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Glossary

Acoustic Doppler Current Profiler (ADCP)	A seabed mounted instrument that measures current velocities over a depth range through the water column in addition to water elevation.
Acoustic Wave and Current (AWAC)	A seabed mounted instrument that measures both surface waves, and current velocities over a depth range throughout the water column in addition to water elevation.
Bed Shear Stress	A measure of the force exerted on the seabed by a combination of current flows and wave orbital motions. The higher the bed shear stress, the more likely is sediment erosion.
Critical bed shear stress	The threshold *bed shear stress* above which sediment erosion starts to occur; its value depends upon the properties of the seabed sediment, such as the *particle size distribution.*
Energetic Means	The assumption that, during cable burial, the entire volume of the trench is ejected into the water column; this leads to conservative estimates for *Suspended Sediment Concentrations* and sediment settling depth and allows for consideration of a range of cable installation methodologies.
Forth and Tay Modelling System	A numerical modelling system built specifically for *Inch Cape Offshore Limited* and *Neart Na Gaoithe Offshore Wind Limited* in order to assess environmental impacts; comprises *Hydrodynamic*, *Spectral Wave* and *Particle Tracking* modules.
Hydrodynamic	A numerical model used to predict water levels and current velocities throughout a model domain.
Maximum bed shear stress	The *bed shear stress* that occurs when the current caused by a passing wave is at its highest speed (waves cause oscillating currents, which will reach a peak in one direction before reversing and flowing in the opposite direction).
Mean bed shear stress	The average *bed shear stress* that occurs during the passage of a wave, as the near-bed current flows first in one direction, then in the opposite.
Metocean	Meteorology and oceanography – referring primarily to wind, waves, currents and water levels, plus secondary parameters such as air temperature, humidity, water temperature and salinity.
Metocean Survey	A survey campaign designed to measure *metocean* data in order to help characterise the environment and to support numerical modelling studies; key survey instruments may include wave buoys, meteorological buoys, *Acoustic Doppler Current Profilers* and *Acoustic Wave and Current* meters.

Meteorological Buoys	An instrument that measures *metocean* and wind data.
Near-field	The study area lying within Development Area and Offshore Export Cable Corridor.
Particle Tracking	A numerical model used to predict the transport, deposition, and subsequent erosion of a tracer (such as dredged or scoured sediment) released into the marine environment.
Significant Wave Height	A statistical representation of a wave train to represent the mean trough to crest distance. It is defined as four times the standard deviation of the surface elevation.
Suspended Sediment Concentrations	A measure of the amount of particulate matter (such as sand or silt) held suspended within the water column.
Spectral Wave	A numerical model used to predict wave heights, periods and directions throughout a model domain.
Wave Buoy	A floating anchored device that is used to measure the movement of the water surface which can be analysed to determine wave statistics such as significant wave height, period and direction.

Abbreviations and Acronyms

ADCP	Acoustic Doppler Current Profiler
AWAC	Acoustic Wave and Current
BGS	British Geological Survey
CD	Chart Datum
Cefas	Centre for Environment, Fisheries and Aquaculture Science
COWRIE	Collaborative Offshore Wind Research into the Environment
DECC	Department of Energy and Climate Change
DTI	Department of Trade and Industry
EIA	Environmental Impact Assessment
ES	Environmental Statement
FF	Far-field
FTMS	Forth and Tay Modelling System
FoF	Firth of Forth

FTOWDG	Forth and Tay Offshore Wind Developers Group
GBS	Gravity Base Structure
HD	Hydrodynamic
ICOL	Inch Cape Offshore Limited
JNCC	Joint Nature Conservation Committee
LNR	Local Nature Reserve
MPA	Marine Protected Area
MS	Marine Scotland
MS-LOT	Marine Scotland Licencing Operations Team
MSS	Marine Scotland Science
NF	Near-field
NnG	Neart Na Gaoithe
NNR	National Nature Reserve
OfTW	Offshore Transmission Works
OSP	Offshore Substation Platform
PSD	Particle Size Distribution
PT	Particle Tracking
SAC	Special Area of Conservation
SAS	Surfers Against Sewage
SEA	Strategic Environmental Assessment
SPA	Special Protection Area
SSC	Suspended Sediment Concentrations
SSSI	Site of Special Scientific Interest
SW	Spectral Wave
UKCIP	UK Climate Impacts Programme
UKHO	UK Hydrographic Office
WTG	Wind Turbine Generator

10 Metocean and Coastal Processes

10.1 Introduction

1 This chapter provides an assessment of the predicted effects of the construction, operation and decommissioning of the Inch Cape Offshore Wind Farm and Offshore Transmission Works (OfTW) within the Development Area and Offshore Export Cable Corridor upon metocean and coastal processes.

2 "Metocean" refers to meteorology and oceanography; the main processes of interest are water levels, currents and waves. "Coastal processes" is a generic term that refers to the physical processes affecting the form and evolution of the coastal zone, through sediment erosion, transport and deposition. A coastal processes study considers phenomena such as suspended sediment concentrations (SSC), seabed features (such as sand banks and ripples), and large-scale sediment transport pathways (which in turn influence beach replenishment, coastal erosion/flooding, and similar issues).

3 The Environmental Impact Assessment (EIA) for the Inch Cape Offshore Wind Farm and Offshore Transmission Works (OfTW) will consider metocean and coastal processes within the near-field environment (i.e. encompassing the Development Area or Offshore Export Cable Corridor) in addition to the far-field environment (for example the coastal zone).

4 The following documents support this chapter:

- *Appendix 10A: Metocean and Coastal Processes Assessment*;
- *Annex 10A.1: Development Area Baseline Description*;
- *Annex 10A.2: Modelled Baseline Plots*;
- *Annex 10A.3: Wave Climate Analysis Methodology*;
- *Annex 10A.4: Bed Shear Stress Analysis Methodology*;
- *Annex 10A.5: Modelling of Structures Methodology*;
- *Annex 10A.6: Development Area Scour Potential Assessment*;
- *Annex 10A.7: Modelled Assessment Plots*;
- *Appendix 10B: Data Gap Analysis and Data Review*;
- *Appendix 10C: Hydrodynamic and Spectral Wave Model Calibration and Validation*;
- *Appendix 10D: Proposed Methodology for Metocean and Coastal Processes Assessments*;
- *Appendix 10E: Stakeholder Consultation*; and
- *Appendix 10F: Regional Coastal Processes Baseline Description*.

5 Changes to metocean and coastal processes, due to the Wind Farm and OfTW, may have indirect impacts on a range of other receptors. These are discussed in the following chapters:

- *Chapter 12: Benthic Ecology*;
- *Chapter 13: Natural Fish and Shellfish*;
- *Chapter 14: Marine Mammals*;
- *Chapter 15: Ornithology*;
- *Chapter 17: Cultural Heritage and Marine Archaeology*;
- *Chapter 18: Commercial Fisheries*;
- *Chapter 19: Shipping and Navigation*; and
- *Chapter 21: Other Human Activities*.

10.1.1 Consultation

6 The consultation process is outlined below:

- The Scoping Report for the Inch Cape Offshore Wind Farm was developed by ICOL (formerly SeaEnergy Renewables Limited) and submitted for review in August 2010 (SeaEnergy Renewables Limited, 2010).
- The Scoping Opinion was produced by Marine Scotland in response to the Scoping Report. This collated responses from other stakeholders and was issued to ICOL in March 2011 (Marine Scotland, 2011).
- A methodology statement outlining the intended approach to the metocean and coastal processes modelling and impact assessment for the Wind Farm and Neart na Gaoithe offshore wind farm was developed and issued to Marine Scotland in February 2011 (*Appendix 10D*).
- Feedback on the proposed approach to impact assessment was received from Marine Scotland (on behalf of all relevant stakeholders) in April 2011 (*Appendix 10E*).
- Response to the feedback was issued by ICOL and Mainstream Renewable Power in May 2011 (*Appendix 10E*).

7 In addition to the formal Scoping Opinion and methodology statement consultation, further informal consultation has been undertaken in relation to the assessment of the impacts of the Wind Farm and OfTW with relevant stakeholders. The information received through this consultation, together with the formal Scoping Opinion, response to the methodology statement consultation and recognised best practice, has informed the methodology and scope for the assessment of the impacts on metocean and coastal processes presented in this chapter.

8 The stakeholders accepted the proposed methodology, and stated that "*The proposed methodology is rigorous and well thought out. The proposed modelling methodology is particularly impressive*" (response from Marine Scotland to the proposed methodology – see *Appendix 10E*).

9 However, a number of specific clarifications were requested in the Scoping Opinion and in the response to the methodology statement. These have all been addressed, and are summarised in Table 10.1.

Table 10.1: Consultation Summary

Document	Consultee	Comment	Project Response
Scoping Report	Scottish Natural Heritage	Requested focused survey work for the Development Area on bathymetry, sediment type and seabed features at the site.	A comprehensive programme of surveys has been undertaken including geophysical, geotechnical, metocean and sediment characterisation. A summary of these surveys can be found in Table 10.4*, Section 10.2.1*. The results of these surveys have informed the metocean and coastal processes assessment.
	Marine Scotland Science (MSS) via Marine Scotland Licencing Team (MS-LOT)	Requested inclusion of indicative Wind Turbine Generator (WTG) layouts.	An indicative WTG layout is used within the metocean and coastal processes assessment. The layout was selected to represent the worst case for metocean impacts (see *Section 10.7 and* Figure 10.20 for the modelled layout).
	MSS via MS-LOT	Installation methodologies for the entire infrastructure, including the inter-array cabling and the scour protection, must be detailed to allow assessment of associated impacts.	A number of potential installation methodologies for the Project are outlined in the Design Envelope described in *Chapter 7 : Description of Development*. The parameters that were identified as creating the worst case scenarios in terms of impacts to metocean and coastal processes were selected from the Design Envelope and have been summarised in *Section 10.1.3*. These parameters have been applied in this assessment.
	MSS via MS-LOT	Details of the baseline wind data sources requested.	Long term measured and modelled wind data were obtained from the UK Meteorological Office for use in the metocean and coastal processes assessment (see *Section 10.2.1*).

Document	Consultee	Comment	Project Response
	MSS via MS-LOT	Within the "Suspended Sediment" section [of the method statement], more detail and references were requested to support the statement regarding the likely seasonal nature of SSC levels.	SSC levels are likely to be higher in winter due to the more energetic wave regime and increased bed disturbance. SSC under winter conditions was estimated using the well-known approach based on Soulsby (1995), and using wave, current and seabed sediment samples collected in support of the Project (see *Section 10.2.1*; *Appendix 10A, Annex 10A.1 Section 10A.1.7*, and *Appendix 10F Section 8*).
Methodology Statement	MSS via MS-LOT	Identification of sensitive receptors queried.	*Section 10.2.5* identifies the processes and receptors that are considered within the assessment. Note that this chapter generally examines changes to physical processes whilst other chapters consider the impacts that those changes may have on other receptors (e.g. benthic ecology). The specific chapters and sections, which detail the receptors which are indirectly impacted by changes in metocean and coastal processes, are summarised in the introduction above.
		More detail requested on the reasoning behind the measurements taken during the surveys.	Additional detail was provided in a response to MSS and MS (see *Appendix 10E*). The targeted survey campaigns obtained sufficient information to enable construction, calibration and validation of the metocean numerical modelling system, parameterisation of the baseline, and inputs for the metocean and coastal processes assessment (see *Section 10.2.1*). The Data Gap Analysis and Data Review in *Appendix 10B* provides detail on assessment of the survey measurements' adequacy in context with the impact assessment requirements (*Appendix 10B, Section 3*).

Document	Consultee	Comment	Project Response
		Assessment methods for sediment regime queried, especially with respect to sandbank stability and bed forms.	The study has fully considered the potential impact of the development on different aspects of the sediment regime. This includes changes to: • sediment transport pathways, sources and sinks; • bed forms and features (including sandbanks and sandbank stability); • erosion; • deposition; • suspended load and SSC; and • bed load.
		Definitions of cumulative and in-combination requested.	This has been addressed, and is clarified in *Section 10.7* and *Chapter 4: Process and Methodology*, *Section 4.7*.

10.1.2 Policy and Plans

10 The *UK Marine Policy Statement* (HM Government, 2011) and *Scotland's National Marine Plan – Pre-consultation Draft* (The Scottish Government, 2011) outline the objectives and issues associated with offshore wind farm developments (amongst other marine related issues). These policies note that offshore wind farm foundation designs are likely to have an effect on hydrodynamics and consequent sediment movement. This includes potential scouring of sediments around the substructures of Wind Turbine Generators (WTGs).

11 *The Marine Renewable Energy and the Natural Heritage: An Overview and Policy Statement* (Scottish Natural Heritage, 2008) also provides high level guidance on the potential issues and appropriate mitigation measures for a range of developments, including offshore wind farms. With regard to metocean and coastal processes, it suggests that the Wind Farm and OfTW in the Development Area operational phase may attenuate waves and tides, and that these effects should be understood by undertaking modelling-based assessments at the design stage. This chapter describes the modelling-based assessments that have been undertaken.

10.1.3 Design Envelope and Embedded Mitigation

12 The potential development parameters and scenarios are defined as a Design Envelope and presented in *Chapter 7: Description of Development*. The assessment of potential impacts on metocean and coastal processes is based upon the worst case scenario as identified from this Design Envelope, and is specific to the potential impacts assessed in this chapter.

13 Key parameters for the worst case scenario for each potential impact are detailed in Tables 10.2 and 10.3 and *Appendix 10A, Sections 10A.1.2.1 and 10A.4.7*. For this assessment these include consideration of the design, construction and operation of: WTGs, meteorological masts (met masts), foundation and substructures, Offshore Substation Platforms (OSPs), inter-array cables and export cables.

14 For the WTGs, OSPs and met masts, Gravity Base Structures (GBS) represent a worse case than jacket foundations for:

- Impacts on water levels, currents and waves, and thus on the wider sediment transport regime. This is because GBS offer the greatest total blocking effect to the passage of currents and waves (i.e. they have the greatest cross-sectional area within the water column).
- Pre-installation dredging, and consequent impacts on SSC and seabed features. This is because the dredged sediment volumes are significantly larger than would be produced by drilling for jacket foundations.
- Jackets represent a worse case for sediment scour and associated impacts, since scour protection will be built into any GBS foundation concept.
- For cable installation (both Offshore Export Cables and inter-array cables) a variety of cable installation methodologies are considered. For the purposes of this assessment it is assumed that the entire trench volume is suspended. This is a conservative assumption which provides a consideration of all potential cable installation methodologies. For the purposes of this assessment any installation methodology, which results in suspension of the entire trench volume, is known as installation by energetic means.

Table 10.2: Worst Case Scenario Definition – Development Area

Potential Impact	Design Envelope Scenario Assessed
Construction (and Decommissioning)	
Modification to water levels due to the presence of construction vessels.	Specific parameter are not explicitly included in the Design Envelope scenario for impacts resulting from construction vessels as conclusions are taken from the existing evidence base
Modification to currents due to the presence of installation vessels.	As per the modification to water levels due to the presence of construction vessels.
Modification to waves due to the presence of installation vessels.	As per the modification to water levels due to the presence of construction vessels.

<table>
<tr><th>Potential Impact</th><th>Design Envelope Scenario Assessed</th></tr>
<tr><td>Increase in SSC due to dredging prior to GBS installation.</td><td>Release of sediment due to foundation dredging prior to GBS installation have been modelled using the following parameters:
Maximum volume of dredged material per WTG = 28,503 m³, as per the Design Envelope for 65 m diameter GBS (based on an inverted truncated conical pit with depth five metres, top (sea bed surface) diameter 95 m, and base diameter 75 m).
Maximum volume of dredge material per OSP = 114,012 m³ as OSPs have been modelled as four tightly spaced WTGs.
Number of structures assessed = 213 WTGs, five OSPs and three met masts. These were considered for scenarios based on both the minimum spacing of structures (to investigate overlap of impacts) and the maximum coverage of the Development Area (to investigate the greatest area of impact).
This scenario also covers the potential impacts of drilling for jacket foundations, which would produce significantly smaller sediment volumes than GBS dredging.

It should also be noted that the modelled scenario considers both impacts from single GBS locations and the macro effect across the Development Area. For this assessment the worst case estimate of dredged material has been used for the model. In reality, it is unlikely that the largest excavations will be necessary across the entire Development Area and therefore the results should be considered as conservative at a macro level. (Appendix 10A, Section 10A.1.2.1 and 10A.4.7)</td></tr>
<tr><td>Increase in SSC due to scour pit formation around jacket foundation structures.</td><td>Release of sediment due to scour around jacket structures:
WTG/OSP/met mast jacket leg diameter = three metres.
Jacket leg spacing for WTG/OSP/met mast = 20 m, 30 m, 40 m and 60 m (a range was tested for sensitivity).
Number of structures assessed = 213 WTGs, five OSPs, three met masts. These were considered for scenarios based on both the minimum spacing of structures (to investigate overlap of impacts) and the maximum coverage of the Development Area (to investigate the greatest area of impact).</td></tr>
</table>

Potential Impact	Design Envelope Scenario Assessed
Increase in SSC due to inter-array cable burial.	As per the modelled scenario for the Offshore Export Cable Corridor (see Table 10.3). The modelling location closest to the Development Area was considered as representative of the Development Area due to the homogeneity in sediment at this location and across the Development Area. The installation methodology is by energetic means.
Modification to seabed features due to deposition of sediment from GBS dredging.	Deposition of suspended sediment as per "Increase in SSC due to dredging prior to GBS installation" (above).
Modification to seabed features due to deposition of sediment from jacket scour.	Deposition of suspended sediment as per "Increase in SSC due to scour pit formation around jacket foundation structures" (above).
Modification to seabed features due to deposition of sediment from inter-array cable burial.	Deposition of suspended sediment as per "Increase in SSC due to inter-array cable burial" (above).
Modification to seabed features due to impacts from jack-up vessels.	Impacts resulting from jack-up vessels are taken from the existing evidence base.
Operation	
Modification to water levels due to the presence of maintenance vessels.	Impacts resulting from maintenance vessels are taken from the existing evidence base.
Modification to currents due to the presence of maintenance vessels.	As per the modification to water levels due to the presence of maintenance vessels.
Modification to waves due to the presence of maintenance vessels.	As per the modification to water levels due to the presence of maintenance vessels.

Potential Impact	Design Envelope Scenario Assessed
Modification to water levels due to the presence (blocking effect) of subsurface structures.	In order to represent the impact of the WTG, OSP and met mast substructures a scenario was chosen to represent both the spread of infrastructure across the entire Development Area to consider local impacts, and the total Project blocking area to consider macro impacts. The modification of hydrodynamics due to the presence of GBS is represented by: • Number of WTGs modelled = 328. This is a deliberately conservative number of WTGs that represents complete the maximum coverage of the Development Area at the minimum proposed spacing of WTGs and therefore allows assessment across the entire Development Area. • In order to ensure that the conclusions are not unrealistically conservative a GBS diameter of 50 m has been used. When combined with the modelled number of substructures, the total blocking area exceeds that of the large Design Envelope GBS diameter (65 m) combined with the smaller Design Envelope maximum number of WTGs (213) plus OSPs and met masts. • These scenarios combined ensure that a representative local and macro worst case is represented.
Modification to currents due to the presence (blocking effect) of subsurface structures.	As per the modification to water levels due to the presence of subsurface structures.
Modification to waves due to the presence (blocking effect) of subsurface structures.	As per the modification to water levels due to the presence of subsurface structures.
Modification to seabed features and the far-field sediment transport regime due to the presence of subsurface structures and the effects of these on the hydrodynamic and wave regimes.	As per the modification to water levels due to the presence of subsurface structures.
Increase in SSC due to inter-array cable re-burial.	As per the equivalent scenario for the construction phase.
Modification to seabed features due to deposition of sediment from inter-array cable re-burial.	As per the equivalent scenario for the construction phase.

Table 10.3: Worst Case Scenario Definition – Offshore Export Cable Corridor

Type of Effect	Scenario Assessed
Construction (and Decommissioning)	
Modification to water levels due to the presence of installation vessels.	Specific parameter are not explicitly included in the Design Envelope scenario for impacts resulting from construction vessels as conclusions are taken from the existing evidence base
Modification to currents due to the presence of installation vessels.	As per the modification to water levels due to the presence of installation vessels.
Modification to waves due to the presence of installation vessels.	As per the modification to water levels due to the presence of installation vessels.
Increase in SSC due to Offshore Export Cable burial.	Release of sediment during cable burial: • Trench depth = two metres. The range of cable burial depths is zero to three metres, with protection where burial is not feasible; the target depth is one metre. Two metres was chosen as being sufficiently conservative to represent the macro impacts of SSC from burial across the Offshore Export Cable Corridor. • Trench width = one metre. Three indicative lengths of cable were assessed, to cover the range of sediments found across both the Offshore Export Cable and inter-array cables. These were each five kilometre lengths – one near the shore end of the Offshore Export Cable, one near the mid-point, and one near the Development Area, as seen in Figure 10.19. • Installation of the Offshore Export Cable is by energetic means. • The rate of cable burial depends on a number of factors, such as the vessel used, the water depth, the technique employed and the sediment type. The Design Envelope details the cable lay rate which will be between 300 – 500 m/hr. For the purposes of assessment the average burial rate of 400 m/hr per hour was used. In practice the scale of the other assumptions that would affect the resulting impacts, such as the volume of the discharged material, far exceeds the very small potential variation that might result if a different lay rate was modelled. As such this is considered an appropriate parameter to represent a worse case.

Type of Effect	Scenario Assessed
Modification to seabed features due to deposition of sediment from Offshore Export Cable burial.	Deposition of suspended sediment as per "Increase in SSC due to Offshore Export Cable burial" (above).
Operation	
Modification to water levels due to the presence of maintenance vessels.	Impacts resulting from maintenance vessels are taken from existing evidence base.
Modification to currents due to the presence of maintenance vessels.	As per the modification to water levels due to the presence of maintenance vessels.
Modification to waves due to the presence of maintenance vessels.	As per the modification to water levels due to the presence of maintenance vessels.
Modification to water levels, currents and waves due to the presence (blocking effect) of subsurface structures.	No effect assessed: the Offshore Export Cable will offer either no, or minimal blocking, of currents and waves.
Increase in SSC due to Offshore Export Cable re-burial.	As per the equivalent scenario for the construction phase.
Modification to seabed features due to deposition of sediment from Offshore Export Cable re-burial.	As per the equivalent scenario for the construction phase.

15 A range of Embedded Mitigation measures to minimise environmental effects are captured within the Design Envelope (see *Section 4.5.2*). The assessment of effects on metocean and coastal processes has taken account of the following Embedded Mitigation measures:

- A study will be carried out to predict the effects of secondary scour from cable protection and to inform design with the intention of reducing secondary scour. Scour protection will be built into any GBS concepts (if these are employed).
- If the GBS foundation option is chosen, sediment dredged during preparation work for installation will be reused within the works where practicable. This will manage the deposition of sediment across the Development Area.
- Cables will be suitably buried or will be protected by other means when burial is not practicable.

16 These measures would be delivered as part of the Project (see *Appendix 7A: Draft Environmental Management Plan, Section 7A.5*).

10.2 Baseline Environment

10.2.1 Data Sources

17 The main metocean and coastal processes and parameters that are relevant to this assessment include:

- Water level;
- Tidal currents;
- Wave heights;
- SSC; and
- Sediment transport regime.

18 In order to provide a robust description of the baseline and define these parameters, an extensive review of available data was undertaken, including a gap analysis to identify any additional information that would be required for the metocean and coastal processes assessment. Full details of this data review and gap analysis are provided in *Appendix 10B*. Two main sources of data were utilised:

- Data collected on behalf of the Project, through dedicated metocean, geophysical, geotechnical and ecological survey campaigns; and
- Other data sources, such as supporting information on the Project and third party data sets.

19 The key contributing data types that are relevant to the metocean and coastal processes assessment are as follows:

- Wave data – Statistical details on average and extreme wave heights, periods, directionality and other relevant parameters. Data were collected through the deployment of moored wave buoys or seabed mounted Acoustic Wave and Current (AWAC) meters deployed in or around the Development Area. Additionally, longer term third party data sets were obtained from hindcast models, which are validated against measured data sets.
- Tidal data – Statistical details on tidal heights, current speeds and other relevant parameters. Data were collected through the deployment of Acoustic Doppler Current Profilers (ADCPs) or AWACs. Longer term and independent data sets (both measured and modelled) were obtained from third parties.
- Bathymetric data – Water depth and seabed profile mapping collected through geophysical survey which uses acoustic measurements to provide a high resolution map of the seabed.
- Sediment and suspended sediment data – Data on the seabed, material characteristics collected through grabbing seabed sediment samples and deploying sediment traps. In order to give spatial context across the Development Area and Offshore Export Cable Corridor and at depths beyond the seabed surface, analysis of this data is carried out in

conjunction with geophysical and geotechnical data to provide maps of sediment characteristics.

20 These sources and types of data are outlined in Table 10.4 and Table 10.5.

21 Figure 10.1 (metocean) and Figure 10.2 (geophysical and geotechnical) show the location of surveys undertaken for the Project in support of the metocean and coastal processes assessment. Full details of the relevant surveys undertaken for the Project are provided in the referenced survey reports. *Appendix 10A, Annex 10A.1* provides details of the baseline conditions, and has been based in part on these surveys.

