Code: UKCAL-CWF-CON-EIA-RPT-00007-7B01

Volume 7B Proposed Development (Offshore) Appendices

Appendix 2-1 Marine and Coastal Processes Baseline Technical Report

Caledonia Offshore Wind Farm Ltd

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Volume 7B Appendix 2-1 Marine and Coastal Processes Technical Report

Code	UKCAL-CWF-CON-EIA-RPT-00007-7B01
Revision	Issued
Date	18 October 2024

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Acronyms and Abbreviations

AWAC	Acoustic Wave and Current Profiler
BEIS	Department for Business, Energy and Industrial Strategy
BGS	British Geological Survey
BOWL	Beatrice Offshore Wind Farm Limited
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CREW	Centre of Expertise for Waters
DECC	Department of Energy and Climate Change
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EMODnet	European Marine Observation and Data Network
FLiDAR	Floating Light Detection and Ranging
LAT	Lowest Astronomical Tide
MHWS	Mean High Water Springs
MLWS	Mean Low Water Springs
MORL	Moray Offshore Renewables Limited
MSL	Mean Sea Level
NCMPA	Nature Conservation Marine Protected Area
OECC	Offshore Export Cable Corridor
OSP	Offshore Substation Platform
OWF	Offshore Wind Farm
PMF	Priority Marine Feature
PSA	Particle Size Analysis

RCP	Representative Concentration Pathway
SPM	Suspended Particulate Matter
SSC	Suspended Sediment Concentration
SSSI	Site of Special Scientific Interest
TCE	The Crown Estate
TSM	Total Suspended Matter
UKHO	UK Hydrographic Office
WTG	Wind Turbine Generator
ZoI	Zone of Influence

1 Introduction

1.1 Overview

1.1.1.1 This technical report presents the detailed baseline description of Marine and Coastal Processes in relation to the Caledonia Offshore Wind Farm (OWF), referred to as the Proposed Development (Offshore). Specifically, this report considers Marine and Coastal Processes seaward of Mean High Water Springs (MHWS), which for the purposes of this technical report, include the following elements:

- 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.

1.1.1.2 This baseline description sets out the 'conceptual understanding' of the marine and coastal system in which the Proposed Development (Offshore) is located and describes how the processes operating within this system link together and evolve in response to applied natural and anthropogenic forces. This understanding underpins the assessments of potential impacts resulting from the Proposed Development (Offshore), and specifically Caledonia North and Caledonia South, on Marine and Coastal Processes as described in:

- Volume 2, Chapter 2: Marine and Coastal Processes;
- Volume 3, Chapter 2: Marine and Coastal Processes; and
- Volume 4, Chapter 2: Marine and Coastal Processes.

1.2 Purpose and Structure

1.2.1.1 The primary purpose of this technical report is to provide a contemporary and comprehensive analysis of site-specific and regional Marine and Coastal Processes data within the study area. It has been produced to support the baseline understanding required to inform assessments within the Marine and Coastal Processes EIAR chapters.

1.2.1.2 The technical report has been structured as follows:

- Definition of the study area;
- Outline of the data sources used to inform the characterisation;
- A review of the baseline (existing and future) conditions of the study area; and
- Identification of Designated Sites of relevance to Marine and Coastal Processes.

1.3 Scope and Methodology

1.3.1 Study Area

1.3.1.1 The baseline description of the Marine and Coastal Processes environment provides a regional (far-field) overview prior to focusing on the study area. The EIAR recognises the different types of activities associated with the Proposed Development (Offshore) and the Marine and Coastal Processes present within the study area.

1.3.1.2 Descriptions in each baseline section refer to the following sub-areas:

- Caledonia OWF (i.e., Array Area) (including Wind Turbine Generators (WTGs), Offshore Substation Platforms (OSPs) and inter-array/interconnector cables);
- Caledonia Offshore Export Cable Corridor (OECC); and
- Landfall Site (in the context of the Aberdeenshire coast).

1.3.1.3 The Caledonia OWF is comprised of the Caledonia North Site and the Caledonia South Site and, where valuable, descriptions of baseline characteristics differentiate between these areas.

1.3.1.4 It is of note that the OECCs include the transition from offshore to nearshore[i] marine process environmental conditions.

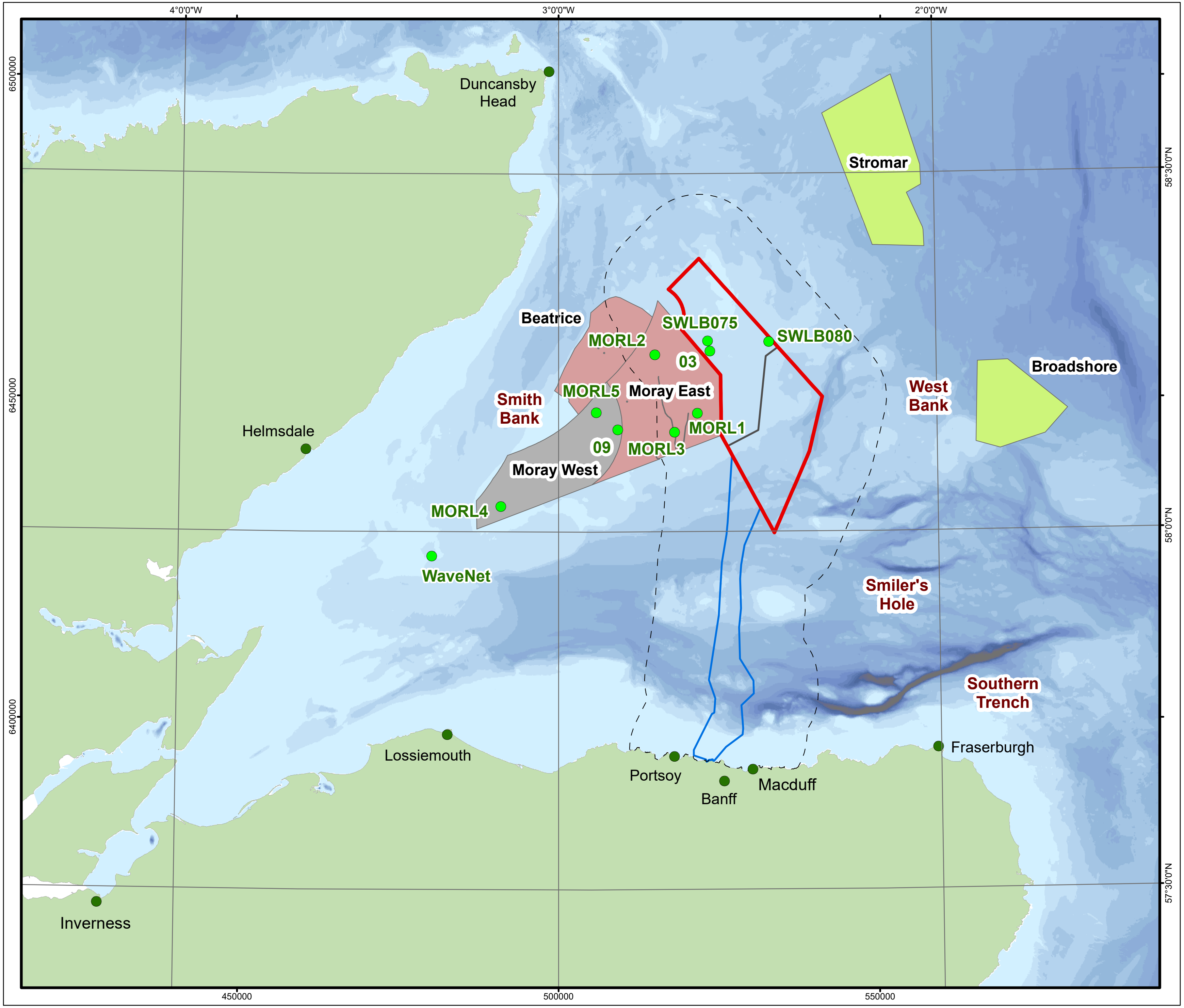
1.3.1.5 The study area is shown in Figure 1-1, which includes the Proposed Development (Offshore) comprising the Caledonia OWF, Caledonia OECC and Landfall Site (up to MHWS), as well as buffer zones to represent a potential Zone of Influence (ZoI) for impacts that might be created within the main areas of activity. The buffer zones are scaled to conservatively represent the equivalent distance of one tidal excursion on a mean spring tide and comprises a distance of 10km from the limit of the Proposed Development (Offshore) (see Section 2.1.2).

1.3.1.6 The Moray Firth is a large embayment covering a surface area of approximately 5,230km^2. Often, the Moray Firth is divided in two parts, as follows (Robinson *et al*., 2009[1]):

- The inner Moray Firth located to the west of the line drawn from Helmsdale to Lossiemouth; and
- The outer Moray Firth from the east of this limit to a line from Duncansby head to Fraserburgh.

1.3.1.7 The Proposed Development (Offshore) is located in the outer Moray Firth (Figure 1-1). The proposed Landfall Site is at Stake Ness, Aberdeenshire, located along the southern coast of the outer Moray Firth.

[i] Area defined as the region from the upper limit of intertidal area (MHWS) to the location where the waves are breaking.



Caledonia OWF
Offshore Export Cable Corridor
Overall Boundary North South Site Division
10km Zone of Influence
Wave Buoys

Offshore Wind Farm (Status)

Offshore Wind Farm - Operational
Offshore Wind Farm - Under Construction
Offshore Wind Farm - Concept/ Early Planning

Depth (m)

0 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
>200

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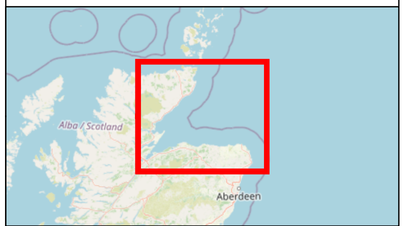

0 10 20 30 km

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GEODETIC PARAMETERS WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE Figure 1-1: Marine and Coastal Processes Study Area	
STATUS Approved	SCALE 1:800,000
DRAWING NUMBER N/A	SHEET NO 01 of 01 / REV N/A

1.3.2 Data Sources

1.3.2.1 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 1-1. This includes:

- Data available from a number of marine data portals;
- Existing physical processes investigations within the Caledonia OWF and in the vicinity of the study area (also see Table 1-2);
- 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;
- Project-specific geophysical, geotechnical and benthic surveys within the Caledonia OWF and Caledonia OECC (Figure 1-2 and Figure 1-3); and
- 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).

Table 1-1: Key source of information for Marine and Coastal Processes.

Source	Summary	Spatial Coverage
General		
National Marine Plan Interactive (NMPi) mapping tool (Marine Scotland, 2024[2])	Interactive map containing data on geology, morphology, surficial sediments, coastal processes, and hydrodynamics.	Full coverage
Marine Scotland Regional Assessments (Marine Scotland, 2021[3])	Regional summaries of coastal processes and hydrodynamics.	Partial coverage
Offshore Energy Strategic Assessment 4 (OESEA4), Department for Business, Energy and Industrial Strategy (BEIS, 2022a[4])	Regional characterisation of geology, morphology, surficial sediments, coastal processes, and hydrodynamics.	Partial coverage
Department for Energy and Climate Change (DECC), Strategic Environmental Assessment 5 (SEA5) (Holmes *et al*., 2004[5])	Regional characterisation of geology, morphology, surficial sediments, coastal processes, and hydrodynamics.	Partial coverage
Beatrice Offshore Windfarm (BOWL) Environmental Statement and associated surveys and technical reports (BOWL, 2010[6]; 2012[7])	Regional and site-specific characterisation of geology, morphology, surficial sediments, coastal processes, and	Partial coverage

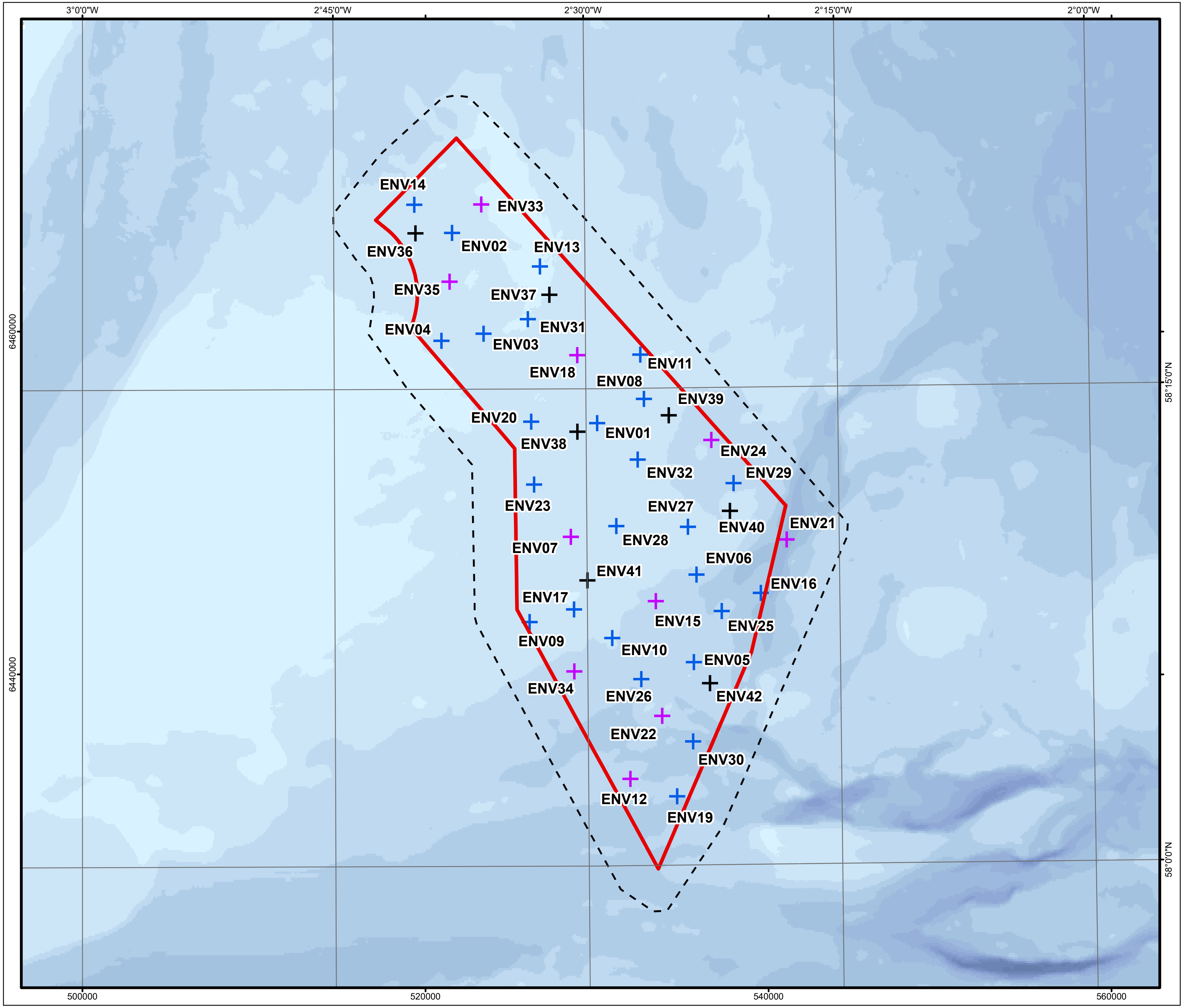
Source	Summary	Spatial Coverage
	hydrodynamics, including survey and model outputs.	
Moray East OWF Environmental Statement and associated surveys and technical reports, (Moray Offshore Renewables Limited (MORL), 2012[29]; Moray Offshore Windfarm (East) Limited, 2017[35])	Regional and site-specific characterisation of geology, morphology, surficial sediments, coastal processes and hydrodynamics, including survey and model outputs.	Partial coverage
Moray West OWF Environmental Statement, scoping report and associated surveys and technical reports (MORL, 2016[34]; Moray Offshore Windfarm (West) Limited 2018[41])	Regional and site-specific characterisation of geology, morphology, surficial sediments, coastal processes and hydrodynamics, including survey and model outputs.	Partial coverage
Stromar Environmental Impact Assessment (EIA) Offshore Scoping Report (Stromar Offshore Wind Farm Ltd, 2024[8])	Regional and site-specific characterisation of geology, morphology, surficial sediments, coastal processes and hydrodynamics, including survey and model outputs	Partial coverage
Strategic environmental Assessment – SEA5 (DECC, 2004[9])	Regional characterisation of geology, morphology, surficial sediments, coastal processes, and hydrodynamics.	Partial coverage
Beatrice Oil and Gas Field Decommissioning EIA (Repsol Sinopec Resources UK Limited, 2018[10])	Regional and site-specific characterisation of geology, morphology, surficial sediments, coastal processes and hydrodynamics, including survey and model outputs.	Partial coverage
Offshore Oil and Gas Licensing 28th Seaward Round Moray Firth – Habitats Regulations Assessment Stage 2 – Appropriate Assessment (DECC, 2015[11])	Regional and site-specific characterisation of geology, morphology, surficial sediments, coastal processes and hydrodynamics, including survey and model outputs.	Partial coverage
Hydrodynamic Data		
Atlas of UK Marine Renewables Energy Resources (ABPmer *et al*., 2017[12])	Low resolution modelled hindcast wave, wind and hydrodynamic data. Summary data provided only.	Full coverage
SEASTATES Metocean Data and Statistics Map (ABPmer, 2018[13])	Modelled hindcast wave and hydrodynamic data.	Full coverage (Caledonia OWF and Caledonia OECC)

Source	Summary	Spatial Coverage
Caledonia Metocean Measurements	Wave (period, height and direction) and current (speed and direction)	Caledonia OWF
Centre for Environment, Fisheries and Aquaculture Science (Cefas) Wavenet data (Cefas, 2024[14])	Wave (period, height and direction) and current (speed and direction)	Partial coverage
United Kingdom Hydrographic Office, Admiralty Tables (UK Hydrographic Office (UKHO), 2024[15])	Tidal gauges.	Partial coverage
Morphology		
European Marine Observation and Data Network (EMODnet, 2024[16])	Interactive map with bathymetry, geology and sediment layers available for download.	Full coverage (Caledonia OWF and Caledonia OECC)
Joint Nature Conservation Committee (JNCC) Coastal Directory Series: Regional Report 3 - North-east Scotland: Cape Wrath to St. Cyrus (Barne *et al*., 1996[17])	Regional characterisation of geology, morphology, coastal processes and form.	Partial coverage
UKHO Admiralty Chart data (UKHO, 2024[15])	Interactive map with bathymetry.	Partial coverage
British Geological Survey (BGS) Offshore GeoIndex Map (BGS, 2020[18])	Seabed sediment maps (with a 16-class Folk classification) and boreholes records from point location. Data gaps exist I the coastal zone.	Full coverage (Caledonia OWF and Caledonia OECC)
The Proposed Development (Offshore) – Caledonia OWF and Caledonia OECC, environmental baseline survey (Volume 7B, Appendix 4-1: Environmental Baseline Report (Array Area) and Volume 7B, Appendix 4-2: Environmental Baseline Report (Offshore Export Cable Corridor))	Project-specific geophysical, geotechnical and benthic surveys (including water sampling).	Full coverage (Caledonia OWF and Caledonia OECC)
Strategic Environmental Assessment 5 – SEA5 Seabed and Superficial Geology and Sediments Survey report, (Holmes *et al*., 2004[5])	Regional characterisation of geology, morphology, surficial sediments and sediment transport, including geophysical survey outputs.	Partial coverage

Source	Summary	Spatial Coverage
OWF Ground Conditions Feasibility Assessment – NE4 Soil Thickness Study (Vysus Group, 2021[19])	Borehole data on sediment thickness.	Partial coverage
Future Changes		
Coastal Futures Interactive Map (IHE Delft, 2021[20])	Sea level rise predictions for coastal locations.	Full coverage
Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report: Impacts, Adaption and Vulnerability (IPCC, 2022[21])	Predictions of future changes as a result of climate change, including sea level rise predictions for coastal locations and modifications to hydrodynamic regimes.	Partial coverage
UK Climate Projects Science report (UKCP18) Marine Report (Palmer *et al*., 2018[22])	Sea level rise predictions for coastal locations.	Partial coverage
Dynamic Coast - Coastal Erosion in Scotland (Centre of Expertise for Waters (CREW), 2021[23])	Predictions of future changes as a result of climate change, including sea level rise prediction and its impact on coastal area.	Full coverage
Sea Level Projection Tool – NASA Sea Level Change Portal (NASA, 2024[24])	Sea level rise predictions for coastal locations.	Partial coverage

Table 1-2: Hydrodynamic instruments deployed within the vicinity of the study area.

Data Source	Latitude (°N)	Longitude (°E)	Period Analysed	Duration
Directional wave buoys in the Caledonia OWF (SWLB075 and SWLB080)	58.27	-2.44	June 2023 to October 2023	5 months (ongoing data collection)
	58.27	-2.61		
Directional wave buoy in the MORL Eastern Development Area	58.17	-2.63	June 2010 to May 2011	~11 months
Acoustic Wave and Current Profilers (AWACs) in the MORL R3 zone	58.25	-2.75	July 2010 to December 2010	100 days
	58.14	-2.70	October 2010 to February 2011	106 days
	58.04	-3.15	July 2010 to January 2011	124 days
	58.17	-2.90	July 2010 to February 2011	103 days
Directional wave buoy in BOWL application site	58.31	-2.81	February 2010 to November 2010	~9 months
Cefas WaveNet Moray Firth wave buoy[14]	57.97	-3.33	August 2008 to January 2011	~2 years
Jacky platform wave buoy	58.18	-2.98	September 2008 to March 2009	~6 months
Beatrice Alpha Oil Platform (Comber, 1993[25])	58.12	-3.09	Summer to winter 1990	<1 year
Outer Moray Firth Geosat Altimeter (Natural Environment Research Council, 1992[26])	-	-	1986-1989	~3 years
Note, also see Figure 1-1 for wave buoy locations.				



