerical model overpredicts SSC values at the shoreline and thus concentrations are expected to be smaller than shown; and

- The plume width remains constant seven hours after the beginning of cable installation activity. However, the SSC reduces to less than 20mg/l as all sediments sand-sized and coarser will have deposit onto the seabed (Figure 2-4). After a week form commencement of activities, the results show that SSC reduces to less than 5mg/l, which corresponds to the natural occurring SSC values in the Caledonia North Site (Paragraph 2.4.3.13 and Figure 2-4). Elevated SSC is expected to continue to disperse, so that no measurable SSC is expected to be present after several tidal cycles.

2.7.1.13 The deposition resulting from the seabed disturbance by the jet trenching activities within the Caledonia North Site and Caledonia North OECC is shown in Figure 2-5. The numerical model indicates that:

- The coarser sediment (sand/gravel) will settle to the seabed relatively quickly (between the order of seconds to less than two minutes) following its releases into the water column (further details concerning the settling sediments characteristics are provided in document Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report);
- Sediment deposition of more than 10mm is expected in the vicinity of the active disturbance in the Caledonia North Site, visible in the results as a line of higher maximum deposition up to approximately 1km wide (north-west to south-east direction) and 5km long (south-west to north-east direction) (see Figure 2-5). The deposition of finer sediment fractions is expected from the advected plume settling out of suspension, with thicknesses between 1mm and 5mm deposited up to approximately 4km wide and 6km long away from the active disturbance area (see Figure 2-5). Deposition thicknesses of less than 1mm are predicted to occur downstream of the disturbance, representing the advection of finer sediment fractions, particularly during spring tidal conditions up to approximately 15km from the jet trenching activities in the Caledonia North Site;
- Within the Caledonia North OECC and as a consequence of the relatively benign tidal regime (see Section 2.4.3), the sediment deposition is simulated to remain within 1km from the area of disturbance and in the order of 2mm to 3mm, which corresponds to the size of a very coarse sand or very fine gravel, respectively (Figure 2-5).

[ii] This is an artifact of the way the numerical model calculates concentrations due to a smaller size in coastal area (as further discussed in Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report).

- Sediment accumulation of less than 1mm will not be measurable in practice and would not result in a change of sediment type. Of note is that the model does not include re-suspension. In reality, any fine sediments which are deposited will be re-suspended and dispersed further with subsequent tides; and
- The greatest deposition thicknesses are predicted to occur immediately adjacent to activities associated with Caledonia North. Given that deposition occurs on the seabed next to which the disturbance occurs, it is not expected that this will result in a change in the seabed sediment characteristics.

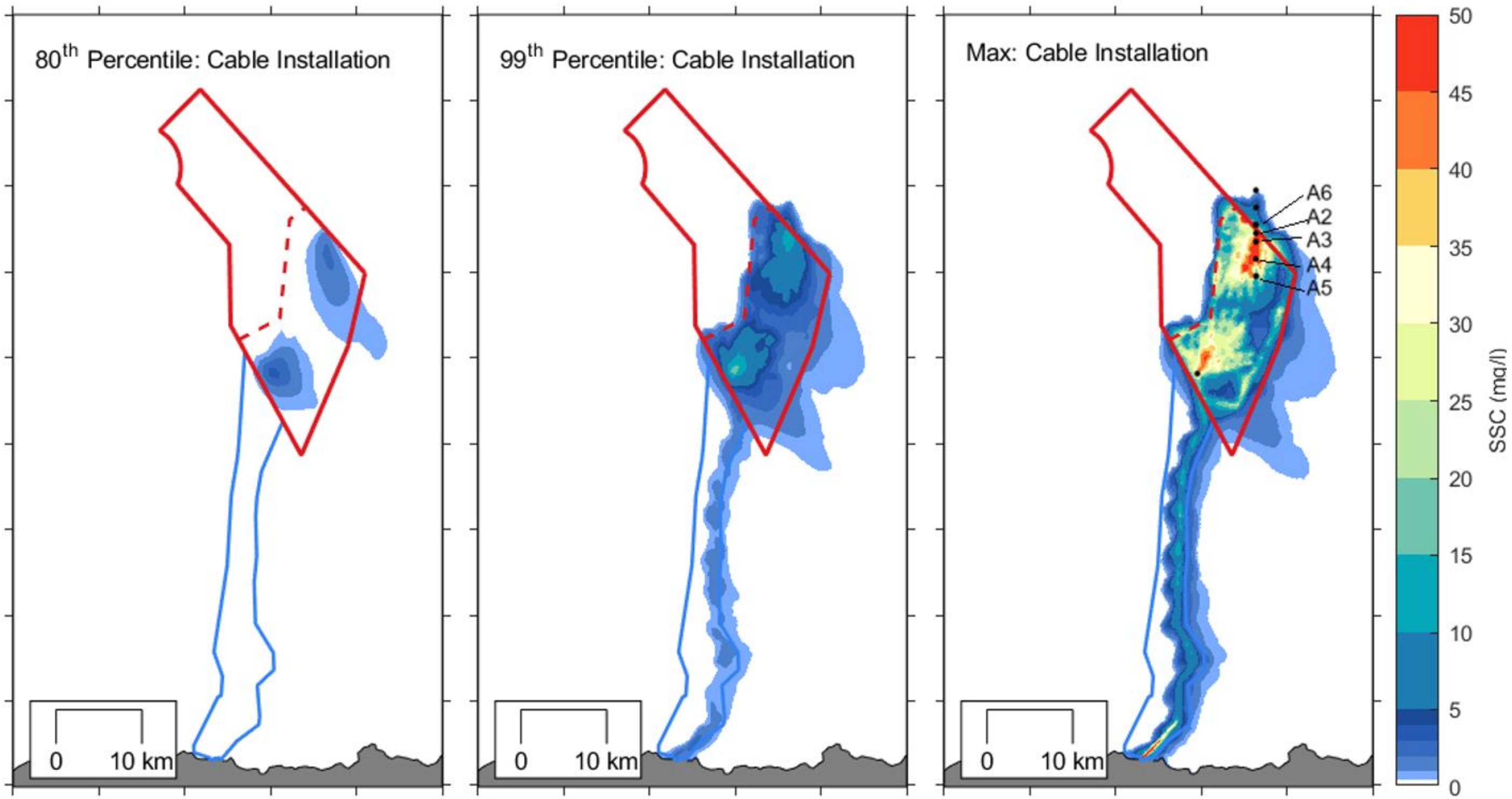


Figure 2-4: Modelled 80th percentile[iii] (left). 99th percentile[iv] (middle) and maximum[v] (right) suspended sediment concentration from the particle tracking model simulation for cable installation using the Jet trencher at six different locations named A1 to A6[vi].

[iii] The 80th percentile plot for cable installation shows the value that the SSC is exceeded for 20% of the time, or 144 hours (for example, 6 days).

[iv] The 99th percentile plot for cable installation shows the value that the SSC is exceeded for 1% of the time, or 7.2 hours (for example, approximately half of a tidal cycle).

[v] The maximum SSC demonstrates the maximum concentrations that can be expected to occur at the given grid cell across the whole simulation period (for example, 30 days).

[vi] Locations were chosen on the plume results representing the worst case scenario with more details given in Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report).

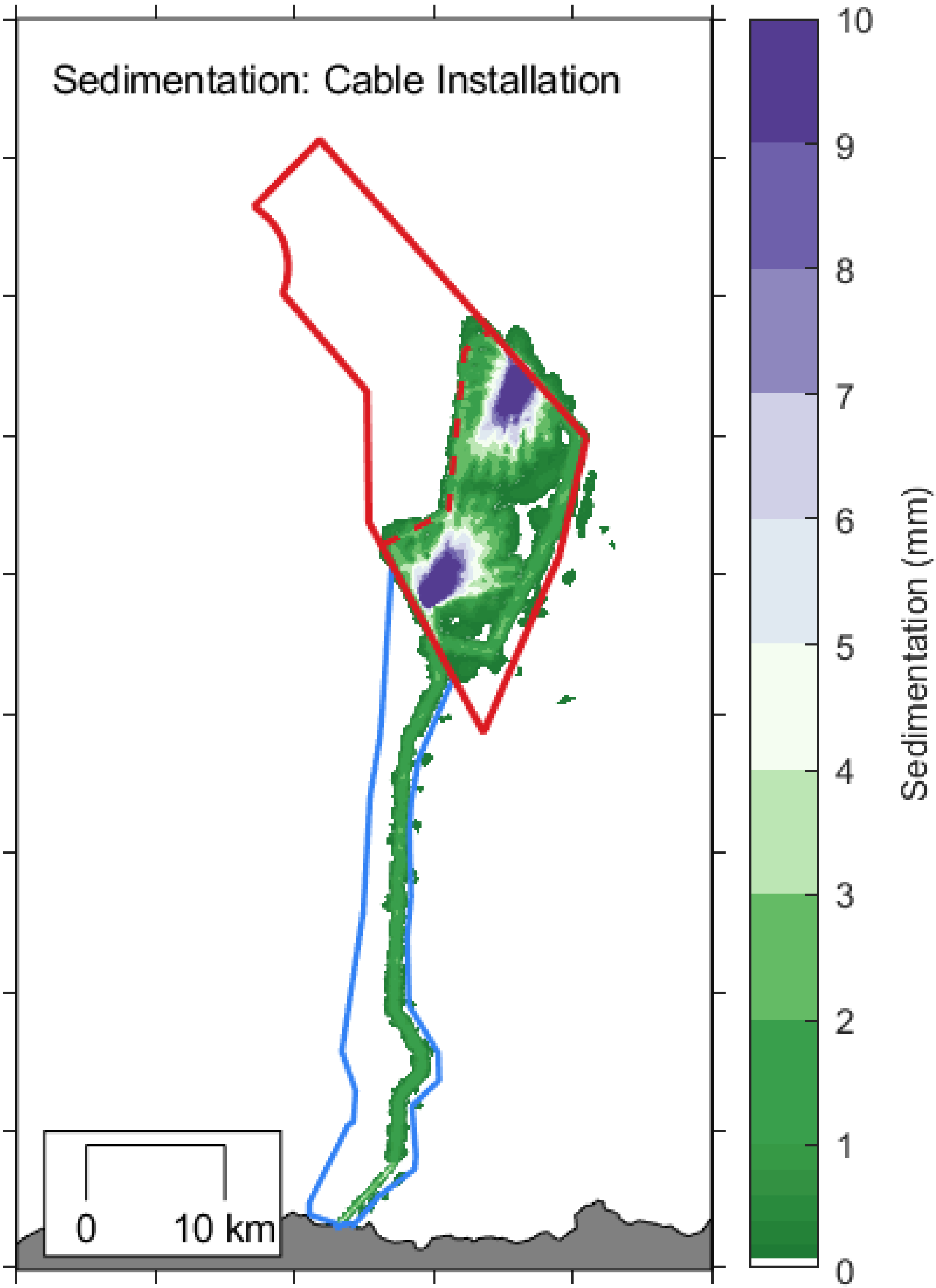


Figure 2-5: Modelled sedimentation from the particle tracking model simulation for cable installation using the jet trencher at the end of the 30 days simulated[vii].

