Rampion 2 Wind Farm

Category 6: Environmental Statement

Volume 4, Appendix 6.1: Coastal processes technical report: Baseline description

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Executive summary

Purpose of this report

This report has been produced for the purpose of characterising the Rampion 2 coastal processes baseline. The study area extends between Beachy Head and Selsey Bill and captures the Rampion 2 Offshore Array Areas, Offshore Export Cable Corridor, landfall and surrounding seabed.

This baseline description provides a conceptual understanding of relevant coastal processes to inform assessments of potential impacts resulting from the Rampion 2 offshore wind farm. It considers the key physical properties of the marine environment, including winds; waves; water levels; currents; the nature and distribution of seabed sediments; sediment transport, including resulting turbidity; and offshore and coastal morphology.

Understanding of coastal processes within the study area has been informed by a range of information sources including:

- Rampion 2 project specific geophysical surveys;
- technical reports and Environmental Statement (ES) for the Rampion 1 Offshore Array Area (ABPmer, 2012);
- geophysical, geotechnical, oceanographic and benthic surveys undertaken to inform the Rampion 1 Environmental Impact Assessment (EIA);
- data available through monitoring initiatives to inform coastal management, including the National Tide and Sea Level Facility and the Southeast Regional Coastal Monitoring Programme; and
- data collected to inform regional seabed mapping initiatives such as the South Coast Regional Environmental Characterisation.

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1. Introduction

1.1 Study description

1.1.1 This study was undertaken by ABP Marine Environmental Research Ltd (ABPmer) on behalf of Rampion Extension Development Ltd (RED), to provide a baseline description of coastal processes in relation to the proposed Rampion 2 Offshore Wind Farm ('Rampion 2').

1.1.2 This baseline description provides a conceptual understanding of relevant processes to inform the assessments of potential effects resulting from the development of Rampion 2.

1.1.3 Coastal processes have been sub-divided into the following categories:

- hydrodynamics;
  - water levels;
  - currents;
  - wind and wave climate;
- morphological regime; and
- sedimentary regime.

1.1.4 The natural variability of the above is explored in the absence of any of the proposed structures for the development. Consequently, this provides the 'baseline' conditions within the study area against which potential impacts of the Proposed Development can be assessed. Many of the datasets used to inform the baseline post-date the construction of Rampion 1 and localised changes associated with the operational Rampion 1 are captured within the baseline for Rampion 2.

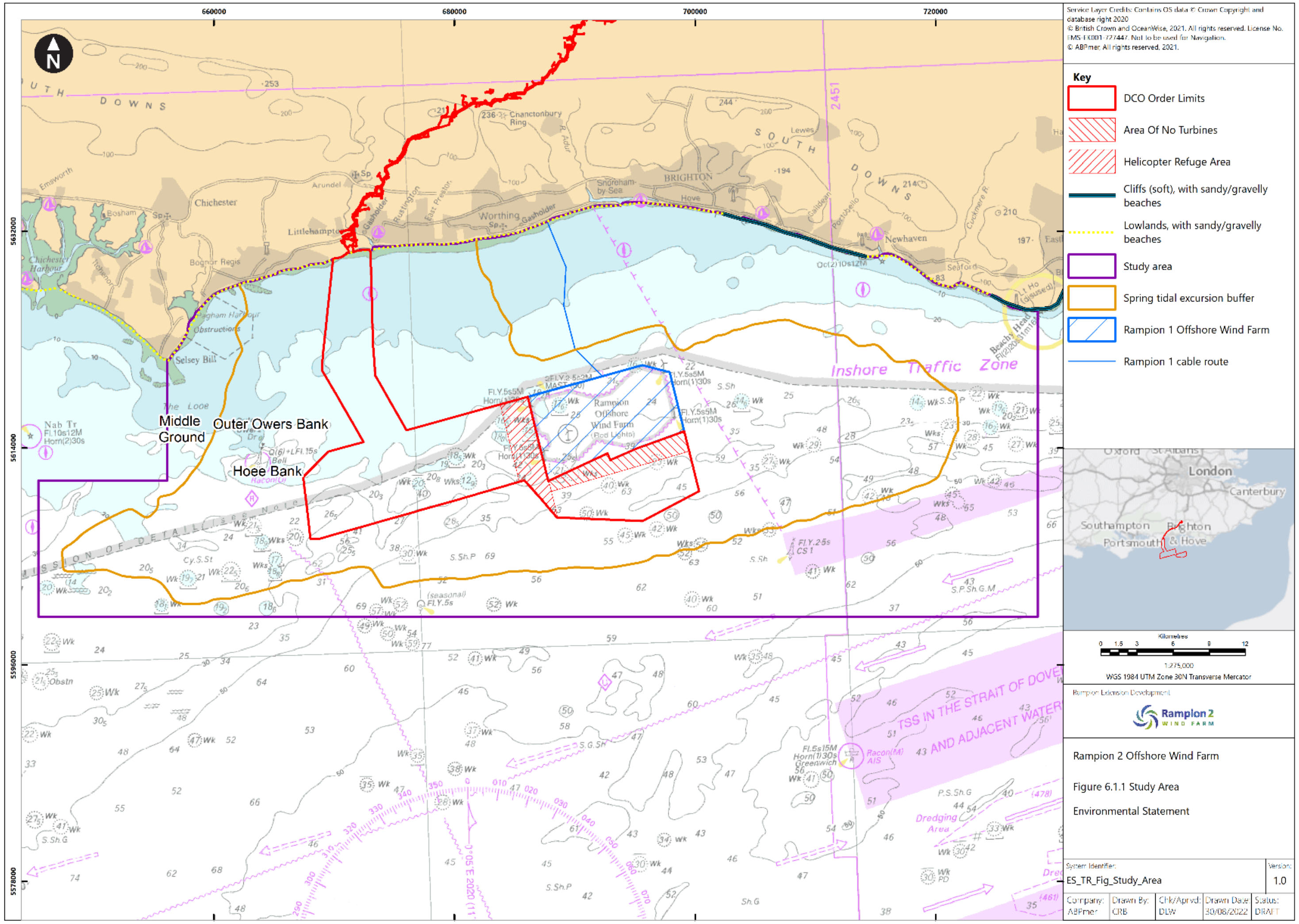
1.2 Study area

1.2.1 The study area for the coastal processes assessment is shown in **Figure 6.1.1**. The overall Zone Of Influence (ZOI), defined by the study area boundary has been determined based on the combined spatial extent of potential effect on waves at adjacent coastlines (between Beachy Head and Selsey Bill), and the likely extent of potential sediment plume effects described by the tidal excursion buffer (describing the greatest distance and direction that water carrying an effect might be carried during one mean spring tide, from any location within the Environmental Statement (ES) Proposed DCO Order Limits).

1.2.2 The Rampion 2 Offshore Array Areas are in the eastern English Channel, between 13km and 25km offshore of Worthing and Brighton on the Sussex coast. The Offshore Export Cable Corridor runs approximately north from the northern edge of the Western Offshore Array Area to a landfall at Climping, west of Littlehampton.

1.2.3 The Rampion 2 Offshore Array Areas and Offshore Export Cable Corridor cover an area of approximately 195.5km^2 and 74km^2 respectively. A full description of the relevant design characteristics of Rampion 2 is given in **Volume 2, Chapter 4: The Proposed Development, Volume 2** of the ES (Document Reference: 6.2.4).

Figure 6.1.1 Study Area



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2. Data sources

2.1 Key information

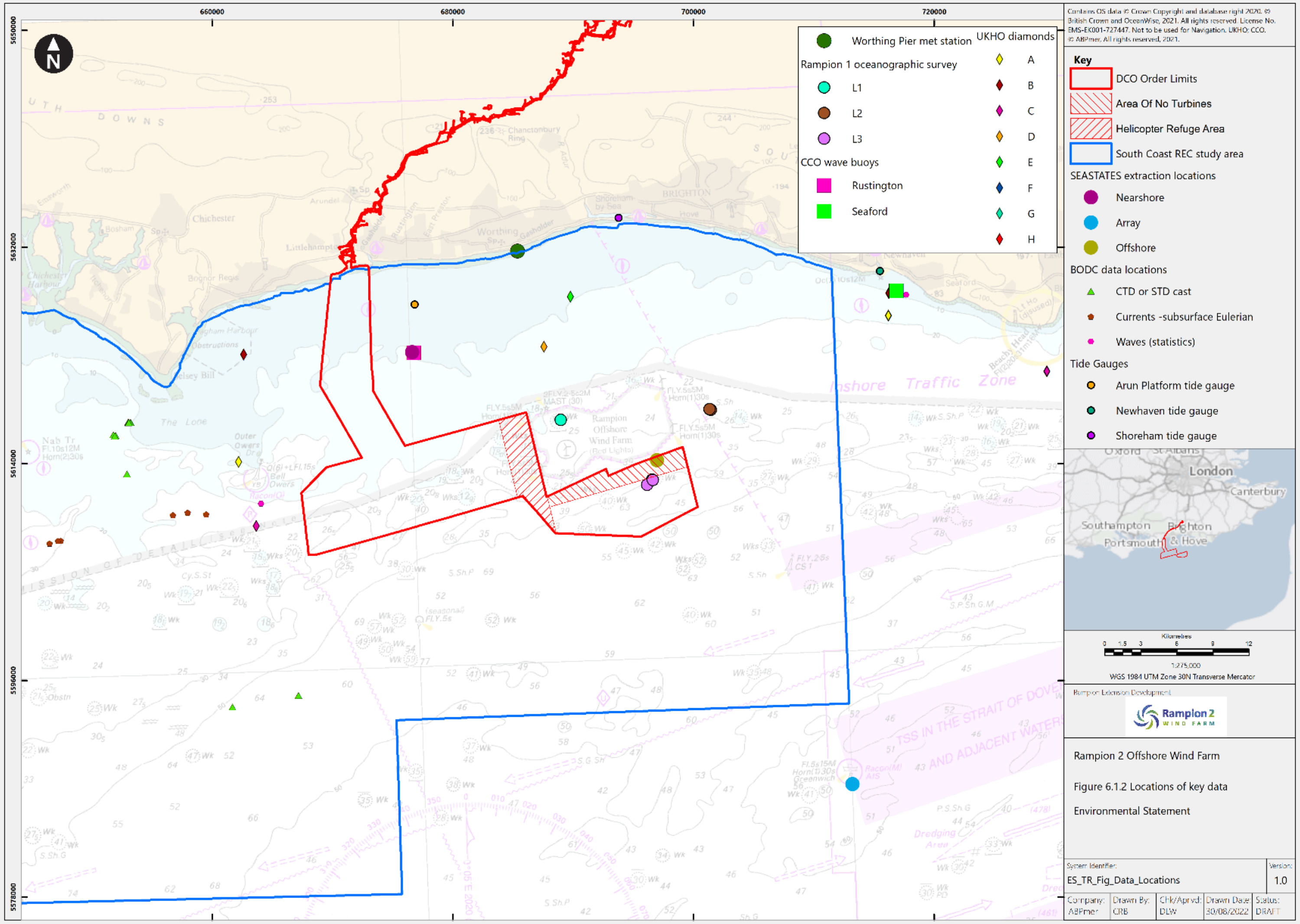
2.1.1 As part of the planning, assessment and development of Rampion 2, a geophysical survey covering the full extent of the development area (including the Offshore Export Cable Corridor) has been undertaken. This has provided information on seabed elevation and surficial sediment type, as well as the nature and thickness of underlying sedimentary units (Osiris, 2020a; 2020b; 2020c). This information has been used to inform baseline understanding alongside existing geophysical, benthic and metocean (meteorological and hydrodynamic) data collected to inform Rampion 1. Baseline understanding has also been developed using data collected as part of wider regional monitoring and characterisation studies. A summary of the key available datasets is provided in **Table 2-1** and shown in **Figure 6.1.2**.

Table 2-1 Key sources of coastal processes data

Source	Date	Summary	Coverage of study area
Geophysical Survey of Rampion 2	2020(a-c)	High resolution geophysical survey of the Rampion 2 Scoping Boundary area.	Complete coverage of the Rampion 2 area. Partial coverage of the wider study area.
Navigation Charts (UKHO)	Accessed November 2020	Description of bathymetry and general seabed type at a regional scale.	Full coverage of the study area.
ABPmer SEASTATES Wave Hindcast Database	Accessed November 2020	Hindcast database of wave height, period and direction (approximately 40 years, 1979 to near present) approximately 5km resolution.	Full coverage of the study area.
ABPmer SEASTATES Tide and Surge Hindcast Database	Accessed November 2020	Hindcast database of water levels, current speed and direction (approximately 40 years, 1979 to near present) approximately 2km resolution.	Full coverage of the study area.
NOAA Climate Forecast System	Accessed November 2020	Hindcast database of wind speed and direction (approximately 40 years, 1979 to near present) approximately 2km resolution.	Full coverage of the study area.

Source	Date	Summary	Coverage of study area
Reanalysis (CFSR)			
Rustington Wave Buoy (Channel Coastal Observatory)	Accessed November 2020	Observations of wave height, period and direction (approximately 10 years used, January 2010 to near present).	Point location 4nm SSE of Littlehampton Harbour, inside the study area.
Rampion 2 Benthic Survey	7 December 2020 to 28 February 2021	Benthic survey including sediment grab samples at multiple locations within the Proposed DCO Order Limits. Data to be reported in Environmental Statement.	Selected locations within the Proposed DCO Order Limits.
National Tide and Sea Level Facility (Newhaven)	Accessed November 2020	Tide gauge collecting water level data since 1990	Point Location
Geophysical Survey of Zone 6 (Osiris Projects Ltd)	2010 to 2011	High resolution geophysical survey of the Round 3 Zone 6 area, including the present extent of Rampion 1 and parts of the Rampion 2 Scoping Boundary.	Partial coverage of the study area.
Geotechnical Survey of Zone 6 (Fugro Geoconsulting Ltd)	2011	Geotechnical survey of the Round 3 Zone 6 area, including the present extent of Rampion 1 and parts of the Rampion 2 Scoping Boundary.	Partial coverage of the study area.
Metocean Survey (EMU Ltd)	2011	Measurements of water levels, currents and waves at three locations (two for three months and one for six months) in the Round 3 Zone 6 area, including the present extent of Rampion 1 and parts of the Rampion 2 Scoping Boundary.	Partial coverage of the study area.
Benthic Survey (EMU Ltd)	2011	Benthic survey including sediment grab samples at 59 locations in the Round 3 Zone 6 area, including the present extent of Rampion 1 and parts of the Rampion 2 Scoping Boundary.	Partial coverage of the study area.

Figure 6.1.2 Locations of key data



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2.2 Further supporting information

2.2.1 Further to the data sets described above, a number of key reports and data sources have also been used which hold direct relevance to this project. These include, but are not limited to:

- Regional Beach Management Plan 2017: Selsey Bill to Climping. Report – ENVIMSE100035/R-01 (Environment Agency, 2017);
- Beachy Head to Selsey Bill Shoreline Management Plan 2 (South East Coastal Group, 2006);
- Southeast Regional Coastal Monitoring Programme (Channel Coastal Observatory, 2022);
- Standing Conference on problems Associated with the Coastline (SCOPAC) Sediment Transport Study (New Forest District Council, 2017);
- Strategic Environmental Assessment Area 8 Superficial Seabed Processes and Hydrocarbon Prospectivity (Tappin et al., 2007);
- JNCC Coastal Directory Series: Coasts and seas of the United Kingdom. Regional Report 8 Sussex: Rye Bay to Chichester Harbour (Barne et al., 1998);
- Coastal flood boundary conditions for the UK: update 2018. Project SC060064 (Environment Agency, 2019);
- The Eastern English Channel Marine Habitat Map. Science Series Technical Report 139 (James et al., 2007);
- The South Coast Regional Environmental Characterisation (James et al., 2010);
- The MALSF synthesis study in the central and eastern English Channel (James et al., 2011);
- Eastern English Channel Regional Environmental Assessment (Royal Haskoning, 2002);
- Sand banks, sand transport and offshore wind farms (Kenyon and Cooper, 2005);
- South Coast Marine Aggregate Regional Environmental Assessment (EMU, 2012); and
- UK Atlas of Marine Renewable Energy (ABPmer et al., 2008).

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3. Hydrodynamic Regime

3.1 Overview

3.1.1 The hydrodynamic regime includes the following key parameters:

- water levels;
- currents;
- winds (as a driving force for waves and surge processes);
- waves; and
- temperature, salinity and stratification

3.1.2 These parameters are described in more detail in the following sub-sections. This information is also used to develop a conceptual understanding of the sedimentary and morphological regimes (see **Sections 4 and 5**).

3.2 Water levels

3.2.1 Water levels in the study area vary with both a predictable tidal signal and variable non-tidal signals related to meteorological influences.

Tidal water levels

3.2.2 The region is characterised by a complex macro tidal regime (i.e., maximum or typical tidal range between 4m and 6m) (Pingree & Griffiths, 1979) (**Table 3-1**). Water levels resonate as a standing wave within this part of the English Channel due to the geometry and location of a degenerate amphidromic point, which is located on land (inland of Weymouth).

