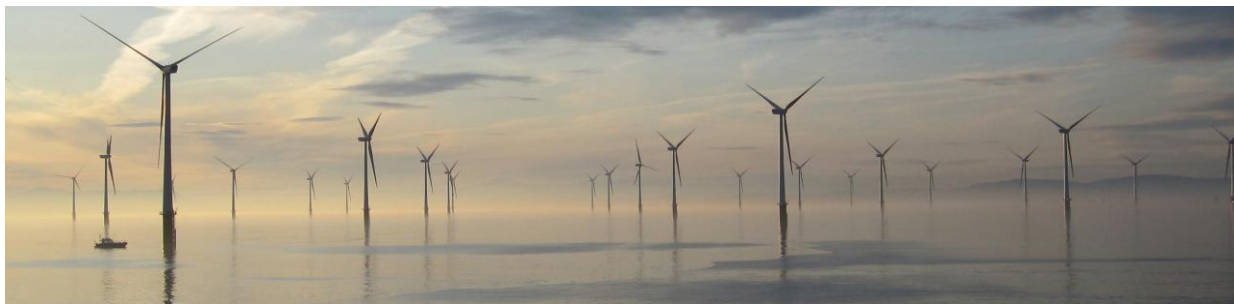




Rampion Offshore Wind Farm



ES Section 6 – Physical Environment

RSK Environmental Ltd

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6 PHYSICAL ENVIRONMENT

6.1 Introduction

- 6.1.1 This section of the Environmental Statement (ES) provides details of the physical environment, including bathymetry, shallow geology, seafloor sediments, oceanography and meteorology and water quality, in and around the area in which the Rampion Offshore Wind Farm (the Project) and its offshore export cable route will be located. It also describes the potential impacts and any measures proposed to mitigate such impacts on the physical environment which may arise as a result of the development.
- 6.1.2 Project site surveys and existing literature have been used to characterise the 139km² offshore wind farm area. Environmental impacts are discussed with regard to the infrastructure options being considered together with the options for their installation, operation and decommissioning.

6.2 Legislation and Policy Context

National Policy Statements (NPS)

- 6.2.1 NPS provide the primary basis on which the Secretary of State is required to make its decision.
- 6.2.2 The overarching NPS for Energy (EN-1) (July 2011) (Department of Energy and Climate Change (DECC), 2011a) states that the potential for adverse effects on the water environment as a result of infrastructure development:
- “could lead to adverse impacts on health or on protected species and habitats and could, in particular, result in surface waters, groundwaters or protected areas failing to meet environmental objectives established under the Water Framework Directive (WFD)”.*
- 6.2.3 The National Policy Statement (NPS) for Renewable Energy Infrastructure (EN-3) (July 2011) has the following statements which are of relevance to geology and physical processes.
- 6.2.4 Paragraph 2.6.192 states that:
- “The construction, operation and decommissioning of offshore energy infrastructure can affect the following elements of the physical offshore environment:*
- *Waves and tides - the presence of the wind turbine foundations can cause indirect effects on flood defences, marine ecology and biodiversity, marine archaeology and potentially, coastal recreation activities;*

- *Scour effect - the presence of wind turbine foundations and other infrastructure can result in a change in the water movements within the immediate vicinity of the infrastructure, resulting in scour (localized seabed erosion) around the structures. This can indirectly affect navigation channels for marine vessels and marine archaeology;*
- *Sediment transport - the resultant movement of sediments, such as sand across the seabed or in the water column, can indirectly affect navigation channels for marine vessels; and*
- *Suspended solids - the release of sediment during construction and decommissioning can cause indirect effects on marine ecology and biodiversity."*

6.2.5 Paragraph 2.6.194 states that:

"The Environment Agency (EA) regulates emissions to land, air and water out to 3nm. Where any element of the wind farm or any associated development included in the application to the [Secretary of State] is located within 3nm of the coast, the EA should be consulted at the pre-application stage on the assessment methodology for impacts on the physical environment."

6.2.6 Paragraph 2.6.195 states that:

"Beyond 3nm, the MMO is the regulator. The applicant should consult the MMO and Centre for Environment, Fisheries & Aquaculture Science (Cefas) on the assessment methodology for impacts on the physical environment at the pre-application stage."

6.2.7 Paragraph 2.6.197 states that:

"The assessment should include predictions of the physical effect that will result from the construction and operation of the required infrastructure and include effects such as the scouring that may result from the proposed development."

Water Framework Directive (WFD)

- 6.2.8 The WFD (200/60/EC) establishes a framework for an integrated approach to the protection, improvement and sustainable use of Europe's water bodies, and requires all member states to achieve good ecological and chemical status of their water bodies (including coastal waters up to 1 nautical mile (nm) offshore) by 2015.
- 6.2.9 Under the WFD, the Environment Agency (EA) is responsible for monitoring water quality and reports the data against Environmental Quality Standards (EQS).

6.2.10 Numerous marine sites have been identified around the UK coastline due to their rare, important or sensitive nature. These sites can subject to statutory or non-statutory designation at a local, national or international level. The following designations include areas, habitats or features that could be influenced by alteration of the seabed caused by infrastructure installation and operation. If it is determined that the installation or operation of infrastructure relating to the Project could affect the physical environment; and as a consequence has the potential to alter any designated area, this has been highlighted in Section 6.5.

- The Marine Conservation Zone (MCZ) project was established to allow recommendations to be made to the Government on which areas should be established as Marine Conservation Zones (to meet the requirements of the Marine and Coastal Planning Act 2009). The Joint Nature Conservation Council (JNCC) and Natural England are due to submit their recommendations by 2012 with designation of Tranche 1 sites in 2013.
- The EC Habitats Directive suggests that Member States must contribute to a coherent European ecological network of protected sites by designating Special Areas of Conservation (SACs) for habitats listed in Annex 1. Annex 1 habitats include sub littoral features such as sandbanks and reefs.
- Marine Sites of Nature Conservation Importance (MSNCI) are areas of special interest due to their habitats, flora, fauna, unusual geology or geomorphological features. The designation 'Marine Sites of Nature Conservation Importance' is a non-statutory designation, and allocated by the local authorities or wildlife trusts.
- Biodiversity Action Plans (BAPs) are another non-statutory designation. BAPs aim to identify important biological and habitat resources along with action plans to aid the recovery of species or habitat under threat.
- Site of Special Scientific Interest (SSSI) is a conservation designation protecting the best examples of the UK's flora, fauna, or geological or physiographical features. SSSI designation may extend into intertidal areas out to the jurisdictional limit of local authorities, generally Mean Low Water.

6.3 Assessment Methodology

6.3.1 The requirements of the Cefas document (Offshore wind farms – guidance note for Environmental Impact Assessment in respect of the Food and Protection Act (FEPA) and Coast Protection Act (CPA) requirements, Version 2 – June 2004) in relation to the potential effects from wind farm installation and operation are listed below and are discussed and addressed within this Section.

- Scour around turbine structures and all cables;

- Wind farm array design and the affect of this on hydrodynamics and sedimentation;
 - Non-linear interaction of waves and currents and the affect on sediment mobilisation;
 - Cumulative effect of the Project when combined with other construction activities in the locale; and
 - The implications of climate change over the Project lifecycle.
- 6.3.2 A Scoping Report was submitted to the Infrastructure Planning Commission (IPC) in September 2010. A Scoping Opinion (IPC, 2010) was received from the IPC in October 2010 incorporating comments from a wide range of consultees. A copy of the Scoping Report, the consultee scoping responses and a summary of the scoping responses is included in Appendices 5.1 and 5.2.
- 6.3.3 The comments relevant to the physical environment have been included in Table 6.1, which also states where the comments have been addressed within the chapter.

Table 6.1 Relevant Scoping Responses

Stakeholder	Summary Comments	Location addressed
Havant Borough Council	Impacts on marine currents and implications for coastal processes, existing and planned defences and consideration of management plans for Hampshire / Isle of Wight / West Sussex should be included.	Section 6.5.43
Marine Management Organisation (MMO)	Sedimentological work should include a detailed assessment of any impacts to sediment transport and particularly any effect to the coastline	Section 6.5.50 and Appendix 6.4
MMO	Scour and Sediment transport pathways should be given very careful consideration including modelling data	Section 6.5.54 and Appendix 6.4
Natural England (NE)	NE welcome the plan for a full study into the potential impacts on coastal processes and oceanographic forces. This study should be conducted in combination with surrounding projects and should explore potential changes to both subtidal and intertidal geomorphology and sediment transport	Section 6.5.50-43 6.5.54 and Appendix 6.4
Southern Water	Only concern is potential impact on long sea outfalls	Section 19.6.13
Surfers Against Sewage	Interruption of offshore wave transmission and reduction in offshore swell energy	Section 6.5.67 and Appendix 6.4

- 6.3.4 The scope of the assessment was modified accordingly to take account of the above consultee responses and the opinions of the IPC, and reported the Draft ES.

Formal Pre-application Consultation

- 6.3.5 As detailed in Section 5 – EIA Methodology, an extensive programme of engagement has been undertaken with regard to the Project, details of which are provided in the Consultation Report for the Project (Document 5.1). This included publication of the Draft ES as part of the Section 42 and Section 48 consultation in June 2012.
- 6.3.6 Following a review of consultee feedback on the Draft ES, and discussions with consultees, modifications have been made to the Project and the assessment of impacts to the physical environment. The main changes made to the assessment are as follows:
- Assessment updated to reflect changes to the worst-case design characteristics of the proposed development including updated quantitative assessment of the longshore sediment transport regime
 - Updated quantitative assessment of the potential reduction in wave heights in the study area and also at specified surfing locations;
 - Assessment of the potential effects with respect to relevant designated sites located within the “far-field” now included;
 - Assessment updated with reference to WFD;
 - Updates to the assessment of the likelihood of cable exposure; and
 - The addition of assessment of settling velocities related to disturbed sediments;
- 6.3.7 Full details of the consultation process and associated responses are presented in Document 5.1 (Consultation Report).

Establishment of Baseline Environment

- 6.3.8 The baseline conditions which already exist within and around the Project site are described to allow potential impacts to be identified, discussed and, where possible, quantified.
- 6.3.9 The English Channel has been the subject of a number of studies and surveys during recent years (the outlines of some of which are illustrated in Figure 6.1) and there is consequently a large amount of background data regarding the physical environment in the region of the planned Project. In addition to these studies and the survey data described later, Jepessen C-MAP nautical charts were used to supplement data in certain areas. The studies which are particularly relevant to the Project are listed in Table 6.2.

Table 6.2 Existing Studies Providing Background Data to the Project

Study	Source	Reference
Department of Trade and Industry (DTI) Strategic Environmental Assessment Area 8 (SEA8) - Superficial Seabed Processes and Hydrocarbon Prospectivity	DECC	Tappin, Mason & Rocks, 2007
SEA8 Technical Report – Hydrography	DECC	Uncles & Stephens, 2007
DTI Strategic Environmental Assessment Area 8 (SEA8) - Geology and Sediment Processes	DECC	Tyrrell, 2004
The South Coast Regional Environmental Characterisation (REC) survey	Cefas	James <i>et al.</i> , 2010
The Eastern English Channel Marine Habitat Map (EECMH)	Cefas	James <i>et al.</i> , 2007
Coasts and Seas of the United Kingdom. Region 8 Sussex: Rye Bay to Chichester Harbour	JNCC	Barne <i>et al.</i> , 1998

Commissioned Surveys / Reports

- 6.3.10 A number of surveys and reports have been completed as part of the Environmental Impact Assessment (EIA) for the Project. Those surveys relevant to the physical environment section of the ES are listed in Table 6.3. The reports identified in Table 6.3 have been provided as Appendices to this ES and the final column of the table lists the Appendix in which the report is contained.

Table 6.3 Rampion Offshore Wind Farm Commissioned Surveys

Report Subject	Author	Year	Report Reference	Appendix No.
Geotechnical	Fugro Geoconsulting Ltd	2011	J11056-2 (01)	6.1
Metocean	EMU Ltd	2011a	11/J/1/01/1743/1157	6.2
Coastal Processes Baseline Assessment	ABPmer	2011	R.1853	6.3
Coastal Processes Assessment	ABPmer	2012	R. 1945	6.4
Benthic Habitat	EMU Ltd	2011b	11/J/1/03/1836/1222	7.2

Geophysical Surveys

- 6.3.11 Marine geophysical surveys conducted during 2010 provided high resolution imaging of the export cable corridor (termed *Section 1*) and the north of the offshore wind farm area (termed *Section 2*). *Section 3*, the southern part of the site, was not surveyed at this time (see Figure 6.2 for survey sections). A total of 4,860 line kilometres of data were acquired by Osiris Projects for Sections 1 (Survey Report No. C10011 Volume 2) and 2 (Survey Report No. C10011 Volume 3a). The survey lines were run at 50m intervals, with cross lines at 750m intervals and data were acquired primarily based on reflected acoustic energy, using the following non-invasive techniques:

- Multi beam echo sounder;
- Side scan sonar;
- Pinger sub-bottom profiler;
- Boomer sub-bottom profiler; and
- Magnetometer.

6.3.12 During 2011, a further survey (Survey Report No. C11030 Volume 2 Extension) was undertaken in the northeast corner of *Section 3* (see Figure 6.2). The survey only covered a small part of *Section 3* and was undertaken at a coarser resolution than the previous surveys. The line spacing was set at 150m for the main survey lines with cross lines at 1,500m intervals. Approximately 290 line km of survey data were acquired as part of the study. As with the studies conducted in 2010, the 2011 survey utilised multi-beam echo sounders, side scan sonar, boomer sub bottom profiler and Magnetometer for data acquisition. Pinger sub bottom profilers were not used during the survey of *Section 3*. It is noted that this survey resolution is coarser than the previous surveys, however before turbines and cables are installed more detailed data will be collected.

6.3.13 Key information from the geophysical surveys is included in section 6.4 - Marine Physical Environment Baseline Conditions.

Geotechnical Survey

6.3.14 A marine geotechnical survey was undertaken by Fugro Geoconsulting Limited at the beginning of 2011. The survey provided measurements of the physical properties of the seabed sediments along with core samples to aid in the identification of soil provinces at 13 locations within the export cable corridor (*Section 2*) and in the north of the Project site. The following survey equipment was used during this survey:

- Vibrocorer; and
- Cone Penetrometer Tests (CPTs).

6.3.15 Key information from the geotechnical surveys is included in Section 6.4. Detailed descriptions of the survey equipment and results can be found in the Fugro Survey Report presented in Appendix 6.1 (Rampion Offshore Wind Farm Site Investigation Quadrant 99, English Channel. Report number J11056-2 (01)).

Metoccean Survey

6.3.16 A three month Metoccean survey and assessment was undertaken by EMU Limited and three buoys were deployed across the Project site on 01 September 2010. Buoys 1 and 2 were recovered in February 2011 but Buoy 3 was left out for approximately 3 months longer to provide 6 months' worth of oceanographic

data. The survey objectives were to capture low frequency, high energy events and high frequency, low energy events in order to establish a description of the Project site conditions (EMU, 2011a).

6.3.17 The buoys recorded:

- Directional wave parameters;
- Current profiles;
- Water levels;
- Suspended sediment concentrations;
- Water temperature;
- Wind speed, gust and direction; and
- Air temperature and pressure.

6.3.18 Full results of the Metocean study are provided in Appendix 6.2.

Coastal Processes Studies

6.3.19 ABPmer undertook a coastal processes baseline assessment study (ABPmer Report No. 1853) in 2011 examining the Project area. The study classed the Project boundary (area covering the array and export cable corridor) as the 'near field environment' and the wider environment within which the wind farm could potentially cause effects as 'far field environment'. The baseline study examined the following issues:

- **Hydrodynamic regime:** Water levels, currents and waves;
- **Sediment regime:** seabed sediment distribution, bedload and suspended sediment transport;
- **Morphodynamic regime:** the form and function of both the coast and offshore, the morphodynamic regime is defined as a response to both the hydrodynamic and sediment regime.
- An ABPmer report (Rampion Offshore Wind Farm: Coastal Processes Assessment ABPmer Report No.1945, 2012) combines the baseline information from the earlier report (Report No.1853) with Project design information (see Section 2a – Offshore Project Description). A full explanation of the design characteristics considered within the coastal processes assessment is provided in Appendix 6.4. Using this; alongside other information, ABPmer produced a series of numerical models. The models examined the impact that the Project would have on the physical environment. The inputs into the models were worst case scenarios in

keeping with the Rochdale Envelope approach to environmental impact assessment.

Benthic Habitat Survey

6.3.20 A benthic habitat survey was undertaken by EMU Limited in 2011 (EMU Report no. 11/J/1/03/1836/1222). It was designed to characterise the seabed habitat conditions and communities present within the Project site, including the export cable corridor, and a wider study area. The site was surveyed using grab sampling and beam trawling techniques and data were collected from 59 sampling stations. At 23 of these sites additional sediment samples were taken to test for contaminants. Only the data relating to sediment grain size and contaminants will be discussed in this Section (Appendix 7.2 provides the whole survey report).

Identification and Assessment of Impacts and Mitigation Measures

6.3.21 Impacts to the physical environment have been assessed using expert judgement and following current guidance on offshore wind farm development. The following documents were among those consulted to ensure that potential impacts to the physical environment (realistic and likely worst case scenarios) have been identified and discussed appropriately:

- Using the Rochdale Envelope. Advice Note Nine: Rochdale Envelope. PINS (April 2012);
- Offshore Wind Farms: Guidance Note For Environmental Impact Assessment an Respect of FEPA and CPA requirements: Version 2 (Department for Environment, Food and Rural Affairs (Defra), Cefas and Department of Transport (DfT), (2004);
- Coastal Process Modelling for Offshore Wind Farm Environmental Impact Assessment: Best Practise Guide. Collaborative Offshore Wind Research into the Environment (COWRIE) Ltd (2009);
- General Advice on Assessing Potential Impacts of and Mitigation for Human Activities on MCZ features, Using Existing Regulation and Legislation. JNCC and Natural England (2011).

6.3.22 Using the above guidance; potential impacts and changes to the physical environment were identified and assessed and the following factors considered:

- **Magnitude of Change:** A large magnitude change is likely to cause a direct adverse permanent or long-term impact on the integrity/value of the receptor whereas a small change would be one that is likely to have a minor adverse impact but recovery is expected in the short-term. Table 6.5 states the magnitudes of change that have been used in the assessment of impacts on the physical environment.

- **Duration:** Considers how long the impact will affect the environment. It can either be short-term (several months), medium-term (several years) or long-term impacts (life of the project i.e. tens of year and upwards).
- **Reversibility:** Whether irreversible (permanent) or reversible (temporary).
- **Timing and frequency:** Does an impact only happen once or does it have re-occurring affects. Is an impact affected by seasonality.

Sensitivity

6.3.23 The sensitivity of the physical environment to changes incurred through the installation and presence of wind turbines and associated infrastructure has been assessed using expert knowledge, examples from Round 1 and Round 2 offshore wind farms and information obtained from relevant subsea projects. The assessment of sensitivity considers how readily and to what degree, particular elements of the environment are prone to change. If the elements are of high value and are prone to deterioration this change is important. High quality environments which are intolerant of change are the most sensitive. Table 6.4 gives an overview of the range of sensitive features considered during the assessment.

Table 6.4: Importance/Sensitivity

Sensitivity	Rationale
High	Areas of contaminated seabed Special Areas of Conservation (SAC) classified due to their physical characteristics (e.g. shallow sandbanks <20m deep) Special Protection Areas (SPA) where conservation objectives include maintaining habitats that include sub-tidal sandbanks and intertidal mudflats and saltmarsh Seabed features/soils at high risk of damage during construction
Medium	Seabed features/soils with moderate risk of damage during construction Potential Annex I habitats (i.e. shallow sandbanks)
Low	Seabed features/soils with low risk of damage during construction Features which have a high recoverability rate

Table 6.5: Magnitude of Impact

Magnitude	Examples
Large	Change is likely to cause a direct adverse permanent or long-term (more than 10 years) impact on the integrity/value of the receptor. Permanent damage to sandbank/protected seabed feature. Impacts which are long term and affect physical processes e.g. sediment transport beyond the vicinity of the turbines and cables
Medium	Change is likely to impact adversely the integrity/value of the receptor but recovery is predicted in the medium term (5-10 years) and there is predicted to be no permanent impact on its integrity. Permanent changes to the local seabed topography in vicinity of the project (but not causing changes to regional sediment processes)

Magnitude	Examples
	Locally increasing sediment re-suspension and deposition to levels significantly higher than natural levels.
Small	Change is likely to adversely impact the integrity/value of the receptor but recovery is expected in the short term (0-4 years). Increasing sediment suspension and deposition to levels which are comparable to natural levels
Negligible	No impact detectable
Beneficial	Change is likely to beneficially impact the integrity / value of the receptor

Significance of Impact

- 6.3.24 An assessment has been made of the significance of impacts, which is a function of the magnitude of the change and the sensitivity of the receptor. The categories in Table 6.6 have been used when classifying the overall significance of impacts for the purpose of this Environmental Statement.