[vii] The results presented are highly conservative as the model does not simulate the resuspension of sediment once it is deposited onto the seabed. In reality, deposited material will be re-suspended in response to the tide and wave regimes.

Seabed Preparation

2.7.1.14 Seabed preparation includes:

- Seabed levelling, which will be required around specific foundation types that need to be placed onto a flat seabed, such as jacket foundations with suction caissons and jacket foundations with pin pile, as well as for areas of scour protection where required; and
- Sandwave clearance (the removal of sections of mobile bedforms), which may be necessary for cable installation activities in order to ensure effective cable burial below the level of the stable bed.

2.7.1.15 In the worst case scenario, the largest sediment volume likely to be removed for seabed levelling within the Caledonia North Site is of the order of 27,240,000m^3, to be excavated using a TSHD. Whilst the hopper is being filled, overspill is likely to result in a near-surface sediment plume composed primarily of fine sediments. Once each hopper is filled, dredged material (spoil) will be returned to the seabed.

2.7.1.16 Once the dredger moves to discharge a full hopper load, the majority of the finer sediments are expected to have already been lost to overspill, although this will vary based on the sediment type and filling rate. During spoil disposal, sediments will be discharged as a highly turbid dynamic plume, with the coarser sediment fraction falling quickly to the seabed (on timescales of minutes to tens of minutes) with limited opportunity to be advected away by tidal currents, leading to a correspondingly greater localised depth of accumulation on the seabed. Finer sediments in the spoil will remain in suspension for longer, forming a passive plume which will then be advected by tidal current and/or waves.

2.7.1.17 Based on the geophysical survey, sandwaves are not observed within Caledonia North but only soft ripples and ripples (Paragraph 2.4.3.11 see Volume 7B, Appendix 4-1: Environmental Baseline Report (Array Area) and Volume 7B, Appendix 4-2: Environmental Baseline Report (Offshore Export Cable Corridor)). Consequently, sandwave clearance activity is unlikely to happen. If needed, the disposal of dredge sediment by TSHD will take place in a licensed marine disposal site.

Foundation Drilling

2.7.1.18 Whilst a range of foundations are considered for application as part of Caledonia North, monopile foundations will be installed into the seabed using standard piling techniques. In some locations, the particular geology may present as an obstacle to piling, in which case, some or all of the seabed material might be drilled within the pile footprint to assist in the piling process; however, at this stage it is difficult to predict with certainties where these potential areas are located.

2.7.1.19 The impact of drilling operations mainly relates to the release of drilling spoil, at or above the water surface, which will put sediment into suspension and ultimately result in the subsequent redeposition of that material to the seabed. The nature of the disturbance will be determined by the rate and total volume of material to be drilled, the seabed and sub-bottom material type, and the drilling method (affecting the texture and grain size distribution of the drill spoil). It should be noted that whilst the drilling of monopile WTG and OSP foundations could give rise to increased SSCs, the worst-case scenario in terms of maximum temporary disturbance has been assumed to be dredging associated with the installation of jacket with suction caisson foundations (Table 2–12). However, numerical modelling outputs in relation to drilling are provided below.

2.7.1.20 Numerical modelling has simulated drilling at ten locations (monopile foundations of up to 14m diameter at the seabed) for a period lasting, approximately, 20 hours per monopile, located in the south part of Caledonia North Site, where sediment is finer and so will potentially have a greater dispersal. As it is currently unknown if spoil from drilling will be released from the seabed or at the surface, the worst case scenario assumption considers a surface release as the higher currents, relative to those near-bed, will result in a greater SSC dispersion n (for more details on numerical model parametrisation, see Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report). The results are summarised as follows:

- The maximum SSC of more than 5mg/l is constrained within 5km in a north to south direction and 1km in east to west direction from the release location (see Figure 2-6). SSC of more than 1mg/l is observed up to 30km to the south-east of the release location. After 6 days, a notable decrease of SSC is observed to less than 4mg/l at release location and extend to, approximately, 20km south-east. Considering the average SSC within the Caledonia North Site (5mg/l), this change is likely to be indiscernible from background conditions; and
- Sediment deposition is shown to be up to 2mm within several hundreds meters from the foundation, reducing rapidly to less than 1mm at distance more than 1km from the release location (Figure 2-6).

2.7.1.21 The numerical model resolution (500m) does not allow to predict accurately the spoil mound directly next to the activity (less than 10m). Monitoring spoil mound arising from drill at Inner Dowsing OWF showed a 3m thickness (Bureau of Ocean Energy Management (BOEM), 2017[75]). Mounds from drilling activities were expected during the construction phase of Moray West OWF (Moray West, 2018[76]), however, this effect is small-scale (order of 0.1 to one metre) and highly localized (10 to 100m wide from individual foundations), as well as occurring intermittently. Further, monitoring of drill arising mounds on the Lynn and Inner Dowsing OWF found that after four months, mounds had been reduced from 3m to 1.2m due to natural processes. However, this figure is only presented as a guide as sediment and oceanographic conditions are slightly different at Caledonia North (Hornsea Project Four, 2022[77]).

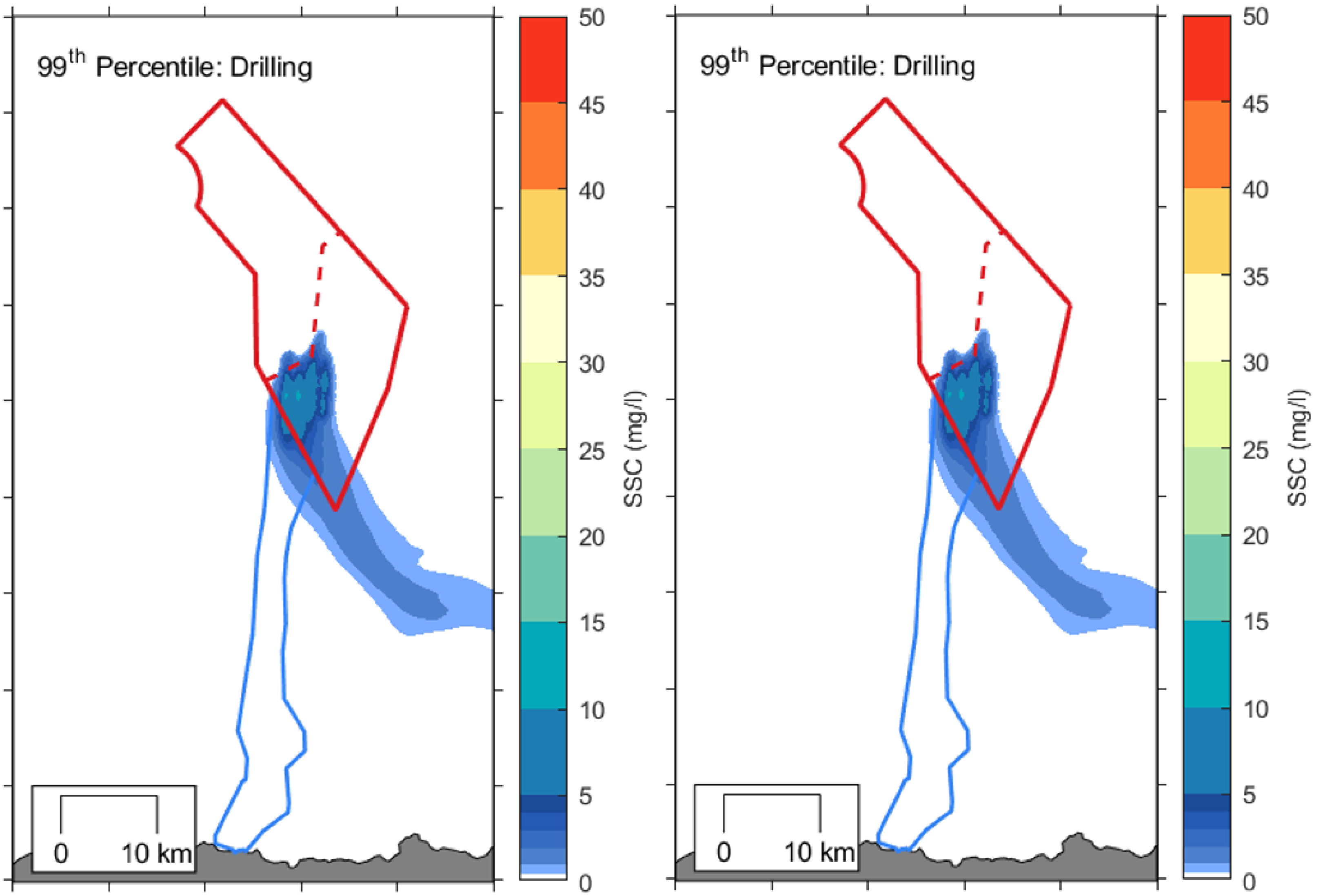


Figure 2-6: Modelled 99th percentile suspended sediment concentration (left) and sedimentation (right) from the particle tracking model simulation for foundation installed by drilling.

HDD Operations

2.7.1.22 The subsea export cable ducts will be installed underneath the intertidal area using trenchless installation techniques, with HDD techniques as identified within the worst case scenario (as outlined in Table 2–12). The drilling activity utilises a viscous drilling fluid which consists of a mixture of water and bentonite, a non-toxic, naturally occurring clay mineral. The release of drilling fluid and drill cuttings from HDD operations will result in a plume of elevated SSC. The drilling fluid has an overall density and viscosity similar to seawater and so is expected to behave in a similar manner.

2.7.1.23 Results from the numerical model demonstrate that:

- The maximum SSC during the 15-day period over which the statistics were calculated indicates a result plume up to 6km long (in east to west direction) and 2.5km wide (in the north to south direction) (Figure 2-7). The highest SSC (above 50mg/l) is simulated to occur over an area of less than 1km long (in east to west direction) and 500m width (in north to south direction). SSC reduces to 15mg/l within 3km east to west and approximately 700m north to south within 3.6 hours;
- SSC is advected along the coast (following tidal axis; Paragraph 2.4.3) to distances of up to 8km to the east and 6km to the west, although concentrations at this distance are limited to below 1mg/l (Figure 2-7). All measurable SSC will have dispersed after 3 days (Figure 2-7). Considering generally higher background SSC conditions along the coast, these changes are likely to be indiscernible from background conditions; and
- Sediment deposition is predicted within several hundreds of meters of the exit pits, reducing rapidly to below 1mm (Figure 2-7). The maximum extent of deposition is predicted to be approximately 700m from release, with deposition less than 0.1mm identified at these distances. This deposition is small-scale, highly localised and is likely to be rapidly redistributed by wave action.