3.2.3 Tidal water level range varies across the study area, increasing gradually from 4m at the western boundary (around Selsey Bill) to 6.5m at the eastern boundary (around Beachy Head) (**Figure 6.1.3**). At the landfall, the mean spring range is around 5.5m, with the mean neap range being approximately half of the mean spring range.

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Figure 6.1.3 Spatial variation in mean spring tidal range

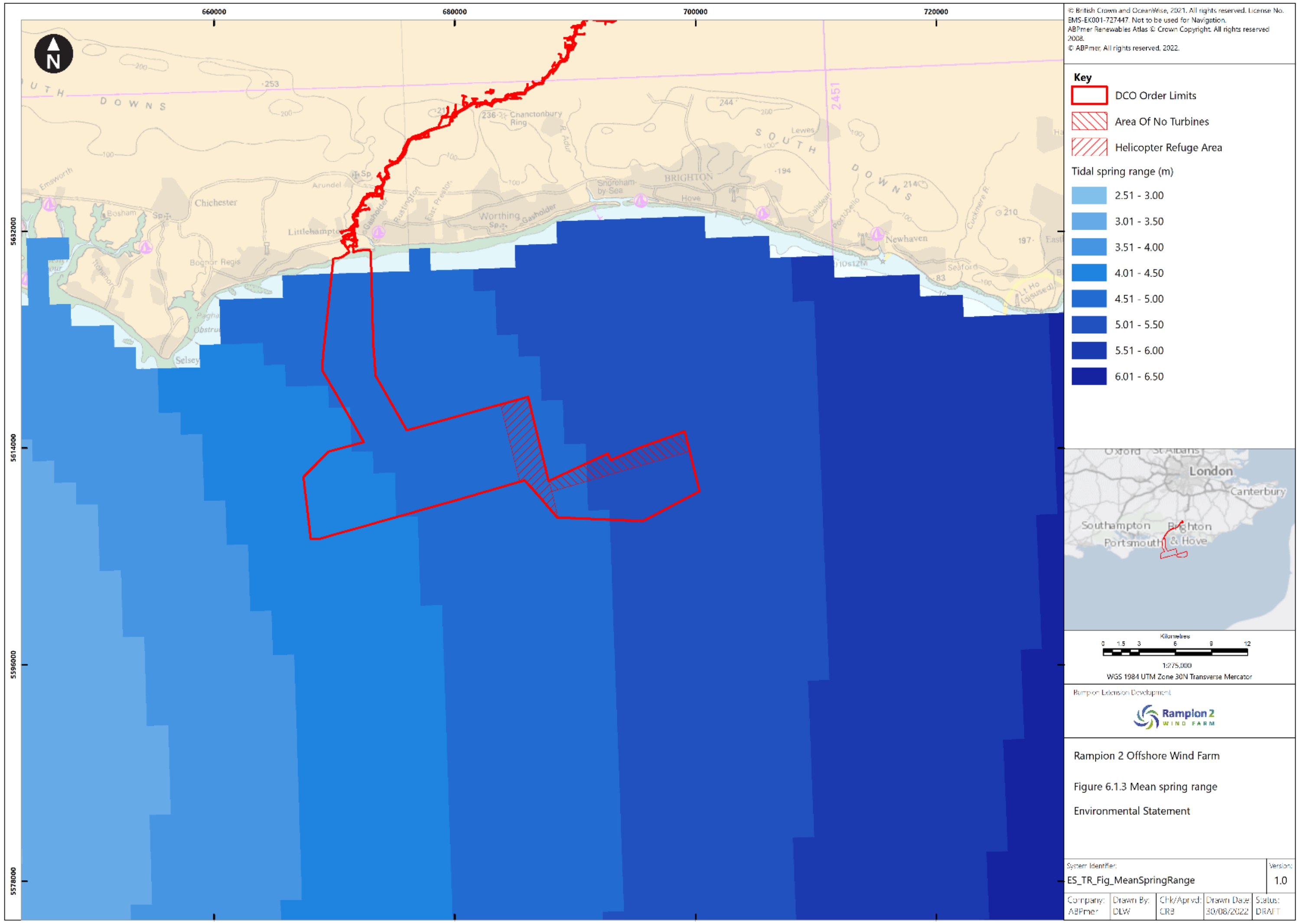

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Table 3-1 Tidal water levels

Tidal water level		Littlehampton[1] (m LAT)	Arun Platform [2] (m LAT)	Rampion 1		Newhaven[4] (m LAT)
				L2 AWAC[3] (m)	L3 AWAC[3] (m)	
Highest Astronomical Tide	HAT	6.50	6.43	7.21	6.62	7.30
Mean High Water Springs	MHWS	5.90	5.85	6.39	5.96	6.69
Mean High Water Neaps	MHWN	4.40	4.6	4.99	4.62	5.22
Mean Sea Level	MSL	-	-	3.54	3.21	3.56
Mean Low Water Neaps	MLWN	1.70	1.96	2.08	1.81	2.10
Mean Low Water Springs	MLWS	0.40	0.71	0.68	0.46	0.77
Lowest Astronomical Tide	LAT	-0.10	0.04	0.00	0.00	0.16
Mean Spring Range	MHWS to MLWS	5.50	5.14	5.71	5.50	5.92
Mean Neap Range	MHWN to MLWN	2.70	2.64	2.91	2.81	3.12

[1] UKCO (2021); [2] CCO (2018); [3] EMU (2011); [4] NTSLF (2021)

Non-tidal influences on water level

3.2.4 In addition to the astronomical tide, water levels may be influenced by regional scale meteorological patterns of air pressure and wind. For example, higher than average atmospheric pressure causes the water level to be relatively depressed (negative surge) whilst low pressure causes water levels to be relatively elevated (positive surge). Either effect can be enhanced or reduced by the additional effect of winds if sufficiently strong and persistent enough, depending upon the direction, location and timing. Moving low pressure systems and associated strong and persistent wind fields generate a strong positive surge (storm surge). The difference between the predicted astronomical tidal water level and that observed is termed the residual.

3.2.5 Across the study area, increases in extreme water level elevations are observed from west to east (Environment Agency, 2019). The increase in extreme water levels across this axis coincides with the observed increase in mean spring range from co-range observations and harmonic analyses of the available tide gauge data (**Table 3-1**).

3.2.6 Water levels for a series of extreme surge return periods are provided for the landfall in **Table 3-2**. The values are set out as absolute levels (and therefore include the tidal and surge components) and are based on statistical analysis of long-term water level data.

Table 3-2 Extreme tidal level statistics at the landfall; baseline year 2017 (Environment Agency, 2019)

Return period (years)	Elevation (m, above Ordnance Datum Newlyn, ODN)
2	3.41
5	3.51
10	3.58
25	3.68
50	3.76

Future baseline

3.2.7 Mean sea level within the Zone Of Influence (ZOI) for the project is likely to change over the lifetime of the wind farm (expected 30-year minimum operational period). This change is generally accepted to include contributions from global eustatic changes in mean sea level and as a result of regionally varying vertical (isostatic) adjustments of the land.

3.2.8 Information on the rate and magnitude of anticipated relative sea level change in the English Channel during the 21st Century is available from UKCP18 (Palmer et al., 2018). It is predicted that by 2060, relative sea level could have risen by approximately 0.35 to 0.4m above present day (2021) levels (Representative Concentration Pathway (RCP) 8.5; 95 percentile) at the landfall with rates of change increasing over time.

3.2.9 A rise in sea level will allow larger waves, and therefore more wave energy, to reach the coast in certain conditions and consequently result in an increase in local rates or patterns of erosion and the equilibrium position of coastal features. Sea level rise may also result in a loss of intertidal habitat through the process of 'coastal squeeze' caused by the presence of coastal defences preventing natural roll back of the coast.

3.2.10 The UKCP18 also includes projections of changes to storm surge magnitude in the future as a result of climate change. However, it is found that UKCP18 projections of change in extreme coastal water levels are dominated by the increases in mean sea level with only a minor (less than 10 percent) additional contribution due to atmospheric storminess changes over the 21st century (Palmer et al., 2018).

3.3 Currents

3.3.1 The English Channel is a semi-enclosed sea that narrows towards the east. Tidal flow through the study area is from the southwest on the flood and northeast on the ebb tide. The main axis of flow within the Offshore Array Areas is broadly east-northeast to west-southwest and broadly aligned to the coast and the narrowing in the central and eastern parts of the Channel results in spatial variations in current speed.

3.3.2 Speeds of up to 2m/s are observed between the Isle of Wight and the Cotentin Peninsula (France). These then reduce eastwards to between 0.5m/s to 1.25m/s in the offshore part of the study area. Further eastwards and inshore, current speeds reduce to approximately 0.25m/s before increasing again towards the Dover Strait (ABPmer, 2017) (**Figure 6.1.4**). During neap tides, depth averaged peak current are typically half of that observed on spring tides.

3.3.3 Current speeds at locations in and nearby to central/ eastern areas of the Rampion 2 Offshore Array Areas from the Rampion 1 oceanographic survey are shown in **Figure 6.1.5**. At the western end of the Rampion 1 Offshore Array Areas, peak spring flows are typically around 1.3m/s whereas at the eastern end they are more generally around 1.0m/s. Close inshore at the landfall, they are generally around 0.6m/s.

3.3.4 Spring tidal ellipses illustrate the approximate distance and direction over which water is displaced during one mean spring tide (one flood and one ebb). The length of the ellipses is generally proportional to the associated peak current speed. They are quite highly rectilinear in the Rampion 2 Offshore Array Areas, becoming more rotary within the Offshore Export Cable Corridor. Within the Offshore Array Areas, they are generally in the range seven to 9km but are more typically four to 6km in the Offshore Export Cable Corridor.

3.3.5 The expected vertical profile in current speed for open water un-stratified flows is apparent at all the Acoustic Wave and Current (AWAC) device deployment locations, i.e. exhibiting a decrease in current speed towards the bed.

3.3.6 Patterns of net tidal current drift are both temporally and spatially variable. However, the flood tide is marginally stronger than the ebb tide and this leads to a general net residual flow to the northeast, especially on spring tides (ABPmer, 2012). This is an important consideration in the net advection of material raised into suspension.

3.3.7 There is a bedload parting zone and a divide in the direction of sediment transport south of the Isle of Wight (**Section 5.1**), as a result of residual tidal flow patterns.

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Figure 6.1.4 Peak current speeds

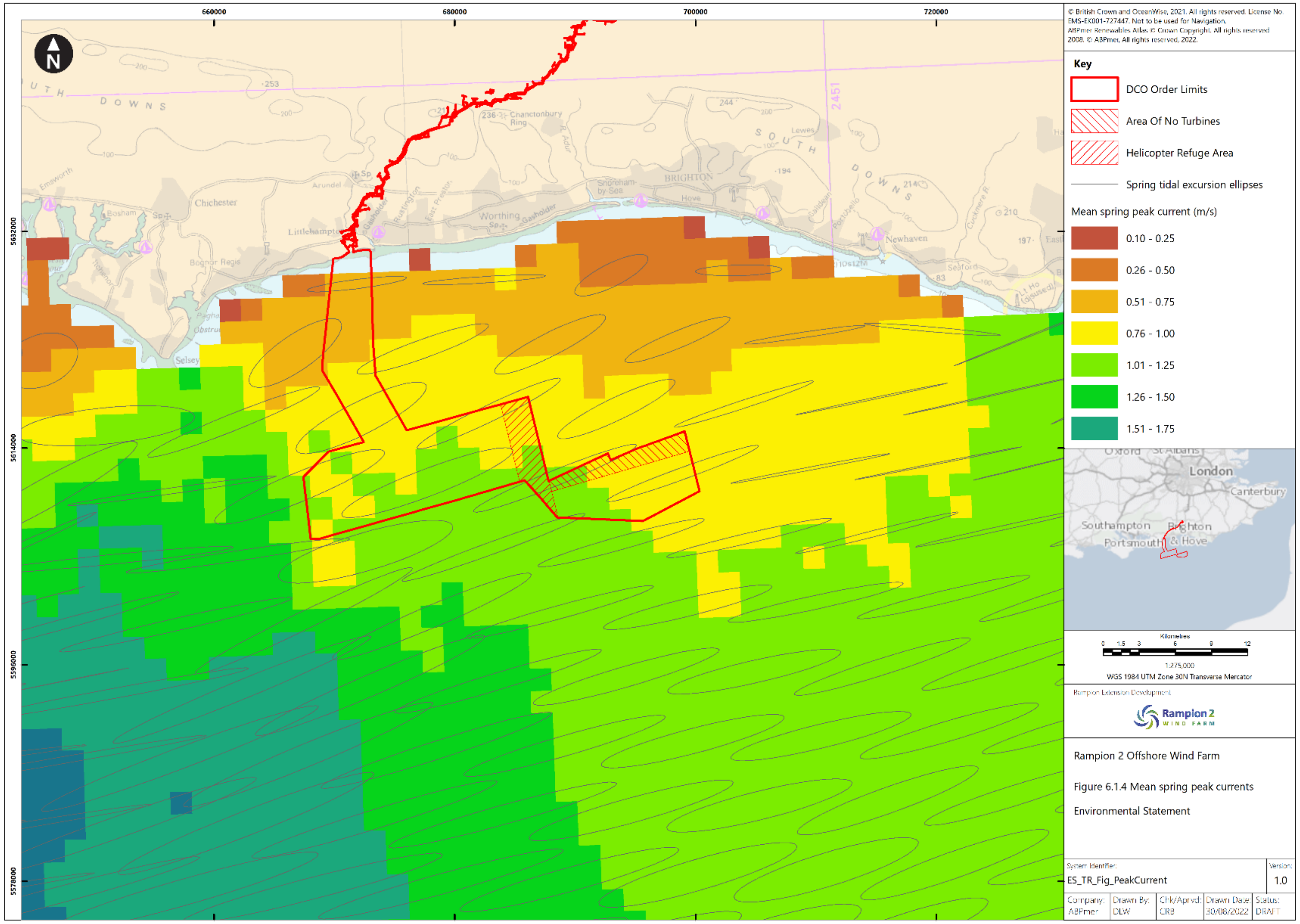

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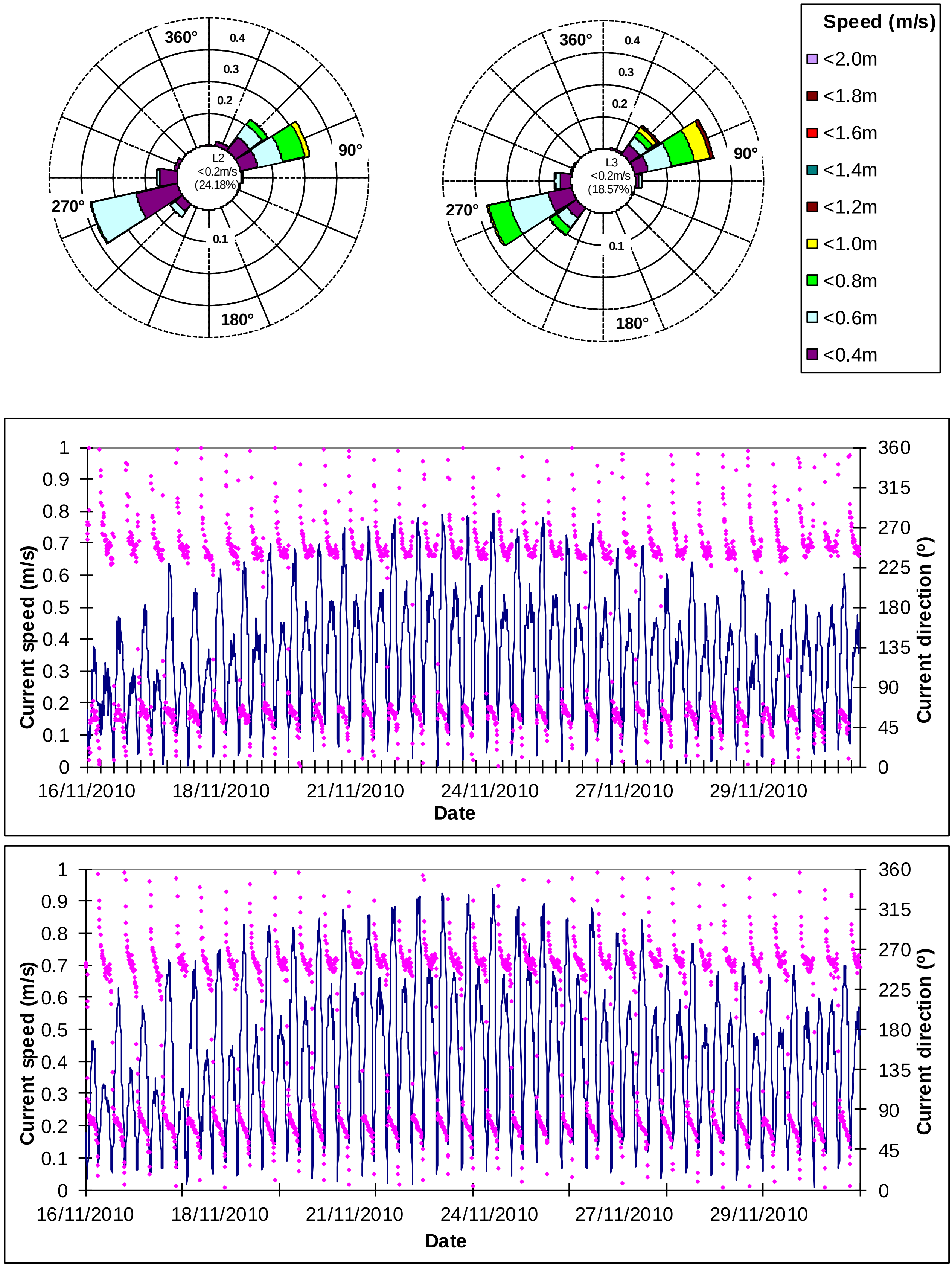
Figure 6.1.5 Summary of current speed and direction at oceanographic survey locations L2 and L3 from the central/ eastern Rampion 2 Offshore Array Areas



Wave induced currents

3.3.8 In addition to astronomically driven tidal currents, meteorological forcing may also cause an increase in locally observed current speeds. In addition to storm surges, wave induced currents have the potential to induce sediment mobility. Individual waves propagating through a fluid induce circular to elliptical movements through the water column. In shallow water less than the closure depth for waves, this motion extends to the seabed resulting in an oscillatory nearbed current. This is mainly the case for the shallower areas of the Channel, with depths less than approximately 20m.