Table 6.6: Table for Assessment of Overall Significance

	Sensitivity		
Magnitude	High	Medium	Low
Large	Major	Major / Moderate	Moderate
Medium	Major / Moderate	Moderate	Minor
Small	Moderate	Minor	Minor
Negligible	Minor	Negligible	Negligible

Scope of the Assessment

- 6.3.25 This section specifically addresses the physical features within the Project site and cable corridor that have the potential to be affected by the construction, operation and decommissioning of the proposed offshore wind farm.
- 6.3.26 Table 6.7 highlights how typical wind farm construction and operation creates various sources of impact to marine physical features.

Table 6.7: Wind farm construction impacts to marine physical features

Potential Receptor	Source of impact	Potential Impact
Seabed morphology	Turbine foundation installation Cable trenching Sandwave pre-sweeping. Rock placement / mattresses at cable crossing points, cable entries and turbine foundations	Disturbance and change to seabed morphology
Seabed sediment	Thermal radiation losses from the cable will increase temperature in sediment	Temperature increase due to thermal radiation from cables
Water column	Sediment suspension and deposition during installation of turbine foundations and cables Sandwave pre-sweeping	Increase in suspended sediment levels and re-deposition Contaminated sediment re-suspension
Sediment transport	Installing turbine on the seabed	Change to pattern of erosion and deposition around turbines and cables
Hydrodynamics	Installing turbine on the seabed	Change to current/tidal pattern

6.4 Marine Physical Environment Baseline Conditions

- 6.4.1 This section addresses the baseline conditions at the Project site and offshore cable corridor relating to bathymetry, shallow geology, seafloor sediments, oceanography and meteorology and water quality.

Bathymetry

- 6.4.2 The East English Channel is predominantly shallow with water depths in the range of 10m – 40m below chart datum. Maximum depths are in the region of 85m (Browning, 2002) and close to the Project site the Admiralty Charts (2011) suggest depths of 59m in places.
- 6.4.3 For the purpose of the geophysical survey, the Project site was treated as three distinct sections (Figure 6.2); *section 1* being the export cable corridor, whilst *sections 2 and 3* are sections of the overall development area.
- 6.4.4 Although the morphology of the seabed in the English Channel has not been directly influenced by glacial processes, the events of the Pleistocene (Ice Age) have had an important effect. The variations in sea level during episodes of glaciation were responsible for periods of deposition and erosion. The numerous Palaeochannels which are predominant features in many parts of the Channel

were formed when the sea level dropped, allowing fluvial processes to incise deep river channels. The channels were subsequently altered by marine processes and partially or fully filled with marine sediment.

Export Cable Corridor (Section 1)

- Between the northern inshore limits and the south east corner of the cable corridor there is a difference in elevation of 25.3m: with heights of 2.3m above Lowest Astronomical Tide (LAT) to the north and 23m below LAT in the south east corner.
- Figure 6.3 shows major contours in blue (10m intervals) and minor contours in black (2m intervals), indicating that the seabed slopes from NNW to SSE. In the north-east of *Section 1* the gradient between 2m above LAT and 2m below LAT is approximately (0.5° to 0.4°). In the north-west corner the seabed slope has the same orientation (NNE to SSE) but a shallower gradient of 0.2°.
- Throughout the rest of *Section 1* (Figures 6.3 and 6.4) and (between the 2m below LAT and the 22m below LAT contours) the seabed gradients are small and are commonly between 0.11° and 0.03°. Within the central and southern parts of *Section 1* there are a number of rock ridges with local gradients of up to 5° (see Figure 6.5).

Northwestern Part of Rampion Offshore Wind farm Site (Section 2)

- Seabed levels across *Section 2* range from 18m below LAT, close to the NW corner and 61.3m below LAT in the SW corner.
- There is a distinct feature which runs across the centre of *Section 2*, orientated south west to north east and then west to east. Osiris (2010b) describe this feature as an escarpment with the top of the escarpment broadly following the 30m below LAT contour and the south of the escarpment lying between the 42m and 46m below LAT contours. This escarpment is the northern edge of a large palaeovalley known as the Northern Palaeovalley.

- 6.4.5 There are steep gradients at the east and west ends of the escarpment but these are shallower in the centre.

Area to the North of the escarpment

- The depth ranges from 18m below LAT in the north-west corner to approximately 42m below LAT at co-ordinates 688395mE and 5613000mN (Point 1, Figure 6.6).
- The seabed in the northern part of *Section 2* is irregular and undulating with numerous rock ridges between 1m and 3m in height.

- Gradients throughout the north are generally less than 1° but can reach 4° on the edges of some of the ridges.
- To the east there is a rocky plateau which has been subject to bedding and jointing with resistant beds standing 2m higher than the surrounding seabed (Figure 6.7). The southerly edge of the plateau marks the edge of the escarpment in this area. Numerous “cuts” (up to 6m in depth and with a maximum gradient of 4°) are visible through the plateau (orientated roughly north – south).

6.4.6 Much of the northern part of *Section 2* dips to the south / south east and is gently undulating. In the South west corner of the northern part of *Section 2* the seabed (in the vicinity of point 1 in Figure 6.6) shows much more variation in depth over relatively small distances with subsequent steeper gradients of up to 10°.

Area to the South of the escarpment

- The depths in the southern part of *Section 2* range between 29.5m below LAT and 61.3m below LAT.
- In the western part of the southern section, to the south of the escarpment there is a gently dipping plateau (Area 1, Figure 6.8). The plateau is orientated NE – SW and has an average gradient of 1°. There are a large number of sand and gravel ridges (with the same NE – SW orientation) running along the length of the plateau.
- To the south and south east of the plateau (Area 2, Figure 6.8) is a large sand / gravel wave field with waves up to 8m high in places. The sediment waves are orientated NNW to SSE, are asymmetrical, and the faces are steepest on the ENE face, suggesting a prevailing WSW current.
- To the south of Area 2 (Figure 6.8) the water depth increases rapidly from 46m at the edge of the bedforms to 58m at the edge of the survey extent.
- The southern part of *Section 2* has two areas of apparent scour (or areas of lack of deposition), the deepest and most prominent of these being Area 3 (Figure 6.8) (Point 2, Figure 6.6). This feature is orientated NNE-SSW with the westerly edge having gradients of up to 10°. The water depth at the base of the scour pit is 56m below LAT. The area of less severe scour (Area 4, Figure 6.8) is much larger, has a similar NNE – SSW orientation and exhibits water depths of between 42m and 50m below LAT. Within and around this area of scouring there are a large number of bedforms (low order megaripples) orientated NW-SE or NNW-SSE.

Section 3

- The depths across *Section 3* vary between 28m below LAT in the NE and SE corners and greater than 54m below LAT at the southerly limits. Figure 6.9 shows that *Section 3* has three distinct features: Area 1; Area 2 and Area 3. Area 1, to the north of *Section 3* is a large area of low amplitude sand / gravel waves. The water depth here is between 28m and 42m below LAT and the sand / gravel waves exhibit gradients up to 14° on their E or ENE sides. The south of this area slopes towards Area 2, which is a distinct trough that runs through the centre of *Section 3* on an ENE – WSW orientation.
- The trough running through the centre of *Section 3* (Area 2 in Figure 6.9) is roughly delineated by the 40m below LAT contour. Within the trench the water depth ranges from 42 to 46m below LAT in the east and 48-54m below LAT to the west with the presence of low-amplitude sand / gravel waves.
- To the south of the trough there is a prominent ridge/sandbank termed Area 3 in Figure 6.9. The ridge/sandbank has numerous low-amplitude sand and gravel waves (with heights of up to 6m) and associated mega-ripples. To the south of the ridge the depth to the seabed increases quickly to approximately 56m below LAT.

Geology and Seabed Sediments

- 6.4.7 The following geological definitions will provide background information useful to the understanding of this section of the ES.

Grain Size

- 6.4.8 Table 6.8 summarises the most commonly used definitions of sediment grain-sizes termed the Wentworth and Folk grain size definitions.

Table 6.8: Particle grain size (Wentworth (1922) and Folk (1954) definitions)

Wentworth Grade	Size Range (mm)	(µm)	Millimeters	Folk Grade
Boulder	>256		>256	Gravel
Cobble	64 – 256		>64	
Pebble	4 – 64		>4	
Granule	2 – 4		>2	
Very coarse sand	1 – 2		>1	Sand
Coarse sand	0.5 – 1	(500-1,000 µm)	>1/2	
Medium sand	0.25 – 0.5	(250-500 µm)	>1/4	
Fine sand	0.125 - 0.25	(125-250 µm)	>1/8	
Very fine sand	0.0625 - 0.125	(62.5-125 µm)	>1/16	
Coarse silt	0.0313 - 0.0625	(31.3-62.5 µm)	>1/32	Mud
Medium silt	0.0156 - 0.0313	(15.6-31.3 µm)	>1/64	
Fine silt	0.0078 - 0.0156	(7.8-15.6 µm)	>1/128	
Very fine silt	0.0039 - 0.0078	(3.9-7.8 µm)	>1/256	
Clay	<0.0039	(<3.7 µm)	<1/256	

- 6.4.9 The size fraction larger than sand (granules, pebbles, cobbles and boulders) is often collectively called gravel and the size fraction smaller than sand (silt and clay) is collectively called mud.
- 6.4.10 The seabed of the east English Channel is generally interpreted as comprising a thin layer (veneer) of mobile Holocene sand and gravel overlying non-mobile lag deposits. These mixed grained deposits overlay older, more consolidated deposits of Tertiary and Cretaceous age (90-30 million years old). A summary of the soil units sampled at the Project site can be found in Table 6.9.

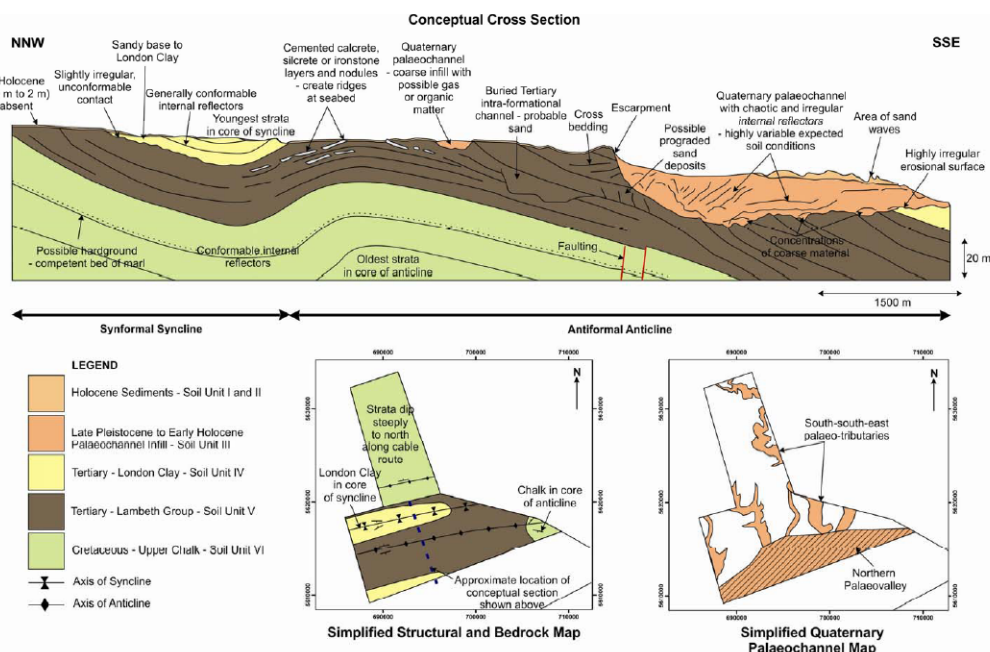
Geological Overview

- 6.4.11 The Project site is described by Fugro (2011) as having a gently folded and eroded bedrock profile comprising the London Clay Formation, overlying the Lambeth Group and the Cretaceous Upper Chalk Group. The bedrock profile is superimposed locally by Quaternary palaeochannels/ palaeovalleys and a thin covering of more recent Holocene Sediments. Figure 6.10 shows a conceptual cross section (NNW – SSE) across the Project area, highlighting the general situation. The geology comprises of both Tertiary (London Clay and Lambeth group) and a small area of Cretaceous chalk in the south east corner. Table 6.9 summarises the soil units sampled by Fugro during geotechnical sampling at the site.
- 6.4.12 A thin layer of lag deposit (sandy gravel and gravelly sand) overlies the bedrock and some of the palaeochannel/palaeovalley features, it is present as a blanket deposit in the north of the Project site, becoming more sporadic towards the south (Fugro, 2011). Geophysical and geotechnical surveys suggest that the lag deposits can be between 0.2m and 3.7m thick but predominantly exhibit a thickness of less than 0.5m.

Table 6.9: Summary of Soil Units Sampled at the Rampion Site (Fugro, 2011)

Soil Units	Formation Name	Summary Soil Description
I	Mobile Holocene Sediments	Very loose to medium dense SAND locally with gravel and shell fragments
IIa	Holocene Lag Deposits	Medium dense to dense slightly gravelly to gravelly fine to coarse SAND locally very silty
IIb		Sandy GRAVEL locally with cobbles and medium beds of very loose to medium dense sand
IIIa	Late Pleistocene to Early Holocene Channel Infill	Very dark brown spongy PEAT, with putrid odour
IIIb		Very soft to soft CLAY interbedded with sandy SILT
IIIc		Loose to dense silty fine SAND with thin laminae to thin beds of slightly sandy to sandy clay locally with laminae of black staining and occasional gravel
IIId		Sub-angular to sub-rounded fine to coarse GRAVEL of mixed lithologies
IVa	Tertiary Sediments - London Clay	Firm to hard locally firm slightly sandy CLAY locally with fine gravel-sized shell fragments, pockets and laminae of fine to medium sand
IVb		Thinly to thickly interlaminated very stiff to hard slightly sandy CLAY and fine to medium SAND with traces of fine black silica sand and evidence of bioturbation (burrows)
IVc		Dense to very dense slightly clayey to very silty fine SAND with pockets and layers of cemented sand and siltstone
IVd		Stiff to very hard slightly sandy CLAY locally with pockets and laminae of slightly silty sand
IVe		Very dense slightly clayey silty fine SAND locally with pockets of black clay
Va	Tertiary Sediments - Lambeth Group	Stiff to very stiff locally hard slightly sandy CLAY with fine gravel-sized pockets of sand
Vb		Hard to very hard slightly sandy SILT locally with gravel-sized pockets of very weak calcareous siltstone and fine to coarse gravel-sized shell fragments, chalk and flint. Locally with closely spaced thin laminae of fine sand
Vc		Medium dense to very dense silty fine SAND with sub-angular to sub-rounded medium gravel
Vd		Very stiff to hard slightly sandy CLAY with traces of fine gravel-sized pockets of black staining
Ve		Very stiff to very hard thinly interlaminated to medium interbedded slightly sandy to sandy CLAY and medium dense to very dense slightly clayey to slightly silty fine to medium SAND locally with sand-sized to fine gravel-sized shell fragments and with gravel-sized clasts of claystone
Vf		Very stiff to very hard dark locally slightly sandy locally laminated CLAY locally with very closely to closely spaced thin to thick laminae of greenish grey fine sand
Vg		Thin to medium interbedded calcareous SANDSTONE and very dark grey fine SAND with few fossils
Vh		Very hard sandy CLAY locally with medium to coarse sand-sized pockets of sand
Vi		Medium dense to very dense locally slightly silty fine to medium SAND locally silty and clayey
Vj		Hard to very hard sandy SILT with coarse gravel-sized pockets and laminations of fine silica sand
VIa	Cretaceous Sediments - Upper Chalk	White clayey sandy fine to coarse GRAVEL. Structureless granular chalk - grain supported with intergranular chalk clay
VIb		Structureless CHALK composed of white silt and fine to coarse blocky gravel with few angular fine to coarse gravel-sized black flint. Chalk clasts are very weak, low density (Grade Dm)
VIc		Structureless CHALK composed of white silt and fine to coarse blocky gravel. Chalk clasts are weak, medium density (Grade Dc)
VId		Structureless CHALK composed of white silt and fine to coarse angular and blocky gravel. Chalk clasts are weak, low to medium density (Grade Dc)

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Figure 6.10: Conceptual Cross Section across the WF site NNW - SSE (Fugro, 2011)

6.4.13 Osiris (2010b) describes the lag deposits as below:

The coarseness of the lag deposit increases with distance from shore from fine to coarse rounded to sub rounded, gravel and cobbles. Where the deposit is interpreted to comprise sandy gravel, the sand is generally coarse grained (0.5 to 1.0mm), poorly to moderately well sorted, with a high carbonate content (predominately shell fragments). Within the lag deposit, megaclasts (coarse fraction) are mainly composed of flint derived from the underlying Chalk bedrock and Tertiary gravels, either by seabed or cliff erosion processes, during the last sea level rise.

6.4.14 The lag deposits are overlain with fine grained, Holocene sediments. These sediments are highly mobile and as a result of seabed currents have locally formed sand wave fields. Fugro (2011) describing these mobile sediments as below:

Mobile sediments locally overlie older deposits, particularly within the Northern Palaeovalley at the Rampion site. At the Rampion site mobile sediments have locally formed large to very large sandwaves many of which were formed during the early Holocene and demonstrate a west to east current direction. Soil Unit I varies in the sampled soil between 0.1m to 6.0m thick. The thickest deposit of mobile sediments sampled is in borehole (BH_16), which is located in a sandwave

field in the Northern Palaeovalley. The sandwaves cover an area of approximately 21km² to the south of the escarpment. The mobile sediments consist predominantly of loose to medium dense fine sand (Table 6.9) and are underlain either by a sand layer which has an increase in fines content (silty sand) and greater interpreted relative density (medium dense to very dense) (Soil Unit III, in BH_16) or by an older bedrock deposit (Soil Unit IV, V, VI). The interpreted relative density and apparent reduction in fines content indicates that Soil Unit I may have the potential for scour when seabed structures are emplaced.

6.4.15 Figure 6.11 illustrates the significant features within Section 2. The plateau gently slopes from the English coast towards the centre of the English Channel. At the edge of the plateau is a steep escarpment the edge of which roughly corresponds with the 30m bathymetric contour and is the northern edge of the Northern Palaeovalley, a significant feature of this part of the English Channel. For most of the area it cuts across Palaeogene and Cretaceous sediments. To the east and west of the Project site there are visible escarpments of 10m to 14m (part of the same feature) which again approximately correspond with the 30m bathymetric contour.

6.4.16 The sediments within the Northern Palaeovalley consist of deposits of Quaternary infill overlying older Tertiary and Cretaceous systems. In addition there are also a number of smaller channels which run into the North of the Northern English Channel (Figure 6.11). At one time these were fluvial tributaries before being influenced by marine conditions and eventually in filled with sediment of Pleistocene age. These infill deposits are generally interpreted as being between 10 to 30m thick and classified as Sands and Shelly Sands.

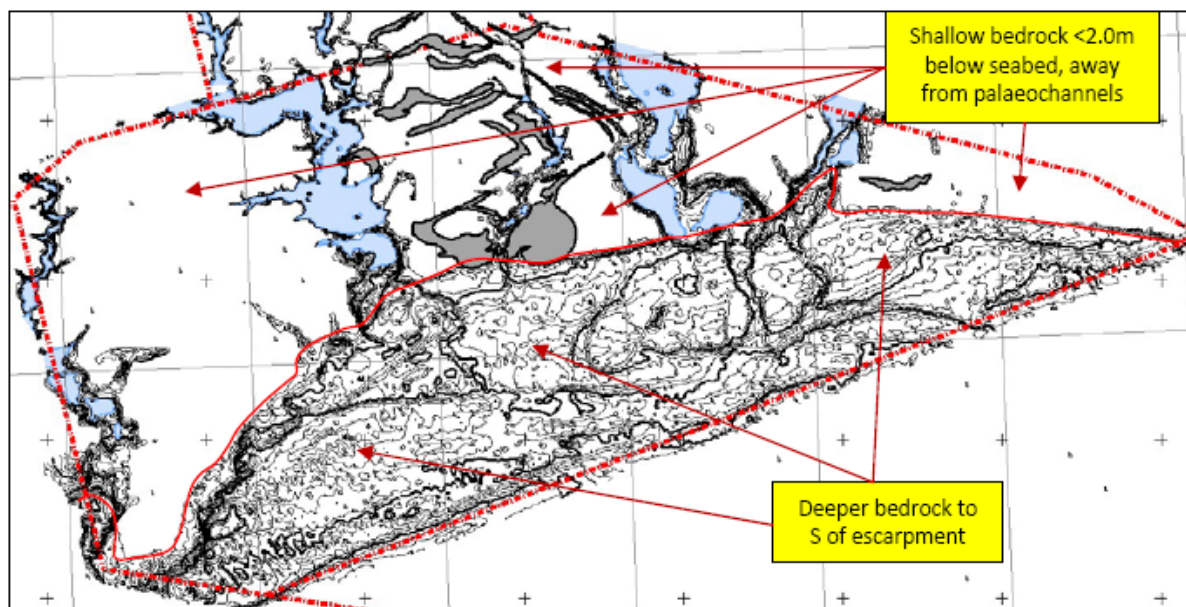


Figure 6.11: Isopachyte - Illustrating the location of palaeochannels

6.4.17 Numerous rock outcrops and ridges have been identified throughout the Project site. It has been inferred by Fugro (2011) that these features are associated with

highly competent (hard, partially cemented and cemented) beds of calcretes, silcretes and ironstone within the Lambeth Group which also occur at depth. The largest outcrops are up to 3m in height.