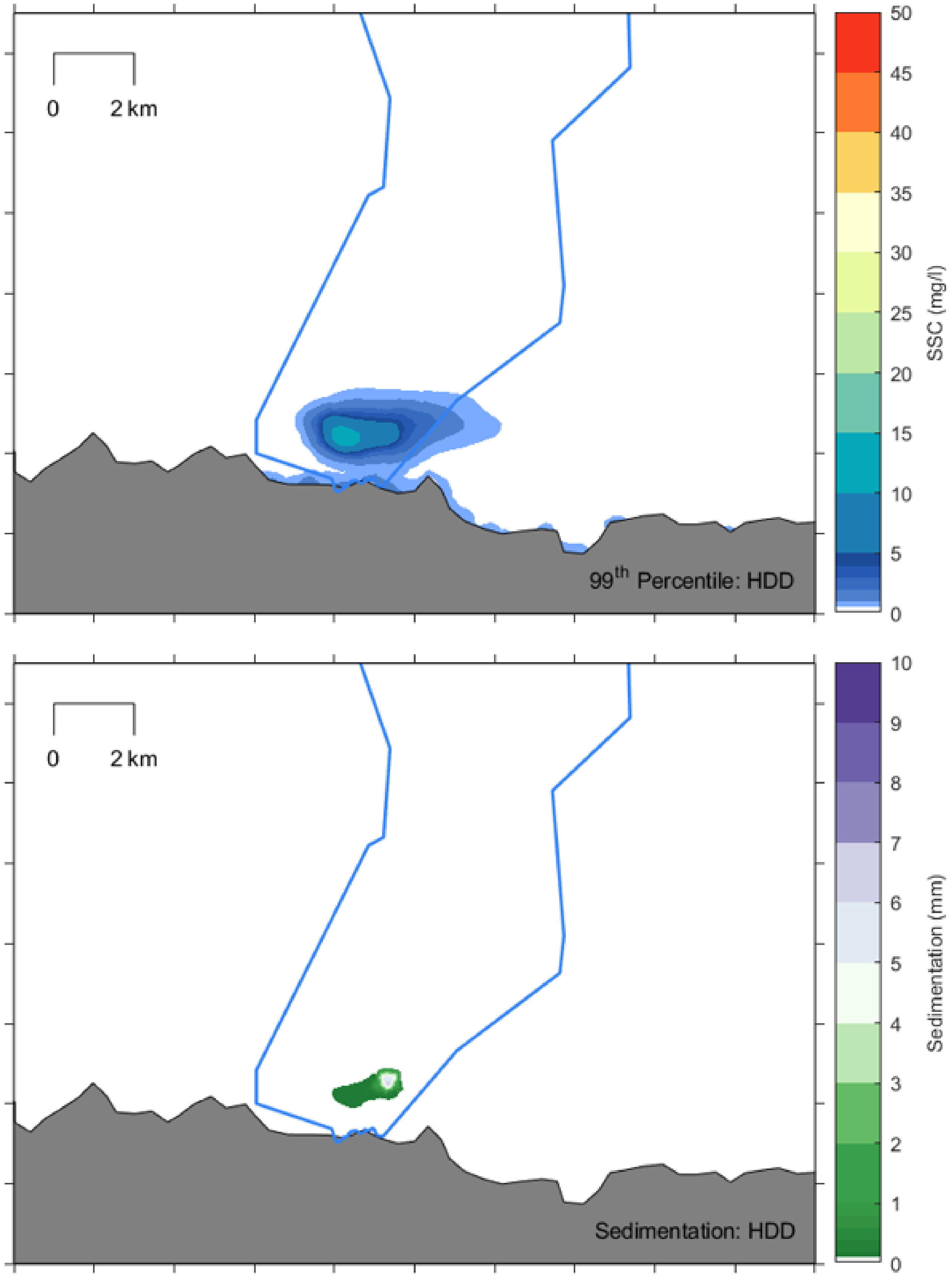


Figure 2-7: Modelled 99th percentile suspended sediment concentration (top) and sedimentation (bottom) from the particle tracking model simulation for HDD.

2.7.1.24 Both cable installation using jetting techniques and foundation drilling activities may produce sediment plumes with SSC up to thousands of mg/l, however these concentrations will be spatially restricted and short-lived. Elevated SSC may be advected by tidal currents up to 20km away, but only for the foundations installations, although these concentrations will be low. In the majority of cases, elevated SSC will be indistinguishable from background levels (Paragraph 2.4.3.13) up to three days after the cessation of activities.

2.7.1.25 The associated deposition from sediment plumes is generally in the order of tens of mm within several hundreds of metres from the point of disturbance, reducing to low tens of mm beyond this. Sediment deposition is generally not measurable beyond 1km away from the associated activities except during cable installation activities up to circa 6km and is therefore generally small-scale and restricted to the near-field. This deposition is likely to become integrated into the local sediment transport regime and will be redistributed by tidal currents.

Magnitude of Impact

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

Sensitivity of Receptor

2.7.1.27 The sensitivity to the following receptors have been considered in the assessment of increases in SSCs and changes to seabed levels:

- The coast at the Landfall site;
- Cullen to Stake Ness SSSI (Figure 2-1);
- Nearby sub-tidal sandbanks named the Smith Bank (Figure 2-1);
- Nationally designated site: Southern Trench MPA (Figure 2-1); and
- Areas of undesignated seabed.

2.7.1.28 Based on model results, the coast at the Landfall Site (within the Caledonia North OECC) might be affected by increased of SSC during cable installation and HDD operations. Due to the undesignated status of the coast at the Landfall Site and its high capacity to accommodate an increase of SSC the receptor sensitivity has been assessed as negligible.

2.7.1.29 The Cullen and Stake Ness SSSI is designated due to its geological characteristics, below the quaternary sediment, and as such will not be sensitive to increases in SSC. However, due to the designated status of this receptor, the sensitivity has been assessed has medium.

2.7.1.30 The increase of SSC and associated seabed level change within Caledonia North was simulated to remain close to the area of disturbance or propagate towards the east, whereas the Smith Bank is located to the west of the Caledonia North Site. This receptor sensitivity has been assessed as low due to its district level of importance and moderate ability to accommodate the changes.

2.7.1.31 The burrowed muds present in the Southern Trench MPA (as discussed in Application Document 9: MPA Assessment) msy be directly impacted by construction activities such as cable installation (Figure 2-4 and Figure 2-5), with a potential removal of burrowed mud and/or change of sediment type. Based on the potential long-term recovery of burrowed muds, rarity and designated status, this receptor sensitivity has been assessed as high.

2.7.1.32 Areas of undesignated seabed are expected to be subject to changes in seabed levels due to the increased of SSC. However, due to the fact that it is undesignated and exposed to similar processes, this receptor sensitivity has been assessed as negligible.

Significance of Effect

2.7.1.33 The significance of effect determined for each receptor based on Table 2–10 is summarised in Table 2–14. For all receptors, the overall effect during construction of increased SSC and change of seabed level is **Not Significant in EIA terms**.

Table 2–14: Significance of effect of increase of suspended sediment concentration and change of seabed level for all receptors.

Receptor	Sensitivity	Magnitude of Impact	Significance of Effect
The coast at the Landfall Site	Negligible	Low	Negligible
Cullen to Stake Ness SSSI	Medium	Low	Minor
Smith Bank subtidal sandbank	Low	Low	Negligible
Southern Trench MPA	High	Low	Minor
Areas of undesignated seabed	Negligible	Low	Negligible

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

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

- Pre-lay cable trenching using jet trenching tool at the seabed;
- Use of cable protection measures; and
- Foundation installation using drilling techniques.

Jet Trencher

2.7.1.35 Cable installation using jetting tools has been identified as the worst-case scenario with the greatest potential for direct impacts to seabed morphology. As described in Table 2–12, this activity would be used to excavate a trench with a width of 15m and a depth of 3m. The trenched sediment volume will be forced into suspension above the seabed, subsequently settling within several meters of the trench, as outlined previously in Paragraph 2.7.1.13. Displaced material will not be removed from the sedimentary system, and these small-scale changes in bed levels are likely to be quickly redistributed by hydrodynamic processes.

Cable Protection Measures

2.7.1.36 As far as practicable, all offshore cables will be buried. However, where it is not possible to bury cables to an adequate depth it may be necessary to install cable protection to prevent scour and minimise the risk of cable exposure. The worst case scenario option for cable protection is outlined in Table 2–12, consisting of rock berms with a maximum height of 1.5m and a width at the seabed of 20m, comprising a total area of 2,340,000m^2 within the Caledonia North Site and 1,800,000m^2 for the Caledonia North OECC. With respect to cable crossings, the installed rock berms will have a maximum height of 1.5m, seabed width of 20m and length of 150m, comprising a total area of 36,000m^2 within the Caledonia North Site and 24,000m^2 for the Caledonia North OECC.

2.7.1.37 The implementation of rock berms (as worst case) will result in a change in the seabed profile of up to 1.5m, in addition to a change in substrate type, with potential effects which may last over the operational period. These could result in increased drag forces resulting in localised scour, which is discussed further in Section 2.7.2. The presence of cable protection measures may also have the potential to cause a direct, but highly localised, blockage of bedload sediment transport processes, two worst case scenarios have been identified:

- Installation of rock berms in areas of mobile, sandy sediments (Paragraph 2.4.3.12); and
- Installation of rock berms in areas with a thin veneer of overlying sand (Paragraph 2.4.3.9).

2.7.1.38 In areas of sand, active sediment transport processes are indicated by the presence of mobile bedforms such as ripples and soft ripples. In these areas, the installation of rock berms will result in a change to sediment substrate and could potentially affect the benthic fauna and flora (Volume 3, Chapter 4: Benthic Subtidal and Intertidal Ecology). However, following installation and under favourable hydrodynamic conditions, an initial period of sediment accumulation would be expected to occur, creating a smooth slope against the cable protection. Once any void spaces have been infilled, saltation is expected to be largely unaffected by the presence of the cable protection such that existing transport process (including bedform migration) will remain unaffected.

2.7.1.39 Areas of low deposition rates with a lack of bedforms suggest low sediment transport rates. Any installation of cable protection is therefore unlikely to inhibit sediment transport processes, although its presence will result in a change to sediment substrate.

Foundation Drilling

2.7.1.40 As described in Paragraph 2.7.1.19, foundation drilling, should it be required, will result in the deposition of drill arisings on the seabed, resulting in the formation of localised spoil mounds. Based on the numerical modelling results these are likely to be minimal, with a maximum extent of 1km from the foundation and maximum thicknesses of 2mm, which is less than expected at Moray West OWF (Paragraph 2.7.1.21)..

2.7.1.41 The patterns of processes governing the overall evolution of the systems (the flow regime, water depths and sediment availability) are at a much larger scale than the proposed local works. As a result, proposed modifications to seabed morphology (outside of cable protection) are not considered likely to influence the overall form and function of the system and eventual recovery via natural processes is therefore expected.