Caledonia OWF

Survey Area

Station Type

- Camera Only Stations
- PSA and Macrofauna Station
- PSA, Macrofauna, eDNA, Chemistry and Water Station

Depth (m)

- 0 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 100
- 100 - 110
- 110 - 120
- 120 - 130
- 130 - 140
- 140 - 150
- 150 - 160
- 160 - 170

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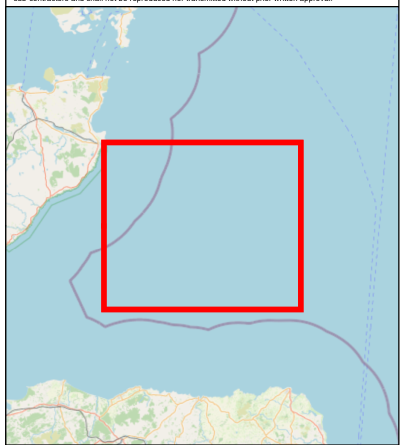

0 5 10 km

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Figure 1-2: Geophysical Survey Stations Within the Caledonia OWF

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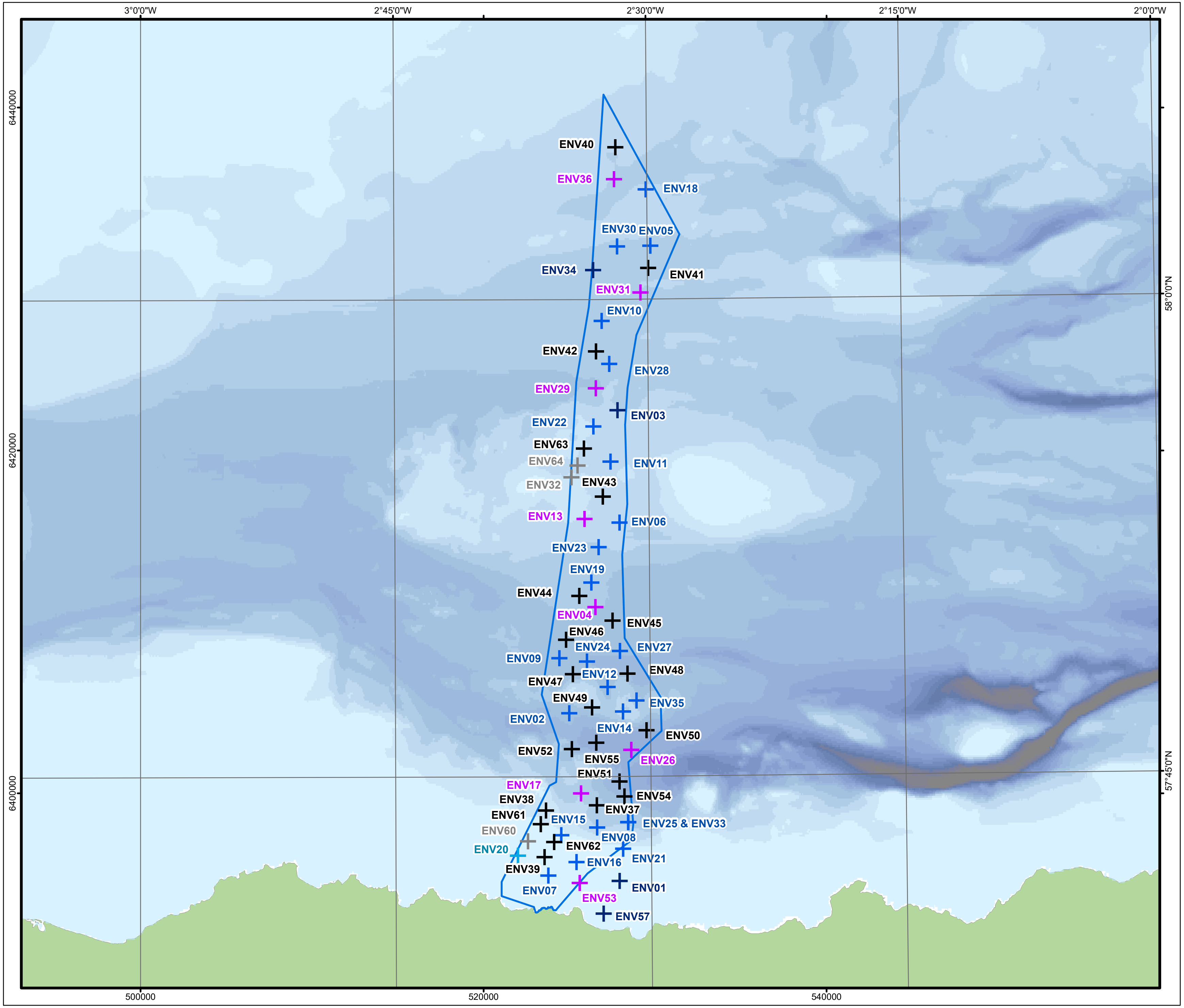

Offshore Export Cable Corridor

Station Type

- Camera Only Station
- PSA and Macrofauna Station
- PSA, Macrofauna, eDNA, Chemistry and Water Station
- Macrofauna Only Station
- Camera, PSA and Macrofauna Station
- No data acquired

Depth (m)

0 - 50	170 - 180
50 - 60	180 - 190
60 - 70	190 - 200
70 - 80	>200
80 - 90	
90 - 100	
100 - 110	
110 - 120	
120 - 130	
130 - 140	
140 - 150	
150 - 160	
160 - 170	

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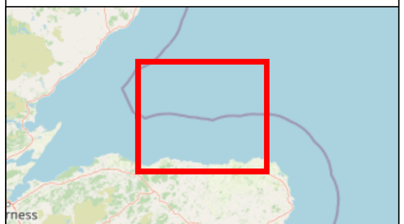

0 5 10 km

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Figure 1-3: Geophysical Survey Stations Within the OECC

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2 Baseline Environment

2.1 Hydrodynamics Regime

2.1.1 Waves

Regional Overview

2.1.1.1 Wave energy is dependent on the friction action of the wind on the sea surface that drives directional sea-surface and storm surge currents. These in turn drive non-directional rotational near-bed currents when wind and swell waves interact with the seabed (Tappin *et al.*, 2011[27]). The wave regime frequently plays an important role in the erosion, transport and deposition of sediments, although it's influence on the seabed varies with changes in bathymetry and wind patterns.

2.1.1.2 Nearly all wave action in the Moray Firth is generated further offshore in deeper water. Swell wave conditions experienced within the Moray Firth are dominated by waves generated from between 0°N and 40°N (approximately 57%), with little swell from other directions due to restricted fetch lengths (Ramsay and Brampton, 2000[28]). Based on the UK Atlas of Marine Renewable Energy Resources (ABPmer *et al.*, 2017[12]), the annual significant wave height in the outer Moray Firth varies from 0.75m in the summer to 2.25m in the winter (Figure 2-1).

2.1.1.3 In the inner Moray Firth, the WaveNet Moray Firth buoy recorded the most frequent wave direction from north-east (18% of the record), whilst almost 75% of the record is comprised of waves from north-east and east. The most frequent wave heights were recorded between 1m and 1.5m (45% of the record) and the most frequent mean wave period was between 5 and 6 seconds (28% of the record).

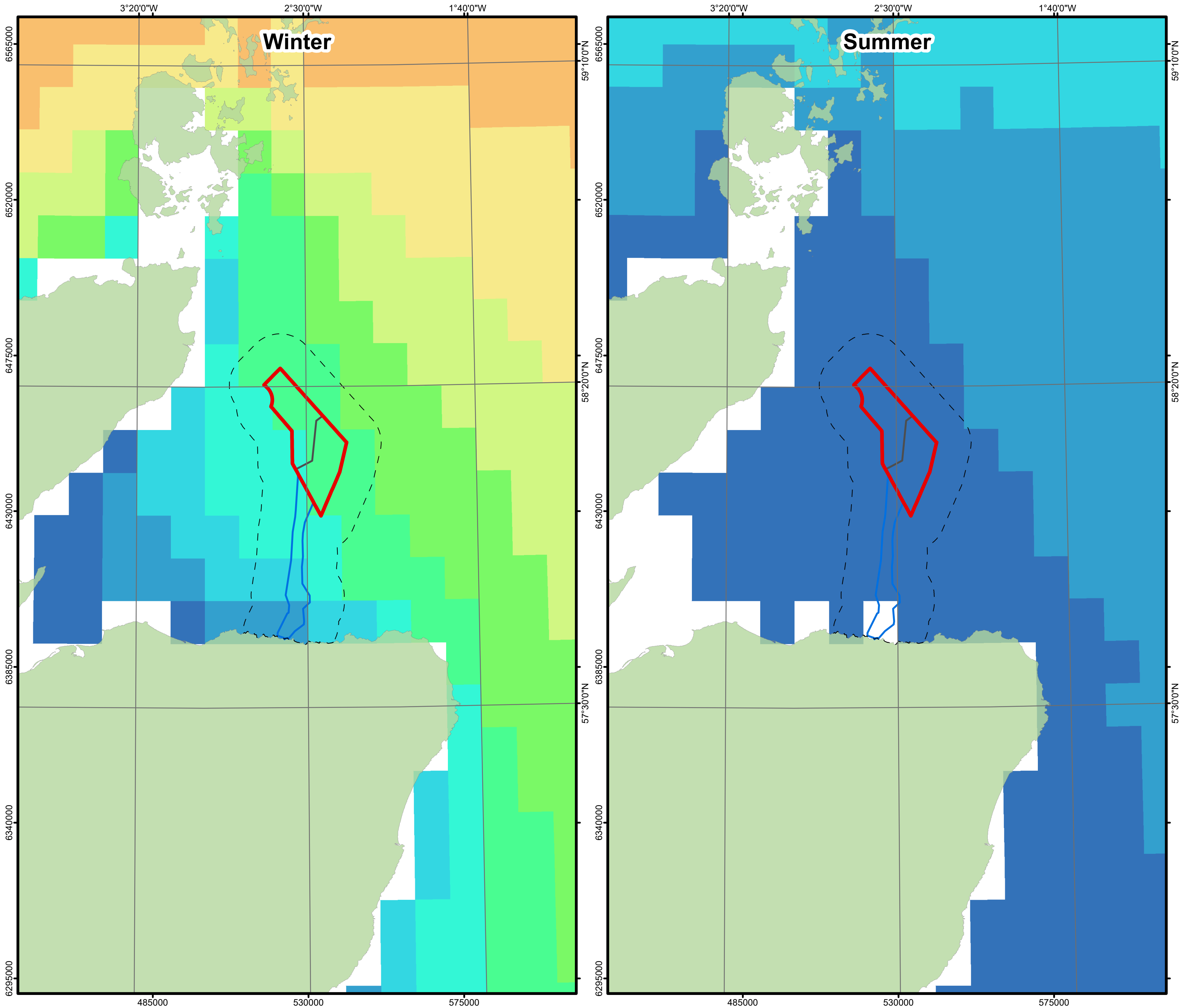
2.1.1.4 The wave data used to inform the Environmental Statement of the Moray East OWF (MORL, 2012[29]) showed that the most frequent wave direction was from the north-east and north-northeast (15 to 40%) and the most frequent wave heights between 0.5m and 1.5m (50 to 75%) of all waves. The largest significant wave height observed exceeded 6 m, and typically approaches from either the east or east-southeast.

2.1.1.5 In the near field of the Proposed Development (Offshore), the most frequent mean wave periods are between 3 and 4 seconds (35% of the record) based on data from the MORL Wave Buoy, indicative of locally generated wind waves. However, the MORL AWAC 3c showed that the most frequent mean wave periods are between 7 and 8 seconds (50% of the record), indicative of swell waves. This variation is explained by the different times at which the data were collected (Table 1-2). MORL AWAC 3c recorded wave data from

October to January, a period which is typically characterised by more stormy conditions, whilst the MORL Wave Buoy captured almost a full year of data.

2.1.1.6 In the outer Moray Firth, wave data collected at the Beatrice Alpha oil platform showed a significant wave height of 1.5m in the winter and 1m in the summer, with a largest wave height of 8m and 3m for the winter and summer, respectively (Comber, 1993[25]). The wave regime in the outer Moray Firth includes both swell waves generated elsewhere in the North Sea and locally generated wind waves.

2.1.1.7 In the Moray Firth, wind and waves are critical energy inputs to the coastal system as it is characterised by low tidal current energy (Reid and McManus, 1987[30]; Hansom, 2021[31]), which suggests that waves are the main factors of sediment transport (Holmes *et al*., 2004[5]; MORL, 2012[29]).



- Caledonia OWF
- Offshore Export Cable Corridor
- Overall Boundary North South Site Division
- 10km Zone of Influence

Mean Winter Wave Height (m)

- < 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- 2 - 2.25
- 2.25 - 2.5
- 2.5 - 2.75
- 2.75 - 3
- 3 - 3.5

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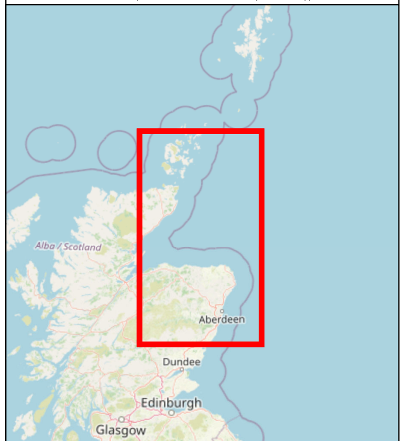

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GEODETIC PARAMETERS WGS 84 / UTM zone 30N (EPSG: 32630)	

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Figure 2-1: Wave Height in Winter and Summer (ABPmer, 2008)

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Caledonia OWF

2.1.1.8 The initial five months (June to October 2023) of wave data collected by two Floating Light Detection and Ranging (FLiDAR) buoys deployed within the Caledonia OWF (SWLB075 and SWLB080; see Figure 1-1 and Table 1-2) have been used to make an initial assessment of the local wave climate[ii]. The two buoys are located approximately 10km apart with a similar water depth of approximately 55m.

2.1.1.9 The data related to wave height is similar between the two FLiDAR buoys deployed. The mean wave height recorded was 1.23 ± 0.02m, with a maximum of 10.5 ± 0.5m and minimum of 0.2m± 0.5m. The most frequent wave height was observed at between 0 and 1m for 60% ± 1% of the record.

2.1.1.10 The data related to the wave period is also similar between the FLiDAR buoys deployed. The wave period varies from 11.3 ± 0.1 seconds to 2.78 ± 0.02 seconds. The most frequent wave period was observed between 4 and 5 seconds for 42.5 ± 0.5% of the record. The data showed that the wave period was comprised between 3 and 6 seconds for 82 ± 1% of the record. These results can be explained by the wind direction coming from land for 50% of the time (i.e., north, north-west and south-east) which does not allow the development of a long fetch[iii]. Also, the high period observed can be considered to be the result of wind blowing from the east and north-east, which has more time to develop in open water (also see Section 2.1.3).

2.1.1.11 A noticeable difference is observed when looking at the wave direction between the two FLiDAR buoys. SWLB075 showed the highest frequency of waves coming from the north-east (36%), whereas SWLB080 showed that waves come mostly from both north-east and east (25 ± 2%). Also, SWLB080 recorded a higher frequency of waves coming from the south-east (19.5%) compared to SWLB075 (7.8%). These results can be explained by the wave buoy location, as SWLB080 is located further to the south-east than SWLB075. In contrast, waves originating from the north have a slightly higher frequency at SWLB075 (18%) when compared to SWLB080 (10%).

2.1.1.12 The data from ABPmer's SEASTATES database (ABPmer, 2018[13]) differs slightly from the FLiDAR buoys data, noting Figure 2-2 shows that:

- Wave height is observed up to 1m for approximately 50% of the record, whereas it was recorded to be 60% from the FLiDAR buoys;
- The highest frequency of waves originates from the south-east (26% of the record), whereas SWLB075 and SWLB080 recorded a frequency for the same direction of 7.8% and 19.5%, respectively;

[ii] It should be noted that data collection is ongoing via these two FLiDAR buoys, with data available to inform this baseline characterisation from June 2023 to October 2023 at the time of writing.
[iii] The distance travelled by wind or waves across open water.

- Waves coming from the south-west represent 22.5% of the annual wave climate, whereas the FLiDAR buoys recorded 7.5 ± 1.5% for the same direction; and
- Waves coming from the north-east accounted for approximately 20% of the record, which is lower than the data recorded by the FLiDAR buoys (36% and 27% for SWLB075 and SWLB080, respectively).

2.1.1.13 Overall, the data from ABPmer's SEASTATES database (ABPmer, 2018[13]) corresponds better with the data from the SWLB080 (compared to SWLB075), even if a noticeable difference is observed. Longer datasets (more than five months) are likely to increase the correlation between deployed buoys and ABPmer's SEASTATES database. The initial five months of FLiDAR data were available to inform the EIAR, which mostly correspond to the summer period. Conversely, data from ABPmer's SEASTATES database (ABPmer, 2018[13]) is based upon decades of hindcast measurements.

Caledonia OECC

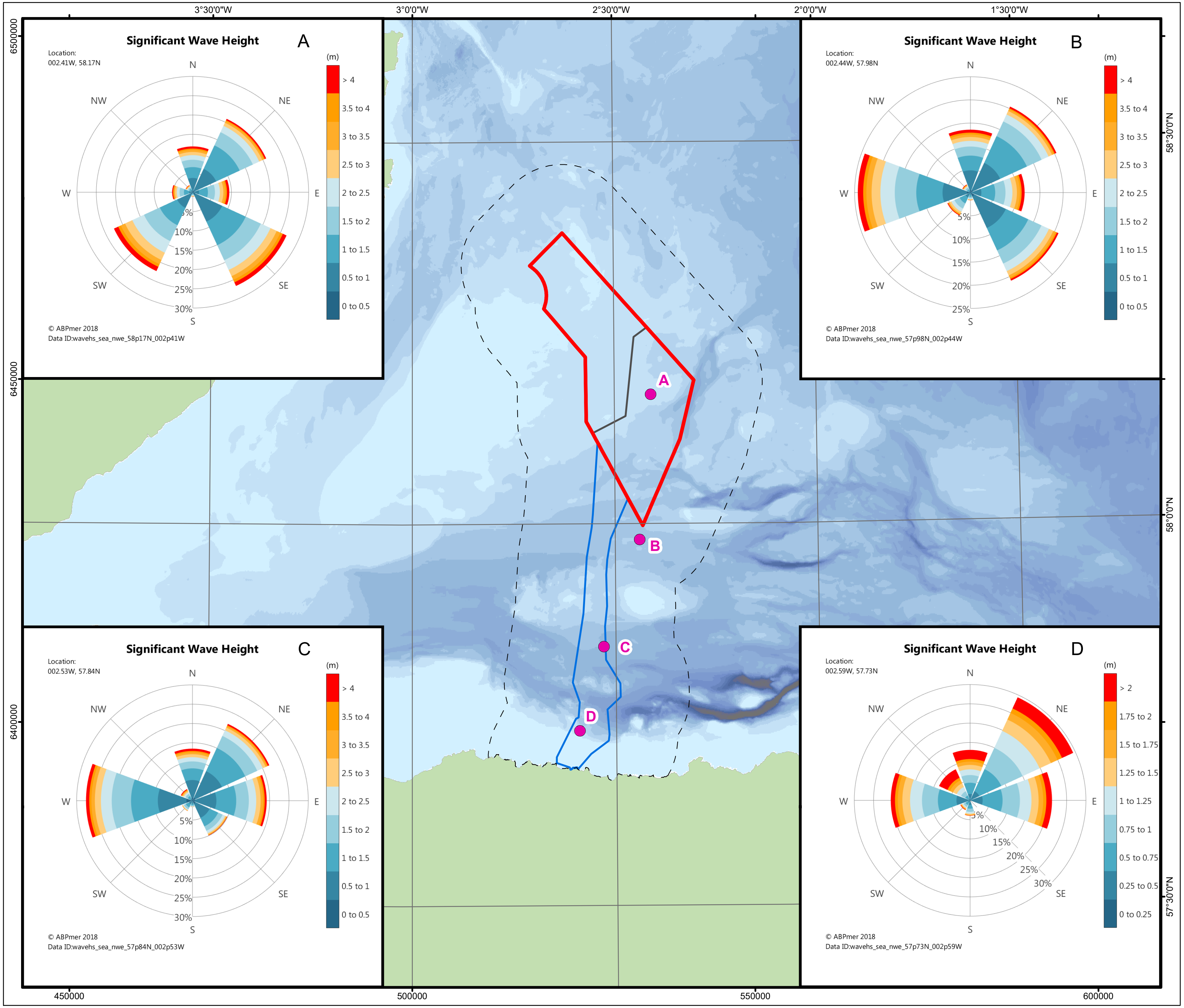
2.1.1.14 The data from ABPmer's SEASTATES database (ABPmer, 2018[13]) shows that the mean wave height along the Caledonia OECC is approximately 1.5m (Figure 2-2). The highest frequency of wave height is comprised between 0 and 1m along the Caledonia OECC; however, it varies from around 55% nearer the coast to 45% further offshore. Along the Caledonia OECC, the highest frequency of wave direction is observed from the west (25 ± 1%) and the north-east (21%). The data from the Caledonia OECC shows the highest frequency of waves from the south-east (21%) compared to data closer to the coast (10%). Also, waves coming from the east are less frequent in the Caledonia OECC further offshore (12%) than in the area closer to the coast (19%).

2.1.1.15 Significant wave height along the Caledonia OECC was modelled for four wind directions of 20m/s each (north, east, south, and west) and results are summarised below (Moray Offshore Windfarm (West) Limited, 2018[41]):

- Easterly wind creates the highest significant wave height simulated decreasing from north (8m) to south (4m) along the Caledonia OECC;
- Westerly wind induces the lowest significant wave height simulated with a constant value of 4m along the Caledonia OECC;
- Southerly wind shows a significant wave height between 5 and 2m decreasing from north to south along the Caledonia OECC; and
- Northerly wind will potentially generate a significant wave height of 5m along the Caledonia OECC.

Landfall Site

2.1.1.16 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; Figure 2-2) (ABPmer, 2018[13]).



Caledonia OWF
Offshore Export Cable Corridor
Overall Boundary North South Site Division
10km Zone of Influence (ZoI)
Significant Wave Height Locations (ABPmer, 2018)

Depth (m)
0 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
>200

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0 10 20 30 km

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CONTRACTOR REV: 01
GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)
DRAWING TITLE:
Figure 2-2: Significant Wave Height Within the Proposed Development (Offshore) from ABPmer Seastates (ABPmer, 2018)
STATUS: Approved
SCALE: 1:750,000
DRAWING NUMBER: N/A
SHEET NO: 01 of 01
REV: N/A

2.1.2 Tides

Regional Overview

2.1.2.1 The Moray Firth is classified as a mesotidal with a tidal range of between 3 and 3.5m. Tidal range in the inner Moray Firth varies between 3.5 to 4m, whereas the outer Moray Firth has a tidal range of between 2.5 and 3m (Figure 2-3; ABPmer, 2017[12]). The mean spring range measured at Fraserburgh, at the south-eastern limit of the Moray Firth and located to the southeast of the Proposed Development (Offshore), is 3.7m (MORL, 2012[29]).

2.1.2.2 The mean peak tidal currents decrease from the outer Moray Firth to the inner Moray Firth (Figure 2-4; ABPmer, 2017[12]). The stronger tidal currents observed in the outer Moray Firth are essentially due to the passage of a tidal wave current through the Pentland Firth (north-east) and off Rattray Head (south-east), where the mean spring peak flow can reach up to 1.5m/s (ABPmer, 2012[32]). Further inshore, local gyral patterns occur, resulting in benign current speeds of generally less than 0.5m/s (mean spring peak flow) (Adams and Martin, 1986[33]; ABPmer, 2017[12]).

2.1.2.3 Near to Wick, to the north-west of the Moray Firth, the peak spring current varies from 0.26 to 1.25m/s, with an annual occurrence of currents greater than 1m/s occurring between 11 to 20% of the time. Near Fraserburgh (south-east of the Moray Firth), peak spring current varying from 1.76 to 2m/s, with an annual occurrence of tidal currents greater than 1m/s between 40 and 50% (ABPmer, 2017[12]).

2.1.2.4 Available data on peak spring current speeds show variability between the different locations of measurements. For example, Moray East OWF survey (adjacent to the Proposed Development (Offshore)) showed peak spring current speeds around 0.45 to 0.5m/s, whereas Moray West OWF survey (lying approximately 15km west of the Proposed Development (Offshore)) measured peak spring current speeds of around 0.3m/s (MORL, 2016[34]; Moray Offshore Windfarm (East) Limited, 2017[35]). Data from the Beatrice OWF, which is located approximately 5km north-west of the Proposed Development (Offshore), showed a slightly higher current speed (by order of 5 to 10%) at the northern end of the OWF site due to the influence of the Pentland Firth and, correspondingly, less than average at the southern end (ABPmer, 2012[32]).

2.1.2.5 Alongside a varying current speed, tidal streams present in the Moray Firth are complex and variable in direction. Tidal currents are generally to the south or south-east during the flood tide and to the north during the ebb tide. However, regional tidal ellipses indicate variation in the Moray Firth. Based on the UK Renewables Atlas (ABPmer, 2017[12]), tidal excursion ellipses are generally rotatory in the centre of the Moray Firth, becoming more rectilinear both further offshore (oriented generally north-northwest to south-southeast), and closer to the coast (oriented parallel to the shoreline) (Figure 2-5).

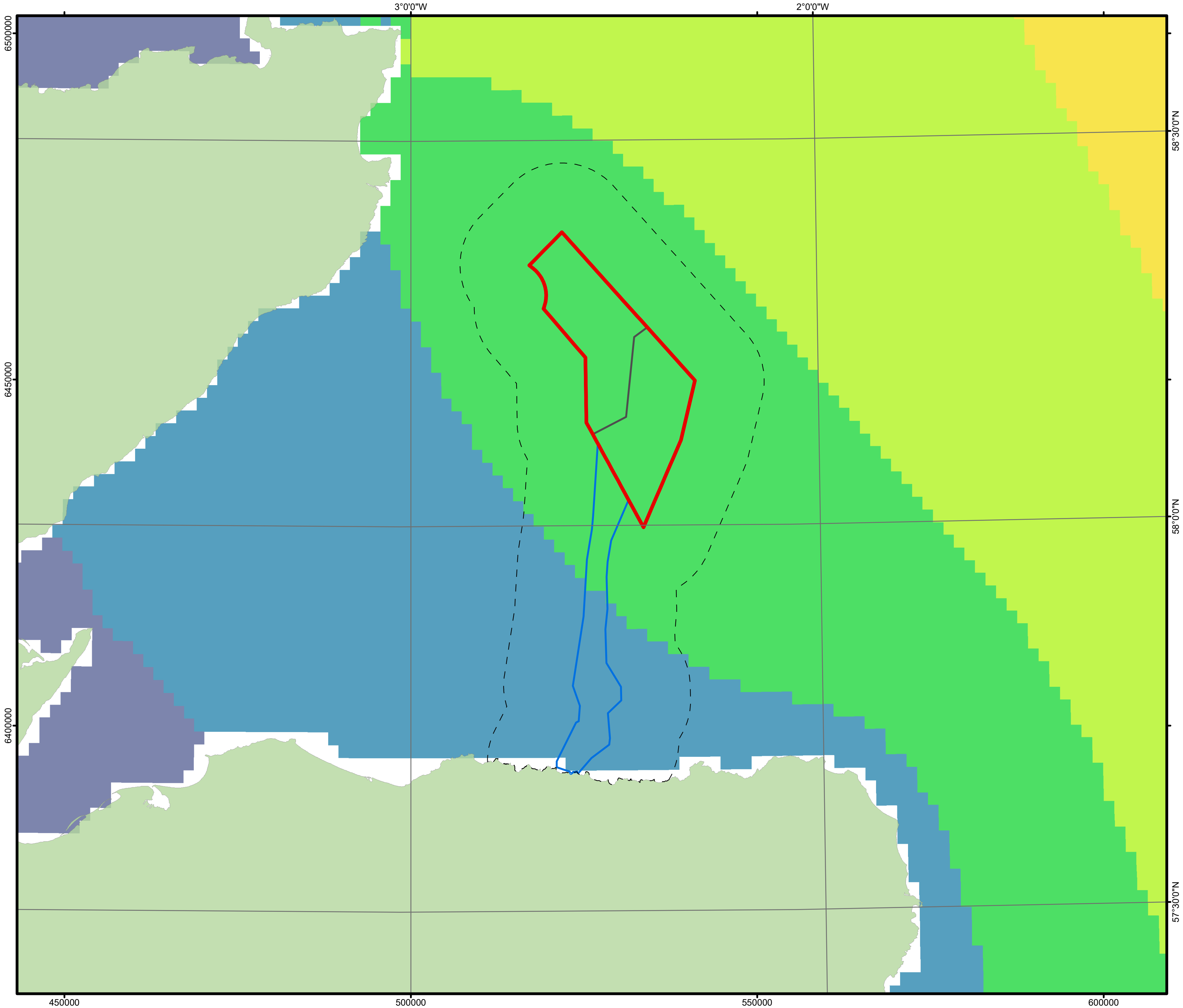
2.1.2.6 Tidal excursion ellipses in the Moray Firth show an increase of 5km from the inner Moray Firth to outer Moray Firth. Local gyral patterns are observed in the centre of the Moray Firth, west of the Proposed Development (Offshore), with excursion ranging from 2 to 4km. In the northern part of the Moray Firth, tidal excursion ellipses range from 6 to 9km with a south-west to north-east direction, whereas in the southern part of the Moray Firth, the east to west directed tidal ellipses excursion varies between 4 and 10km, which aligns with the direction of the sediment transport (see Section 2.2.4) (Figure 2-5; ABPmer, 2017[12]).