Earthquakes

- 6.4.18 The English Channel is in an area of very low seismicity with no significant earthquake risk. On the morning of 14 July 2011 an earthquake with a magnitude of 3.9 hit the English Channel. The epicentre was approximately 80km SSE of Portsmouth (BGS, 2011). It was the largest event since a magnitude 5 event in 1878. There has been 1 other significant event recorded in the area, which occurred in 1734 and had a magnitude of 4.5.

Sediment Transport and Mobility

- 6.4.19 Seabed sediments are subjected to a natural winnowing effect from directional forces, namely ocean, wind, storm surge and tidal currents along with non-directional currents from wind and swell. These currents dictate the amount of seafloor shear stress the grains are subjected to and ultimately the level of sediment transport and mobility. Seafloor sediment processes have a direct effect on the evolution of the coast, the foreshore and the seafloor itself. This in turn has a direct impact on the coastal dynamics as they relate to coastal flooding. The seafloor sedimentary processes are predominantly influenced by the sediment type and availability.
- 6.4.20 Within the eastern English Channel tidal currents are the predominant factor in sediment mobilisation and transport. However, in the shallower, near shore waters exposure to wind waves (and occasional swell waves) can act in combination with currents mobilising larger volumes of sediment. There are two main mechanisms by which sediment is transported and these are bed-load transport where grains of sediment move along the seabed, and suspended-load transport where sediments are suspended in the water column.
- 6.4.21 ABPmer Ltd conducted a coastal processes baseline assessment for the Project. Their findings are included in the coastal processes report in Appendix 6.4 and summarised as follows:

Due to the varied hydrodynamic forcing conditions observed and recorded during the study, the sediment transport in the vicinity of the wind farm area can be broadly split and discussed as being two different regimes: coastal and offshore. The distinction is important for understanding the relationship between the offshore wind farm coastline receptors and any potential impacts.

Coastal Sediment Transport

- 6.4.22 Broad scale mapping indicates that the sediments within the coastal zone, potentially influenced by the Project, comprise of gravels, sandy gravels and sand. The coast between Selsey Bill and Beachy Head is defended by a variety of

hard structures, such as groyne structures, and the coastline is subjected to a dominant west to east drift. However at certain locations, for example between Peacehaven Heights to Harbour Heights no defenses exist and instead the natural presence of shingle ridges acts to protect the shoreline. Tidal currents are generally not strong enough to transport the gravel observed at the coast, with the primary mechanism being bed-load transport as a result of wave action. There is potential for suspended load transport, however, observed currents are not energetic enough to keep large grain sizes in suspension. A study by SCOPAC (2004) suggests variable sediment transport rates in the shoreward far-field region and highlighted the presence of groynes and harbour sinks as barriers to flow.

Offshore Sediment Transport

- 6.4.23 The known sediment pathways through the far-field study region are primarily to the east and northeast in relation to the tidal currents. Tidal dominance in the area has been responsible for the creation of well sorted bed-form features such as sandbanks, sand and gravel waves and megaripples with Osiris' geophysical surveys identifying a northeast alignment of bed-form features. The tidal activity and the availability of finer sand and silt suggest that suspended sediment transport will be significant and the abundance of bed form features indicates that bed-load transport is also significant.

Process Controls on sediment mobility

- 6.4.24 An assessment has been made of sediment mobility within (and close to) the Project site by identifying the modal sizes of available sediments (from grab sample data) and calculating the bed shear stresses required to initiate transport (using standard methods described by Soulsby, 1997). The potential for mobility due to currents and waves is calculated based on the time series current and wave observations from the acoustic wave and current meter (AWAC) site surveys. Table 6.10 provides a summary of the modal grain size classes used for the analysis of sediment mobility, their frequency in occurrence and critical shear stress values for transport.

Table 6.10: Summary of the main sediment types within (and close to) the application site including associated theoretical bed shear stress thresholds for mobility (*adapted from ABPmer, 2011*).

Common Modal Size (µm)	Common Modal Size (mm)	Size Class (Wentworth)	Number of occurrences in 52 Samples	Threshold Bed Shear Stress for Mobility (N/m ²)
>38500	38.5	Pebble gravel	0	33.49
6000-38500	6–38.5	Granule gravel	4	4.92
3000-6000	3-6	Very course sand	3	2.02
750-3000	0.75-3	Course sand	1	0.35
302.5-750	0.3025–0.75	Medium sand	19	0.2
187.5-302.5	0.1875-0.3025	Fine sand	22	0.17
47.5-187.5	0.0475-0.1875	Very fine sand	3	0.1

Potential Mobility Due to Tidal Currents

- 6.4.25 Data from the EMU (2011a) AWAC deployments (Figure 6.16) were used to calculate an equivalent bed shear stress time-series (due to currents only). Figure 6.12 shows calculated bed shear stress values against threshold values for mobility of the sediment grain sizes given in Table 6.10. Typical current speeds at the site are $>1\text{ms}^{-1}$ on a spring tide and approximately half of this on a neap tide. Between the 2yr and 50yr return period for wave conditions there is a potential for currents of between 1.5 and 2ms^{-1} , and consequently a strong potential for sediment mobilisation of grain sizes that would be undisturbed under normal conditions.
- 6.4.26 Table 6.11 shows that at nearly all states of tide, tidal currents have a large potential for sediment mobilisation. Sediment up to 0.3025mm (medium sand) can be transported at nearly all states of the tide and coarse sand (0.75mm) can be mobilised during peak spring conditions. Within the Project site it is therefore likely that the predominant sediment mobility will be under spring flood conditions due to marginally higher current speeds and associated residuals. Results from the metocean survey show residual tidal flow with a predominant NE to ENE orientation. This is the same orientation as the Northern Palaeovalley which runs through the Project site. The observed residual direction and ENE trend in predicted sediment displacement is consistent with previously published information. The pattern can be readily explained as a result of the relatively higher peak flood current speeds, which lead to a longer net duration of eastward flowing currents.

Table 6.11: Estimated Potential Sediment Mobility (due to Tidal Currents only) at three Locations across the Project Site. (Adapted from ABPmer, 2011)

Location (Depth (<i>Chart Datum</i> (CD)) and Bed Sediment Size)		Sediment Fraction						
		Course Silt (0.0475mm)	Fine Sand (0.1875mm)	Medium Sand (0.3025mm)	Coarse Sand (0.75mm)	Very Coarse sand (3mm)	Granule Gravel (6mm)	Pebble Gravel (38.5mm)
L1 (28m (CD); d ₅₀ bed of 0.2846mm)	Mobility Summary	Mobile at nearly all states of the tide, except at the lowest neaps	Mobile at nearly all states of the tide, except at the lowest neaps	Mobile at nearly all states of the tide, except at the lowest neaps	Mobile during all states of spring tides	Not mobile	Not mobile	Not mobile
	Mobility % time	59%	43%	37%	13%	0%	0%	0%
L2 (24m (CD); d ₅₀ bed of 0.2576mm)	Mobility Summary	Mobile at nearly all states of the tide, except at the lowest neaps	Mobile at nearly all states of the tide, except at the lowest neaps	Mobile at nearly all states of the tide, except at the lowest neaps	Mobile only during peak spring tides	Not mobile	Not mobile	Not mobile
	Mobility % time	47%	29%	22%	7%	0%	0%	0%
L3 (45m (CD); d ₅₀ bed of 0.3382mm)	Mobility Summary	Mobile at nearly all states of the tide, except at the lowest neaps	Mobile during spring tides and peak neap conditions	Mobile during spring tides and peak neap conditions	Mobile during all states of spring tides	Not mobile	Not mobile	Not mobile
	Mobility % time	59%	43%	37%	16%	0%	0%	0%

* d₅₀ is defined as the grain diameter which 50% of the sediment sample is smaller (finer) than.

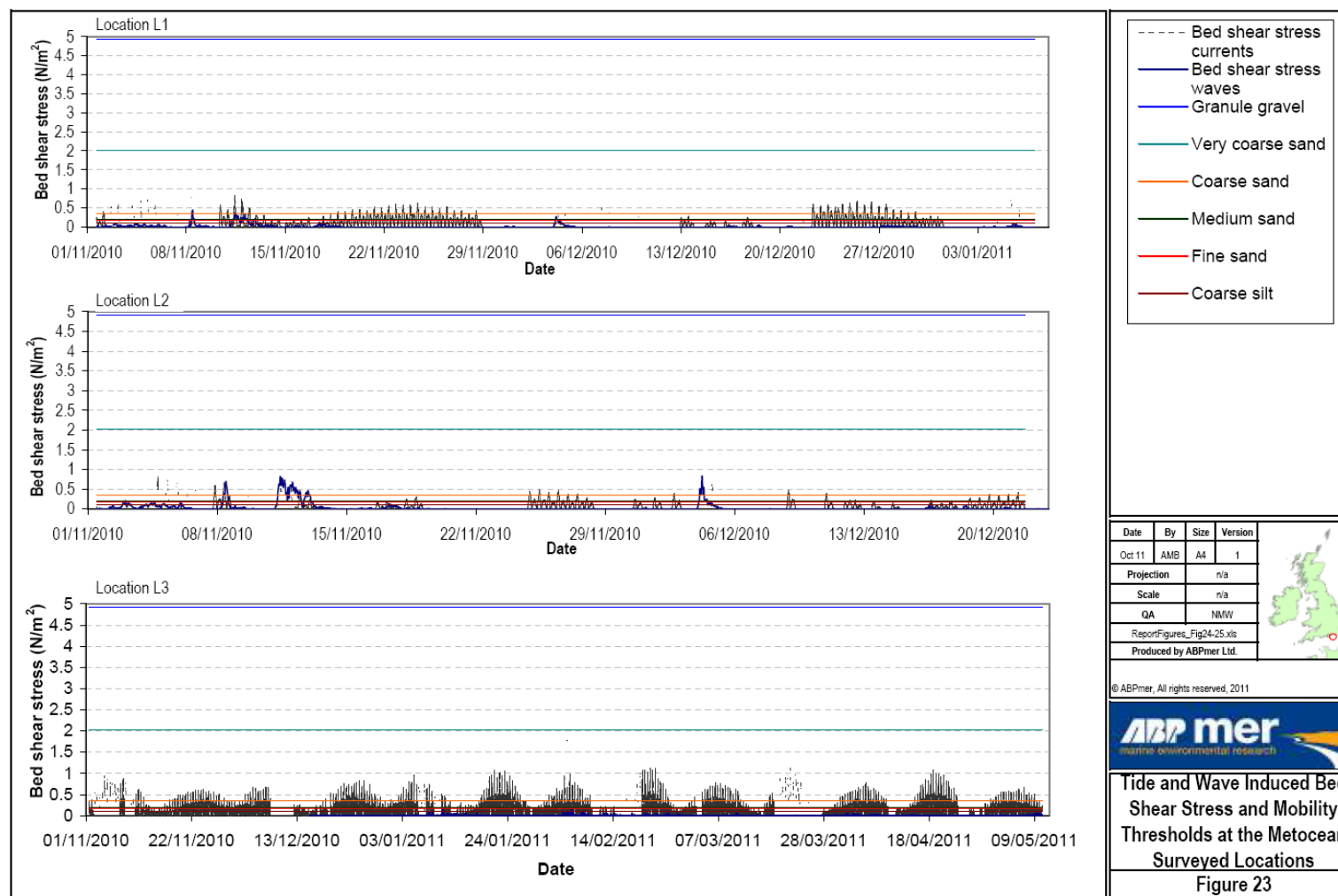


Figure 6.12: Tide and Wave Induced Bed Shear Stress and Mobility Thresholds at the Metocean Surveyed Locations (ABPmer, 2011)

Potential Mobility due to waves

6.4.27 ABPmer, 2011 state that:

Significant wave heights are generally less than 4m across the site as represented through the approximately 6 month metocean survey period. Present understanding of wave-dominant transport is considered to differ between the nearshore and offshore environments. Secondary information indicates that the dominant transport mechanism in the nearshore is due to waves, with tidal dominance in the offshore environment (HR Wallingford, 2003; SCOPAC, 2004).

6.4.28 Within Sections 2 and 3 of the Project site there is considered to be an existing, but limited, influence from waves. The near bed orbital current velocities associated with wave activity are not enough to cause significantly higher bed shear stress and resulting sediment mobility. Figure 6.12 shows the effect of wave action on bed shear stress and as previously discussed it also plots bed shear stress in relation to currents. The results suggest that waves only move sediment a small proportion of the time in this area and have only a limited influence compared to tidal currents. When waves do have the capacity to mobilise sediment they occur as isolated events. This is summarised in Table 6.12.

6.4.29 Overall, tidal currents associated with spring tidal flows generate the same or much larger shear stresses during the spring-neap tidal cycles, which have a longer duration than the sporadic wave events. This also shows that in the long term the influence of wave events are of a much lower significance in the mobilisation of sediment. This observation is the same across the three metocean survey sites. Therefore, the combined effect of currents and waves was not investigated any further.

Table 6.12: Spatial variation in sediment mobility due to waves at the metocean survey locations across the application site (ABPmer, 2011)

Location (Depth and Bed Sediment Size)		Sediment Fraction							
		Course Silt (0.0475mm)	Fine Sand (0.1875mm)	Medium Sand (0.3025mm)	Coarse Sand (0.75mm)	Very Coarse sand (3mm)	Granule (6mm)	Gravel	
L1 (28m (CD); d50 bed of 0.2846mm)	Mobility Summary	Mobile under isolated event	Not mobile	Not mobile	Not mobile	Mobile	Mobile		
	Mobility % time	0.53%	0.36%	0.03%	0.00%	0.00%	0.00%		
L2 (24m (CD); d50 bed of 0.2576mm)	Mobility Summary	Mobile under isolated event	Not mobile	Not mobile	Not mobile	Not mobile	Mobile		
	Mobility % time	1.31%	0.86%	0.80%	0.58%	0.00%	0.00%		
L3 (45m (CD); d50 bed of 0.3382mm)	Mobility Summary	Mobile under isolated event	Not mobile	Not mobile	Not mobile	Mobile	Mobile		
	Mobility % time	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%		

* d50 is defined as the grain diameter at which 50% of the sediment sample is finer than.

Oceanography and Meteorology

- 6.4.30 A desktop study and a metocean survey were undertaken to determine the oceanographic and meteorological conditions across the Project site and cable route corridor. These conditions are important for an understanding of the sediment transport and seabed geology as both are principally governed by the wave and tidal regime of the area.

Waves

- 6.4.31 In the majority of cases, waves are formed by wind. When wind acts locally on the sea surface the transfer of energy creates wind waves. Swell waves are also formed by wind acting on the sea surface but they tend to be formed by sustained periods of wind acting on the sea surface. Prolonged wind events cause the height of waves to increase as they move across the sea; and the further they travel (assuming the wind remains) the larger the waves become. The distance the wave travels is called the "fetch" and a long fetch leads to a longer wave period which in turn means waves have more power. The significant wave height (Hs) is defined as a wave height which is four times the standard deviation of the surface elevation.
- 6.4.32 Of all the areas of the UK coastline, the English Channel and eastern English coastline are the most sheltered with a long term mean significant wave height (Hs) of 1.5m or less (Cotton *et al.*, 1999). In the near shore (shallow water) environment wave action is the predominant influence on sediment erosion, transport and deposition. However, in the offshore environment tidal currents have a greater influence on sediment transport pathways.
- 6.4.33 The Health and Safety Executive (HSE) has conducted a number of studies to ensure that offshore installations (predominantly oil and gas facilities) can withstand extreme metocean conditions. Figure 6.13 presents the modelled 100 year significant wave heights in UK waters, and shows that the Hs expected at the Project site is approximately 8.5m.
- 6.4.34 In the Eastern English Channel, Paphitis *et al.* (2010) (in ABPmer, 2011) showed that within this region and at the coastline, wave action with the potential to disturb seabed sediments occurs on average, 20% of the time. Further offshore, in water depths greater than 30m this reduces to less than 1% a year, *i.e.* in depths greater than 30m waves interact with the seabed less than 1% of the time.
- 6.4.35 Table 6.13 summarises wave data collected by EMU Ltd as part of the Rampion Offshore Wind Farm Metocean Survey and Assessment and the results are described briefly below:
- At the L1 and L2 AWAC stations to the north of the Project site (Figure 6.16) the most frequent waves originate in the SW between 32% - 39% of the time. The most frequent waves have a height of between 0.5m and 1m and occur

up to 53% of the time. The maximum wave height at the sites is 4.08m (the largest wave recorded during the AWAC survey) with an orientation of SSW.

- At the L3 AWAC deployment, to the south of the Project site, the dominant wave direction is from WSW. The most frequent waves have a height of between 0.5m and 1m, and occur up to 48% of the time. The maximum wave height recorded at L3 was 3.26m and had a SW orientation.
- The most frequent mean wave period recorded at all three sites is between 3 and 4 seconds and occurs up to 47% the time. The peak, observed mean wave period shows a range of between 6.7 and 7.3 seconds.