Magnitude of Impact

2.7.1.42 The magnitude of impact is therefore considered to be noticeable but not permanent, and generally restricted to the near-field. The magnitude has therefore been assessed as low.

Sensitivity of Receptor

2.7.1.43 The sensitivity of the following receptors have been considered in the assessment of potential impacts to seabed morphology:

- Nearby sub-tidal sandbanks named the Smith Bank (Figure 2-1);
- Nationally designated site: Southern Trench MPA (Figure 2-1); and
- Areas of undesignated seabed.

2.7.1.44 The sensitivity of smith Bank receptor has been assessed as low due to its district level of importance and moderate ability to accommodate any changes to SSC.

2.7.1.45 The Caledonia North OECC crosses the Southern Trench MPA (for a length of 22km), where cable protection might be needed, and jet trenching activities will occur impacting the burrowed muds. Based on the potential long-term recovery of burrowed muds, rarity and designated status, the sensitivity of this receptor has therefore been assessed as high.

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

Significance of Effect

2.7.1.47 The significance of effect determined for each receptor based on Table 2–10 is summarised in Table 2–15. For all receptors, the overall effect of increased SSC and change of seabed level during construction is **Not Significant in EIA terms**.

Table 2–15: Significance of effect of potential impact to seabed morphology for all receptors.

Receptor	Sensitivity	Magnitude of Impact	Significance of Effect
Smith Bank subtidal sandbank	Low	Low	Negligible
Southern Trench MPA	High	Low	Minor
Areas of undesignated seabed	Negligible	Low	Negligible

Impact 3: Modifications to Littoral Transport, Coastal Behaviour (Erosion), including the Landfall Site

2.7.1.48 The offshore export cables will make landfall at Stake Ness, approximately 1.5km west of Whitehills, Aberdeenshire (Figure 2-1). Full details of the worst case scenario are provided in Table 2–12, while a full description of coastal characteristics are provided in Volume 7B, Appendix 2-1: Marine and Coastal Processes Baseline Technical Report. The assessment separately considers the potential for impacts associated with:

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

Conceptual Understanding of Change

2.7.1.49 The Landfall Site is characterised by small pocket beaches, which are constrained and isolated by rock headlands (Ramsay and Brampton, 2000[65]). Sediment transport along the coastline is primary influence by waves (coming from the east) through the process of longshore drift (Hansom, 2021[78]).

2.7.1.50 The MHWS has shown a decrease (i.e., shoreward migration) of approximately 10m±5m for the three pocket beaches located at the Landfall Site in the past 50 years (Hansom 2017[68]), which suggests that the sediment input is mostly likely to occur during storm events..

2.7.1.51 Coastal erosion is predicted to occur such that the existing shoreline is predicted to migrate, approximately 10m from the current position at the Landfall Site by 2065 (Dynamic Coast, 2024[79]). The details of the proposed future strategies to mitigate coastal erosion are not currently available and therefore a full and detailed assessment of long-term future change is not possible. If available before the anticipated start date of construction, these plans could be considered within the cable burial studies undertaken to inform engineering requirements.

HDD Operations

2.7.1.52 As outlined in Table 2–12, HDD has been identified as the worst case scenario for trenchless installation. HDD involves drilling a long borehole underground using a drilling rig located within the landfall compound. This technique avoids interaction with surface features and is used to install ducts through which cables can be pulled. HDDs can vary in length depending on the ground conditions, with the maximum length proposed for Caledonia North being 1.2km (see Table 2–12).

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

Construction of HDD Exit Pits

2.7.1.54 HDD will be used to install the export cables at the Landfall Site, with a maximum of two HDD exit pits. The HDD exit pits will be excavated as required for each export cable installation, which has been assessed as being located within the Caledonia North OECC subtidal area (subtidal exit pit) in line with embedded mitigation measures as provided in Table 2–11. The exit pit will be located in the subtidal area (between 10m and 40m), and the total volume of excavated material is anticipated to be 1,222m^3, corresponding to 611m^3 per pit. The excavated material may be temporarily piled up to the side of the pit and used as backfill when the pits are closed.

2.7.1.55 The storage of this excavated material may form temporary spoil mounds, which, depending on their position in the subtidal (and hence the water depth in which they are situated), may have the potential to modify the nearshore wave regime through the differently distributed transmission of wave energy across the beach. This could theoretically result in a morphological response although this would be highly localised to the area around mounds. Of note is that it is expected that the mounds will be eroded due to the nearshore processes and especially during storm events.

2.7.1.56 Once the duct has been installed, the pit may be secured through the use of rock or grout bags to prevent collapse and manage natural infill. The period between duct installation and cable installation may be up to nine months.

Although the pits may be present for this long, the potential for these temporary features to modify the wave regime will be limited as they will be temporarily infilled. Accordingly, water depths within their footprint will remain similar to baseline levels.

Cable Protection Measures

2.7.1.57 The requirement for cable protection at the Landfall Site is not presently known but will be confirmed as part of the CaP. The presence of cable protection measures has the potential to cause a direct (albeit highly localised) blockage of littoral sediment transport, similar to that described in Section 2.7.1.35. Cable protection measures could also cause a morphological response through modification of the local nearshore wave regime and associated patterns of sediment transport.

2.7.1.58 The HDD exit pit will be within the subtidal zone, with no cable protection required shoreward of this mark. Within the subtidal zone (seaward of the HDD exit pit), rock berms could potentially be used to protect the export cables, although cable burial is the preferred method of cable protection where practicable (as outlined in Table 2–11). Water depths at 1.2km distance offshore from the Landfall Site (approximate exit pit location) range generally between 13 to 20m (LAT) (EMODnet, 2020[80]). As outlined in Table 2–12, any rock protection utilised within the subtidal zone will not exceed 1.5m above seabed, and therefore rock berms constructed to the worst case scenario parameters will not be uncovered at low water minimising the impact on littoral transport, which directed towards east at the Landfall Site. The impact of rock protection will occur for waves exceeding 6.5m (with D = 8.5m based on worst case scenario of HDD exit pit located at 10m depth minus rock berms protection of 1.5m)[viii], an event which occurs 1 in 100 year event at Landfall Site (see details in Volume 7B, Appendix 2-1: Marine and Coastal Processes Baseline Technical Report).

2.7.1.59 Rock berms, where required, will be designed to meet cable protection requirements for the specific section of cable and therefore in shallow waters are likely to not require the worst case scenario parameters. The form of cable protection within the nearshore zone will be selected in order to ensure littoral transport is not impeded, with full details provided within the CaP.

Magnitude of Impact

2.7.1.60 In terms of the potential for cable protection measures to modify the wave regime, the dominant wave direction along the Aberdeenshire coast is from the west and the north-east. Cable protection measures would be oriented approximately perpendicular to the shore and would therefore present interference to the passage of incoming waves. Cable protection in shallow areas could therefore theoretically act in a similar manner to a submerged

[viii] Based on the equation of breaking shallow water waves (H >0.75*D with H the wave height and D the water depth; University of Hawaii).

offshore breakwater, affecting wave transformation processes closer to the shore and potentially leading to wave focusing and subsequently enhanced coastal erosion. This could result in changes to the beach morphology as well as further alterations to littoral sediment transport, which in the nearshore zone is driven primarily by the wave regime. The use of HDD means that any modification of littoral transport processes from landfall installation is likely to be temporary and restricted to the near-field. While the HDD activity itself is not expected to have any impact on the coastal morphology, the excavation of HDD exit pits and the deposition of temporary spoil mounds could result in short-term and localised morphology change. These changes would not be expected to persist once HDD exit pits are backfilled following cable installation, and consequently the magnitude of change has therefore been assessed as low.

Sensitivity of Receptor

2.7.1.61 Water depths (minimum of 13m LAT) at this distance (1.5km offshore from the Landfall Site) are such that the installation of 1.5m high rock berms, would result in a light permanent change and would have a slight impact on coastal behaviour in both the near-field and far-field. Once more detailed nearshore surveys have been carried out, the form of cable protection within the nearshore zone will be selected in order to ensure impacts to sediment transport and beach morphology are minimised, details of which are provided within the CaP. On this basis, the magnitude of change to littoral transport and coastal behaviour is assessed to be low.

2.7.1.62 The following receptors have been considered in the assessment of changes to littoral transport and coastal behaviour, including erosion, resulting from installation of the offshore export cables at the Landfall Site:

- The coast at the Landfall site; and
- Nationally designated site: Southern Trench MPA (Figure 2-1).

2.7.1.63 The beach in this location is a dynamic environment, subject to both natural and anthropogenic change under baseline conditions. Accordingly, it is assessed to have high capacity to accommodate the proposed changes. Also, due to the undesignated status of the coastline at the Landfall Site, the sensitivity of this receptor has been assessed as negligible.

2.7.1.64 The Southern Trench MPA is designated for its inshore sublittoral sediments such as burrow muds, with the closest sites located approximately 4.5km from the exit pit location. Despite the localised effect (less than 1km) of the activities associated with Caledonia North at the Landfall Site, the very low capacity of burrow mud to accommodate changes and the status of designated site, the sensitivity of this receptor is considered high.

Significance of Effect

2.7.1.65 The significance of effect determined for each receptor based on Table 2–10 is summarised in Table 2–16. For all receptors, the overall effect during construction of modifications to littoral transport is **Not Significant in EIA terms**.

Table 2–16: Significance of effects of modifications to littoral transport and coastal behaviour for all receptors.

Receptor	Sensitivity	Magnitude of Impact	Significance of Effect
Coast at the Landfall Site	Negligible	Low	Negligible
Southern Trench MPA	High	Low	Minor

2.7.2 Operation

Impact 4: Potential Impacts to Seabed Morphology

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

Conceptual Understanding of Change

2.7.2.2 The installation of cable protection could result in a local increase in the elevation of the seabed by up to 1.5m, with a sloped side profile, representing a total surface of 2,340,000m^2 within the Caledonia North Site and 1,800,000m^2 within the Caledonia North OECC.

2.7.2.3 Cable protection would be placed onto the seabed surface above the cable and therefore could directly trap sediment, locally impacting down-drift locations. The height of rock protection at cable crossings would also be up to 1.5m above the surrounding seabed, with a length up to 150m and width of 20m, which represent a total area of change of 24,000m^2 in the Caledonia North OECC and 36,000m^2 in the Caledonia North Site.

2.7.2.4 Following installation an initial period of sediment accumulation would be expected to occur, creating a smooth slope against the cable protection due to sediment transport induced by waves (predominantly) and tidal currents. The process of wedge formation may take place over a period of a few weeks to months, depending on rates of sediment transport. The sediment transport due to tides is potentially orientated south-east and so an accumulation of sediment is expected to the west of the cable protection, whereas sediment transport by waves will accumulate sediment to the east of the cable protection, as they are coming mostly form north-east, south-east and east (Paragraph 2.4.3.3).