Table 10.4: Data Collected on Behalf of the Project

Data Source	Study/Data Name	Survey Overview
ICOL / Neart Na Gaoithe (collected by Partrac)	Metocean survey (Partrac, 2010)	Metocean data in and around the Development Area: • Four ADCP moorings situated across the FTOWDG area with one in the Development Area; seven months of data from December 2009 to July 2010; both elevations and current velocity profiles measured; • Four moored wave buoys situated across the FTOWDG area with one in the Development Area; seven months of data from December 2009 to July 2010; wave heights, periods and directions measured; • One meteorological buoy moored at Neart na Gaoithe; seven months of data from December 2009 to July 2010; wind velocity and other meteorological parameters measured; • One AWAC meter deployed at Neart na Gaoithe for two months from May 2010, to measure near-bed currents, turbulence and Total Suspended Solids (inferred from optical backscatter); • Limited suspended sediment concentration data at Neart na Gaoithe collected on 12 July 2010 (six samples at each of three depths in the water column); and • A Particle Size Distribution (PSD) obtained from a sediment trap deployed at Neart na Gaoithe during the main metocean survey.

Data Source	Study/Data Name	Survey Overview
ICOL (collected by iXSurvey)	Geophysical surveys (Development Area – IXSurvey, 2011 and Offshore Export Cable Corridor – Osiris Projects, 2012a, 2012b)	Geophysical surveys covering the entire Development Area and Offshore Export Cable Corridor, to provide information on seabed bathymetry, seabed features, and sediment distribution: • Multi Beam Echo Sounder (provided two metres resolution bathymetry data); • Single Beam Echo Sounder; • Side Scan Sonar; and • Sub-Bottom Profiler.
ICOL (collected by Fugro)	Geotechnical survey (Fugro, 2011, 2012)	Geotechnical surveys within the Development Area, to provide details of the vertical sediment profile: • Three boreholes drilled in September 2011 near the proposed met mast location; and • Nine additional boreholes drilled in February/March 2012 to give wider spatial coverage of the Development Area.
ICOL (collected by AMEC)	Benthic surveys (see *Appendix 12A: Benthic Ecology Baseline Development Area*)	Benthic surveys within the Development Area, which included: • 113 grab samples of surface sediment (59 within the Development Area), collected between March and May 2012, which were analysed to obtain PSD information; and • Limited Suspended Sediment Concentration data collected in the Development Area in May 2012 (14 samples at various locations and depths in the water column).
ICOL (collected by EMU Ltd)	Benthic surveys (see *Appendix 12C: Benthic Ecology Baseline Offshore Export Cable Corridor*)	Benthic surveys within the Offshore Export Cable Corridor, which included: • Six grab samples of surface sediment along the proposed cable corridor, collected in July 2012, which were analysed to obtain PSD information.

Table 10.5: Other Data Sources used in the Assessment

Data Source	Study/Data Name	Data Theme(s)	Data Location
ICOL / Mainstream	Scoping Studies	Environmental baseline	Development Area
HR Wallingford reports	Review of existing information (HR Wallingford, 2010) Various background reports (engineering and survey design)	Water quality (turbidity); environmental baseline	East coast of Scotland/At Development Area

Data Source	Study/Data Name	Data Theme(s)	Data Location
ICOL	Inch Cape Design Envelope	Project design parameters	Development Area and Offshore Export Cable Corridor
Mainstream	Neart na Gaoithe Design Envelope	Project design parameters	Neart na Gaoithe site
Seagreen	Scoping Report (Seagreen Wind Energy, 2011)	Project design parameters	Firth of Forth site
Intertek METOC (for ICOL)	The Forth and Tay Modelling System (FTMS, developed specifically for this assessment)	Metocean (hydrodynamics and waves); sediments	Regional Study Area, Development Area, Offshore Export Cable Corridor
Joint Nature Conservation Committee (JNCC)	UK SeaMap 2010 (McBreen *et al*., 2011)	Seabed habitats/ landscapes	East coast of Scotland
Scottish Natural Heritage	Coastal Cells in Scotland: Cell 1, St Abb's Head to Fife Ness; Cell 2, Fife Ness to Cairnbulg Point (Ramsay and Brampton, 2000a, 2000b)	Shoreline processes	East coast of Scotland
British Geological Survey (BGS)	Tay and Forth: Seabed Sediments (BGS, 1986a), Solid Geology (BGS, 1986b), Quaternary Geology (BGS, 1987) General geology and sediment maps: Holmes (1977); Holmes *et al*. (1993); Holmes *et al*.(2004); Pantin (1991); Gatliff *et al*. (1994) BGS online core and surface grab sample archives	Geology, sedimentology, sediment features, sediment thickness and sediment transport	Tay and Forth
UK Hydrographic Office (UKHO)	Various contemporary charts (Admiralty Charts 175 and 190); Tide Tables; Co-tidal Charts	Bathymetry, tidal streams, water levels	East coast of Scotland
C-MAP	Electronic chart database (C-MAP, 2007)	Bathymetry	East coast of Scotland
British Oceanographic Data Centre and Proudman Oceanographic Laboratory	Data inventories and data holdings	Current measurements Wave measurements Surge data	Various port and offshore sites
Scottish Environment Protection Agency	River inflows	Freshwater/ sediment inputs	Major rivers

Data Source	Study/Data Name	Data Theme(s)	Data Location
Centre for Environment, Fisheries, and Aquaculture Science (Cefas)	WaveNet data inventory and data holding (Cefas, 2011)	Wave measurements	Firth of Forth
UK Met Office	Data summary	Meteorological data	Eastern Scotland
Coastal Councils	Shoreline Management Plans	Shoreline processes, coastal processes	Tayside; Fife; East Lothian; Angus
Department of Trade and Industry (DTI); Department for Business, Enterprise and Regulatory Reform	Strategic Environmental Assessment (SEA) 3; SEA5; 2007 Atlas of Renewable Energy	Regional geomarine assessment; synoptic oceanographic parameters	Regional
Department of Energy and Climate Change (DECC)	UK Offshore Energy SEA (DECC, 2009)	Regional geomarine assessment	Regional
Scottish Executive (report by Faber Maunsell and Metoc)	Scottish Marine Renewables SEA (Scottish Executive, 2007)	Regional geomarine assessment	Regional
The Tay Estuary Forum	The Tay Estuary Coastal References Database (covering literature, reports and academic dissertations/theses)	Geology; sedimentology; fluvial flows	Tay and Forth

Figure 10.1: Metocean Surveys Undertaken to Support the Project

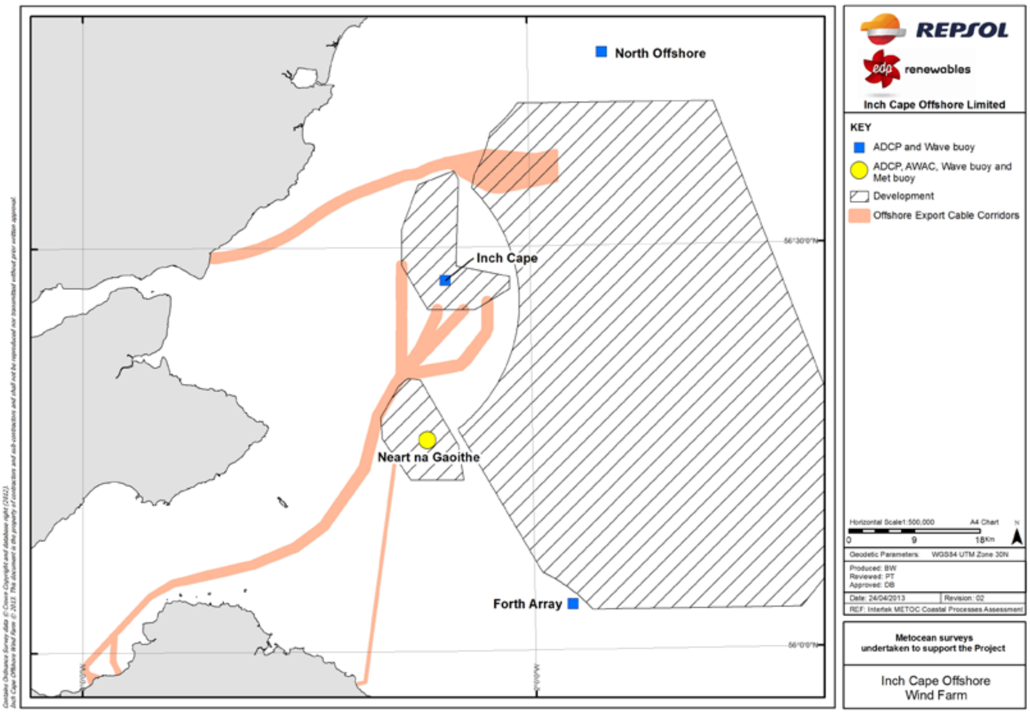
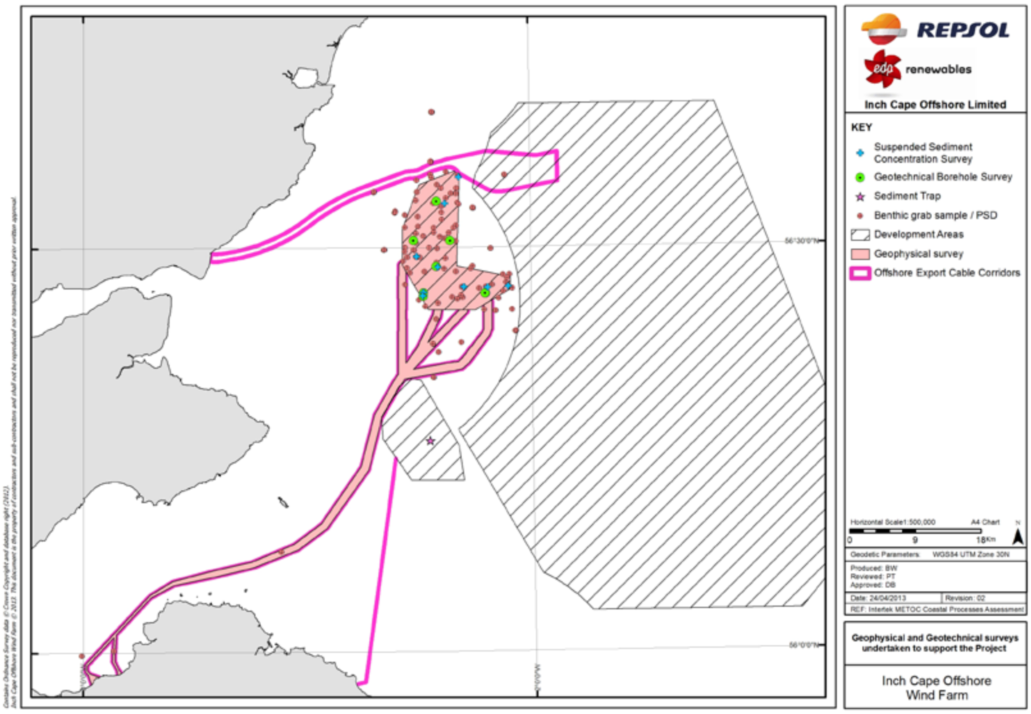


Figure 10.2: Geophysical, Geotechnical and Other Environmental Surveys Undertaken to Support the Project



10.2.2 Baseline – Regional Study Area

22 To reflect the fact that the assessment considers effects upon metocean and coastal processes in the near- and far-fields, the Regional Study Area captures both the local environment (i.e. the Development Area and Offshore Export Cable Corridor) and the wider regional environment (i.e. the marine offshore areas around the proposed Neart na Gaoithe and Firth of Forth projects, coastal waters, and the east Scottish coastline). The near-field encompasses just the Development Area and the Offshore Export Cable Corridor, while the far-field describes all other locations, including the Scottish coastal zone.

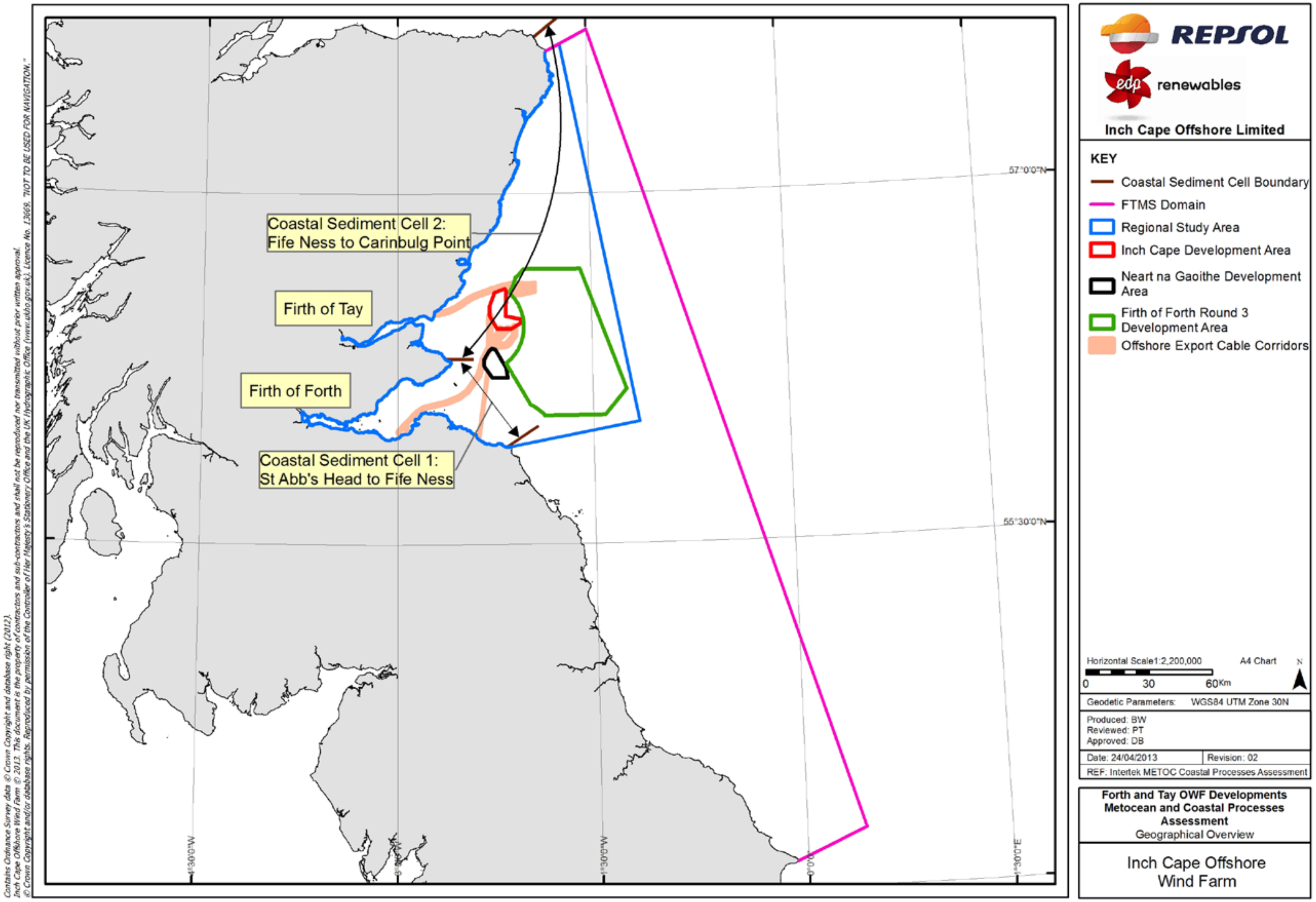
23 The northerly and southerly extents of the Regional Study Area are defined by coastal sediment cell boundaries (Ramsay and Brampton, 2000a and 2000b). The study area also encompasses the upper reaches of the Firths of Forth and Tay, and extends far enough offshore to encompass the Development Area and Offshore Export Cable Corridor and the Neart na Gaoithe and Firth of Forth projects. The Regional Study Area is shown in Figure 10.3.

24 The domain of the numerical model, the Forth and Tay Modelling System (FTMS), extends beyond the limits of the Regional Study Area – extending further offshore, and further south along the English coast. This ensures that all far-field processes will be fully captured within the model domain. The FTMS domain is shown in Figure 10.3, in relation to the Regional Study Area.

25 The FTMS was developed specifically to undertake the metocean and coastal processes assessments for the Wind Farm and OfTW and the Neart na Gaoithe wind farms. It was constructed and validated using metocean survey data collected on behalf of the Project (Table 10.4), which were supplemented by third party data (Table 10.5). The main components of the FTMS are: a hydrodynamic model to replicate water levels and tidal currents; a wave model to replicate wave propagation; and a sediment model to replicate the transport and deposition of disturbed or released sediment. Further details of the FTMS are provided in *Section 10.4.2*.

26 The existing physical environment within the Regional Study Area has been described using a range of field data, existing literature and model outputs informed by a survey campaign. The baseline metocean and sediment regimes on a regional basis are described in full in *Appendix 10F, Sections 7 and 8*.

Figure 10.3: Geographical Overview of the Regional Study Area and FTMS Domain



10.2.3 Baseline – Development Area

27 In addition to the regional description of baseline conditions, a more detailed analysis of the Development Area has been undertaken. This analysis uses the site-specific data obtained during the surveys described in Table 10.4. This analysis considered bathymetry and seabed sediments, physical oceanographic processes (tides, and waves during both average and storm events), and the sediment (suspended and bedload) transport regime. The full details of this analysis are provided in *Appendix 10A, Annex 10A.1*; the following provides a summary.

Water Levels and Currents

28 Water depths within the Development Area (encompassing about 150 km^2) range between 35.5 m and 63.3 m Chart Datum (CD), with a mean water depth of 49.3 m CD. The mean spring tide range is approximately 4.6 m.

29 The tidal currents are strongly rectilinear in form with a principle tidal axis orientated north to north north-east and south south-west. The peak spring tidal currents are normally within 0.6 m/s – 0.7 m/s. Corresponding peak neap current speeds are approximately 0.3 m/s – 0.4 m/s. The peak total current speed recorded during the metocean survey during a storm event reached approximately 1.05 m/s.

Wave Regime

30 The Development Area receives waves most frequently from a north north-easterly direction (22.5 degrees); mean wave periods range between two and nine seconds; and significant wave heights up to 6.2 m were recorded by *in situ* instrumentation. Waves also arrive from both the south-eastern and south-western quadrants but these form only a minor component of the wave direction spectrum. Wave breaking rarely occurs at the Development Area; only under extreme marine conditions.

Sediment Regime

31 The seabed forms a broad oval plain with a shallower region in the centre of the Development Area and deeper regions in pockets across the area, especially in the south-eastern region. The seabed is characterised by two main geomorphological features which are sandbank areas, one in the northwest and a shallower bank in the centre of the Development Area. There are no other major features. These sandbank areas have a relief of approximately 12 m – 17 m above the surrounding seabed. Across the Development Area there is an almost complete absence of bedform features. Megaripples are faintly discernible on open plain areas and are often associated with shallower, gravel-rich areas. This suggests the Development Area is not highly dynamic.

32 Surficial sediments form a relatively thin veneer (0 m – 0.5 m thick) and are characterised dominantly by medium sand (distributed across the Development Area, including in deeper areas), with generally a minor mud fraction and a variable gravel component. Where gravel is present in minor amounts it is generally ‘very fine’ to ‘fine’ (two to eight millimetres), whereas in areas of richer gravel deposits particle sizes can range up to approximately 20 mm - 30 mm, or even greater

in isolated pockets. The vertical profile of Quaternary sediments comprises contemporary sands/gravels, over inter-bedded sand and silt overlying stiff, hard (boulder) clay.

33 The ambient tidal current regime is not sufficiently powerful to generate significant sediment transport on either the spring or neap tidal phases. Fine and medium sand are transported by the tidal currents but only during spring tides and only during higher current speeds in the tidal cycle. Therefore, the Development Area is classified as 'slightly mobile' during the summer months.

34 The Development Area can be classified as 'moderately mobile' during the winter months, when sands are mobile for 15 - 20 per cent of the time within any year. Storm conditions with waves in excess of 5.5 m significant wave height, and a mean wave period of > 8 s – 8.5 s are predicted to mobilise sediments across the Development Area, and such conditions have a return period of > 1 in 10 years.

35 Fair-weather SSC are very low (< 15 mg/l). This is nominally due to tidal re-suspension only, and does not include any storm events. No SSC measurements were obtained during winter storm conditions, but using the largest winter wave measured, coincident with the storm surge peak spring tide, the peak winter SSC has been estimated to be 81 mg/l (using the method of Soulsby, 1995). A net directional suspended sediment transport in the direction of the flood tidal axis (south – south south-west) exists, but residual tidal transport of suspended fine sediments is not judged to be significant on an annual basis.

36 Tidal excursion during spring tides has the potential to transport very low settling velocity material up to 7.2 km (north) and 8.7 km (south). However, the dominant sediment types in the Development Area – medium and fine sand – will settle out over much shorter distances, typically up to about 500 m. The larger gravel fractions will settle out almost immediately should they ever be disturbed, travelling no more than a few tens of metres.

37 Fluvial inputs of freshwater from the Rivers Forth, Tay and Eden are small in relation to the tidal (marine) volume. Concentrations of suspended sediment in fluvial discharges are low and therefore input of fluvial sediments is minor.

10.2.4 Baseline – Offshore Export Cable Corridor

38 A summary of baseline conditions along the Offshore Export Cable Corridor is provided below. This baseline description is based on data sources described in Table 10.4 and Table 10.5, specifically including:

- Water level, tidal current and wave data collected during the metocean survey, obtained from third party sources, and modelled within the FTMS;
- Seabed sediment information obtained from the geophysical surveys and from third party sources; and
- SSC collected during the metocean survey, obtained from third party sources, and calculated using standard techniques based on knowledge of metocean and seabed sediment conditions.

Water Levels and Currents

39 There is little spatial variation in hydrodynamic conditions throughout the region, and tidal range and tidal currents are fairly uniform along the Offshore Export Cable Corridor. Similar hydrodynamic conditions (water levels and currents) as described for the Development Area will be experienced along the Offshore Export Cable Corridor, other than as the corridor approaches landfall, where the water depth will be reduced (see Figure 10.4). Current directions in the near-coast region will tend to align parallel with the coastline.

Wave Regime

40 As the Offshore Export Cable Corridor approaches the landfall and enters the Firth of Forth, wave period decreases and wave height diminishes (see Figure 10.5). Close in to the Landfall, the Offshore Export Cable Corridor will be sheltered from most key directions of wave propagation, and wave heights here (both average and extreme) will be lower than in the Development Area. As the water depth shallows towards Landfall, wave breaking will become much more common than offshore, since it will occur at much smaller wave heights. Wave direction will also be modified through refraction in shallow water.

Sediment Regime

41 The main sediment type along the Offshore Export Cable Corridor is muddy sand, although there is some variability depending on location. Close to the Development Area, sand is the dominant fraction. Throughout the middle of the corridor, finer fractions such as silt and mud dominate, although there is still a sizeable sand component. The Firth of Forth is largely filled with Quaternary sediments where sands and muds dominate. Gravel is found throughout the corridor but in generally small quantities.

42 In the deeper, offshore parts of the Offshore Export Cable Corridor, sediment mobility and SSC will follow a pattern very similar to that described previously for the Development Area. In shallower coastal waters, wave interaction with the sea floor will be much more common, to the extent that sediment movement due to wave action may be common (e.g. in the surf zone), particularly where the surficial sediments are unconsolidated. SSC will consequently rise, although these might be strongly linked to the prevailing waves and tidal currents, and any bedforms that exist in these regions are likely to be dynamically mobile rather than stable and long-lived.

43 Concentrations of suspended sediment in fluvial discharges are low, and even in the Firth of Forth it is considered that the influence of fluvial sediments is not substantial to the Wind Farm or OfTW.