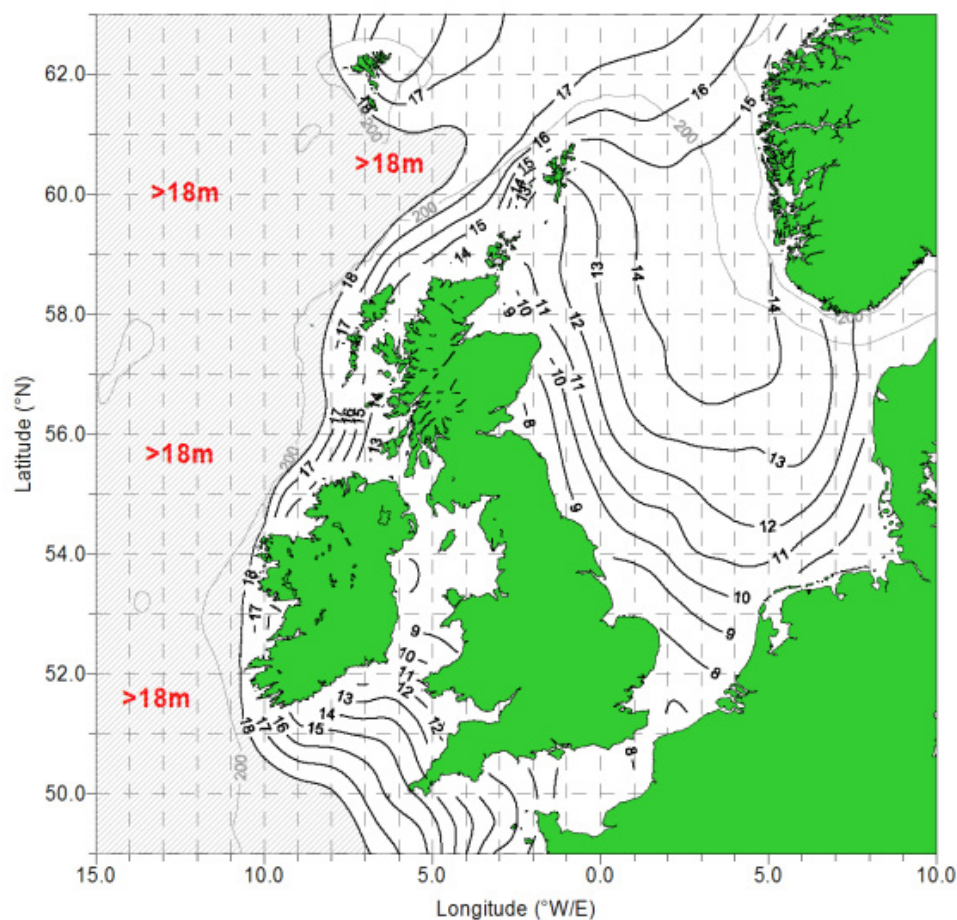


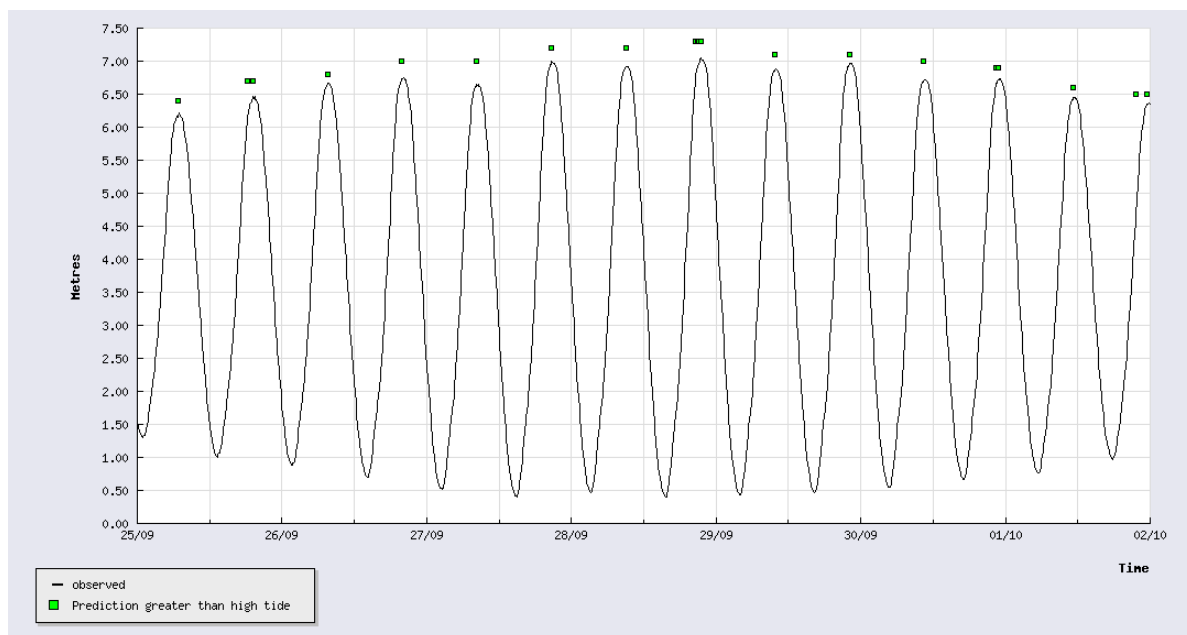
Figure 6.13: 100 Year Significant Wave Height (Hs) (HSE, 2005)

Table 6.13: Summary of frequency analysis of observational wave records (adapted from ABPmer, 2011)

Buoy / Deployment	Dates of Deployment	Most Frequent Wave Direction and Percentage of Record	Most Frequent Wave Height and Percentage of Record	Maximum Observed Significant Wave Height and Associated Direction Sector	Most Frequent Mean Wave Period and Percentage of Record	Peak Observed Mean Wave Period and Associated Direction Sector
Rampion OWF AWAC L1	01/11/2010 to 07/01/2011	SW (39%)	0.5 - 1m (49%)	3.75m (S)	3 - 4 seconds (43%)	7.1 seconds (SW)
Rampion OWF AWAC L2	01/11/2010 to 18/02/2010	SW (32%)	0.5 - 1m (53%)	4.08m (SSW)	4 - 5 seconds (46%)	7.3 seconds (SW)
Rampion OWF AWAC L3	15/12/2010 to 10/05/2011	WSW (30%)	0.5 - 1m (48%)	3.26m (SW)	3 - 4 seconds (47%)	6.7 seconds (SW)
Rustington wave buoy (CCO)	01/11/2010 to 30/12/2010	SW (34%)	0.5 - 1m (40%)	3.86m (S)	3 - 4 seconds (37%)	7.8 seconds (SW)
Long term regime						
Rustington wave buoy (CCO)	09/07/2003 to 31/12/2010	SW (41%)	0.5- 1m (37%)	4.81m (SSW)	3 - 4 seconds (46%)	10 seconds (SE, S, SW)
Seastates model output (offshore location)	01/01/2000 to 31/12/2009	WSW (39%)	0.5- 1m (36%)	5.61m (SSW)	3 - 4 seconds (41%)	11 seconds (SW, WSW)
Percentages are rounded to integers						

Tides (astronomical)

- 6.4.36 The English Channel is a macro-tidal area experiencing a large variation in tidal height: from 2m in Bournemouth to 11m on the French coast at St. Malo. The Rampion Scoping Report (September 2010) suggested a tidal range across the site of approximately 5m under spring tides.
- 6.4.37 Data from the Brighton Meteorological and Tide Site (25/09/2011 – 02/10/2011) (Figure 6.14) shows high water values of between 6.25 and 7m the high tidal values being related to the near equinoctial (yearly maximum) spring tides.
- 6.4.38 The Project Metocean survey completed by EMU (2011a) recorded the water level at three locations within the Project Site (Figure 6.16) and also includes data from a nearby ASLF's AWAC station (Table 6.14). The results from all locations (Figure 6.16) show recorded Mean High Water Spring (MHWS) values of 6.10m, 6.39m, 5.96m, 5.60m with Highest Astronomical Tides (HAT) of 6.80m, 7.21m, 6.62m and 6.30m respectively. The average of the mean spring ranges from all 4 monitoring sites is 5.42m.



**Figure 6.14: Tidal heights from the Brighton Meteorological and Tide Site
(25/09/2011 - 02/10/2011)**

Table 6.14: Water Level Statistics (EMU, 2011a)

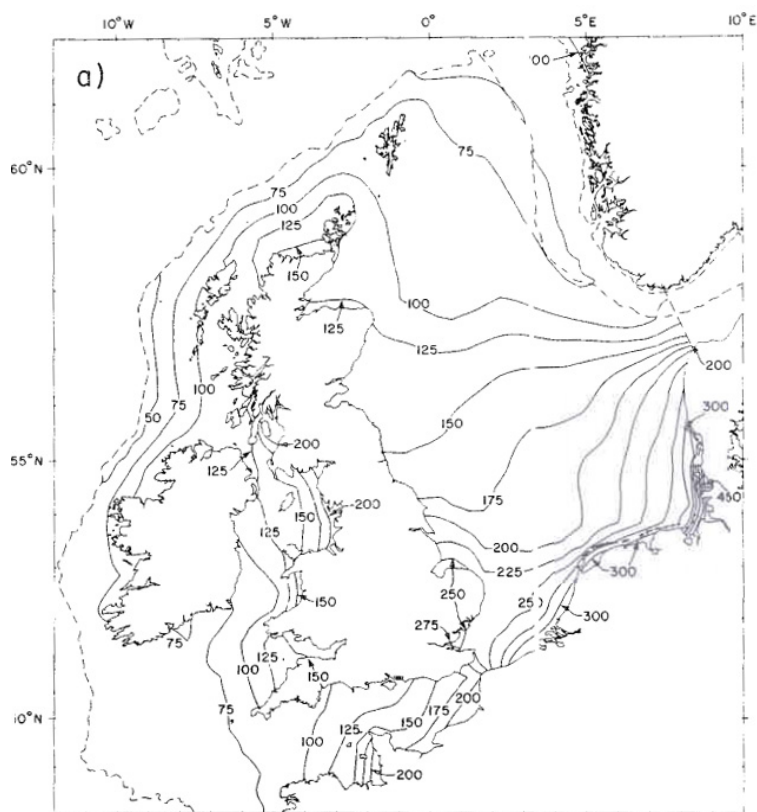
Observations from Metocean Survey Locations 1, 2 and 3 and the ASLF AWAC Deployment				
Astronomical Statistics	L1	L2	L3	ASLF AWAC
HAT (m)	6.80	7.21	6.62	6.30
MHWS (m)	6.10	6.39	5.96	5.60
MHWN (m)	4.78	4.99	4.62	4.37
MSL (m)	3.38	3.54	3.21	3.09
MLWN (m)	1.99	2.08	1.81	1.80
MLWS (m)	0.67	0.68	0.46	0.57
LAT (m)	0.00	0.00	0.00	0.00
MSR (m)	5.43	5.71	5.50	5.04
MR (m)	4.11	4.31	4.15	3.80
MNR (m)	2.80	2.91	2.81	2.56
MHWI (m)	10.94	10.92	10.93	10.98
MLWI (m)	17.16	17.33	17.3	17.25
Maximum Observed Positive Residual (Surge) (m)	0.51	0.51	0.54	0.33

Tides (atmospheric factors)

- 6.4.39 The astronomical tidal values outlined above are the predictable portion of tidal height. Atmospheric conditions, e.g. passage of atmospheric depressions and highs, can significantly increase or decrease the overall water level (termed surges or storm surges in more extreme cases). Table 6.15 presents figures for the positive and negative surges for two locations over return periods of 1, 10, 50 and 100 years. Data recorded from the Arun Platform (which is located approximately 4km offshore and to the south west of Worthing) suggest that for a 1 year return period a positive residual surge of 0.91m and a negative surge of 0.73m.
- 6.4.40 Storm surges can occur in the English Channel during severe events. The geography of the area has a funnelling effect and as a result coastal areas in the East English Channel experience greater levels of surge than areas in the west. Modelling and observations indicate a storm surge could potentially increase the sea level by between 1.25m and 1.5m (50 year extreme surge height) in the vicinity of the Project site (Table 6.15).

Table 6.15: Extreme Surge Statistics

Return Period (years)	Arun Platform		Newhaven NTSLF	
	Positive Residual (m)	Negative Residual (m)	Positive Residual (m)	Negative Residual (m)
1	0.91	0.73	0.95	0.63
10	1.08	0.85	1.11	0.73
50	1.20	0.93	1.22	0.79
100	1.25	0.97	1.27	0.81


Figure 6.15: Storm Surge Elevation (cm) 50yr return period, Flather (1986)

Currents

- 6.4.41 The main source of currents within the English Channel are from semi-diurnal (M2) tides and these stir the entire water column in most of the English Channel and the southern North Sea resulting in well-mixed waters throughout the year. Typical tidal current speeds reach approximately 1.8ms^{-1} in the English Channel but can reach much higher values off headlands e.g. 4.6ms^{-1} off Portland Bill (Tappin *et al.*, 2007). The Renewables Atlas (ABPmer *et al.*, 2008) suggests that at a regional scale, speeds of up to 2ms^{-1} are observed between the Isle of Wight and the Cotentin Peninsula (Cherbourg Peninsula) which is located in Normandy

and this reduces to between 0.5ms^{-1} and 1.25ms^{-1} in the vicinity of the Project site.

- 6.4.42 The Metocean survey and assessment undertaken by EMU (2011a) recorded data from 3 monitoring stations within the Project site (Figure 6.16). The measured current velocities at the 3 AWAC sites show mean spring tidal values of 0.8ms^{-1} at Site 1, 0.7ms^{-1} at Site 2 and 0.9ms^{-1} at Site 3 (Table 6.16). The same table gives extreme flood and ebb velocities for the same locations for 1, 10, 50 and 100 year return periods. These were derived by fitting the datasets to a Weibull probability distribution. The largest extreme values occur under flood conditions; with highest values occurring at Site 3. These depth averaged flood current velocities range from 1.57ms^{-1} (1yr return period) to 1.84ms^{-1} (100yr return period).
- 6.4.43 On a regional scale, the dominant tidal wave orientation is west to east in the English Channel and this is substantiated by the orientation of many surveyed sand wave fields etc. including those recorded during the Project's geophysical surveys. However, many studies including Coggan *et al.* (2009) discuss a bedload parting zone between the Isle of Wight and the Cotentin peninsula. Sediment transport to the east of this line is predominantly to the east and to the west of the line bedload transport is predominantly west.
- 6.4.44 Although tidal currents in the English Channel are mainly driven astronomically, they can also be influenced at a local level by storm surges associated with pressure systems or the propagation of wave induced orbital currents caused by the transit of waves. Modelling completed by Flather (1986) suggests that; based on a 50yr storm surge event the current velocity could be increased by up to 0.6ms^{-1} (Figure 6.17) in the vicinity of the Project site.
- 6.4.45 The coastal processes baseline assessment completed by ABPmer (2011) (Appendix 6.3) presents an output of information on maximum orbital velocities from their Seastates model. Figures from the Seastates model seem to agree with the work of Flather (1986) and indicate that for a 50 year return the orbital velocity associated with wave generated currents for the Project site is approximately 0.5ms^{-1} .

Table 6.16: Current Velocity recorded at the 3 AWAC deployments. Adapted from (EMU, 2011a)

Return Period	Current state	AWAC Location		
		1	2	3
N/A	Mean Spring Rate ms^{-1}	0.8	0.7	0.9
N/A	Mean Neap Rate ms^{-1}	0.4	0.4	0.5
1	Flood current velocity ms^{-1}	1.53	1.48	1.57
1	Ebb current velocity ms^{-1}	0.92	0.98	1.28
10	Flood current velocity ms^{-1}	1.67	1.63	1.71
10	Ebb current velocity ms^{-1}	0.99	1.07	1.39

		AWAC Location		
Return Period	Current state	1	2	3
50	Flood current velocity ms^{-1}	1.76	1.72	1.8
50	Ebb current velocity ms^{-1}	1.03	1.13	1.47
100	Flood current velocity ms^{-1}	1.8	1.76	1.84
100	Ebb current velocity ms^{-1}	1.05	1.15	1.5

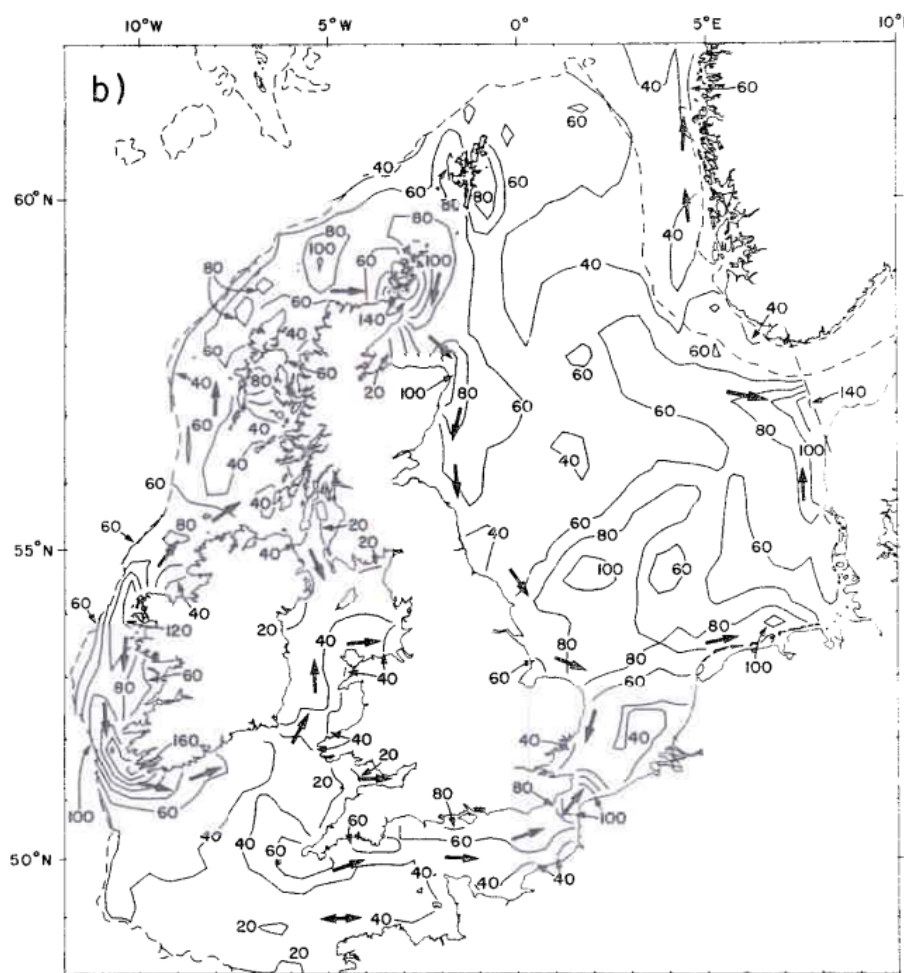
Table 6.17: Maximum orbital current velocities (ms^{-1}) at the seabed associated with a series of low frequency, high magnitude storm events (ABPmer, 2011)

	Return Period (years)	Significant Wave Height H_s (m)	Zero Crossing Wave Period T_z (s)	Orbital Velocity (ms^{-1})
Seastates (nearshore) Depth = 9.9m (CD)	2	4.18	7.14	1.52
	5	4.44	7.35	1.64
	10	4.64	7.51	1.74
	25	4.9	7.72	1.87
	50	5.09	7.87	1.96
Seastates (Application Site) Depth = 33m (CD)	2	4.83	7.46	0.37
	5	5.1	7.67	0.43
	10	5.29	7.81	0.47
	25	5.47	7.94	0.51
	50	5.52	7.98	0.52
Seastates (Offshore) Depth = 54m (CD)	2	5.41	7.44	0.09
	5	5.6	7.57	0.11
	10	5.71	7.65	0.11
	25	5.83	7.73	0.12
	50	5.9	7.78	0.13

6.4.46 In addition to the Metocean assessment conducted by EMU (EMU, 2011a), ABPmer as part of a coastal Processes Baseline Assessment for the Project (ABPmer, 2011) also present data from the BODC data archive and Total tide (UKHO tidal diamonds). The BODC data are presented below and have been recorded at locations to the south of Selsey Bill. Table 6.18 shows that the highest depth averaged current speed (ms^{-1}) is a peak flood value of 1.57ms^{-1} at Site B (depth 18m). The lowest depth averaged current speed is a peak flood value of 0.85ms^{-1} at site C (depth 21m).

Table 6.18: Summary of BODC data and current properties (ABPmer, 2011)

Site No.	BODC ID	Depth of Deployment (m)	Start Date	End Date	Depth Averaged Current Speed (ms^{-1})	
					Peak Flood	Peak Ebb
A	49879	13	14/09/1984	01/10/1984	1.47	1.45
	49880	18	14/09/1984	01/10/1984	1.42	1.38
B	100283	18	28/04/1985	21/05/1985	1.57	1.5
	100271	26	28/04/1985	18/05/1985	1.44	1.42
C	49923	13	10/12/1983	17/12/1983	0.87	0.84
	49935	21	10/12/1983	17/12/1983	0.85	0.84

**Figure 6.17: Storm Surge Current Speed 50yr return period (cms^{-1}), derived from the distributions of maximum computed elevation and current (Flather, 1987)**

Wind Speeds

- 6.4.47 It is important to consider the pattern and magnitude of wind / wind speed because it is relevant to the creation of waves. However the wind does not have a direct impact on the hydrodynamic system. In 2007 BERR commissioned a project as part of the Strategic Environmental Assessment (SEA) process to investigate primary resources relevant to renewable energy (ABPmer *et al.*, 2008). The wind resource map (Figure 6.18) shows that the Project site falls into six cells of modelled data. As the renewable energy wind resource model is aimed specifically at offshore wind farms the data have been provided at heights of 80m and 100m above sea level. The data show a difference in the wind regime between the nearshore and offshore portions of the offshore wind farm. With an annual wind speed at 100m of between 4.48 and 6.73ms⁻¹ in the nearshore quadrant and between 8.59 and 9.88ms⁻¹ in the offshore cells.
- 6.4.48 EMU Limited, as part of the Project's metocean study deployed a meteorological buoy between 25 January 2011 and 10 May 2011. The wind roses (Figure 6.19) show the results of the deployment alongside data from the Worthing Pier meteorological station (part of the Channel Coastal Observatory (CCO)) collected and analysed by ABPmer (2011). The results from the buoy deployment show the predominant wind direction is WSW, followed by W and WNW. Approximately 65% of the record contains wind speeds of 3 to 9ms⁻¹. The Worthing Pier data during the same time period showed a different prevailing wind direction, namely NNE followed by SW with dominant wind speed of 3 to 5ms⁻¹.

Water Quality

- 6.4.49 During installation, sediment will be suspended into the water column, which could potentially cause damage to sensitive habitats and species. Of particular concern are issues of seabed smothering, sediment plumes and the re-suspension of contaminants. A desktop study, metocean survey and modelling studies were undertaken to provide baseline conditions against which any changes can be evaluated.
- 6.4.50 The Environment Agency (EA) web site presents recent data on ecological and water quality for coastal waters in the vicinity of Worthing. Currently the Water Quality Status is classified as Good and Ecological Status classified as Moderate. The EA predict that quality status will remain the same until 2015.
- 6.4.51 A number of bathing waters designated under the EC Bathing Water Directive are located close to the Project, the closest one being Lancing beach approximately 1km east of the cable landfall. The status of designated bathing waters is not sensitive to contaminant concentrations but is dependent on bacterial concentrations. Water quality is tested weekly by the EA during the bathing season (May to September). Throughout 2012 the water quality at Lancing beach reached or exceeded minimum water quality standards.