2.7.2.5 Accordingly, for all areas in which cable protection is used, it is not expected that the presence of the cable protection devices will continuously affect patterns of sediment transport following the initial period of accumulation. It follows that any changes on seabed morphology away from the cable protection will also be very small due to the relatively low tidal flow at the seabed. The extent of the cable protection measures does not constitute a continuous blockage along the cable route corridor. The use of cable protection measures in the nearshore zone has the potential to both locally trap sediment, potentially impacting downdrift locations, and modify the transmission of waves, thereby influencing patterns of littoral sediment transport and beach morphology. No cable protection measures will be necessary within the intertidal zone.

Magnitude of Impact

2.7.2.6 As a result, proposed modifications to seabed morphology (outside of cable protection) are not considered likely to influence the overall form and function of the system. The magnitude of impact is therefore considered to be noticeable and permanent, but generally restricted to the near-field. The magnitude has therefore been assessed as low.

Sensitivity of Receptor

2.7.2.7 The sensitivity of the following receptors have been considered in the assessment of potential impact to seabed morphology during operation phase:

- Nationally designated site: Southern Trench MPA (Figure 2-1); and
- Area of undesignated seabed.

2.7.2.8 The Caledonia North OECC crosses the Southern Trench MPA, where cable protection might be needed. Due to designated site status, the importance of burrowed mud and the site’s high sensitivity to disturbance, this receptor’s sensitivity has been assessed as high.

2.7.2.9 Areas of undesignated seabed within the Caledonia North Site and Caledonia North OECC can potentially be affected. Since this seabed area is undesignated, the sensitivity of this receptor has been assessed as negligible.

Significance of Effect

2.7.2.10 The significance of effect determined for each receptor based on Table 2–10 is summarised in Table 2–17. For all receptors, the overall effect of seabed modifications during O&M is **not significant in EIA terms**.

Table 2–17: Significance of effects of potential impacts to seabed morphology for all receptors.

Receptor	Sensitivity	Magnitude of Impact	Significance of Effect
Southern Trench MPA	High	Low	Minor
Areas of undesignated seabed	Negligible	Low	Negligible

Impact 5: Seabed Scouring

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

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

2.7.2.12 As scour is a dynamic process, its greatest extent (depth and footprint) will develop during high energy periods and will therefore be short-lived. Equilibrium principles are such that, once the energy reduces, the scour holes will begin to refill (DECC, 2005[61]).

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

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

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

Conceptual Understanding of Change

2.7.2.15 Scour assessment for EIA purposes is considered here for monopiles and jackets with suction caissons, with the worst case scenario outlined in Table 2–12.

2.7.2.16 Scouring around suction caissons is currently not well understood as there is limited information available from the field. The scale of local scouring is mainly related to the scale and shape of the structure as well as sediment properties, such as the angle of repose. Scour holes will continue to deepen and widen until equilibrium scour depth is reached, which eventually accommodates and dissipates the increased flow velocities and near-bed vortices. Scour depths are expected to be limited by the presence of stiff glacial tills across much of Caledonia North, which is likely to resist or inhibit scour. Evidence from the Kentish Flats OWF, as outlined in ABPmer (2010[11]), indicates that the siliciclastic sedimentary rock underlying sands, same as Caledonia North, have limited the depth to which scour forms. It is assumed that the vertical resistance to scour, by the underlying soils, does not constrain the potential horizontal scour radius.

2.7.2.17 For monopiles with a maximum diameter of 14m (WTGs and OSPs), the maximum depth of scour is predicted to be of the order of 18m (based on Breusers *et al*., 1977[81]). However, this is based on the assumption of an unlimited depth of sandy soil, and the depth of scour at this location is likely to be lower due to the underlying geology and the thickness of quaternary sediment (Paragraph 2.4.3.8). Scour holes are assumed to develop down to the thickness of the Holocene sand layer, shown by site-specific surveys to be, in places, to a maximum depth of 18m. The scour holes may develop with the radius of an approximately conical scour hole as a function of 1:2 of the scour depth. Based on Volume 7B, Appendix 2-1: Marine and Coastal Processes Baseline Technical Report, the scour holes may be maximal (i.e., 18m), in the western area, where quaternary deposit thickness reaches 40m, whereas the features may be limited to 10m in the eastern part of the Caledonia North Site.

2.7.2.18 Scour caused around foundations will, however, be limited by the installation of scour protection where required. For an array consisting of 77 WTGs, there will be scour protection of up to 3,632m^2 per foundation for monopiles, or 11,500m^2 per foundation for jackets with suction caissons. There may be the opportunity for some secondary scour around this protection, although there is limited numerical basis for the prediction of this secondary scour.

2.7.2.19 Post-construction monitoring data from the Hornsea One OWF identified minor bathymetric changes around foundations with scour protection in the Year 2 surveys. These changes are of the order of between 20cm to 40cm, and may indicate secondary scour processes, although at some sites this cannot be distinguished from natural sediment mobility processes (Ørsted, 2021[82]). The coastal environment within Caledonia North shows a similar annual wave height (between 1.26m to 1.5m) to the Hornsea One OWF as well as surficial seabed sediment (sand and coarse sand); however, the spring and neap peak flow are lower at Caledonia North, as well as the water depth. Consequently, it is expected the secondary scour will be lower than the one observed at the Hornsea One OWF.

2.7.2.20 Based on the post-construction monitoring of Barrow OWF (located in the eastern Irish Sea), the scour diameter never exceeds 50m width from the protection. Knowing that Barrow OWF presents finer sediment (mud to muddy sand), stronger tidal flow (mean spring flow of 0.54m/s) and similar waves characteristic to Caledonia North, the scour due to the protection is expected to be of a smaller extent within the Caledonia North Site and the Caledonia North OECC.

Magnitude of Impact

2.7.2.21 There is also the expectation that cable protection measures may result in scour development. Given the dimensions of any protection, including its extent along the cable route, it is anticipated that any such morphological response will be on a smaller scale than expected around the foundations. Due to the installation of scour protection where required for engineering purposes, in addition to the underlying geology of the area, scour is likely to be limited to secondary scour around protection to a depth limited to that of the underlying stiff till. It is assumed that where scour protection is not required for engineering purposes, the resulting scour will be small-scale and localised. This change, while permanent, is therefore likely to be restricted in scale and limited to the near-field, and has therefore been assessed as of low magnitude.

Sensitivity of Receptor

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

- Nationally designated site: Southern Trench MPA (Figure 2-1);
- Nearby sub-tidal sandbanks named the Smith Bank (Figure 2-1); and
- Areas of undesignated seabed.

2.7.2.23 The Caledonia North OECC overlaps with the Southern Trench MPA where the presence of burrowed muds is recorded (Figure 2-1). The sensitivity of this receptor has been assessed as high due to the very low capacity of the burrow muds to accommodate the changes and its designated status.

2.7.2.24 The Smith Bank is located to the west of the Caledonia North Site. This receptor sensitivity has been assessed as low due to its district level of importance and moderate ability to accommodate the changes.

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

Significance of Effect

2.7.2.26 The significance of effect determined for each receptor based on Table 2–10 is summarised in Table 2–18. For all receptors, the overall effect of seabed scouring during O&M is **Not Significant in EIA terms**.

Table 2–18: Significance of effects of seabed scouring for all receptors.

Receptor	Sensitivity	Magnitude of Impact	Significance of Effect
Southern Trench MPA	High	Low	Negligible
Smith Bank sub-tidal sandbank	Low	Low	Negligible
Areas of undesignated seabed	Negligible	Low	Negligible

Impact 6: Modifications to the Wave and Tidal Regimes and Associated Impacts to Morphological Features

2.7.2.27 The installation of WTG and OSP foundations has the potential to result in a localised blockage of waves and tides, which could lead to changes to seabed morphology. This blockage will commence when offshore construction begins, increasing incrementally up to the worst case scenario, which is outlined in Table 2–12.

Conceptual Understanding of Change

Tidal Regime

2.7.2.28 The interaction between the tidal regime and the foundations of the windfarm infrastructure will result in a general reduction in current speed and an increase in levels of turbulence in a narrow, localised wake due to frictional drag effects. Incident flows will be decelerated immediately upstream and downstream of each foundation, with separation around the structure resulting in localised acceleration and the creation of vortices. Within the extent of the Caledonia North Site, the effect on tidal currents will be evident as a series of narrow and discrete wake features extending downstream along the tidal axis from each foundation. For smaller structures such as the foundations of Caledonia North, the wake signature is expected to naturally dissipate within a distance in the order of ten to twenty obstacle diameters downstream (Li *et al*., 2014[83]; Cazenave *et al*., 2016[84]; Rogan *et al*., 2016[85]).

2.7.2.29 Numerical modelling has been undertaken to quantify change in hydrodynamic flows and water levels, with details of the model scenarios and method presented in Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report.

2.7.2.30 Numerical modelling results for water levels show changes less than 0.001m for both spring and neap conditions, which would be indiscernible from natural variation.

2.7.2.31 Changes in depth average current speed and direction are predicted to be small in absolute and relative terms. The worst case scenarios, simulated during spring tide, of flows increase and decrease are predicted to be less than 0.02m/s and 0.03m/s respectively (Figure 2-8), which represent approximately a change of 3.5% of the flow speed (Paragraph 2.4.3.5).

2.7.2.32 The highest flow speed modification, in term of distance, is simulated during spring high water (Figure 2-8), with a decrease of flow, observed in the lee of the structure, 3.5km downwind, however values are simulated to be below 0.01m/s after 400m. The increase of flow is shown to occur adjacent to the structure, with a maximum observed distance of 6.5km in one area located in the south of the Caledonia North Site, and again the value is below 0.01m/s after few hundreds meters from the WTG foundations. In the centre of the Caledonia North Site these wakes are suggested to overlap; however, this is largely mitigated by the separation distance (minimum of 944m between WTG foundations) and it remains within the Caledonia North Site, with simulated changes representing less than 2% of the baseline.

2.7.2.33 The change of current direction is expected to be less than 2 degrees, although greater diversions in flow will occur directly adjacent to the structures.