Figure 10.4: Regional Water Level (m) and Current Velocity Field (m/s) for a Mean Spring Tide across the Outer Firths Area from the FTMS

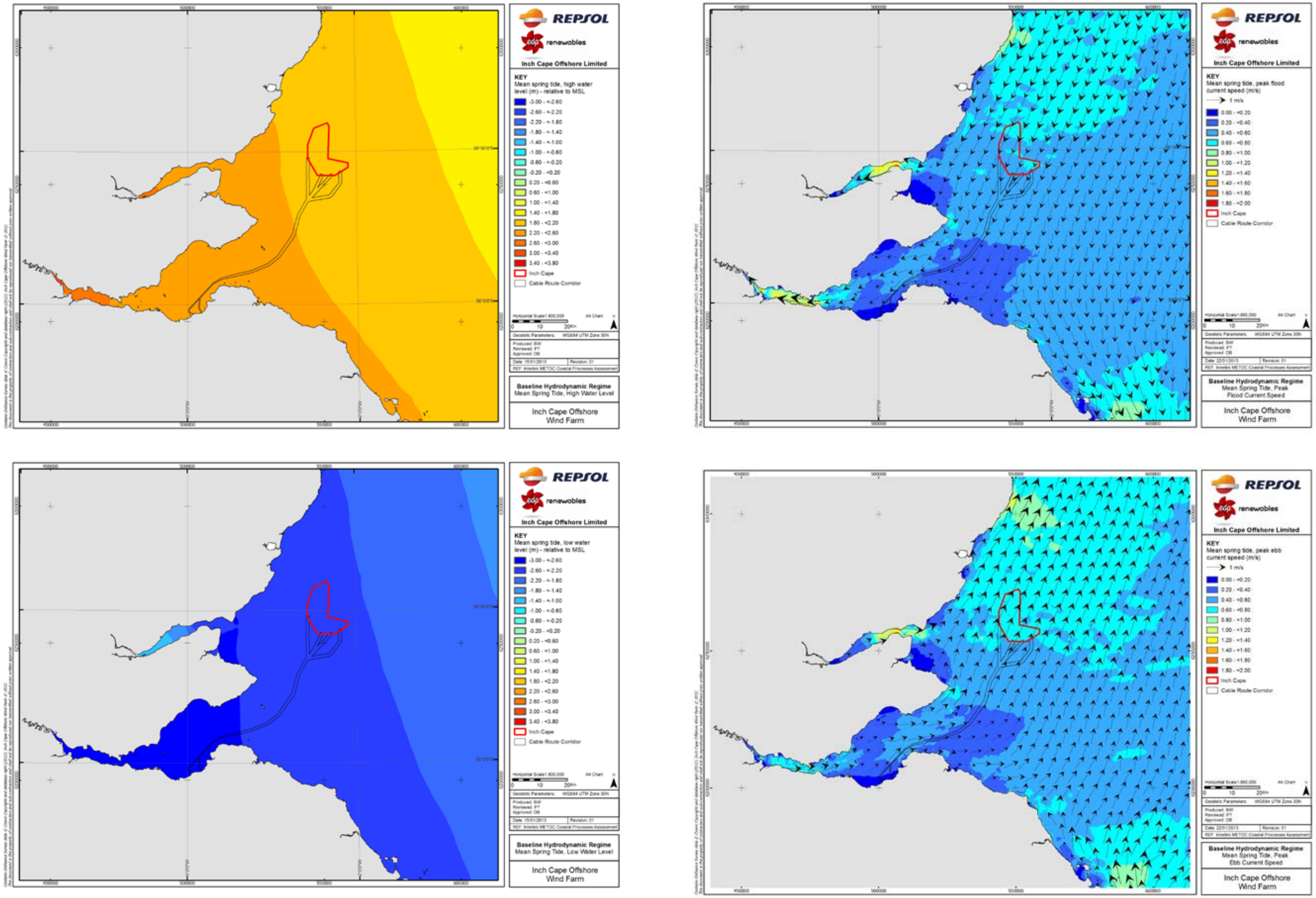
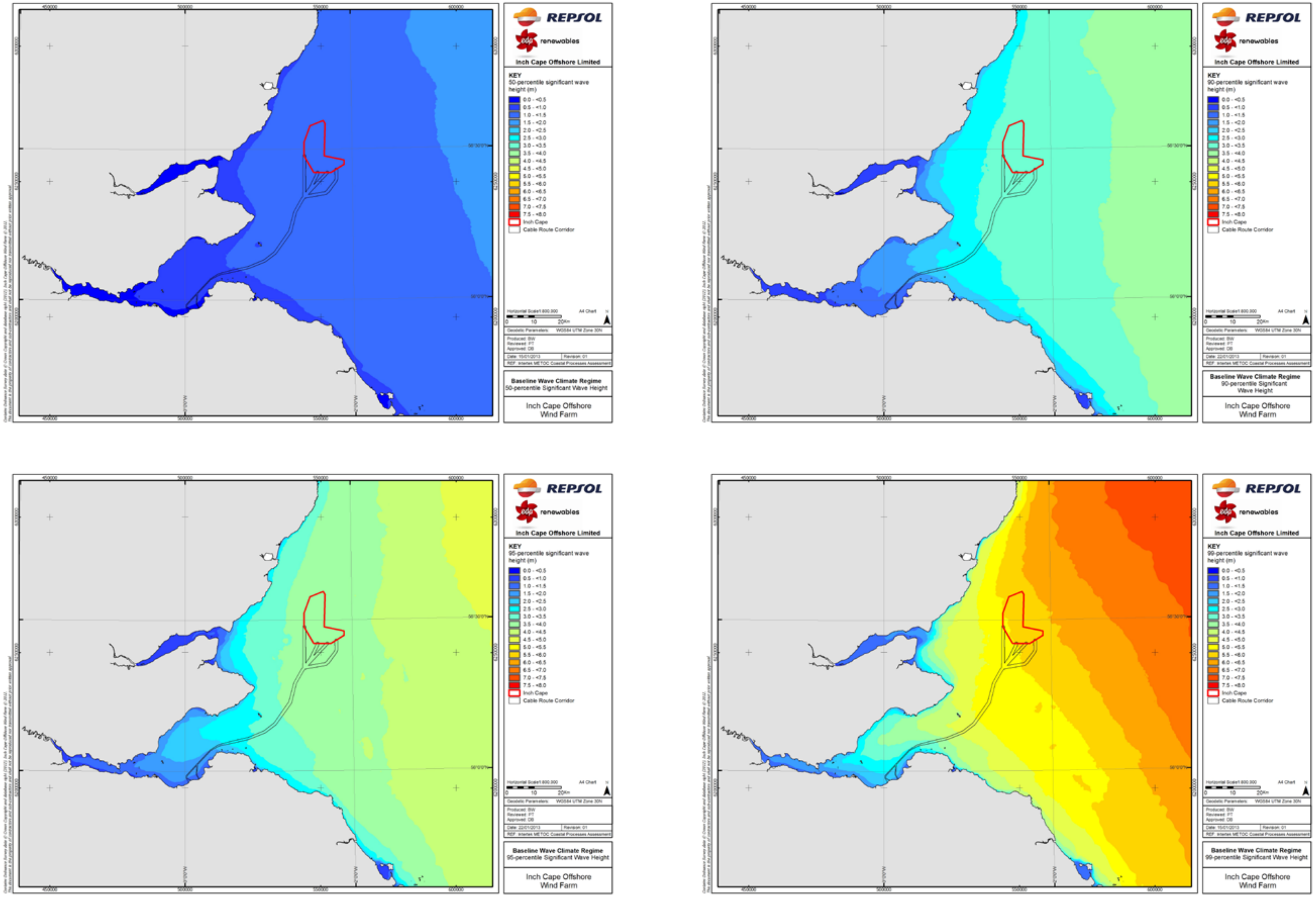


Figure 10.5: Regional Significant Wave Height (m) across the Outer Firths area from the FTMS



10.2.5 Consideration of Key Receptors

48 Changes to metocean and coastal processes due to the Project may have indirect impacts on many different receptors. These are discussed in the following relevant chapters:

- *Chapter 12: Benthic Ecology;*
- *Chapter 13: Natural Fish and Shellfish;*
- *Chapter 14: Marine Mammals;*
- *Chapter 15: Ornithology;*
- *Chapter 17: Cultural Heritage and Marine Archaeology;*
- *Chapter 18: Commercial Fisheries;*
- *Chapter 19: Shipping and Navigation; and*
- *Chapter 21: Other Human Activities*.

49 However, some key receptors may be directly impacted by changes to the metocean and sediment regimes. These are outlined below. With these noted exceptions, the metocean and sediment regimes are considered to be processes, rather than receptors in their own right. This chapter therefore quantifies the predicted changes to these processes (for example, in terms of current velocity and SSC), but does not apply EIA significance criteria to them. This approach is in line with COWRIE (Collaborative Offshore Wind Research into the Environment) guidelines (Lambkin *et al*., 2009). *Section 10.3* provides detail on the assessment methodology.

Seabed Features

50 Seabed features such as sandbanks are considered to be a receptor since they may be directly affected by a change in the sediment regime. A small number of seabed features have been identified throughout the Development Area, as noted in the metocean and coastal processes baseline description (*Section 10.2.2*). These seabed features are assessed in terms of all physical (i.e. metocean or sediment) processes that might cause a substantive change to their form or stability.

Designated Nature Conservation Sites

51 *Chapter 9: Designated Nature Conservation Sites* provides a full description of conservation designations that have been considered in this ES. Selected sites have been considered within the metocean and coastal processes assessment (see below, and Table 10.6) and quantified changes have been considered at their locations.

52 For the purposes of this chapter there are considered to be two types of designated nature conservation sites:

- designated sites which have geological interest features which may be directly impacted by any changes to metocean and costal processes; and

- designated sites whose interest features are not geological. Therefore, any changes to the metocean and sediment regimes have the potential to indirectly impact the qualifying conservation interest.

53 Only designated sites which have geological interest features are assessed within this chapter. All other designated sites have been considered and the potential changes have been quantified. In addition, this information is used to inform the assessment of impacts in the relevant receptor chapters, as listed above.

54 Table 10.6 lists the designated nature conservation sites that have been considered for the metocean and coastal processes chapter. Note that some of these designations are spatially coincident. Where designated sites that have specific geological interest features are identified; a distinction is made between geological features that are potentially relatively responsive to changes in the sediment regime (such as salt marshes, sand banks and mud flats) and those which are relatively resistant to changes in the sediment regime (such as reefs and maritime cliffs). These are referred to as low tolerance and high tolerance features, respectively.

Table 10.6: Summary of Designated Sites Considered as Receptors

Designation	Sites Considered
Special Protection Area (SPA)	Firth of Forth (3) Buchan Ness to Collieston Coast (3) Forth Islands (3) Fowlsheugh (3) St Abb's Head to Fast Castle (3) Upper Solway Flats and Marshes (1) Slamannan Plateau (3)
Special Area of Conservation (SAC)	Berwickshire and North Northumberland Coast (1) Isle of May (2) Firth of Tay & Eden Estuary (1) River South Esk (3) River Teith (3) River Tay (3)
Site of Special Scientific Interest (SSSI)	Barns Ness Coast (1) Barnsmuir Coast (1) Eden Estuary (1) Elliott Links (1) Fife Ness Coast (1) Firth of Forth (1) Inner Tay Estuary (1) Isle of May (2) Montrose Basin (1) Pease Bay Coast (2) Rickle Craig – Scurdie Ness (1) Sands of Forvie and Ythan Estuary (1) Siccar Point (2) St Abb's Head to Fast Castle (2) St Andrews - Craig Hartle (1) Tayport - Tentsmuir Coast (1) Whiting Ness - Ethie Haven (2)

Designation	Sites Considered
Potential Marine Protected Area (MPA)	Firth of Forth Banks Complex (1)
Ramsar sites	Ramsar sites are created to protect wetland habitats and are also either designated as SPAs or SACs (see *Chapter 9: Designated Nature Conservation Sites*, Figure 9.1) see *Chapter 3: Regulatory Requirements*, *Section 3.4.4* for further information on the Ramsar Convention. The assessment of potential effects of the Project on Natura 2000 sites includes an assessment of the effects on the habitats for which the relevant Ramsar sites are designated and is therefore directly relevant to the assessment of effects on Ramsar sites.
National Nature Reserve (NNR)	Forvie (3) Isle of May (3)
Local Nature Reserve (LNR)	Aberlady Bay (3) Montrose Basin (3) Eden Estuary (3)
(1) Low tolerance geological features: the receptor contains geological interest features, some or all of which are potentially quite responsive to changes in the sediment regime (such as salt marshes, sand banks and mud flats). (2) High tolerance geological features: the receptor contains geological interest features, all of which are relatively resistant to changes in the sediment regime (such as reefs and maritime cliffs). (3) Designated site has no geological features.	

<u>Surfing and Leisure Beaches</u>

55 Surfing, kite surfing, windsurfing, sea/surf kayaking and canoeing activities are undertaken along the east coast of Scotland (Surfers Against Sewage (SAS), 2009). The most popular venues in the regional study area have been identified from a variety of published and online sources (East Lothian Council, 2010; Magicseaweed, 2013; Momentum Surf Shop, 2013). In addition to this, a number of beaches on the east coast are of interest from a general leisure and recreational perspective. For the purposes of considering the impact of metocean and coastal processes on any surfing or leisure beaches, a number of representative locations have been selected where impacts of the Project can be quantified. These beaches, from north to south, include:

- Stonehaven;
- Lunan Bay;
- Arbroath ;
- St Andrews;
- Kingsbarns;
- Gullane;
- North Berwick;
- Tantallon/Seacliff;

- Belhaven Bay;
- White Sands;
- Thorntonloch;
- Pease Bay;
- Coldingham; and
- Berwick-upon-Tweed/Spittal.

56 Changes to the metocean and coastal processes regimes have the potential to affect the quality of surfing and related activities, through changes in the magnitude, frequency/duration and nature of the resource. Good surfing beaches require the right combination of offshore topography and wave type, to create waves that propagate and break in a suitable fashion. Changes to either the wave regime or the seabed can deleteriously affect the resource, with potential for effects on tourism and recreation (see *Section 21.6 - 21.8*).

57 The potential impacts on these receptors are quantified in this chapter in terms of:

- Wave height;
- Wave period (which can affect the location, frequency and nature of wave breaking);
- Wave direction (for the same reasons as wave period); and
- Exceedance of the critical bed shear stress (which influences seabed morphology and features such as sand bars, and thus the nature of surfing breaks).

58 These quantified parameters are then used in the assessment of the receptors which is detailed in *Section 21.5.1*.

10.2.6 Baseline without the Project

The Project under the Future Baseline

59 The quantified changes to metocean and coastal processes due to the Project have been assessed under present climatic conditions (i.e. with no sea level rise or increased storminess). Under a future climate scenario, the quantified changes due to the Project infrastructure are likely be marginally different to the changes predicted under present climatic conditions as described in the following section and in *Appendix 10A, Section 10A.5*.5

60 However, it is considered that the modelling results for present climatic conditions are representative of impacts due to the Project under future climatic conditions. This is because predicted impacts are only very small outwith the Development Area (as described in *Sections 10.6* to *10.8*), and within the Development Area, the modelled effects of climate change are likely to cause only small changes to the predicted quantified changes. In addition to this, there is a high level of uncertainty in assessing future baseline under climate

change. As such, it is considered appropriate that the impact assessment has been carried out using the current baseline.

Climate Change Projections

61 The combination of future sea level rise and potentially increased storminess (giving higher wind speeds and wave heights) is an important issue for future coastal change. The consequences in terms of coastal processes are likely to be most evident along the shorelines, where much of the wave energy is finally dissipated. The advancing position of mean high water on beaches will lead to wave energy dissipation higher up on the foreshore with anticipated beach loss and scour in front of sea walls, or increased frequency of overtopping of coastal dunes or structures. Effects would also apply to offshore areas where the profile of sandbanks may reduce relative to local water depths, introducing greater exposure to offshore waves (i.e. there is less wave shoaling and larger waves, therefore can run up the shore). The impact of increased wave energy may have consequences for the sediment transport within the area.

62 Research for the Department for Environment, Food and Rural Affairs by the UK Climate Impacts Programme (UKCIP) provides estimates of future changes to the metocean climate. A time horizon of 50 years has been considered for the Project. By the end of this period, the UKCIP projections suggest an increase in water level of about 0.35 m, and an increase in extreme wave heights and wind speeds of about 10 per cent.

63 The following briefly summarises the findings of this climate change investigation.

Water Levels and Tidal Currents

64 The predicted change to water level due to climate change as expected is seen throughout the tidal cycle. An increase of about 0.35 m is predicted for the Regional Study Area, in line with UKCIP projections. Slightly lower or higher increases are predicted near the head of the Firths of Forth and Tay.

65 The predicted change to tidal currents due to climate change is varied, with both increases and decreases to current speeds predicted in different locations across the Regional Study Area. Typically, current speeds are seen to vary by no more than 0.01 m/s, with a decrease in speed generally more likely than an increase. Peak changes of up to +0.1 m/s and -0.3 m/s are seen in some isolated locations within the Firths of Forth and Tay.

Wave Heights

66 The projected increase in storminess gives predicted wave heights that are greater than the current baseline conditions. The projected 10 per cent increase in offshore wave heights and wind speeds results in an increase of 0.2 m – 0.4 m across the Regional Study Area (for the 50-percentile significant wave).

Seabed Features, SSC and Sediment Transport Regime

67 SSC, the stability and evolution of seabed features such as sand waves, and the regional-scale sediment transport regime are all influenced by the ease with which seabed sediment is eroded. Stronger near-bed currents associated with tidal or wave action will increase the likelihood of sediment erosion. An important parameter is the critical shear stress. This describes the threshold at which bed sediments start to move under the prevailing current conditions. Critical shear stress is dependent upon the sediment properties, in particular the distribution of particle grain sizes.

68 Exceedance of the critical shear stress under conditions of maximum bed shear stress is predicted to increase due to climate change, typically between 2 and 4 per cent across the Regional Study Area. Peak changes are predicted to be between 6 and 12 per cent, these changes occurring in shallow water areas close to the coast. These values refer to the increased percentage of the total time for which the critical shear stress is exceeded, rather than a relative change compared to the baseline.

69 Exceedance of the critical shear stress under conditions of mean bed shear stress is predicted to decrease across most of the Regional Study Area. The greatest predicted reduction in critical shear stress is between 5 and 10 per cent, in the upper Firth of Forth. As before, these values refer to the decreased percentage of the total time for which the critical shear stress is exceeded, rather than a relative change compared to the baseline.

70 The predicted changes in the exceedance of critical shear stress are likely to cause a small change in sediment processes throughout the Regional Study Area. Some locations, particularly near-shore, could see a rise in the frequency of sediment entrainment, particularly under storm conditions. This could in turn have an effect on local SSC levels and the stability of bedforms, and thus potentially on the wider sediment transport regime.

10.2.7 Guidance and Methods

71 The best practice guidance for the assessment of impact of offshore wind farms on metocean and coastal processes has been followed. Key references are:

- COWRIE - *Coastal Process Modelling for Offshore Wind Farm Environmental Impact Assessment: Best Practice Guide* (Lambkin *et al*., 2009); and
- Marine Consents Environment Unit (2004) – *Offshore Wind Farms: Guidance note for Environmental Impact Assessment In respect of FEPA and CPA requirements*.

72 In addition, although the majority of the surveys undertaken to support the Project (such as the metocean survey) had been completed prior to issue of the Cefas guidelines for data acquisition (Cefas, 2012), the data obtained during these surveys were acquired and analysed in line with these recent guidelines.

10.3 Assessment Methodology

73 In summary, the assessment includes the following:

- Construction, calibration and validation of a hydrodynamic modelling system (the FTMS);
- Determination of baseline conditions through analysis of existing data, newly acquired survey data, and subsequent modelling of baseline conditions using the FTMS;
- Assessment of the change to baseline tidal and wave conditions due to the Project. This has been achieved by including structures within the FTMS to represent the effect of the WTGs and OSPs and their foundations on the hydrodynamic regime. The predicted change to conditions due to the Wind Farm and OfTW has been determined by subtracting the baseline scenario results from the 'with-development' scenario results;
- Assessment of the fate and behaviour of disturbed sediment due to any activities relating to the Project, using the FTMS;
- Assessment of the amount of scour that might result around the structures through the use of well-known empirical equations, combined with relevant sediment information obtained in the field surveys, and flow information obtained from the FTMS;
- Assessment of cumulative effects due to the Wind Farm and OfTW (the offshore components of the Project), and due to other developments and activities together with the Project; and
- Recommendation of appropriate mitigation measures where appropriate to minimise any changes to physical processes.

10.4 Assessment Methodology

10.4.1 Methodology

74 The methodology used to assess the significance of any effects resulting from the Project on the identified receptors is in line with the EIA methodology detailed in *Chapter 4: Process and Methodology*, *Section 4.4.3*. The magnitude of the effect is assessed as either negligible, low, moderate or high, as defined in Table 10.7. In this assessment the magnitude takes into account the spatial scale of an effect, and the temporal scale allowing for the frequency and duration of the effect and the recoverability of the receptor. The stated magnitudes are applicable to the receptors; seabed features, and designated sites with geological interest features.

Table 10.7: Magnitude of Effects

Magnitude	Description
High	Permanent loss of, or large alteration to, the feature across >20% of its area; or loss of, or large alteration to, the entire feature for >20% of the time (after allowing for the frequency of disturbance and the speed of recovery). The feature will have low tolerance to environmental change and will be highly dynamic under normal conditions.
Moderate	Permanent loss of, or large alteration to, the feature across >5% of its area; or loss of, or large alteration to, the entire feature for >5% of the time (after allowing for the frequency of disturbance and the speed of recovery). The feature will have medium tolerance to environmental change and will only respond to higher energy events from the normal range of environmental conditions.
Low	Permanent loss of, or large alteration to, the feature across >1% of its area; or loss of, or large alteration to, the entire feature for >1% of the time (after allowing for the frequency of disturbance and the speed of recovery). The feature will have high tolerance to environmental change and will only respond to the most severe, relatively infrequent events.
Negligible	Permanent loss of, or large alteration to, the feature across <1% of its area; or loss of, or large alteration to, the entire feature for <1% of the time (after allowing for the frequency of disturbance and the speed of recovery). The feature will have very high tolerance to environmental change and is unlikely to be substantively affected by foreseeable events.

75 The sensitivity of a receptor is evaluated as either low, moderate or high, as defined in Table 10.8. Sensitivity is a measure of the quality, value, rarity or importance of a receptor.

Table 10.8: Sensitivity to Change of Receptors

Sensitivity	Description
High	The receptor is rare or unique. It represents an important example of its type, and its loss would lead to a marked depletion in the national or international resource of similar receptors.
Moderate	The receptor is an average example of its type. Similar receptors are nationally widespread but unusual in the local vicinity (which for this assessment is taken to be the Firths of Forth and Tay and the neighbouring coastline and offshore area). The loss of the receptor would not cause a marked depletion in the national or international resource of similar receptors.
Low	The receptor is either relatively common, or does not possess any qualities that make it a particularly important, interesting or valuable example of its type. Its loss would not be of serious concern in terms of the local or national resource of similar receptors.

76 The following sensitivities are assigned to the receptors considered as part of the metocean and coastal processes assessment:

- Designated sites with geological features: these are considered to have high sensitivity. Such designations have been made precisely because of the national or international quality, value, rarity or importance of the sites and their features.
- Seabed features: these are considered to have low sensitivity. Features such as sand banks are relatively common around the UK coast. Those seabed features considered to be of greater value are covered by existing or proposed designations (such as the potential Marine Protected Area (MPA) of the Firth of Forth Banks Complex).

77 The significance of the impact is assessed as Negligible/Minor to Major, as described in *Chapter 4* and shown in Table 10.9.

Table 10.9: Significance of Impacts

Magnitude of Impact	**Sensitivity of Resource/Receptor**		
	Low	Moderate	High
Negligible	Negligible/Minor	Minor	Minor/Moderate
Low	Minor	Minor/Moderate	Moderate
Moderate	Minor/Moderate	Moderate	Moderate/Major
High	Moderate	Moderate/Major	Major

78 For the purposes of this assessment, those residual positive and negative effects indicated as Major and Moderate/Major will be regarded as being significant effects.

79 The above EIA methodology relates to identified receptors (see *Section 10.2.5*). The metocean and coastal processes assessment also considers changes to processes. These processes are assessed by quantifying the predicted change in the process, but they are not assigned a magnitude, sensitivity or significance in EIA terms. This is because a predicted change in the metocean regime, or sedimentary and coastal processes, does not necessarily imply an effect if there are no receptors present that are sensitive to the change. This approach is in line with COWRIE guidelines (Lambkin et al., 2009). The subsequent impact of any change in process upon other receptors, such as benthic ecology, is assessed in the relevant technical chapter.

80 Changes to the following processes have been considered within the assessment:

- Water level;
- Tidal currents;
- Wave heights;
- SSC; and

- Sediment transport regime.

10.4.2 Numerical Modelling

81 The modelling assessment included the construction, calibration and validation of a hydrodynamic and spectral wave model (the FTMS), using the well-accepted and industry-standard MIKE 21 modelling system (DHI, 2009a, 2009b, 2009c), as recommended in the COWRIE guidelines (Lambkin *et al*., 2009). This FTMS has been calibrated and validated using the data collected through the survey campaigns as described in Table 10.4. The model construction, calibration and validation is detailed in full in *Appendix 10C*. The FTMS was used to determine any changes resulting from the Wind Farm and OfTW to the oceanographic regime (meaning water levels, currents and waves but not winds), the sedimentary environment and the resulting coastal processes.

82 The modelling system allowed the baseline environmental conditions to be modelled, against which the impacts and effects due to each individual project, and also any cumulative effects of all proposed regional offshore wind farm developments with associated OfTW (the Project, Neart na Gaoithe and Firth of Forth projects), have been assessed.

83 Any changes to the modelled physical processes or parameters (waves, currents and resulting sediment dynamics) were determined by subtracting the baseline (existing situation) modelled results from the 'with-development(s)' modelled results. This enabled the magnitude and spatial extent of any change due to the development(s) to be quantified. A value greater than zero therefore indicates an increase in the modelled parameter (for instance water level), and a value less than zero indicates a reduction in that parameter. It should be noted that this technique of assessing the relative difference between two different modelled scenarios allows very small changes to be determined (e.g. at the scale of millimetres for the difference in water levels). However, this does not imply that the absolute values predicted by the model are of a similar accuracy, and in fact a much wider tolerance is acceptable here.

84 Impacts have been assessed in both the near-field and the far-field. As per the COWRIE best practice guidance (Lambkin *et al*, 2009), the near-field study considers the interaction between structures and the effect of the development within the Development Area, whereas the far-field study considers the general effect of the development *as a whole* on the surrounding area. The far-field study also includes the assessment of cumulative effects from the Neart na Gaoithe and Firth of Forth projects.