3.3.9 The amplitude of these nearbed oscillatory currents is termed the orbital velocity, which can be estimated as a function of wave height, period and the local water depth (Dean and Dalrymple, 1991) and are estimated in **Table 3-3** for a series of extreme wave events. The return period wave conditions are calculated from the SEASTATES hindcast model output (ABPmer, 2012) for representative nearshore and offshore locations (**Figure 6.1.2**).

Table 3-3 Wave height, period and orbital velocity associated with extreme storm events

Depth	Return period (years)	Significant wave height Hs(m)	Wave period Tz (s)	Nearbed orbital velocity (m/s)
Nearshore depth: 9.9m (LAT)	2	4.18	7.14	1.52
	5	4.44	7.35	1.64
	10	4.64	7.51	1.74
	25	4.90	7.72	1.87
	50	5.09	7.87	1.96
Array depth: 33m (LAT)	2	4.83	7.46	0.37
	5	5.10	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
Offshore depth: 54m (LAT)	2	5.41	7.44	0.09
	5	5.60	7.57	0.11
	10	5.71	7.65	0.11

Depth	Return period (years)	Significant wave height Hs(m)	Wave period Tz (s)	Nearbed orbital velocity (m/s)
	25	5.83	7.73	0.12
	50	5.90	7.78	0.13

3.3.10 From **Table 3-3** it is apparent that the highest nearbed orbital current amplitudes will be found in the shallower parts of the ZOI. Here, current velocities are in excess of 1m/s for a 1 in 2-year return period storm event and are approximately 2m/s for a 1 in 50-year event, which could occur during the lifetime of the Proposed Development. Orbital current speeds of this magnitude are considerably greater than observed peak spring tidal flow speeds.

3.3.11 Within the Offshore Array Areas orbital current speeds are considerably less and range between 0.4m/s to 0.5m/s for the 1 in 2-year to 1 in 50-year return period respectively. The implications of these findings for sediment mobility within the Proposed DCO Order Limits and the wider ZOI area are discussed further in **Section 5.6**.

3.3.12 A discussion on wave height and period is provided in **Section 3.5** below.

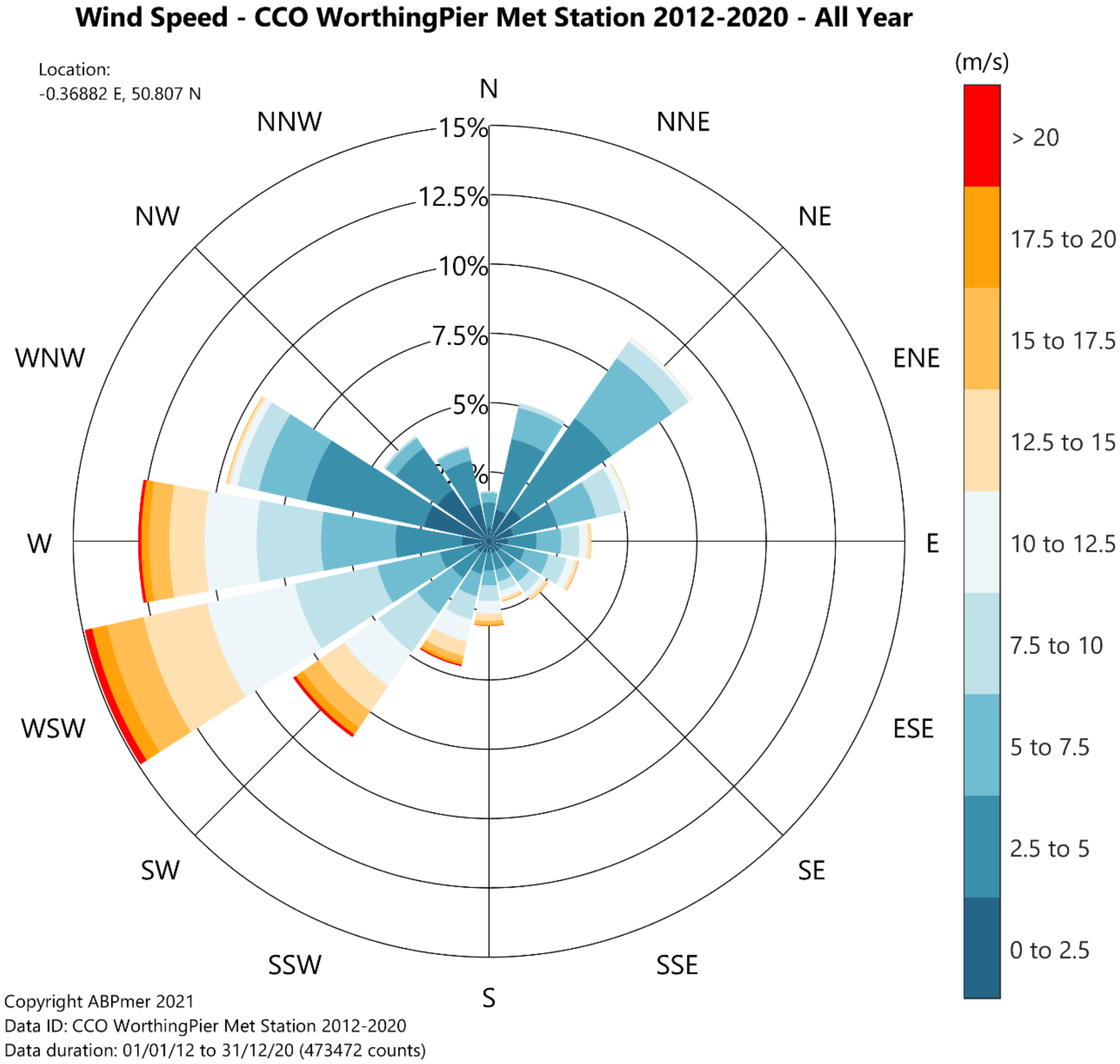
3.4 Winds

3.4.1 Although not part of the hydrodynamic regime, the wind regime is relevant to the generation of waves. The relationship between wave generation and meteorological forcing means that the wind and wave regimes are similarly episodic and exhibit both seasonal and inter-annual variation in proportion with the frequency and magnitude of changes in wind strength and direction.

3.4.2 The Worthing Pier met station provides a long-term record of wind data within study area, with data available (via Channel Coast Observatory) back to 2012. A frequency analysis of the data is presented as a wind rose in **Figure 6.1.6** and shows that:

- the dominant wind direction is from the west-southwest, with winds occurring from this direction around 15 percent of the time;
- winds from the southwesterly quadrant account for approximately 40 percent of the record;
- the strongest winds observed in the record are all originate from the southwesterly quadrant, with maximum observed speeds in excess of 30m/s; and
- wind speeds are 7.5m/s or less for around 65 percent of the time, whilst wind speeds of 2.5m/s (or less) account for approximately 17 percent of the record.

Figure 6.1.6 Wind rose for Worthing Pier (2012 to 2020)



3.5 Waves

3.5.1 The wave regime in the English Channel is a combination of wind waves and swell waves. Wind waves are the result of the local transfer of wind energy to the water surface and swell waves are wind waves that would have been created as the result of a storm event and then propagated from outside the area of generation.

3.5.2 The English Channel is predominantly influenced by swell waves coming from the Atlantic Ocean (ABPmer, 2012) and have significant wave heights in excess of 4m over 50 percent of the time under winter conditions (Paphitis et al., 2010). As the swell waves propagate into the Channel, significant wave heights reduce to 2.4m in the Western Approaches and reduce further to 0.9m into the eastern part of the Channel. Under summer conditions, wave heights are approximately half of winter conditions.

3.5.3 Extremes analysis has been undertaken using long-term wave hindcast data from the ABPmer SEASTATES model (ABPmer 2013). Estimates of extreme wave height and period for representative locations offshore, in the Rampion 2 Offshore Array Areas and nearshore at the landfall are outlined in **Table 3-3.** The table shows that the wave period for extreme wave conditions is approximately seven seconds and that significant wave height reduces inshore as follows:

- 5.4m (1 in 2-year event) to 5.9m (1 in 50-year event) offshore;
- 4.8m (1 in 2-year event) to 5.5m (1 in 50-year event) in the Rampion 2 Offshore Array Areas; and
- 4.2m (1 in 2-year event) to 5.1m (1 in 50-year event) nearshore.

3.5.4 The observed wave climate in the central and eastern part of the Rampion 2 Offshore Array Areas within the Proposed DCO Order Limits is summarised using the Rampion 1 oceanographic survey (**Figure 6.1.2)** with data presented in **Table 3-4**. It is important to note that the survey covers only a two to four-month winter period and is therefore expected to contain some seasonal bias (ABPmer, 2012). The slender monopiles installed in Rampion 1 have been assessed in **Appendix 6.3 Coastal processes technical report: Impact assessment, Volume 4** (Document Reference: 6.4.6.3) to cause no measurable difference to waves in the Rampion 1 Offshore Array Areas, therefore, descriptions of wave climate based on data from before or after the construction of Rampion 1 are equally representative:

- at L2 (east) the dominant wave direction is from the southwest, with waves originating from this sector around 30 percent of the time;
- at the same location, wave heights of up to approximately 4m were observed although the most frequent wave heights are between 0.5m to 1m accounting for approximately 50 percent of all waves;
- at L3 (central area) the dominant wave direction is from the west-southwest to southwest, with wave originating from this direction approximately 30 percent of the time;
- wave heights of up to approximately 3.3m were observed here, although the most frequent wave heights are between 0.5m to 1m accounting for approximately 50 percent of all waves;
- at all locations, the larger waves observed during the survey period all approached from either the southwest or south-southwest; and
- the dominant wave direction and larger waves conform to the dominant swell direction of approaching waves into the English Channel.

3.5.5 A frequency analysis of the data is presented as **Table 3-4** and shows that:

- the most frequent mean wave periods are between three and four seconds, accounting for between approximately 43 percent and 47 percent, respectively of the records. These short wave-periods and the close correlation between the predominant wind and wave coming directions are indicative that more locally generated wind waves tend to dominate the wave regime within the Proposed DCO Order Limits and wider ZOI;
- peak-mean wave-periods are, approximately, seven seconds. These longer period waves typically approach from the southwest and although are longer

are typically still within the range of wind waves and not necessarily characteristic of swell waves; and

- areas within the Proposed DCO Order Limits and wider ZOI are therefore, predominantly influenced by wind waves. Occasional larger, longer period swell waves will also come from similar directions (predominantly southwest) due to the long open fetches in that direction from the long axis of the English Channel, the Western Approaches and the wider North Atlantic.

3.5.6 The Rustington Wave Buoy provides a long-term record (17 years) of data from a location inshore of the Offshore Array Areas, covering the period January 2004 to December 2020 (**Figure 6.1.2**). Analysis of the record shown in **Figure 6.1.7** shows that the most frequent wave direction is from the southwest to south-southwest, which accounts for approximately 60 percent of the record. This is largely consistent with the metocean observations above despite the differing length of the records. The largest wave height observed at Rustington was 5.72m which approached from the southwesterly quadrant. Swell waves with periods of over ten seconds are also observed.

Table 3-4 Frequency analysis of observational wave records within and nearby to the Proposed DCO Order Limits

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 L2	01/11/2010 to 18/02/2010	SW (32%)	0.5 to 1 m (53%)	4.08 m (SSW)	4 to 5 seconds (46%)	7.3 seconds (SW)
Rampion OWF AWAC L3	15/12/2010 to 10/05/2011	WSW (30%)	0.5 to 1 m (48%)	3.26 m (SW)	3 to 4 seconds (47%)	6.7 seconds (SW)
Rampion OWF AWAC L3	15/12/2010 to 10/05/2011	WSW (30%)	0.5 to 1 m (48%)	3.26 m (SW)	3 to 4 seconds (47%)	6.7 seconds (SW)

Percentages are rounded to integers

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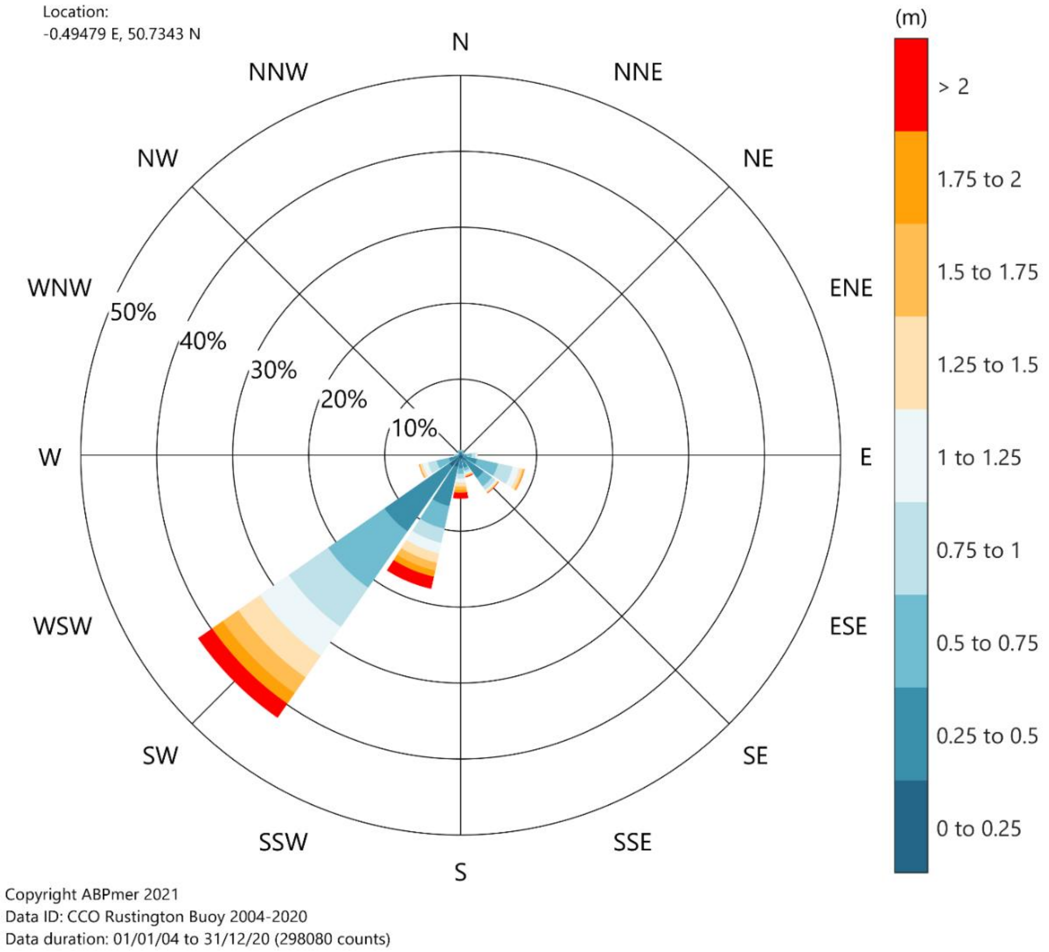
Figure 6.1.7 Wave rose for the Rustington wave buoy (2004 to 2020)



Influence of waves on coastal erosion

3.5.7 Wave action at the coastline has a controlling influence on erosion processes and sediment transport rates; with rates and direction influenced by both wave height and direction of the waves reaching the coast (**Section 4.1**).