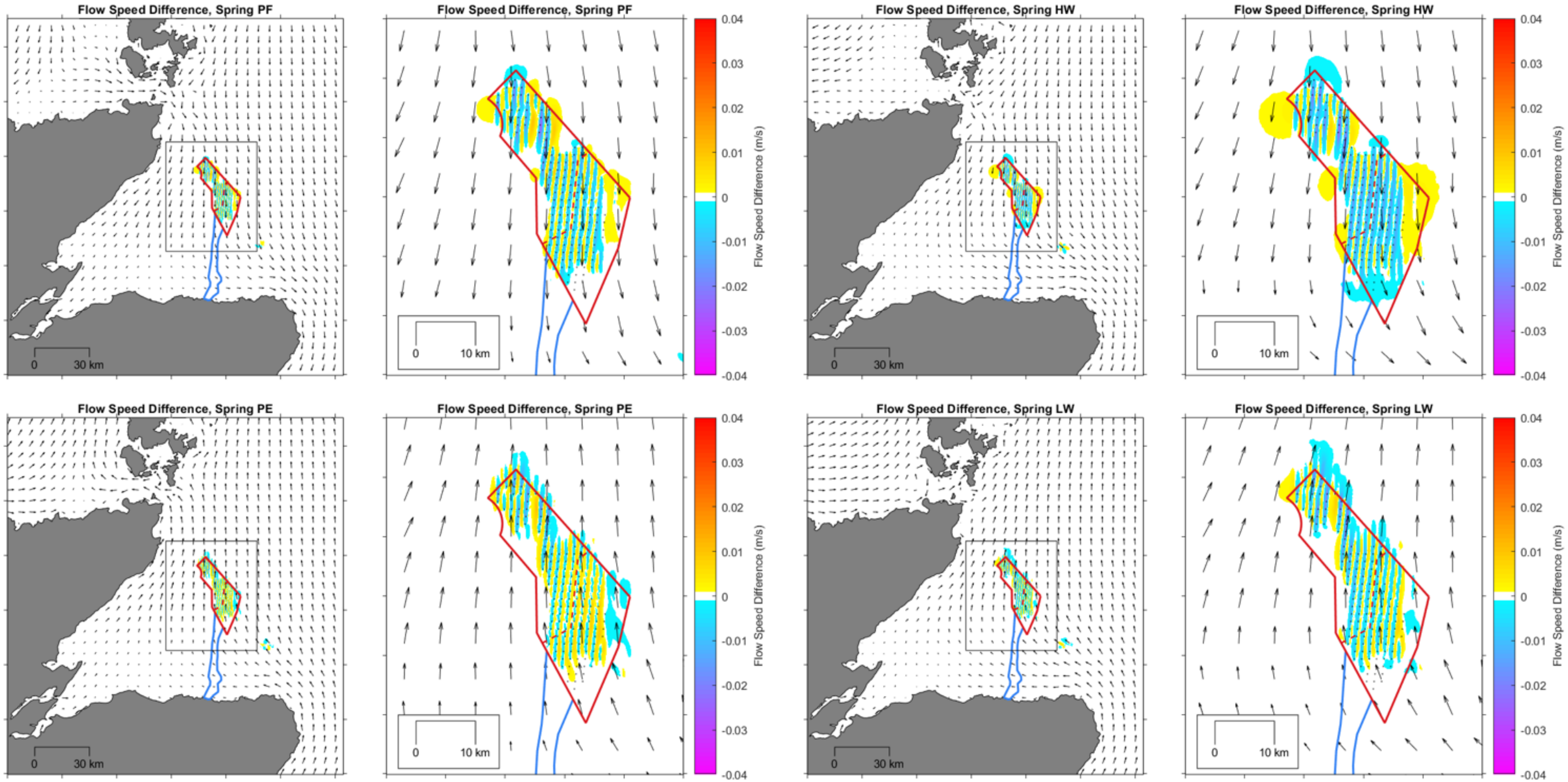


Figure 2-8: Modelled change in current speed at varying tidal stages on a mean spring tide.

Wave Regime

2.7.2.34 The presence of the foundations in the sea also has the potential to modify the wave regime passing through an OWF. The primary effects on waves (as identified by Christensen *et al.*, 2013[86]) are caused by:

- Drag forces against passing waves in contact with the foundation;
- Reflection (and scattering) of wave energy off the face of the foundation; and
- Diffraction of wave energy around the structure.

2.7.2.35 Wave energy is transmitted through a water body as an oscillatory motion which is strongest at the sea surface but reduces exponentially over depth. Long-period swell-waves transmit the greatest amount of wave energy and with a deeper influence through a water body compared to short-crested wind-waves which transmit most of their energy close to the sea surface.

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

2.7.2.37 The wave model considers waves originating from eight cardinal directions (north, north-east, east, south-east, south, southwest, west and north-west) and simulates waves during extreme events including the 1 in 1, 1 in 10 and 1 in 50 years annual recurrence interval (see details in Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report). Waves are mostly coming from the north, north-east, east and south-east (representing approximately 80%) and so these directions will be assessed in the paragraphs below.

2.7.2.38 Reduction of wave height (H_s hereafter) for all scenario is observed only for waves originating from north-west, west and south-west, with changes less than 0.1m observed up to 6.3km (see Figure 2-9). Based on Section 2.4.3, waves are mostly coming from the north, north-east, east and south-east (representing approximately 80%), which means that the changes simulated will potentially occur only for 15% of the waves crossing the Caledonia North Site.

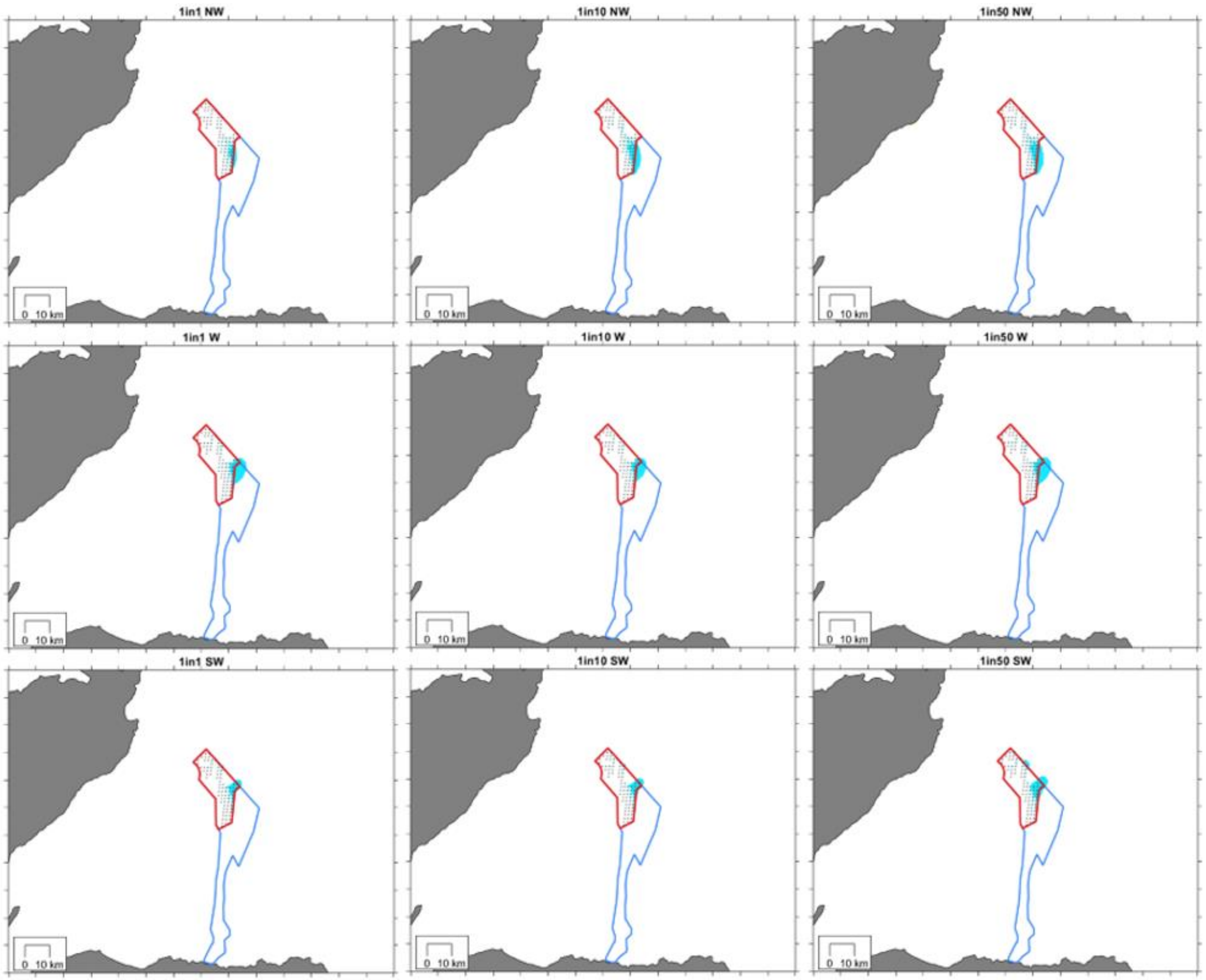


Figure 2-9: Difference in modelled H_s for the 1 in 1 year annual recurrence interval events (left column), 1 in 10 annual recurrence interval events (middle column) and 1 in 50 annual recurrence interval events (right column) for three wind direction: north-west (top row), west (middle row) and south-west (bottom row).

Magnitude of Impact

2.7.2.39 Changes in the tidal regime may indirectly impact seabed morphology in a number of ways. In particular, there is a close relationship between flow speed and bedform type (Easton *et al*., 2011[87]; Damen *et al*., 2018[88]) and, therefore, any changes to flows have the potential to alter seabed morphology over the lifetime of Caledonia North. In the immediate near-field (within 1km) there may be a localised reduction in current speed of up to 0.03m/s during high current conditions (equivalent to 3.5% decrease), which can potentially lead to localised reductions in seabed mobility. However, although this change is noticeable, it is restricted in both spatial and temporal extent, with localised variation throughout the tidal cycle. Although in the Moray Firth, sediment transport is wave-dominated, as tidal current energy is low (Holmes *et al*., 2004[58]). On this basis, the magnitude of impact to the tidal regime is assessed to be low.

2.7.2.40 Similarly, any changes in the wave regime may contribute to changes in seabed morphology due to alteration of sediment transport patterns. Within the study area, sediment transport is dominated mostly by wave energy, and wave-driven sediment transport alone becoming important to shallow coastal waters, located away from Caledonia North. As described, the reduction to the H_s remains in Caledonia North, there is no pathway of effect on the nearshore wave climate. This also limits any potential for impact on coastal erosion or processes. Impacts on the wave regime will therefore be noticeable and permanent within Caledonia North and might potentially impact the sediment transport. The magnitude of impact to the wave regime is therefore assessed to be low.

Sensitivity of Receptor

2.7.2.41 The sensitivity of the following receptors have been considered in the assessment of modifications to the wave and tidal regime and associated impacts to morphological features:

- The coast at the Landfall Site;
- Cullen to Stake Ness SSSI (Figure 2-1);
- Nearby sub-tidal sandbanks named the Smith Bank (Figure 2-1);
- Nationally designated site: Southern Trench MPA (Figure 2-1); and
- Area of undesignated seabed.

2.7.2.42 Coastal receptors, including the Landfall Site and Cullen to Stake Ness SSSI, are under the influence of waves and tides, and therefore may be impacted by changes to the wave and tidal regime. The sensitivity of these receptors has been assessed as medium due to the designated status of Cullen to Stake Ness SSSI and negligible to the undesignated status of Landfall Site.

2.7.2.43 The Smith Bank, located in the west of the Caledonia North Site, is likely to be impacted by the changes to wave regime, as sediment transport are wave-dominated. The sensitivity of this receptor has therefore been assessed as low due to its district level of importance and moderate capacity to accommodate to changes.