85 Table 10.10 outlines all of the different potential impacts that were assessed. This table identifies a number of ways in which the Project could affect metocean and coastal processes – for example, by altering the wave climate. For each of these potential effects, the table describes the modelling tools that were used to investigate the effect in both the near-field and far-field. It also notes the key physical processes that were included in the modelling, and the parameters relating to the metocean and sediment regimes that were ultimately assessed.

Table 10.10: Summary of Assessment Topics and Modelling Techniques Applied

Potential Effect	Near-Field (NF)	Far-Field (FF)	Processes Included	Changes Modelled
Changes to hydrodynamics (water levels and current flows)	FTMS Hydrodynamic (HD) module (using the fine model resolution around the Development Area).	FTMS HD module (using the flexible resolution of the model mesh to assess over the entire model domain).	Bifurcation of flow around structures (NF). Localised acceleration of currents (NF). Change in general circulation (FF). Change in tidal symmetry, orientation (FF). General change in energy of hydrodynamic regime (NF/FF).	Water level. Current speeds and direction.
Changes to the wave climate	FTMS Spectral Wave (SW) module (using the fine model resolution around the Development Area).	FTMS SW module (using the flexible resolution of the model mesh to assess over the entire model domain).	Refraction. Shoaling. Bottom dissipation. Wave breaking. White capping. Wind-wave generation. Directional spreading. Frequency spreading. Wave-current interaction. General change in energy of the wave regime.	Wave Height. Wave Direction. Wave Period.
Changes to sediment regime	FTMS HD and SW modules. FTMS Particle Tracking (PT) module. Site-specific (and regional) sediment grain size data. Standard equations to determine the locations and frequency of occurrence of sediment mobilisation (based on bed shear stress and sediment data).		Near-bed tidal currents. Near-bed wave orbital velocities. Seabed sediment size distributions. Bed shear stress. Critical shear stress for entrainment. Sediment transport pathways.	Frequency of exceedance of critical shear stress Sediment transport pathways.
Development of scour pits around structures and the subsequent fate of scoured material released to the water column	Empirical scour equations plus sediment data.	FTMS PT module.	Scour around jacket legs due to acceleration of flow.	Equilibrium scour depth, scour pit dimensions, temporal evolution, volume of sediment displaced SSC. Deposited sediment thickness and extent .

Potential Effect	Near-Field (NF)	Far-Field (FF)	Processes Included	Changes Modelled
Fate of dredged material from GBS preparations	FTMS PT module plus sediment data.	FTMS PT module.	Dispersion and settling of discharged material due to dredging.	SSC. Deposited sediment thickness and extent.
Fate of disturbed material during cable burying	FTMS PT module plus sediment data.	FTMS PT module.	Dispersion and settling of disturbed sediment due to cable burial.	Estimate of disturbed material volumes SSC. Deposited sediment thickness and extent.

10.4.3 Modelled Assessment Scenarios

86 This section provides additional detail on the worst case scenarios detailed in *Section 10.1.3* that have been considered in the FTMS, detailing some of the important assumptions made. Further information can be found in *Appendix 10A, Sections 10A.1.2.1 and 10A.4.7*.

GBS Foundations Preparation Assessment Scenario

87 Seabed preparation for the installation of GBS foundations will result in sediment disturbance and elevated SSC. Preparation methods are described in *Chapter 7, Section 7.6*, but the details relevant to the modelling exercise are summarised here. The worst case assessment assumes that all dredged material is deposited at the foundation bases in order to complete a balanced backfill. Any removal of material from the Development Area will be of lesser impact than this scenario. In preparation for GBS foundations, the seabed will be dredged and the removed seabed sediment taken up to the dredger vessel at the surface for temporary storage while the gravity foundation is installed. This dredged material will then be returned to the seabed via a fall-pipe arrangement and deposited in a controlled manner around the base of the foundation. Some of the dredged material will be reinstated in the pit after the foundation is installed, and the remaining material will be built up around the foundation in layers. The technique applied, the volume of material removed, and the depth and rate of discharge will be dependent on the type and size of foundations, the seabed sediment composition, and the vessel used. The worst case scenario modelled makes the following conservative assumptions:

- The largest dredged area will be circular, with a diameter of 95 m around each WTG. An inner circle (75 m diameter) will be dredged to a five metres depth, with sloping sides in an outer circle – 10 m around the inner circle. A sediment porosity of 60 per cent was assumed (i.e. 60 per cent of the volume dredged will be sediment, and 40 per cent will be water, which is a typical split for near-surface seabed sediments). The volume of each dredged pit will be 28,500 m^3. This is an inherently conservative assessment which allows for consideration of a worst case at an individual WTG location. As a result, when considered across the entire Development Area the extrapolated values will be higher than is expected.

- It was assumed that all of this material will be discharged into the water column, close to the seabed at each WTG location. Since 100 per cent of the dredged material is released, this assumption also allows for the overspill that might occur during the initial dredging of the sediment which will be a lesser impact than the modelled worst case.
- It was assumed that the dredged material will be released five metres above the seabed, and will be subject to advection and dispersion by the ambient currents while falling through the water column toward the seabed. The expected height of the fall-pipe will be between one metre and five metres from the seabed. The greater the release height, the greater the size of the resulting deposition footprint.
- It was assumed the dredging and backfilling process will be on a continual basis, with the backfilling around each foundation base taking 24 hours to complete, and the commencement of backfilling the next excavation pit starting immediately after the previous one. In reality, it is likely to take several days to complete the preparation of each base, which may be undertaken in several phases, and there will be periods between the completion of one base, and the commencement of backfilling the next. However, this assessment is not sensitive to the precise duration of backfilling, since most of the sediment settles quickly and it is this which primarily influences the deposition footprint.
- It was assumed that the material was discharged at a constant rate; in reality the material is likely to be discharged in controlled phases. As before, the assessment is not sensitive to this assumption since the rate of settling is the key consideration. The deposition footprint will be similar whether discharged rapidly or slowly, and constantly or in phases.
- Momentum of the release via the fall-pipe was not modelled. Therefore, sediment was introduced into the model at five metres above the bed, at a constant rate, but was not given any downward momentum. This will lead to a larger deposition footprint than might actually occur as the released sediment will in fact have a downward momentum and will settle more quickly, leading to a smaller, but thicker deposition footprint. The larger footprint is considered to be conservative since deposition depths close to the foundation will be large under any feasible scenario.
- Since the spatial variation in conditions across the Development Area, in terms of the hydrodynamic regime, the sediment type and the PSD, are very small, it was assumed that the actual modelled locations selected (16 representative WTGs near the middle of the Development Area) will not lead to any noticeable variation in the resulting impacts of SSC or deposition footprint.

88 In order to determine the indicative worst case impacts (in terms of disruption to the seabed, elevated SSC and changes to sediment processes) that might occur at the site due to GBS foundation preparation, two neighbouring lines of WTGs (each with eight WTGs) through the middle of the Development Area were selected for modelling. The modelled

deposition footprints from these 16 WTG locations were then extrapolated across the rest of the Development Area.

89 A representative PSD for the dredged sediment was applied. This was based on the sediment samples taken throughout the Development Area, which showed reasonable uniformity. Full details of the modelling inputs, including the PSD, are provided in *Appendix 10A, Section 10A.4.7*.

90 The results from the 16 representative WTGs modelled were extrapolated in order to estimate sediment settling depths across the entire Development Area. This technique allowed for dredged sediment impacts from 213 WTGs, five OSPs and three met masts. Met masts area equivalent to WTGs in terms of the volume of dredged sediment, while each OSP was treated as being equivalent to the sediment disturbance of four WTGs due to their greater size.

Cable Burial Assessment Scenario

91 For the purposes of the modelled worst case scenario for the burial of the Offshore Export and inter-array cables, a burial depth of two metres and a trench width of one metre were assumed. The Design Envelope states that trench depths are likely to very between zero and three metres, with a target depth of one metre. The greatest trench depth (three metres) will not be used extensively for the inter-array and Offshore Export cables, so the modelled depth of two metres represents a reasonable and conservative estimate when averaged across the Development Area and Offshore Export Cable Corridor.

92 The rate of trenching depends on a number of factors, such as the vessel used, the trenching technique applied, the water depth and the sediment type. The Design Envelope details the cable lay rate which will be between 300 – 500 m/hr. For the purposes of assessment the average burial rate of 400 m/hr per hour was used. In practice the scale of the other assumptions that would affect the resulting impacts, such as the volume of the discharged material, far exceeds the very small potential variation that might result if a different lay rate was modelled. As such this is considered an appropriate parameter to represent a worse case. For a trench depth of two metres and width of one metre, this equates to a maximum volume of displaced material of 800 m^3 per hour (conservatively assuming 100 per cent liberation during trenching) (Pyrah, 2011).

93 For the Offshore Export Cable Corridor, to assess the potential changes to the physical environment from the cable burial activities, the FTMS Particle Tracking module was used to model a moving discharge (at a rate of 400 m per hour). Three representative locations were modelled: one close to the Development Area; one approximately mid-way along the Offshore Export Cable Corridor; and one close to landfall, as can be seen in Figure 10.19.

94 Specific PSD data were available near the Development Area, with a modal average for three PSD sample sites calculated. PSD data for the remaining two sites on the Offshore Export Cable Corridor were modelled based on available BGS data. It was assumed the sediment consisted of equal parts of very fine sand and mud at these locations. Collected PSD data

(see *Appendix 12C – Benthic Ecology Baseline Offshore Export Cable Corridor*) within the Offshore Export Cable Corridor indicate that the PSD applied for the near-shore and midpoint assessments (50 per cent sand, 50 per cent mud) are in good agreement with the measured values (approximately 60 per cent sand, 40 per cent mud), and the modelled scenario is therefore valid. Full details of the modelling inputs, including the PSD, are provided in *Appendix 10A Section 10A.4.7*. For impacts from the inter-array cable burial activities in the Development Area, the results from the Offshore Export Cable Corridor (modelled location closest to the Development Area) are considered to be representative. This is based on the fact that the trench width and depth, and the trenching techniques anticipated, are equivalent, and the sediment characteristics and hydrodynamic conditions at the offshore location along the Offshore Export Cable Corridor are similar to conditions within the Development Area.

Scour Assessment Scenario

95 For the purposes of the scour assessment, it was determined that if GBS were employed as the foundation type, scour protection would certainly be required, and that adequate scour protection and mitigation options would be included in the engineering design of the bases. Any impact due to scour around GBS will therefore be minimised as a matter of course. As such, the worst case scenario in terms of impacts on the environment due to potential scour will be from jacket structures, and the scour assessment therefore assumed jacket structures would form the foundation type. The empirical assessment of scour around the jacket structures is detailed in full in *Appendix 10A (Annex 10A.6)*.

96 This assessment determined that the maximum volume of scoured material from a single jacket structure (for the largest proposed WTG) will be 4,990 m^3, and that it would take at least 12 days for the equilibrium depth scour pits to develop. The fate of the potential scoured material was modelled using the FTMS Particle Tracking module. In order to be conservative, the maximum volume of scoured material (4,990 m^3 per WTG), which was based on peak spring tide rates, was released at 16 WTGs in the middle of the Development Area over a 16-day period (i.e. roughly one spring-neap cycle). This is a conservative estimate as it is unlikely that this WTG installation rate not be achieved in practice. However, as the results were not particularly sensitive to the installation rate, this was considered not to be overly conservative. The same 16 WTG locations, and the same representative PSD, were used as in the GBS foundation preparation scenario, and the material was discharged 2 m above the seabed (which is considered to be a realistic height for sediment disturbance based on the size fractions present).

97 As with the GBS dredging assessment, the results from the 16 representative WTGs modelled were extrapolated in order to estimate sediment settling depths across the entire Development Area. This technique allowed for scoured sediment impacts from 213 WTGs, five OSPs and three met masts. Met masts area equivalent to WTGs in terms of the volume of scoured sediment, while each OSP was treated as being equivalent to four WTGs due to their greater size and number of piles.

Far-field Sediment Transport

98 In order to assess any changes to the general hydrodynamic regime, and consequently the net movement of any naturally occurring suspended sediment from the Development Area, a continuous discharge of suspended sediment released over a spring-neap cycle was modelled using the FTMS particle tracking module. The release was modelled from 16 selected locations in the middle of the Development Area. These are representative of the situation throughout the Development Area, since the hydrodynamic regime and surface sediment composition are both fairly homogenous.

99 The same release was modelled with and without the Wind Farm and OfTW in place. The outputs were visually compared in order to identify any changes to the net sediment transport pathway due to the Project. It should be noted that this scenario does not represent any specific discharge of sediment resulting from the Project, but instead aims to identify any significant changes to the net far-field transport of suspended sediment.

10.5 Impact Assessment – Development Area

100 Full details of the impact assessment, including all relevant plots showing the size and spatial extent of predicted impacts, are provided in *Appendix 10A* and its Annexes. A summary of results and representative plots are provided within this chapter. The assessment is divided into the Development Area specific, or near-field assessment, and the regional, or far-field assessment where relevant.

101 Table 10.10 in *Section 10.4.2* lists the physical processes that have been considered during the metocean and coastal processes assessment. The processes described in *Section 10.4.1* have been assessed.

10.5.1 Effects of Construction

Water Levels, Currents and Wave Heights

102 The effects of the Wind Farm and OfTW on water levels, currents and wave heights during the construction phase will be proportionally less than during the operational phase. The additional infrastructure involved in construction, such as dredging vessels or jack-up rigs, will cause no meaningful change in metocean conditions. This is because the installation vessels and associated infrastructure will be too small, spatially dispersed and transient to cause any meaningful change in the hydrodynamic or wave regimes.

Suspended Sediment Concentrations

103 The discharge of dredged sediments during the preparation of GBS foundations will lead to elevated concentrations of suspended sediment. Very localised peaks up to 4000 mg/l above background levels are predicted, but these typically drop to 100 mg/l or less within about 100 m of the discharge point. These short-lived SSC peaks are high compared to normal measured background levels (which are less than 15 mg/l on average, but likely to exceed 80 mg/l during winter storms). The resulting plumes will not be advected beyond

the immediate vicinity of the Development Area, and they will settle out within 1 - 2 hours of discharge.

104 The magnitude of the change in SSC due to GBS dredging during the construction phase will lead to significantly higher than ambient concentrations, but this effect will only last for the duration of the dredging phase (between several hours to several days at each WTG location), with concentrations returning to ambient conditions very quickly.

105 Elevated SSC levels will also result from the development of scour pits around jacket leg structures, should this design option be used in preference to GBS. Two representative plots of the suspended sediment plumes resulting from the scour around jacket foundations are shown in Figure 10.6 and Figure 10.7, for 16 selected WTGs near the centre of the Development Area (results for other WTG locations will be similar). These plots show snapshots of the plumes at two particular states of the tide (one ebbing and one flooding); different tidal states will give different plume shapes. Although peak concentrations very close to the scour pits are predicted to be between 10 mg/l and 100 mg/l above background (compared with ambient concentrations of less than 15 mg/l on average, or 80 mg/l during winter storms), these elevated concentrations will occur very close to the structures. Beyond about 100 m of the structures, concentrations will be less than 10 mg/l above background concentrations, reducing to less than one mg/l beyond one kilometre. These impacts will be transient and the suspended sediment will settle out within one hour of release. Once equilibrium scour depths are reached (within one month), no further development of the scour pit under normal tidal conditions will result.

Figure 10.6: Suspended Sediment Concentration due to Scouring around Jacket Structures – Six days after 'Commencement'

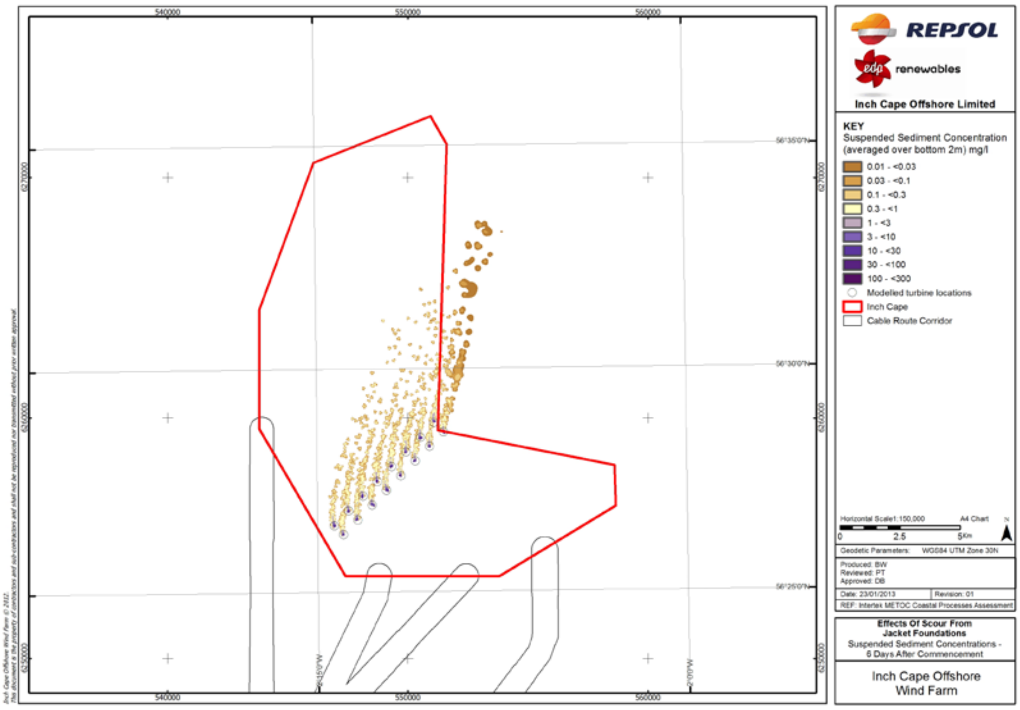
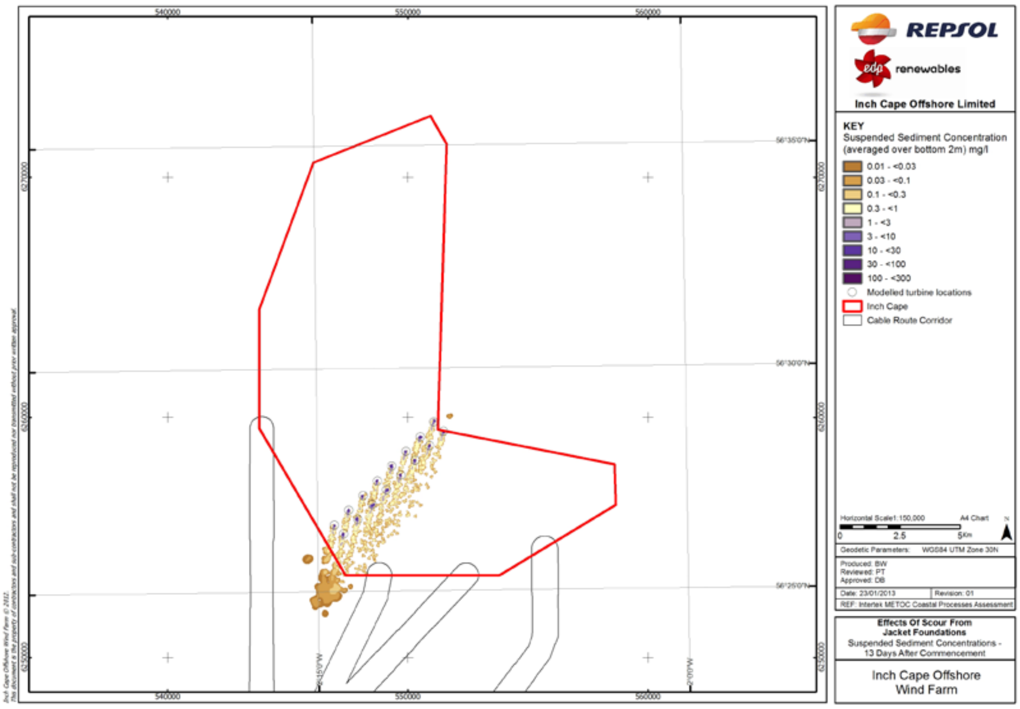


Figure 10.7: Suspended Sediment Concentration due to Scouring around Jacket Structures – 13 days after 'Commencement'



106 In the event of drilling for jacket foundations, the pattern of sediment release will be broadly similar to that for the GBS dredging scenario, but the total amount of sediment released will be very much smaller. The GBS dredging scenario therefore represents the worst case.

107 The process of inter-array cable burial might lead to very localised increases in SSC. Within a few hundred metres of the cable, average SSC due to cable burial has predicted values typically between 3 mg/l – 10 mg/l above background concentrations, with peaks up to 300 mg/l. Higher concentrations, probably in the thousands of mg/l, will occur very close to the inter-array cables but these will be limited to within a few tens of metres of burial activities. Most of the resulting sediment plume will settle out within tens or a few hundred metres of the cable, over a period of seconds or minutes. The finest (mud and silt) sediment fractions will persist for longer in the water column and be carried further, but even these will generally not be advected beyond the near-field vicinity of the cable (< 3 km), and will settle out within a few hours of disturbance.

108 It is possible that elevated SSC impacts might result from two construction activities combined. This could arise through GBS dredging at the same time as cable burial, or jacket leg scour pit development at the same time as cable burial. As a worst case, the impacts identified above for the individual activities would be additive. For example, GBS dredging (maximum SSC up to 4000 mg/l above background) and cable burial by energetic means (maximum SSC up to 300 mg/l above background) could in theory combine to give a maximum SSC of up to 4300 mg/l above background. However, the potential for combined SSC impacts is unlikely to cause substantially higher impacts than those from the construction activities considered in isolation. First, there is little substantial difference in

the predicted SSC since it tends to be the case that one activity or the other will dominate SSC impacts (most notably GBS dredging). Second, the additive impacts would only arise if the activities were being undertaken in close proximity and at a similar time, which is likely to occur infrequently, if at all. For all construction activities, the predicted SSC impacts are localised and transient. As such, the impacts from different construction activities on SSC can effectively be considered as independent.

Sediment Transport Regime

109 The sediment regime is influenced by changes to the suspended sediment or bedload transport rates. Since changes to SSC during the construction phase are relatively localised and short-lived, the corresponding change to the sediment transport regime is considered to be small.

Seabed Features – Impacts of Sediment Deposition from GBS Dredging

110 The sediment deposition footprint resulting from dredging for GBS foundations is likely to cover the Development Area with varying thickness, generally less than three centimetres with peaks between one metre and two metres around each WTG, OSP or met mast foundation. Table 10.11 gives the area covered by deposited sediment at or above selected settling depths, as a percentage of the Development Area.

Table 10.11: Development Area Coverage due to Sediment Deposition from GBS Dredging

Thickness of Settled Sediment	Percentage of Development Area Covered at this Thickness or Greater
3 mm	14.9%
3 cm	8.0%
5 cm	6.7%
30 cm	2.7%
3 m	0.0%

111 The predicted deposition footprint from the discharge of dredged material within the Development Area is shown in Figure 10.8. This plot is based on a greater number of WTGs than will actually be installed, in order to illustrate how impacts from individual WTGs might overlap at close WTG spacing. Even with this conservatism, the deposition of dredged material will remain within the Development Area.

112 Although these changes are likely to be long-lived or permanent through the life of the Project, the deposited sediment covers only a small portion (<10 per cent) of the Development Area to depths of a few centimetres or more. As such the magnitude of this

effect on seabed features is considered to be moderate in the near-field and negligible in the far-field.

113 The sensitivity of seabed features is low (see *Section 10.4.1*).

114 The significance of the impact is therefore minor/moderate in the near-field and negligible/minor in the far-field.

<u>Seabed Features – Impacts of Jacket Scour Pits</u>

115 The adoption of jacket foundations may result in scour pit formation. The scour assessment (*Appendix 10A, Annex 10A.6*) determined that, depending on the size of the jacket structures employed, the worst case maximum scour depth will be 6.7 m; the maximum lateral scour extent will be 12 m; and the maximum volume of scoured material from a single jacket structure will be about 5,000 m^3 (this worst case analysis assumed that surficial sediments would extend to 10 m below seabed, but, in reality, shallow sub-surface geological conditions across the Development Area may limit scour depths to less than this.). The scour assessment also determined that scour will predominantly occur on spring tides, but low rates of scour will occur on neap tides. It is likely to take at least 12 days for the maximum equilibrium-depth scour pits to develop. No overlap of scour pits will result, so combined impacts between individual legs or between WTG foundations will not occur, and scour will be local rather than global (global scour occurs when local scour pits from individual legs or structures overlap, and the whole seabed is subject to scouring effects). The total area covered by scour pits equates to less than 0.1 per cent of the Development Area.

116 Although these changes will be permanent through the life of the Wind Farm, since the scour pits cover only a very small percentage (<1 per cent) of the Development Area, the magnitude of this effect on seabed features is considered to be negligible in the near-field. The magnitude of the effect is also negligible in the far-field.