3.5.8 Under calm conditions with no storms (significant wave heights less than 0.5m), waves are not seen to move large sediment volumes in the offshore environment but have a limited sediment disturbance effect for transport by currents.

3.5.9 At the coast, under normal conditions, waves are again not seen to move large volumes of sediment. However, the occurrences of larger waves associated with storms have the potential to cause water movement at the seabed at the coastline and within the shallower nearshore parts of the Offshore Export Cable Corridor and the Offshore Array Areas.

3.5.10 Focusing on the eastern English Channel, Paphitis et al. (2010) showed that wave action has the potential to disturb seabed sediments over 20 percent of the time on an annual time scale at the coast. Further offshore and towards the Offshore Array Areas within the Proposed DCO Order Limits, this reduces to between 5 to 20 percent of time during the year. Further offshore in the middle of the eastern English Channel, this again reduces to less than 1 percent across a year.

Future baseline

3.5.11 There is evidence to suggest that longer-term changes in storminess have taken place across northwest Europe (e.g. Alexandersson et al., 2000). These changes may be related to long-term changes in the strength of the North Atlantic Oscillation, a hemispheric atmospheric mass with centres of action near Iceland and over the subtropical Atlantic (Visbeck et al., 2001).

3.5.12 Modelling as part of UKCP18 (Palmer et al., 2018) currently gives the most up-to-date projection of the likely future wave climate. Changes in climate over the 21st century may include changes in mean wind speed and direction which will in turn affect the wave regime. The findings indicate that in the English Channel in the vicinity of the study area, mean annual maxima significant wave heights between 1981 to 2000, and between 2081 to 2100 will increase by less than 0.2m.

3.6 Temperature, salinity and stratification

3.6.1 Across the study area, the mean sea surface temperatures for summer and winter are typically around 16 and 7 degrees, respectively, with the highest temperatures observed in August and coolest in February. Sea surface temperatures in this region are strongly influenced by the movement of water along the English Channel, modifying the effects of the region's proximity to continental Europe. In winter, relatively warm waters move up the English Channel, and are considerably warmer than the coastal waters of Holland, Belgium and Germany, which have a strong (cold) continental influence (Barne et al., 1998).

3.6.2 Salinity values are highest along the centre of the English Channel owing to the eastward movement of Atlantic water. Salinity values decrease towards the coast although remain above 34.5 g/kg. The exception to this is at river mouths, owing to freshwater discharge. Within the study area, waters are well mixed throughout both winter and summer months although transient and shallow thermoclines may develop in warm summers to the east of the study area, in waters south of Dungeness (Barne et al., 1998; McBreen et al., 2011).

Future baseline

3.6.3 There are a now a number of North-West European Shelf (NWS) seas climate projections for the end of the 21st Century and there is good agreement on the sign of the temperature change on the NWS among the end of century climate projections (Tinker and Howes, 2020). For the English Channel region, annual mean sea surface temperature projected change between 1960 to 1989 and 2069 to 2098 is expected to rise quite significantly, with modelled estimates provided in Tinker et al. (2016) of +3.13 degrees ±0.82 degrees. There is considerable uncertainty regarding future salinity. Most 21st Century projections suggest UK shelf seas (including the English Channel), and the adjacent Atlantic Ocean, will be less saline than present, driven by ocean circulation changes in response to climate change (Dye et al., 2020).

4. Morphological regime

4.1 Coastal characteristics

4.1.1 Rampion 2 is located within a large embayment of open aspect, bound by two prominent headlands, Selsey Bill and Beachy Head. These features form the boundaries of a distinct coastal cell, as identified within the shoreline management plans (SMPs) as sub-cell 4d.

4.1.2 The coastline of sub-cell 4d can be described according to its solid geology and its degree of exposure to climatic and tidal influences. It is characterised by low-lying land with associated sandy/gravelly beaches and coastal plains in the west and chalk cliffs to the east (**Figure 6.1.1**). The low-lying lands to the west, extending from Selsey to Shoreham-by-Sea are currently below high water. Eastwards between Brighton and Beachy Head, the beach is backed by chalk cliffs, which are part of the South Downs chalk ridge. South flowing rivers dissect the chalk ridge, cutting deep channels into the chalk that are subsequently filled with alluvium (Antoine et al., 2003). These rivers are the Arun, Adur, Ouse and Cuckmere Rivers and are considered to be associated with north to south running paleochannels which connected with the Northern Paleovalley (Antoine et al., 2003; Gupta et al., 2004; Gupta et al., 2007).

4.1.3 In the nearshore environment, there is a wide shelf along the coast of this sub-cell, where the 20m LAT depth contour is generally 15 to 20km offshore. The cross-shore sediment profile characteristic for this sub-cell is a low-lying coastal plain or chalk cliff, with a beach shingle frontage to depths greater than 10m. Further away from the coast, the shingle deposits fine up to sandy deposits characteristic of the permanently sub-tidal environment. The described deposits are characteristic of a historic fluvial source and inputs from the backing cliffs (Antoine et al., 2003; Gupta et al., 2004). These sources are predominantly closed now with the construction of cliff facing defences and the reduction in the size of the fluvial input.

4.1.4 The shoreline management policy for much of the coastline is ‘hold the line’; for some local areas of dunes and other dynamic coastal morphology the policy is ‘Managed Realignment’; and for a few areas of natural cliffs the policy is ‘No Active Intervention’. Erosion of the shingle beaches is managed locally through the local use of (for example) shore perpendicular wood or rock groynes, shore parallel breakwaters, and/or beach nourishment and reprofiling. Accretion at harbour mouths is managed by maintenance dredging, if and where required.

Landfall

Present day setting and historic evolution

4.1.5 The Rampion 2 landfall at Climping is located within SMP Policy Unit 4D20 (Littlehampton to Poole Place) with the Environment Agency being responsible for coastal management along this section of coastline.

4.1.6 The area of Climping beach forms part of the Arun to Pagham Strategy ('the strategy') which was signed off by the Environment Agency in 2015. The strategy option for the location of the landfall is to maintain in the short-term using a reactive patch and repair maintenance approach until this is no longer economically viable either because the annual maintenance budget is exceeded or the costs for re-instatement of the present defences following significant damage exceeds the budget available.

4.1.7 The beach consists of mixed sand and shingle sediment with a 1:7.5 slope to the sand foreshore and sediment transport in an easterly direction (**Figure 6.1.8**). Sand dunes span for just over a kilometre immediately to the east of the cable landfall. A series of timber groynes are in place as well as a failed seawall in the immediate location where the cable will make landfall (Environment Agency, 2017).

4.1.8 The Environment Agency (2020a) provide a detailed characterisation of the frontage between Poole Place and the River Arun (locations shown in **Figure 6.1.9**: key details are summarised here:

- Longshore transport is dominated by west to east movement due to the dominant southwesterly waves (see **Figure 6.1.8**). Shorter periods of southeasterly waves do move sediment towards the west. However, this may be limited by the changes in the shoreline orientation such that westward movement tends to work over shorter sections of the coast, rather than mobilising sediment across the whole frontage.
- Sediment arriving from the west currently passes through the frontage and builds up at the River Arun training wall, although some bypassing occurs, as evidenced by the need to regularly dredge sand and shingle from the mouth of the Arun to maintain a clear channel. This material is currently recycled onto the Climping frontage by the EA as part of their maintenance works.
- Wave records show that swell waves are important and longer period waves from the southwest have resulted in overwashing of the shingle ridge where it fronts lower lying land.
- The plan shape of the current frontage is highly likely to be the result of a response to coastal management rather than variations in natural processes or geological resistance. Maps dating back to 1813 show that groynes have been present along this section of the frontage for over 200 years, locally holding material and thereby reducing erosion, whilst starving adjacent stretches. This has created a coastline shape that includes several ‘back-steps’.
- As approaches to coastal management have evolved over time, so has the plan shape: these changes are indicated by the exposure of undulating field wall foundation levels, which suggest that the frontage has been eroded in the past (at least prior to 1887 OS mapping) but has since accreted. The latter is almost certainly largely due to coastal management measures although likely to also relate to sediment supply fluctuations, both natural and as a result of management updrift.
- For over 200 years the coast west of the dune section at the landfall has been held in much the same position, with the beach in front of the dunes growing seaward in response to continued sediment transport, with sediment being

retained by the presence of the western training arm of the river Arun. This has allowed the development of the slightly higher dunes, developing over what is likely to have been a lower shingle ridge.

- Historic mapping shows that the River Arun has been significantly influenced by anthropogenic intervention, which has in turn influenced shoreline behaviour on either side of the mouth. Even before the earliest OS maps from the 1830s the river had been trained with embankments and training walls constructed along its banks and at the mouth, disconnecting the estuary with its natural floodplain. Prior to these changes it is possible that a tidal delta existed at the mouth of the Arun.
- The tidal prism would have reduced as a result of training and reclamation works which would have in turn reduced flows and sediment transport, potentially resulting in the breakdown of any tidal delta. Sands and gravels that formed the delta could have become pushed onshore and subsequently alongshore possibly contributing to the formation of the dune system now present to the west of the Arun western training wall. There are gravel bars on the eastern side of the Arun that suggest onshore transport pathways but the same features are not seen on the western side.
- It is likely that the chalk bedrock provides some resistance to erosion and there is little evidence of foreshore lowering from either the beach profiles (which cover the medium-term), or historic mapping, which do not show any significant change in the position of mean low water. Based on available evidence it is considered that the lower intertidal and subtidal are highly likely to change very slowly.

4.1.9 Damage to the Mill Road embankment has incrementally increased from 2006, but especially since Storm Imogen (2018), and Storm Ciara (2020). During the latter storm, the coastal frontage at Climping was severely damaged and overtopped in January and February 2020, and widespread flooding occurred inland as far as the A259 and beyond. Damage was also sustained to a number of the timber groynes. The Environment Agency have since constructed a large shingle embankment, which at the time of writing has held up well, when subjected to further high tides. However, this is not seen as long-term option and the Environment Agency is reviewing future options for the beach management of this frontage (Planning Inspectorate, 2020).

Future baseline

4.1.10 In order to better understand the effects that a change in beach management would have on the wider frontage between Poole Place and the River Arun training wall, the Environment Agency convened an expert panel of geomorphologists to assess the likelihood of different coastal evolution scenarios across the frontage (Environment Agency, 2020a; 2020b). Key findings from this work are summarised below and in **Figure 6.1.9** and **Figure 6.1.10**. It is understood that these evolution scenarios do give some consideration to likely sea level rise over the analysis period i.e. 10-50 years). However, it is noted that coastal response to sea level rise will be extremely complex: rates of change in shoreline position will be dependent upon a wide range of factors including hinterland topography, geology and sediment supply, the latter of which may well vary in response to changing patterns of erosion and nearshore sediment transport resulting from sea level rise.

4.1.11 Along the landfall frontage (immediately east of the car park and along Mill Road where the land is lower lying) the future shoreline position will be determined by water levels and sediment availability rather than erosion. Under current conditions, water overwashing the shingle barrier will flood the low-lying area to the north, all the way to the Arun where ground levels are at about 1 to 1.5 mODN, but the water will flow out into the Arun as the tide falls. In future, it is possible that a permanent channel may develop through the low-lying area. However, there is currently insufficient information and certainty to form a robust prediction and it is therefore equally possible that there will still be a continuous shingle barrier of different height and volume, which would roll landwards as a feature of the frontage.

4.1.12 It is also noted that the information set out in **Figure 6.1.9** and **Figure 6.1.10** was provided before the severe breaching event in February 2020. In light of this, The Environment Agency produced an update note reviewing observed change against the 10-year predictions previously set out (Environment Agency, 2020b). Given the more rapid failure of the Climping car park walls (at the western end through the gap between the tank trap blocks and the continued erosion of the clay on which the wall is founded) the assumed stability of this section over the next few years is no longer valid. The outlines of future beach positions at the eastern end of the car park shown in **Figure 6.1.10** are therefore likely to shift westwards

Figure 6.1.8 Sediment transport rates (m^3/year) at the landfall at Climping (Environment Agency, 2017)

Figure 6.1.9 Coastal evolution scenarios between Poole Place and the River Arun: projected change in the next 10 years, based on expert geomorphological assessment (Environment Agency, 2020a)

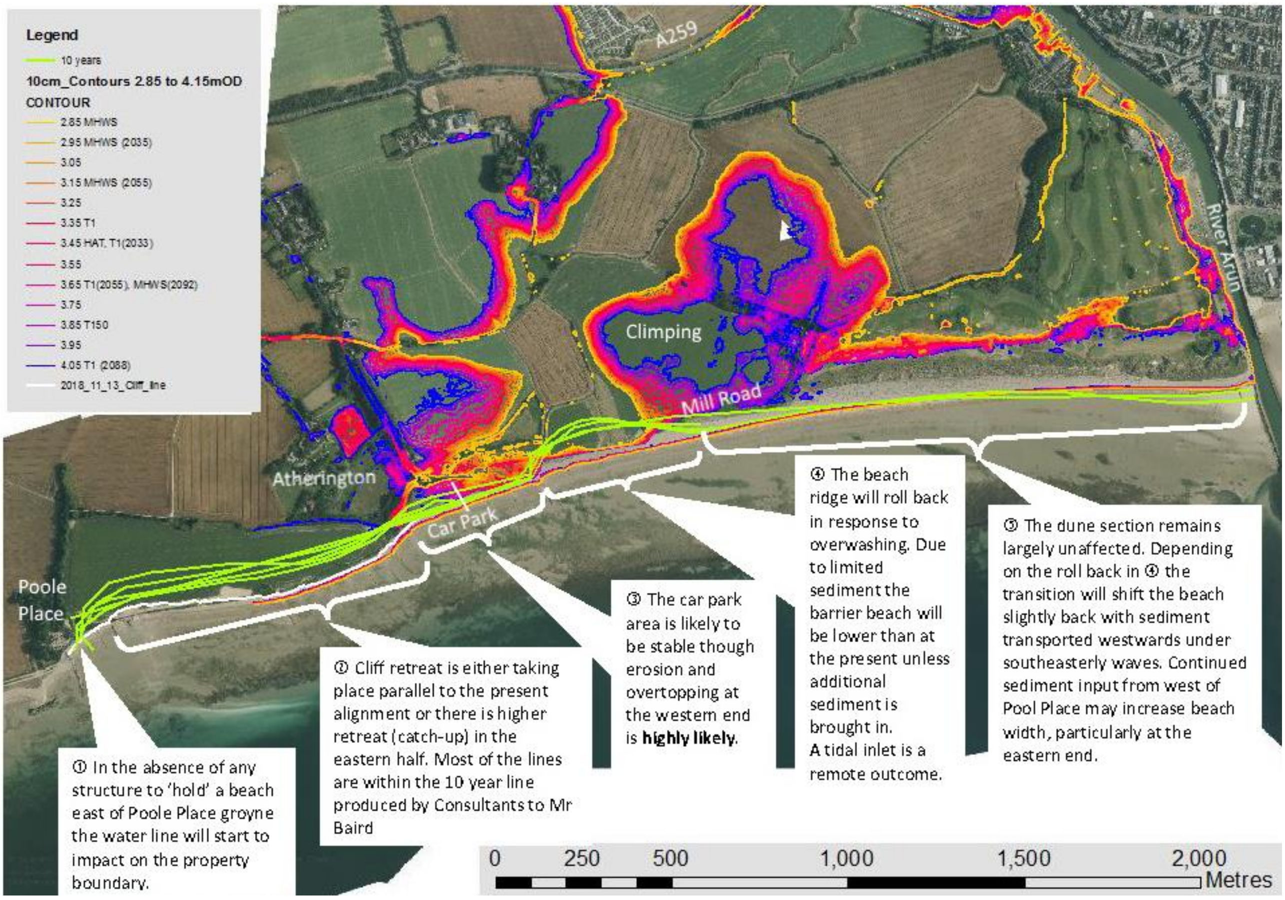
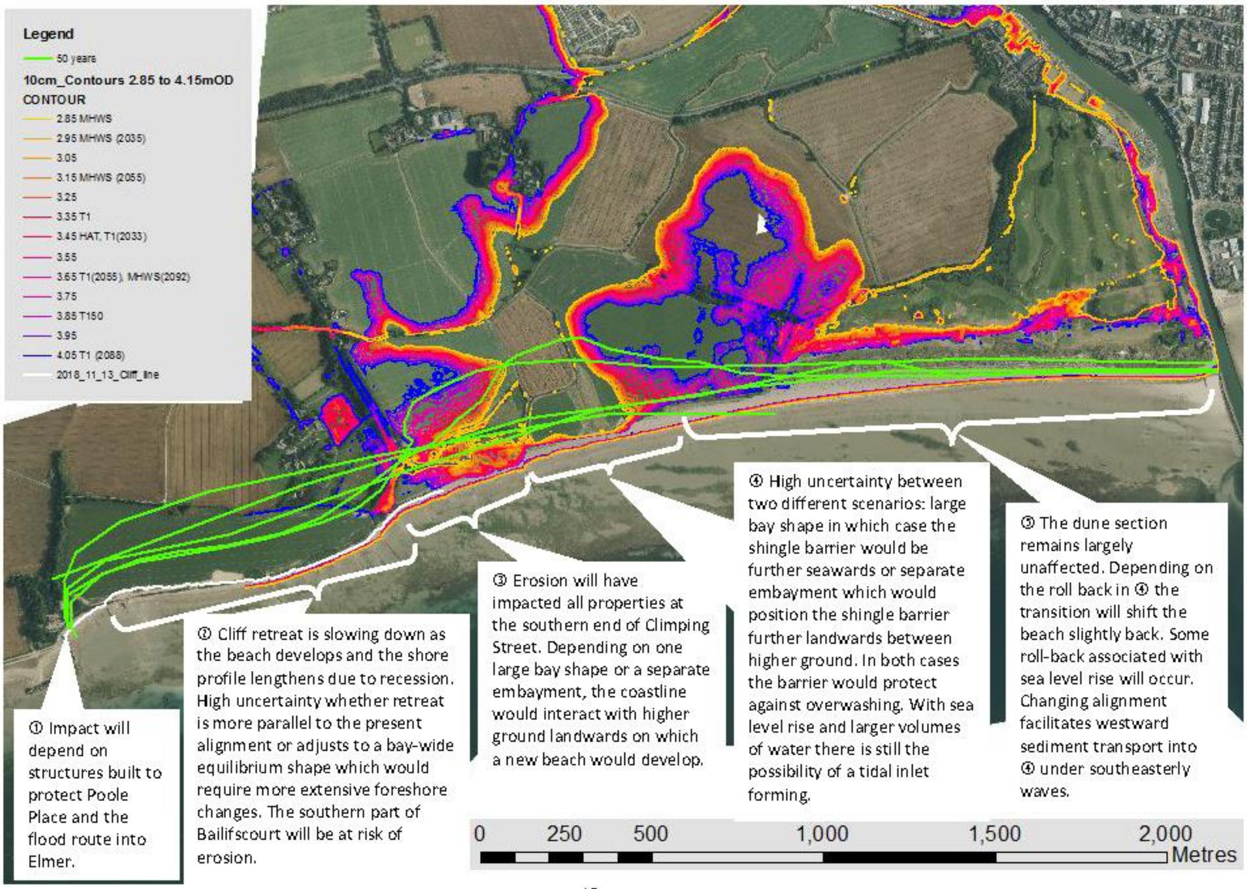