2.1.2.7 From previous studies at Moray East and Beatrice OWFs, results correlate to the UK Renewables Atlas data (ABPmer, 2017[12]). These show that residual tidal currents, over a period of days to weeks, are generally directed into the Moray Firth to the south-southwest (ABPmer, 2012[29]; MORL, 2012[32]).

2.1.2.8 Variations in current speeds and direction also occur in response to the presence of notable seabed and coastal features, for example Smith Bank, which induces localised gyres, and the Southern Trench, both of which are discussed further in Section 2.2.3 (BEIS, 2022b[36]).

2.1.2.9 Near bed peak spring tidal currents in the Southern Trench are estimated to exceed 0.7m/s in some parts, oriented west to east, although tidal currents outside of the trench generally range from around 0.35 to 0.65m/s (Holmes *et al*., 2004[5]). The Smith Bank is exposed to semi-diurnal tidal forcing. The mean neap tidal range is 1.4m, the mean spring tidal range is 2.8m, and the maximum (astronomical) tidal range is 4m. The tidal current axis is aligned approximately north by north-east (ebb) and south by south-west (flood). Peak tidal current speeds over the Smith Bank are generally 0.25m/s during mean neap tides and 0.50m/s during mean spring tides (ABPmer, 2012[32]).

2.1.2.10 Tides in the Moray Firth lie in the range 3.5m at springs, but they generate relatively weak currents because, rather than being directed into the Moray Firth, the tidal wave crosses its entrance. Therefore, tidal current is largely incapable of bedload sediment transport beyond fine sand-sized material and smaller (Holmes *et al*., 2004[5]; MORL, 2012[29]; see Section 2.2.4). However, the co-incidence of a north-easterly gale and high spring tides can elevate water levels considerably along the coast, producing locally significant erosion along the southern Moray Firth coast (Hansom, 2021[31]).



Caledonia OWF

Offshore Export Cable Corridor

Overall Boundary North South Site Division

10km Zone of Influence

Mean Spring Tidal Range (m)

- 1.51 - 2
- 2.01 - 2.5
- 2.51 - 3
- 3.01 - 3.5
- 3.51 - 4

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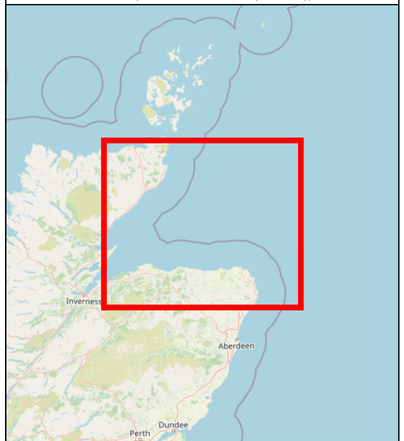

0 10 20 30 km

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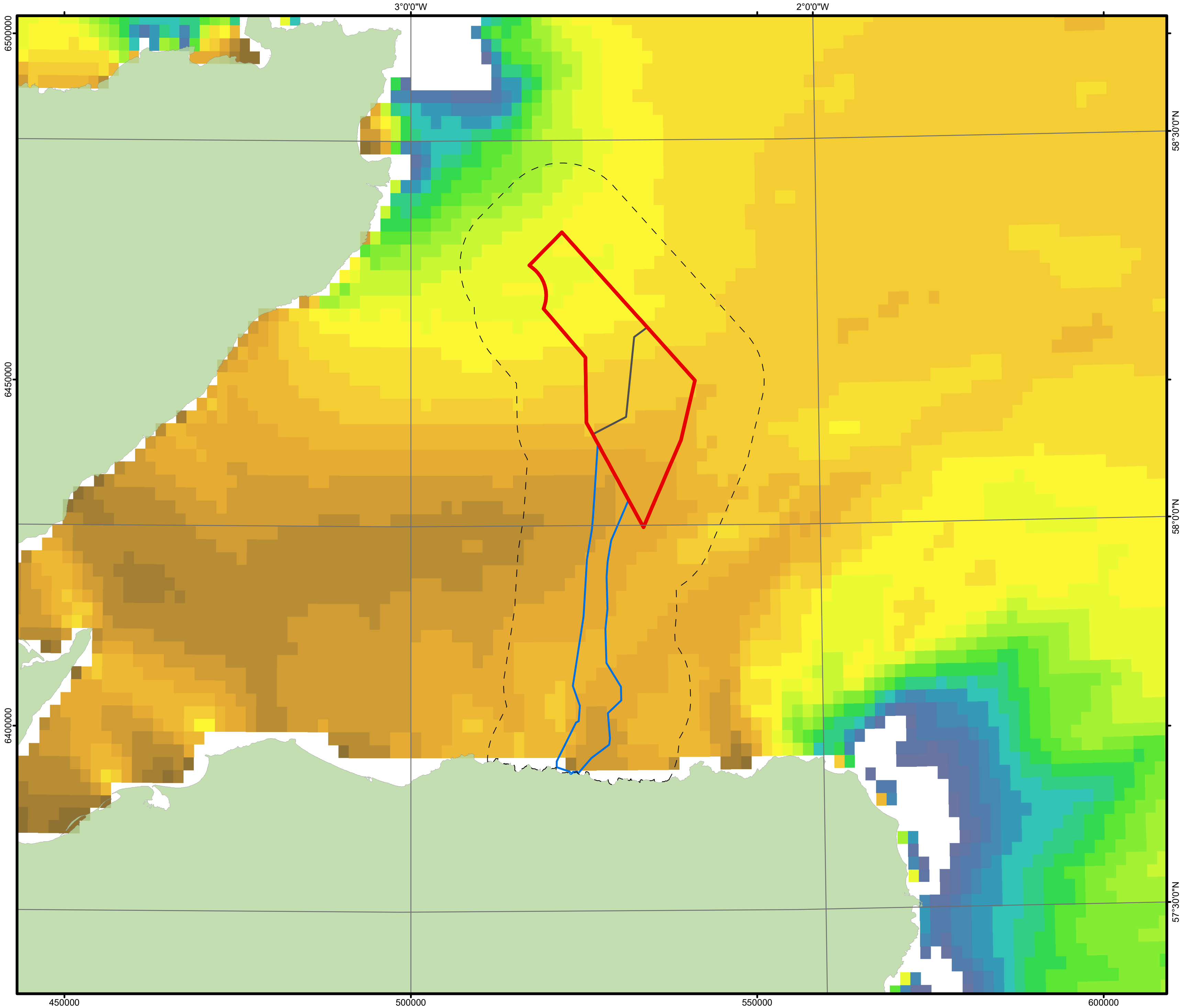
GEODETIC PARAMETERS WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE Figure 2-3: Mean Spring Tidal Range (ABPmer, 2008)	
STATUS Approved	SCALE 1:750,000
DRAWING NUMBER N/A	SHEET NO 01 of 01 — REV N/A



Caledonia OWF
Offshore Export Cable Corridor
Overall Boundary North South Site Division
10km Zone of Influence (ZoI)

Peak Flow for Mean Spring Tide (m/s)

<0.1	0.61 - 0.65
0.11 - 0.15	0.66 - 0.7
0.16 - 0.2	0.71 - 0.75
0.21 - 0.25	0.76 - 0.8
0.26 - 0.3	0.81 - 0.85
0.31 - 0.35	0.86 - 0.9
0.36 - 0.4	0.91 - 0.95
0.41 - 0.45	0.96 - 1
0.46 - 0.5	1.01 - 1.05
0.51 - 0.55	1.06 - 1.1
0.56 - 0.6	1.11 - 1.15

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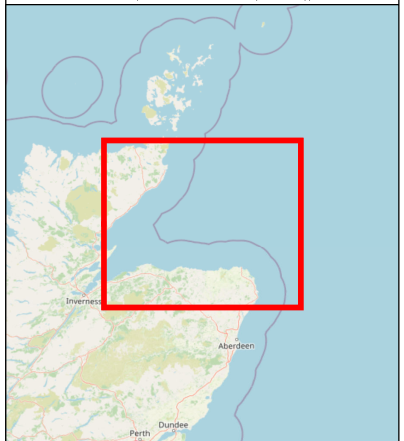

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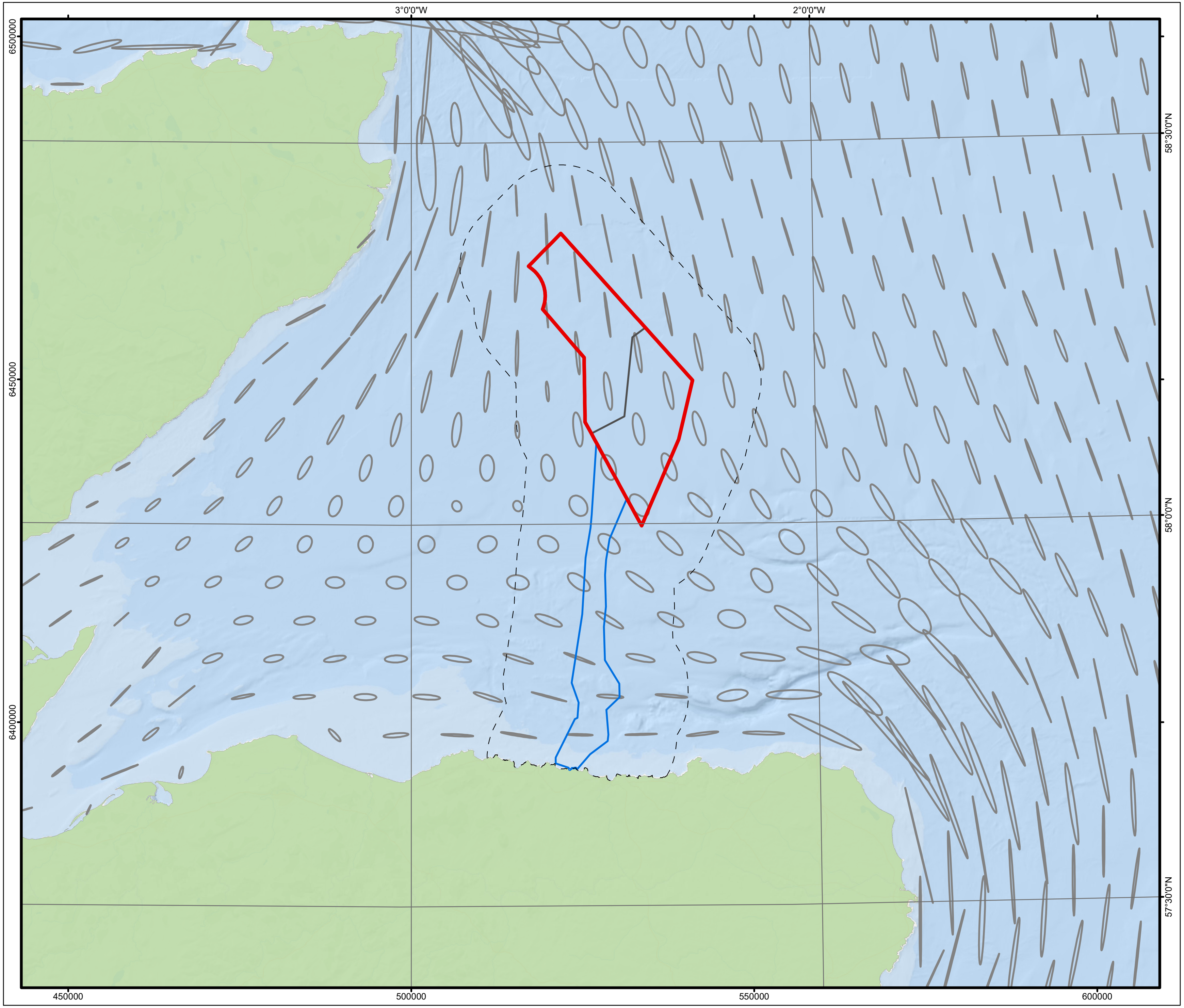
CONTRACTOR REV: 01
GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)
DRAWING TITLE:

Figure 2-4: Peak Spring Tidal Current Speed (ABPmer, 2008)

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



Caledonia OWF
Offshore Export Cable Corridor
Overall Boundary North South Site Division
10km Zone of Influence
Tidal Excursion Ellipses

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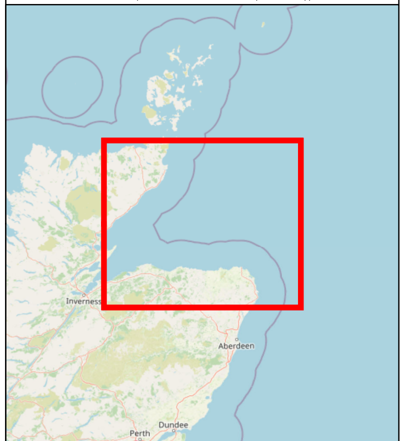

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01	09/09/2024	Approved	EV	BB	DH
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CALEDONIA Offshore Wind Farm

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CONTRACTOR DRAWING NO UKCAL1_GO_WNF_MPR_MAP_00069	CONTRACTOR REV 01
GEODETIC PARAMETERS WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE Figure 2-5: Tidal Excursion Ellipses (ABPmer, 2008)	
STATUS Approved	SCALE 1:750,000
DRAWING NUMBER N/A	SHEET NO 01 of 01 · REV N/A

Caledonia OWF

2.1.2.11 Based on the UK Renewables Atlas (ABPmer, 2017[12]), the spring tidal range varies between 2 and 3m within the Caledonia OWF, whereas the neap tidal range varies between 1 and 2m (Figure 2-3). The peak spring tidal flow varies between 0.26 to 0.75m/s increasing from south to north (ABPmer, 2017[12]; Figure 2-4). This spatial pattern is due to the influence of higher current speeds through the Pentland Firth. Tidal currents are generally directed to the south or south-southeast on the flood tide and to the north or north-northwest during the ebb tide.

2.1.2.12 The tidal excursion ellipses decrease from the north to south of the Caledonia OWF, from 6 to 3km (ABPmer, 2017[12]; Figure 2-5). At the northern end of the Caledonia OWF, tidal ellipses are generally rectilinear and directed north south, becoming more rotary towards the southern end of the Caledonia OWF, where they are oriented north-west to south-east (ABPmer, 2017[12]; Figure 2-5).

2.1.2.13 Within the Caledonia North Site the spring tidal range varies between 2 and 3m, whereas the neap tidal range varies between 1 and 2m (Figure 2-3). The peak spring tidal flow varies between 0.26 to 0.46m/s increasing from south to north (ABPmer, 2017[12]; Figure 2-4). This spatial pattern is due to the influence of higher current speeds through the Pentland Firth. Tidal currents are generally directed to the south or south-southeast on the flood tide and to the north or north-northwest during the ebb tide (ABPmer[12], 2017;).

2.1.2.14 The tidal excursion ellipses decrease from the north to south of the Caledonia North Site, from 6 to 4km (ABPmer, 2017[12]; Figure 2-5). Within Caledonia North, tidal ellipses are generally rectilinear and directed north south.

2.1.2.15 Within the Caledonia South Site, the spring tidal range varies between 2 and 3m, whereas the neap tidal range varies between 1 and 2m (Figure 2-3). The peak spring tidal flow varies between 0.26 to 0.4m/s increasing from south to north (ABPmer, 2017[12]; Figure 2-4). This spatial pattern is due to the influence of higher current speeds through the Pentland Firth. Tidal currents are generally directed to the south or south-southeast on the flood tide and to the north or north-northwest during the ebb tide.

2.1.2.16 The tidal excursion ellipses in Caledonia South become more rotary towards the south, where they are oriented north-west to south-east, from 4 to 3km (ABPmer, 2017[12]; Figure 2-5).

2.1.2.17 Two FLiDAR buoys were deployed in the Caledonia OWF of the Proposed Development (Offshore) (SWLB075 and SWLB080) and recorded the current direction and speed during October 2023, which can be used to describe the tidal flow as it covered a full spring/neap cycle. The FLiDAR buoy located in the north of the Caledonia OWF (SWLB075) measured an average speed at the surface (specifically at 2m below the sea surface) of 0.19m/s with a maximum of 0.57m/s. The FLiDAR buoy located the south of the Caledonia OWF (SWLB080) measured an average speed slightly higher of 0.22m/s with a maximum of 0.7m/s. The value measured at mid-water depth (specifically at 26m depth) showed the same result for both buoys with an average speed of 0.27m/s with a maximum flow of 0.81m/s). The average current and maximum speed measured near-bed (specifically at 56m) also showed the same results between the buoys with values of 0.08m/s and 0.36m/s, respectively.

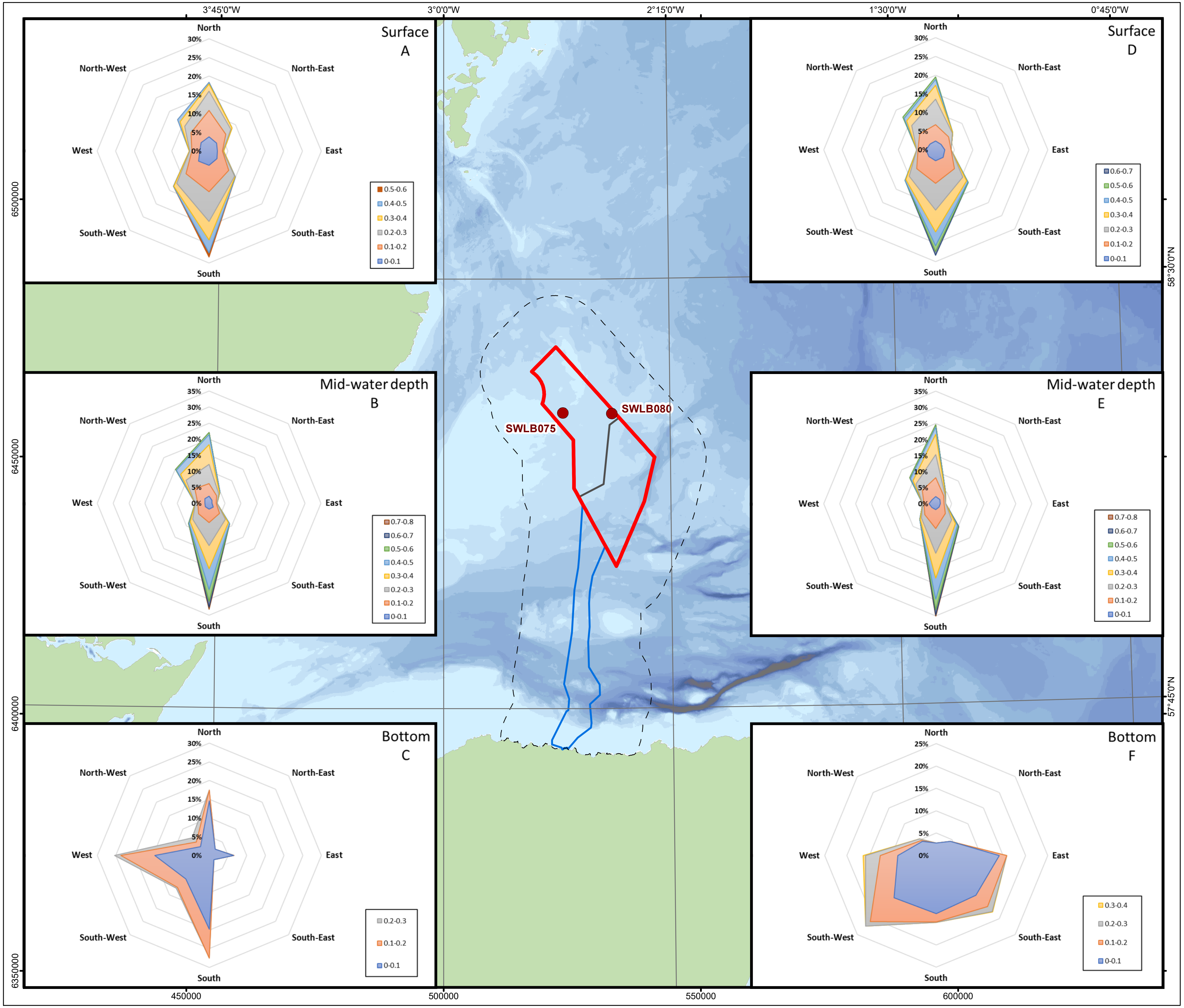
2.1.2.18 At the surface, both FLiDAR buoys showed that currents progress mostly southwards for 28.2 ± 0.2% of the time, followed by a northward direction for 18.5 ± 0.3% of the time (Figure 2-6). The less frequent direction is observed for east and west, with value of 5 ± 1% of the time on average for both FLiDAR buoys and in both directions. Current directions were measured at 10% ± 3% on average for all the other directions (i.e., south-west, north-east, south-east and north-west). For both FLiDAR buoys, the highest current speed was observed when going southward (0.25m/s and 0.29m/s on average for SWLB075 and SWLB080, respectively), whereas the lowest current speed was observed when going eastward (0.1m/s on average for both FLiDAR buoys).

2.1.2.19 At mid-water depths, current followed the same trend as the surface for both FLiDAR buoys, with 34 ± 1% of the time currents going southward on average, followed by 23 ± 1% of the time going northward on average (Figure 2-6). The less frequent direction was observed for east, north-east and west with values of 4.5 ± 1.5% of the time on average for both FLiDAR buoys and in each direction. For 12 ± 3% for the time on average, currents were measured to go north-west and south-east for both FLiDAR buoys. For both FLiDAR buoys, the highest current speed was observed when going southward (0.33m/s), whereas lowest current speed was observed when going eastward (0.12m/s on average).

2.1.2.20 Near-bed current flow at SWLB075 was shown to be predominately towards the south and west (26 ± 1% on average). Currents to the north and south-east contributed to 17.5% and 12.5% of the flow, respectively. The predominant near-bed current flow at SWLB080 was shown to be orientated to the south-west (22.4% on average), followed by flow to the east, south, west and south-east (16.3 ± 1.5%) (Figure 2-6).

2.1.2.21 As shown in Figure 2-6, current flow from the north and north-west direction contributed a smaller proportion of the time (2 ± 0.3% of the time on average) at SWLB075, with flow from the north, north-east and north-west occurring 4.2 ± 1% of the time (on average) at SWLB080.

2.1.2.22 Overall, data collected by both FLiDAR buoys showed a southward tidal residual current. Data collected at the surface and midwater depths are comparable at both SWLB075 and SWLB080. However, near-bed data indicates a difference in the flow regime, especially regarding the current direction (Figure 2-6). This can be explained by a difference of seabed morphology between the two locations, which influence the local near bed hydrodynamics (Easton *et al.*, 2011[37]; see Section 2.2.3).