117 The sensitivity of seabed features is low (see *Section 10.4.1*).

118 The significance of the impact is therefore negligible/minor in both the near-field and far-field.

<u>Seabed Features – Impacts of Sediment Deposition from Jacket Scour Sediment Deposition</u>

119 The deposition footprints resulting from scoured material will be localised around the WTG bases, with a maximum thickness of 1.1 m. Beyond 200 m from the WTG base, any deposition will be less than one millimetre thick and therefore immeasurable. Table 10.12 gives the area covered by deposited sediment at or above selected settling depths, as a percentage of the Development Area.

Table 10.12: Development Area Coverage due to Sediment Deposition from Jacket Scour

Thickness of Settled Sediment	Percentage of Development Area Covered at this Thickness or Greater
5 cm	3.1%
50 cm	0.4%

120 The predicted deposition footprint due to the scoured material across the Development Area is shown in Figure 10.9. This plot is based on a greater number of WTGs than will actually be installed, in order to illustrate how impacts from individual WTGs might overlap at close WTG spacing. Even with this conservatism, impacts are limited to the Development Area.

121 Although changes are likely to be long-lived in the prevailing metocean conditions, the deposited sediment covers only a small portion (<5 per cent) of the Development Area to depths of a few centimetres or more. Therefore, the magnitude of this effect on seabed features is considered to be low in the near-field. The magnitude of the effect is negligible in the far-field.

122 The sensitivity of seabed features is low (see *Section 10.4.1*).

123 The significance of the impact is therefore minor in the near-field and negligible/minor in the far-field.

Seabed Features – Impacts of Sediment Deposition from Cable Burial

124 As stated in *Suspended Sediment Concentrations* above, the deposition footprint resulting from the inter-array cable burial process is predicted to extend to a maximum of three kilometres either side of the inter-array cable route. However, the more distant parts of this deposition footprint will be very thin – typically <1 mm beyond one kilometre distance. Peak deposition depths up to five millimetres are predicted, averaged across a corridor of about 100 m width either side of the inter-array cable. Very close to the cable (within metres or a few tens of metres of it) a depth in the order of centimetres is possible.

125 Since deposition thicknesses are low and the deposition footprint is mostly confined to the immediate area of the cable route, the magnitude of this effect on seabed features is considered to be low in the near-field. The magnitude of the effect is negligible in the far-field.

126 The sensitivity of seabed features is low (see *Section 10.4.1*).

127 The significance of the impact is therefore minor in the near-field and negligible/minor in the far-field.

Seabed Features – Impacts of Jack-up Vessels

128 The use of jack-up vessels to provide stable or fixed working platforms will lead to indentations left on the seabed by the barge legs and large anchors. On completion of the operation, these may leave an impression when removed from the seabed. The exact nature of the initial disturbance will likely vary depending upon the design and dimensions of the leg or anchor, and the geotechnical properties of the seabed sediment in the area where the jack up vessels are located. However, these effects are likely to be both localised and short-term.

129 Since the impacts are both small and transient, the magnitude of this effect on seabed features is considered to be negligible in both the near-field and far-field.

130 The sensitivity of seabed features is low (see *Section 10.4.1*).

131 The significance of the impact is therefore negligible/minor in both the near-field and far-field.

Figure 10.8: Deposition Thickness due to GBS Dredging – after all Material has Settled

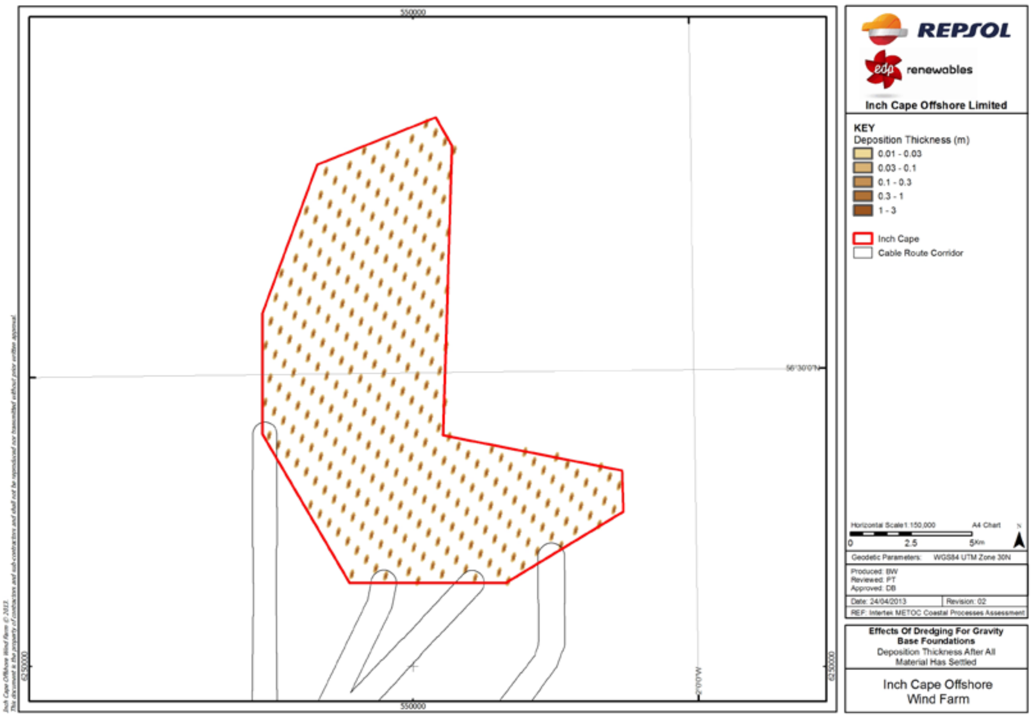
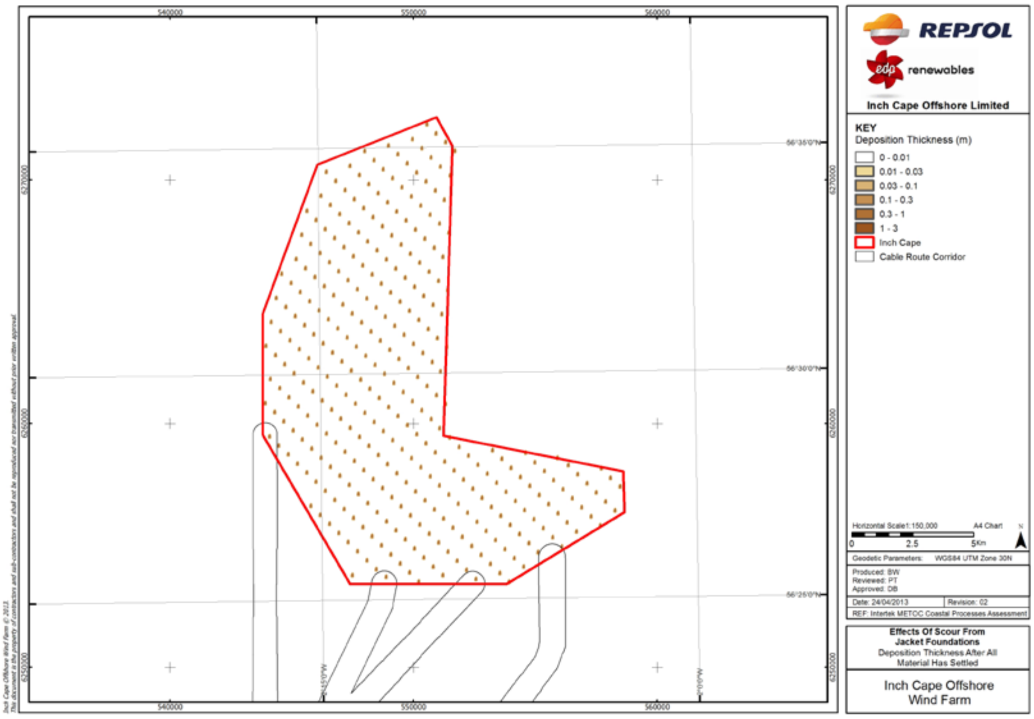


Figure 10.9: Deposition Thickness due to Scouring around Jacket Structures – after all Scoured Material has Settled



<u>**Designated Nature Conservation Sites with Geological Features**</u>

132 All of the designated sites are distant from the Development Area (>10 km), except for the potential Firth of Forth Banks Complex MPA. Extrapolating the results of the GBS dredging scenario, the MPA is likely to experience only a very small increase in SSC (probably less than 30 mg/l) for a brief period during the construction of nearby WTGs. Settled sediment depths will be low – much less than one centimetre. None of the other designated sites is predicted to experience any meaningful change in metocean processes or the sedimentary environment due to construction activities. Considerations of the implications of likely significant effects on any non-geological qualifying features of the designated sites are detailed in the following chapters:

- *Chapter 12: Benthic Ecology*;
- *Chapter 13: Natural Fish and Shellfish*;
- *Chapter 14: Marine Mammals*; and
- *Chapter 15: Ornithology*.

133 Because impacts are small and/or transient, the magnitude of impacts from Development Area construction activities on designated sites with geological features is negligible in the far-field (there are no such sites in the near-field). This applies to both low tolerance sites such as sand banks and high tolerance sites such as maritime cliffs.

134 The sensitivity of designated sites is high (see *Section 10.4.1*).

135 The significance of the impact is therefore minor/moderate in the far-field.

Surfing and Leisure Beaches

136 All of the surfing and leisure beaches are distant from the Development Area (>10 km). None of these beaches is predicted to experience any meaningful change (i.e. anything that would be measurable) in metocean processes or the sedimentary environment due to construction activities. The impacts of these changes are assessed in *Section 21.6 - 21.8*.

Summary of Effects

137 Table 10.13 summarises the predicted effects on metocean and coastal processes due to works within the Development Area construction phase.

Table 10.13: Summary of effects – Construction phase in the Development Area

Process	Effect
Water levels, currents, waves	No meaningful change.
SSC	Peaks of 4000 mg/l due to GBS dredging discharge, dropping to <100 mg/l less than 100 m from the GBS location and settling within 1 – 2 hours. Peaks of <100 mg/l due to jacket scour reducing to less than 1 mg/l beyond one kilometre. Peaks up to 300 mg/l (spatial average) due to cable burial, most settling out within 10s to 100s of metres from the cable. Finer sediment fractions will not be advected beyond the near-field vicinity of the cable (< 3 km).
Sediment/disturbance footprints	6.7% of Development Area covered at >5 cm due to GBS dredging discharge. 0.1% of Development Area covered by jacket scour pits. 3.1% of Development Area covered at >5 cm due to jacket scour discharge. Sediment settling depths up to 5 mm (spatial average) due to cable burial.

10.5.2 Effects of Operation and Maintenance

Water Levels and Tidal Currents

138 The predicted change in water level due to the operation and maintenance of the works within the Development Area is very small (up to ±1.5 mm or approximately 0.03 per cent of the mean spring tidal range at the Development Area) and generally localised to the near-field (Figure 10.10 and Figure 10.11). In practice such a predicted change will not be measurable.

139 The predicted change in tidal currents due to the operation and maintenance of the Development Area is small (between +0.02 m/s and -0.04 m/s, which is equivalent to between three per cent and seven per cent of peak currents on a mean spring tide). Furthermore, these changes are restricted to the immediate vicinity of the Development Area (Figure 10.12 and Figure 10.13). Although the frequency and duration of this effect is considered to be permanent during the lifetime of the works within the Development Area the impacts are very local to the Development Area, and the predicted change is comparable with the natural variability that is likely to be experienced at the Development Area. It should be noted, however, that the localised change to flow could lead to scour around the structures (see *Section 10.5.1*).

140 The changes noted here are due to the presence of GBS, which is the worst case scenario. The presence of maintenance vessels will cause no meaningful change in hydrodynamic conditions. This is because the vessels will be too small, spatially dispersed and transient to cause any meaningful change in the hydrodynamic regime.

Wave Heights

141 The predicted effect on wave heights due to the operation and maintenance of the Development Area is considered to be small (up to 0.03 m, which is about two per cent of average significant wave height, or 0.5 per cent of the highest significant wave likely in any one year). Effects are restricted to offshore, up to a maximum 10 km from the Development Area (Figure 10.14 and Figure 10.15). Although the frequency and duration of this effect is considered to be permanent during the lifetime of the Development Area works (when wave forcing exists), the predicted change is localised to the Development Area, and is comparable to the natural variability that is likely to be experienced at the Development Area.

142 The changes noted here are due to the presence of GBS, which is the worst case scenario. The presence of maintenance vessels will cause no meaningful change in wave conditions. This is because the vessels will be too small, spatially dispersed and transient to cause any meaningful change in the wave regime.

Figure 10.10: Difference in Mean Spring Tide High Water Level (m) in the Development Area – Near-Field

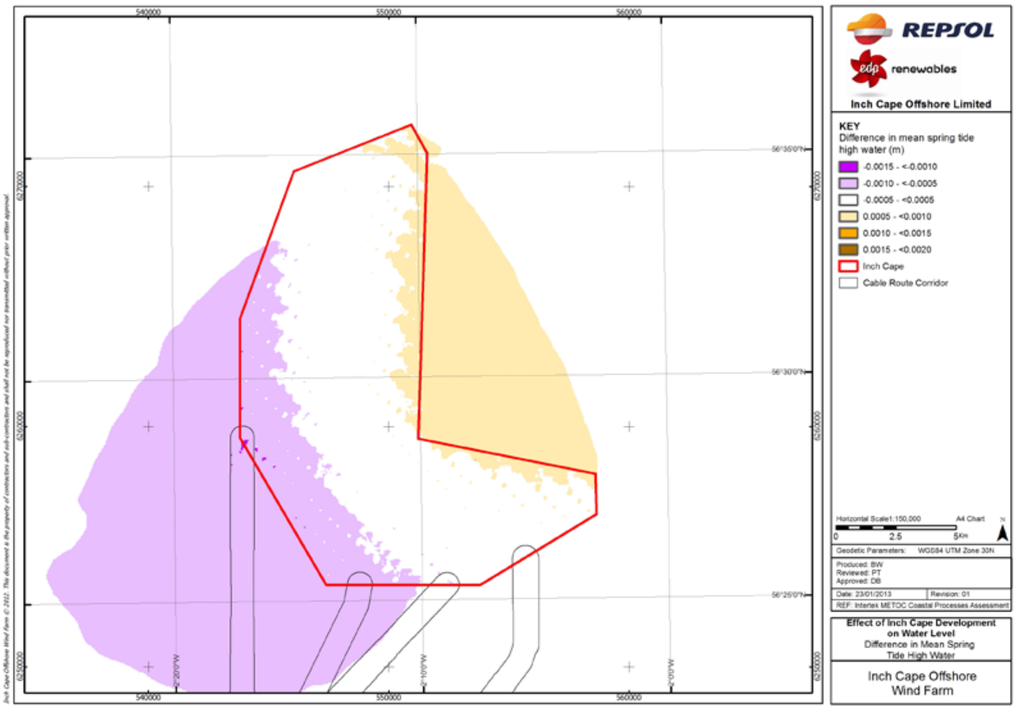


Figure 10.11: Difference in Mean Spring Tide Low Water Level (m) in the Development Area

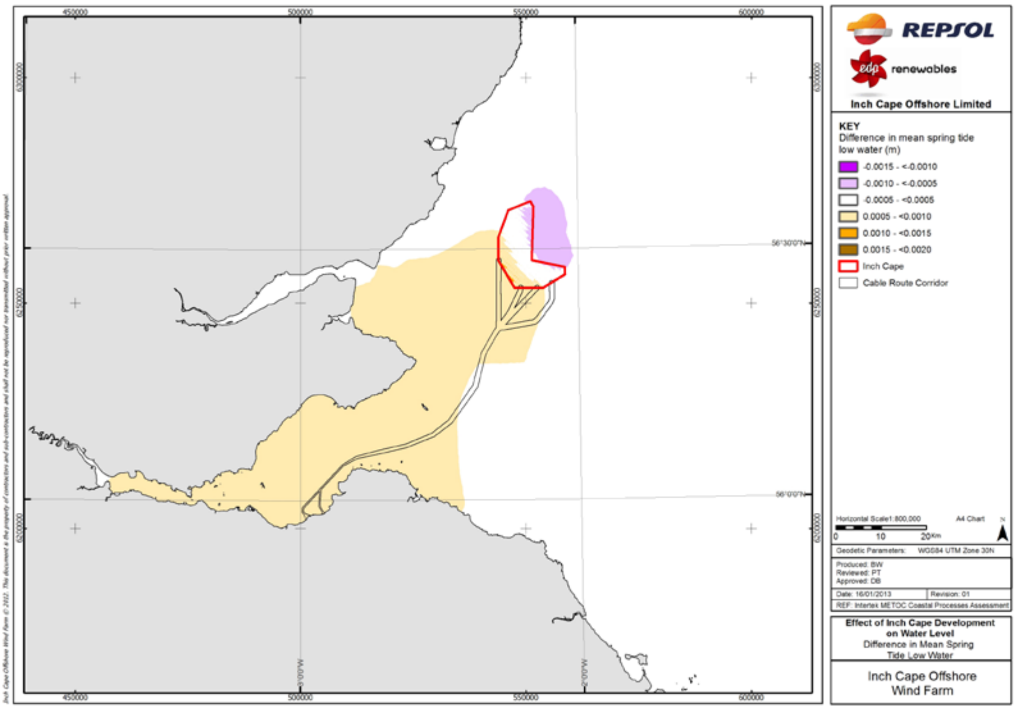


Figure 10.12: Difference in Mean Spring Tide Peak Flood Current Speed (m/s) in the Development Area – Near-Field

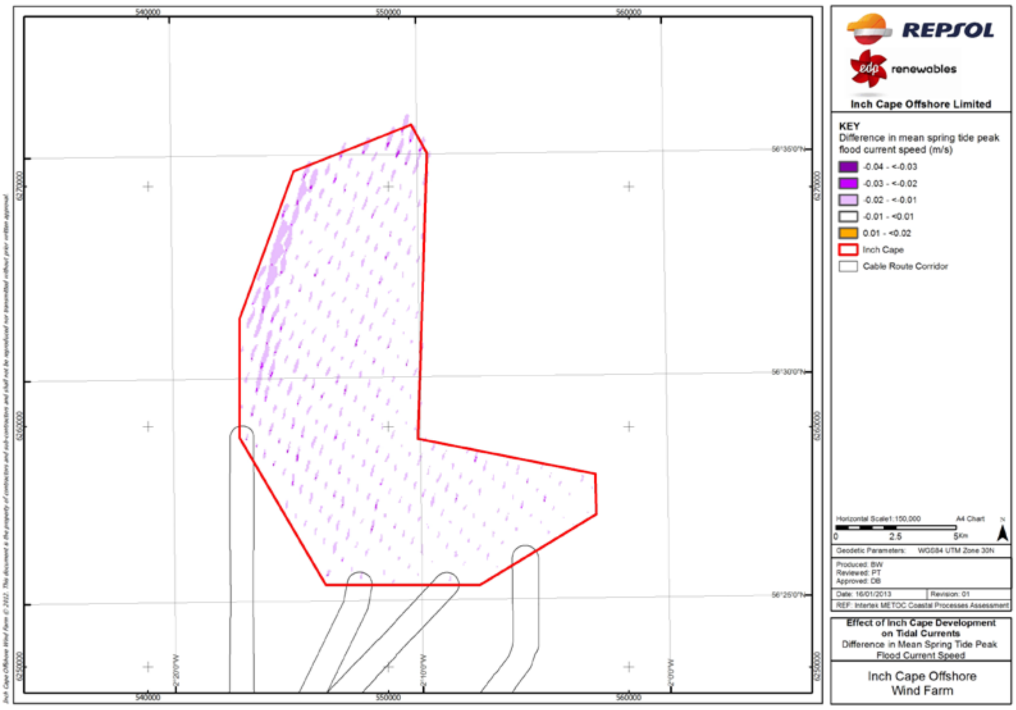


Figure 10.13: Difference in Mean Spring Tide Peak Ebb Current Speed (m/s) in the Development Area – Near-Field

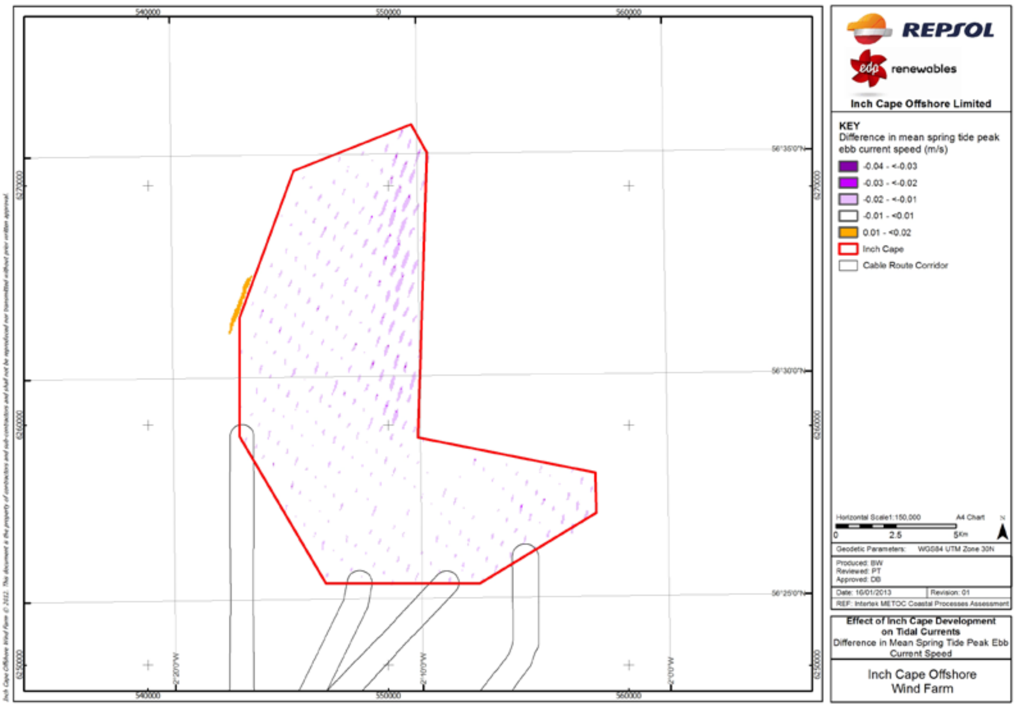


Figure 10.14: Difference in 50-percentile Significant Wave Height (m) in the Development Area – Near-Field

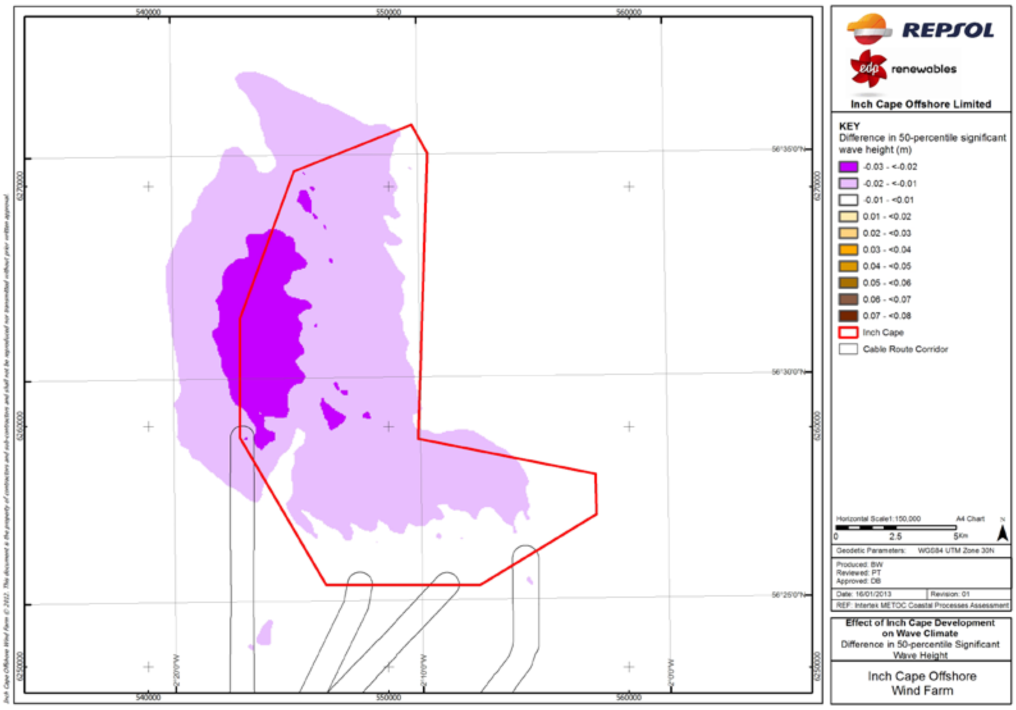
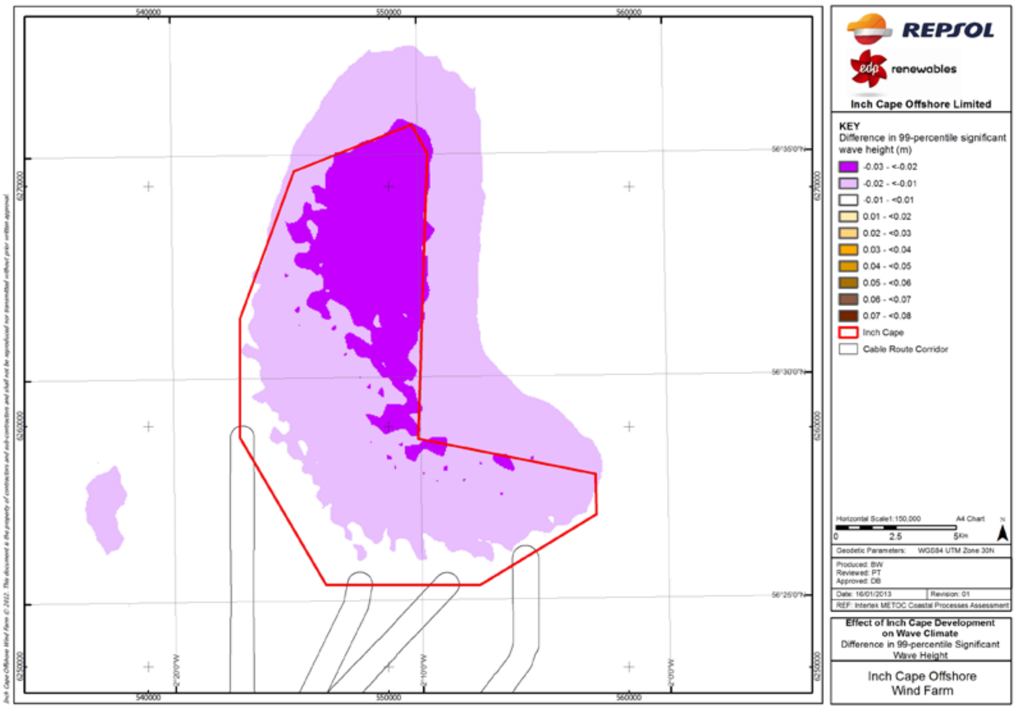


Figure 10.15: Difference in 99-percentile Significant Wave Height (m) in the Development Area – Near-Field



Suspended Sediment Concentrations

143 The ability of the metocean regime to mobilise seabed sediments is described by the relationship of the bed shear stress to the critical shear stress. These terms are explained in *Section 10.2.6* (Seabed Features, SSC and Sediment Transport Regime).