2.7.2.44 The Southern Trench MPA offshore limit is located approximately 25km from the southern coast of the Moray Firth and consequently might be impacted by the change of wave and tidal regime. In combination with its designated status, the sensitivity of this receptor has been assessed as high.

2.7.2.45 Areas of undesignated seabed around and within the Caledonia North Site may be sensitive to wave regime changes, as sediment transport in this area is wave-dominated. However, since this area of seabed is undesignated, the sensitivity of this receptor has been assessed as negligible.

Significance of Effect

2.7.2.46 The significance of effect determined for each receptor based on Table 2–10 is summarised in Table 2–19. For all receptors, the overall effect of modifications to wave and tidal regime during O&M is **Not Significant in EIA terms**.

Table 2–19: Significance of effects of modifications to wave and tidal regimes and associated impacts to morphological features for all receptors.

Receptor	Sensitivity	Magnitude of Impact	Significance of Effect
The coast at the Landfall Site	Negligible	Low	Negligible
Cullen to Stake Ness SSSI	Medium	Low	Minor
Smith Bank subtidal sandbank	Low	Low	Negligible
Southern Trench MPA	High	Low	Minor
Areas of undesignated seabed	Negligible	Low	Negligible

2.7.3 Decommissioning

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

2.7.3.2 The Caledonia North infrastructure will be decommissioned in accordance with the decommissioning plan in addition to the best environmental practice at the time. Of note is that this may indicate that infrastructure such as cables should be retained in situ. For the purposes of undertaking this worst case scenario assessment, it is assumed that the decommissioning phase of works is a reverse of the construction process, should there be a requirement to remove the seabed infrastructure.

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

Impact 7: Increase in SSCs and Changes to Seabed Levels

2.7.3.4 Impacts arising from decommissioning activities are considered to be equal to, or less than, those which occur during construction.

2.7.3.5 Taking the significance of effect defined during construction, the overall effect of an increase of SSC and changes to seabed levels during decommissioning is considered to be **Negligible and Not Significant in EIA terms**.

2.7.3.6 However, the potential for these changes to impact other EIA receptor groups are considered elsewhere, in particular:

- Volume 3, Chapter 3: Marine Water and Sediment Quality;
- Volume 3, Chapter 4: Benthic Subtidal and Intertidal Ecology;
- Volume 3, Chapter 5: Fish and Shellfish Ecology;
- Volume 3, Chapter 7: Marine Mammals; and
- Volume 3, Chapter 8: Commercial Fisheries.

Impact 8: Potential Impacts to Seabed Morphology (Sandbanks and Notable Bathymetric Depressions)

2.7.3.7 Impacts arising from decommissioning activities are considered to be equal to, or less than, those which occur during construction.

2.7.3.8 Taking the significance of effect defined during construction, the overall effect of potential impacts to seabed morphology during decommissioning is considered to be **Negligible and Not Significant in EIA terms**.

Impact 9: Modifications to Littoral Transport, Coastal Behaviour (Erosion), including the Landfall Site

2.7.3.9 Impacts arising from decommissioning activities are considered to be equal to, or less than, those which occur during construction.

2.7.3.10 Taking the significance of effect defined during construction, the overall effect of modifications to littoral transport, coastal behaviour (erosion), including the Landfall Site during decommissioning is considered to be **Negligible and Not Significant in EIA terms**.

2.8 Cumulative Effects

2.8.1 Overview

2.8.1.1 The list of developments identified for assessing cumulative impacts is presented in Volume 7A, Appendix 7-1: Cumulative Impact Assessment Methodology. In Table 2–20, the potential for cumulative effects with each of these developments is examined, and an assessment of the cumulative effects presented.

Table 2–20: Projects considered within the Marine and Coastal Processes CIA.

Development	Potential for Significant Cumulative Effect	Comment
Caithness HVDC	Yes	Subsea cables located within the ZoI (0km from the Caledonia North Site and 0km from the Caledonia North OECC). If intermittent activities overlap temporally with the construction or the O&M of Caledonia North, there is a potential for cumulative increase SSC and associated sediment deposition.
SHEFA-2	Yes	Subsea cables located in the ZoI (0km from the Caledonia North Site and 0km from the Caledonia North OECC). If intermittent activities overlap temporally with the construction or the O&M of Caledonia North, there is a potential for cumulative increase SSC and associated sediment deposition.
Stromar OWF OECC	Yes	The Stromar OECC located within the ZoI (7.6km from the Caledonia North Site and 7.6km from the Caledonia North OECC). If intermittent activities overlap temporally with the construction or the O&M of Caledonia North, there is a potential for cumulative increase SSC and associated sediment deposition. Potential to cumulative changes to hydrodynamics, waves and sediment transport.

2.8.2 Construction

Impact 1: Cumulative Increases in SSC and Change to Seabed Levels

2.8.2.1 Due to the uncertainty associated with the exact timing of other developments and activities, there is insufficient data on which to undertake a quantitative or semi-quantitative assessment. As such, the discussion presented here is qualitative. It is considered highly unlikely that each of the identified developments would be undertaking major maintenance works, in particular asset reburial or repairs, as these are infrequent occurrences during the lifetime of developments. The interaction between sediment plumes generated by construction activities associated with Caledonia North and those from nearby external maintenance activities could theoretically occur in two ways:

- Where plumes generated from the two different activities meet and coalesce to form one larger plume; or
- Where maintenance activities occurs within the plume generated by construction activities associated with Caledonia North (or vice versa).

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

2.8.2.3 Sediment plumes from O&M activities are generally short-lived, with major maintenance works infrequent. Any impacts from operational OWF export cables, and subsea cables are therefore likely to be short-lived and of localised extent, with limited opportunity to overlap with activities associated with Caledonia North. During the construction of Caledonia North, three activities were simulated (cable installation, HDD and foundation installation), which can have an effect on SSC levels and seabed level. The results are details in Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report, and can be summarised as follow:

- Any increase of the SSC during cable installation is mainly constrained within the Caledonia North Site and Caledonia North OECC due to the benign tidal currents (maximum depth averaged current of 0.7m/s) and the low proportion of fine sediment (less than 10% of fine sediment);
- HDD works are shown to increase the SSC of more than 0.5mg/l in an area of 2.5km to the west and 4km to the east of the disturbance point; and
- Foundation installation activity is simulated to reach 5mg/l within 5km of the disturbance point, in a north-south direction and within 1km in an east-west direction. An increase of 1mg/l is observed 30km to the south-east of the release location, which remains lower than the natural level of SSC within the Moray Firth, which is less than 5mg/l throughout the year (Paragraph 2.4.3.13).

Magnitude of Impact

2.8.2.4 Given the short-lived nature of the sediment plumes and their highly localised behaviour, alongside the location of other infrastructure, there is not anticipated to be a notable overlap with concentrated sediment plumes created from other industry activities. On this basis, the magnitude of cumulative increases in SSC and change to seabed level is assessed to be low.

Sensitivity of Receptor

2.8.2.5 The sensitivity of the following receptors have been considered in the assessment of cumulative increases in SSCs and changes to seabed levels:

- The coast at the Landfall Site;
- Cullen to Stake Ness SSSI (Figure 2-1);
- Nearby sub-tidal sandbanks named the Smith Bank (Figure 2-1);
- Nationally designated site: Southern Trench MPA (Figure 2-1); and
- Areas of undesignated seabed.

2.8.2.6 Based on model results, the coast at the Landfall Site might be sensitive to cumulative increases in SSC, if maintenance work on other infrastructure (such as subsea cable, maintenance dredging in port and other OWF OECCs) occurs during cable installation and HDD operations of Caledonia North. The sensitivity of this receptor has been assessed as negligible due to its high capacity to accommodate the changes and its undesignated status.

2.8.2.7 Due to the designated status of the Cullen and Stake Ness SSSI, its sensitivity has been assessed as medium.

2.8.2.8 The Smith Bank is considered insensitive to SSC and associated bed level changes, however as the feature is considered to be of district level importance, its sensitivity has been assessed as low.

2.8.2.9 As presented in Paragraph 2.7.1.30, the burrowed muds present in the Southern Trench MPA might be directly impacted by construction and O&M activities (see Application Document 9: MPA Assessment). The two subsea cables (Caithness HVDC and SHEFA-2) and Stromar OECC crosses the Southern Trench MPA. Due to the rarity, very low capacity to accommodate changes and designated status of this receptor, the sensitivity has been assessed as high.

2.8.2.10 Areas of undesignated seabed are expected to be subject to changes in seabed levels due to the increases in SSC as described above. Since this area of seabed is undesignated, the sensitivity of this receptor has been assessed as negligible.

Significance of Effect

2.8.2.11 The significance of effect determined for each receptor based on Table 2–10 is summarised in Table 2–21. For all receptors, the overall cumulative effect of increased SSC and change of seabed level during construction is **Not Significant in EIA terms**.

Table 2–21: Significance of effect of cumulative increase of suspended sediment concentration and change of seabed level for all receptors.

Receptor	Sensitivity	Magnitude of Impact	Significance of Effect
The coast at the Landfall Site	Negligible	Low	Negligible
Cullen to Stake Ness SSSI	Medium	Low	Minor
Smith Bank subtidal sandbank	Low	Low	Negligible
Southern Trench MPA	High	Low	Minor
Areas of undesignated seabed	Negligible	Low	Negligible

2.8.3 Operation

Impact 2: Cumulative Modifications to the Wave and Tidal regime and associated potential impacts to the sediment transport regime

2.8.3.1 Blockage effects from the installation of Caledonia North infrastructure have the potential to combine with those from other developments within the region.

2.8.3.2 Numerical hydrodynamic modelling, as presented in Paragraph 2.7.2.29, indicates that the change to tidal flows is restricted to within 1.5km of Caledonia North, which remains really close to the area of disturbance. In addition, the potential cumulative impact is expected to happen exclusively during a spring tide, as the changes in tidal heights during neap are only located within Caledonia North.

Magnitude of Impact

2.8.3.3 The reduction of H_s is always simulated within Caledonia North with values less than 0.1m, as observed for the tide, providing no additional impact to the already existing baseline expected from Caledonia North. Within the Moray Firth, sediment transport is wave-dominated, as tidal current energy is low (Holmes *et al*., 2004[58]). Consequently, the cumulative tidal blockage effects is unlikely to result in any discernible change sediment transport. Additionally, the noticeable changes on tidal flow are restricted within the Caledonia North Site and at small temporal extent, with localised variation throughout the tidal cycle. On this basis, the magnitude of cumulative impact to the tidal regime is assessed to be negligible.

2.8.3.4 Any changes in the wave regime may contribute to changes in sediment transport patterns and potentially influence seabed morphology. As outlined in Section 2.7.2.38, the reduction of Hs is minimal and constraint within the

Caledonia North Site and observed only for 15% of the time. Caledonia North is not expected to add impacts to the already existing wave regime. The magnitude of cumulative impact to the wave regime is therefore assessed to be negligible.