Caledonia OWF
Offshore Export Cable Corridor
Overall Boundary North South Site Division
10km Zone of Influence (ZoI)
Buoy

Depth (m)

0 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
>200

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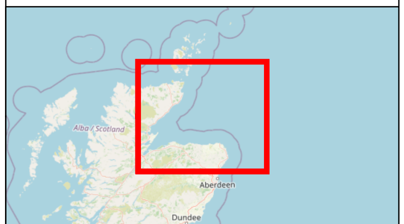

0 10 20 30 km

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CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_MPR_MAP_00080
CONTRACTOR REV: 01
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STATUS: Approved
SCALE: 1:1,000,000
DRAWING NUMBER: N/A
SHEET NO: 01 of 01
REV: N/A

Caledonia OECC

2.1.2.23 Based on the UK Renewables Atlas (ABPmer, 2017[12]), the spring tidal range varies between 2 and 4m along the Caledonia OECC with an increase from the offshore towards the coast (Landfall Site). The neap tidal range varies between 1 and 2m (Figure 2-3). The peak spring tidal flow varies between 0.11 to 0.50m/s along the Caledonia OECC (ABPmer, 2017[12]; Figure 2-4).

2.1.2.24 Variations in the tidal regime occurs along the Caledonia OECC due to the presence of bathymetric changes, including seabed features such as the Southern Trench which is located in the southern part of the Caledonia OECC, with the deepest parts outside the Caledonia OECC to the south-east (see Section 2.2.3 for further detail on this seabed feature). Near-bed peak spring tidal currents in the Southern Trench are estimated to exceed 0.7m/s in some parts, oriented east-west, although tidal currents adjacent to the Trench generally range from around 0.35 to 0.65m/s (DECC, 2004[38]).

2.1.2.25 The tidal excursion ellipses increase along the Caledonia OECC from approximately 2 to 4km (ABPmer, 2017[12]; Figure 2-5). At the northern end of the Caledonia OECC, tidal ellipses are more rotary, becoming generally rectilinear and directed east-west closer to the shore (ABPmer, 2017[12]; Figure 2-5). This variation is explained by the deflection of the southerly flood eastwards as it approaches the coast due to the influence of the coastline orientation.

Landfall Site

2.1.2.26 Along the southern shore of the Moray Firth, a notable feature of the tidal current pattern is a flood lasting approximately nine hours of the tidal cycle, with an insignificant ebb flow for the remaining three hours. This phenomenon occurs up to 13km offshore and is a result of the southern Moray coastline sheltering the area from the north flowing ebb current (Barne *et al*., 1996[39]). The resultant residual current is an eastward flow along the southern shore of the outer Moray Firth (DECC, 2016[40]).

2.1.2.27 Along the southern shore of the Moray Firth, tidal excursion ellipses are rectilinear, directed east-west, and vary from 1 to 10km from the inner Moray Firth to the outer Moray Firth (Figure 2-5). Based on the UK Renewables Atlas (ABPmer, 2017[12]), the tidal ellipse excursion within the nearshore extent of the Caledonia OECC, towards the Landfall Site, varies from 2 to 3km, and is orientated to the east-west.

2.1.2.28 The tidal range at Buckie, approximately 13km to the west of the Landfall Site, is 3.4m for springs and 1.6m for neaps. At Fraserburgh, located approximately 25km to the east of the landfall Site, the tidal range is 3.7m and 1.8m for spring and neap tides, respectively (Moray Offshore Windfarm (West) Limited, 2018[41]).

2.1.3 Non-tidal

2.1.3.1 Superimposed on regular tidal behaviours are various non-tidal influences, which mainly originate from meteorological effects. An example of a non-tidal influence is surges, formed by rapid changes in atmospheric pressure causing the water levels to fluctuate considerably above or below the tidal level. This effect can be further impacted by the wind strength and direction. Moving low pressure systems and associated strong and persistent wind fields may generate strong positive surges, often referred to as a 'storm surge' (Stromar Offshore Wind Farm Ltd, 2024[8]). The height of a 1-in-50 year return period storm surge has been defined as 1.25m at the nearby Moray East OWF, which is immediately adjacent to Proposed Development (Offshore) (MORL, 2012[29]).

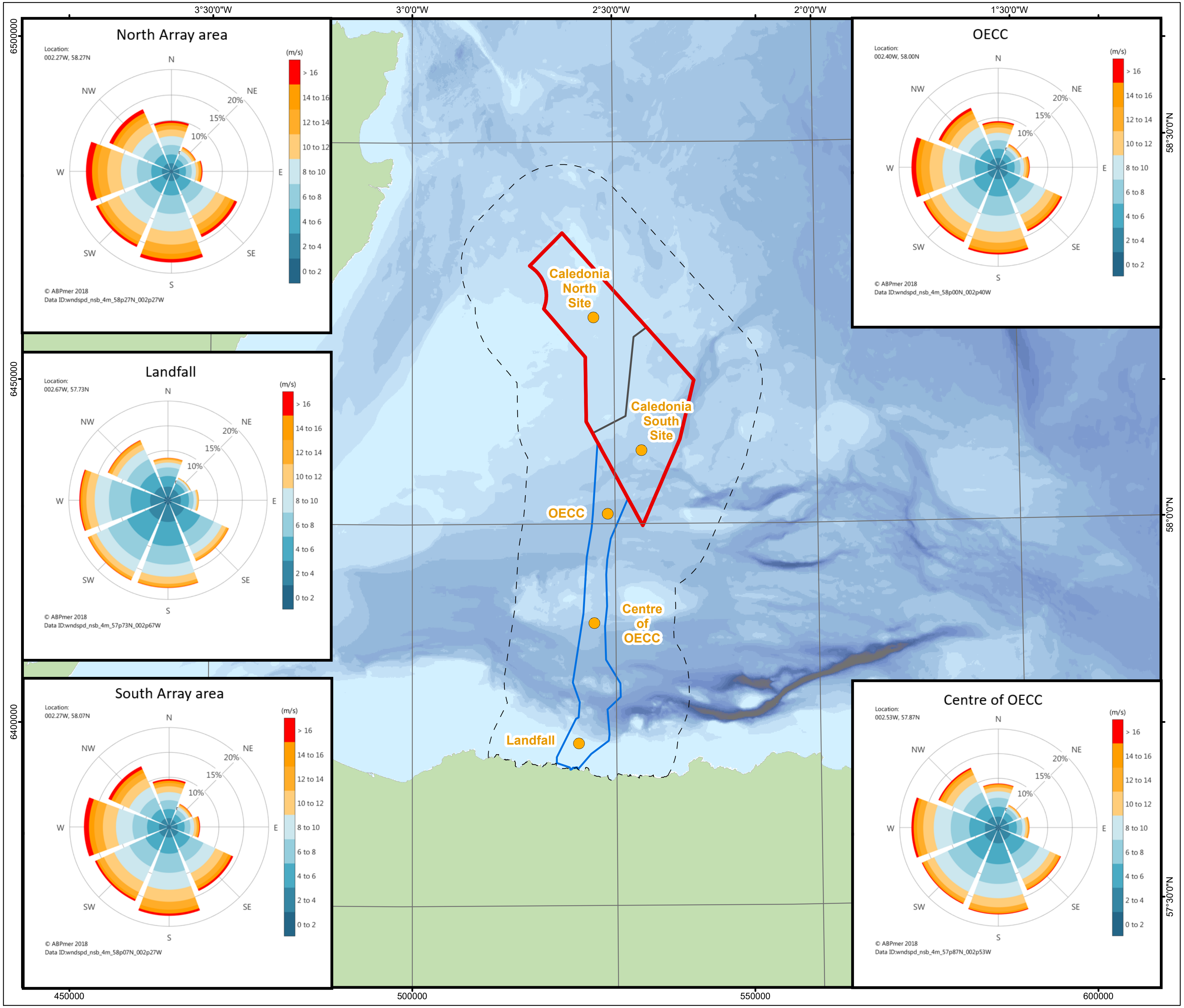
2.1.3.2 Storm surges may cause short-term modification of astronomically driven tidal currents. Under an extreme storm surge (1-in-50 year return period), current speeds may be more than twice that encountered under normal peak spring tide conditions (Flather *et al*., 1998[42]), which means that surface tidal flow could reach up to 1m/s in the north of the Caledonia OWF and 1.4m/s in the south of the Caledonia OWF during a storm event (ABPmer, 2017[12]). However, in the Moray Firth, the magnitude of surge currents is predicted to decrease rapidly with distance into the Moray Firth (ABPmer, 2012[32]) and, therefore, the northeastern section of the Proposed Development (Offshore) would likely experience the greatest effects.

2.1.3.3 Large storm surges in the Moray Firth are reported to be of relatively small amplitude (approximately 1 to 1.25m) within the Caledonia OWF, in contrast with larger values observed elsewhere such as the southern North Sea (MORL, 2012[29]). Findings by the National Oceanography Centre (2010[43]) provided positive a surge height of 1m for a 10-year return period surge, and 1.2m for a 100-year return period.

2.1.3.4 As winds control non-tidal water level, it is relevant to study and understand wind behaviour in the vicinity of the Proposed Development (Offshore). A long-term hindcast record of wind data within the study area has been derived from ABPmer's SEASTATES models (ABPmer, 2018[13]; Figure 2-7). Wind directions are similar between the Caledonia OWF, along the Caledonia OECC and at the Landfall Site. Winds originate mostly from the west, south-west and south for 17 ± 1% of the time, followed by winds coming from south-east, north and north-west for 12 ± 2%. A small proportion of wind, approximately 6%, comes from the north-east and east (ABPmer, 2018[13], Figure 2-7).

2.1.3.5 Despite a similar direction, wind data exhibits a difference in the mean wind speed within the study area. At the Landfall Site, data shows an annual mean wind speed of 6.2m/s, which increases offshore along the Caledonia OECC to reach 7.4m/s (ABPmer, 2018[13]). The same trend is observed between the south and the north of the Caledonia OWF with an increase of wind speed from 7.8m/s in the south to 8.4m/s in the north (ABPmer, 2018[13]).

2.1.3.6 The Moray Firth is also influenced by non-tidal residual circulation patterns, most notably the Fair Isle Current, which transports Atlantic water into the North Sea through the Fair Isle Channel before flowing southward down the Scottish east coast (Turrell *et al.*, 1992[44]; BEIS, 2022a[4]). Shoreward of the Fair Isle Current, which approximately follows the 100m depth contour into the North Sea, local currents transport water into the Moray Firth through the Pentland Firth, where they circulate in an anticyclonic residual circulation cell around the Smith Bank, which remains largely separated from the marginal waters (McManus, 1992[45]; Figure 2-7; also see Section 2.1.2).



Caledonia OWF

Offshore Export Cable Corridor

Overall Boundary North South Site Division

10km Zone of Influence (ZoI)

Wind Roses

Depth (m)

0 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
>200

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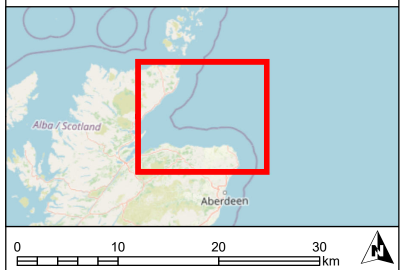

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GEODETIC PARAMETERS WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE Figure 2-7: Wind Roses at Five Locations Within the Proposed Development (Offshore) (ABPmer, 2018)	
STATUS Approved	SCALE 1:750,000
DRAWING NUMBER N/A	SHEET NO 01 of 01 / REV N/A

2.1.4 Frontal Systems and Stratification

Background

2.1.4.1 Frontal zones mark boundaries between water masses, including tidally mixed and stratified areas, and are numerous on the European continental shelf (BEIS, 2022a[4]). Fronts play an important role in enabling the circulation and transport of nutrients and heat, and frequently reoccurring fronts (e.g., spatially and/or seasonally) are widely recognised as supporting enhanced biological activity (NatureScot, 2024[46]).

2.1.4.2 Stratification is a hydrodynamic feature characterised by vertical density gradients over relatively short distances within the water column and it is related to the distribution of seawater temperature and salinity. Naturally occurring stratification occurs along the southern coast of the Moray Firth due to seasonal heating of the upper water column and vertical fronts are also observed between regions of slight freshwater influence coming from the Moray Firth (Adams and Martin, 1986[33]; Connor *et al*., 2006[47]).

2.1.4.3 The Caledonia OECC crosses a thermal front, which is present between 40 to 50% on average across all seasons of the year along the south coast of the Moray Firth (NatureScot, 2024[46]). In autumn and winter, the front is located close to the coast (less than 20km) and maintained by tidal currents. In spring and summer, the additional stratification generated by summer warming and less frequent storm events generates additional surface thermal fronts that extend beyond the coastal zone. These can overlap with the Caledonia OWF for approximately 40% of the time in summer (Miller *et al*., 2014[48]; Figure 2-8).

2.1.4.4 Temperature and salinity data from the Moray East OWF (MORL, 2012[29]), immediately adjacent to the west of northern part of the Proposed Development (Offshore) (Figure 1-1), shows that in the summer the water becomes seasonally stratified. This is due to temperature-related density differences between warmer surface waters and cooler deeper waters, typically forming a weak thermocline between 10 to 15m water depth.

2.1.4.5 Field data from the Moray East OWF indicated that there is no significant freshwater/salinity contribution to the observed stratification. This is explained by the distance from the coast (approximately 25km and 45km from the northern and southern coasts, respectively) where temperature and salinity may fluctuate to a greater extent due to more highly variable local riverine input (MORL, 2012[29]; Figure 2-8).

2.1.4.6 The stratification breaks down towards the end of summer such that the water column can be considered well mixed during the winter months. This is due to the increased frequency of high-energy storm events and a reduced rate of heat input (Figure 2-8).

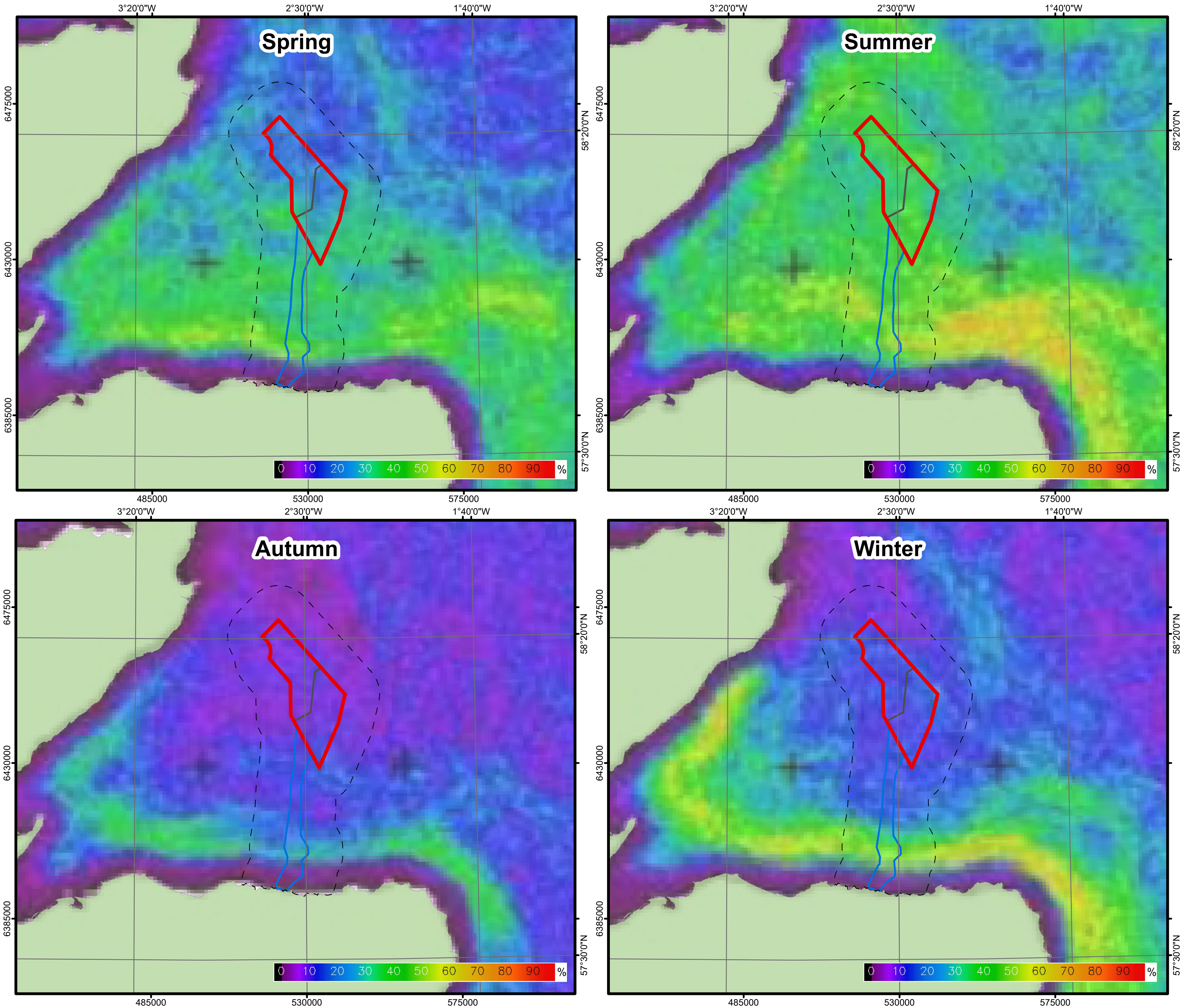
Caledonia OWF

2.1.4.7 Results from the project-specific benthic survey, including water sampling, across the Caledonia OWF showed that two stations (ENV18 and ENV34; Figure 1-2) present a well-mixed profile, whereas for the other 33 stations a thermocline is observed between 5 and 20m, with the temperature being stable beyond the thermocline (i.e., 8 ± 0.3°C; see Volume 7B, Appendix 4-1: Environmental Baseline Report (Array Area)).

2.1.4.8 All stations recorded stable salinity profiles apart from station ENV12, which showed a halocline between approximately 10 and 25m. Data were collected during spring (from March to June 2023) and support the results from Miller *et al*. (2014[48]), which showed that at the south of the Caledonia OWF (station ENV12), the water column is typically more often stratified (see Volume 7B, Appendix 4-1: Environmental Baseline Report (Array Area)).

Caledonia OECC

2.1.4.9 All stations within the Caledonia OECC recorded slightly decreased salinity in the surface waters except for station ENV53 (closest to the coast; Figure 1-3), which showed a consistent salinity throughout the water column (see Volume 7B, Appendix 4-2: Environmental Baseline Report (Offshore Export Cable Corridor)).



Caledonia OWF

Offshore Export Cable Corridor

Overall Boundary North South Site Division

10km Zone of Influence

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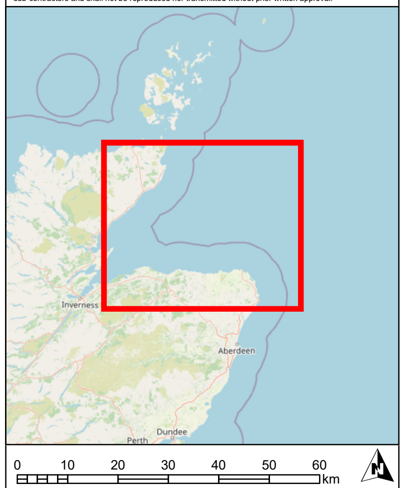

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GEODETIC PARAMETERS WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE Figure 2-8: Comparison of Thermal Front Frequency for All Seasons (Miller et al., 2014)	
STATUS Approved	SCALE 1:1,500,000
DRAWING NUMBER N/A	SHEET NO 01 of 01; REV N/A

2.2 Geology, Surficial Sediments, Seabed Morphology and Sediment Transport

2.2.1 Geology

Background

2.2.1.1 The bedrock geology of the Moray Firth is characterised predominantly of Cretaceous rocks, with both Jurassic and Permo-Triassic rocks along the southern/inner margins of the Moray Firth (Figure 2-9). This includes the Humber and Lias Group and a belt of chalk across the outer Moray Firth (MORL, 2012[29]; BGS, 2024[49]).

2.2.1.2 The presence of the chalk belt has been shown to correlate with the thinning of the surficial sediment layer towards the east, such that the chalk starts where the sediment is approximately 10m or less (Vysus Group, 2021[19]). The belt is overlain by an extensive layer of glacial till (clay, sand and gravel debris deposited from ice sheets), which is commonly observed to be over 100m thick, underneath a veneer of marine sand (Holmes *et al*., 2004[5]; MORL, 2012[29]). This layer of marine sand was found to range from approximately 1 to 30m across the Moray East OWF and West Development Areas, with thicker deposits within bathymetric deeps (Moray Offshore Windfarm (West) Limited, 2018[41]).

2.2.1.3 The bedrock geology is overlain by an extensive blanket of Quaternary glacial and post-glacial deposits, comprising layers of till and mud sediments. According to Chesher and Lawson (1983)[50], the thickness of these Quaternary sediments in the entire Moray Firth is commonly observed around 70m, whereas data from the BGS Offshore GeoIndex indicates a quaternary deposit thickness mostly between 5m and 20m (Figure 2-10; BGS, 2024[49]).

2.2.1.4 Within the Moray East OWF, located to the west of the Proposed Development (Offshore), data collected showed a quaternary thickness greater than 50m, whereas BGS data suggested a thickness comprises between 5 and 20m (BGS, 2024[49]). Vysus Group (2021[19]) noted that the quaternary sediment thickness is correlated to water depth, with the shallowest water areas interpreted to represent areas with increased sediment deposition and, therefore, soil thickness.

2.2.1.5 BGS data has shown the presence of thicker quaternary patches, with thickness comprising between 30 and 50m, located in the south and inner Moray Firth for the largest section (approximately 25 ± 3km long; BGS, 2024[49]). Two patches of quaternary thickness <5m are observed near Fraserburgh (south-east of the Moray Firth), possibly correlated with strong tidal current associated with the headlands (Figure 2-11; BGS, 2024[49]; see Section 2.1.2).

Caledonia OWF

2.2.1.6 The western part of the Caledonia OWF is underlain by Lower Cretaceous strata, predominantly calcareous argillite with local sandstones, which is largely synonymous with the Cromer Knoll Group as defined in the southern North Sea (Andrews *et al*., 1990[51]). In the east, the Caledonia OWF is underlain by Upper Cretaceous chalk and marl, with a minimal proportion in the far eastern extent of the Caledonia OWF underlain by Palaeogene deltaic and submarine-fan sediments (Figure 2-9 and Figure 2-10; BGS, 1984[51]; Andrews *et al*., 1990[52]).

2.2.1.7 Quaternary deposit thickness data from BGS indicates sediment thicknesses between 5 and 20m within the majority of the Caledonia OWF, with isolated areas of thicker deposits towards the north (Figure 2-11; BGS, 2024[49]). However, this is not consistent with borehole data collected in the northern, southern and western part of the Caledonia OWF, which showed a quaternary thickness varying from 10 to 40m westward (Vysus Group, 2021[19]).

2.2.1.8 Deposit thickness contours from Vysus Group (2021[19]) showed broadly similarly trends to the BGS deposit thickness interpretation in the eastern half of the Caledonia OWF. However, the updated interpretation indicates rapid thickening towards the west. The presence of the chalk bedrock has been shown to correlate with the thinning of the quaternary deposits towards the east, such that the chalk starts where the sediment is approximately 10m or less (Vysus Group, 2021[19]).

Caledonia OECC

2.2.1.9 The bedrock geology underlying the majority of the Caledonia OECC is comprised of lower Cretaceous strata, which is largely synonymous with the Cromer Knoll Group as defined in the southern North Sea (Figure 2-9; Andrews *et al*., 1990[51]). From approximately 20km from the coast, several strips of Jurassic and permo-triassic rocks parallel to the coast composed the bedrock geology with an increase in age towards the coast (Figure 2-10; Andrews *et al*., 1990[51]).