144 During Development Area operation and maintenance in the Development Area, the slightly greater frequency of sediment mobilisation predicted in some parts of the Development Area may give rise to more frequent and periodically higher concentrations of sediment in the water column. However, the largely sandy nature of the Development Area means that the majority of any re-suspended sediments will return very quickly (within minutes) to the bed.

145 The small increase in critical shear stress exceedance may have a greater impact on the re-suspension of silts. These fractions of the sediment are re-suspended more readily, and once in suspension are susceptible to transport by tidal and residual currents. An increase in the frequency may potentially lead to a medium-to-long term winnowing (removal) of the silts from the surface sediments across the Development Area. This is of little importance as the silt forms only a minor fraction (typically <2 per cent across the Development Area) of the seabed sediments and removal has no direct consequence for the sediment stability.

146 In the event that re-burial of the inter-array cables is required during the lifetime of the works in the Development Area, it is considered that the resultant impacts on SSC will be no greater than those due to the initial burial (see *Section 10.5.1*).

Sediment Transport Regime

147 The sediment transport regime in the Development Area will experience only small changes during the operational phase, with the predicted frequency of exceedance of the critical shear stress changing typically by ±1 - 2 per cent. This change is restricted to the immediate vicinity of the Development Area. The frequency and duration of this change is considered to be permanent during the lifetime of the works in the Development Area. The changes in the exceedance of the critical shear stress due to the development are shown in Figure 10.16 and Figure 10.17. These show exceedance due to the combined current and wave shear stress, when taken as a mean across a wave cycle (i.e. the full wavelength from crest to crest or trough to trough), and when considering the maximum wave orbital velocity (i.e. the maximum speed of the water particles in their circular motion due to the passing of a wave).

148 Results from the modelling predict that there will be no important change to the residual sediment transport pathway as shown in Figure 10.18. This figure shows a comparison of the sediment transport pathway under the pre- and post-development metocean regimes. Based on analysis of the field data (*Appendix 12A*) and the hydrodynamic and wave modelling, regular, medium/large scale changes in the general bed level (bathymetry) are not expected to occur due to the Development Area infrastructure.

Figure 10.16: Difference in the Exceedance of Critical Shear Stress (%) in the Development Area – Based on the Combined (Currents Plus Waves) Mean Bed Shear Stress – Near-Field

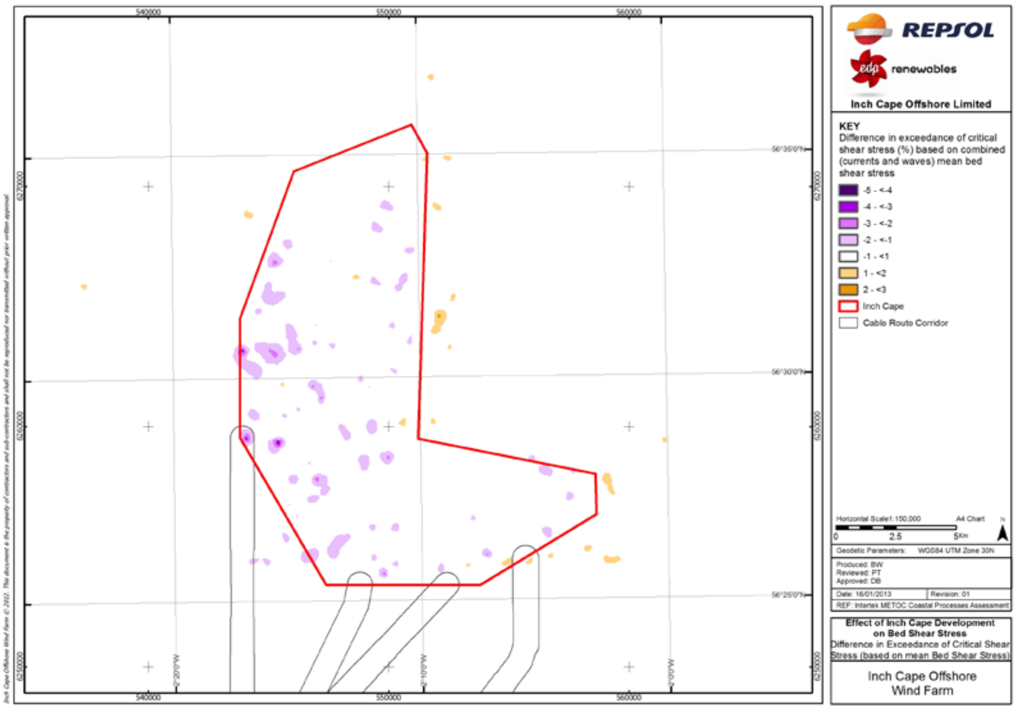


Figure 10.17: Difference in the Exceedance of Critical Shear Stress (%) in the Development Area – Based on the Combined (Currents Plus Waves) Maximum Bed Shear Stress – Near-Field

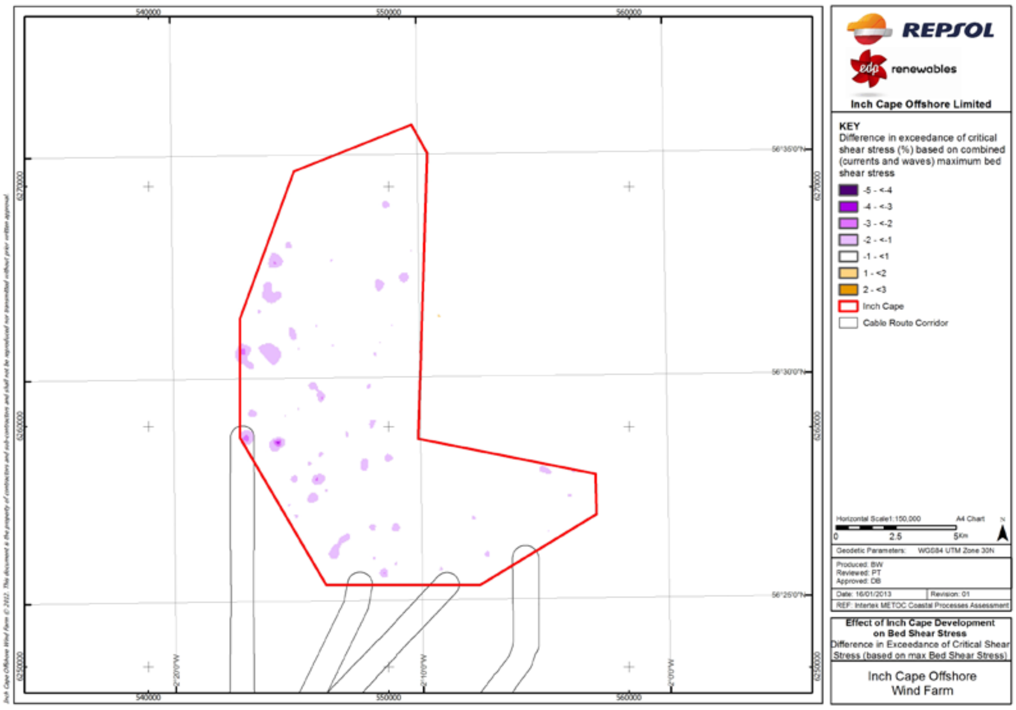
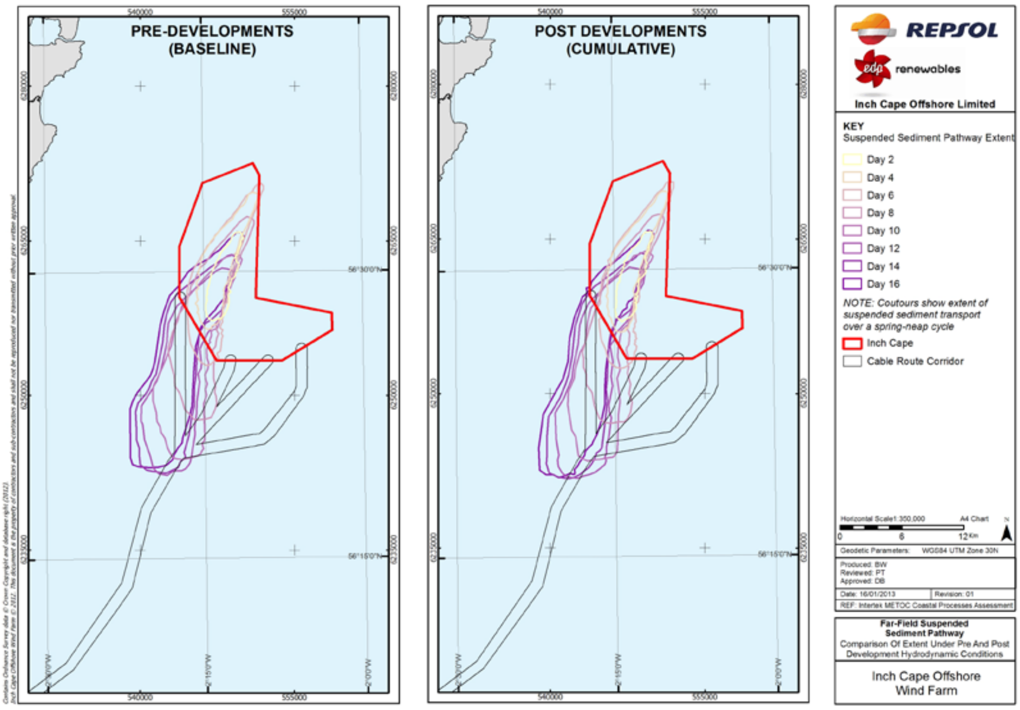


Figure 10.18: Impact of Works in the Development Area on Suspended Sediment Pathways



<u>**Seabed Features – Impacts due to the Modified Hydrodynamic and Wave Regimes**</u>

149 The predicted changes in the bed stress due to waves and currents in combination (described under *Sediment Transport Regime* above) indicate only low increases in the time (frequency) that the critical bed shear stress for sediment transport is exceeded. Based on analysis of the site-specific PSD (*Appendix 12A*) and the hydrodynamic and wave modelling, no dramatic changes in seabed morphology are predicted. The small absolute change in the critical shear stress exceedance will drive only small changes to seabed morphology processes that are within the range that occurs naturally across the Development Area. Although the Development Area is not considered to be wave-dominated in terms of sediment transport, it is the larger waves, rather than tidal currents, which lead to the excess bed shear stress required for the mobilisation of sediment. Therefore, any resulting bedforms will be stationary and ephemeral rather than translational (migratory – which form under tidal conditions), and will be limited to within the Development Area. The baseline classification for the Development Area as 'slightly mobile' during summer months and 'moderately mobile' during winter months will remain unchanged post-development.

150 Since the frequency with which the critical shear stress is exceeded changes by up to about two per cent in the Development Area, the magnitude of the effect on seabed features is considered to be low in the near-field. The magnitude of the effect is negligible in the far-field.

151 The sensitivity of seabed features is low (see *Section 10.4.1*).

152 The significance of the impact is therefore minor in the near-field and negligible/minor in the far-field.

Seabed Features – Impacts of Sediment Deposition from Cable Re-burial

153 In the event that re-burial of the inter-array cables is required during the lifetime of the works in the Development Area, it is considered that the resultant impacts on seabed features will be no greater than those due to the initial burial (see *Section 10.5.1* for this assessment).

Designated Nature Conservation Sites with Geological Features

154 Predicted impacts from the works within the Development Area on designated sites with geological features during the operational phase can be summarised as follows:

- A predicted change in tidal level (high or low water on spring or neap tides) of less than one millimetre at all designated sites, which equates to less than 0.02 per cent of the mean spring tidal range;
- A predicted maximum change in current speed of less than 0.4 cm/s at all designated sites, which equates to considerably less than one per cent of the peak current on a mean spring tide;
- A predicted maximum change in significant wave height of less than 0.01 m, which equates to considerably less than one per cent of the average significant wave height, or 0.2 per cent of the highest significant wave likely in any one year; and
- A predicted change of considerably less than one per cent in the exceedance of the critical bed shear stress.

155 At most designated sites, the predicted changes are much lower than the upper limits stated above, dropping to effectively zero at many of the sites (i.e. well below the limit of what would be measurable).

156 Since the frequency with which the critical shear stress is exceeded changes by less than one per cent, and tidal levels, currents and wave heights change by less than one per cent of their typical values, the magnitude of the effect on designated sites with geological features is considered to be negligible in the far-field (there are no such sites in the near-field). This applies to both low tolerance sites such as sand banks and high tolerance sites such as maritime cliffs.

157 The sensitivity of designated sites is high (see *Section 10.4.1*).

158 The significance of the impact is therefore minor/moderate in the far-field.

Surfing and Leisure Beaches

159 Predicted quantified changes from the works within the Development Area on surfing and leisure beaches during the operational phase can be summarised as follows:

- A predicted change in tidal level (high or low water on spring or neap tides) of less than 0.5 mm at all surfing and leisure beaches, which equates to less than 0.01 per cent of the mean spring tidal range;
- A predicted maximum change in current speed of less than 0.4 cm/s at all surfing and leisure beaches, which equates to considerably less than one per cent of the peak current on a mean spring tide;
- A predicted maximum change in significant wave height of less than 0.01 m, which equates to considerably less than one per cent of the average significant wave height, or 0.2 per cent of the highest significant wave likely in any one year;
- Only very small predicted changes to wave period and direction; and
- A predicted change of considerably less than one per cent in the exceedance of the critical bed shear stress.

The impacts of these changes are assessed in *Section 21.6 - 21.8*.

Summary of Effects

160 Table 10.14 summarises the predicted effects on metocean and coastal processes due to the Development Area operation and maintenance phase.

Table 10.14: Summary of Effects – Operation and Maintenance Phase in the Development Area

Process	Effect
Water levels	Up to ±1.5 mm or approximately 0.03% of the mean spring tidal range in the Development Area.
Currents	Between +0.02 m/s and -0.04 m/s in the Development Area, which is equivalent to between 3% and 7% of peak currents on a mean spring tide.
Waves	Up to 0.03 m in the Development Area, which is about 2% of average significant wave height, or 0.5% of the highest significant wave likely in any one year.
Sediment transport regime	Frequency of exceedance of the critical shear stress changes by ±1 - 2% in the Development Area.

10.5.3 Effects of Decommissioning

161 The potential effects of decommissioning are considered to be equivalent to and potentially lower than the worst case effects assessed for the construction phase. The approach to decommissioning is described in *Section 7.12*. A decommissioning plan will be prepared in accordance with the requirements of the *Energy Act 2004* (see *Section 3.2.5*) and will be subject to approval from the Department of Energy and Climate Change (DECC) prior to implementation.

10.6 Impact Assessment – Offshore Export Cable Corridor

162 Full details of the impact assessment, including all relevant plots showing the size and spatial extent of predicted impacts, are provided in *Appendix 10A* and its Annexes. A summary of results and representative plots are provided within this chapter. The assessment is divided into the site specific, or near-field assessment, and the regional, or far-field assessment where relevant.

163 *Section 10.3* should be consulted for details of the assessment methodology.

10.6.1 Effects of Construction

Water Levels, Currents and Wave Heights

164 The effects of the construction on water levels, currents and wave heights during the construction phase of the Offshore Export Cable will be very small. The additional infrastructure involved in construction, such as ploughing or trenching vessels, will cause no meaningful change in metocean conditions. This is because the installation vessels and associated infrastructure will be too small, spatially dispersed and transient to cause any meaningful change in the hydrodynamic or wave regimes.

Suspended Sediment Concentrations

165 In assessing SSC impacts from Offshore Export Cable burial, both the intertidal and subtidal zones have been considered.

166 The process of Offshore Export Cable burial in the subtidal zone might lead to very localised increases in SSC. Averaged across an FTMS model element, which are approximately 200 m in size along the Offshore Export Cable Corridor, the predicted SSC due to cable burial has values typically between three mg/l – 10 mg/l above background concentrations, with peaks up to 300 mg/l. Higher concentrations, probably in the thousands of mg/l, will occur very close to the cable but these will be limited to within a few tens of metres of burial activities. Most of the resulting sediment plume will settle out within tens or a few hundred metres of the Export Cable, over a period of seconds or minutes. The finest (mud and silt) sediment fractions will persist for longer in the water column and be carried further, but even these will generally not be advected beyond the near-field vicinity of the Export Cable (< 3 km), and will settle out within a few hours of disturbance.

167 In the intertidal zone, any construction activities undertaken at high water will cause impacts that are similar to those described above for the subtidal zone. Construction activities in the intertidal zone undertaken at low water will cause no immediate impact on SSC, but may subsequently cause an impact on the rising tide. This impact will be no greater than that predicted above for the subtidal zone, which conservatively assumes that the entire volume of the trench is suspended during burial by energetic means. Furthermore, the increase in SSC above background levels due to cable burial activities may be less pronounced in the intertidal zone, since locally elevated SSC may result naturally from the action of waves in shallow water.

168 The above results hold for both the Cockenzie and Seton Sands landfall sites, since these have similar environments in respect of potential SSC impacts.

Sediment Transport Regime

169 Installation of the Offshore Export Cable will cause no meaningful change to the metocean environment, and only spatially limited and short-lived increases in SSC. It is therefore considered that Offshore Export Cable construction activities will cause no meaningful change to the sediment transport regime.

170 It is assumed that the Export (and inter-array) Cables will be Cables will be suitably buried. If burial is not practicable then the option exists to use rock placement or other methods for protection where cable burial is not possible. Rock protection is a common practice, and an assessment is generally undertaken to determine a stable rock size for the oceanographic conditions expected along the Export Cable (the required protection may vary as wave exposure increases into shallower waters). Since the rocks will be substantially larger than the surrounding sediment along the Offshore Export Cable Corridor, scour may occur around the periphery of the rock mound, a phenomenon termed 'secondary scour'. Rates of secondary scour are typically very low, highly localised, and in the form of a strip running adjacent to the rock mound. Greater secondary scour rates might be expected in the shallowest part of the Offshore Export Cable Corridor, where sediment re-suspension by waves ordinarily occurs. This can be prevented by either placement of a fine gravel filter layer next to the rocks, or through use of an anti-scour apron. The former is more widely used. Where the Export Cable cannot be buried, and rock armouring is required, scour may therefore occur. A study will be undertaken to ensure the rock is graded to minimise scour once the final cable route and laying methods have been determined.

Seabed Features – Impacts of Sediment Deposition from Cable Burial

171 As stated in *Suspended Sediment Concentrations* above, the deposition footprint resulting from the Export Cable burial process is predicted to extend to a maximum of three kilometres either side of the Offshore Export Cable Corridor. However, the more distant parts of this deposition footprint will be very thin – typically <1 mm beyond one kilometre distance. Peak deposition depths up to five millimetres are predicted, although this represents an average value across an FTMS grid cell which have a spatial resolution of approximately 200 m along the Offshore Export Cable Corridor. Within each FTMS grid cell there will be spatial variation in the settled depth, and a depth in the order of centimetres is possible very close to the Export Cable (within metres or a few tens of metres of it).

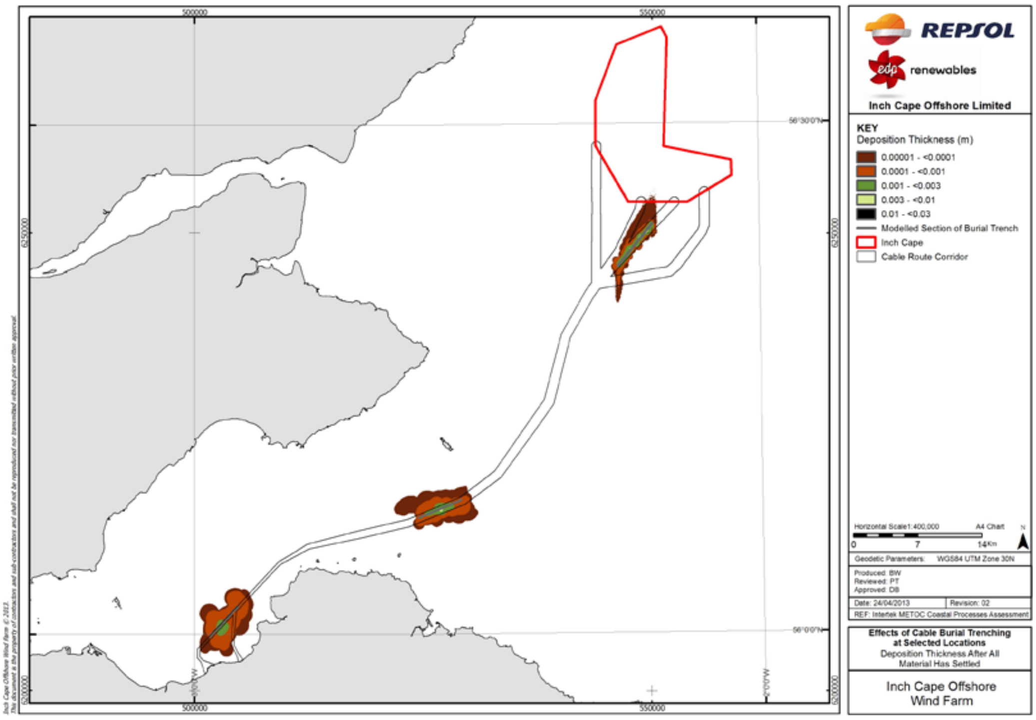
172 The predicted deposition footprints at the three representative modelled locations along the Offshore Export Cable Corridor are shown in Figure 10.19. The predicted footprint is thin and the deposited material will be very similar to the surface sediment.

173 Since deposition thicknesses are low and the deposition footprint is mostly confined to the immediate area of the Offshore Export Cable Corridor, the magnitude of this effect on seabed features is considered to be low in the near-field. The magnitude of the effect is negligible in the far-field.

174 The sensitivity of seabed features is low (see *Section 10.4.1*).

175 The significance of the impact is therefore minor in the near-field and negligible/minor in the far-field.

Figure 10.19: Deposition Thickness due to Cable Burial – Three Selected Locations in the Offshore Export Cable Corridor



<u>**Designated Nature Conservation Sites with Geological Features**</u>

176 None of the designated sites is predicted to experience any meaningful change in metocean processes or the sedimentary environment due to Offshore Export Cable construction activities. SSC due to construction activities are predicted to be effectively zero at these sites, and will cause no measurable change from background concentrations.

177 Because impacts are small and/or transient, the magnitude of impacts from Offshore Export Cable construction activities on designated sites with geological features is negligible in the far-field (there are no such sites in the near-field). This applies to both low tolerance sites such as sand banks and high tolerance sites such as maritime cliffs.

178 The sensitivity of designated sites is high (see *Section 10.4.1*).

179 The significance of the impact is therefore minor/moderate in the far-field.

Surfing and Leisure Beaches

180 None of the surfing and leisure beaches is predicted to experience any meaningful change in metocean processes or the sedimentary environment due to Offshore Export Cable construction activities.

181 The impacts of these changes are assessed in *Section 21.6 - 21.8.*

Summary of Effects

182 Table 10.15 summarises the predicted effects on metocean and coastal processes due to the Offshore Export Cable construction phase.

Table 10.15: Summary of Effects – Offshore Export Cable Construction Phase

Process	Effect
Water levels, currents, waves	No meaningful change.
SSC	Peaks up to 300 mg/l (spatial average across a model grid cell) due to cable burial, most settling out within 10s to 100s of metres from the cable. Finer sediment fractions will not be advected beyond the near-field vicinity of the cable (< 3 km).
Sediment footprints	Sediment settling depths up to 5 mm (spatial average across a model grid cell) due to cable burial.