Sensitivity of Receptor

2.8.3.5 The sensitivity of the following receptors have been considered in the assessment of cumulative modifications to the wave and tidal regime and associated impacts to sediment transport regime:

- The coast at the Landfall Site;
- Cullen to Stake Ness SSSI (Figure 2-1);
- Nearby sub-tidal sandbanks named the Smith Bank (Figure 2-1);
- Nationally designated site: Southern Trench MPA (Figure 2-1); and
- Area of undesignated seabed.

2.8.3.6 Coastal receptors, including the Landfall Site and Cullen to Stake Ness SSSI, are under the influence of waves and tides, and therefore may be sensitive to change of wave and tidal regime. Due to the designated status of Cullen and Stake Ness SSSI receptor, its sensitivity has been assessed as medium. However, the coast at Landfall Site is undesignated and consequently its sensitivity has been assessed as negligible.

2.8.3.7 The Smith Bank, located to the west of the Caledonia North Site, is likely to be impacted by the changes to wave regime, notably during period of waves coming from the north, north-east, east and south-east. Due to its district level of importance and moderate capacity to accommodate the changes, the sensitivity of this receptor has therefore been assessed as low.

2.8.3.8 The Southern Trench MPA offshore limit is located approximately 25km from the southern coast of the Moray Firth and consequently might be impacted by the change of wave and tidal regime. Due to the presence of burrow mud having a very low capacity to accommodate and the designated status of the Southern Trench MPA, the sensitivity of this receptor has been assessed as high.

2.8.3.9 Areas of undesignated seabed around and within the Caledonia North Site can potentially be sensitive to wave regime changes, as sediment transport in this area is wave-dominated. Since this area of seabed is undesignated, the sensitivity of this receptor has been assessed as negligible.

Significance of Effect

2.8.3.10 The significance determined for each receptor based on Table 2–10 is summarised in Table 2–22. For all receptors, the overall effect of cumulative modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime during O&M is **Not Significant in EIA terms**.

Table 2–22: Significance of effect of cumulative modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime for all receptors

Receptor	Sensitivity	Magnitude of Impact	Significance of Effect
The coast at the Landfall Site	Negligible	low	Negligible
Cullen to Stake Ness SSSI	Medium	Low	Minor
Smith Bank subtidal sandbank	Low	Low	Negligible
Southern Trench MPA	High	Low	Minor
Areas of undesignated seabed	Negligible	Low	Negligible

2.9 In-combination Effects

2.9.1.1 In-combination impacts may occur through the inter-relationship with another EIAR topic that may lead to different or greater environmental effects than in isolation. There is also the potential for in-combination impacts resulting from onshore and offshore works. These are identified within Volume 6 of this EIAR, and are therefore not repeated here.

2.9.1.2 The potential in-combination effects for Marine and Coastal Processes receptors resulting from effects between works associated with Caledonia North are described below.

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

2.9.1.3 A conclusion of the potential effects on the Southern Trench MPA have been presented in Application Document 9: Marine Protected Area (MPA) Assessment.

2.9.1.4 The potential inter-relationships which are relevant to this Marine Coastal Processes assessment are summarised in Table 2–23.

Table 2–23: Marine and Coastal Processes inter-relationships.

Description of Impact	Consideration within the EIA	Explanation
Construction		
Increases in SSC and change to seabed levels	▪ Volume 3, Chapter 3: Marine Water and Sediment Quality; ▪ Volume 3, Chapter 4: Benthic Subtidal and Intertidal Ecology; ▪ Volume 3, Chapter 5: Fish and Shellfish Ecology; ▪ Volume 3, Chapter 7: Marine Mammals; and ▪ Volume 3, Chapter 8: Commercial Fisheries.	Benthic communities, fish species and marine mammals could be adversely affected by increased suspended sediment concentrations, which consequently could also impact commercial fisheries.
Potential impact to seabed morphology (sandbanks and notable bathymetric depressions)	▪ Volume 3, Chapter 3: Marine Water and Sediment Quality; ▪ Volume 3, Chapter 4: Benthic Subtidal and Intertidal Ecology; ▪ Volume 3, Chapter 5: Fish and Shellfish Ecology; ▪ Volume 3, Chapter 7: Marine Mammals; and ▪ Volume 3, Chapter 8: Commercial Fisheries.	Benthic communities, fish species and marine mammals could be adversely affected by disturbance of seabed habitats, which consequently could also impact commercial fisheries.
Operation		
Potential impacts to seabed morphology	▪ Volume 3, Chapter 3: Marine Water and Sediment Quality; ▪ Volume 3, Chapter 4: Benthic Subtidal and Intertidal Ecology; ▪ Volume 3, Chapter 5: Fish and Shellfish Ecology; ▪ Volume 3, Chapter 7: Marine Mammals; and ▪ Volume 3, Chapter 8: Commercial Fisheries.	Benthic communities, fish species and marine mammals could be adversely affected by disturbance of seabed habitats, which consequently could also impact commercial fisheries.
Seabed scouring	▪ Volume 3, Chapter 3: Marine Water and Sediment Quality; ▪ Volume 3, Chapter 4: Benthic Subtidal and Intertidal Ecology; ▪ Volume 3, Chapter 5: Fish and Shellfish Ecology; ▪ Volume 3, Chapter 7: Marine Mammals; and ▪ Volume 3, Chapter 8: Commercial Fisheries.	Benthic communities, fish species and marine mammals could be adversely affected by disturbance of seabed habitats, which consequently could also impact commercial fisheries.
Modifications to the wave and tidal regimes	▪ Volume 3, Chapter 3: Marine Water and Sediment Quality;	Benthic communities, fish species and marine mammals

Description of Impact	Consideration within the EIA	Explanation
and associated impacts to morphological features	▪ Volume 3, Chapter 4: Benthic Subtidal and Intertidal Ecology; ▪ Volume 3, Chapter 5: Fish and Shellfish Ecology; ▪ Volume 3, Chapter 7: Marine Mammals; and ▪ Volume 3, Chapter 8: Commercial Fisheries.	could be adversely affected by disturbance of seabed habitats, which consequently could also impact commercial fisheries.
Decommissioning		
Increases in SSC and change to seabed levels	▪ Volume 3, Chapter 3: Marine Water and Sediment Quality; ▪ Volume 3, Chapter 4: Benthic Subtidal and Intertidal Ecology; ▪ Volume 3, Chapter 5: Fish and Shellfish Ecology; ▪ Volume 3, Chapter 7: Marine Mammals; and ▪ Volume 3, Chapter 8: Commercial Fisheries.	Benthic communities, fish species and marine mammals could be adversely affected by increased suspended sediment concentrations, which consequently could also impact commercial fisheries.
Potential impact to seabed morphology (sandbanks and notable bathymetric depressions)	▪ Volume 3, Chapter 3: Marine Water and Sediment Quality; ▪ Volume 3, Chapter 4: Benthic Subtidal and Intertidal Ecology; ▪ Volume 3, Chapter 5: Fish and Shellfish Ecology; ▪ Volume 3, Chapter 7: Marine Mammals; and ▪ Volume 3, Chapter 8: Commercial Fisheries.	Benthic communities, fish species and marine mammals could be adversely affected by disturbance of seabed habitats, which consequently could also impact commercial fisheries.

2.10 Transboundary Effects

2.10.1.1 The Offshore Scoping Report (Volume 7, Appendix 2) detailed that any impacts upon Marine and Coastal Processes receptors as a result of construction, operational and decommissioning activities associated with Caledonia North will be highly localised to the study area and will not give rise to effects on the marine environment beyond UK waters. Transboundary impacts were therefore scoped out with regards to Marine and Coastal Processes in the Offshore Scoping Report. Since the publication of the Scoping Opinion (Volume 7, Appendix 3), no new potential transboundary effects have been identified, and so it remains scoped out of this Marine and Coastal Processes chapter.

2.11 Mitigation Measures and Monitoring

2.11.1 Construction

2.11.1.1 No additional mitigation measures beyond those outlined in Table 2–11 are proposed for the construction phase.

2.11.2 Operation

2.11.2.1 No additional mitigation measures beyond those outlined in Table 2–11 are proposed for the O&M phase.

2.11.3 Decommissioning

2.11.3.1 No additional mitigation measures beyond those outlined in Table 2–11 are proposed for the decommissioning phase.

2.12 Residual Effects

2.12.1 Construction Effects

2.12.1.1 All identified construction effects were assessed as not significant in EIA terms following the implementation of embedded mitigation. The residual effects during construction are therefore also considered to be **Not Significant in EIA terms**.

2.12.2 Operation Effects

2.12.2.1 All identified O&M effects were assessed as not significant in EIA terms following the implementation of embedded mitigation. The residual effects during O&M are therefore also considered to be **Not Significant in EIA terms**.

2.12.3 Decommissioning Effects

2.12.3.1 All identified decommissioning effects were assessed as not significant in EIA terms following the implementation of embedded mitigation. The residual effects during decommissioning are therefore also considered to be **Not Significant in EIA terms**.

2.13 Summary of Effects

2.13.1.1 Table 2–24 presents a summary of the significant effects assessed within this EIAR, any mitigation required, and the residual effects are provided.

Table 2–24: Summary of Effects for Marine and Coastal Processes.

Potential Impact	Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
Construction					
Impact 1: Increases in SSC and change to seabed levels	Low	High	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 2–11.	Minor (not significant)
Impact 2: Potential impacts to seabed morphology (sandbanks and notable bathymetric depressions)	Low	High	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 2–11.	Negligible (not significant)
Impact 3: Modifications to littoral transport, coastal behaviour (erosion), including at the Landfall Site	Low	High	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 2–11.	Negligible (not significant)
Operation and Maintenance					
Impact 4: Potential impacts to seabed morphology	Low	High	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 2–11.	Negligible (not significant)

Potential Impact	Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
Impact 5: Seabed scouring	Low	High	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 2–11.	Negligible (not significant)
Impact 6: Modifications to the wave and tidal regimes and associated impacts to morphological features	Low	High	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 2–11.	Negligible (not significant)
Decommissioning					
Impact 7: Increases in SSC and change to seabed levels	Low	High	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 2–11.	Negligible (not significant)
Impact 8: Potential impacts to seabed morphology (sandbanks and notable bathymetric depressions)	Low	High	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 2–11.	Negligible (not significant)
Impact 9: Modifications to littoral transport, coastal behaviour	Low	High	Minor	No mitigation required above and beyond embedded mitigation	Negligible (not significant)

Potential Impact	Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
(erosion), including at the Landfall Site				measures outlined in Table 2–11.	
Cumulative					
Cumulative increases in SSC and change to seabed levels (construction)	Low	High	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 2–11.	Minor (not significant)
Cumulative modifications to the wave and tidal regime and associated potential impacts to the sediment transport regime (operation)	Low	High	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 2–11.	Negligible (not significant)

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