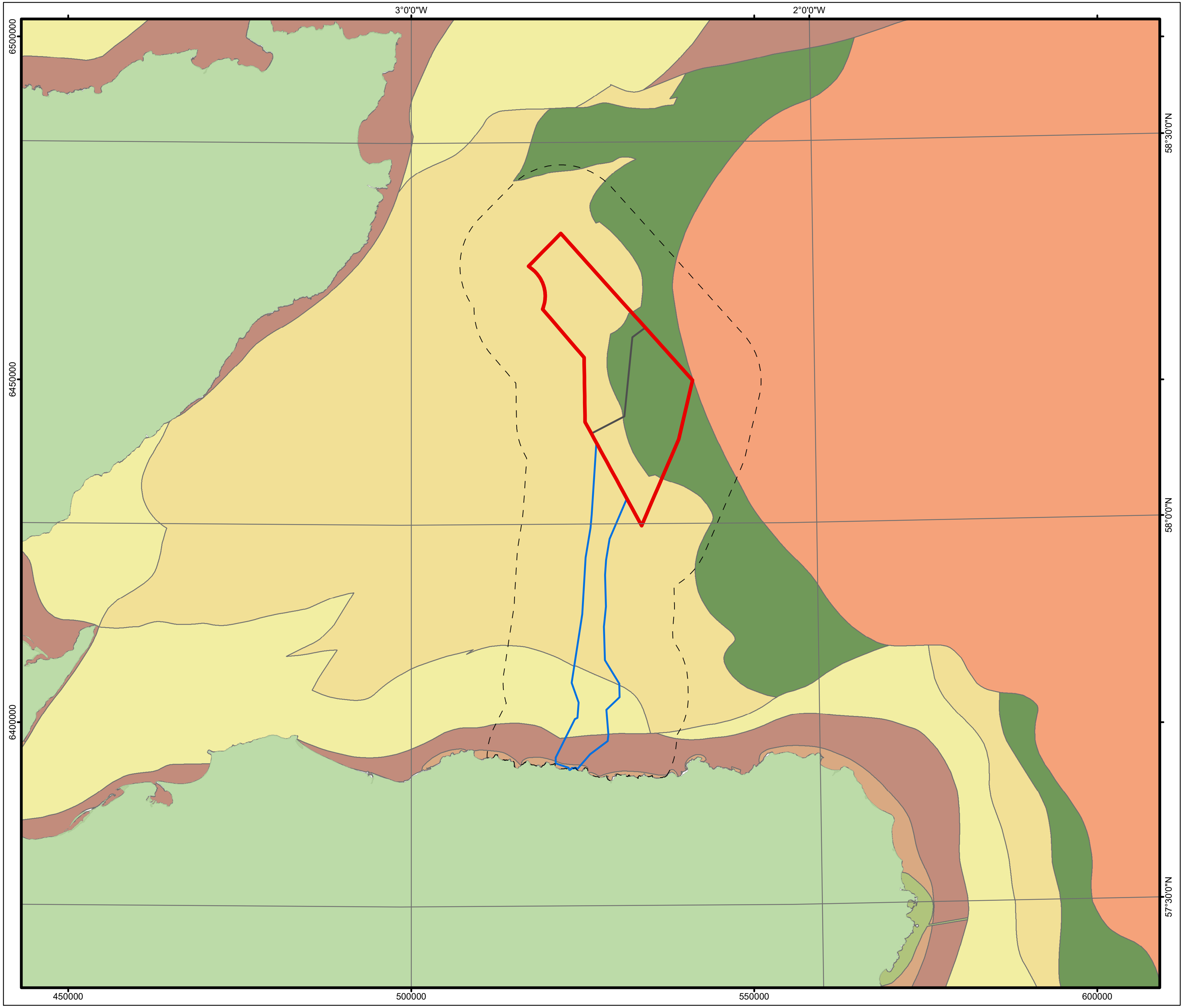
2.2.1.10 Based on BGS data, the quaternary deposit is comprising between 5 and 20m, except for a 10km width patch, located approximately 8km offshore, where the sediment thickness can reach 50m (Figure 2-11; BGS, 2024[49]).

Landfall Site

2.2.1.11 In the vicinity of the Landfall Site, the bedrock geology is characterised by the following three types of formation (Figure 2-9 and Figure 2-10):

- 1) Old Red Sandstone supergroup from the Devonian;
- 2) Crinian and Tayvallich subgroups from the Precambrian; and
- 3) Southern Highland group from the Precambrian.

2.2.1.12 The Precambrian rocks are assigned to the Daldarian Supergroup, which corresponds to a thick and variable succession of largely sedimentary rocks. Many comprise a variety of schists, but slate and schistose grit dominate at the coast (Holmes *et al*., 2004[5]).



Caledonia OWF
Offshore Export Cable Corridor
Overall Boundary North South Site Division
10km Zone of Influence

Bedrock Lithologies (Category)

Chalk
Igneous
Mesozoic interbedded
Mesozoic mudstones
Metamorphic
Palaeozoic sedimentary
Tertiary interbedded

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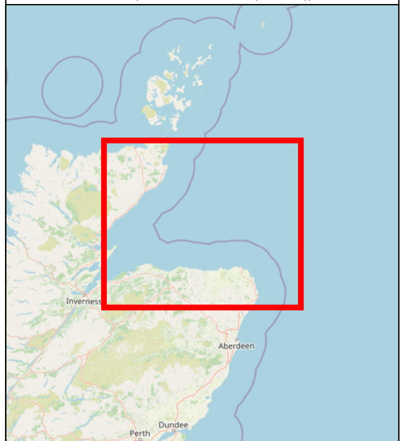

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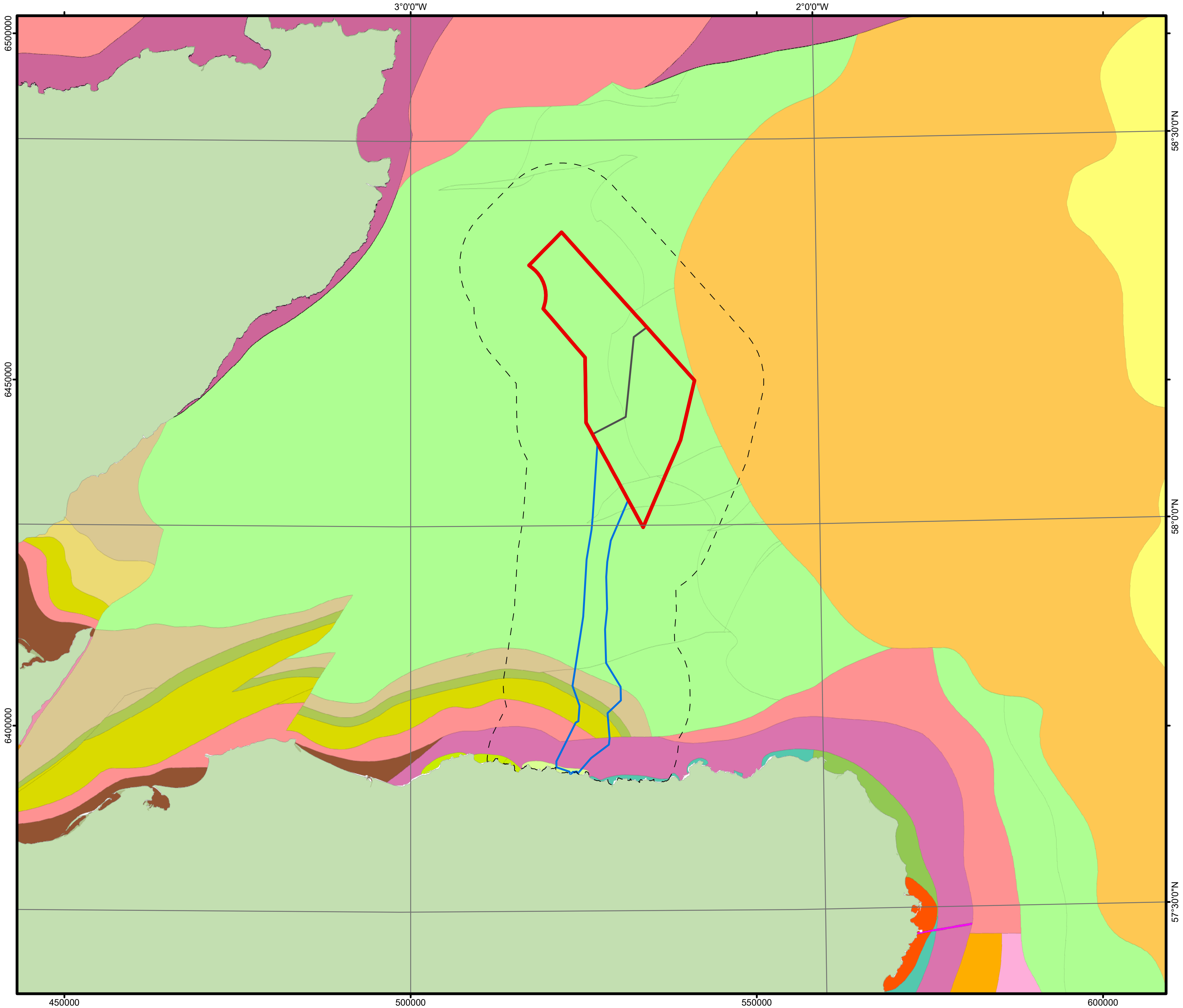
STATUS: Approved	SCALE: 1:750,000
DRAWING NUMBER: N/A	SHEET NO: 01 of 01; REV: N/A



- Caledonia OWF
- Offshore Export Cable Corridor
- Overall Boundary North South Site Division
- 10km Zone of Influence

Bedrock Lithostratigraphical Units (BGS, 2020)

- Sandstone (Undifferentiated)
- Sandstone (Undifferentiated) and Rock, Siliciclastic, Argillaceous
- Sandstone (Undifferentiated) and Rock, Siliciclastic, Argillaceous
- Sandstone (Undifferentiated) and Mudstone and Coal
- Rock, Siliciclastic, Argillaceous
- Rock, Siliciclastic, Argillaceous and Sandstone (Undifferentiated)
- Rock, Siliciclastic, Argillaceous and Sandstone (Undifferentiated)
- Rock, Siliciclastic, Argillaceous and Sandstone (Undifferentiated)
- Rock, Siliciclastic, Argillaceous with Sandstone (Undifferentiated) with Limestone
- Mudstone and Sandstone (Undifferentiated) and Lignite
- Mudstone and Siltstone (Undifferentiated) and Sandstone (Undifferentiated)
- Mudstone and Gypsum-Stone
- Conglomerate
- Conglomerate and Sandstone (Undifferentiated) and Siltstone (Undifferentiated) and Mudstone with Evaporites
- Metasedimentary Rock
- Metasedimentary Rock
- Quartzite
- Granitic-Rock

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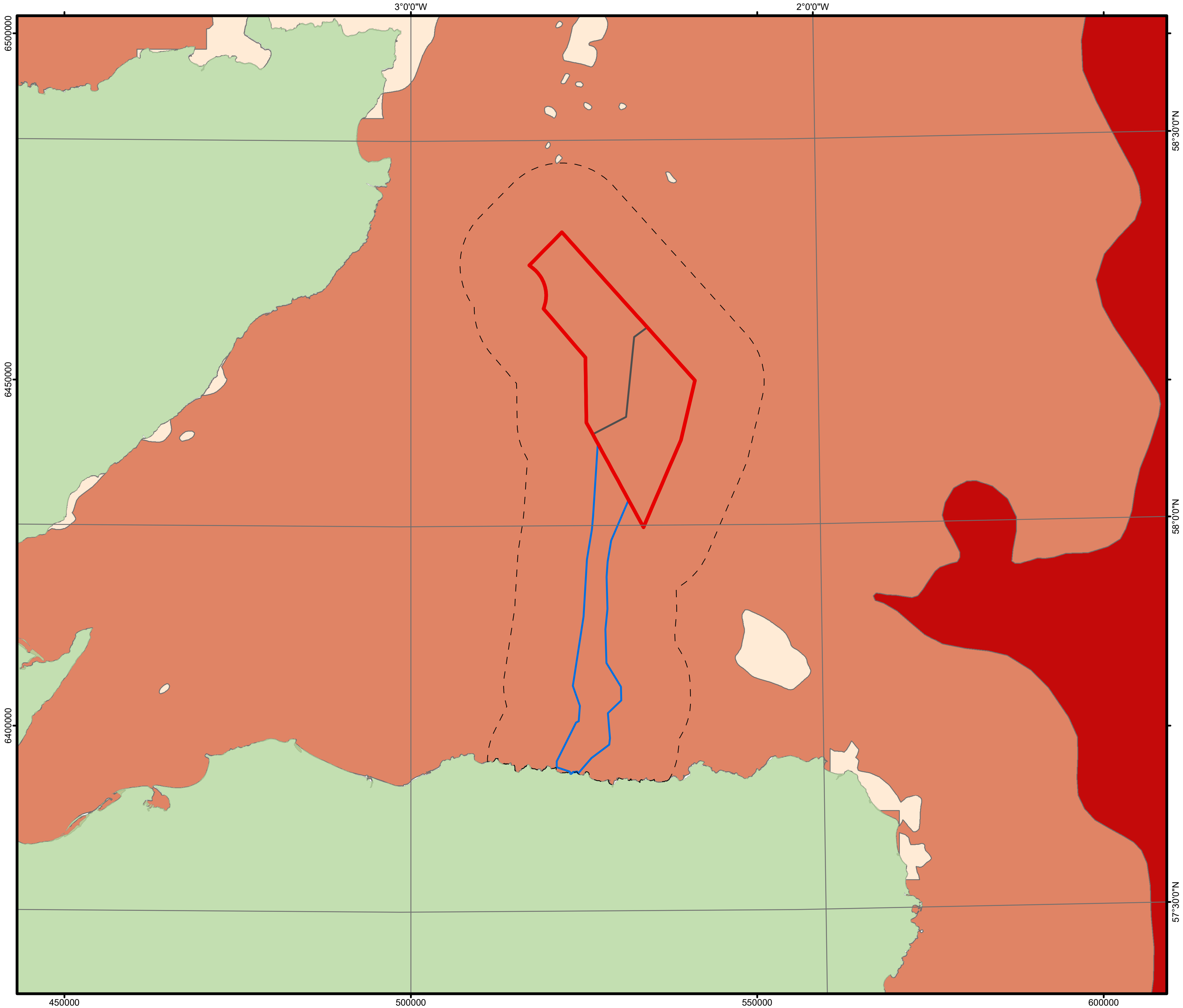
DRAWING TITLE Figure 2-10: Bedrock Lithostratigraphic Units (BGS, 2020)	
STATUS Approved	SCALE 1:750,000
DRAWING NUMBER N/A	SHEET NO 01 of 01 / REV N/A



Caledonia OWF

Offshore Export Cable Corridor

Overall Boundary North South Site Division

10km Zone of Influence

Quaternary Deposit Thickness (Category)

< 5m

5m - 50m

> 50m

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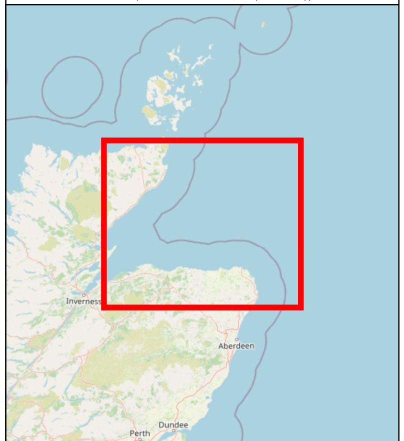

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GEODETIC PARAMETERS
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DRAWING TITLE

Figure 2-11: Quaternary Deposit Thickness (BGS, 2022)

STATUS
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DRAWING NUMBER
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SHEET NO
01 of 01

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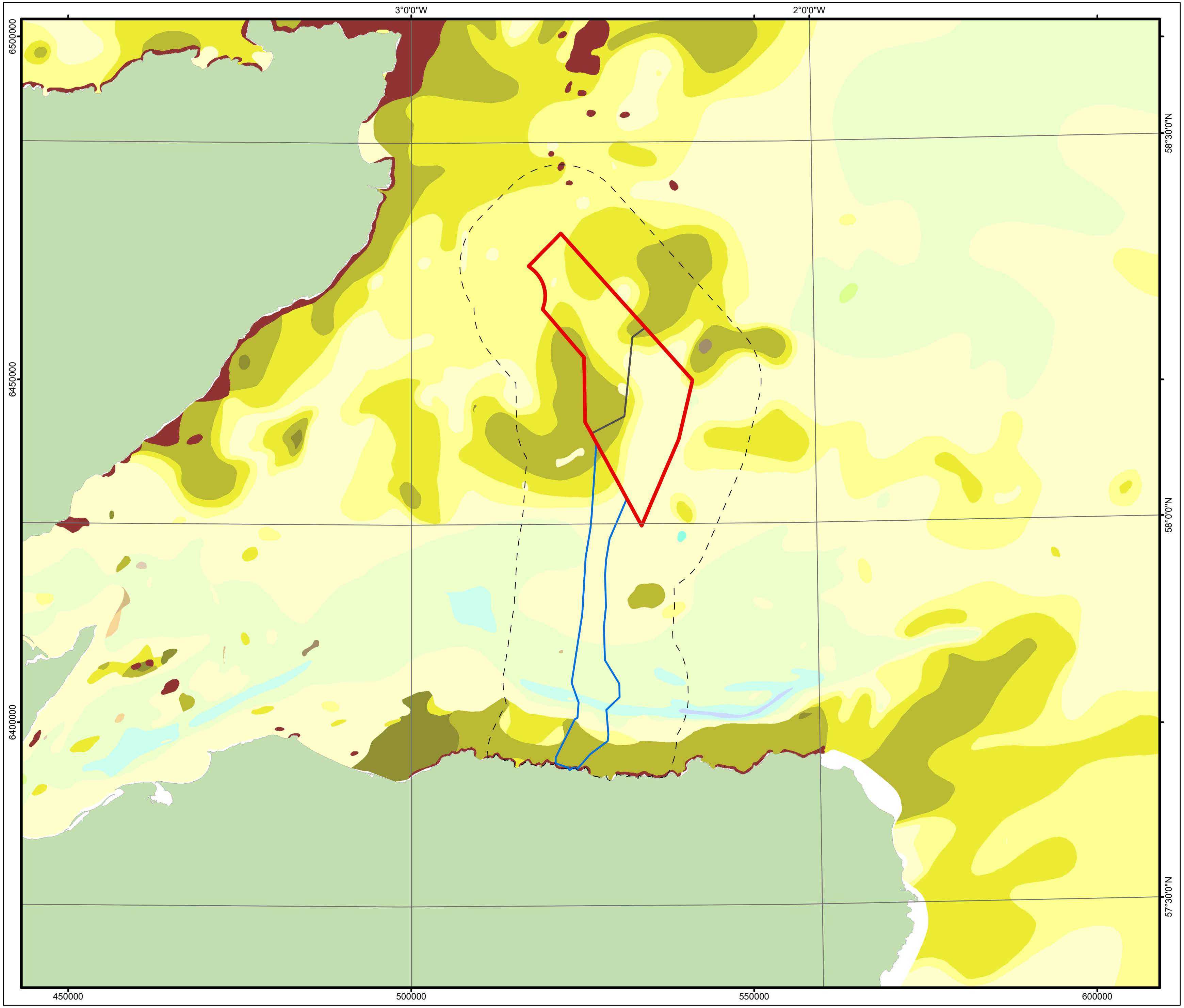
2.2.2 Surficial Sediments

Background

2.2.2.1 Surficial sediments in the Moray Firth consist mainly of Holocene sediments, the distribution of which reflects both the glacial history of the area and the present hydrodynamic regime (BEIS, 2022b[36]). The presence of exposed pre-quaternary rocks is observed in areas of high tidal current such as in the north-east and along the south-east coast of the Moray Firth (Figure 2-12; see Section 2.1.2).

2.2.2.2 The distribution of sediment types in the outer Moray Firth is generally reflective of the water depth, with a larger gravel fraction on the banks of the Smith Bank and close to the coast. The presence of muddy sediments is generally restricted to water depths greater than 70m, such as Smiler's Hole and the approaches to the inner-most Firths (Andrews *et al.,* 1990[51]). This is corroborated by Vysus Group (2021[19]), which identified a correlation between coarser sediment and shallower water, attributed to the more energetic hydrodynamics in these areas. Enclosed basins within the region act as sinks for fine-grained sediments settling out of suspension, with relatively high mud content (30 to 65% fines) within the deepest parts. The exception to this pattern is along the axes of the Southern Trench, where high current speeds within constricted channels lead to well-sorted sands with a minor composition of silt and fine-grained sand; however, fine-grained sediments do accumulate on the flanks of the trench explained by the fast currents (Holmes *et al*., 2004[5]). Further information on the Southern Trench is provided in Section 2.2.3.

2.2.2.3 Sediment samples taken within the Smiler's Hole basin are classed as muddy sands, with polymodal distribution patterns consistent with an environment allowing both sedimentation of the finest-grained muds and a process of re-suspension under conditions of stronger near-bed currents.



Caledonia OWF
Offshore Export Cable Corridor
Overall Boundary North South Site Division
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

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0 10 20 30 km

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GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)

DRAWING TITLE: Figure 2-12: Surficial Seabed Sediments (Folk, 1954)

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SCALE: 1:750,000
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2.2.2.4 As part of the baseline characterisation of seabed sediments for the Moray East OWF, a comparison was made between side-scan sonar evidence from the Eastern Development Area, benthic grab sample data (Gribble and Leather, 2011[53]) and seabed sediment maps available from the BGS (BGS, 1984[52]; 1987[54]). This comparison revealed only partial agreement, with some variation along the crest and flanks of the Smith Bank. This suggested asymmetry with the coarsest sediments (sandy gravels) with occasional rock outcrops distributed on the north and east flanks (MORL[29]). Superficial sediments on the crest of the Smith Bank can be greater than 2m thick in places but are generally relatively thin (approximately 0.5m; Holmes *et al*., 2004[5]). These variations are likely to relate to the differences in sampling density between the surveys. It should also be noted that the BGS sediment maps are compiled from a relatively low density of samples in this area. Therefore, although these can support broad-scale characterisation, site-specific sampling campaigns are required to provide more accurate data.

Caledonia OWF

2.2.2.5 Regional-scale sediment maps from EMODnet (2024)[16], sourced from BGS datasets (Figure 2-12), indicate that within Caledonia OWF the surficial seabed sediments are typically comprised of sands and gravels, with a small proportion of fines (less than 10%). This is supported by the site-specific geophysical survey which shows, on average for the 34 stations, that there is 8.8% of fines present in the sediment samples (see Volume 7B, Appendix 4-1: Environmental Baseline Report (Array Area); Table 2-1).

2.2.2.6 The proportion of finer sediments increases towards the south-east of the Caledonia OWF (within the Caledonia South Site), with primarily sand and some muddy sand present in the east (EMODnet, 2024[16]). Amongst the 15 stations sampled in the Caledonia OWF showing less than 1% gravel composition, 11 were found in the Caledonia South Site. This supports the data shown on Figure 2-12 indicating the coarsest sediments are found in the Caledonia North Site (EMODnet, 2024[16]; see Volume 7B, Appendix 4-1: Environmental Baseline Report (Array Area)). However, grab samples and side-scan survey data from the Moray East OWF (Gribble and Leather, 2011[53]) identified higher sand content along the eastern margin of the Eastern Development Area (immediately to the west of Caledonia North), rather than the sandy gravels identified from the BGS data. The majority of the benthic samples from the Moray East OWF were found to have a unimodal distribution, and were primarily poorly sorted, indicative of low seabed sediment mobility (MORL, 2012[29]).

2.2.2.7 To the north of the Southern Trench is an isolated plateau, the top of which ranges from approximately 40 to 50m depth relative to Lowest Astronomical Tide (LAT). Seabed photography reported by Holmes *et al*. (2004[5]) identified a seabed 'armour' in this region characterised by well-rounded pebbles, cobbles and boulders, with relatively small areas of coarse-grained sand. This contrasts with the blanket of muddy sands mapped on the plateau by BGS and may be partly related to storm processes prior to the survey (Holmes *et al.*, 2004[5]).

2.2.2.8 Particle Size Analysis (PSA) has been carried out across the Caledonia OWF as part of the site-specific benthic ecology characterisation, details of which are provided in Table 2-1 and Figure 2-13 (see Volume 7B, Appendix 4-1: Environmental Baseline Report (Array Area)). Mean particle size varied from 45µm at station ENV21 to 2,881µm at station ENV13, with an average mean grain diameter of 439 ± 613µm.