10.6.2 Effects of Operation and Maintenance

Water Levels, Currents and Wave Heights

183 It is expected that the Export Cable will predominantly be buried. In cases where this is not practicable, rock placement or other protection techniques may be employed. In all cases, the infrastructure of the Offshore Export Cable Corridor will present only a very small profile to currents and waves, and will therefore not influence these processes in any meaningful way.

184 The presence of maintenance vessels will cause no meaningful change in metocean conditions. This is because the vessels will be too small, spatially dispersed and transient to cause any meaningful change in the hydrodynamic or wave regimes.

Suspended Sediment Concentrations and Sediment Transport Regime

185 It is expected that the Offshore Export Cable will predominantly be buried. In cases where this is not practicable, rock placement or other protection techniques may be employed. It is not anticipated that there will be any large or sustained changes to SSC or the sediment transport regime during normal operation of the Export Cable. If maintenance or remedial

action (such as re-burial) is required, it is considered that the resulting effects will be similar to or less than those caused by construction activities (see *Section 10.6.1*).

Seabed Features

186 Seabed features in the Offshore Export Cable Corridor will not be subject to large or sustained changes during normal operation of the Export Cable. If maintenance or remedial action (such as re-burial) is required, it is considered that the resulting effects will be similar to or less than those caused by construction activities (see *Section 10.6.1*).

187 The magnitude of this effect on seabed features is therefore considered to be low in the near-field. The magnitude of the effect is negligible in the far-field.

188 The sensitivity of seabed features is low (see *Section 10.4.1*).

189 The significance of the impact is therefore minor in the near-field and negligible/minor in the far-field.

Designated Nature Conservation Sites with Geological Features

190 None of the designated sites is predicted to experience any meaningful change in metocean processes or the sedimentary environment due to Offshore Export Cable operation and maintenance activities. The infrastructure of the Offshore Export Cable Corridor will present only a very small profile to currents and waves, and will therefore not influence these processes in any meaningful way. If maintenance or remedial action is required, it is considered that the resulting effects will be similar to, or less than, those caused by construction activities (see *Section 10.6.1*).

191 Because impacts are small and/or transient, the magnitude of impacts from Offshore Export Cable operation and maintenance activities on designated sites with geological features is therefore considered to be negligible in the far-field (there are no such sites in the near-field). This applies to both low tolerance sites such as sand banks and high tolerance sites such as maritime cliffs.

192 The sensitivity of designated sites is high (see *Section 10.4.1*).

193 The significance of the impact is therefore minor/moderate in the far-field.

Surfing and Leisure Beaches

194 None of the surfing and leisure beaches is predicted to experience any meaningful change in metocean processes or the sedimentary environment due to Offshore Export Cable operation and maintenance activities.

195 The impacts of these changes are assessed in *Section 21.6 - 21.8.*

Summary of Effects

196 Table 10.16 summarises the predicted effects on metocean and coastal processes due to the Offshore Export Cable operation and maintenance phase.

Table 10.16: Summary of Effects – Offshore Export Cable Operation and Maintenance Phase

Process	Effect
Water levels, currents, waves	No meaningful change.
SSC	Similar to the construction phase (see Table 10.15).
Sediment footprints	Similar to the construction phase (see Table 10.15).

10.6.3 Effects of Decommissioning

197 The potential effects of decommissioning are considered to be equivalent to and potentially lower than the worst case effects assessed for the construction phase. The approach to decommissioning is described in *Section 7.12*. A decommissioning plan will be prepared in accordance with the requirements of the *Energy Act 2004* (see *Section 3.2.5*) and will be subject to approval from the DECC prior to implementation.

10.7 Cumulative Impacts

198 Two levels of cumulative impact have been considered:

- Cumulative impacts of the Wind Farm and the OfTW (the Project); and
- Cumulative impacts of the Project (the Wind Farm and OfTW) and other projects.

199 These two levels of cumulative impact are discussed separately in this chapter in *Sections 10.7.1 – 10.7.3 and 10.7.4 – 10.7.6* respectively. With respect to the assessment of cumulative impacts of the Project with other projects, a number of developments and activities were identified with the potential to interact with the Project. These are detailed in *Section 4.7.*

10.7.1 Cumulative Impacts of the Wind Farm and OfTW during Construction

Water Levels, Currents and Wave Heights

200 The cumulative impacts of the Wind Farm and OfTW on water levels, currents and wave heights during the construction phase will be proportionally less than during the operational phase. The additional infrastructure involved in construction, such as dredging vessels or jack-up rigs, will cause no meaningful change in metocean conditions. This is because the installation vessels and associated infrastructure will be too small, spatially dispersed and transient to cause any meaningful change in the hydrodynamic or wave regimes.

Suspended Sediment Concentrations and Sediment Transport Regime

201 The primary impacts from the Wind Farm and OfTW on SSC and the sediment transport regime during the construction phase may arise from:

- Dredging for GBS preparation, and the associated sediment deposition; or
- Scour and deposition around jacket structures, in the event that this design option is taken forward in preference to GBSs; and
- Burial operations for the inter-array cables and Offshore Export Cable.

202 The independent studies of these processes for the works in the Development Area (see *Section 10.5.1*) and Offshore Export Cable Corridor (see *Section 10.6.1*) indicate that effects are both spatially localised and short-lived. GBS dredging activities are likely to lead to only a very small increase in SSC (less than 30 mg/l beyond a few hundred metres from the discharge point) for a brief period following release. Impacts due to the energetic burial of Export Cables and inter-array cables are likely to be of a similar magnitude (no more than 30 mg/l beyond a few hundred metres from the discharge point). If dredging and cable burial coincide, the resultant rise in SSC could be up to 60 mg/l, or even more if these activities occur in very close proximity. These concentrations are high compared to normal measured background levels (which are less than 15 mg/l on average, but likely to exceed 80 mg/l during winter storms). However, such concentrations will be limited in both space (extending no more than a few kilometres from the discharge point) and time (settling out within a few hours of release). It is therefore considered that the cumulative effects on SSC and the sediment transport regime due to the Wind Farm and OfTW will be no greater than those effects already evaluated for the individual construction activities.

Seabed Features

203 The primary impacts from the Wind Farm and OfTW on seabed features during the construction phase may arise from:

- Deposition of sediment dredged during GBS preparation; or
- Deposition of sediment scoured from around jacket structures, in the event that this design option is taken forward in preference to GBSs; and
- Deposition of sediments during burial operations for the inter-array cables and Offshore Export Cable.

204 The independent studies of these processes for the Development Area works (see *Section 10.5.1*) and Offshore Export Cable Corridor works (see *Section 10.6.1*) indicate that effects are both spatially localised and short-lived. It is therefore considered that the cumulative effects on seabed features due to the Project will be no more significant than those effects already evaluated for the individual construction activities. As such, the chapter sections referenced above will be consistent for the magnitude of effects, the sensitivity of the receptor, and the significance of impacts.

205 Since the impacts are both small and transient the magnitude of this effect on seabed features is considered to be low in the near-field and negligible in the far-field,

206 The sensitivity of seabed features is low (see *Section 10.4.1*).

207 The significance of the impact is therefore minor in the near-field and negligible/minor in the far-field.

Designated Nature Conservation Sites with Geological Features

208 None of the designated sites with geological features is predicted to experience any meaningful change in metocean processes or the sedimentary environment due to cumulative Wind Farm and OfTW construction activities. The closest receptor is the potential Firth of Forth Banks Complex MPA. This is likely to experience only a very small increase in SSC (probably less than 30 mg/l) for a brief period during nearby dredging activities. Impacts due to the energetic burial of inter-array cables are likely to be of a similar magnitude (no more than 30 mg/l). If dredging and cable burial coincide, the resultant rise in SSC could be up to 60 mg/l at the potential Firth of Forth Banks Complex MPA. These concentrations are high compared to normal measured background levels (which are less than 15 mg/l on average, but likely to exceed 80 mg/l during winter storms). However, such concentrations will be limited in both space (extending no more than a few kilometres from the discharge point) and time (settling out within a few hours of release).

209 Settled sediment depths due to GBS dredging activities will be low – much less than one centimetre at the potential Firth of Forth Banks Complex MPA. Settled sediment depths due to the energetic burial of inter-array cables will be smaller still (less than one millimetre).

210 Since all other designated sites are much further from the Project than the potential Firth of Forth Banks Complex MPA, they will experience very much lower impacts. Impacts at all designated sites will be small and transient. It is therefore considered that the cumulative effects on designated sites with geological features due to the Wind Farm and OfTW will be no more significant than those effects already evaluated for the individual construction activities.

211 The magnitude of impacts from Wind Farm and OfTW construction activities on designated sites with geological features is therefore negligible in the far-field (there are no such sites in the near-field). This is because impacts are small and/or transient. This applies to both low tolerance sites such as sand banks and high tolerance sites such as maritime cliffs.

212 The sensitivity of designated sites is high (see *Section 10.4.1*).

213 The significance of the impact is therefore minor/moderate in the far-field.

Surfing and Leisure Beaches

214 None of the surfing and leisure beaches is predicted to experience any meaningful change in metocean processes or the sedimentary environment due to cumulative Project construction activities.

215 The impacts of these changes are assessed in *Section 21.6 - 21.8.*

10.7.2 Cumulative Impacts of the Wind Farm and OfTW during Operation and Maintenance

Water Levels, Currents and Wave Heights

216 Cumulative effects on water levels, currents and wave heights due to the Wind Farm and OfTW during operation will reflect combined effects from the works in the Development Area and the Offshore Export Cable Corridor. It is expected that the Offshore Export Cable will predominantly be buried. In cases where this is not practicable, rock placement or other protection techniques may be employed. In all cases, the infrastructure of the Offshore Export Cable Corridor will present only a very small profile to currents and waves, and will therefore not influence these processes in any meaningful way.

217 The presence of maintenance vessels will cause no meaningful change in metocean conditions. This is because the vessels will be too small, spatially dispersed and transient to cause any meaningful change in the hydrodynamic or wave regimes.

218 Therefore, the cumulative effects of the Wind Farm and OfTW on water levels, currents and wave heights during operation will be equivalent to those from the works in the Development Area alone, as described in *Section 10.5.2*.

Suspended Sediment Concentrations and Sediment Transport Regime

219 Cumulative effects on SSC and the sediment transport regime due to the Wind Farm and OfTW during operation will be primarily due to:

- Modification of the hydrodynamic regime by Development Area infrastructure, which will affect the frequency of exceedance of critical bed shear stress; and
- Potential maintenance activities on the Export and inter-array Cables (such as re-burial).

220 The analysis of these effects for the Development Area works (see *Section 10.5.2*) and the Offshore Export Cable Corridor works (see *Section 10.6.2*) suggests that the cumulative effects will be no greater than the effects of the individual processes or activities.

Seabed Features

221 The Development Area works impact assessment found that changes to seabed features during the operational phase of the Wind Farm will be confined to the Development Area (the significance of the effect is considered to be minor in the near-field and be negligible/minor in the far-field). The Offshore Export Cable Corridor works assessment found that there would be no large or sustained changes to seabed features during normal

cable operation (the significance of the effect is considered to be minor in the near-field and be negligible/minor in the far-field).

222 Given the limited spatial extent of potential impacts, it is not considered that cumulative impacts on seabed features during the operational phase of the Project will be no more significant than impacts on the works in the Development Area or Offshore Export Cable Corridor in isolation. Therefore, the significance of the cumulative impact is taken to be the worst case from either the works in the Development Area or the Offshore Export Cable Corridor, i.e. minor in the near-field and be negligible/minor in the far-field

Designated Nature Conservation Sites with Geological Features

223 It is considered unlikely that operation and maintenance activities within the Offshore Export Cable Corridor will cause any meaningful effects at the designated sites. Therefore, cumulative effects on operation and maintenance activities due to the Project will be equivalent to those due to the Development Area works alone.

224 The magnitude of the effect on designated sites with geological features is considered to be negligible in the far-field (there are no such sites in the near-field). This applies to both low tolerance sites such as sand banks and high tolerance sites such as maritime cliffs.

225 The sensitivity of designated sites is high (see *Section 10.4.1*).

226 The significance of the impact is therefore minor/moderate in the far-field.

Surfing and Leisure Beaches

227 It is considered unlikely that operation and maintenance activities within the Offshore Export Cable Corridor will cause any meaningful effects at the surfing and leisure beaches. Therefore, cumulative effects on operation and maintenance activities due to the Project will be equivalent to those due to the Development Area works alone.

228 The impacts of these changes are assessed in *Section 21.6 - 21.8*.

10.7.3 Cumulative Impacts of the Wind Farm and OfTW during Decommissioning

229 The potential effects of decommissioning are considered to be equivalent to and potentially lower than the worst case effects assessed for the construction phase. The approach to decommissioning is described in *Section 7.12*. A decommissioning plan will be prepared in accordance with the requirements of the *Energy Act 2004* (see *Section 3.2.5*) and will be subject to approval from the DECC prior to implementation.

10.7.4 Cumulative Impacts of the Project with Other Projects during Construction

230 An approach to the assessment of cumulative and in-combination impacts was presented in a *FTOWDG Discussion Document (FTOWDG, 2010)*. Potential cumulative effects were identified in the FTOWDG document as:

- alteration of local hydrodynamic conditions (i.e. waves and tidal flows);
- changes to the sedimentary environment (e.g. SSC, sediment transport pathways, patterns and rates, and sediment deposition); alteration of sedimentary seabed structures (e.g. sandbanks and other large scale bedforms); and
- indirect effects of the above changes on other environmental receptors (e.g. benthos, fisheries etc.).

231 In collaborating in the assessment of potential cumulative effects the FTOWDG members committed to commissioning a collaborative metocean survey (*see Section 10.2.1*) and a physical processes/regional modelling study (*see Section 10.4.3*). The Firth of Forth project developers remained separate due to timing of their project. ICOL and the developers of Neart na Gaoithe were assigned a copy of the FTMS to run a variety of scenarios relevant and specific to each EIA.

232 This assessment has utilised the FTMS to assess the potential cumulative changes to the metocean regime and sedimentary environment.

233 The requirement to assess cumulative impacts with other projects was assessed using the FTMS, by considering changes to the hydrodynamic regime with the Project in place. The Neart na Gaoithe and Firth of Forth projects taken forward to a full cumulative impact assessment, due to their proximity to the Project and the high likelihood of interaction.

234 The Cockenzie Power Station decommissioning and subsequent potential redevelopment lies close to the Offshore Export Cable Corridor. It was not considered that any aspects of this development would cause cumulative impacts with the Project since it has only very minor marine elements. In addition to this it is not anticipated that there will be major overlap in programme of activities that occur in proximity i.e. near shore cabling works and any shoreline works, due to the short duration of these elements of the works, and the known programme durations.

235 All other identified developments and activities were scoped out on the basis of distance from the Project; the predicted changes in metocean conditions due to the Wind Farm and OfTW were negligible at these sites (change in water level <0.5 cm; change in current speed <0.5 cm/s; change in wave height <1 cm).

236 Therefore, the metocean and coastal processes cumulative impact assessment has considered the Project being developed in conjunction with:

- The Neart na Gaoithe offshore wind farm and associated offshore transmission infrastructure; and

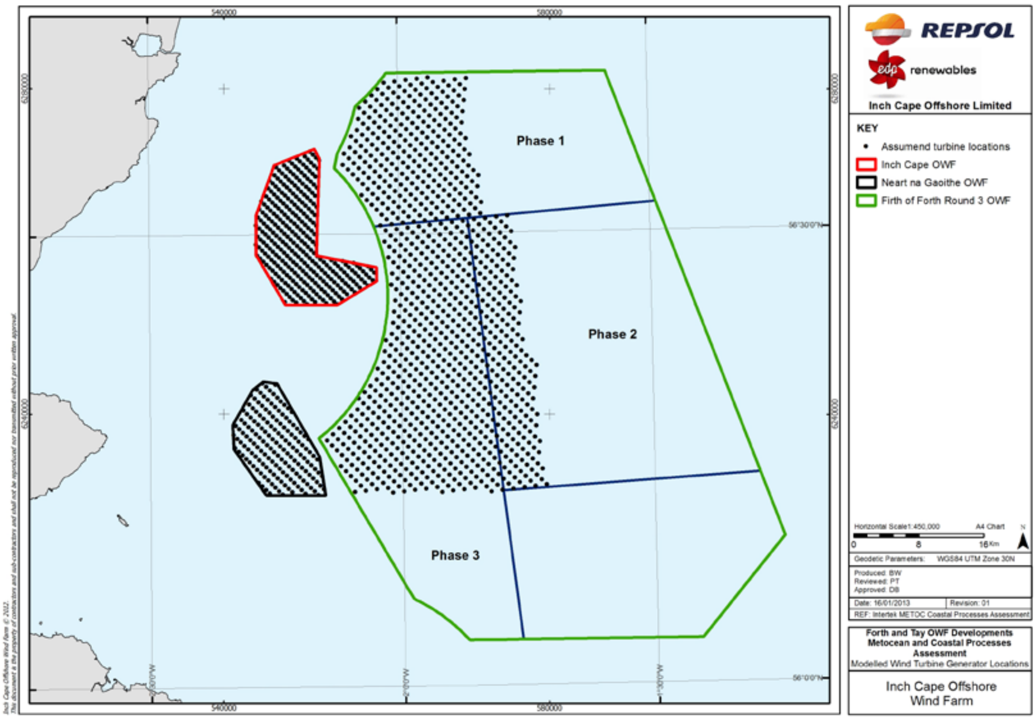
- The Firth of Forth wind farm and associated offshore transmission infrastructure.

237 Table 10.17 summarises the parameters for these two developments that were considered in the cumulative impact assessment. These parameters were agreed by FTOWDG members. In terms of presumed wind farm layouts, the modelled worst-case scenario is presented in Figure 10.20. Complete coverage of the entire sites with WTGs was assumed for both the Wind Farm and Neart na Gaoithe. Modelling complete coverage of the entire Firth of Forth project at maximum capacity would have resulted in the inclusion of more than 3,000 WTGs, which was considered extreme and unrepresentative of the worst case scenario. Since the actual location of the WTGs was unknown at the time of modelling, the 1,000 modelled WTGs were located as close as possible to the Development Area and the Neart na Gaoithe site, in order to ensure that modelled cumulative impacts were conservative. When the proposed location of the Phase 1 Firth of Forth WTGs became known in greater detail, it became clear that the modelled layout was indeed conservative, in terms of both the number of WTGs modelled and their proximity to the Development Area. It was decided to retain this modelled layout with its in-built conservatism in order to offset some of the uncertainties inherent in modelling-based metocean and coastal processes assessments.

Table 10.17: Summary of Scenario Definitions and Modelling Parameters – Other Projects

Type of Effect	Scenario Assessed
Operation	
Modification to water levels due to the presence (blocking effect) of subsurface structures.	Modification of hydrodynamics due to the presence of GBSs: For the Neart na Gaoithe offshore wind farm cumulative impact assessment: • Modelling parameters based on direct discussion with the Neart na Gaoithe project team. • Number of WTGs modelled = 126. This is a deliberately conservative number of WTGs that represents complete coverage of the Neart na Gaoithe site at a spacing of 1008 m x 630 m. • By contrast, the maximum likely number of the largest (worst case) WTGs is 75. • GBS diameter = 35 m. For the Firth of Forth offshore wind farm cumulative impact assessment modelling parameters based on Seagreen's *Scoping Report* (*Firth of Forth – Seagreen Wind Energy, 2011*): • Number of WTGs modelled = 1000. This is based on the awarded capacity of the development. • Spacing of WTGs = 856 m x 535 m, placed as close as possibly to the Development Area. Both the spacing and the location of the WTGs are conservative, and are designed to maximise cumulative impacts with the Wind Farm and Neart na Gaoithe. • GBS diameter = 50 m.

Figure 10.20: Modelled WTG Locations for the Cumulative Assessment



238 Operational phase cumulative effects have been explicitly considered in the modelling. For the construction and decommissioning phases, the other developments have not been modelled explicitly. Assessment of cumulative effects during the construction and decommissioning phases has therefore been based on the principle that the effects of the installation and decommissioning of individual WTGs within Neart na Gaoithe and Firth of Forth projects will be of no greater significance than the effects arising from the installation and decommissioning of individual WTGs within the Development Area. This is justified on the basis that installation and decommissioning activities tend to be short-lived and generally localised. As such, any potential overlap between these activities in adjacent developments will be both unlikely and of little importance.

239 All relevant details of the assessment, and plots showing predicted cumulative impacts, are provided in full in *Appendix 10A* and its Annexes. However, selected plots are included in this chapter.

240 Table 10.10 lists the physical processes that have been considered during the metocean and coastal processes assessment. The following processes and impacts have been assessed as part of the cumulative impact assessment:

- Changes to water levels, current speeds and wave heights;
- Changes to SSC;
- Changes to the sediment transport regime;
- Impacts on seabed features; and

- Impacts on designated sites with geological interest features.

Water Levels, Currents and Wave Heights

241 The cumulative impacts of the Project with other projects on water levels, currents and wave heights during the construction phase will be proportionally less than during the operational phase. The additional infrastructure involved in construction, such as dredging vessels or jack-up rigs, will cause no meaningful change in metocean conditions.

Suspended Sediment Concentrations and Sediment Transport Regime

242 The assessment of cumulative Project effects on SSC and the sediment transport regime (see *Section 10.7.1*) indicates that effects are both spatially localised and short-lived. It is therefore considered that the cumulative effects on these processes due to the Project with other projects will be no greater magnitude or significance than those effects already evaluated for the Project in isolation.

Seabed Features

243 The primary impacts from the Project with other projects on seabed features during the construction phase may arise from:

- Deposition of sediment dredged during GBS preparation; or
- Deposition of sediment scoured from around jacket structures, in the event that this design option is taken forward in preference to GBSs; and
- Deposition of sediments during burial operations for the inter-array cables and Offshore Export Cable.

244 The assessment of these processes for the Project (see *Section 10.7.1*) indicates that effects are both spatially localised and short-lived. It is therefore considered that the cumulative effects on seabed features due to the Project with other projects will be no greater magnitude or significance than those effects already evaluated for the Project. As such, *Section 10.7.1* should be consulted for details of the magnitude of effects, the sensitivity of the receptors, and the significance of impacts.

Designated Nature Conservation Sites with Geological Features

245 None of the designated sites with geological features is predicted to experience any meaningful change in metocean processes or the sedimentary environment due to cumulative construction activities of the Project with other projects. The closest receptor is the potential Firth of Forth Banks Complex MPA. This is likely to experience only a very small increase in SSC (probably less than 30 mg/l) for a brief period during nearby dredging activities, and a similar increase due to energetic cable burial (see *Section 10.7.1*). Settled sediment depths will be low – less than one centimetre in total due to combined dredging and cable burial activities.

246 Because impacts are small and/or transient, the magnitude of cumulative impacts from construction activities on designated sites with geological features is therefore negligible in the far-field (there are no such sites in the near-field). This applies to both low tolerance sites such as sand banks and high tolerance sites such as maritime cliffs.

247 The sensitivity of designated sites is high (see *Section 10.4.1*).

248 The significance of the impact is therefore minor/moderate in the far-field.

Surfing and Leisure Beaches

249 None of the surfing and leisure beaches is predicted to experience any meaningful change in metocean processes or the sedimentary environment due to cumulative construction activities of the Project with other projects.

250 The impacts of these changes are assessed in *Section 21.6 - 21.8.*

10.7.5 Cumulative Impacts of the Project with Other Projects during Operation and Maintenance

Water Levels and Tidal Currents

251 The predicted cumulative effects on water level due to the operational phase of the Project with other projects are more widespread than those from the Project on its own, with a change in water level predicted in the Forth and Tay estuaries, and as far south as Torness Head. Figure 10.21 presents the predicted cumulative changes to water level (mean spring tide). However, the predicted effect is very small (<0.07 per cent of the mean spring tidal range), and will not be measurable. Although some overlap of effects from different developments is predicted, the resulting change is still very small.

252 The predicted cumulative effects on tidal currents due to the Project with other projects are small (up to a maximum of seven per cent increase or decrease, depending on the location and the state of the tide), and localised to the near-field of each development. Figure 10.22 shows the predicted cumulative changes to peak tidal currents on a mean spring flood tide. No overlap of changes from any of the developments under the modelled 'worst case' scenario is predicted. (Note that, in Figure 10.22, it appears that the ICOL and Neart na Gaoithe offshore projects cause modification to the current speed while the Firth of Forth does not. This is in fact a consequence of the FTMS model resolution, which was coarser in the Firth of Forth project area. This relative coarseness causes the impacts to be spatially smoothed).

253 The changes noted here are due to the presence of GBS, which is the worst case scenario. The presence of maintenance vessels will cause no meaningful change in hydrodynamic conditions. This is because the vessels will be too small, spatially dispersed and transient to cause any meaningful cumulative change in the hydrodynamic regime.

Wave Heights

254 The predicted cumulative effects on wave heights due to the Project with other projects are small (up to 0.03 m reduction, which is <2 per cent of average significant wave height or <0.5 per cent of the highest significant wave likely in any one year), although the affected areas are larger than those for impacts from the Project on its own. Figure 10.23 shows the predicted cumulative changes to significant wave height (90 percentile).