Figure 6.1.10 Coastal evolution scenarios between Poole Place and the River Arun: projected change in the next 50 years, based on expert geomorphological assessment (Environment Agency, 2020a)



4.2 Seabed morphology

4.2.1 Within the English Channel, seabed topography and sediment substrate are variably influenced by the structure and composition of underlying bedrock, the configurations and composition of geological features originating from former terrestrial and marine environments. These morphological states, combined with the sediment input from fluvial and anthropogenic sources and the interactions with near bed tidal and wave induced currents, bring about the contemporary morphodynamic regime within the Proposed DCO Order Limits and wider ZOI.

4.2.2 The seabed morphology within the study area has been described using Rampion 1 and Rampion 2 geophysical surveys (Gardline, 2020a; 2020b; 2020c and Osiris 2010b; 2010c) along with interpretation of the seabed morphology from a range of sources including the South Coast Regional Environmental Characterisation (James et al., 2010).

Rampion 2 Offshore Array Areas

4.2.3 Water depths across the Offshore Array Areas vary from approximately 13m LAT (on a rocky outcrop in the northwest of the site) to approximately 65m LAT (within a broad depression) in the southeast on the site. Seabed gradients across the survey area are generally less than one degree, dipping towards the south although the seabed undulates across much of the Offshore Array Areas, influenced by the underlying geology (**Figure 6.1.11**).

4.2.4 Sandwaves are prevalent over much of the central and eastern Offshore Array Areas trending northwest to southeast, with wave heights of up to 2m relative to the surrounding seabed. Wavelengths reach 25m and gradients on the flanks reach up to 30 degrees (Gardline, 2020a; 2020b).

4.2.5 Some significant seabed depressions are present in the northwest of the Offshore Array Areas. The largest of these is approximately 345m across and 12.5m deep, with gradients reaching 20 degrees on its flanks. Smaller depressions, interpreted as spudcan imprints associated with the existing Rampion 1 Windfarm, are observed at the margins with the Rampion 1 site. Maximum depths are approximately 1.5m and are associated with gradients reaching 24 degrees on the sides (Gardline, 2020a; 2020b).

4.2.6 Sedimentary bedform features (including sand waves and megaripples) have been mapped within the Proposed DCO Order Limits, with the axes of these features broadly aligned perpendicular to the direction of flow (**Figure 6.1.12** and **Figure 6.1.13**).

4.2.7 Given known relationships between sediment availability, flow speeds and bedform development (from Belderson et al., 1982), it is expected that the bedforms present are active. This is evidenced through comparison of 2020 geophysical data from Rampion 2, Rampion 1 in 2010 and multibeam bathymetry collected by UKHO in 2015 (southeast of the Offshore Array Areas) (**Figure 6.1.13**).

4.2.8 The asymmetry of the sandwaves along with the easterly displacement of the features between the two bathymetric surveys (**Figure 6.1.13**) points to a general easterly direction for sediment transport. This is entirely consistent with known sediment transport pathways across the wider study area (**Figure 6.1.14**) and with the analysis of the hydrodynamic data which identifies flood dominance, particularly during spring tides (**Section 3.3**). The rate of sandwave migration appears to reduce from west (Profile 1) to east (Profile 2), with rates of migration of around 2m/year observed along Profile 1.

4.2.9 The offshore environment in depths greater than approximately 20m LAT is not considered to provide a significant feed to the nearshore and the coastline. This is because sand is the dominant sediment offshore, gravels dominate the beaches and nearshore areas, and previous studies do not identify any onshore movement of sediment from these depths. Instead, what is identified is a small onshore feed of shingle from depths less than approximately 20m LAT based on wave conditions (New Forest District Council, 2017), particularly during storms (Paphitis et al., 2010). This feed is only observed to occur where potentially mobile shingle exists, which is a finite resource as re-supply from further offshore is unlikely due to limited gravel mobility at greater depths.

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Figure 6.1.11 Bathymetry within the proposed DCO Order Limits

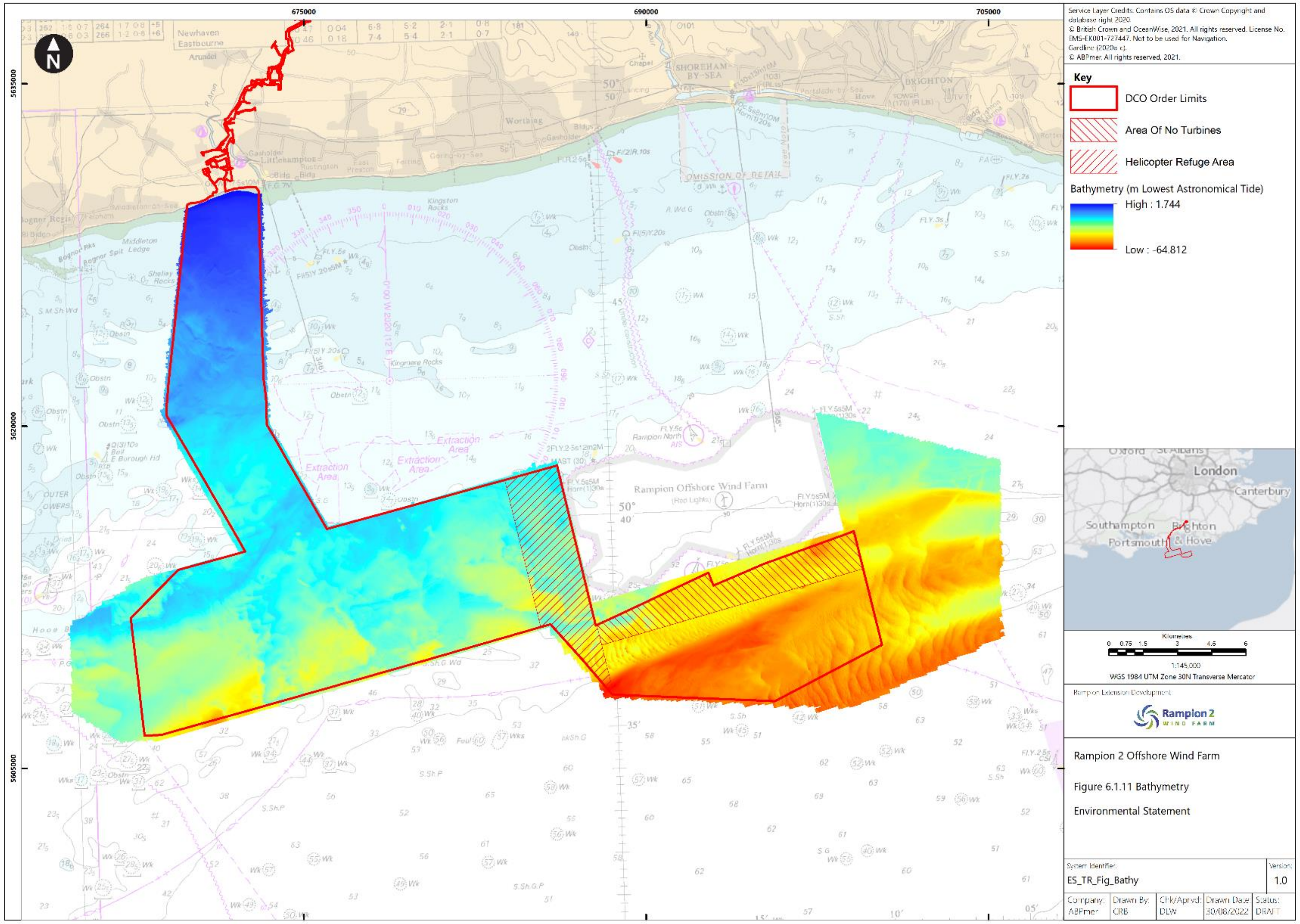
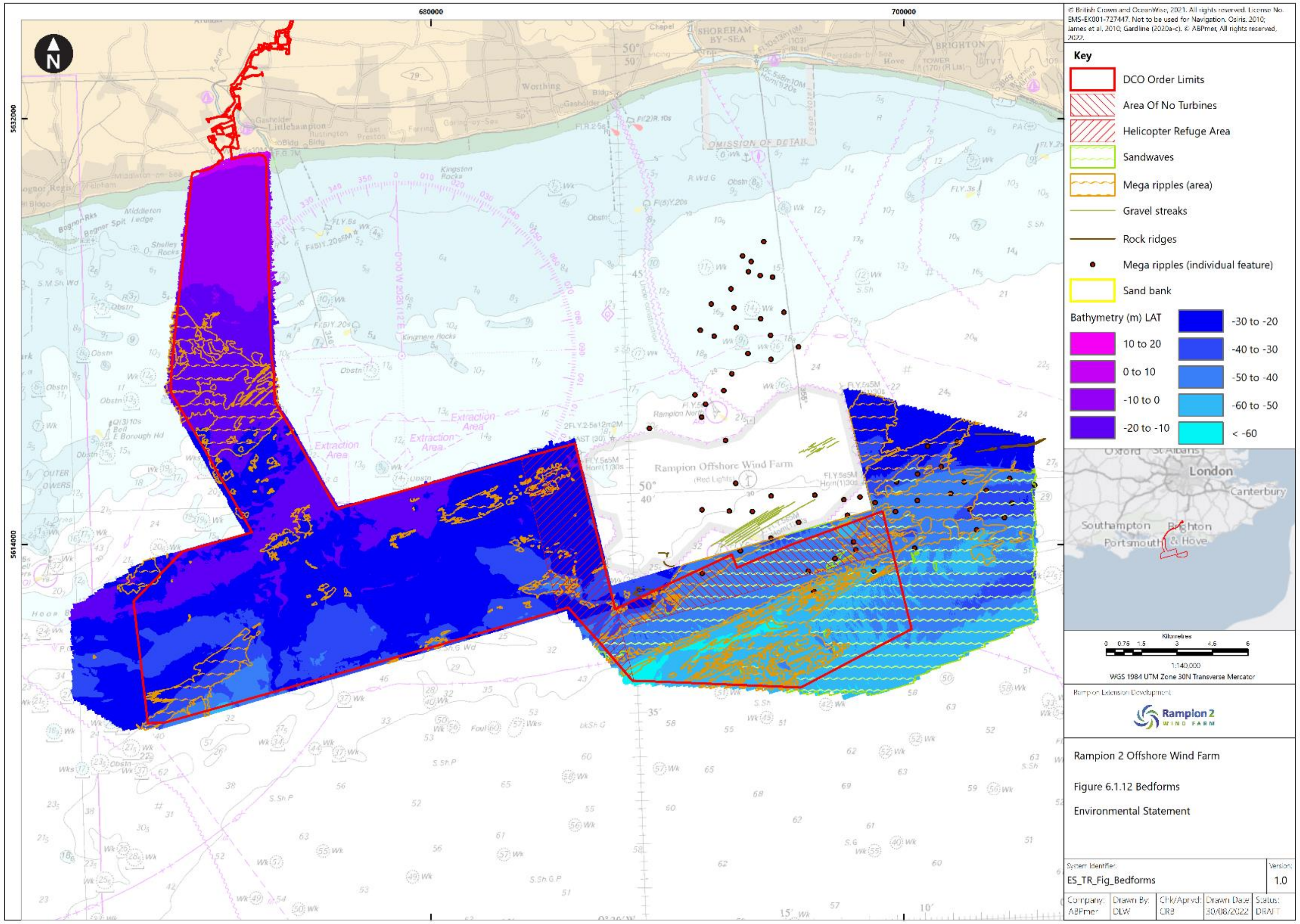


Figure 6.1.12 Bedforms within the proposed DCO Order Limits



Offshore Export Cable Corridor

4.2.10 The seabed undulates across much of the Offshore Export Cable Corridor, influenced by the underlying geology. Water depths within the Offshore Export Cable Corridor are greatest at the southern end where they reach approximately 28m LAT within a significant seabed depression (**Figure 6.1.11**).

4.2.11 Seabed gradients across the Offshore Export Cable Corridor are generally less than one degree, dipping towards the south. The dipping strata in the bedrock frequently approach the seabed and are orientated from northwest to southeast. Occasional rocky outcrops are observed, especially towards the coast, with seabed gradients reaching ten degrees (Gardline, 2020c).

4.2.12 Megaripples are present towards the southern end of the Offshore Export Cable Corridor (ECC) with heights of 0.2m and wavelengths reaching 7m (Gardline, 2020c) (**Figure 6.1.12**).

Future baseline

4.2.13 Whilst there is a high degree of likelihood that climate change (and sea level rise) will contribute to morphological change at the coast, there is a far greater degree of uncertainty with regards to how the seabed in offshore parts of the study area might respond. Larger and/or more frequent storms could theoretically result in greater movement of material at the bed, with greater rates of coastal erosion potentially increasing the supply of sediment to some areas. This in turn, could influence bedform distribution and/or morphological behaviour. But confidence in any future projections of change such as this is extremely low.