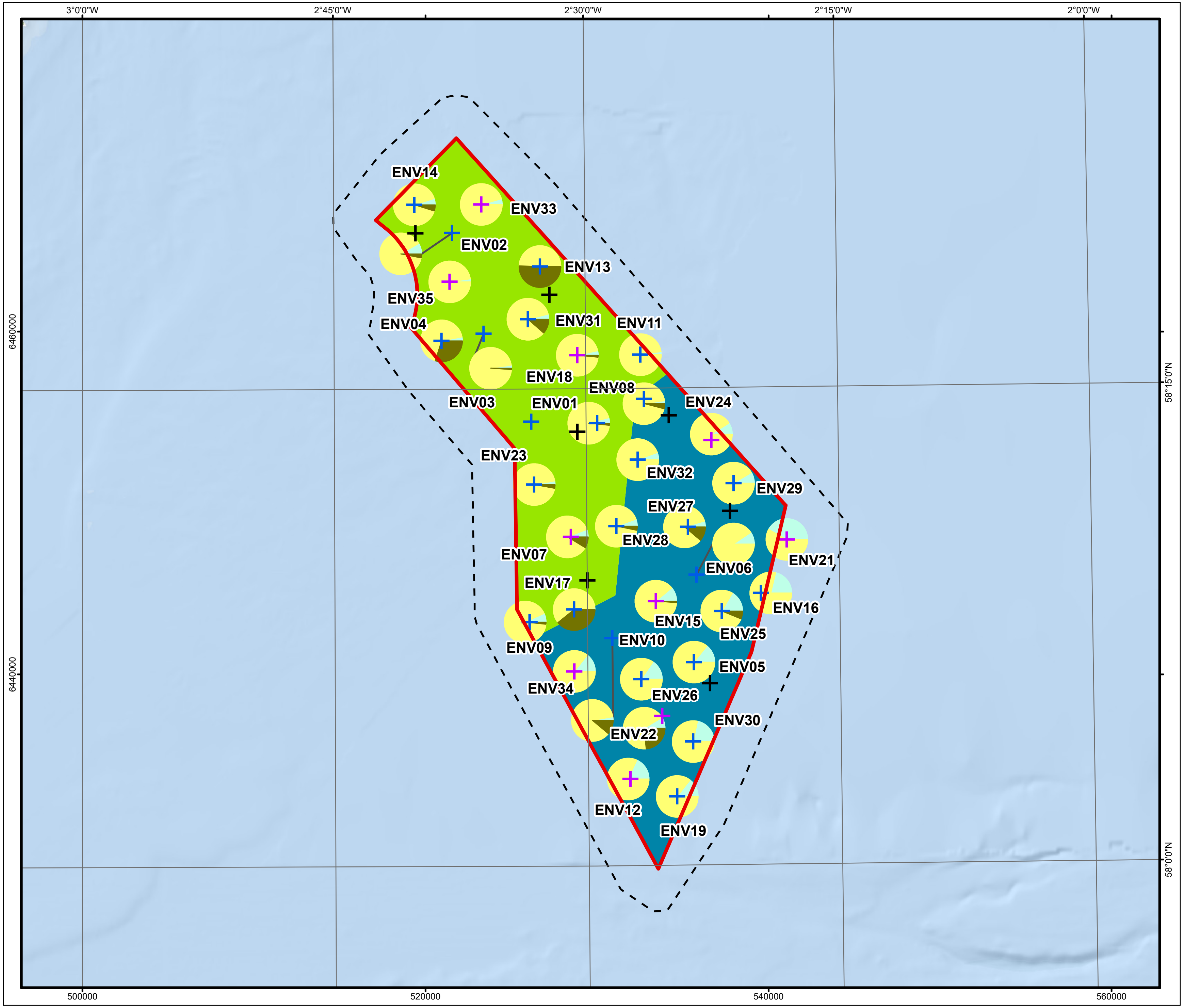
2.2.2.9 Across the Caledonia OWF, sand (i.e., sediment size comprised between 0.063 and 2 mm) was the dominant fraction accounting for between 49.0 and 97.1% of the sediment. Station ENV13 was an exception to this with gravel (i.e., sediment size greater than 2 mm) being the dominant fraction accounting for 50.2% of the sediment, resulting in this station being classified as sandy gravel under the Folk 16 classification[iv] (Folk, 1954)[55]. Gravel was absent at three stations (ENV12, ENV21 and ENV30) and negligible (less than 1%) at 12 stations (Figure 2-13).

2.2.2.10 Under the modified Folk 16 classification (Folk, 1954[55]), stations ranged from muddy sand to sandy gravel, with these classifications being confirmed by the analysis of the relative proportions of fines, sand and gravel. Similar results as reported from the Moray East OWF are observed in the Caledonia OWF, in that samples recorded a very poorly sorted to moderately sorted particle size distribution (Folk and Ward, 1957[56]).

Table 2-1: Summary of particle size analysis across the Caledonia OWF.

Sediment Type	Minimum Fraction (%)	Mean Fraction (%)	Maximum Fraction (%)	Standard Deviation
Fines (<0.063 mm)	0.8	8.8	41.9	8.3
Sands (0.063 – 2 mm)	49	84.6	97.1	11.8
Gravel (>2 mm)	0.0	6.5	50.2	11.9

[iv] Technical descriptive classification of sedimentary rocks in 16 classes.



Caledonia OWF
Caledonia North Site
Caledonia South Site
Survey Area

Station Type

Camera Only Stations
PSA and Macrofauna Station
PSA, Macrofauna, eDNA, Chemistry and Water Station

PSA Results

Fines
Sand
Gravel

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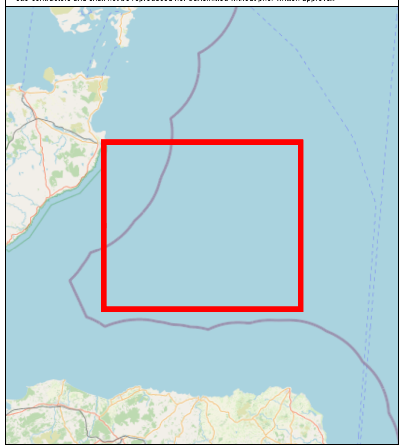

0 5 10 km

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

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CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_MPR_MAP_00084
CONTRACTOR REV: 01
GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)
DRAWING TITLE:

Figure 2-13: Sampled Proportion of Fines, Sand and Gravel Within the Caledonia OWF

STATUS: Approved
SCALE: 1:300,000
DRAWING NUMBER: N/A
SHEET NO: 01 of 01
REV: N/A

Caledonia OECC

2.2.2.11 Surficial sediments along the Caledonia OECC are characterised mainly by sands and gravels close to the Caledonia OWF, with the mud content of sediments increasing towards the shore, as shown in Figure 2-12. Sediments generally become progressively finer as water depth increases, with isolated patches of coarser sediment associated with bathymetric highs. Between approximately 8 and 20km offshore, the surficial sediments are classified as muddy sand, with a band of sandy mud approximately 10km offshore (Figure 2-12). This corresponds to the Southern Trench feature, shown on Figure 1-1 (also see Section 2.2.3).

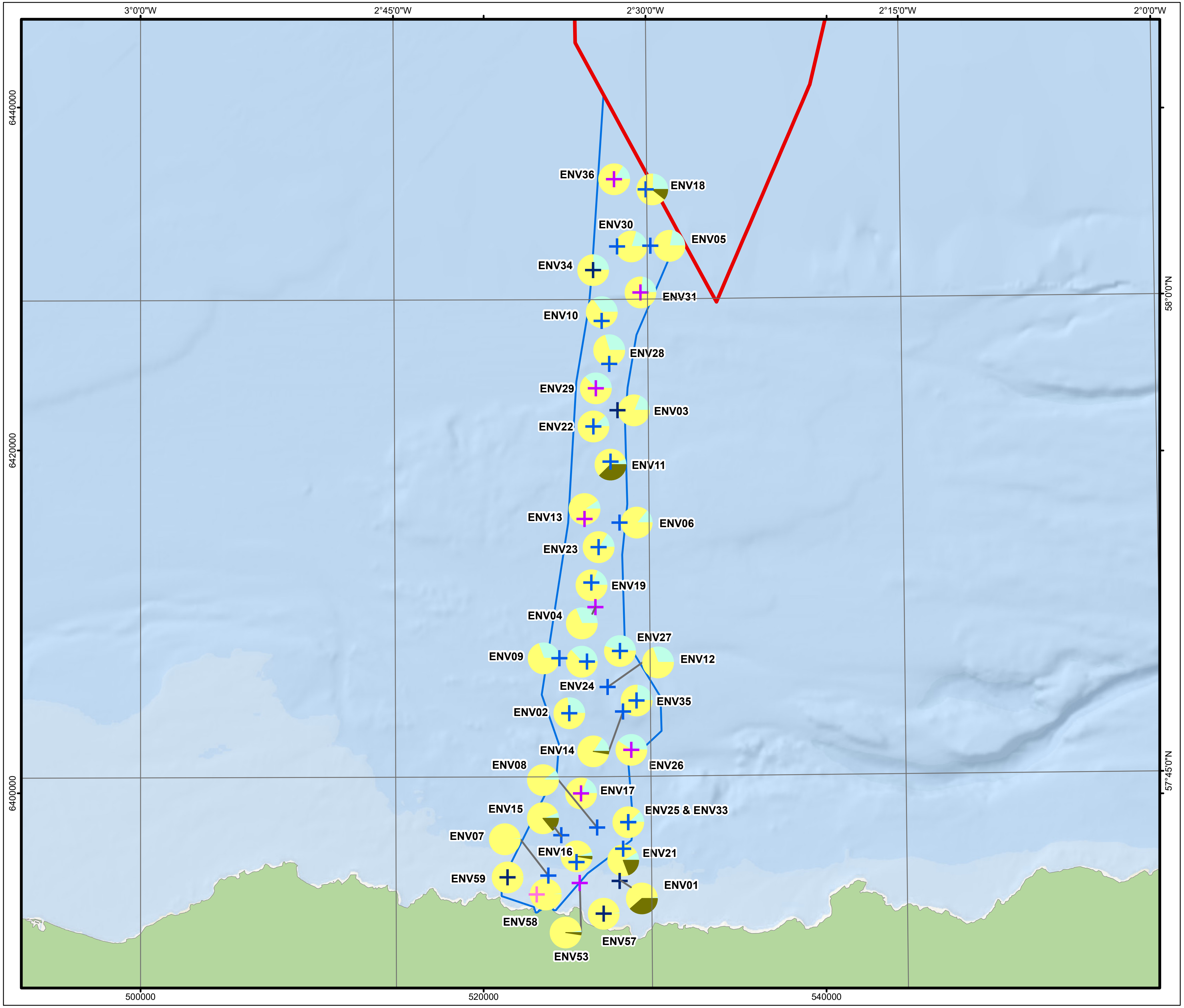
2.2.2.12 Analysis of grab samples from a western section of the Southern Trench indicate that samples located along the trench flanks and open parts of the trench are characterised by muddy fine sand (mud fraction typically less than 10%; Holmes *et al*., 2004[5]). This is consistent with the presence of Burrowed Mud Priority Marine Feature (PMF) in this area, designated as part of the Southern Trench Nature Conservation Marine Protected Area (NCMPA; NatureScot, 2024[46]). Within 10km of the coastline, the seabed is characterised by increased gravel and coarse sediment as the water depth decreases.

2.2.2.13 The results of PSA along the Caledonia OECC, collected as part of the site-specific benthic ecology characterisation, are shown in Table 2-2 and Figure 2-14 The results indicate that mean particle size varied from 41µm at station ENV27 to 1,813µm at station ENV11 (see Volume 7B, Appendix 4-2: Environmental Baseline Report (Offshore Export Cable Corridor)).

2.2.2.14 The five sampled stations closest to the shore in water depths of less than 35m (ENV07, ENV53, ENV57, ENV58 and ENV59) were dominated by sand (greater than 95%). Samples were described as moderate to moderately well sorted based on Folk and Ward (1957[56]) statistics. These stations recorded negligible (less than 5%) fines and gravel content.

2.2.2.15 By contrast, the 24 stations sampled in water depths greater than 70m (ENV02 to ENV06, ENV08 to ENV10, ENV12, ENV17, ENV19, ENV23 to ENV31, ENV33 to ENV36) recorded poorly to very poorly sorted sediment classified as muddy sand under the modified Folk classification (Folk, 1954[55]). These stations were dominated by fine sand to very fine sand, with fines content ranging from 11% at station ENV08 to 45% at station ENV27, and gravel content less than 1%.

2.2.2.16 The nine remaining stations (ENV01, ENV11, ENV13 to ENV16, ENV18, ENV21 and ENV22) recorded variable gravel content ranging from less than 1% at station ENV13 to 39% at station ENV01. Fines content was also variable across these stations, ranging from 1.8% at station ENV01 to 25% at station ENV18. Overall, there was a clear trend associated with water depth (i.e., finer sediments were observed in samples collected in deeper waters).



Caledonia OWF
Offshore Export Cable Corridor

Station Type

- Camera Only Station
- PSA and Macrofauna Station
- PSA, Macrofauna, eDNA, Chemistry and Water Station
- Camera, PSA, Macrofauna and Chemistry Station
- Macrofauna Only Station
- Camera, PSA and Macrofauna Station
- No data acquired

PSA Results

- Fines
- Sand
- Gravel

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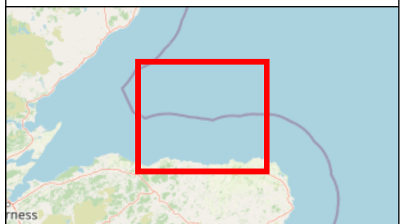

0 5 10 km

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

CALEDONIA Offshore Wind Farm
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CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_MPR_MAP_00147	CONTRACTOR REV: 01
GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE: Figure 2-14: Sampled Proportion of Fines, Sand and Gravel across the OECC	
STATUS: Approved	SCALE: 1:300,000
DRAWING NUMBER: N/A	SHEET NO: 01 of 01 — REV: N/A

Table 2-2: Summary of particle size analysis across the Caledonia OECC.

Sediment Type	Minimum Fraction (%)	Mean Fraction (%)	Maximum Fraction (%)	Standard Deviation
Fines (<0.063 mm)	1.1	18.5	45.2	12.2
Sands (0.063 – 2 mm)	54.8	78	98.8	12.3
Gravel (>2 mm)	0	3.4	38.6	9.2

Landfall Site

2.2.2.17 Towards the shore, along the Caledonia OECC, the mud content of sediments increases, with seabed sediments becoming progressively finer as water depth increases. Enclosed basins within the area act as sinks for fine-grained sediments settling out of suspension, with relatively high mud content (30 to 65% fines) within the deepest parts. The exception to this pattern is within the Southern Trench, with high current speeds along the axis leading to well-sorted fine sands with little silt content (Holmes *et al.*, 2004[5]). Within 10km of the coastline, the seabed is characterised by increased gravel and coarse sediment as the water depth decreases.

2.2.3 Seabed Morphology

Background

2.2.3.1 The seabed morphology of the Moray Firth is seen to be variable and irregular. In the inner Moray Firth, the seabed slopes, rarely more than 1°, gently from the shore to a depth of around 50 to 70m. The outer Moray Firth is characterised by a number of banks, the largest being the Smith Bank, and deep-water channels, the deepest being the Southern Trench (Figure 1-1; Brookes *et al.*, 2013[57]; EMODnet, 2024[16]). Sand ribbons and sand waves have been identified in the vicinity of the north coast of the Moray Firth. Longitudinal and transverse sand patches have been observed as the dominant bedform in the centre of the outer Moray Firth, which suggests an active bedload transport (Moray Offshore Windfarm (East) Limited, 2017[35]).

2.2.3.2 The deepest area of the Moray Firth is the Southern Trench, an enclosed basin approximately 220m deep and 58km long, formed predominantly as a result of glacial processes, including subglacial hydrology and potentially catastrophic meltwater flooding (Brooks *et al.*, 2013[57]; BEIS, 2022a[4]). The Southern Trench lies directly to the east of the OECC and 10km offshore parallel to the southern shoreline between the coastal ports of Banff and Fraserburgh (Figure 1-1; Robinson *et al.*, 2009[1]). Like other enclosed seabed basins in the Moray Firth, the Southern Trench acts as a sink for fine-grained sediments, although this has been mainly found to occur on the trench flanks only (Brooks *et al*., 2013[57]).

2.2.3.3 The morphology of the Southern Trench is irregular. The western part of the trench is orientated east-west, whereas the eastern part of the trench shows an east-northeasterly direction (Brooks *et al*., 2013[57]). A cross-sectional profile of the trench also suggests an asymmetry between a steep north-facing slope and a shallower south-facing slope (Long and Stoker, 1986[58]). The SEA5 multibeam survey revealed that, in places, the trench is very steep sided with slope angles of more than 50°, but average gradients are generally in the range of 6 to 22° (Holmes *et al*., 2004[5]). There is evidence of gravity-driven slumping, slump scarp faces, more than 1km long, and slide deposits (Holmes *et al*., 2004[5]; Hirst *et al*., 2012[59]).

2.2.3.4 The orientation of the Southern Trench is broadly similar to other trenches mapped in the outer Moray Firth, which also trend approximately east-west. The trenches in the outer Moray Firth range from 1.5 to 58km, and around three quarters of them have a length greater than 10km (Bradwell *et al*., 2008[60]).

2.2.3.5 Another deep area within the Moray Firth, named Smiler' Hole, is located approximately 15km to the east of the Caledonia OECC and 30km offshore from the southern coast of the outer Moray Firth. It is an enclosed arcuate basin with the convex side facing north. Smiler's Hole is 25km long and more than 175m deep. The overall trend of increasing mud content with water depth on the basin flanks is consistent with the Smiler's Hole acting as a sink for fine-grained sediments (Holmes *et al*., 2004[5]).

2.2.3.6 Many large-scale features of the modern seabed topography are a result of marine reworking of former glaciogenic bedforms. The Moray Firth is characterised by isolated and irregular shallow banks, including the Smith Bank, which divide a series of tunnel valleys formed sub-glacially by the flow of pressurised water, which act as sinks for fine-grained sediments (Holmes *et al*., 2004[5]; Graham *et al*., 2009[61]).

2.2.3.7 The Smith Bank is a morphological high point at a depth of 35m and measuring approximately 35km long and 20km wide. The Smith bank is located in the north-west area of the Moray Firth and oriented from south-west to north-east (Figure 1-1; Holmes *et al*., 2004[5]; Moray Offshore Windfarm (West) Limited, 2018[41]). The Smith Bank is separated from the Caithness coast to the north by a relatively deep channel up to 70m (Moray Offshore Windfarm (West) Limited, 2018[41]). Water depth across the site range from approximately 35 to 55m LAT with the greatest depths found along the south-eastern margin of the site (Holmes *et al*., 2004[5]). The north-west flank is slightly steeper, but its seabed slope does not exceed 0.5°. Estimates from the BGS regional data indicate that the seabed area of the bank, in less than 50m depth of water, is approximately 40km^2 (BGS, 2024[49]). The position, elevation and orientation of the Smith Bank are associated with the underlying Smith Bank Fault block and the distribution patterns of moraines underlying the seabed sediments do not appear to be related to the overall elevation of the Smith Bank (Holmes *et al*., 2004[5]).

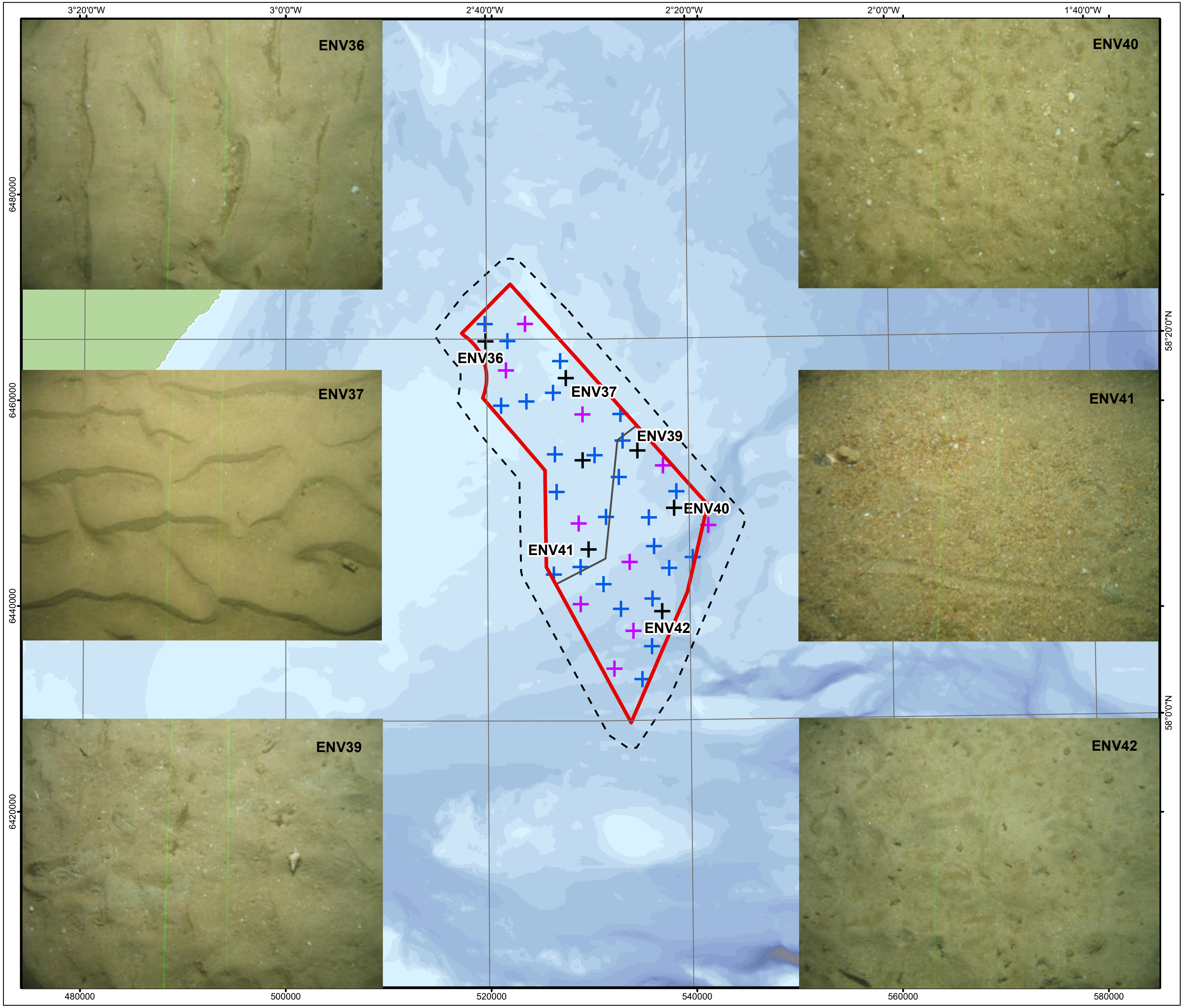
2.2.3.8 On the north flank of the Smith Bank, Holmes *et al*. (2004[5]) showed the presence of sand patches and sheets with sediment waves ranging from approximately 0.5 to 1.5m height and with wavelengths of approximately 50m. These sediment waves are found approximately 45 to 60m deep and migrate to the south and in the same direction as the bottom flow measured by FLiDAR buoys SWLB075 and SWLB080 in the Caledonia OWF (Figure 1-1; Holmes *et al*., 2004[5]; see Section 2.1.2).

2.2.3.9 Geophysical data show a large number of raised sand ridges over the edges of the Smith Bank, which stand between 0.3 and 1.2m above the surrounding seabed in both north-northwest to south-southeast and east to west directions. This is likely related to the direction of waves and consistent published literature on the origin of these features dominated by waves in a relatively tidally benign environment (Osiris, 2011[62]; MORL, 2012[29]; see Section 2.1.1).

Caledonia OWF

2.2.3.10 Across the Caledonia OWF, water depths range between approximately 35 and 100m LAT; however, depths are mostly comprised between 50 and 60m LAT (see Volume 7B, Appendix 4-1: Environmental Baseline Report (Array Area)). The shallowest depths are found in the north-eastern part of the Caledonia OWF, associated to the eastern edge of the Smith Bank, and the deepest area is located in the south-east, corresponding to the east part of a trench, which is approximately 19km long orientated south-west to north-east (Figure 1-1).

2.2.3.11 Results of the drop-down video investigation from the geophysical survey carried out in the Caledonia OWF show the presence of soft ripples for seven analysed stations, with more pronounced ripples at stations ENV36 (57m deep) and ENV37 (50m deep) located in the north of the Caledonia OWF as shown on Figure 2-15 (see Volume 7B, Appendix 4-1: Environmental Baseline Report (Array Area)). This result supports previous geophysical data showing sand ridges on the edges of Smith Bank, but also an active sediment transport in the north of the Caledonia OWF.