255 The changes noted here are due to the presence of GBS, which is the worst case scenario. The presence of maintenance vessels will cause no meaningful change in wave conditions. This is because the vessels will be too small, spatially dispersed and transient to cause any meaningful cumulative change in the wave regime.

Figure 10.21: Cumulative Difference to Mean Spring Tide High Water Level (m) due to the Project with Other Projects

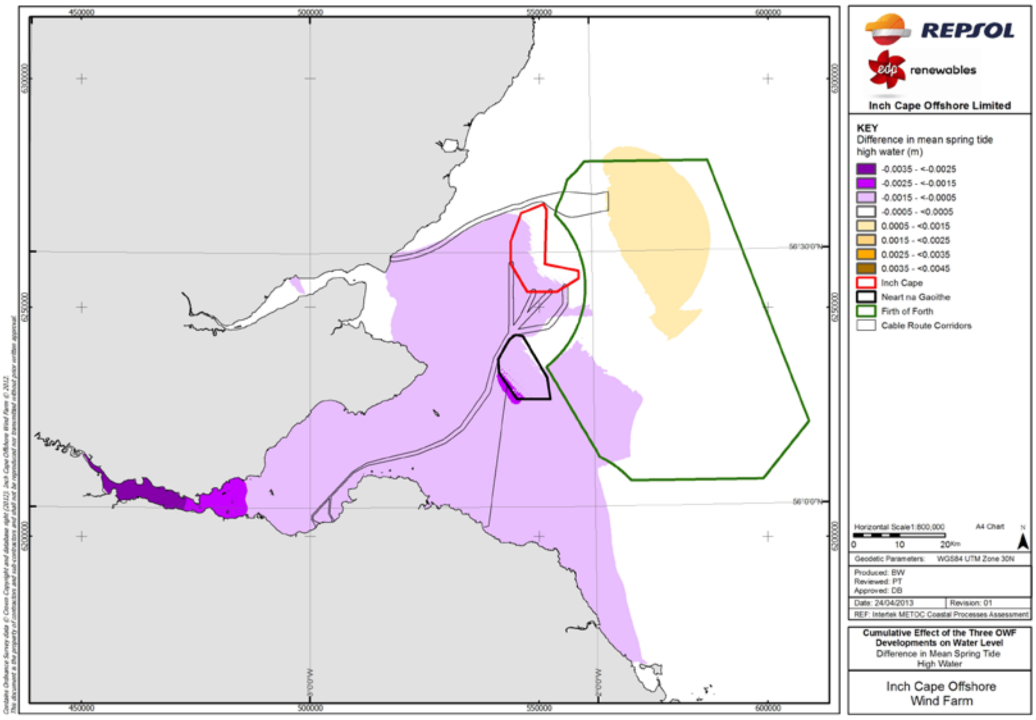


Figure 10.22: Cumulative Difference to Mean Spring Tide Peak Flood Current Speed (m/s) due to the Project with Other Projects

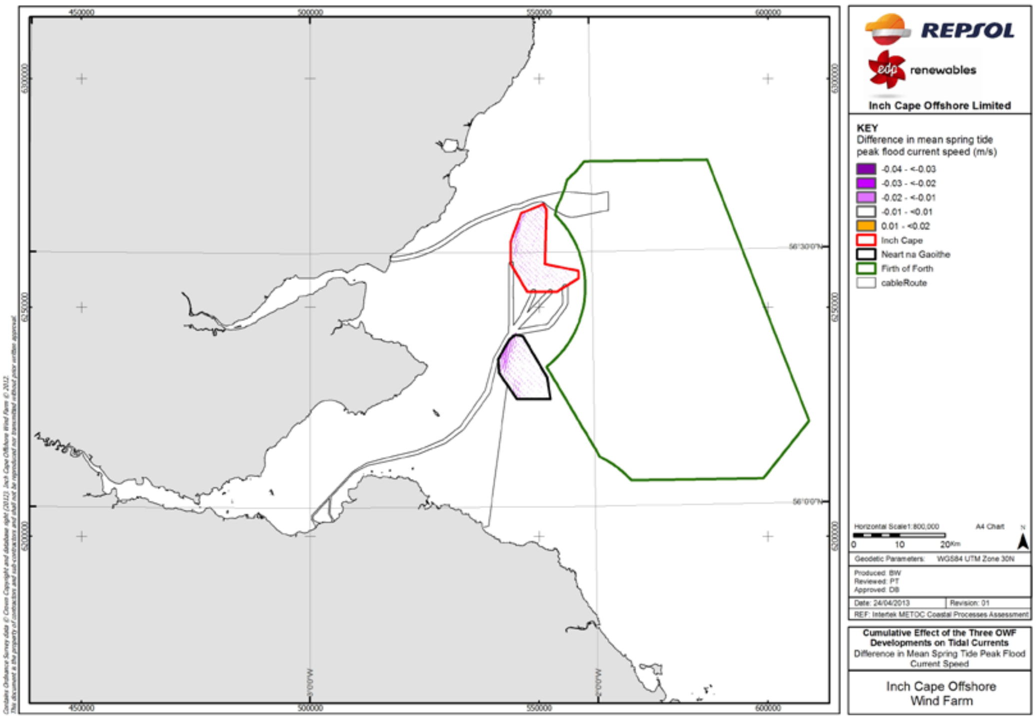
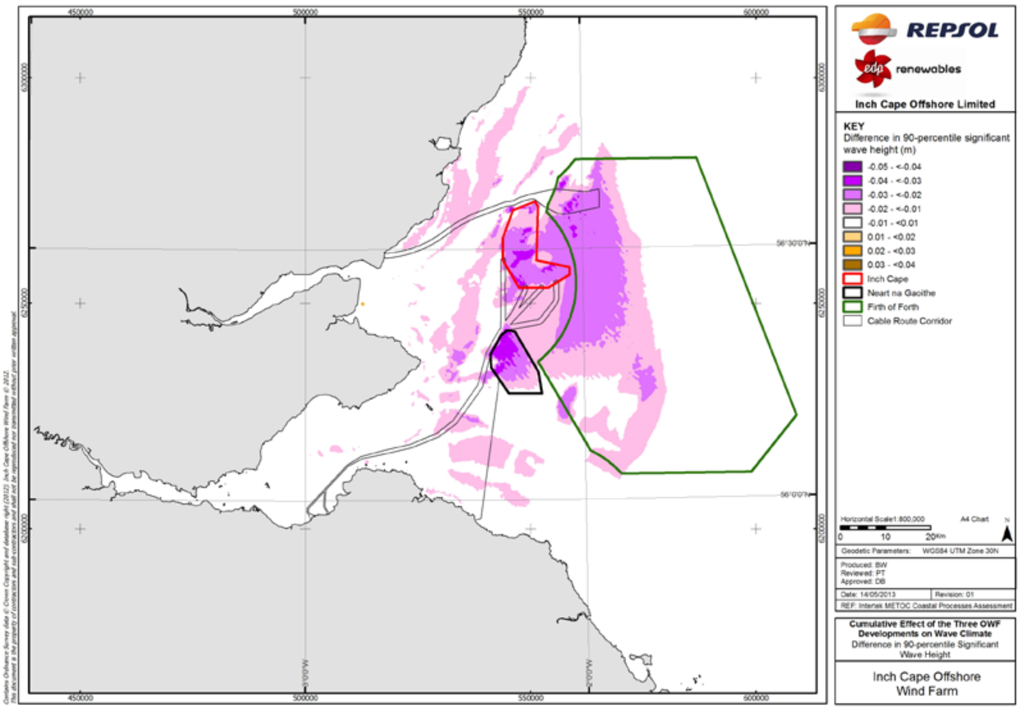


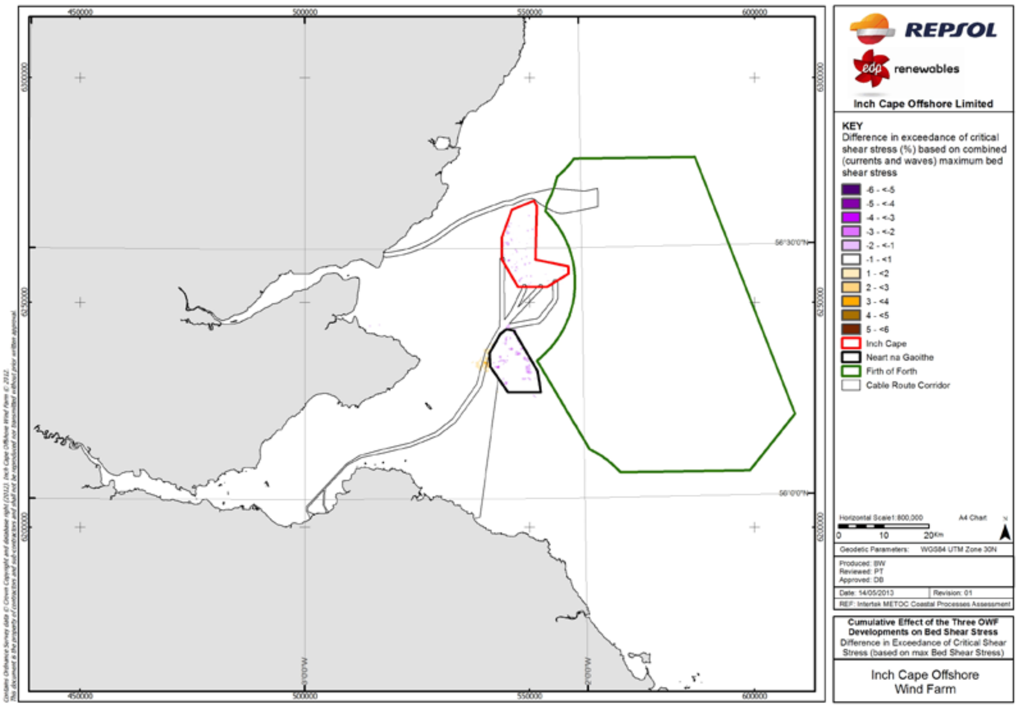
Figure 10.23: Cumulative Difference to 90-percentile Significant Wave Height (m) due to the Project with Other Projects



Suspended Sediment Concentrations and Sediment Transport Regime

256 The predicted cumulative changes to the sediment regime due to the Project with other projects are small, with the predicted exceedance of the critical shear stress changing typically by one per cent - two per cent in the Development Area (very similar to the changes predicted for the Project on its own). Meaningful cumulative changes in the critical shear stress exceedance are not predicted outwith the Development Area, with the exception of the Neart na Gaoithe and Firth of Forth project; clearly, these changes are due primarily to the addition of WTGs in these areas in the cumulative assessment modelling. Figure 10.24 shows the predicted cumulative changes to the exceedance of critical shear stress due to the combined wave and current bed shear stress (the maximum bed shear under peak wave orbital velocity is plotted). Since the predicted changes in both the near-field (Development Area) and far-field are very similar to those predicted for the Project on its own, it is concluded that the cumulative effects on SSC or the sediment transport regime due to the operational phase of the Project with other projects are no greater magnitude or significance than those due to the Project on its own.

Figure 10.24: Cumulative Difference to Exceedance of Critical Shear Stress (%) due to the Project with Other Projects – based on Combined (Currents Plus Waves) Maximum Bed Shear Stress



Seabed Features

257 The cumulative modelling predicts only low increases in the time (frequency) that the critical bed shear stress for sediment transport is exceeded, during operation of the Project with other projects. These increases are very similar to those predicted for the Project alone. No significant changes in seabed morphology are predicted. Therefore, the cumulative impacts

on seabed features due to the operational phase of the Project with other projects are no greater magnitude or significance than those due to the Project on its own.

258 Since the frequency with which the critical shear stress is exceeded changes by up to about two per cent in the Development Area, the magnitude of the effect on seabed features is considered to be low in the near-field. The magnitude of the effect is negligible in the far-field.

259 The sensitivity of seabed features is low (see *Section 10.4.1*).

260 The significance of the impact is therefore minor in the near-field and negligible/minor in the far-field.

Designated Nature Conservation Sites with Geological Features

261 Predicted impacts from the Project with other projects during the operational phase can be summarised as follows:

- a predicted change in tidal level (high or low water on spring or neap tides) of less than four millimetre at all designated sites, which equates to less than 0.1 per cent of the mean spring tidal range;
- a predicted maximum change in current speed of less than 0.8 cm/s at all designated sites, which equates to less than 1.5 per cent of the peak current on a mean spring tide;
- a predicted maximum change in significant wave height of less than 0.02 m, which equates to less than 1.5 per cent of the average significant wave height, or 0.4 per cent of the highest significant wave likely in any one year; and
- a predicted change of considerably less than one per cent in the exceedance of the critical bed shear stress.

262 At most designated sites, the predicted changes are much lower than the upper limits stated above, dropping to effectively zero at many of the designated sites (i.e. well below the limit of what would be measurable).

263 Since the frequency with which the critical shear stress is exceeded changes by less than one per cent, the magnitude of the effect on designated sites with geological features is considered to be negligible in the far-field (there are no such sites in the near-field). This applies to both low tolerance sites such as sand banks and high tolerance sites such as maritime cliffs.

264 The sensitivity of designated sites is high (see *Section 10.4.1*).

265 The significance of the impact is therefore minor/moderate in the far-field.

Surfing and Leisure Beaches

266 Predicted impacts from the Project with other projects on surfing and leisure beaches during the operational phase can be summarised as follows:

- a predicted change in tidal level (high or low water on spring or neap tides) of less than 1.5 mm at all surfing and leisure beaches, which equates to less than 0.03 per cent of the mean spring tidal range;
- a predicted maximum change in current speed of less than 0.4 cm/s at all surfing and leisure beaches, which equates to considerably less than one per cent of the peak current on a mean spring tide;
- a predicted maximum change in significant wave height of less than 0.02 m, which equates to less than 1.5 per cent of the average significant wave height, or 0.4 per cent of the highest significant wave likely in any one year;
- only very small predicted changes to wave period and direction; and
- a predicted change of considerably less than one per cent in the exceedance of the critical bed shear stress.

267 The impacts of these changes are assessed in *Section 21.6 - 21.8*.

10.7.6 Cumulative Impacts of the Project with Other Projects during Decommissioning

268 The potential effects of decommissioning are considered to be equivalent to and potentially lower than the worst case effects assessed for the construction phase. The approach to decommissioning is described in *Section 7.12*. A decommissioning plan will be prepared in accordance with the requirements of the *Energy Act 2004* (see *Section 3.2.5*) and will be subject to approval from the DECC prior to implementation.

10.8 Impact Interactions

269 Impact interactions relating to seabed features and designated nature conservation sites with geological interest features are discussed below. These are the receptors specifically identified for the metocean and coastal processes assessment.

270 The potential for individual impacts from the Project (i.e. the Wind Farm and the OfTW) to interact and create new, or more significant impacts on seabed features and designated nature conservation sites with geological interest features has been assessed. Identified mechanisms for impact interactions on these receptors would be through a combination of:

- direct impacts on suspended sediment concentrations or the seabed due to erosion (e.g. scour) or deposition of disturbed sediments; and
- indirect impacts due to a change in the sediment transport regime.

271 However, the assessment predicts that there will be no significant change in the sediment transport regime due to the Project, as is considered in *Section 10.5.1 and 10.7.1*. As such, no impact interactions have been identified.

272 The potential for impacts from other projects to interact with the impacts identified in the impact assessment and cumulative impact assessment to result in a greater effects has been assessed. As considered for the Project in isolation no such interactions are identified.

10.9 Mitigation

10.9.1 Development Area

273 The metocean and coastal processes assessment has adopted a realistic but conservative approach, and has assessed worst case scenario impacts of the Project in isolation and cumulatively. Despite this approach the assessment has concluded that changes to the metocean regime and the sedimentary environment within the near-field and far-field due to Development Area activities will be of no more than Minor/Moderate to the identified receptors.

274 Based on the outputs from this impact assessment, it has been concluded that the embedded mitigation detailed in *Section 10.1.3* is appropriate to reduce any potential residual impacts relating directly to metocean and coastal processes to an acceptable level. As such no additional mitigation will be required in the Development Area.

10.9.2 Offshore Export Cable Corridor

275 The metocean and coastal processes assessment has concluded that changes to the metocean regime and the sedimentary environment within the near-field and far-field due to Offshore Export Cable activities will be no more than Minor to the identified receptors both in isolation and cumulatively. For the purposes of this assessment, only effects indicated as Major and Moderate/Major will be regarded as being significant effects (see *Section 10.4*).

276 Based on the outputs from this impact assessment, it has been concluded that the embedded mitigation detailed in *Section 10.1.3* is appropriate to reduce any potential residual impacts relating directly to metocean and coastal processes to an acceptable level. As such no additional mitigation will be required in the Offshore Export Cable Corridor.

10.10 Conclusions and Residual Impacts

10.10.1 Development Area

277 The proposed activities may potentially affect the metocean and coastal processes in and around the Development Area.

278 The near-field and far-field impacts to metocean and coastal processes due to works in the Development Area have been assessed. The significance of impacts on seabed features and designated sites from the construction, operation and maintenance, and decommissioning phases of the development have been determined.

279 The residual impacts for the Development Area are summarised in Table 10.18 (NF = near-field, FF = far-field). As all the mitigation considered for the Development Area in this

Chapter was Embedded Mitigation and therefore considered in the assessment conclusions, only residual effects have been presented in this table.

Table 10.18: Summary of Effects and Mitigation – Development Area

Effect	Receptor	Residual Effect
Construction		
Modification to the seabed through deposition of dredged material for GBSs	Seabed features	NF – Minor/Moderate FF – Negligible/Minor
Modification to the seabed through scour pit formation around jacket foundations	Seabed features	NF – Negligible/Minor FF – Negligible/Minor
Modification to the seabed through deposition of scoured material for jacket foundations	Seabed features	NF – Minor FF – Negligible/Minor
Modification to the seabed through deposition of material disturbed during cable burial	Seabed features	NF – Minor FF – Negligible/Minor
Modification to the seabed through disturbance by installation vessels	Seabed features	NF – Negligible/Minor FF – Negligible/Minor
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (geological) – both low and high tolerance	NF – N/A FF – Minor/Moderate
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (non-geological)	NF – N/A FF – Negligible
Operation and Maintenance		
Modification to the seabed due to changes in the metocean and sediment regimes	Seabed features	NF – Minor FF – Negligible/Minor
Modification to the seabed through deposition of material disturbed during cable re-burial	Seabed features	NF – Minor FF – Negligible/Minor
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (geological) – both low and high tolerance	NF – N/A FF – Minor / Moderate
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (non-geological)	NF – N/A FF – Negligible
Decommissioning		
Modification to the seabed through removal of infrastructure	Seabed features	NF – Minor/Moderate FF – Negligible/Minor
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (geological) – both low and high tolerance	NF – N/A FF – Minor/Moderate
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (non-geological)	NF – N/A FF – Negligible

10.10.2 Offshore Export Cable Corridor

280 The proposed activities may potentially affect the metocean and coastal processes in and around the Offshore Export Cable Corridor.

281 The near-field and far-field impacts to metocean and coastal processes due to the works in the Offshore Export Cable Corridor have been assessed. The significance of impacts on seabed features and designated sites from the construction, operation and maintenance, and decommissioning phases of the Offshore Export Cable have been determined.

282 Offshore Export Cable residual impacts are summarised in Table 10.19 (NF = near-field, FF = far-field). As all the mitigation considered for the Offshore Export Cable Corridor in this Chapter was Embedded Mitigation and therefore considered in the assessment conclusions, only residual effects have been presented in this table.

Table 10.19: Summary of Effects and Mitigation – Offshore Export Cable Corridor

Effect	Receptor	Residual Effect
Construction		
Modification to the seabed through deposition of material disturbed during cable burial	Seabed features	NF – Minor FF – Negligible/Minor
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (geological) – both low and high tolerance	NF – N/A FF – Minor/Moderate
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (non-geological)	NF – N/A FF – Negligible
Operation and Maintenance		
Modification to the seabed due to changes in the metocean and sediment regimes	Seabed features	NF – Minor FF – Negligible/Minor
Modification to the seabed through deposition of material disturbed during cable re-burial	Seabed features	NF – Minor FF – Negligible/Minor
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (geological) – both low and high tolerance	NF – N/A FF – Minor/Moderate
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (non-geological)	NF – N/A FF – Negligible
Decommissioning		
Modification to the seabed through removal of infrastructure	Seabed features	NF – Minor FF – Negligible/Minor
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (geological)	NF – N/A FF – Minor/Moderate

Effect	Receptor	Residual Effect
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (non-geological)	NF – N/A FF – Negligible

10.10.3 Cumulative Impacts

The Project (Wind Farm and OfTW)

283 The near-field and far-field impacts to metocean and coastal processes due to the Project have been assessed. The significance of impacts on seabed features and designated sites from the construction, operation and maintenance, and decommissioning phases of the development have been determined.

284 The residual impacts for the Project are summarised in Table 10.20 (NF = near-field, FF = far-field). As all the mitigation considered for the Project in this Chapter was Embedded Mitigation and therefore considered in the assessment conclusions, only residual effects have been presented in this table.

Table 10.20: Summary of Effects and Mitigation – the Project

Effect	Receptor	Pre-Mitigation Effect
Construction		
Modification to the seabed through deposition of dredged material for GBS	Seabed features	NF – Minor/Moderate FF – Negligible/Minor
Modification to the seabed through scour pit formation around jacket foundations	Seabed features	NF – Negligible/Minor FF – Negligible/Minor
Modification to the seabed through deposition of scoured material for jacket foundations	Seabed features	NF – Minor FF – Negligible/Minor
Modification to the seabed through deposition of material disturbed during cable burial	Seabed features	NF – Minor FF – Negligible/Minor
Modification to the seabed through disturbance by installation vessels	Seabed features	NF – Negligible/Minor FF – Negligible/Minor
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (geological) – both low and high tolerance	NF – N/A FF – Minor
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (non-geological)	NF – N/A FF – Negligible
Operation and Maintenance		
Modification to the seabed due to changes in the metocean and sediment regimes	Seabed features	NF – Minor FF – Negligible/Minor

Effect	Receptor	Pre-Mitigation Effect
Modification to the seabed through deposition of material disturbed during cable re-burial	Seabed features	NF – Minor FF – Negligible/Minor
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (geological) – both low and high tolerance	NF – N/A FF – Minor/Moderate
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (non-geological)	NF – N/A FF – Negligible
Decommissioning		
Modification to the seabed through removal of infrastructure	Seabed features	NF – Minor/Moderate FF – Negligible/Minor
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (geological) – both low and high tolerance	NF – N/A FF – Minor/Moderate
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (non-geological)	NF – N/A FF – Negligible

The Project with Other Projects

285 The near-field and far-field impacts to metocean and coastal processes due to the Project with other projects have been assessed. The significance of impacts on seabed features and designated sites from the construction, operation and maintenance, and decommissioning phases of the development have been determined.

286 The residual impacts for the Project with other projects are summarised in Table 10.21 (NF = near-field, FF = far-field). As all the mitigation considered for the Project with other projects in this Chapter was Embedded Mitigation and therefore considered in the assessment conclusions, only residual effects have been presented in this table.

Table 10.21: Summary of Effects and Mitigation – the Project with Other Projects

Effect	Receptors	Pre-Mitigation Effect
Construction		
Modification to the seabed through deposition of dredged material for GBSs	Seabed features	NF – Minor/Moderate FF – Negligible/Minor
Modification to the seabed through scour pit formation around jacket foundations	Seabed features	NF – Negligible/Minor FF – Negligible/Minor
Modification to the seabed through deposition of scoured material for jacket foundations	Seabed features	NF – Minor FF – Negligible/Minor
Modification to the seabed through deposition of material disturbed during cable burial	Seabed features	NF – Minor FF – Negligible/Minor
Modification to the seabed through disturbance by installation vessels	Seabed features	NF – Negligible/Minor FF – Negligible/Minor
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (geological) – both low and high tolerance	NF – N/A FF – Minor
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (non-geological)	NF – N/A FF – Negligible
Operation and Maintenance		
Modification to the seabed due to changes in the metocean and sediment regimes	Seabed features	NF – Minor FF – Negligible/Minor
Modification to the seabed through deposition of material disturbed during cable re-burial	Seabed features	NF – Minor FF – Negligible/Minor
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (geological) – both low and high tolerance	NF – N/A FF – Minor/Moderate
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (non-geological)	NF – N/A FF – Negligible
Decommissioning		
Modification to the seabed through removal of infrastructure	Seabed features	NF – Minor/Moderate FF – Negligible/Minor
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (geological) – both low and high tolerance	NF – N/A FF – Minor/Moderate
Modification to the hydrodynamic regime, sediment regime and seabed	Designated sites (non-geological)	NF – N/A FF – Negligible

10.11 Habitats Regulations Appraisal

287 The predicted effects from the construction, operation and maintenance, and decommissioning phases of the Project alone and in combination with other projects, on metocean and coastal processes are Negligible/Minor to Minor/Moderate for any geological interests of the designated sites detailed in *Chapter 9*. Therefore, there are no Habitats Regulations Appraisal concerns which need to be addressed with regard to metocean and coastal processes in this chapter.

288 Considerations of the implications of likely significant effects on any non-geological qualifying features of the designated sites are detailed in the following chapters:

- *Chapter 13: Natural Fish and Shellfish*;
- *Chapter 14: Marine Mammals*;
- *Chapter 15: Ornithology*.

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