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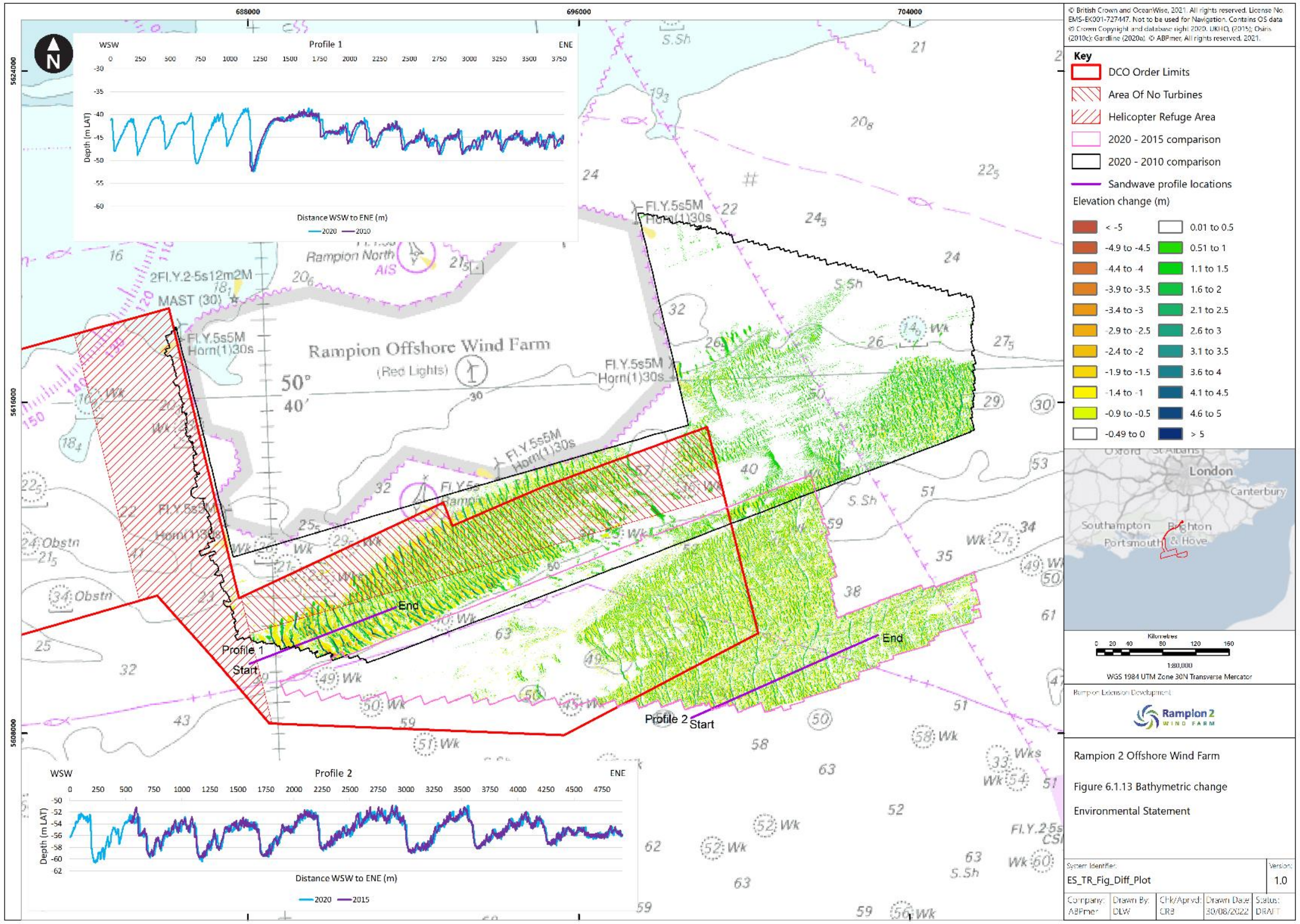
Figure 6.1.13 Bathymetric change in central and eastern parts of the Offshore Array Areas (2010 to 2020)



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5. Sedimentary regime

5.1 Overview

5.1.1 Factors that significantly control the sediment regime within the study area are the sediment sources for transport and deposition and the prevailing hydrodynamic conditions. Sediment sources dictate the type and volume of sediment available and the mechanism required for transport.

5.1.2 The two primary mechanisms of sediment transport within the Proposed DCO Order Limits and wider ZOI are:

- suspended-load transport. This mechanism refers to particles of sediment that are carried above the seabed within the water column; and
- bed-load transport. This mechanism refers to all sedimentary grains that move, roll or bounce (saltation) along the seabed as they are transported by currents, waves or the combination of both factors. This mode of transport is principally related to coarser material (sands and gravels).

5.1.3 These two mechanisms of transport can be variably controlled or dominated by different processes for example:. currents, waves or some combination of the two), which can also vary spatially in relation to conditions at the coastline and offshore contexts. The sediment transport across the study area varies from the coastline to offshore locations. This is due to the dominant hydrodynamic forcing conditions across the two environments.

5.1.4 Understanding of regional scale sediment transport pathways is obtained from work by Kenyon (1970) and Stride (1982) and shows that dominant transport pathways are predominantly governed by tidal conditions (**Figure 6.1.14**). A bedload parting or divergence exists between the Isle of Wight and the Cotentin Peninsula (France) with a convergence zone further east off Dungeness (Grochowski et al., 1993b).

5.1.5 Within and nearby to the Offshore Array Areas within the Proposed DCO Order Limits, the dominant transport pathway is eastwards (**Figure 6.1.14**). This direction relates to the dominant flood residual observed and discussed in **Section 3.3**. At a local level, differences occur in the dominant hydrodynamic forcing factors along with the available sediment. This brings about a difference in the sediment regime at the coast and offshore locations and is discussed in more detail in the following sections.

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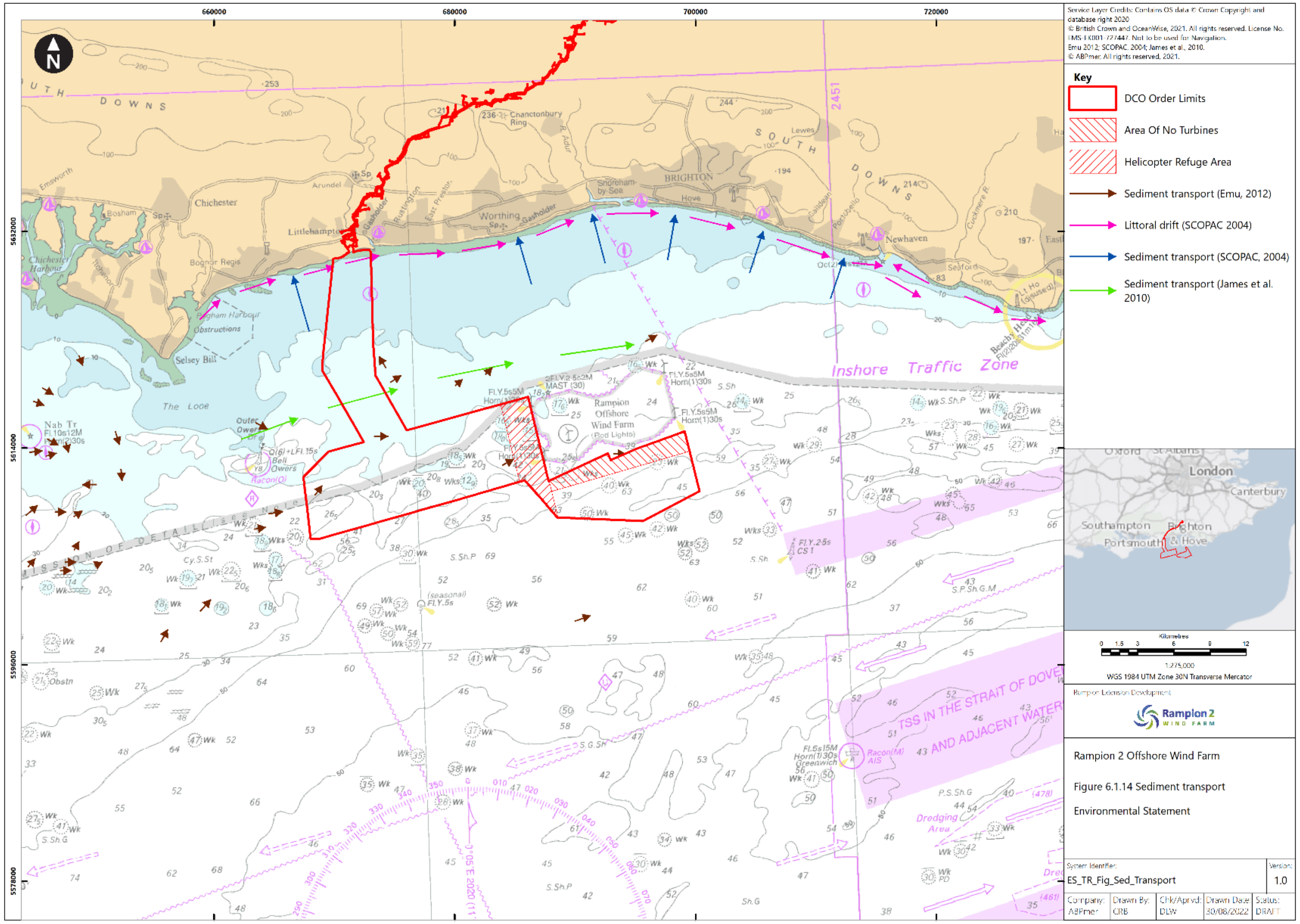
Figure 6.1.14 Sediment transport pathways in the wider ZOI



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5.2 Nearshore sediment transport

5.2.1 Along the coastline, there is a dominant west to east net drift. Existing broad-scale mapping suggests gravels, sandy gravels and sand are the expected dominant sediments that make up the seabed at the coast. The coastline along this frontage is also defended with a series of groyne structures, which results in the observable sediment accumulation updrift of the structures. Supplies of new sedimentary material from the land are mainly through the Rivers Arun, Adur and Ouse (New Forest District Council, 2017).

5.2.2 The drift direction at the coastline is predominantly influenced by the wave conditions, which originates from the west-southwest to southwest (**Figure 6.1.7**). This is because the tidal currents are generally not strong enough to move the gravels present at the coastline. Sediment is transported at the coastline primarily as bedload transport in relation to the wave conditions. Studies by SCOPAC (New Forest District Council, 2017) indicate an onshore and littoral drift of shingle due to waves and wave-assisted kelp rafting. Although there is the potential for suspended sediment transport, this has not been quantified as the dominant sediment is coarser material which would need much more energetic tidal conditions to keep such sediments in suspension.

5.2.3 The sediment transport rates are seen to be variable in relation to the amount of energy and sediment available and the presence of barriers to flow, such as groynes or harbour sinks (New Forest District Council, 2017). Broadly, higher transport rates are observed to the west in line with the incident wave approach and the annual average spring peak currents (**Figure 6.1.4**). No large scale bedform features are observed at the coastline, although there is the known abundance of coarse-grained material for transport.

5.3 Offshore sediment transport

5.3.1 Transport pathways through the study area are primarily to the east and east northeast in relation to the tidal currents (Paphitis et al., 2010; Barne et al., 1998; Tappin et al., 2007; Brampton et al., 1998). This is also confirmed through numerical modelling (HR Wallingford, 1993; 2010; Grochowski et al., 1993a; 1993b) and field studies (New Forest District Council, 2017). The tidal dominance leads to the formation of well-sorted distributions and tide-dominant bedform features. This includes sand banks and areas of sand and gravel waves and megaripples as identified by BGS (1989; 1990) and in the South Coast Regional Environmental Characterisation (James et al., 2010). On the basis of the observed current speeds across the study area and known relationships between flow speed, sediment availability and bedform development, these bedforms are expected to be ‘active’.

5.3.2 The geophysical survey completed by Gardline (2020a; 2020b; 2020c) and Osiris (2010b; 2010c) also identify large areas of sand waves and megaripples within the Rampion 2 Offshore Array Areas, where, consistent with the regional description above, the crests are asymmetric, and indicate local bedload transport to the northeast (**Figure 6.1.13**). The dominance of tidal activity and the availability of some finer grained material does also suggest that there is potential for suspended sediment transport in offshore areas.

5.4 Suspended sediments

5.4.1 Regional scale assessments of suspended particulate matter (SPM) have been carried out by Cefas (2016) using satellite remotely sensed images calibrated against SmartBuoys. These were used to create a map of SPM for surface waters around the UK continental shelf. Within the study area, surface SPM values typically range between 10 to 20mg/l during winter and generally less than 4mg/l during summer (**Figure 6.1.15**).

5.4.2 Cefas (2016) is broadly consistent with the findings of the Rampion 1 oceanographic survey. Suspended sediment concentrations (SSC) within central and eastern areas parts of the Offshore Array Areas within and nearby to the Offshore Array Areas within the Proposed DCO Order Limits were calculated from Optical Backscatter Sensors (OBS) mounted on a frame 0.5m above the seabed. At the three metocean survey locations (**Figure 6.1.2**) values of 5 to 10mg/l are commonly observed nearbed during the (wintertime) survey period although values exceeding 10mg/l also frequently occur. Fluctuation in current flow speeds with respect to the spring-neap cycles correspond with similar variation in SSC. This relationship is illustrated in **Figure 6.1.16**, for survey location L3. The results at the shallower measurement locations (L1 and L2; both 25mLAT) also show that SSC is significantly increased during periods of increased wave activity (EMU 2011).

5.4.3 Due to the seasonal nature of the frequency and intensity of storm events, levels of SSC will likely follow a broadly seasonal pattern with higher values observed during larger storms that occur more frequently during late spring, winter and early autumn. It is also possible that seasonal blooms of marine plankton may also contribute to apparent seasonality in measurements of total turbidity, but this is not directly associated with the resuspension of (inorganic) sediments.

Figure 6.1.15 Average suspended particulate matter concentration 1998-2015 (Cefas, 2016)