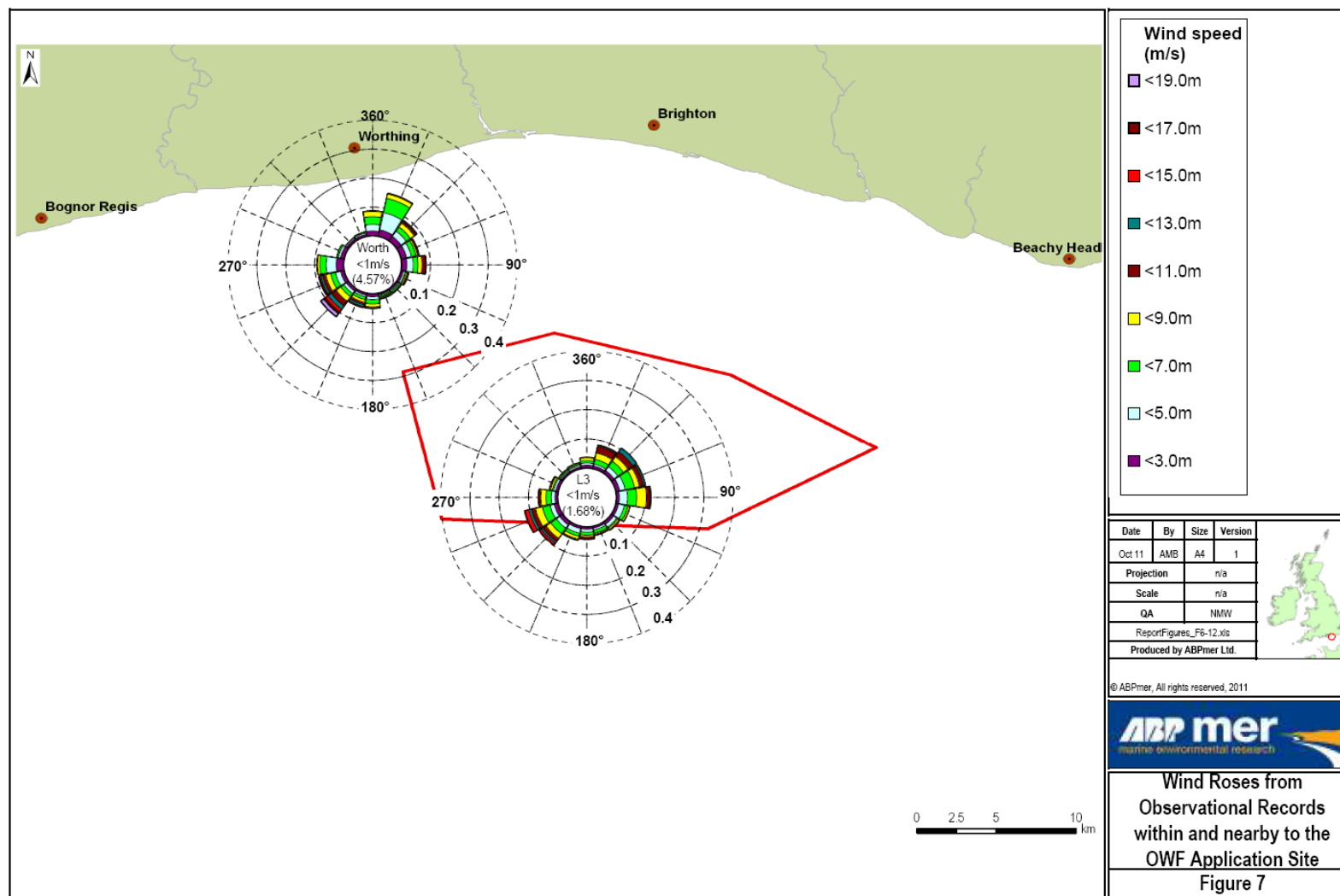


Figure 6.19: Wind Roses from Observational Records within and nearby to the Project site (ABPmer, 2011)

Temperature

6.4.52 The sea surface temperatures (SST) show a strong yearly cycle (Figure 6.20). The English Channel receives inputs from the sea to the west and from English and French river systems. The input of water from the west comprises of warm saline water from the Bay of Biscay (Rennell's Current) and also from a southerly current originating in the Irish channel. The English Channel can be split into eastern and western areas (Figure 6.21). Due to the shallow profile and the influence of strong tidal currents the water in the eastern English Channel is well mixed with an even salinity and temperature from the seabed to the surface.

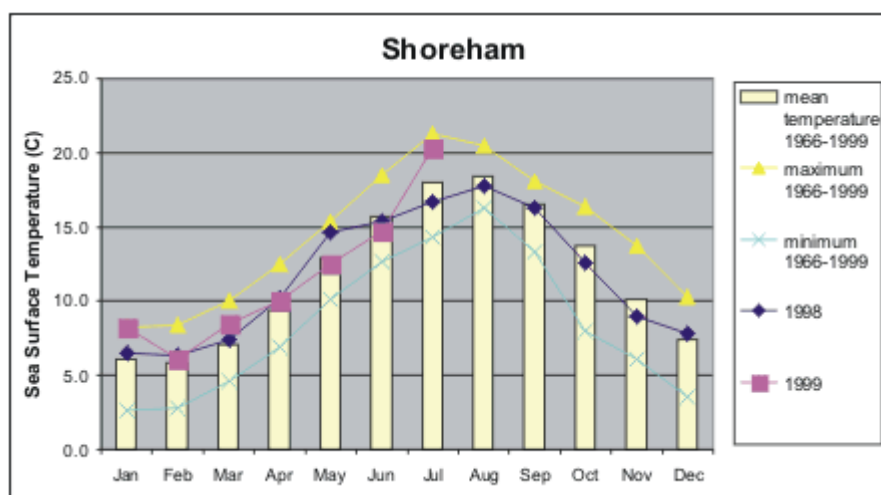


Figure 6.20: Monthly mean sea-surface temperatures at Shoreham (iacMST, 2004, originally from MAFF)

Salinity

6.4.53 The salinity of the English Channel is also primarily influenced by the warm saline water from the Atlantic (specifically the Bay of Biscay – Rennell's Current), and a southerly current of relatively fresh water from the Irish channel and from the many large freshwater inputs from both England and France. The flow of water in the English Channel is west to east and as the water moves eastward the various freshwater inputs reduce the overall salinity. The mean annual salinity decreases from between 35.4 and 35.5ppt (parts per thousand) in the western entrance of the Channel to 35.2 at the Strait of Dover on the central axis, and to approximately 34.7 around the Isle of Wight and off the Bay of Seine. Salinity in the English Channel undergoes an annual cycle, being highest in the winter and lowest in the summer.

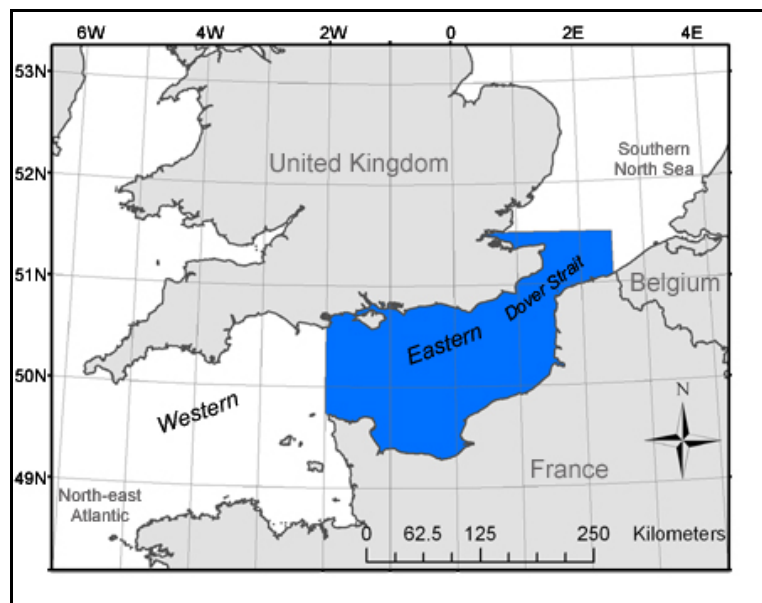


Figure 6.21: Map of the division between the eastern and western English Channel

Suspended Sediment

- 6.4.54 Water and Suspended Particulate Matter (SPM) contained within it is transferred from the Atlantic to the southern North Sea via the English Channel. During this process some SPM drops out of suspension and is deposited whilst additional SPM enters the water column from English and French river systems. The larger suspended sediment sinks include estuaries, the Dover Strait and eventually the southern North Sea.
- 6.4.55 Within the eastern English Channel additional suspended material comes from French and English sources such as:
- Riverine inputs;
 - Erosion of wave cut cliffs and platforms;
 - Mobilisation of seabed sediments;
 - Locally produced biogenic material; and
 - Influx from the western English Channel.
- 6.4.56 The sediment input from English rivers is significantly less than that from French sources. The mean riverine discharge from English catchments is approximately 4.5×10^4 tonnes per annum (ta^{-1}) (Herrington *et al.*, 1995), whereas the discharge from the River Seine alone is an order of magnitude greater at $5\text{-}10 \times 10^5 \text{ta}^{-1}$ (Avoine, 1987). A study by Velegrakis *et al.* (1999) suggests that the level of suspended material is greatly influenced by atmospheric forcing and as a result will be elevated in winter and spring. As part of the same study SPM surveys (of surface water) were undertaken at a variety of locations during September and

November 1994. The results of this sampling programme showed greater levels of SPM in coastal waters than in offshore waters and; SPM concentrations within the Project site of 2mg/l.

- 6.4.57 As part of the Project's metocean study (EMU, 2011a), the AWAC equipment deployed at the 3 monitoring locations measured Optical Backscatter (OBS) in Fluorimetric Turbidity Units (FTU). These measurements were converted to a Suspended Sediment Concentration (SSC). The SSC data presented in Table 6.19 show the estimated SSC concentrations to be variable across the Project site. At all three locations the most common estimate for SSC is between 5-10mg/l with highest estimated levels of SSC (90-95mg/l) occurring at the deeper location (L3).
- 6.4.58 There is a general temporal trend indicating that changes in tidal current flows associated with the spring-neap cycles correspond to variations in SSCs. This relationship is most evident at L3 (the deepest of the AWAC deployments), but at the shallower L1 and L2 sites the same relationship is evident, suggesting that tides are still the dominant control mechanism. The data shows that during storm events waves interact with the seabed at the shallower sites causing elevated SSCs.
- 6.4.59 During one recorded storm event (04/12/2010 – 08/12/2010) wave heights increased by 3m resulting in an increase in SSC from 5-15mg/l to 30-35mg/l. Similar wave events occurring at L3 did not show the same elevation of suspended sediment.

Table 6.19: OBS estimated suspended sediment concentrations (SSC) approximately 0.5m above the seabed. (Adapted from ABPmer, 2011)

Estimated SSC (mg/l)	L1 (%)	L2 (%)	L3 (%)	Estimated SSC (mg/l)	L1 (%)	L2 (%)	L3 (%)
0-5	9.24	27.26	14.23	50-55	-	0.03	2.23
5-10	62.48	50.48	35.3	55-60	-	0.01	1.53
10-15	24.43	13.31	15.57	60-65	-	0.01	1.01
15-20	2.36	3.88	4.76	65-70	-	-	0.66
20-25	0.76	1.83	2.88	70-75	-	-	0.68
25-30	0.31	0.98	3.29	75-80	-	-	1
30-35	0.18	0.76	3.86	80-85	-	-	1.21
35-40	0.14	0.72	3.84	85-90	-	-	0.71
40-45	0.04	0.38	2.88	90-95	-	-	0.82
45-50	0.07	0.35	2.86				

Sediment Contamination

- 6.4.60 Contaminants can enter shelf waters via a number of pathways. Sources can be diffuse in nature e.g. urban or agricultural run-off entering river systems and eventually coastal waters. Pollution can also enter waterways via point sources such as sewage outfalls or industrial releases. Common anthropogenic pollutants

found in estuaries, harbours and coastal waters include pesticides, herbicides, antifouling agents used to protect the hulls of ships, and those contained in fuel and lubricants. In addition to the pathways outlined above, it is possible for metals and other contaminants to enter coastal waters through processes such as dry deposition. According to Otten *et al.* (1989) (in Tappin *et al.*, 1992) atmospheric inputs may be significant in the English Channel for some metals. OSPAR (2000) suggest that atmospheric sources are particularly important for mercury and lead. Residence times in the atmosphere are short for most substances as they tend to be deposited by rain (wet deposition) or through sedimentation (dry deposition) OSPAR (2000).

- 6.4.61 Certain metals and other pollutants tend to partition to SPM, meaning that concentrations of contaminants can be much higher in sediments than in the water column. In fact Cefas (2007) suggest that contaminant concentrations in most sediments are at least 3 orders of magnitude higher than those measured in seawater samples.
- 6.4.62 In a constituent paper to the DECC Strategic Environmental Assessment (SEA) Area 8 study, Voisey *et al.* (2004) suggest that metal concentrations are generally highest near the shore in the western part of the channel in Lyme Bay. The report also suggests that to the east of the Solent there are relatively high concentrations of mercury. OSPAR (2000) suggests that due to short atmospheric residence times, deposition decreases from land to sea.
- 6.4.63 To help assess the potential impact of dumping dredged material at sea, Cefas developed assessment criteria based around a combination of chemical and ecotoxicological datasets. The final product of this research was to create two action levels which can be used as part of a larger assessment to determine if seabed sediments can be disturbed or moved without major implication to the surrounding environment. These non-statutory action levels are commonly used to assess the impacts associated with the disposal of dredged materials and focus on the concentration of key contaminants within the sediment (Table 6.20).
- 6.4.64 Grab samples collected in and around the Project site (Appendix 7.2) were subject to analysis for several contaminants including:
- Metals – arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), tin (Sn), barium (Ba), aluminium (Al), zinc (Zn), vanadium (V), and iron (Fe); and
 - Total Petroleum Hydrocarbons (TPH).
- 6.4.65 The full results of the contaminants analysis can be found in Appendix 7.2. EMU (2011b) summarises the results as:

Eleven of the sites sampled supported levels of contaminants in excess of Action Level 1, for one or more metals, specifically arsenic, at all eleven sites, and chromium, at four of these sites.

- 6.4.66 The levels recorded by EMU are higher than would be expected in the type of sediment found at the Project site. Concentrations of arsenic present in the grab samples exhibited a range of 8.13mg/kg to 38mg/kg compared to the Cefas Action Level 1 concentration of 23mg/kg. Chromium concentrations at the locations sampled by EMU (2011b) had a range of 4.04mg/kg to 43.7mg/kg compared to the Cefas Action level of 40mg/kg.

Table 6.20: Cefas Action Levels

Contaminant / Compound	Action Level 1	Action Level 2
	mg / kg dry weight (ppm)	
As	23	100
Hg	0.3	3
Cd	0.4	5
Cr	40	400
Cu	40	400
Ni	20	200
Pb	50	500
Zn	130	800

6.5 Predicted Impacts on Marine Physical Environment

Rochdale Envelope

- 6.5.1 The Rochdale Envelope approach to impact assessment (see Section 5 – EIA Methodology) enables developers to incorporate a degree of flexibility into a project as it does not expect all of the project details to be finalised before an environmental impact assessment is undertaken. The premise of the Rochdale Envelope approach is that the realistic worst case scenario is identified, so that the possible impacts of the project can be seen to fall within an envelope somewhere between the ‘best’ and ‘worst’ case scenario.
- 6.5.2 Section 2a - Offshore Project Description identifies the realistic worst case construction options for the Project in terms of the implications to the physical environment. The logic and justification behind these choices are described in Section 2a and in Appendix 6.4 – the hydrodynamic modeling report.
- 6.5.3 A summary of the worst case construction / engineering scenarios is presented in Table 6.21.

Table 6.21: Worst case scenarios assessed by ABPmer (ABPmer, 2012)

Design feature	Design options
Wind farm site layouts	A compressed layout will provide the greater blockage to the hydrodynamics.
Wind turbines	A higher number of small turbines will create the worst-case in terms of numbers of foundations, a higher number of foundations will tend to create a greater blockage to the hydrodynamics.

Design feature	Design options
Foundations	Installation of monopile by drilling will create a worst-case in terms of suspended solids (from drill arisings), and possible as a result of deposit of drill arisings on the seabed. Selection of a foundation type which requires seabed levelling would also constitute a worst-case in terms of seabed disturbance.
Offshore substation	It is expected that the substations will have a similar type of foundation to those used for the turbines, gravity bases would be a worst-case.
Cables	Deeper burial of the cable will constitute a worst-case for suspended solids (assuming jetting is used). Routing the cable over exposed rock will constitute a worst-case in terms of effect on local hydrodynamics (very localised).
Construction and installation	Installation of foundation piles by drilling will create a worst-case in terms of suspended solids. If the cables are installed using jetting, this will create worst-case suspended solids levels.
Operation and Maintenance	Highest number of gravity bases being used is a worst-case for effects on hydrodynamics. Replacement of any scour protection throughout the operational lifetime of the project would constitute a worst case in terms of seabed disturbance.
Decommissioning	The effects of decommissioning the wind farm will be determined by the choice of turbine foundation used. Worst-case effects of decommissioning could vary, with removal of foundations to depths below seabed potentially creating maximum disturbance, conversely leaving infrastructure in place on the seabed may also have a continuing effect on hydrodynamics.

6.5.4 ABPmer have undertaken hydrodynamic modeling of the effects of the installation and operation of wind farm components in the Project Site, the modeling used realistic worst-case scenarios. The following were considerations in compiling the worst-case scenario:

- *For wave and tidal blockage, it is the combination of a larger number of smaller units, placed closer together that provides the greatest potential blockage.... it is the layout which contains the greatest number of gravity base structures (GBS) that may be considered the option with the greatest potential impact;*
- *Accordingly, it is considered that the layout containing 80 x 4MW GBS structures and 95 monopile structures (175 structures in total) that presents the realistic worst case scenario.*
- *When considering sediment sources from scour and GBS ground preparation, the larger number of GBS units (4MW turbine layout) presents the greatest potential sediment source.*
- *When considering sediment sources from piling activities, it is the monopile structures that present the greatest potential sediment source.*

- 6.5.5 Two substations will be installed within the wind farm, as yet their locations are undecided. It is likely that they will be built on jacket or monopole foundations. In terms of effects on sediment hydrodynamics, jacket and monopole foundations are likely to produce the least change. Substation foundations have not been included in the hydrodynamic modeling, however given that there will only be two sites, and that they will be installed using foundations that have lowest effect on hydrodynamics, it is likely that any changes to the modeling results would be negligible if, once their position is determined, they were included.

Installation

Bathymetry

- 6.5.6 During installation of the offshore wind farm components, a number of construction activities will affect the bathymetry of the seabed. The most significant of these are the effects of vessels used for installation of turbines (particularly the foundations e.g. heavy lift vessel, jack-up barges or anchored barges) and the installation of the offshore cable.
- 6.5.7 In the case of the turbines, the detailed engineering study will identify the best technical solution for the type of turbine foundation installed, array design etc. Due to the size of the Project site and the variability in seabed conditions it is likely that a variety of foundation types will be used (see Section 2a – Offshore Project Description). Foundations, transition pieces, nacelles and blades can be installed using either a heavy lift vessel or jackup barge, with the worse-case scenario being the jackup barge. A report commissioned by COWRIE (2010) collated and examined information regarding the effects of scour at offshore wind farm sites. Post installation surveys at several projects including Barrow and Kentish Flats showed the presence of large indentations / scour holes where the jackup legs had been positioned. Subsequent surveys however illustrate that these depressions in-filled over time. Modelling undertaken by ABPmer (2012) for the Project estimated the worst case scenario for the level of damage caused by jack-up platform spud cans. The modelling assumed that the Jack up legs left a 30m² footprint. The results of the modelling showed that the effects of jack-up legs are confined to the array and do not overlap with any coastal process receptors. Accordingly the effects of jack-up legs are considered to be of a small magnitude, have only a localised effect and are temporary on medium term time-scales. The potential effect on the bathymetry of the seabed is therefore considered of negligible significance.
- 6.5.8 Throughout the installation process, a variety of vessels will work on site. Depending on the activities undertaken, some of the larger barges will maintain position using up to six anchors. The anchors for such vessels are large and ABPmer (2012) suggest that they can be between 1.5m and 3m in length. Unless sediments are very soft anchors do not penetrate the sediment to any great depth due to gravity alone. Once on the seabed the anchor is dragged until the

fluke penetrates the sediment until it holds, where the shear strength of the sediment is greater than the load on the anchor. The barges working on wind farm projects need to anchor in a suitable position to allow them to conduct their work. As such, anchor handling tugs are used to drop the anchors out to a pre-determined distance, relative to the water depth. The barge then hauls on the winch until the anchor holds. The setting and removal process can produce seabed scars and seabed mounds. ABPmer (2012) assessed the impact of anchors as follows:

The effects of anchors are confined to the array and do not overlap with any coastal process receptors. Accordingly these are therefore of small magnitude, having only a localised effect and are temporary on short term time scales. The potential effect is therefore considered of negligible significance.