Caledonia OWF
Overall Boundary North South Site Division
Survey Area

Station Type

Camera Only Stations
PSA and Macrofauna Station
PSA, Macrofauna, eDNA, Chemistry and Water Station

Depth (m)

0 - 50	110 - 120
50 - 60	120 - 130
60 - 70	130 - 140
70 - 80	140 - 150
80 - 90	150 - 160
90 - 100	160 - 170
100 - 110	

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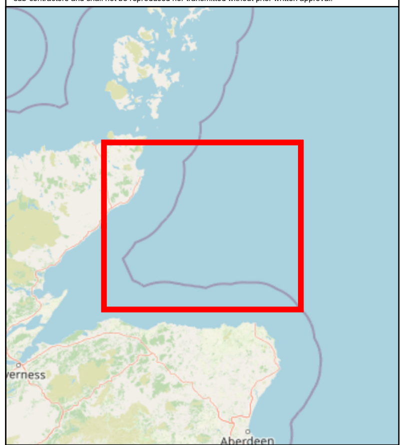

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01	09/09/2024	Approved	EV	BB	DH

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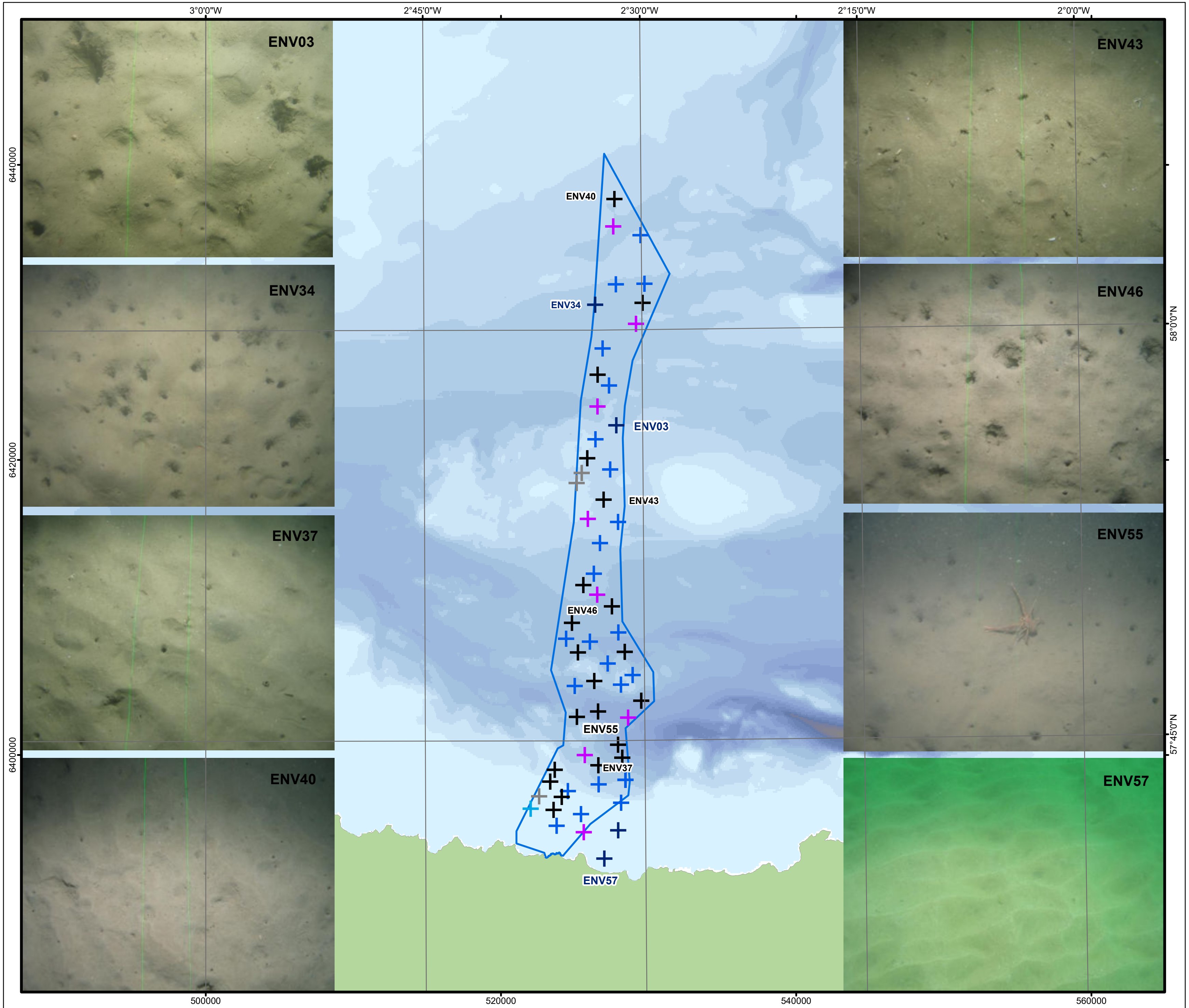
CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_MPR_MAP_00082	CONTRACTOR REV: 01
GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE: Figure 2-15: Seabed Morphology of the Caledonia OWF	
STATUS: Approved	SCALE: 1:500,000
DRAWING NUMBER: N/A	SHEET NO: 01 of 01 — REV: N/A

Caledonia OECC

2.2.3.12 Water depth across the Caledonia OECC vary up to 109m LAT in the southeast, approximately 10km from shore, with an average gradient of less than 1° (see Volume 7B, Appendix 4-2: Environmental Baseline Report (Offshore Export Cable Corridor)).

2.2.3.13 In the south of the Caledonia OECC, prominent north to south orientated ridges with localised gradients up to 70° are interpreted as outcropping bedrock. In the central part of the Caledonia 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. These results correlate the tidal ellipse excursion observed in the centre of the Caledonia OECC (see Section 2.1.2). Ripples, with north to south orientated crests, were seen during the Caledonia OECC geophysical survey within the furrows with wavelengths of approximately 1m, and heights of less than 0.1m (Figure 2-16). Gradients associated with the ripples were negligible.



Offshore Export Cable Corridor

Station Type

- Camera Only Station
- PSA and Macrofauna Station
- PSA, Macrofauna, eDNA, Chemistry and Water Station
- Macrofauna Only Station
- Camera, PSA and Macrofauna Station
- No data acquired

Depth (m)

- 0 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 100
- 100 - 110
- 110 - 120
- 120 - 130
- 130 - 140
- 140 - 150
- 150 - 160
- 160 - 170
- 170 - 180
- 180 - 190
- 190 - 200
- >200

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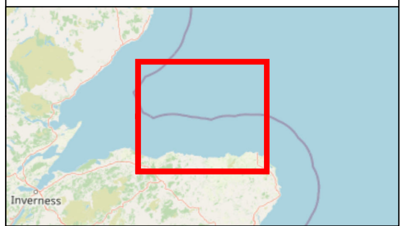

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REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	09/09/2024	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm

GoBe APEM Group

CONTRACTOR DRAWING NO UKCAL1_GO_WNF_MPR_MAP_00085	CONTRACTOR REV 01
GEODETIC PARAMETERS WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE Figure 2-16: Seabed Morphology of the OECC	
STATUS Approved	SCALE 1:350,000
DRAWING NUMBER N/A	SHEET NO 01 of 01 / REV N/A

Landfall Site

2.2.3.14 The outer Moray Firth and Caithness coast is characterised by Devonian sedimentary rocks of the Old Red Sandstone Supergroup, which are exposed to winter storms. Therefore, these sections have few accretionary habitats such as sand dunes, except in sheltered bays.

2.2.3.15 The Landfall Site in located in the vicinity of Whitehills in the east and Portsoy in the west (Figure 1-1). Between these two locations, small pocket beaches occur which are isolated and constraints by rocks headlands (Ramsay and Brampton, 2000[28]). The coastal area is generally plateau-like with 30 to 90m high cliffs, generally fronted by a rocky platform and cut in places by deep ravines (Barne *et al*., 1996[39]).

2.2.3.16 Most of the present-day beach material along the Aberdeenshire coast near the proposed Landfall Site has been provided by past marine erosion of these cliffs. There is very little present-day supply of beach material from cliff erosion (Ramsay and Brampton, 2000[28]).

2.2.3.17 The land formations and geomorphological processes in Banff Bay (approximately 5km east of the Landfall Site) have been studied by Hansom (2021[31]). The sand and shingly beach is enclosed between rock promontories which form a small bay at the mouth of the River Deveron. Beach sediments dominantly derived from glacial deposits washed down by the River Deveron and possible from offshore glacial deposits. In present times, there is little fresh supply of beach sediments.

2.2.4 Sediment Transport

Background

2.2.4.1 Sediment transport is a crucial link in the interaction between hydrodynamic regime and coastal morphological evolution. There are two main mechanisms of sediment transport:

- 1) Bedload transport, which refers to all sedimentary grains that move, roll or bounce (saltation) along the seabed as they are transported by currents. This mode of transport is principally related to coarser material (i.e., sands and gravels); and
- 2) Suspended load transport, which refers to particles of sediment that are carried above the seabed by currents and are supported in the water column without recourse to saltation.

2.2.4.2 Regional scale assessment by Reid and McManus (1987[30]) suggested that bedload sediment is transported into the Moray Firth from the north, passing along the north coast towards the inner Moray Firth, parallel to the tidal axis flow (Figure 2-17). Reid and McManus (1987[30]) stated that tidal currents may be sufficient to transport sediments if wave energy has initiated movements. This was reinforced by Holmes *et al*. (2004[5]) modelling analysis, which showed that observed sediment transport directions were correlated with tidal currents when modified by stormy conditions and storm surge.

2.2.4.3 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[5]; MORL, 2012[29]). This is supported by the general lack of contemporary large scale bedform features in the outer Moray Firth, indicating low sediment transport energy, as well as the observed trend of decreasing sediment grain size with increasing water depth within the Moray Firth. This reflects the relative importance of wave energy to sediment transport processes (MORL, 2012[29]).

2.2.4.4 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. This correlates both the flow direction and speed observed along this coast as sandwaves occur in area of less velocity (less than 0.5m/s) (Reid and McManus, 1987[30]; Andrews *et al*., 1990[51]; see Section 2.1.2). A variety of lineation has also been observed running into the innermost part of the Moray Firth, where the asymmetry of sand waves suggests net movement to the south-west, corresponding to the tidal current following the northern coast of the Moray Firth (Reid and McManus, 1987[30]).

2.2.4.5 During calm weather (absence or low wind), mean peak spring tide near-bed current speeds and directions modelled were not found to closely follow observed sediment transport directions in the Moray Firth; however, stormy conditions (strong wind and waves) in conjunction with the same tidal scenario was found to more closely correlate with the observed net sediment transport directions (Holmes *et al*., 2004[5]).

2.2.4.6 The background concentration of Suspended Particulate Matter (SPM) was particularly low during normal weather conditions, in the absence of storm events, and as a result the instrument (AWAC device positioned in the Moray East OWF) was only able to profile the bottom 15m of the water column (ABPmer, 2010[63]). However, during strong storm events the entire water column (40m) was profiled. This analysis indicates that tidal currents modified by stormy conditions and storm surge (typically directed into the Moray Firth along the north coast; see Section 2.1.1) are the major influence on the net movement of seabed sediments in the Moray Firth.

2.2.4.7 In specific areas, such as the Southern Trench, near-bed currents alone can transport fine-grained sand along the deep-water axes of the Southern Trench. This is because of an acceleration due to lateral constrictions in trench-axis configuration (Brooks *et al*., 2013[57]).

2.2.4.8 Suspended Sediment Concentration (SSC) has been inferred from surveys undertaken at the Moray East and Beatrice OWFs, located immediately to the west of the Proposed Development (Offshore). SSC data are typically less than 10mg/l with short periods of very high concentrations (more than

100mg/l) for Moray East OWF and typically less than 5mg/l, rarely exceeding 10mg/l for Beatrice OWF (MORL, 2012[29]). No correlation between the tidal regime and SSC was observed; however, the data did indicate a slight correlation between the greater wave heights and SSC.

2.2.4.9 The relatively lower values observed within the Beatrice OWF Array Area can be explained by (MORL, 2012[29]):

- Little fine sediment available in the surficial seabed sediment;
- Tidal currents generally being of insufficient strength to mobilise the majority of surficial sediment; and
- There being no significant fluvial source of SSC in the outer Moray Firth.

2.2.4.10 For example, the increase of SSC to 50mg/l was associated with a significant wave height of 4.5m during the storm event on the 17 February 2020 within the Beatrice OWF. At the southern end of the Beatrice OWF, the period of elevated SSC is greater as a result of a shallow water depth.

2.2.4.11 Due to the seasonal nature of the frequency and intensity of storm events, SSC will likely follow a seasonal pattern with higher values during winter and autumn, which corroborate available SSCs values, derived from satellite data, in the Moray East OWF showing SSC values in less than 10mg/l and 5mg/l during winter and summer, respectively (Figure 2-18; Dolphin *et al*., 2011[64]).

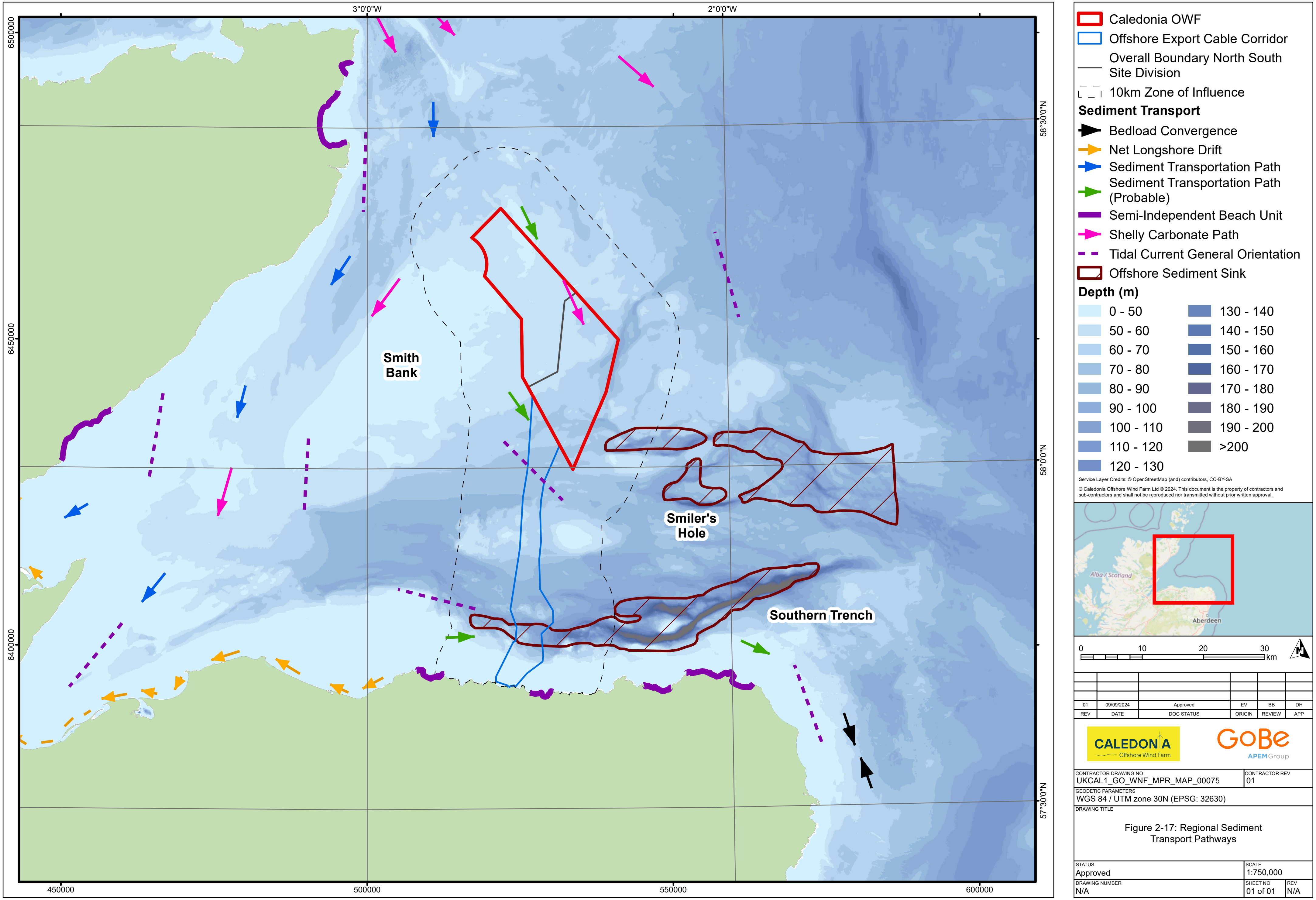
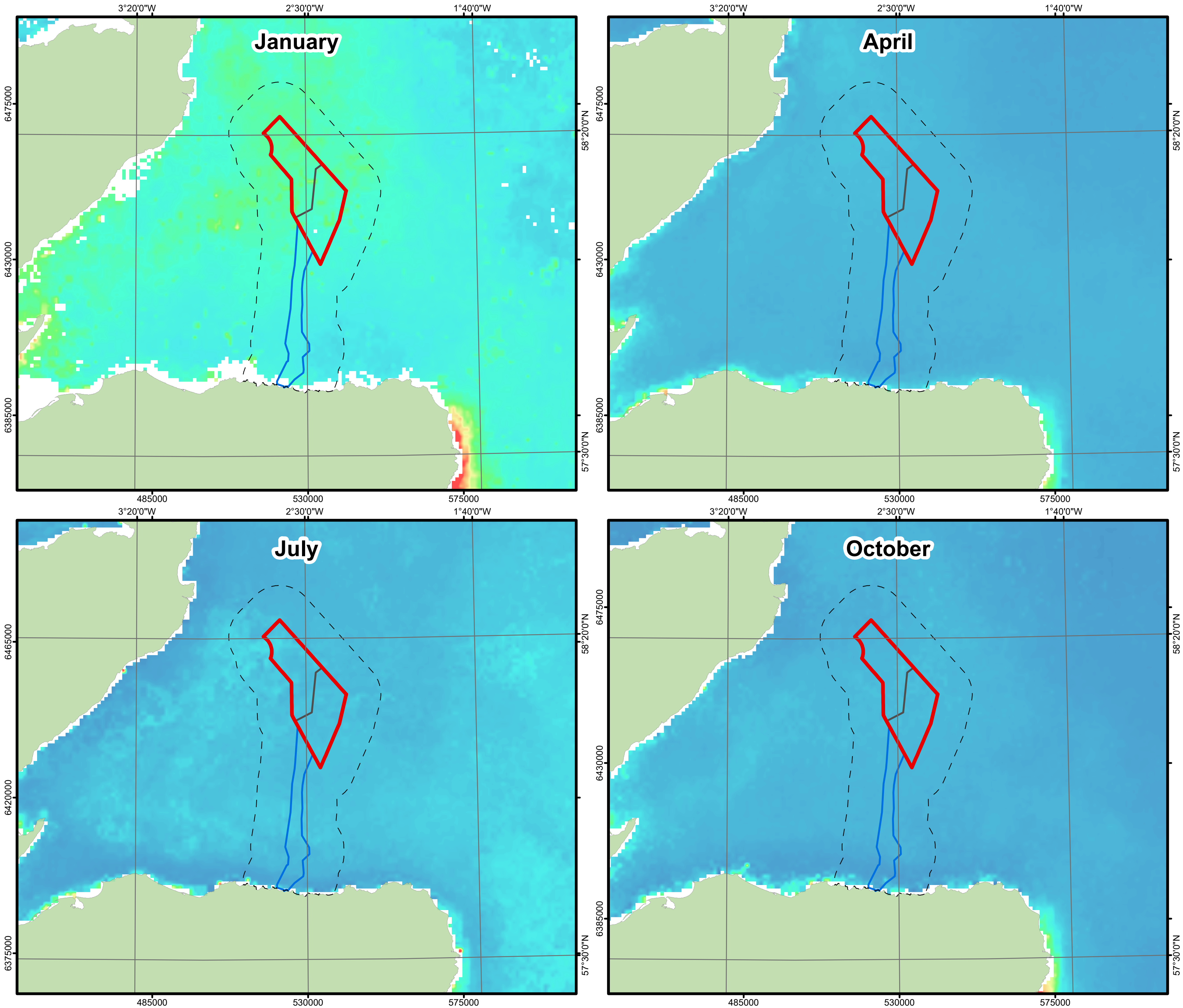


Figure 2-17: Regional Sediment Transport Pathways



Caledonia OWF
Offshore Export Cable Corridor
Overall Boundary North South Site Division
10km Zone of Influence

SPM Concentrations (mg/l) (CEFAS, 1998-2015)

High : 5

Low : 0

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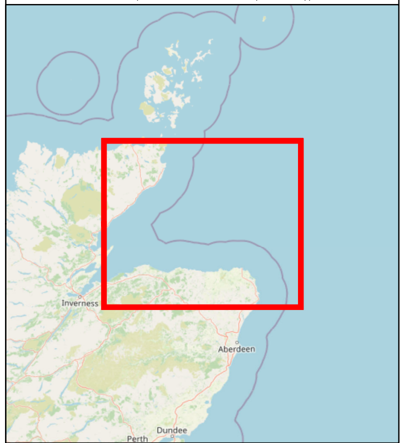


0 10 20 30 40 50 60 km

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

CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_MPR_MAP_00076

CONTRACTOR REV: 01

GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)

DRAWING TITLE

Figure 2-18: Suspended Particulate Matter (SPM) (Cefas, 1998 - 2015)

STATUS: Approved

SCALE: 1:1,500,000

DRAWING NUMBER: N/A

SHEET NO: 01 of 01

REV: N/A

Caledonia OWF

2.2.4.12 SSCs are typically low in the Caledonia OWF, 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 (Figure 2-18; Cefas, 2016[65]).

2.2.4.13 Based on the sediment type in the Caledonia OWF, the SSC is expected to be higher in the south due to the presence of finer sediment (see Section 2.2.2). However, the southern part of the area (within the Caledonia South Site) shows the lowest current and the deepest water depths, which means that sediment mobilisation will possibly occur only during extreme storm events.

2.2.4.14 Tidal current time-series from two FLiDAR buoys (SWLB075 and SWLB080) have been used to estimate the potential sediment mobility of sediments within the Caledonia OWF during a spring and neap tidal phase in October 2023. The bed shear stresses and corresponding critical depth-averaged current speed values required for the transportation of different sediment grain sizes have been calculated using standard methods described by Soulsby (1997[66]), and are provided in Table 2-3. The results show that no sediment mobility is expected at both FLiDAR buoy locations. These results were expected as the maximum measured current speeds observed at the seabed (i.e., 56m deep) were 0.34m/s and 0.4m/s for SWLB0075 and SWLB80, respectively. These speeds are below the minimum critical depth averaged current necessary to enhance the finest sediment mobility (i.e., coarse silt at 0.48m/s).

2.2.4.15 Pictures from the seabed in the Caledonia OWF where the FLiDAR buoys are located show the presence of soft ripples, which means that sediment are mobile. The estimated potential sediment mobility results in Table 2-3 support previous observations stating that sediment transport, in the Moray Firth, cannot be explained by tidal currents only, but these are wave-dominated (see Section 2.2.4).

Table 2-3: Estimated potential sediment mobility within the Caledonia OWF at FLiDAR buoy locations SWLB075 and SWLB080.

Size Class	Grain Size (upper boundary) (mm)	Threshold of Bed Shear (N/m^2)	Corresponding Critical Depth-averaged Current Speeds (m/s)	Spring Sediment Mobility (%)*	Neap Sediment Mobility (%)*
Granule gravel	4.0	3.007	1.32	0	0
Very coarse sand	2.0	1.166	0.908	0	0

Size Class	Grain Size (upper boundary) (mm)	Threshold of Bed Shear (N/m^2)	Corresponding Critical Depth-averaged Current Speeds (m/s)	Spring Sediment Mobility (%)*	Neap Sediment Mobility (%)*
Coarse sand	1.0	0.481	0.643	0	0
Medium sand	0.5	0.262	0.524	0	0
Fine sand	0.25	0.189	0.492	0	0
Very fine sand	0.125	0.153	0.489	0	0
Coarse silt	0.0625	0.120	0.477	0	0
* Percentage of time that sediment is mobile.					

Caledonia OWF

2.2.4.16 SSCs are low within the Caledonia OECC (less than 5mg/l) with a slight increase further inshore. This is explained by shallower water depths inducing an elevated impact on the seabed (and thus sediment resuspension) by the combined effects of tide, waves and wind (Figure 2-18; Cefas, 2016[65]).

Landfall Site

2.2.4.17 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[28]). However, the beach material within these bays is relatively dynamic, being redistributed depending upon storm conditions and river flows. Banff beach, approximately 5km from the Landfall Site at Stake Ness, is backed on all sides by hard linear defences. Wave reflections from these defences are causing beach lowering along the eastern side of the bay (Ramsay and Brampton, 2000[28]).

2.2.4.18 Along the coastlines of the mid and inner Moray Firth, waves are the primary influence upon sediment transport through the process of longshore drift (MORL, 2012[29]; Moray Offshore Windfarm (West) Limited, 2018[41]). Hansom (2021[31]) explained that a westerly wave produced net longshore drift direction along the Moray Firth south coast towards the inner Moray Firth.

2.3 Future Baseline Environment

2.3.1.1 A consideration of the future baseline, including the associated variation, is provided in the context of the anticipated operational lifespan of the Proposed

Development (Offshore). For the current purposes, the Representative Concentration Pathway (RCP) 8.5 (high emissions) scenario in terms of greenhouse-gas emissions has been considered (Palmer *et al*., 2018[22]). UKCP18 suggests an increase in mean sea level (MSL) of 0.5 to 0.6m by 2100 along the coast of the Moray Firth (Palmer *et al*., 2018[22]). Future changes in storm surges have been predicted to be indistinguishable from background variation (Lowe *et al*., 2009[67]), although extreme surge level event frequency is likely to increase (IPCC, 2022[21]). Hansom *et al*. (2017[68]) showed that the Moray Firth coast is composed of 59% soft coastlines (specifically sand and mud) and suggests, in the last 50 years, relative proportions of coastal retreat (22%), advance (16%) and no change (62%).