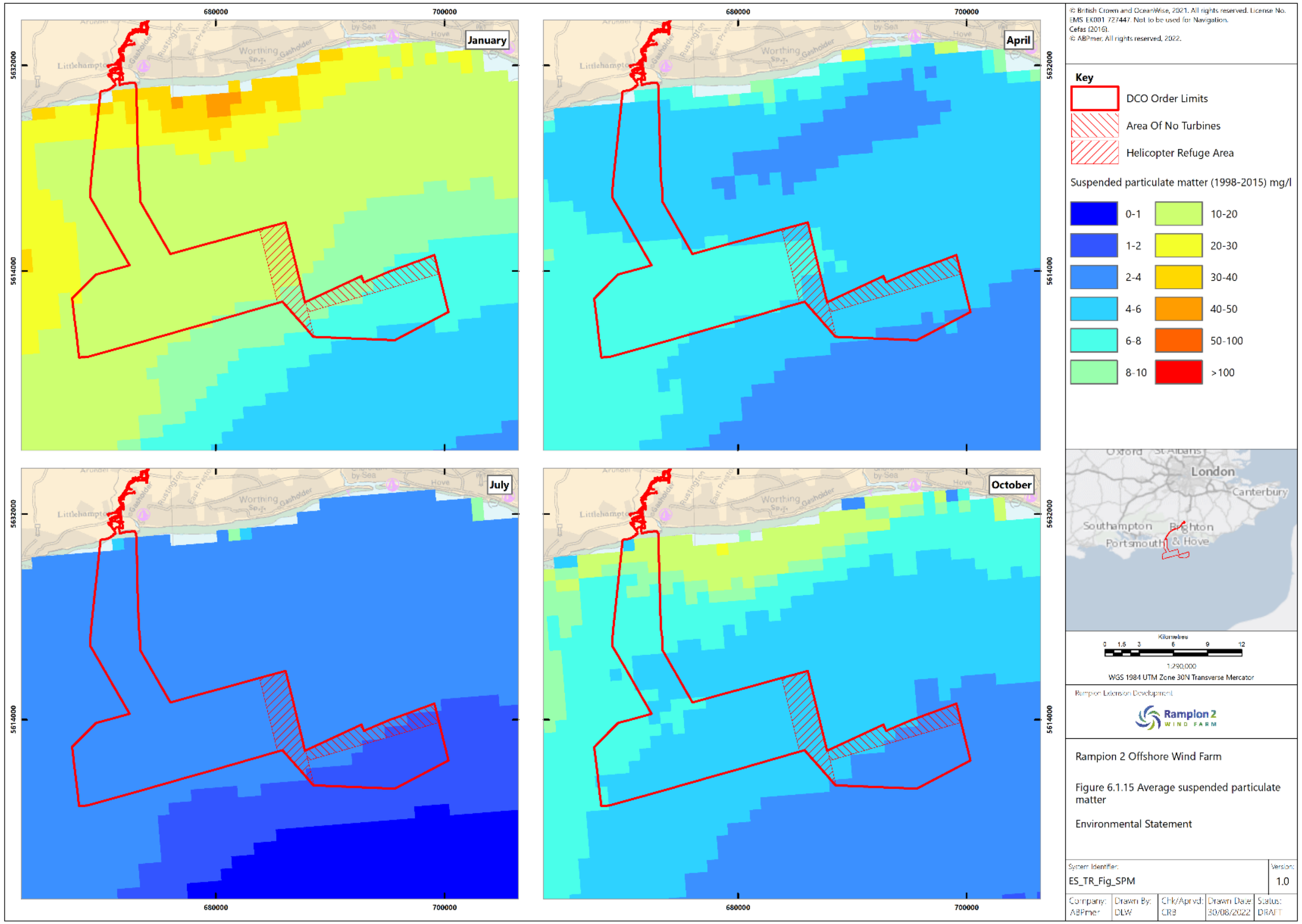

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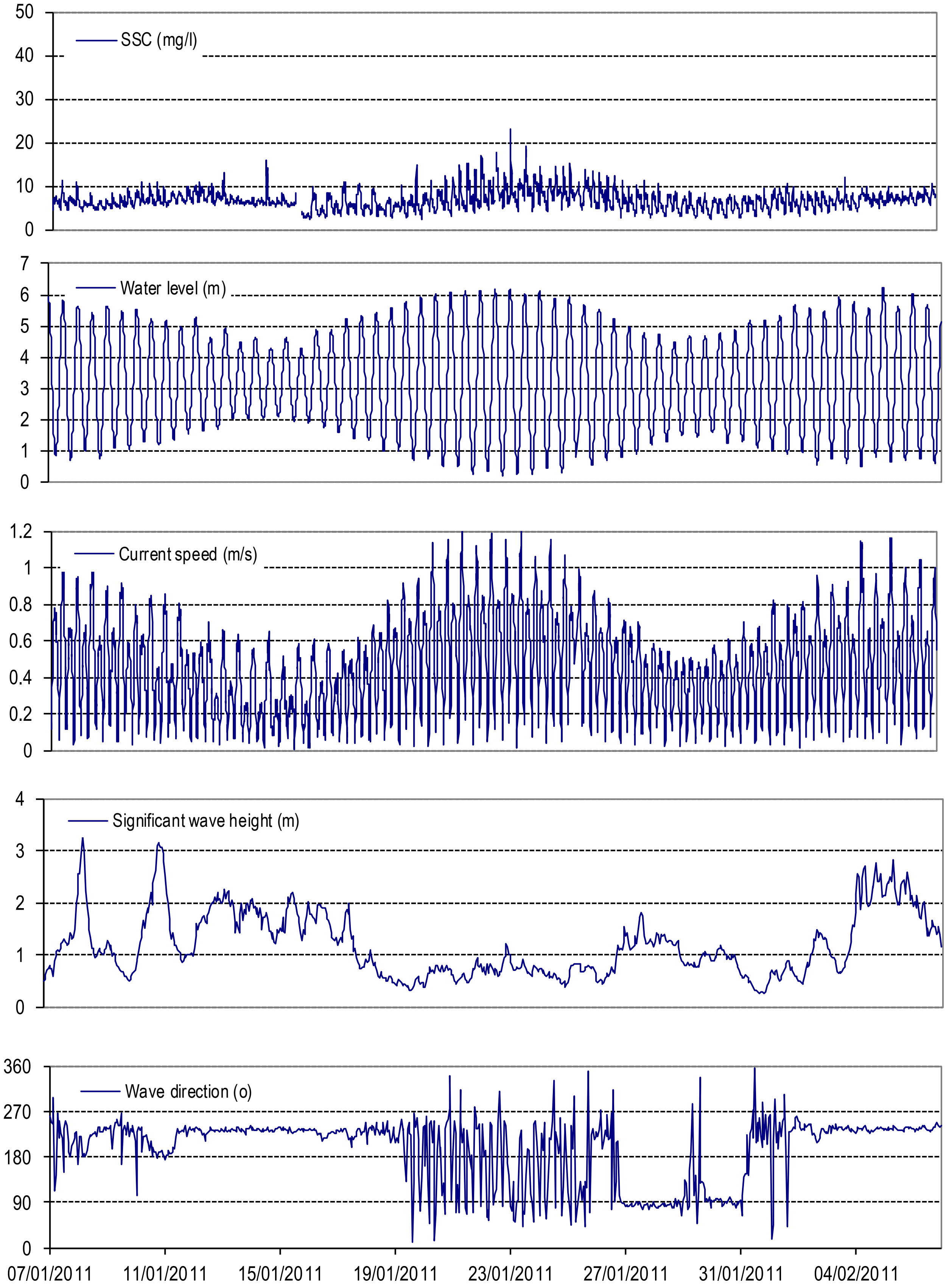
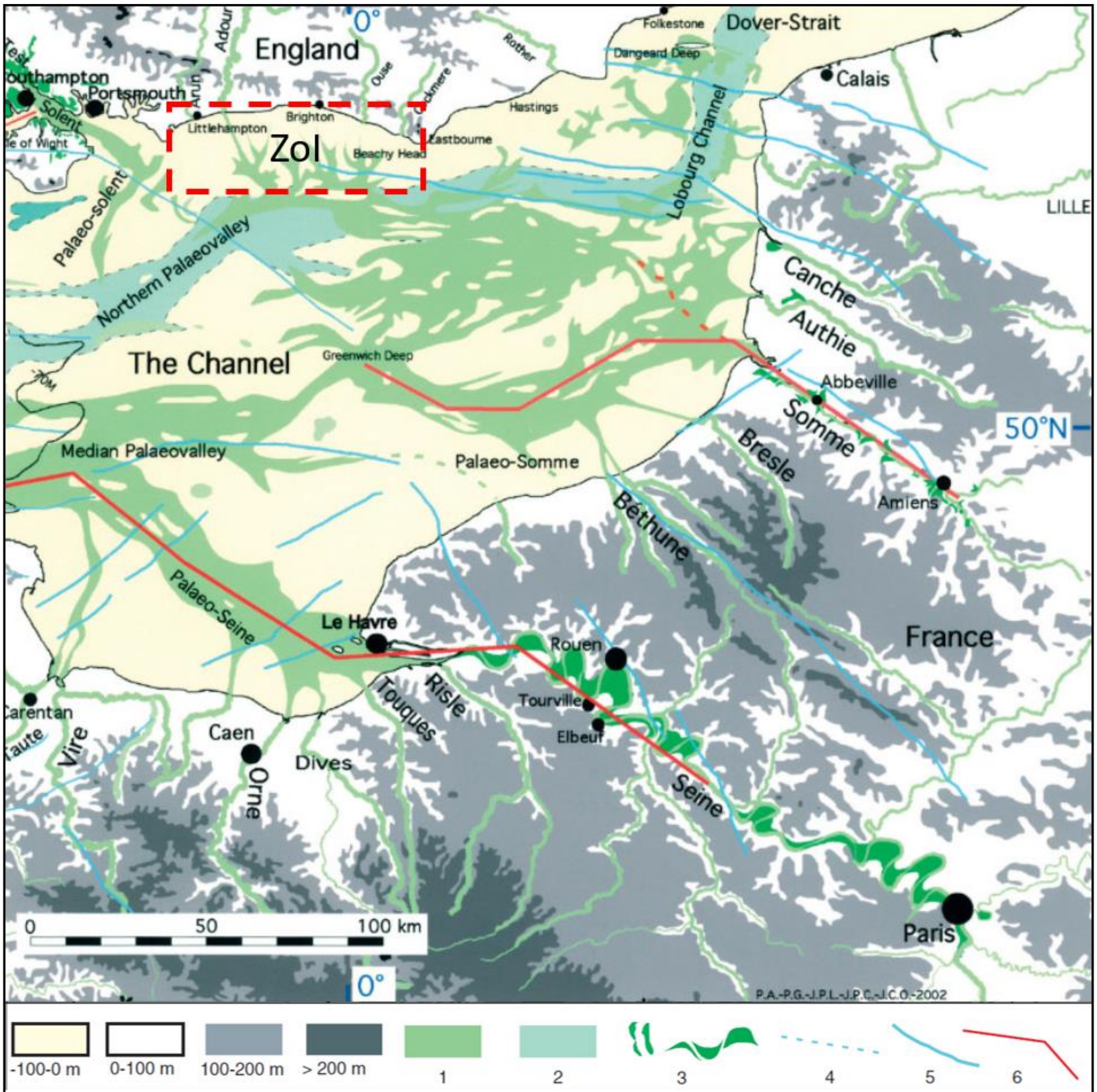
Figure 6.1.16 Relationship between suspended sediment concentrations and selected hydrodynamic variables. Location L3; water depth -49m LAT



5.5 Seabed sediments

5.5.1 The geomorphology of the English Channel is characterised by the presence of a network of drowned palaeovalleys and channels formed within the last 10,000 years during the Holocene transgression (Velegrakis et al., 1999; Velegrakis, 2000; Gupta et al., 2007; Paphitis et al., 2010) (**Figure 6.1.17**). These in turn contribute to the two characteristically different types of deposits that occur within the region (Velegrakis et al., 1999; Velegrakis, 2000). The seabed surface across large parts of the wider study area is characterised by a hard seabed substrate (**Section 5.6**).

Figure 6.1.17 Extent of paleovalleys in the eastern English Channel (from Antoine et al., 2003)



The Pleistocene fluvial systems in the eastern English Channel, northern France and southeastern England area. 1, River Manche (Channel River) submerged fluvial network (infilling: 10 to 90m in thickness, up to 140m in the Hurd deep) according to Auffret *et al.* (1982) and Lericolais (1997); 2, unfilled palaeovalleys (Northern Palaeovalley, according to Auffret *et al.,* 1982); 3, main terrace concentrations (according to Hallegouet and Gibbard, 2003); 4, main faults (according to B. Hallegouet); 5, main faults (according to Lagarde *et al.,* 2003); 6, longitudinal profiles (shown elsewhere in Antoine *et al.,* 2003). All references listed in Antoine *et al.,* 2003. The approximate outline of the Rampion 2 ZoI is shown

5.5.2 Modern sediments are controlled by the present hydrodynamic regime, they form a thin veneer (less than 0.5m) of fine sediment (James et al., 2010; Gafeira et al., 2010) over areas of exposed bedrock.

5.5.3 The older sediments make up the paleovalley and channel infill and the deposits relate to the fluvial characteristics of the paleo-environment prior to submergence and are therefore coarser (BGS, 1989; 1990).

5.5.4 Seabed sediment mapping across the wider ZOI is based on the geophysical surveys undertaken to inform Rampion 1 (Osiris, 2010a; 2010b; 2010c), as well as work undertaken for the South Coast Regional Environmental Characterisation (James et al., 2010). Based on the Folk (1954) classification, the sediments that occur in the study area are primarily composed of muddy sandy Gravel (msG), sandy Gravel (sG), gravely Sand (gS), slightly gravely Sand ((g)S), gravely muddy Sand (gmS) and sandy muddy Gravel (smG).

5.5.5 The locations of grab samples are provided in **Figure 6.1.18,** with sediment composition described according to the Folk (1954) sediment classification system. The grab samples are shown overlying seabed sediment maps interpreted from the project specific geophysical surveys (Gardline 2020; 2020b; 2020c). The seabed within the Proposed DCO Order Limits predominantly comprises coarse-grained sediments (sands and gravels); the thickness of this sediment layer is relatively thin and there is also outcropping bedrock present in a few locations. Sediment grain sizes include pebble gravel to fine sand in varying proportion. However, most samples contained medium sand, which was the most common specific sediment grain size present. Detrital carbonate sediments, (shell fragments) were commonly less than 10 percent sediment mass, making only a small contribution to the sediment deposits (EMU, 2010). Fines (muds and clays) typically comprise less than 1 to 2 percent of the seabed sediment, occasionally up to 5 percent and up to a maximum of 25 percent in a few locations within the nearby Rampion 1 array area (EMU, 2010).

5.5.6 In terms of the modern Holocene sediments, there is generally a fining trend from the coast through to the offshore environment in the eastern English Channel (New Forest District Council, 2017; Paphitis et al., 2010). However, analysis undertaken by ABPmer (2012) investigating the association between sediment size and depth within the ZOI did not show any clear correlation. This is considered to relate to the known diversity of sediment deposits in relation to present and past hydrodynamic regimes as the observed grain size distribution suggest that both modern sediments and paleochannel infill deposits have been collected.

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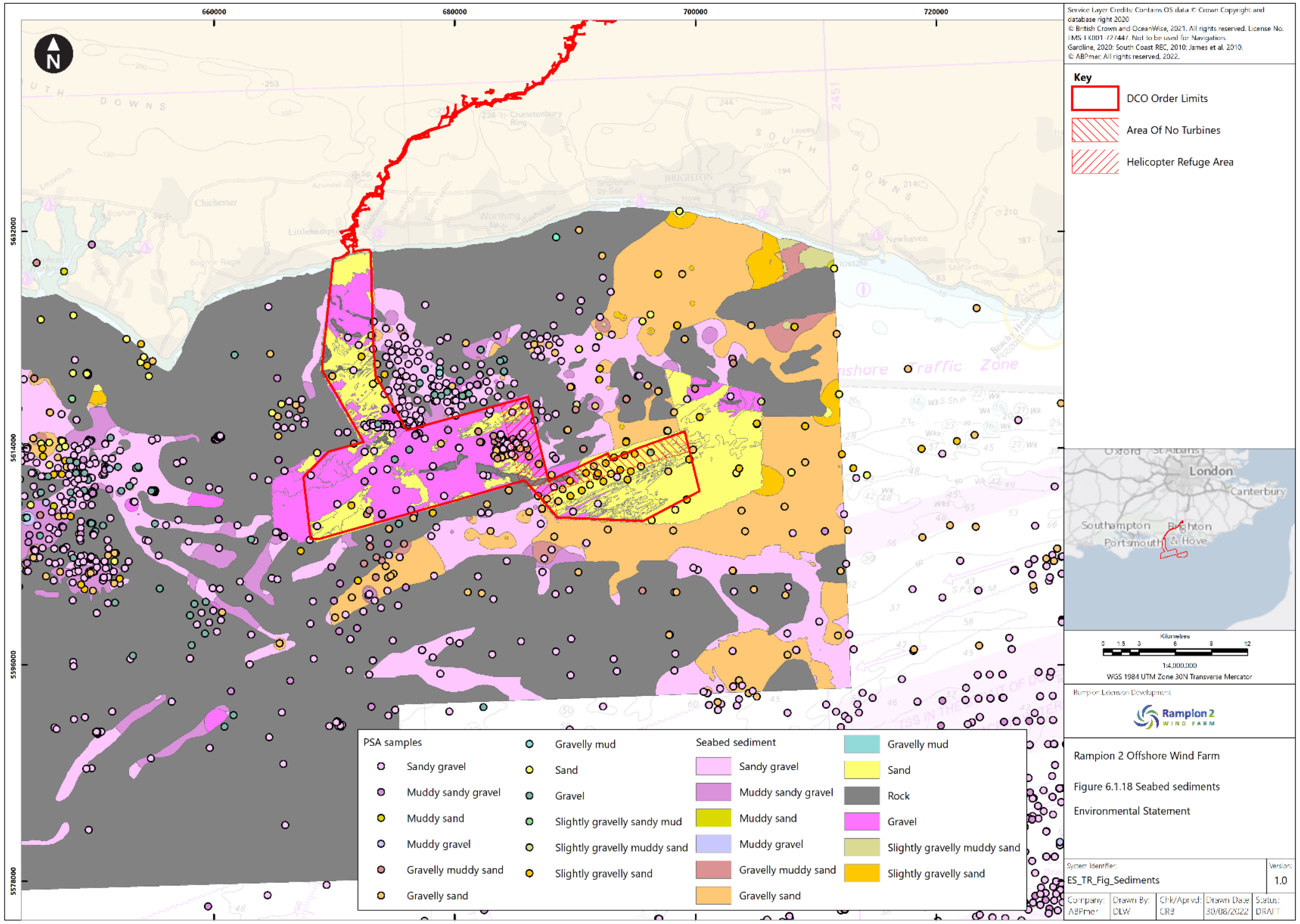
Figure 6.1.18 Seabed sediments



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5.6 Sediment sub-strata

5.6.1 The following discussion on the composition and distribution of the sub-strata and solid geology within the Proposed DCO Order Limits is based primarily on the interpretations from the Rampion 2 geophysical survey completed by Gardline (2020a; 2020b; 2020c), complemented by Rampion 1 surveys (Osiris, 2010a; 2010b; 2010c). Isopachyte data showing the thickness of Holocene, Quaternary and paleochannel infill material is shown in **Figure 6.1.19**.

5.6.2 The solid geology across the wider study area comprises Cretaceous and Tertiary deposits (BGS, 1995). The Cretaceous deposits comprise older Upper Cretaceous Chalk beds with bands of flints. The Tertiary deposits include sand, gravels and clays with occasional limestone bands (for the younger Eocene and Palaeocene deposits). The Tertiary sequences sub-crop beneath seabed sediments within the study area at varying depths.