- 6.5.9 The Osiris geophysical surveys of Section 1 and Section 2 of the Project site show the presence of seabed features such as rock ridges, sandwave fields and megaripple fields. It is highly likely that array or export cables will need to be laid around, through or over these features. Where cables cannot be routed around rock ridges they will most likely run over the top of them. To support the cable and ensure that all as laid angles etc. are within engineering tolerances, rock placement or concrete mattresses may be required. The potential effects of mattressing will be dependent upon its extent. The requirement for mattressing is considered to be limited. It is considered that the maximum height of protection that would be required could result in an elevation of the seabed profile by up to 1m. This will alter the bathymetry of the ridge but the impact will be negligible due to the very localised nature.
- 6.5.10 Some sections of cable may need to be laid through sandwave / megaripple fields. If an alternate route cannot be found then sandwave pre-sweeping may be required. During this process the tops of the sandwaves are removed with a Trailing Hopper Suction Dredger (THSD) to leave a flat surface for the cable lay and burial equipment to run along. The presence of sandwaves indicates that the environment is dynamic and it is likely that the sandwaves will re-form over a relatively short period of time. As a result the impact of sandwave pre-sweeping can be classed as having low sensitivity, a small magnitude and therefore of minor significance.

Geology and Seabed Sediments

- 6.5.11 The impact caused by the installation of turbines will vary depending on the type of foundations selected. The type of foundations will be determined during the ongoing engineering feasibility studies. The installation of gravity base, monopile, tripod or jacket foundations would cause a small, temporary impact to the seabed sediment over a limited area. The Holocene sediment which covers most of the Project site is predominantly sand containing little or no fine material. Any sediment disturbed as a result of installation activities will quickly fall from suspension and will not be transported a great distance. The piles used for both

monopile and jacket foundations will be driven through the Holocene sediments and into the underlying geology. The damage to geology will be irreversible but limited in scale due to the design of the piles. In some locations holes may need to be pre-drilled for the monopile foundations and it is possible that drilling may occur into and through chalk horizons. If drilling is required and drilling penetrates a chalk horizon it is possible that fine chalk arisings (cuttings) will be created and released into the surrounding environment. ABPmer (2012) point out that drilling is not the preferred installation for monopile foundations; however should monopiles require drilling then this represents the worst case scenario in terms of Rochdale Envelope. In the case of gravity base foundations, pads are created by dredging the area of loose sediment to create an even surface. A layer of gravel and concrete is used for final levelling and to strengthen the pad prior to the arrival of the foundations. Overall the impact can be classified as being of minor significance as each pad is small in relation to the overall size of the offshore wind farm site. Also, it is likely that sediment will be deposited over the base. Gravity base foundations will not affect the underlying geology.

- 6.5.12 ABPmer (2012) estimate seabed arisings as a result of foundation installation as follows:

Assuming preparation over a circle with a diameter of 34m and down to a depth of 2m, the realistic worst case volume of sediment arising per gravity base foundation would be 1,820m³ whilst the realistic worst case for a drilled monopile would be 1,824m³

- 6.5.13 Consequently gravity base foundations would have the greatest impact on the seabed as large pads (clear flat areas) are needed for each foundation to sit on. The use of suction caisson foundations will be limited through the Project site due to the thin veneer of Holocene deposits over much of the area. With the thickness of sediment often less than 1.5m; it is unlikely to be thick enough for the foundations to sink to their optimal depth. However, in areas where the sediment is thick enough i.e. in the palaeochannels these foundations will have negligible magnitude and low sensitivity meaning an overall negligible impact to the seabed sediment and underlying geology.
- 6.5.14 Foundations can be piled using a mechanical hammer mounted on a jack-up platform or vessel such as a barge. The use of a jack-up platform will cause a small amount of sediment mobilisation and the formation of indentation / scour pits around the jack-up spud cans (see Section 6.5.1). Due to the seasonality of storm events, installation work may be scheduled to avoid late autumn, winter and early spring as it is operationally more difficult and dangerous for vessels to work during bad weather. Superficial sediment is mobilised through most tidal states. This mobilisation is further enhanced during larger wave events which occur, approximately, 5 to 20% of the time during the year. It is therefore considered that any depression / scour pit remaining when the jack-up vessel has moved away will be infilled over short to medium timescales (i.e. a period of a

few weeks up to a few years, depending on the initial depth of the pit.) As already stated in Section 6.5, the impact caused by the jack-up platforms is expected to be negligible.

- 6.5.15 The offshore cables required for the Project can be split into two categories: Array cables (between turbines) and export cables (from the offshore substation to the onshore landing point). There are a variety of installation methods available and equipment will be chosen based on engineering studies, informed by the site surveys.
- 6.5.16 Table 6.22 illustrates a variety of burial devices and indicates their suitability in particular sediments. It shows that all devices could be used on the Project; however, rock wheel cutters and chain excavators are not ideal in sand and are only likely to be used in areas where rock outcrops occur.

Table 6.22: Cable burial devices and burial options (BERR, 2008)

Cable Burial Devices	Burial Device Options	Sediment Type					
		Sands	Silts	Gravel	Weak Clays	Stiff Clays	Rock
Cable Burial Ploughs	Conventional narrow share cable ploughs	✓	✓	✓	✓	✓	X
	Advanced cable ploughs	✓	✓	✓	✓	✓	X
	Modular cable ploughs	✓	✓	✓	✓	✓	X
	Rock ripping ploughs	✓	✓	✓	✓	✓	✓
	Vibrating share ploughs	✓	✓	✓	✓	✓	✓
Tracked Cable Burial Devices	Jetting systems	✓	✓	?	✓	X	X
	Rock wheel cutters	P	P	P	✓	✓	✓
	Chain excavators	P	P	✓	✓	✓	X
	Dredging systems	✓	?	?	X	X	X
Free Swimming Remotely operated vehicles (ROVs) with Cable Burial Capability	Jetting systems	✓	✓	?	✓	X	X
	Dredging systems	✓	?	?	X	X	X
Burial Sleds	Jetting systems	✓	✓	?	✓	X	X
	Rock wheel cutters	P	P	P	✓	✓	✓
	Chain excavators	P	P	✓	✓	✓	X

Cable Burial Devices	Burial Device Options	Sediment Type					
		Sands	Silts	Gravel	Weak Clays	Stiff Clays	Rock
	Dredging systems	✓	?	?	X	X	X
KEY ✓ = Should be capable of burial. ? = Performance will be related to the type of sediment and the power delivery to the burial device. P = Performance possible in the sediment type but not an ideal application. X = Unlikely to be capable of burial.							

- 6.5.17 There are numerous types of plough available to bury subsea cables but they fall into two main categories: displacement ploughs and cable burial ploughs. Displacement ploughs create a large V shaped trench in the seabed, with the sediment from the trench being deposited either side. The cable is laid in the trench which can then be backfilled or left to fill in naturally. These ploughs tend to be used for pipeline installation; however, they have been used to lay numerous cables. Displacement ploughs are disruptive and cause short to medium term damage to the seabed.
- 6.5.18 Cable burial ploughs are much less disruptive and cause minimal damage to the seabed. The cutting face on a non-displacement plough is a sharp blade which cuts through sediment without displacing large amounts of material. The cable runs through the plough and is buried as it goes. This kind of plough can be used in most types of sediment but certain types of sand can prove problematic. With this in mind and where possible, cable burial ploughs will be used to keep sediment disruption to a minimum.
- 6.5.19 The third method of cable installation considered in Section 2a - Project Description is jetting. A jetting tool uses jets of high pressure water to fluidise the seabed sediment. Once fluidised, the cable effectively buries itself due to gravity. Sometimes a jetting tool can be combined with a dredger so the fluidised material can be removed from the trench. BERR (2008) suggest that in cohesionless soils the soil can be fluidised with jets at relatively low pressures. The problem for jetting in cohesionless soils is that the trench walls collapse back into the trench. This means that several passes maybe required to achieve the required depth.
- 6.5.20 Tables 6.23 and 6.24 (BERR, 2008) indicate the level of disturbance created whilst using a variety of installation methods and suggests that jetting disturbs the sediment much more than installation using a cable plough.
- 6.5.21 Based on probable installation techniques (i.e. non-displacement plough) the effects on seabed sediments are considered to be of small magnitude, have a

limited spatial extent and are temporary on time scales similar to the duration of installation. The potential impact is therefore considered of minor significance.

Table 6.23: Sediment disturbance caused by a cable installation plough (BERR, 2008)

Tool	Ground Conditions					
	Sand	Silts	Gravels	Clay	Unstructured Rock-Matrix Material	Weak Rock (Chalk)
Conventional Narrow Blade	1	1	1	1	N/A	N/A
Advanced with Jetting	2	3	2	2	2	N/A
Deep Burial	1	1	1	1	1	N/A
Rock Ripping	1	1	1	1	1	4
Vibrating	1	2	1	1	2	6
Level of disturbance 1= Low, 10 = High, N/A = Not applicable						

Table 6.24: Sediment disturbance caused by other cable installation methods BERR, (2008)

Tool		Ground Conditions						
		Sand	Silts	Gravels	Clay	Unstructured Rock	Chalk	Structured Rock
Jetting	Fluidisation	2	2	N/A	N/A	N/A	N/A	N/A
	Erosion	3	4	3	3	N/A	N/A	N/A
Dredging		4	6	4	N/A	N/A	N/A	N/A
Rock Wheel		3	4	3	3	3	8	4
Mechanical chain Excavators		3	4	3	3	3	N/A	N/A
Level of disturbance 1= Low, 10 = High, N/A = Not applicable								

- 6.5.22 The geophysical surveys (Osiris 2010a, 2010b and 2011) identified a number of geological features, including boulders, rock outcrops, ridges, sandwaves and megaripples, distributed throughout the Project site which could potentially impede cable burial. Where possible, cables will be routed around these features to improve burial protection and to reduce the impacts of installation. However, where an alternate route is not available or feasible the installation method will be chosen to cause minimal impact when crossing such features, as discussed below.

Rock outcrops

- 6.5.23 Currently proposed cable routing will avoid all surveyed rock outcrops. However, in the event that rock outcrops are encountered in final route design, it is likely

that a 0.5-0.75m wide, 0.5-1m deep trench will be excavated using a mechanical cutting device. This trench will either naturally infill or can be mechanically infilled. The impact would be small and of minor significance.

Sandwaves / megaripples

- 6.5.24 Pre-sweeping may be required for parts of the cable route which pass through sandwave or megaripple fields. In these areas, the cable will be installed in the wave troughs (where possible). This would allow the cable to be buried below the mobile layer, ensuring it does not become exposed. Where sandwaves cannot be avoided the sandwave crests may be removed with a THSD or similar to create a flatter profile or 'working' profile, for the burial machinery. After pre-dredging of sandwaves has taken place, trenching / burial machinery will be used to install the cable. In these circumstances a relatively large amount of material is removed from the area creating impacts to the seabed sediments. Dredged material can either be locally disposed of (which may assist in recovery of the seabed) or disposed at an approved site; further cable engineering studies will determine requirements for pre-sweeping. Due to the dynamic nature of the seabed the sandwaves will recover to pre-project levels over a relatively short time period. In the case of megaripples it is likely that recovery will take of the order of weeks to months and for sandwaves recovery is likely to take several months. As a result the impact will be of minor significance.

Sediment Transport and Mobility

- 6.5.25 As discussed in section 6.4.26 when the current is strong enough after the offshore wind farm infrastructure is installed, sediment will be mobilised by the increased current around the turbine foundations (i.e. through scour). The increased current occurs in the direction of flow (predominantly to the east – northeast through the Project site) and as such sediment will be mobilised from the east – northeast side of each foundation and travel in suspension in the same direction. An almost equal level of scour and resuspension is likely to occur in the southwest direction, following the other main current direction. Geophysical surveys of the site have identified scour to the northeast and southwest of wrecks. An equilibrium will establish in terms of scour, whereby any scour pit will reach a particular size (governed by the size of the infrastructure on the seabed, seabed sediments and local current speeds) beyond which current speeds at the edge of the scour pit will not be sufficient to remobilize any more sediment. Potential scour pit sizes for the different foundation types being considered are presented in Appendix 6.4.
- 6.5.26 The predominant sediment type over the Project site is medium sand. Once suspended, medium sands will settle out of suspension relatively quickly. The settling velocities related to this sediment size are shown in Table 6.25. Medium sand may settle out over a period of less than a minute (~15 to 22 seconds) from a height of 1m above the seabed when the flows are less than 0.42m/s. During the time specified above, the material has the potential to travel 9m.

Table 6.25: Settling velocities related to medium sands

Sediment classification		Settling velocity(m/s)	Time to fall 1m (minute)	Critical velocity, V _{cr} (m/s)
description	Micron			
Medium sand	500	0.067	0.25	0.42
	355	0.046	0.36	0.40

- 6.5.27 The metocean campaign shows that flow speeds less than 0.42m/s occur during neap tides only, with the peak spring tides being in the range 0.5 to 1.25m/s (depth-averaged) within the array. Sediment mobility analysis (Section 4.6, Appendix 6.4) further corroborates this, showing that medium sands are mobile between 22% and 37% of the time within the site. Mobility over a reduced part of the tidal cycle inherently limits the distance that the sediment could travel.

Oceanography and Meteorology

- 6.5.28 Whilst the turbines and cables are being installed there may be a small, temporary impact on the hydrodynamic regime due to the presence of the installation vessels. However this would only be the case in shallow water and because installation will usually be undertaken in favourable weather conditions any impact would be negligible.

Water Quality

- 6.5.29 Coastal waters have varying levels of suspended sediment with variability arising due to natural processes such as the phase of the tidal cycle (i.e. spring/neap cycle), wave height and current velocity. Any construction activity that disturbs seabed sediment has the potential to increase the suspended sediment concentration (SSC) within the water column beyond background levels. Elevated levels of SSC can have impacts on certain species of fish and depending on where the sediment is deposited there is the potential for damage or alteration to benthic communities (see section 7 - Benthos and Sediment Quality).
- 6.5.30 ABPmer (2012) undertook a coastal processes assessment for the Project which assessed the effect that the installation of wind farm infrastructure would have on the SSCs within the Project site and further afield. The study considered previous SSC monitoring and modelling that took place as part of the Cromer, Nysted and Kentish Flats wind farm projects alongside the results of the modelling conducted for the Rampion Project. All modelling conducted by ABPmer (2012) was undertaken using the worst case scenarios as per the Rochdale Envelope approach adopted throughout this EIA (see section 5). The effects of the Project together with existing local aggregate extraction activities were also considered.

- 6.5.31 The geophysical and geotechnical reports have highlighted the presence of chalk within the Project site and where foundations are piled or drilled into chalk or cables installed through chalk this creates the potential for suspension due to fine particle size. ABPmer (2012) identified that the installation of monopile foundations through drilling rather than pile driving represents the scenario most likely to mobilise chalk into the water column, with drilling having the potential to displace up to 1,470m³ of material per turbine. Drilling represents the worst case and most monopile foundations will more likely be installed using pile driving rather than drilling. Due to the depth of the chalk substrate close to the exposed seabed surface ABPmer (2012) identified that the northeast of the Project site poses the highest risk for chalk arisings (cuttings) due to foundation installation. A series of numerical plume dispersion simulations for silt sized material (20µm) and coarse sand sized material (750µm) were conducted by ABPmer (2012) and comparing these modelled SSCs with those recorded by EMU (2011a) of 5mg/l to 10mg/l and those occurring during storm event in a water depth of 25m of 35mg/l (ABPmer, 2011), ABPmer (2012) concluded that:

The effects of foundation related construction activities with respect to SSC are considered to be of small magnitude, have only a limited spatial effect and are temporary on time-scales similar to duration of installation. The potential effect is therefore considered of minor significance.

- 6.5.32 With regards to cable installation, ABPmer (2012) concluded that the impact due to the installation of array cables was subordinate to the impact due to foundation installation and did not consider array cables in detail. Due to the shallower water and different sediments found in the export cable corridor the impacts due to the installation of export cables were considered in detail.
- 6.5.33 Due to the presence of chalk at or near the surface within the export cable corridor, it is likely that a trenching tool will be used to achieve the target burial depth of 1-2m. It is probable that such a trenching tool will break any clay at / below the surface into large clasts that will be deposited next to the trench. Where a jetting tool has to be used i.e. in areas of thick Holocene sediment there is the possibility of releasing more material into suspension than through other methods of installation. ABPmer (2012) examined evidence from monitoring studies at the Nysted and Kentish Flats wind farms. Evidence from Nysted wind farm (where the predominant sediment type was medium sand with a thickness of 0.5m to 3m, overlaying clay; and installation was completed with jetting and trenching techniques) showed that elevated SSC was recorded 200m from jetting activities with average concentrations of 15mg/l. Evidence from Kentish Flats wind farm where cables were installed using a cable plough suggests that peak concentrations of SSC were equivalent to peaks in natural concentrations. The geology of the Kentish Flats export cable corridor consists of London Clay overlain by a veneer of surface sediments and in places Quaternary deposits of sand and clay (Vattenfall, 2011).

6.5.34 Numerical modelling conducted by ABPmer (2012) for the installation of export cables for the Project using the worst case scenarios for model inputs concluded that:

- *Peak depth-averaged SSCs would be encountered when the installation of the cable was taking place in very shallow (approximately 5m CD) water depths close to the shore. Here, the maximum concentrations of approximately 200mg/l are predicted although these concentrations would typically be very localised (i.e. <2km) to the cable trench;*
- *In deeper water depths encountered at the seaward end of the cable corridor, peak depth averaged SSCs would typically be less than 100 mg/l; and*
- *After 90 hours (and following completion of the cable trenching activities), the plume would have dispersed as a result of advection and diffusion with residual concentrations of 5 to 10mg/l being observed at a distance of approximately 5km to the east of the cable trench.*

6.5.35 Comparing the model outputs again with the levels of SSC recorded by EMU (2011a) of 5mg/l to 10mg/l and those occurring during storm event in a water depth of 25m of 35mg/l (ABPmer, 2011), ABPmer (2012) concluded that with respect to export cable installation:

The effects of cable related construction activities with respect to SSC and bed level changes are considered to be of small magnitude, have only a limited spatial effect and are temporary on temporary time – scales similar to duration of installation. The potential effect is therefore considered of minor significance.

6.5.36 The EA have stated that disturbance of the seabed has the potential to affect the levels of bacterial concentrations in the water column, which has the potential to affect the status of designated bathing waters. This will only be a potential issue for the cable installation, due to the distance of the turbines from the beach receptors. The closest designated beach is Lancing beach approximately 1km east of the cable landfall. The landfall installation schedule will be discussed with the EA and the local Authority with the aim of minimising disruption and other impacts to beach users.

Sediment Contamination

6.5.37 The installation activities associated with both the turbine foundations and cables has the potential to resuspend/remobilise and transport potentially contaminated sediments. The sediment contamination in the case of the Project site is low to moderate (generally low), the impact and level of sediment transport and suspended sediment are of small magnitude, limited spatial extent and are temporary on the scale of installation i.e. of negligible significance. Therefore the remobilisation of sediment is unlikely to affect the water quality status and ecological status of the water body. The overall impact of sediment

contamination is therefore assessed as negligible. The biological impacts of sediment contamination are discussed in Section 7 - Benthos and Sediment Quality.

Operation

Bathymetry

6.5.38 The installation of turbines within the Project site is likely to lead to an alteration of bathymetry around a number of turbine foundations in the form of scour. Boon *et al.* (2004) suggest that scour occurs when a steady current encounters a cylindrical vertical pile; the flow speeds up around the periphery of the pile, producing a “horse shoe vortex” and a highly turbulent wake in the region downstream of the pile. The combined effect is to carry sediment away from the foot of the pile in all directions, creating a scour pit roughly shaped like an inverted cone. There are two different types of scour:

- Clearwater scour: When the current is not strong enough to mobilise sediment however the vortex created around the pile is strong enough to mobilise the sediment immediately around the pile.
- Live-bed scour: This type of scour occurs when the currents travelling across the seabed are strong enough that sediment is mobile over the whole seabed. The resulting scour pits may be similar but because much more sediment is mobile the scour pit may be created then back filled to some degree by fresh sediment in the area.