2.3.1.2 Significant wave height may decrease slightly by up to 0.5m in the Moray Firth according to UKCIP09 (MORL, 2012[29]). This modelled observation correlates the prediction concerning a decrease of wave energy larger than 10% by 2100 in the North Sea (RCP8.5 scenario; Bonaduce *et al*., 2019[69]; Meucci *et al*., 2020[70]). Inter-decadal variability of storminess in the area is observed; for example, relative storminess was high in the early 20th century but decreased up until about 1970, which may be largely due to the influence of local weather in the North Sea (Matulla *et al*., 2007[71]; EDF Energy, 2020[72]).

2.3.1.3 In addition, the United Kingdom is affected by isostatic readjustment, which is a regional change in land surface elevation following the removal of the weight of the British/Irish Ice Sheet. Due to this post-glacial uplift the sea level in the Moray Firth is estimated to change by approximately -0.6 to -0.8mm/year (Palmer *et al*., 2018[22]), although this is being outpaced by rates of global sea level rise (BEIS, 2022b[36]).

2.3.1.4 A slowly rising sea level might potentially enhance erosion by increasing the amount of sediment transport with the westerly longshore drift observed along the southern coast of the Moray Firth, especially in the coastal area located to the west of the proposed Landfall Site at Stake Ness (Merritt *et al*., 2003[73]). At the Landfall Site, individual bay-head units are small and isolated from each other by headlands and relatively deep water (Ramsay and Brampton, 2000[28]). This prevents longshore movement of sediment other than that within the single beach cells and resulting in a low rate of erosion, little accretion and little evidence of significant longshore drift.

2.3.1.5 At the Landfall Site, other non-tidal effects will include the potential for mean sea-level rise as a result of climate change, which is estimated to be 0.08 to 0.14m over a 25-year period, based on a medium emissions scenario (ABPmer, 2012[32]). Sea level rise will potentially have the biggest impact, in particular upon sediment transport and thus erosion, at Banff Bay. This Bay is a dynamic stretch of coast in terms of change, where a small sand spit at the inner margin of the intertidal Deveron delta is subjected to alternating marine and fluvial energies and frequently changes its form (Smith, 1986[74]).

2.3.1.6 The present understanding of climate change predicts variability in many of the parameters affecting stratification (specifically temperature and salinity), but all with a high degree of uncertainty and with unknown net result, it is difficult to draw solid conclusions (MCCIP, 2006[75]).

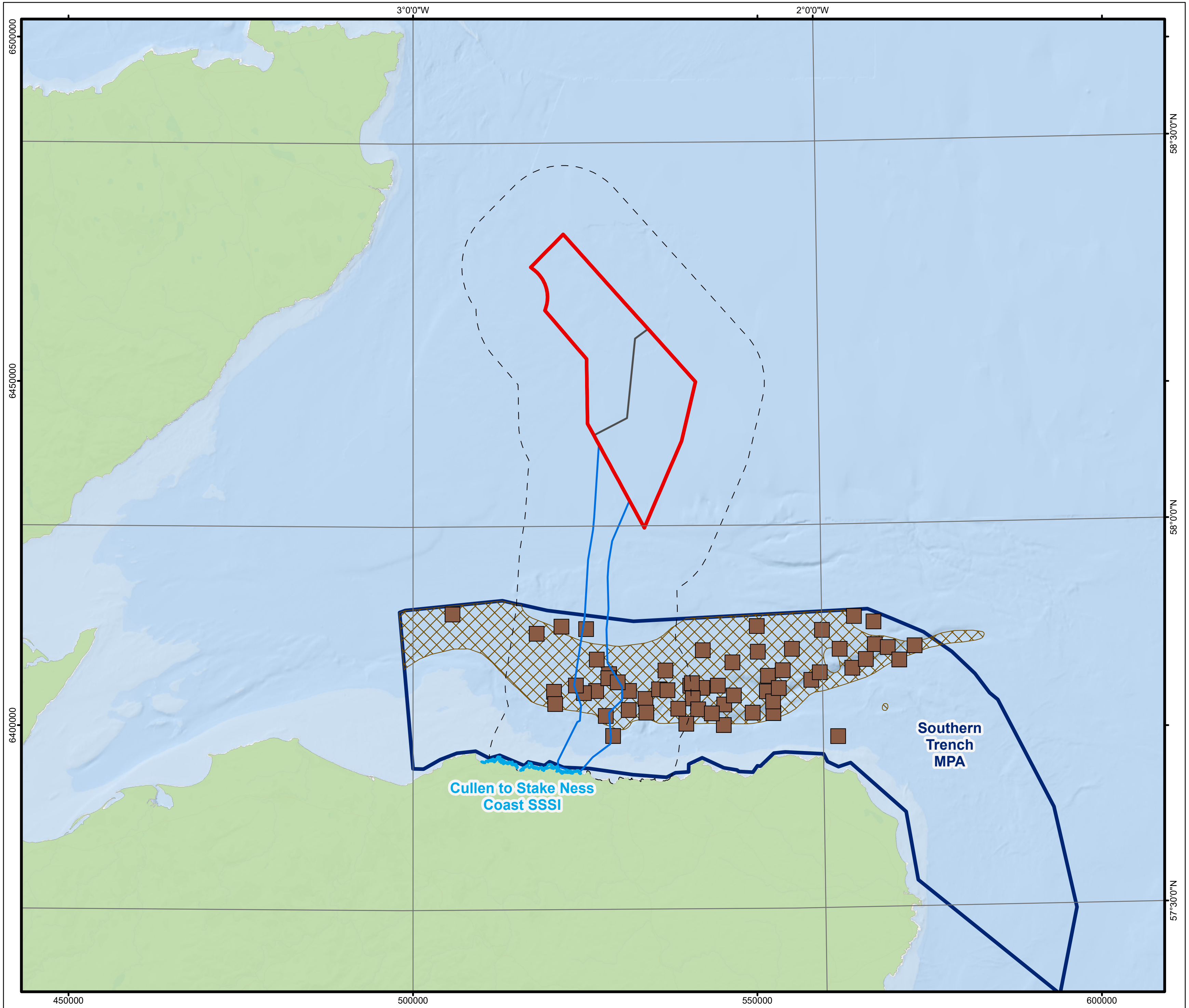
2.4 Designated Sites and Protected Species

2.4.1.1 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 2-19. The Caledonia OECC crosses the Southern Trench NCMPA, which designates the following features related to marine and coastal processes for protection:

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

2.4.1.2 The MPA Assessment (Application Document 19) comprehensively addresses all qualifying features of the Southern Trench NCMPA, including burrowed mud, minke whales, oceanic fronts, shelf deeps, Quaternary of Scotland, and submarine mass movement.

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



Caledonia OWF
Offshore Export Cable Corridor
Overall Boundary North South Site Division
10km Zone of Influence
Marine Protected Areas
SSSI
Burrowed Mud
Burrowed Mud (Area)

Service Layer Credits: © OpenStreetMap (and) contributors, CC-BY-SA
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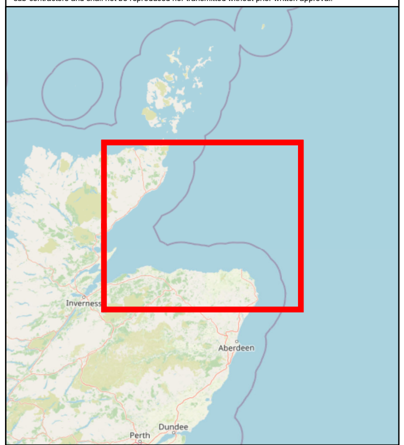

0 10 20 30 km

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

CALEDONIA Offshore Wind Farm
GoBe APEM Group

CONTRACTOR DRAWING NO	CONTRACTOR REV
UKCAL1_GO_WNF_MPR_MAP_00077	01

GEODETIC PARAMETERS
WGS 84 / UTM zone 30N (EPSG: 32630)

DRAWING TITLE
Figure 2-19: Designated Sites of Marine Relevance within the Study Area

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

3 References

[1] Robinson, K.P., Tetley, M.J. and Mitchelson-Jacob, E.G. (2009) 'The distribution and habitat preference of coastally occurring whales (*Balaenoptera acutorostrata*) in the outer southern Moray Firth, northeast Scotland'. Journal of Coastal Conservation 13: 39-48

[2] Marine Scotland (2024) 'National Marine Plan Interactive (NMPi) mapping tool'. Available at: https://marinescotland.atkinsgeospatial.com/nmpi/ (Accessed 14/05/2024)

[3] Marine Scotland (2021) 'Regional Assessments: Moray Firth SMR. Available at: https://marine.gov.scot/sma/region/moray-firth-smr (Accessed 14/05/2024)

[4] Department for Business, Energy and Industrial Strategy (BEIS) (2022a) 'Environmental Baseline Appendix 1d: Water Environment. UK Offshore Energy Strategic Environmental Assessment 4 (OESEA4)'. Available at: https://www.gov.uk/government/consultations/uk-offshore-energy-strategic-environmental-assessment-4-oesea4 (Accessed 14/05/2024)

[5] Holmes, R., Bulat, J., Henni, P., Holt, J., James, C., Kenyon, N., Leslie, A., Long, D., Musson, R., Pearson, S. and Stewart, H. (2004) 'DTI Strategic Environmental Assessment Area 5 (SEA5): Seabed and superficial geology and processes'. BGS Report CR/04/064N

[6] Beatrice Offshore Wind Farm Limited (BOWL) (2010) 'Beatrice Offshore Wind Farm'. Available at: https://marine.gov.scot/sites/default/files/00446498.pdf (Accessed 14/05/2024)

[7] Beatrice Offshore Wind Farm Limited (BOWL) (2012) 'Beatrice OWF Environmental Statement'. Available at: https://marine.gov.scot/data/environmental-statementconstruction-operation-generating-station-and-transmission-works-0 (Accessed 14/05/2024)

[8] Stromar Offshore Wind Farm Ltd (2024) 'Environmental Impact Assessment: Offshore Scoping Report. Proposed Offshore Development'. 04 January 2024. Orsted, BlueFloat Energy and Renatis

[9] Department for Energy and Climate Change (DECC). (2004). Environmental Report Section 5: Physical & Chemical Environment. Strategic Environmental Assessment – SEA5 – Offshore Oil and Gas Licensing

[10] Repsol Sinopec Resources UK (2018) 'Beatrice Decommissioning Programmes Final Version'. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/772806/Beatrice_Decommissioning_Programmes.pdf (Accessed 14/05/2024)

[11] Department of Energy and Climate Change (DECC) (2015) 'Offshore Oil & Gas Licensing 28th Seaward Round. Moray Firth. Blocks 12/21d, 12/26c, 12/30, 13/16b, 13/17, 13/21c,

18/1, 18/2, 18/4, 18/5, 18/9 and 19/15. Habitats Regulations Assessment. Stage 2 - Appropriate Assessment'. March 2015

[12] ABPmer (2017) 'Atlas of UK Marine Renewable Energy. Interactive Map'. Available at: https://www.renewables-atlas.info/explore-the-atlas (Accessed 14/05/2024)

[13] ABPmer (2018) 'SEASTATES Metocean Data and Statistics Interactive Map'. Available at: www.seastates.net (Accessed 14/05/2024)

[14] Centre for Environment, Fisheries and Aquaculture Science (Cefas) (2022) 'Cefas Wavenet data'. Available at: www.cefas.co.uk/cefas-data-hub/wavenet (Accessed 14/05/2024)

[15] United Kingdom Hydrographic Office (UKHO) (2024) 'Admiralty Tide Table'. Available at: https://www.admiralty.co.uk/publications/publications-and-reference-guides/admiraltytide-tables (Accessed 14/05/2024)

[16] European Marine Observation and Data Network (EMODnet). (2024). Available at: https://emodnet.ec.europa.eu/en (Accessed 14/05/2024).

[17] Barne, J.H., Robson, C.F., Kaznowska, S.S., Doody, J.P. and Davidson, N.C. (1996) 'Coasts and seas of the United Kingdom. Region 3 North-east Scotland: Cape Wrath to St. Cyrus'. Peterborough, Joint Nature Conservation Committee (Coastal Directories Series)

[18] British Geological Survey (BGS) (2020) 'GeoIndex Offshore'. Available at: https://www.bgs.ac.uk/map-viewers/geoindex-offshore (Accessed 14/05/2024)

[19] Vysus Group (2021) 'New Leasing Geological Consultancy Support: OWF Ground Conditions Feasibility Assessment – NE4 Soil Thickness Study'

[20] IHE Delft (2021) 'Coastal Futures Interactive Map'

[21] Intergovernmental Panel on Climate Change (IPCC) (2022) 'Sixth Assessment Report: Impacts, Adaption and Vulnerability'. Available at: https://www.ipcc.ch/report/ar6/wg2/ (Accessed 14/05/2024)

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

[23] Centre of Expertise for Waters (CREW) (2021) 'Dynamic Coast - Coastal Erosion in Scotland'. Available at: https://www.dynamiccoast.com/ (Accessed 14/05/2024)

[24] NASA (2024) 'Sea Level Projection Tool'. Available at: https://sealevel.nasa.gov (Accessed 14/05/2024)

[25] Comber, D.P.M. (1993) 'Shoreline response to Relative Sea Level Change: Culbin Sands, Northeast Scotland'. Unpublished PhD thesis, University of Glasgow

[26] Natural Environment Research Council (1992) 'United Kingdom Digital Marine Atlas'. Version 2.0 (NERC/BODC, Birkenhead)

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

[28] Ramsay, D.L. and Brampton, A.H. (2000) 'Coastal Cells in Scotland: Cell 3 – Cairnbulg Point to Duncansby Head'. Scottish Natural Heritage Research, Survey and Monitoring Report, No. 145, 110pp.

[29] Moray Offshore Renewables Limited (MORL) (2012) 'Moray East Offshore Wind Farm Environmental Statement'. Available at: https://www.morayeast.com/document-library/navigate/229/144 (Accessed 14/05/2024)

[30] Reid, G. and McManus, J. (1987) 'Sediment exchanges along the coastal margin of the Moray Firth, Eastern Scotland'. Journal of the Geological Society 144(1): 179-185

[31] Hansom, J.D. (2021) 'Beaches and Dunes of the Moray Firth Coast'. In: Ballantyne, C.K., Gordon, J.E. (Eds.) Landscapes and Landforms of Scotland. World Geomorphological Landscapes. Springer, Cham. Available at: https://doi.org/10.1007/978-3-030-71246-4_22 (Accessed 14/05/2024)

[32] ABPmer (2012) 'Beatrice Offshore Wind Farm, Environmental Statement'. Section 9 - Physical Processes and Geomorphology

[33] Adams, J.A. and Martins, J.H.A. (1986) 'The hydrography and plankton of the Moray Firth'. Proceedings of the Royal Society of Edinburgh, 91B: 37-56

[34] Moray Offshore Renewables Limited (MORL) (2016) 'Moray West Offshore Wind Farm Environmental Impact Assessment Scoping Report'. Available at: https://www.moraywest.com/document-library (Accessed 14/05/2024)

[35] Moray Offshore Windfarm (East) Limited (2017) 'Moray East Offshore Windfarm Alternative Design Parameters. Scoping Report'. March 2017. Available at: https://marine.gov.scot/sites/default/files/00515190.pdf (Accessed 14/05/2024)

[36] Department for Business, Energy and Industrial Strategy (BEIS) (2022b) 'Environmental Baseline Appendix 1b: Geology, Substrates & Coastal Processes'. UK Offshore Energy Strategic Environmental Assessment 4 (OESEA4). Available at: https://www.gov.uk/government/consultations/uk-offshore-energy-strategicenvironmental-assessment-4-oesea4 (Accessed 14/05/2024)

[37] Easton, M.C., Harendza, A., Woolf, D.K. and Jackson, A.C. (2011) 'Characterisation of a tidal energy site: hydrodynamics and seabed structure'. In Proc. Of the 9th European Wave and Tidal Energy Conference, Southampton, UK, 5-9 September 2011

[38] Department for Energy and Climate Change (DECC) (2004) 'Strategic Environmental Assessment – SEA5'. Available at: https://www.gov.uk/government/publications/strategicenvironmental-assessment-5-environmental-report (Accessed 14/05/2024)

[39] Barne, J.H., Robson, C.F., Kaznowska, S.S., Doody, J.P. and Davidson, N.C. (eds.) (1996) 'Coasts and seas of the United Kingdom. Region 3 North-east Scotland: Cape Wrath to St. Cyrus'. Peterborough, Joint Nature Conservation Committee (Coastal Directories Series)

[40] Department of Energy and Climate Change (DECC) (2016) 'UK Offshore Energy Strategic Environmental Assessment 3'. Published March 2016, updated July 2016. Available at: https://www.gov.uk/government/consultations/uk-offshore-energy-strategic-environmental-assessment-3-oesea3 (Accessed 14/05/2024)

[41] Moray Offshore Windfarm (West) Limited (2018) 'Moray West Offshore Wind Farm Environmental Statement'. Available at: https://www.moraywest.com/document-library (Accessed 14/05/2024)

[42] Flather, R.A., Smith, J.A., Richards, J.D., Bell, C. and Blackman, D.L. (1998) 'Direct estimates of extreme storm surge elevations from a 40-year numerical model simulation and from observations'. The Global Atmosphere and Ocean System 6: 165-176

[43] National Oceanography Centre (2010) 'Estimates of Extreme Still Water Levels and Depth-Mean Currents for the North Sea'. pp15. Report prepared for ABPmer

[44] Turrell, W.R., Henderson, E.W., Slesser, G., Payne, R. and Adams, R.D. (1992) 'Seasonal changes in the circulation of the northern North Sea'. Continental Shelf Research 12(2-3): 257-286

[45] McManus, J. (1992) 'A hydrographic framework for marine conservation in Scotland'. Proceedings of the Royal Society of Edinburgh, Section B: Biological Sciences 100: 3-26

[46] NatureScot (2024) 'Conservation and Management Advice. Southern Trench MPA'. December 2020. Available at: https://sitelink.nature.scot/site/10477 (Accessed 14/05/2024)

[47] Connor, D.W., Gilliland, P.M., Golding, N., Robinson, P., Todd, D. and Verling, E. (2006) 'UKSeaMap: the mapping of seabed and water column features of UK seas'. Joint Nature Conservation Committee, Peterborough, ISNB 978-1-86107-590-1

[48] Miller, P.I., Xu, W. and Lonsdale, P. (2014) 'Seasonal shelf-sea front mapping using satellite ocean colour to support development of the Scottish MPA network'. Scottish Natural Heritage Commissioned Report No. 538

[49] British Geological Society (BGS) (2024) 'British Geological Survey Geology Viewer'. Available at: https://www.bgs.ac.uk/map-viewers/bgs-geology-viewer (Accessed 14/05/2024)

[50] Chesher, J.A. and Lawson, D. (1983) 'The geology of the Moray Firth'. Report of the Institute of Geological Science, No. 83/5

[51] Andrews, I.J., Long, D., Richards, P.C., Thomson, A.R., Brown, S., Chesher, J.A. and McCormac, M. (1990) 'United Kingdom offshore regional report: The geology of the Moray Firth'. London: HMSO for the British Geological Survey

[52] British Geological Survey (BGS) (1984) 'Moray Buchan, Sheet 57°N-04°W, Seabed Sediment and Quaternary Geology'. 1:250,000 series, Keyworth: BGS

[53] Gribble, J. and Leather, S. (2011) 'Offshore Geotechnical Investigations and Historic Environment Analysis: Guidance for the Renewable Energy Sector'. Commissioned by COWRIE Ltd (project reference GEOARCH-09)'. Available at: https://www.historicenvironment.scot/media/2376/2011-01-offshore-geotechnical-investigations-and-historic-environment-analysis-guidance-for-the-renewable-energy-sector.pdf (Accessed 14/05/2024)

[54] British Geological Survey (BGS) (1987) 'Caithness, Sheet 58°N-04°W, Seabed Sediments and Quaternary'. 1:250,000 series, Keyworth: BGS

[55] Folk, R.L. (1954) 'The Distinction between Grain Size and Mineral Composition in Sedimentary-Rock Nomenclature'. Journal of Geology 62: 344-359

[56] Folk, R.L. and Ward, W.C. (1957) 'Brazos river bar: a study of the significance of grain size parameters'. Journal of Sedimentary Petrology 27: 3-26

[57] Brookes, K.L., Bailey, H. and Thompson, P.M. (2013) 'Predictions from harbour porpoise habitat association models are confirmed by long-term passive acoustic monitoring'. The Journal of the Acoustical Society of America 134(3): 2523-2533

[58] Long, D. and Stoker, M. (1986) 'Valley asymmetry: Evidence for periglacial activity in the Central North Sea'. Earth Surface Processes and Landforms 11: 525-532

[59] Hirst, N.E., Clark, L. and Sanderson, W.G. (2012) 'The distribution of selected MPA search features and Priority Marine Features off the NE coast of Scotland'. Scottish Natural Heritage Commissioned Report No.500. 132pp.

[60] Bradwell, T., Stoker, M.S., Golledge, N.R., Wilson, C.K., Merritt, J.W., Long, D., Everest, J.D., Hestvik, O.B., Stevenson, A.G., Hubbard, A.L., Finlayson, A.G. and Mathers, H.E. (2008) 'The northern sector of the British Ice Sheet: maximum extent and demise'. Earth-Science Reviews 88: 207-226

[61] Graham, A.G.C., Lonergan, L. and Stoker, M.S. (2009) 'Seafloor glacial features reveal the extent and decay of the last British Ice Sheet, east of Scotland'. Journal of Quaternary Science 24: 117-138

[62] Osiris (2011) 'Moray Firth Round 3 Zone geophysical survey - various reports'

[63] ABPmer (2010) 'Moray Firth R3 OWF Initial Metocean Design Criteria'. Report R.1699

[64] Dolphin, T.J., Silva, T.A.M. and Rees, J.M. (2011) 'Natural Variability of Turbidity in the Regional Environmental Assessment (REA) Areas'. MEPF-MALSF Project 09-P114. Cefas, Lowestoft, 41pp.

[65] Centre for Environment, Fisheries and Aquaculture Science (Cefas) (2016) 'Sediment Climatologies around the UK'. Report for the UK Department for Business. Energy and Industrial Strategy offshore energy Strategic Environmental Assessment programme

[66] Soulsby, R.L. (1997) 'Dynamics of marine sands—A manual for practical applications'. London, Thomas Telford Publications, 249p.

[67] Lowe, J.A., Howard, T.P., Pardaens, A., Tinker, J., Holt, J., Wakelin, S., Milne, G., Leake, J., Wolf, J., Horsburgh, K. and Reeder, T. (2009) 'UK Climate Projections science report: Marine and coastal projections'

[68] Hansom, J.D., Fitton, J.M. and Rennie, A.F. (2017) 'Dynamic Coast - National Coastal Change Assessment: National Overview'. CRW2014/2

[69] Bonaduce, A., Staneva, J., Behrens, A., Bidlot, J.R. and Wilcke, R.A.I. (2019) 'Wave climate change in the North Sea and Baltic Sea'. Journal of Marine Science and Engineering 7(6): p.166

[70] Meucci, A., Young, I.R., Hemer, M., Kirezci, E. and Ranasinghe, R. (2020) 'Projected 21st century changes in extreme wind-wave events'. Science Advances 6(24): eaaz7295

[71] Matulla, C., Schöner, W., Alexandersson H., von Storch H. and Wang X.L. (2007) 'European storminess: late nineteenth century to present'. Climate Dynamics 31: 125-130

[72] EDF Energy (2020) 'The Sizewell C Project. 6.3: Volume 2 Main Development Site. Chapter 20 Coastal Geomorphology and Hydrodynamics'. May 2020

[73] Merritt, J.W., Auton, C.A., Connell, E.R., Hall, A.M. and Peacock, J.D. (2003) 'Cainozoic geology and landscape evolution of north-east Scotland'. Memoir of the British Geological Survey, sheets 66E, 67, 76E, 77, 86E, 87W, 87E, 95, 96W, 96E and 97 (Scotland)

[74] Smith, J.S. (1986) 'The coastal topography of the Moray Firth'. Proceedings of the Royal Society of Edinburgh Section B Biological Sciences 91: 1-12

[75] MCCIP (2006) 'Marine Climate Change Impacts Annual Report Card 2006'. (Eds. Buckley, P.J., Dye, S.R. and Baxter, J.M.), Summary Report, MCCIP, Lowestoft, 8pp. Available at: www.mccip.org.uk (Accessed 14/05/2024)

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