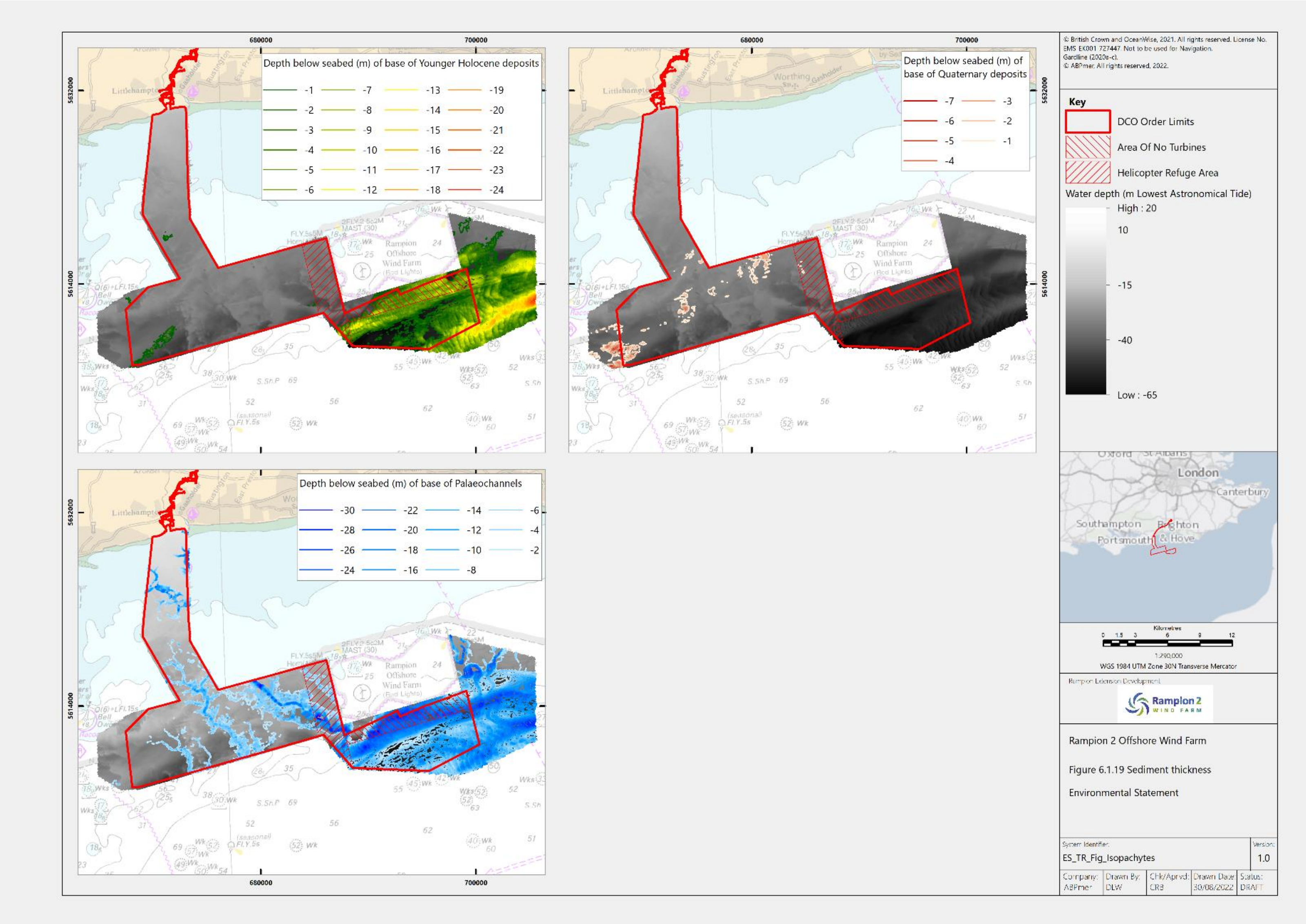
5.6.3 Sub-bottom measurements across the study area indicate that bedrock is present either at or very close to the seabed in many areas (James et al., 2010; Gafeira et al., 2010; Osiris, 2010b; 2010c). A key characteristic of the regional geology is the presence of the sedimentary deposits associated with paleochannels (**Figure 6.1.17**).

5.6.4 Holocene deposits are widespread across central and eastern parts of the Rampion 2 Offshore Array Areas (**Figure 6.1.19**). They are interpreted as comprising predominantly gravel and sand and reach 25m thick in places. They overlie the paleochannels and occasionally bedrock, which is interpreted to comprise Tertiary Claystones to Cretaceous Chalk strata which occasionally subcrop and outcrop in the northeast of the Rampion 2 Offshore Array Areas. The central and eastern parts of the Offshore Array Areas are dominated by a paleo-basin, with two main paleochannels cutting through the bedrock feeding into this basin (Gardline, 2020a).

5.6.5 Within the Western Offshore Array Area, the Quaternary deposits present are interpreted as comprising predominantly gravel and sand (**Figure 6.1.19**) (Gardline, 2020b). The Quaternary deposits are widespread, although are much thinner than in the Southern Offshore Array Area and often too thin to identify on seismic data. Where these are absent, bedrock bedding plains are observed to outcrop and tie with bathymetric data. Bedrock is interpreted to comprise Tertiary Claystones to Cretaceous Chalk strata. These subcrop much of the survey area, occasionally outcropping. Four main paleochannels (along with smaller tributary channels) are present (Gardline, 2020b). These are associated with the former course of the River Arun which drained into the Northern Paleovalley that transects the English Channel south of the Rampion 2 Application area (Osiris 2010b; Paphitis, 2010; Gupta et al., 2004; Antoine et al., 2003) (**Figure 6.1.17**).

5.6.6 Within the Offshore Export Cable Corridor, the Quaternary deposits present are interpreted as comprising predominantly gravel and sand (**Figure 6.1.19**) (Gardline, 2020c). These Quaternary deposits are found throughout much of the route, although are often too thin to identify on seismic data. Where these are absent, bedrock bedding planes are seen to outcrop and tie with bathymetric data. Within the Offshore Export Cable Corridor there are three main paleochannels with smaller tributary channels. Channels are interpreted to comprise interbedded clay, sands and gravels. Acoustic blanking is present within sections of the paleochannels, suggesting the presence of biogenic gas associated with organic materials. Multiple channel units are seen to be cutting into each other suggesting a system that has moved position numerous times.

Figure 6.1.19 Distribution and thickness of sedimentary units



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5.6.7 Bedrock is found throughout the seafloor within the ECC, except when cut through by channel systems. Tertiary rock to Cretaceous Chalk strata, are simply layered and often gently folded creating bedding plains dipping downwards. Tertiary bedrock strata are interpreted to consist of rocks, comprising mainly sands, gravels and clays. Older Cretaceous strata comprise typically limestone (Gardline 2020c).

5.7 Potential mobility due to tidal currents

5.7.1 An analysis of potential seabed mobility in response to tidal currents was presented in ABPmer (2012), based on the hydrodynamic information collected in central/eastern parts of the Rampion 2 Offshore Array Areas (**Figure 6.1.2**). **Table 5-1** sets out the proportion of the time series (two to four-month duration) during which each sediment fraction is potentially mobilised.

5.7.2 It is apparent from **Table 5-1** that tidal currents have the potential to regularly mobilise sand sized material within eastern areas of the Proposed DCO Order Limits. They are of sufficient strength to mobilise up to medium sand (302.5µm) at nearly all states of the tide. Coarse sand (750µm) sediments are also mobilised although this is limited to peak spring conditions only. As discussed in **Section 5.1**, asymmetry in the tidal regime results in net easterly bedload transport of sand within and nearby to the Offshore Array Areas (**Figure 6.1.14**).

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Table 5-1 Estimated potential sediment mobility (tidal currents only)

Location (Depth and bed sediment size)		Sediment fraction: Coarse silt (47.5 µm)	Fine sand (187.5 µm)	Medium sand (302.5 µm)	Coarse sand (750 µm)	Very coarse sand (3000 µm)	Granule gravel (6000 µm)	Pebble gravel (38500 µm)
L2 (24m (CD); d50 bed of 257.6µm)	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); d50 bed of 338.2µm)	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%

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5.7.3 Peak tidal current speeds are similar but may be locally slightly higher in the western Offshore Array Area (as shown in **Figure 6.1.4**). The highest peak current speeds observed in western areas alongside standard empirical equations describing the relationship between hydrodynamic forcing and sediment transport (e.g. Soulsby, 1997) suggests that up to gravel sized material has the potential to be mobilised for short periods of time in these areas during peak spring tides.

5.7.4 Potential mobility of sediment in response to tidal currents is expected to diminish along the Offshore Export Cable Corridor with closer proximity to the coast. However, close inshore, mobilisation of material by wave induced currents will gradually increase, especially landward of the depth of closure which is calculated to be approximately 6.2m LAT (ABPmer, 2016).

5.7.5 The episodes of current exceedance above sediment mobilisation thresholds are not of equal duration on the ebb and flood tide leading to potential variation in the direction of sediment transport for different sized sediment particles. Residual transport of fine sand sized material found to be in an east-northeast direction (ABPmer, 2012).

5.7.6 Residual tidal flow is towards the northeast to east-northeast at L2 and L3. This means that finer material held in suspension will generally be transported in this direction. The observed residual direction and east-northeast trend in predicted sediment displacement is consistent with published information on the direction of net sediment transport in this region (**Figure 6.1.14**). This 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.

5.8 Potential mobility due to waves

5.8.1 The regional wave climate has been discussed in more detail in **Section 3.5**. The available information indicates that the dominant transport mechanism in the nearshore is due to waves, with tidal dominance in the offshore environment (HR Wallingford, 2003; New Forest District Council, 2017; ABPmer, 2012).

5.8.2 Near bed orbital current velocities associated with the waves observed during the Rampion 1 offshore oceanographic surveys were generally not enough to cause significantly higher bed shear stresses and therefore sediment mobility within offshore areas (ABPmer, 2012). This is consistent with the observations of nearbed SSC collected by Emu (2010) and the findings of Paphitis et al. (2010) who found that the occurrence of waves with the potential to disturb seabed sediments across the wider study area only occur approximately 5 to 20 percent of time during the year (**Section 3.5**).

5.9 Future baseline

5.9.1 As previously stated in the Morphological regime 'future baseline' section (**Section 4.2.13**), whilst there is a high likelihood that climate change (and sea level rise) will contribute to change in morphology (including sediment characteristics) at the coast, there is a far greater degree of uncertainty with regards to how the seabed in offshore parts of the study area might respond. Changes in patterns of coastal erosion could potentially lead to change in the type and rate of material delivered offshore areas, potentially resulting in changes to seabed composition. But confidence in any future projections of change such as this is extremely low.

6. Summary

6.1 Overview

6.1.1 This technical report provides a baseline assessment of coastal processes within the Proposed DCO Order Limits as well as across the wider study area. This has primarily been achieved using oceanographic, geophysical and geotechnical data collected during targeted survey campaigns for the Rampion 1 and 2 developments, as well as information collected as part of regional characterisation studies. The findings of the baseline can be summarised as follows:

6.2 Hydrodynamic regime

- The Proposed DCO Order Limits is situated within a macro-tidal setting, with the mean spring tidal range increasing gradually from 4m at the western boundary of the study area (around Selsey Bill), to 6.5m at the eastern boundary (around Beachy Head) (**Figure 6.1.3**).
- Storm surges may cause short term modification to predicted water levels and under an extreme (1 in 50-year return period) storm surge, water levels at the landfall are expected to reach 3.76m ODN. This is approximately 1m above MHWS (**Table 3-2**).
- The tidal currents within the study area are generally energetic with peak spring current speeds in excess of 1m/s in offshore areas. However, there is a general southwest to northeast reduction in current speeds, with velocities highest offshore and slowest inshore, close to the coast (**Figure 6.1.4**).
- The flood tide is marginally stronger than the ebb tide and this leads to a general net residual flow to the northeast, especially on spring tides (**Figure 6.1.5**).
- The wave regime in the English Channel is the outcome of locally generated wind waves and swell waves. Analysis of long-term wave records from the study area show that the most frequent wave direction is from the southwest to south-southwest, with waves occurring from this direction approximately 60 percent of the time (**Figure 6.1.7**).
- Extremes analysis of available long-term wave hindcast data shows a clear increase in wave height with distance offshore. Within the Offshore Array Areas, significant wave heights associated with a 1 in 2-year return period event are expected to be approximately 4.83m whereas for the 1 in 10-year event this value increases to 5.29m (**Table 3-3**).
- Climate change has the potential to influence the hydrodynamic regime over the lifetime of the project. Whilst projections of change to the wave regime are accompanied by significant uncertainty, it is highly likely that relative sea levels will rise in this region during the course of the 21st Century. By 2060, levels could be approximately 0.35 to 0.4m higher than present.

6.3 Morphological regime

- Water depths across the Offshore Array Areas vary from 13m LAT (on a rocky outcrop in the northwest of the site) to 65m LAT (within a broad depression) in the southeast on the Offshore Array Areas. Sandwaves are prevalent over much of the central and eastern parts of the Offshore Array Areas trending northwest to southeast, with wave heights of up to 2m relative to the surrounding seabed (**Figure 6.1.11** and **Figure 6.1.12**).
- The seabed undulates across much of the Offshore Export Cable Corridor, influenced by the underlying geology. Water depths within the Offshore Export Cable Corridor are greatest at the southern end where they reach 28m LAT within a significant seabed depression. Megaripples are present towards the southern end of the Offshore Export Cable Corridor with heights of 0.2m and wavelengths reaching 7m (**Figure 6.1.11** and **Figure 6.1.12**).
- The sand waves and megaripples mapped within the Offshore Array Areas and Offshore Export Cable Corridor have axes broadly aligned perpendicular to the direction of flow. Given known relationships between sediment availability, flow speeds and bedform development, it is expected that these bedforms are active. This has been confirmed to be the case through a comparison between the 2020 survey of the Rampion 2 Offshore Array Areas and the earlier Rampion Zone survey (undertaken in 2010, Osiris Projects 2010a,b,c) (**Figure 6.1.13**).
- The asymmetry of the sandwaves along with the easterly displacement of the features between the 2010 and 2020 bathymetric surveys points to a general easterly direction for sediment transport. This is entirely consistent with known sediment transport pathways across the ZOI (**Figure 6.1.13** and **Figure 6.1.14**).
- The Rampion 2 landfall is located at Climping. The beach frontage consists of mixed sand and shingle sediment with a 1:7.5 slope to the sand foreshore and sediment transport in an easterly direction. A failed seawall and groynes are also present.
- The landfall is located within SMP Policy Unit 4D20 (Littlehampton to Poole Place) with the Environment Agency responsible for coastal management along this section of coastline. The original SMP2 for policy unit 4d20 indicates a policy of ‘Managed Realignment’ although this has evolved to ‘Withdraw Management’ and more recently, ‘Do Minimum’. There is currently ongoing discussion regarding the most appropriate management policy for this stretch of coast.
- In the absence of coastal defence measures, there is potential for pronounced retreat in the position of the coastline at the landfall over the lifetime of the Proposed Development. Expert geomorphological assessment work carried out on behalf of the Environment Agency sets out a range of possible future evolution scenarios over 10 and 50 year time horizons although uncertainty regarding rates of sea level rise and sediment availability means a high degree of uncertainty accompanies the projections (**Figure 6.1.9** and **Figure 6.1.10**).

6.4 Sedimentary regime

- The seabed across the Offshore Array Areas and Offshore Export Cable Corridor is dominated by the presence of coarse-grained sediments (sands and gravels) with outcropping bedrock in places (**Figure 6.1.18**). Holocene deposits are widespread across central and eastern parts of the Rampion 2 Offshore Array Areas whereas in western areas hard substrate is at or close to the surface in most areas. Bedrock is found throughout the seafloor within the Offshore Export Cable Corridor, except when cut through by paleochannel systems (**Figure 6.1.19**).
- Sediments across the Rampion 2 Offshore Array Areas and Offshore Export Cable Corridor are characteristics of two very different depositional environments. The Holocene seabed sediments generally consist of sand, gravelly sand and sandy gravel and have been reworked and deposited by marine processes. The sediments associated with the paleochannels are also sands and gravels but have a fluvial origin, deposited in a terrestrial setting (**Figure 6.1.18**).
- The available evidence suggests that (bedload) material is travelling east-northeast further towards the eastern English Channel (**Figure 6.1.14**). In the offshore environment, tidal currents are the primary agent for mobilising sediment through bedload and suspended load transport. Wave conditions alone do not have enough strength to mobilise large sediment volumes for transport.
- Within the Offshore Array Areas, SSC are typically between 5 to 10mg/l (**Figure 6.1.15**). However, during stormier conditions, near bed current speeds can be increased due to the influence of waves stirring of the seabed, causing a short-term increase in SSC. Coarser sediments may be transported a short distance in the direction of ambient flow or down-slope under gravity before being deposited. Finer material that persists in suspension will eventually be transported east-northeast, the direction of net tidal residual flow.

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7. Acronyms

Table 7-1 Acronyms used in this report

Term	Abbreviation
ABP	Associated British Ports
ABPmer	ABP Marine Environmental Research (Ltd)
AWAC	Acoustic Waves and Currents
BGS	British Geological Survey
CCO	Channel Coastal Observatory
CD	Chart Datum
CFSR	Climate Forecast System Reanalysis
EA	Environment Agency
ECC	(Offshore) Export Cable Corridor
ES	Environmental Statement
HAT	Highest Astronomical Tide
Hs	Significant wave height
LAT	Lowest Astronomical Tide
MALSF	Marine Aggregate License Sustainability Fund
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
NOAA	National Oceanic and Atmospheric Administration
NTSLF	National Tide and Sea Leve Facility
NWS	North-West European Shelf
OBS	Optical Backscatter Sensor

Term	Abbreviation
ODN	Ordnance Datum Newlyn
OS	Ordnance Survey
OWF	Offshore Wind Farm
RCP	Representative Concentration Pathway
RED	Rampion Extension Development Ltd
SCOPAC	Standing Conference on problems Associated with the Coastline
SMP	Shoreline Management Plan
SPM	Suspended Particulate Matter
SSC	Suspended Sediment Concentration
Tz	Zero-crossing wave period
UKCP	United Kingdom Climate Predictions
UKHO	United Kingdom Hydrographic Office
ZOI	Zone of Influence

Unless otherwise stated, this report using standard SI unit conventions and abbreviations. Standard directional abbreviations (e.g., N, NNE, NE, etc) are used to indicate cardinal directions relative to true North. Standard Folk classification grain size abbreviations (e.g muddy sandy Gravel (msG), sandy Gravel (sG), gravely Sand (gS)) are used to indicate sediment type.

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Rampion 2
WIND FARM