6.5.39 Due to the size of the Project site and variation in seabed sediments and morphology across the site, the scour risk will be varied but can be estimated (prior to installation). The tidal currents are such that live-bed scour occurs on a regular basis. However, the seabed sediments across much of the Project site comprise a veneer of sediments over bedrock and this is likely to limit the depth of scour.

6.5.40 If the current is sufficiently strong, scour will begin as soon as a foundation has been installed and will continue until either an equilibrium seabed state is achieved or some form of scour protection is installed or provided. As a result of the above considerations, the expected impact is thought to fall somewhere between being of negligible significance to being of minor significance. This falls in line with the findings of ABPmer (2012) who suggest:

The potential for scour effects resulting from the presence of foundation structures on the seabed are considered to be of limited magnitude, have only an array scale spatial effect and are permanent on medium term time scales. The potential effect upon sediment dynamics is therefore considered of minor significance.

- 6.5.41 Some of the foundation types proposed for the offshore wind farm may require scour protection to protect the foundations and the seabed from excessive erosion through the process of scour. Detailed design, considering factors such as bathymetry, sediment type and sediment thickness will determine whether, and to what level, scour protection may be required. Surveys will be used to monitor scour around the foundations and also any secondary scour that may occur around the edge of any installed protection. Scour can be a major problem for turbine stability and as a result protection is installed and scour rates monitored on a regular basis. ABPmer (2012) suggest that overall only a small proportion of the seabed will be affected by scour pits and estimates this as being between <0.15% and <0.3% of the offshore wind farm area, and will be confined to the array. Due to intensive monitoring regimes and the installation of appropriate protection the impact is thought to be of minor significance.
- 6.5.42 Over much of the Project site the Holocene sediment is less than 1.5m thick. DNV guidance (2004) suggests that a maximum scour depth which requires no mitigation is: $S/D = 1.3m$ where S = scour depth and D = foundation diameter. However, Whitehouse *et al.* (2008) suggest a larger S/D of 1.75m. This means that (using DNV guidelines) where the sediment is less than 1.3m thick a foundation would not need scour protection because the lag deposits which sit below the Holocene sediment are much more cohesive and will prevent scour going any deeper. Once the engineering study has determined exact positions for the turbines, the sediment thicknesses in these locations will be examined. A decision will then be made to determine (in areas of thin Holocene sediment) whether the foundations need scour protection or not and whether it is better to protect the foundation or rely on the lag deposits to restrict scour depth.
- 6.5.43 Due to the risk of damage to subsea cables through fishing and anchoring it is common practice to bury them to a depth of between 1 and 2m. The target depth for cables on the Project is at least 1m below the seabed surface (Section 2a – Offshore Project Description). Throughout the Project site the superficial sediment can be up to 2m thick. If for any reason a cable cannot be buried or is exposed over time and it sits on the surface of the seabed it will be subject to / or potentially subject to scour. Scour will be restricted to the area close to the cable; however it can create situations where the cable would be put at a much higher risk of damage. For example if a cable became exposed, material can be eroded from below the cable itself leading to cable spanning. Cable spanning subjects the cable to excessive forces due to gravity and can leave it more vulnerable to snagging with anchors or fishing gear and it is therefore probable that remedial cable protection works will be required, which could be reburial or the use of rock placement or concrete mattresses. Preliminary cable route engineering studies indicate that between 1- 3% of the route may require cable protection. ABPmer (2012) determined:

The effects of scour potentially resulting from the exposure of export and inter-array cables are considered to be of a small magnitude relative to the range of naturally occurring variability. Effects are also largely localised to the cable route,

short term and temporary. The potential effect upon sediment dynamics is therefore considered of negligible significance.

- 6.5.44 The likelihood of the cables becoming exposed during the project lifetime is very low for the export cable as it will be installed below the depth of mobile sediments at a depth of 1-2m. At the landfall the cables will be installed in HDD ducts below any predicted erosional profile of the beach so any impact is unlikely. Similarly for the majority of the inter-array cables they are located in areas of relatively immobile sediments and will be installed well below the possible effects of mobile bedforms so are unlikely to become exposed. The one exception to this is in the area of large sandwaves to the south of the escarpment, where if turbines are installed the cables may become exposed. In this area a monitoring programme will be required and remedial action taken (most probably reburial by jetting) if the cables become exposed.

Geology and Seabed Sediments

- 6.5.45 As discussed in Section 6.5.63 scour is likely to occur around a number of turbines within the Project site causing sediment to be mobilised around the turbine foundations and deposited a small distance from the same turbine in the direction of current flow (generally northeast). The effect on the sediment erosion and transport will vary across the site and will continue to occur throughout the lifetime of the Project. However, as discussed previously, scour will be controlled where necessary using appropriate scour protection systems so the effect on sediment movement should be kept to a minimum. It is not anticipated that the operation of the offshore wind farm will have any effect on the geology above and beyond installation impacts discussed above. Overall the impact on geology during the operation of the offshore wind farm will be negligible and the impact on seabed sediments will be of minor significance.
- 6.5.46 Section 6.6.9 also notes that the preferred method of protecting cables is burial to a depth of at least 1m below the seabed. In the event that some sections of cable do become exposed it is possible that scour may occur. If this occurs the impact is considered to be of negligible significance.

Sediment Transport and Mobility

- 6.5.47 Section 6.5.50 discusses sediment transport and mobility within the Project site. It is ascertained that there is an existing but limited influence of waves on seabed sediment mobility. The near bed orbital current velocities associated with wave activity are not enough to cause significantly higher bed shear stress offshore in water depths greater than 30m. With this in mind it will be the sediment transport by tidal currents that is the major transport mechanism for sediment within the Project site. In the shallower water such as that in the cable corridor wave action will have a greater influence on sediment mobilisation. Changes to currents or waves will impact sediment mobility and transport to varying degrees throughout the Project area.

- 6.5.48 The presence of turbines will cause a localised increase in current around the turbine foundations, leading to scour. The sediment will be mobilised and carried away from a turbine causing an elliptical scour hole to develop. The majority of the suspended sediment will settle from suspension within a short distance. The amount of scour and the extent of sediment transport will vary across the Project site and will depend on factors such as sediment type, the presence of seabed features and current velocity. When the array layout is finalised an assessment can be made on the amount of sediment mobilised at each turbine foundation. Increased sediment transport will only continue outside the offshore wind farm in the direction of the current flow within the extent of the active seabed scour (live-bed scour).
- 6.5.49 As set out later in Section 6.5.63 the installation of turbines will not significantly alter current speed other than a slight increase in velocity around the foundations themselves. As a result the overall impact of the installation of offshore wind farm infrastructure on sediment transport and mobility within the Project site will be of minor significance.
- 6.5.50 ABPmer (2012) conducted a progressive vector analysis to examine the worst case scenarios in terms of changes to the wave and current regimes along with associated changes to bed shear stress and resultant implications for sediment transport. Details of the model and parameters used can be found in Appendix 6.4. ABPmer (2012) defined the sediment transport regime within the baseline in terms of sediment transport at the bed (bed load transport), sediment transport within the water column (suspended sediment transport) and sediment transport at the coast (longshore sediment transport). ABPmer (2012) reached the following conclusions regarding bed load transport:
- *Very little change is predicted to occur [in tidal current induced bed shear stress] within the near-field, following construction of the array. These very minor changes will not be measurable in practice. Moreover, any differences between baseline and post-development predictions will only reduce with increased distance from the array. Accordingly, no changes to baseline values of tidal bed shear stress are anticipated to occur in the far-field;*
 - *Changes in bed shear stress within the application site are not sufficient to change the size of material that is mobilised nor the duration of the tidal cycle over which this material is mobile; and*
 - *The predicted changes to the tidal regime resulting from the presence of the array would not appreciably affect sediment mobility and consequently the existing seabed form.*
- 6.5.51 A number of designated sites are located within the extent of far-field effects. A consideration of the potential effects with respect to relevant designated sites is provided in Section 6.3.4 of Appendix 6.4, and a summary is presented below. The assessment of potential impacts to nearby designated sites focuses upon the potential for significant modification of the naturally occurring physical processes

that could indirectly impact the habitats they support. Conclusions presented by ABPmer (2012) for each site are:

- *Pagham Harbour: SPA and Ramsar: No significant changes to the wave and tidal regimes are predicted to occur at this location. Correspondingly, there are no significant effects anticipated to occur to the habitats located here.*
- *Beachy Head West: rMCZ: There are no significant changes to the wave and tidal regimes along this frontage, with slight changes to the shoreline sediment transport regime indicated as reductions in the longshore sediment transport rates to the east.*
- *Kingmere: rMCZ: No changes to this regime as a response to the presence of the Rampion Wind Farm are predicted. Only negligible changes to the wave regime are predicted within this site (typically less than 2%, 0.5% and 1% for significant wave heights, directions and periods, respectively.*
- *Offshore Overfalls and East Meridian: rMCZ: No significant changes to the wave, tidal and sediment transport regimes are predicted at these two locations.*
- *Pagham Harbour, Bognor Reef, Selsey East Beach, Felpham, Adur Estuary, Brighton to Newhaven Cliffs, Climping Beach and Seaford to Beachy Head SSSIs. There are no significant changes to the wave and tidal regimes between Selsey Bill and Beachy Head. Slight changes to the shoreline sediment transport regime are indicated, as reductions in the longshore sediment transport rates particularly to the east.*
- *The small change in longshore sediment transport is likely to be comparable or less than the natural variability in rates which result from changing wave conditions experienced on an inter-annual, annual and decadal scale.*

6.5.52 The potential for changes to the bed-load sediment transport regime resulting from the presence of the wind farm infrastructure is considered to be of small magnitude, have only an array scale spatial effect and to be present over the lifetime of the wind farm. The potential effect upon sediment dynamics and thus the existing seabed infrastructure is therefore considered of minor significance.

6.5.53 ABPmer (2012) reached the following conclusions regarding suspended sediment transport:

- *Given the extremely minor predicted changes to the speed and direction of tidal currents with the array in place, it is considered very unlikely that measurable differences to the rate and direction of suspended sediment transport will occur within this region; and*
- *The presence of the array would cause a small reduction in wave heights within and nearby to the site and it is therefore possible that there would be a*

very marginal reduction in the degree to which sediment at the bed is mobilised during these larger wave events.

6.5.54 *The potential for changes to the suspended-load sediment transport regime resulting from the presence of the wind farm infrastructure is considered to be of small magnitude, have only an array scale spatial effect and to be present over the lifetime of the wind farm. The potential effect upon sediment dynamics and thus the existing seabed infrastructure is therefore considered to be of minor significance.*

6.5.55 ABPmer (2012) reached the following conclusions regarding longshore sediment transport:

- *For any given extreme wave event, the effect of the array is to very marginally reduce associated rates of longshore sediment transport;*
- *The most change in potential longshore sediment transport rates during these extreme storm events occur along the coastline between Shoreham-by-Sea to Beachy Head;*
- *Regardless of the wave return period or prevailing wave direction, average percentage reductions in potential longshore sediment transport rates within this coastal cell do not exceed 5% and are more typically less than 2%;*
- *The most likely change (if any) between Selsey Bill and Shoreham-by-Sea would be a net overall increase in the movement of sediment to the east. This change could occur because any periodic transport to the west caused by waves from the southeast could potentially decrease due to a reduction in wave height. (Waves from the southwest which reach this stretch of coastline would be unaltered from baseline conditions since they do not have a fetch pathway through the array);*
- *The most likely change (if any) between Shoreham-by-Sea and Beachy Head would be a net overall decrease in the movement of sediment to the east. This change could occur because waves from the southwest could potentially decrease in height, reducing rates of easterly sediment transport. (Waves from the southeast which reach this stretch of coastline would be unaltered from baseline conditions since they do not have a fetch pathway through the array.); and*
- *Due to the lack of sediment supply, under baseline conditions it is considered that there is limited transport around Beachy Head (SDCG, 2004). Accordingly, absolute changes in the rate of longshore sediment transport here (and to the east of this location) are likely to be very low.*

6.5.56 Whilst the wind farm is shown to have the potential to slightly reduce longshore sediment transport at the coast, primarily through a wave height reduction, climate change has been predicted to increase the wave height. The wave height

reductions shown within this assessment are of a smaller magnitude than the increases indicated by the UKCIP'09 (Lowe *et al.*, 2009). Thus any sediment transport rate changes which may result from the installation of the Rampion wind farm have the potential to be masked by changes resulting from the natural variability introduced through climate change.

- 6.5.57 The potential changes to the coastal sediment transport regime resulting from the presence of the offshore wind farm infrastructure are considered to be of a small magnitude, occur within the coastal environment (far-field domain) and are present over the lifetime of the wind farm. The potential effect upon shoreline sediment dynamics is therefore considered to be of minor significance over the period during which the wind farm is installed.
- 6.5.58 Quantitative assessment of these changes is presented in Appendix 6.4.
- 6.5.59 The presence of various seabed features suggests that artificial seabed ridges, as could be introduced by mattressing, would not be detrimental to sediment transport. The bathymetric features located within the cable route corridor are suggestive of a mobile seabed and in particular do not indicate that (i) there is a sediment shortage; and (ii) these features act as a permanent barrier to sediment transport. Examples of the naturally occurring features present in the cable route corridor are rock outcrops, rock ridges and megaripples. The rock ridges and outcrops occur in the central and southern part and are representative of more resistant bed underlying the Cretaceous limestone geology. A large number of boulders also occur around these features. Poorly-defined gravel and sand megaripples also occur across the section, where these are orientated approximately north-northeast to south-southwest and are generally less than 0.5m high. Evidence from geophysical surveys shows that large wrecks lying across sand wave structures do interrupt the patterns of sand waves, but do not affect the overall migration of the waves over the seabed, hence it can be concluded that there is unlikely to be any significant disruption as a result of the installed mattressing.
- 6.5.60 Of further note is that the direction of the export cable route is such that any protective measures will be unlikely to affect the onshore – offshore sediment exchange that has been documented (SDCG, 2004).

Oceanography and Meteorology

- 6.5.61 Previous work undertaken by Cefas (2005) examined concerns that the installation of offshore wind farms may influence natural coastal processes. The presence of offshore wind farm foundations and transition pieces can potentially cause or exacerbate wave shoaling, breaking, refraction and dissipation. The same report by Cefas (2005) found that wave diffraction effects from a monopiled wind farm reduce the wave climate in the vicinity of the wind farm by 2-5%. Any effects are short lived; decreasing rapidly away from the offshore wind farm and returning to background levels within a distance of 2-3 wind turbine spacing's away. The Project site stretches from approximately 13km to 23km

offshore. The Offshore Project Description (Section 2a) states that the maximum spacing between turbines is likely to be 1.3km, therefore if any alteration of wave characteristics does occur, a return to background levels will be experienced at least 8km from the shore.

- 6.5.62 This was also the finding of environmental impact assessments conducted as part of the Lincs and Dudgeon offshore wind farm projects. The reports suggest (with reference to gravity base structures) that in shallow waters of less than 20m the installation of turbine foundations may result in minor changes to wave conditions. The Project site is predominantly deeper than 20m except for a small area in the very north west corner. Consequently, it is likely that any possible effect would be small and again of minor significance.
- 6.5.63 Section 6.4.3 suggests that typical current speeds at the Project site are $>1\text{ms}^{-1}$ on a spring tide and approximately half of this on a neap tide. Between the 2yr and 50yr return period for wave conditions there is a potential for currents of between 1.5 and 2ms^{-1} . When a steady current encounters a cylindrical vertical pile; the flow speeds up around the periphery of the pile, producing a horseshoe vortex and a highly turbulent wake downstream. This happens around the base of each of the foundations and is limited by factors such as the current velocity, foundation diameter, direction of current etc. Values from the Metocean survey suggest a residual tidal flow that broadly flows northeast to east-northeast across the Project site. This suggests that elevated current velocities would occur to the east-northeast of each pile with turbulence (and potentially scour) occurring to the east – northeast in an elliptical pattern. As the current continues to flow east – northeast it would quickly return to its normal velocity before reaching the next turbine in an array. The change in velocities is likely to cause a medium impact that is of minor significance within the offshore wind farm area; however the impact will be confined to the development area meaning that there will be no impact to currents in the near shore environment (within 12km of the shore).
- 6.5.64 ABPmer (2012) modelled the changes to current speeds using the analysis of spatial results over the entire spring-neap cycle. The report summarised the changes as:
- *The largest current speed changes would occur as flow reductions of up to 0.11ms^{-1} , immediately in the lee of the turbine structures. This is as a consequence of the local blockage effects upon the flow;*
 - *Away from the immediate influence of the structures, but within the array boundary, the changes would dramatically reduce such that changes of c. -0.03ms^{-1} are more typical;*
 - *Changes are predicted as flow reduces and increases to the west and north of the array respectively. The zone of influence under peak conditions can extend outside of the development area, with the greatest spatial extent being to the*

west of the array. Here the more widespread changes are typically no more than $\pm 0.03 \text{ms}^{-1}$ which remains immeasurable in the field;

- *Current speed changes are not predicted to occur along the coast;*
- *The magnitude and spatial scale of the changes in flow speeds would be marginally higher at times of peak flood. This is a direct result of the relative magnitude of the baseline currents at these tidal states; and*
- *Since larger differences are still estimated with the peak flood condition, this suggests that the overall asymmetry of the tide would not be affected by the proposed development within the application area.*

6.5.65 ABPmer (2012) used a regional scale spectral wave model linked to a tidal model to assess the impact that the Project may have on the wind – wave regime. The model examined both the effect within the near field and far field environments and used inputs from a variety of sources including the EMU metocean survey (2011a). Four scenarios were run using a variety of inputs and ABPmer (2012) summarise the results as:

..the greatest effects are noted both within the array and landward of the application area Typically, the greatest spatial extent of change occurs under conditions of Peak Flood when the tide and wave are travelling in the same direction. Small reductions in wave height are observed at the coast with all scenarios and these changes equate to a reduction in the amount of energy reaching the shore. This is of relevance for sediment transport at the coastOnly very small changes are observed in wave period and direction. Although minor, any changes to these parameters also have the potential to influence rates and direction of sediment transport in the littoral zone.

6.5.66 ABPmer also reference the work of Lowe *et al.* (2009) which suggests an increase of 0.5m to 1m of the annual maxima significant wave height (between 1960 and 1990, to 2070 and 2100). This statement implies that increases in wave height due to the effects of climate change (increased storminess) may counteract any reduction in wave height as a result of the offshore wind farm.

6.5.67 Surfers Against Sewage (SAS) raised concerns in response to consultation regarding the interruption of offshore wave energy transmission and a reduction in offshore swell energy, such that surfing conditions are compromised, therefore ABPmer also considered the effect that the Project may have on the swell regime. In addition to considering changes within the study area, SAS requested changes be considered at 11 specific surf locations (detailed in Appendix 6.4). Modelling conducted by ABPmer (2012) determined that:

Changes in swell waves at the coast are only predicted to occur in the immediate lee of the array, with no observable changes occurring outside the frontage

between Brighton and Seaford. At the locations specified by SAS wave height reductions do not exceed 5%. Wave period changes are less than 4%, and more typically less than 2%. Wave directional changes are typically less than 0.5%.

ABPmer (2012) further state that:

SAS consider that changes in wave height of less than 7% are not detrimental to the surfing regime. On this basis, the potential for changes to the surfing conditions resulting from the presence of the wind farm infrastructure are considered to be of low magnitude, have a limited spatial effect although are present over the life-time of the wind farm. The potential effect is therefore considered of minor significance.

Details of potential wave height reductions at each of the specified surf locations are presented in Appendix 6.4.

Water Quality

- 6.5.68 Once all Project infrastructure is installed and the offshore wind farm is operational it is expected that it will have little impact on the SSCs in the area. The only potential increase in SSC would be through the process of scour around the turbines themselves. As discussed previously the volume of material would be small and areas at most risk would have scour protection installed. With this in mind, the impact of SSC due to scour can be classified as being of negligible significance.

Sediment Contamination

- 6.5.69 There is a potential to re-suspend/remobilise and transport potentially contaminated sediments due to scouring around the base of the turbines. The sediment contamination in the case of the Project site is low to moderate (generally low), the impact and level of sediment transport and suspended sediment due to scouring is of small magnitude, limited spatial extent and is temporary on the lifetime of the Project i.e. of negligible significance, the overall impact of sediment contamination is therefore assessed as negligible.

Decommissioning

Bathymetry

- 6.5.70 Section 2a - Offshore Project Description) sets out the decommissioning methodology for the turbines and foundations. Effectively the towers, nacelles and blades will be removed by a jack-up vessel in the reverse order to installation. Therefore, the impacts to the bathymetry outlined above in the installation section will also apply during decommissioning. Monopile foundations and the securing piles used for jacket foundations would undergo a similar removal process, whereby the majority of the structure will be left in the seabed and cut at an appropriate depth below the sediment surface to ensure

they do not become exposed. This mitigates the possibility of any ongoing scour. Other types of foundation would be removed using a jack-up vessel or heavy lift barge so the minor impacts caused during installation would be similar here.

- 6.5.71 It is likely that all offshore cables (apart from the sections which are part of beach landings or those which have become exposed over the lifetime of the Project) will be left *in-situ* and their status on any charts would be changed to out of service. Removing the cables from the seabed would be more damaging to the environment than simply leaving *in-situ*. Where cable is removed from the seabed it is expected that the daily tidal cycle will return the seabed to its prior state over a reasonably short period of time (order of weeks to months). Sections of cable that have become exposed over time would be removed by lifting the cable ends onto a cable retrieval vessel and the cables would be spooled back onto a drum (Section 2a - Offshore Project Description). It is predicted that any trenches left by removed cables will be filled by natural tidal action. Therefore the cable removal is likely to be of low sensitivity, have a small magnitude and be of minor significance.

Geology and Seabed Sediments

- 6.5.72 It is expected that the majority of subsea cables will be left in the seabed so neither the sediment or geology will be affected during decommissioning. Where cables are removed from the seabed it is expected that the daily tidal cycle will return the seabed to its prior state over a reasonably short period of time (order of weeks to months). Sections of cable that have become exposed over time would be removed by lifting the cable ends onto a cable retrieval vessel and the cables would be spooled back onto a drum (Section 2a – Offshore Project Description). It is predicted that any trenches left by removed cables will be filled by natural tidal action. Therefore cable removal is likely to have a small magnitude, be of limited duration and is assessed to be of minor significance.
- 6.5.73 Turbine removal has also been discussed in Section 6.5.70 Sediment will be disturbed around the jack-up legs due to scour; however as with turbine installation the scour holes will backfill over a reasonably small period of time so the overall impact is considered negligible.

Sediment Transport and Mobility

- 6.5.74 The impacts of decommissioning will be similar to those of installation.

Oceanography and Meteorology

- 6.5.75 The removal of infrastructure at the end of the lifetime of the Project will effectively be the reverse of installation. As such, there may be a small, temporary impact on the hydrodynamic regime due to the presence of the jack-up vessels. However this would only be the case in shallow water and because decommissioning will usually be undertaken in favourable weather conditions any impact would be negligible.

- 6.5.76 Once decommissioned, the hydrodynamic regime (i.e. wave and currents) would revert back to a similar situation to that prior to installation (excluding any changes which arise as a result of sea-level change during the operational period).

Water Quality

- 6.5.77 It is likely that the turbine foundations will be left in the seabed and cut below the surface so as not to leave them exposed. The machinery used to cut the top section from the foundation may cause a temporary increase in SSC; however this would be small in comparison to installation activities and as such deemed as being of negligible significance.
- 6.5.78 It is expected that the majority of subsea cables will be left in the seabed so neither the sediment or geology will be affected during decommissioning. If cables are removed from the beach or near shore there will be an associated elevation in SSC. Referring to the modelling output of ABPmer (2012) cable installation in the near shore environment creates the peak SSCs:

Peak depth-averaged SSCs would be encountered when the installation of the cable is taking place in very shallow (approximately 5m CD) water depths close to the shore. Here, the maximum concentrations of approximately 200mg/l are predicted although these concentrations would typically be very localised (i.e. <2km) to the cable trench.

- 6.5.79 It is expected that removal of any cable in the near shore environment would have the same or a lesser impact than that which occurs during installation. With this in mind the impact of cable removal is thought to be of minor significance.

Sediment Contamination

- 6.5.80 The impacts of decommissioning will be similar to those of installation and the overall impact of sediment contamination is therefore assessed as negligible.

6.6 Mitigation

Installation

Bathymetry

- 6.6.1 An engineering study and survey data will be used to determine the likely risk of scour at the base of each turbine and in areas of high risk scour protection will be installed during or soon after the turbines are installed.
- 6.6.2 The basic method of scour protection is to use gravel, possibly boulders, around the base of the foundation in a layer 1 to 1.5m thick of protection, which could extend up to 35m from the foundation. In the case of gravity base structures, this is typically augmented by the use of a skirt penetrating 0.5 to 2m into the

seabed. Other scour protection techniques include the use of frond and concrete mattresses. Depressions / scour caused through installation using jack-up platforms will be mitigated to a minor degree because installation will be scheduled for periods when the meteorological and oceanographic conditions are favourable reducing the effect of wave enhanced scouring.

- 6.6.3 As previously discussed, cables will be buried to a depth of at least 1m below the seabed throughout the site (1-2m in the export cable corridor), mitigating the risk of scour around the cable. In areas of sandwaves (and where possible), cables will be buried in the wave troughs below the mobile layer to avoid exposure. Where this is not possible the sandwaves will be swept at an appropriate time so that they can return to their pre-construction state in a minimal timeframe.

Geology and Seabed Sediments

- 6.6.4 The choice of turbine foundations will be based on the engineering study which is currently being undertaken for the Project. The study incorporates the geotechnical and geophysical survey data along with all other data which has been collected as part of the Project. The study will determine suitable array layouts and suitable foundation types. The final foundation choices will be determined based on factors such as cost and environmental impact.
- 6.6.5 As discussed previously, there are several methods available for cable burial. The chosen installation method will be based on analysis of all the collected datasets. This will be supplemented by previous knowledge regarding installation in similar sediments, allowing the most appropriate and least damaging solution to be selected.
- 6.6.6 Cable routes will be designed to cause minimal damage and as a result will be (where possible) routed around subsea features such as rock ridges. When this is not possible the least damaging method will be chosen to cross such features. When a cable is laid in an area of sandwaves or megaripples it will be buried in the troughs (if possible) to ensure that it is below the level of mobile sediment and hence at less risk of exposure and damage. Features such as sandwaves will only be swept where absolutely necessary.

Sediment Transport and Mobility

- 6.6.7 The assessed effect upon sediment dynamics and thus the existing seabed infrastructure is considered of minor significance. It is therefore probable in most instances no additional mitigation will be required.
- 6.6.8 In areas of high risk of scour and enhanced sediment transport, scour protection will be installed either during or soon after the turbines are installed and this will stabilise the seabed and allow a stable state to be re-established.

- 6.6.9 As previously discussed, cables will be buried to a depth of at least 1m below the seabed or similarly protected throughout the Project site, mitigating the risk of scour and sediment transport associated with the presence of cables.

Oceanography and Meteorology

- 6.6.10 As the effects of installation on oceanographic and meteorological conditions are of minor or negligible significance no additional mitigation measures are anticipated.

Water Quality and Sediment Contamination

- 6.6.11 Where possible, the least disturbing method of installation will be used for both turbine foundations and cables to reduce the levels of suspended sediment. This could include for example the use of piling rather than drilling for the turbine foundation installation and the use of jetting or ploughing in preference to mechanical cutting for the installation of the cables.

Operation

Bathymetry

- 6.6.12 Scouring of the seabed due to the presence of the turbines will be mitigated where necessary by the use of scour protection.

Geology and Seabed Sediments

- 6.6.13 The impacts on geology during operation will be negligible and the effect on seabed sediments will be minor and is will primarily be due to scour around the turbines; therefore any mitigation is likely to be limited to scour protection.

Sediment Transport and Mobility

- 6.6.14 As the effects of the near field changes to sediment transport are of minor impacts significance no mitigation is planned. The minor impact on the far field coastal sediment transport is likely to be more than offset and balanced by the predicted effects of climate change and therefore no mitigation is currently planned.

Oceanography and Meteorology

- 6.6.15 No specific mitigation measures are planned, near field changes to the current field are spatially limited to the close proximity of the offshore wind farm and current speed changes are not predicted to occur along the coast (far-field).
- 6.6.16 In the case of waves the reduction of wave height is likely to reduce erosional tendencies along a well-defended coast and so no mitigation measures are anticipated. This may as a secondary consequence reduce longshore shore

transport. However, the predicted sea-level rise and increased storminess (Inter-governmental Panel on Climate Change (IPCC)) is likely to offset this to a degree.

Water Quality and Sediment Contamination

- 6.6.17 As the impact on water quality and sediment contamination of the offshore wind farm is negligible once the installation is complete no mitigation is required.

Decommissioning

- 6.6.18 The effects and impacts of decommissioning are similar to installation and the mitigation measures applicable to installation activities are also relevant in this instance.

6.7 Significance of Residual Effects

- 6.7.1 Table 6.26 summarises the significance of the residual effects. These are discussed in more detail below and in the ABPmer (2012) Coastal Processes Study (Appendix 6.4).

Installation

Bathymetry

- 6.7.2 The effects of foundation and cable related construction activities with respect to bathymetry are considered to be of small magnitude, have a limited spatial effect and are temporary on short term cycles. The potential effect is therefore considered to be of negligible significance.

Geology and Seabed Sediments

- 6.7.3 The effects of foundation and cable related construction activities with respect to geology and seabed sediments are considered to be of small magnitude, have a very limited spatial effect and are temporary on short term cycles. The potential effect is therefore considered of minor significance.
- 6.7.4 The main concerns with accumulations of sediment and changes to sediment type relate to potential impacts on benthos (e.g. smothering of benthos) and are covered in Section 7 - Benthos and Sediment Quality.

Sediment Transport and Mobility

- 6.7.5 As the potential for changes to the offshore (near-field) sediment transport regime resulting from the presence of the installation vessels are considered to be of low magnitude, have only an array scale spatial effect and are temporary in nature, the effect on sediment transport and mobility during installation is assessed as of negligible significance.

Oceanography and Meteorology

- 6.7.6 The potential for changes to the oceanographic and meteorological conditions resulting from the presence of the installation vessels are considered to be of low magnitude, have only a limited spatial effect and are temporary in nature the effect is assessed as of negligible significance.

Water Quality and Sediment Contamination

- 6.7.7 The effects of foundation and cable related construction activities with respect to SSC and sediment contamination are considered to be of small magnitude, have a limited spatial effect and are temporary on time scale similar to duration of installation. The potential effect is therefore considered of minor significance.

Operation

Bathymetry

- 6.7.8 The potential for changes to bathymetry due to scour effects resulting from the presence of turbine foundations is considered of minor significance as the effects are of limited magnitude, have an array scale spatial effect and are permanent on medium term-scales. The effects due to exposure of export and inter-array cables are considered of negligible significance due to the localised and temporary nature.

Geology and Seabed Sediments

- 6.7.9 The impact on the geology is considered to be of negligible importance as the effects are of low magnitude and spatially very localised. The impact on seabed sediments is considered of minor significance as the effects are of low magnitude, have an array scale spatial effect and are permanent on medium term-scales.

Sediment Transport and Mobility

- 6.7.10 The potential for changes to the offshore (near-field) sediment transport regime resulting from the presence of turbine foundations and cables is considered of minor significance as the effects are of medium magnitude, have an array scale spatial effect and are permanent on medium term-scales. The effects due to exposure of export and inter-array cables are considered of negligible significance due to the localised and temporary nature (ABPmer, 2012). The potential for changes to the coastal sediment transport regime resulting from the presence of the offshore wind farm is considered of minor significance over the lifetime of the Project as the effects are of small magnitude, have a far-field spatial effect and are permanent on medium term-scales. However, this is set in the context that climate change is likely to increase the wave height. Thus any potential effects may be masked by changes resulting from natural variability associated with climate change.

Oceanography and Meteorology

- 6.7.11 ABPmer 2012 modelled a number of different wave scenarios to assess the impact of the offshore wind farm infrastructure on surfing conditions and concluded that the impacts are of small magnitude (based on the worst case foundation scenario, Gravity Based structures) have a limited spatial effect, and are present over the lifetime of the wind farm and are therefore considered of minor significance.

Water Quality and Sediment Contamination

- 6.7.12 The effect on water quality once the offshore wind farm is installed and in operation is negligible.

Decommissioning

- 6.7.13 The effects and impacts of decommissioning are similar to installation and the residual effects applicable to installation activities are also relevant in this phase of the development.

6.8 Cumulative and in-combination Impacts

- 6.8.1 The ABPmer (2012) coastal processes study examined the area surrounding the Project to determine which other activities could cause cumulative impacts when combined with the impacts of construction activities.
- 6.8.2 There no other wind farms in proximity to the proposed Rampion OWF. The closest UK wind farm development is Navitus Bay to the west of the Isle of Wight, a distance of approximately 75km and beyond the natural blockage created by the Isle of Wight.
- 6.8.3 The ABPmer study identified 25 licensed aggregate extraction sites with a further 3 sites under application. These make up what are known as the Owers Bank and Inner Owers Bank aggregate sites. These sites are listed in Table 6.27, and those closest to the Project site are shown in Figure 19.1 (Section 19 – other marine users).

Table 6.26: Summary of Residual Effects and Mitigation Measures

Aspect	Effect	Proposed Mitigation Measures	Sensitivity	Magnitude	Residual Effect
Construction Phase					
Installation of turbine foundations/scour protection	Increase in suspended sediment concentrations as a result of foundation installation activities	Design will minimise the footprint of turbines and scour protection where possible.	Low	Small	Minor
Installation of inter-array & export cables (and cable protection)	Increase in suspended sediment concentration, bed level change and sea bed textural change following re-deposition of suspended sediments as a result of inter-array & export cable burial activities	Techniques that minimise sediment suspension will be used where feasible.	Low	Medium	Minor
Foundation/ cable installation	Indentations and mounds left on seabed by installation vessels e.g. jack-ups, cable burial tools and by the use of large anchors	Use vessels and cable burial tools to minimise disturbance where possible. Plan to perform installation in calm weather conditions	Low	Small	Minor
Foundation/ cable installation	Suspension of contaminated sediment (temporary)	Any contaminants will be rapidly diluted to negligible levels, and widely dispersed.	Medium	Negligible	Negligible
Installation of cable at coast	Disturbance of coastal morphology at the landfall site for export cables	Use of techniques to minimise seabed disturbance e.g. HDD	Medium	Small	Minor
Operational Phase					
Presence of turbine foundations	Scour effects due to the presence of the turbine foundations	Scour protection will be installed where necessary	Low	Small	Minor
Presence of cable	Scour effects due to the exposure of inter-array and export cables and cable protection measures	Cables buried wherever possible. Or cables protected by rock placement or concrete mattresses	Low	Small	Minor

Aspect	Effect	Proposed Mitigation Measures	Sensitivity	Magnitude	Residual Effect
Presence of turbines	Changes to wave and current regimes affecting patterns of near-field (offshore) sediment transport due to the presence of the turbine foundations	Detailed array design.	Low	Medium	Minor
Presence of turbines (using worst case scenario in terms of foundation selection)	Changes to wave and current regimes affecting patterns of far-field (coastal) sediment transport due to the presence of the turbine foundations	Detailed array design and selection of foundations	Medium	Small	Minor
Presence of cable	Disturbance of coastal morphology at the export cable landfall site	Cable buried below the natural level of the seabed	Medium	Negligible	Negligible
Decommissioning Phase					
Removal of inter-array & export cables (and cable protection)	Increase in suspended sediment concentration, bed level change and sea bed textural change following re-deposition of suspended sediments as a result of inter-array & export cable removal activities	Techniques that minimise sediment suspension will be used where feasible.	Low	Medium	Minor
Foundation/ cable decommissioning	Indentations and mounds left on seabed by decommissioning vessels e.g. jack-ups, cable burial tools and the use of large anchors	Use vessels and cable extraction tools to minimise disturbance where possible. Plan to perform decommissioning in calm weather conditions	Low	Small	Minor
Foundation/ cable decommissioning	Suspension of contaminated sediment (temporary)	Any contaminants will be rapidly diluted to negligible levels, and widely dispersed.	Medium	Negligible	Negligible
Absence of turbines	Changes to wave and current regimes affecting patterns of near-field (offshore) sediment transport due to the absence of the turbine foundations	Return to pre wind farm conditions	Medium	Small	Minor

Table 6.27: Aggregate extraction areas in vicinity of Rampion (ABPmer, 2012)

Area Name	Status	Company	Overlap with Cable Corridor?
122/1A	Licensed Area	Tarmac Marine Dredging Ltd	Yes
122/1B	Licensed Area	Tarmac Marine Dredging Ltd	No
122/1D	Licensed Area	Tarmac Marine Dredging Ltd	No
122/1E	Licensed Area	Tarmac Marine Dredging Ltd	No
123E	Licensed Area	Cemex UK Marine Ltd	No
124/1E	Licensed Area	Hanson Aggregates Marine Ltd	No
123D	Licensed Area	Cemex UK Marine Ltd	No
124/1D	Licensed Area	Hanson Aggregates Marine Ltd	No
123A	Licensed Area	Cemex UK Marine Ltd	Yes
124/1A	Licensed Area	Hanson Aggregates Marine Ltd	Yes
123B	Licensed Area	Cemex UK Marine Ltd	No
124/1B	Licensed Area	Hanson Aggregates Marine Ltd	No
122/1F	Licensed Area	Tarmac Marine Dredging Ltd	No
123/F	Licensed Area	Cemex UK Marine Ltd	No
124/1F	Licensed Area	Hanson Aggregates Marine Ltd	No
435/2	Licensed Area	Hanson Aggregates Marine Ltd	Yes
499	Application Area	Hanson Aggregates Marine Ltd	No

Installation

Bathymetry, Geology and sediments, Oceanography and Meteorology

- 6.8.4 Effects on the above physical environment receptors during the construction phase are expected to be limited to the area within the Project site, and will not result in cumulative impacts with other developments.

Water Quality

- 6.8.5 Numerical modelling of suspended sediment concentrations for ‘in-combination’ impacts was undertaken in the ABPmer (2012) coastal processes study. ABPmer (2012) used the 3 aggregate extraction areas closest to the Rampion site boundary (Area 122 / 1B, Area 123B and Area 124 / 1B) to represent the worst case for impacts as per the Rochdale Envelope approach to environmental impact assessment. As a result of the modelling the in-combination impact on suspended sediments through commercial aggregate extraction activities and foundation installation were considered to be of minor significance.
- 6.8.6 The closest extraction areas to the export cable corridor are areas (Area 122/1A; 123/A and 124/1A) which are located approximately 3.8km to the west. HR Wallingford (2010) in ABPmer (2012) suggests that even when extraction works occur at the boundary of Licence Areas, suspended sediment concentrations more than 50mg/l above background levels are only likely to be experienced within 200m of the Licence Area boundary and concentrations more than 20mg/l above background levels are only to be experienced within 1km of the licence area boundary. As such ABPmer (2012) concluded that the potential for substantial interaction between plume(s) arising from aggregate extraction activities and the likely plume from any jetting along the cable route is considered minimal and consequently to be of minor significance.

Operation

Sediment Transport

- 6.8.7 The ABPmer (2012) coastal processes study concluded that any in-combination effects on sediment transport are to an extent counterbalancing and are therefore assessed as negligible. Sediment transport in this region is driven predominantly by the tidal regime through the English Channel. The minor decrease to tidal flow speeds in relation to development array would be negated by the associated increase in flow speeds attributable to dredging at the aggregate sites. The effects of changes in sediment transport are again considered to be local to the wind farm area and aggregate sites, with very little to no change to the coast.

Oceanography and Meteorology

- 6.8.8 The ABPmer (2012) coastal processes report also examined the effects on the oceanographic regime due to the cumulative impacts of the wind farm and nearby aggregates extraction areas. ABPmer (2012) concluded that:

Tides:

It is more likely that the effects of the flow speed reduction due to the array would be minimised by the associated increase in flow speeds in association with the aggregates extraction area. The discussed effects are only predicted to be local to the wind farm area and aggregate sites, with very little to no change extending to the coast.

Waves:

Results of numerical modelling with the potential development, demonstrate that wave heights would predominantly be reduced at all tidal states and for the 10 in 1, 1 in 1 and 1 in 10 year return period wave conditions within and towards the lee of the development area. Changes to the significant wave height in relation to aggregate extraction activities are understood to increase wave height in the lee of the extraction site. Therefore the decrease in the significant wave height in relation to the wind farm development would theoretically be counteracted by the increase in wave heights from the extraction site.

- 6.8.9 Therefore, the effects on oceanography and meteorology are assessed as being negligible.

Bathymetry, Geology and Sediments, Water Quality

- 6.8.10 Effects on these receptors during the operational phase of the Project will be restricted to the area within the Project site, hence will not combine with the effects of other developments to produce cumulative impacts.

Decommissioning

- 6.8.11 The cumulative or in-combination impacts of decommissioning are unknown at this stage, and will be dependent upon activities taking place on other projects at the same time as the decommissioning of the Project. An environmental assessment of the decommissioning options will be carried out in advance of the commencement of decommissioning, potential for cumulative effects will be considered in that assessment. At the stage the assessment is completed more details will be known on the schedule of other projects which could contribute, together with the effects from decommissioning, to cumulative effects on features of the Physical Environment.

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